AUTOSTRADA (A14) : BOLOGNA-BARI-TARANTO

TRATTO: BOLOGNA BORGO PANIGALE - BOLOGNA SAN LAZZARO

POTENZIAMENTO IN SEDE DEL SISTEMA AUTOSTRADALE E TANGENZIALE DI BOLOGNA

"PASSANTE DI BOLOGNA"

PROGETTO DEFINITIVO

IN - VIABILITA' INTERFERITA

I52 - VIA SAN DONATO km 17+043

CV103 - PARTE STRUTTURALE

Relazione di calcolo dell'impalcato e del sistema di isolamento sismico

IL PROGETTISTA SPECIALISTICO	IL RESPONSABILE INTEGRAZIONE PRESTAZIONI SPECIALISTICHE	IL DIRETTORE TECNICO
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CODICE IDENTIFICATIVO												ORDINATORE
RIFERIMENTO PROGETTO			RIFERIMENTO DIRETTORIO				RIFERIMENTO ELABORATO					--
Codice Commessa	Lotto, Sub-Prog, Cod. Appalto	Fase	Capitolo	Paragrafo	W B S	Parte d'opera	Tip.	Disciplina	Progressivo	Rev.		SCALA
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spea ENGINEERING gruppo Atlantia	PROJECT MANAGER: Ing. Raffaele Rinaldesi Ord. Ingg. Macerata N. A1068	SUPPORTO SPECIALISTICO:
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AUTOSTRADA (A14) : BOLOGNA-BARI-TARANTO
TRATTO: BOLOGNA BORGO PANIGALE - BOLOGNA SAN LAZZARO

POTENZIAMENTO DEL SISTEMA TANGENZIALE DI BOLOGNA
TRA BORGO PANIGALE E SAN LAZZARO

PROGETTO DEFINITIVO

OPERE D'ARTE MAGGIORI
Cavalcavia San Donato km 17+043

RELAZIONE DI CALCOLO IMPALCATO E DEL SISTEMA DI ISOLAMENTO SISMICO

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1 PREMESSA

Nell'ambito dei lavori di "Potenziamento del sistema autostradale e tangenziale di Bologna" è prevista la realizzazione del Cavalcavia 107 – Nuovo cavalcavia Rampa RS304.

La presente relazione di calcolo riguarda l'impalcato del cavalcavia che verrà realizzato in sostituzione di quello esistente per adeguare la luce dell'opera alla nuova larghezza della viabilità sottostante.

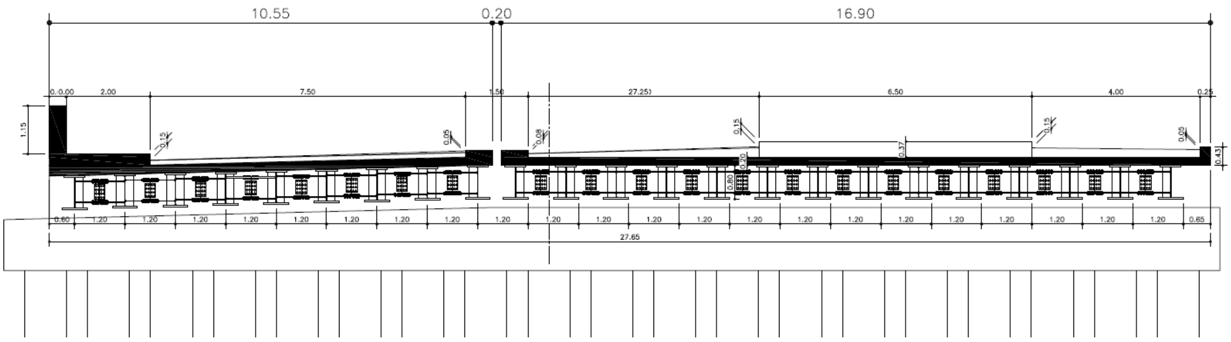
Nel paragrafo che segue si riporta una descrizione sintetica dell'opera.

1.1 DESCRIZIONE SINTETICA DELL'OPERA

Il cavalcavia sostituisce un cavalcavia esistente per il quale è prevista la demolizione e rifacimento.

Il ponte ha una struttura mista acciaio-cls con luce di calcolo 33.00+33.00m e larghezza utile totale pari a 27.65m. Nel dettaglio è presente un giunto longitudinale con varco di 20cm che separa i due semi-impalcati, di larghezza pari a 10.55m e 16.90m.
La struttura portante è costituita da travi principali miste acc-cls di altezza costante pari a 0.80m, con piattabanda sup. di larghezza 0.50m e piattabanda inf. 0.60m.

Ciascuna trave è scomposta in 7 conci, di lunghezza variabile, collegati in cantiere mediante giunti saldati a piena penetrazione.



Le travi principali sono collegate da traversi posti ad interasse costante di 11.00m. Gli irrigidenti trasversali sono invece a passo 2.75m. I traversi sono realizzati con sezione a doppio T ad altezza costante 550mm, spessore d'anima 14mm, piattabanda superiore e inferiore 300x25. Sulle piattabande superiori sono saldati dei pioli tipo Nelson (Φ=19 H=150mm al passo di 20cm) necessari per solidarizzare la soprastante soletta in calcestruzzo armato.
La soletta in calcestruzzo armato che costituisce la piattaforma dell'impalcato, ha uno spessore costante di 20cm. Superiormente la pavimentazione stradale presenta altezza variabile.
L'impalcato è poggiante su dispositivi elastomerici (isolatori) disposti all'intradosso travi.

2 NORMATIVA DI RIFERIMENTO

I calcoli e le disposizioni esecutive sono conformi alle norme attualmente in vigore.

- D. M. Min. II. TT. del 17 gennaio 2018 – Aggiornamento delle «Norme tecniche per le costruzioni»;
- CIRCOLARE 21 gennaio 2019, n.7 – Istruzioni per l'applicazione dell'«Aggiornamento delle "Norme tecniche per le costruzioni"» di cui al decreto ministeriale 17 gennaio 2018»;
- EUROCODICE serie EN 1991: Azioni sulle strutture
- EUROCODICE serie EN 1992: Progettazione delle strutture di calcestruzzo
- EUROCODICE serie EN 1993: Progettazione delle strutture di acciaio
- EUROCODICE serie EN 1994: Progettazione delle strutture composte acciaio-calcestruzzo
- UNI EN 197-1 giugno 2001 – "Cemento: composizione, specificazioni e criteri di conformità per cementi comuni
- UNI EN 206-1 ottobre 2006 – "Calcestruzzo: specificazione, prestazione, produzione e conformità"
- UNI EN 11104 marzo 2004 – "Calcestruzzo: specificazione, prestazione, produzione e conformità", Istruzioni complementari per l'applicazione delle EN 206-1
- Linee guida sul calcestruzzo strutturale - Presidenza del Consiglio Superiore dei Lavori Pubblici - Servizio Tecnico Centrale

3 CARATTERISTICHE DEI MATERIALI

Per la realizzazione dell'opera si prevede l'impiego dei materiali indicati nei paragrafi che seguono. Si indicheranno le caratteristiche prestazionali di resistenza minime e, con particolare riferimento ai calcestruzzi, anche le prescrizioni o caratteristiche da assicurare per garantire i requisiti di durabilità.

3.1 CALCESTRUZZO

Per garantire la durabilità delle strutture in calcestruzzo armato ordinario, esposte all'azione dell'ambiente, si devono adottare i provvedimenti atti a limitare gli effetti di degrado indotti dall'attacco chimico, fisico e derivante dalla corrosione delle armature e dai cicli di gelo e disgelo.

Al fine di ottenere la prestazione richiesta in funzione delle condizioni ambientali, nonché per la definizione della relativa classe, si fa riferimento alle indicazioni contenute nelle Linee Guida sul calcestruzzo strutturale edite dal Servizio Tecnico Centrale del Consiglio Superiore dei Lavori Pubblici ovvero alle norme UNI EN 206-1:2006 ed UNI 11104:2004.

Ai fini di preservare le armature dai fenomeni di aggressione ambientale, dovrà essere previsto un idoneo copriferro; il suo valore, misurato tra la parete interna del cassero e la generatrice dell'armatura metallica più vicina, individua il cosiddetto "copriferro nominale".

Si utilizzano i seguenti tipi di calcestruzzi

Campi di impiego	Classe di esposizione ambientale	Classe di resistenza minima [C(fck/Rck)$_{min}$]	Classe di resistenza adottata [C(fck/Rck)$_{min}$]	Copriferro adottato
Soletta d'impalcato e cordoli	XC4	C28/35	C35/45	40
	XD3			
	XF4			

Tabella 3-1 Classi di cls e copriferri.

In conformità a quanto sopra, le caratteristiche meccaniche del calcestruzzo utilizzate nell'analisi/verifiche sono le seguenti:

Grandezza		u.m.	C35/45
resistenza caratteristica a compressione	f_{ck}	N/mmq	35,00
resistenza di progetto a compressione	f_{cd}	N/mmq	19,83
resistenza caratteristica a trazione	f_{ctk}	N/mmq	2,25
tensione di aderenza cls-armatura	f_{bd}	N/mmq	3,37
tensione massima di compressione (comb. rara)	σ_c	N/mmq	21,00
tensione massima di compressione (comb. quasi perm.)	σ_c	N/mmq	15,75
modulo elastico medio istantaneo	Em	N/mmq	34077

Tabella 3-2 Grandezze meccaniche relative al cls.

3.2 ACCIAIO

3.2.1 Carpenteria metallica

Si utilizzano per le strutture metalliche del viadotto:

Elementi saldati con spessore fino a 40mm S355J2

Elementi saldati con spessore superiore a 40mm S355K2

Elementi non saldati S355J0

In conformità a quanto sopra, le caratteristiche meccaniche dell'acciaio da carpenteria utilizzate nell'analisi/verifiche sono le seguenti:

Grandezza		u.m.	S355
Tensione di snervamento caratteristica (t ≤ 40mm)	f_{yk}	N/mmq	355
Tensione di progetto (t ≤ 40mm)	f_{yd}	N/mmq	338
Tensione di snervamento caratteristica (t > 40mm)	f_{yk}	N/mmq	335
Tensione di progetto (t > 40mm)	f_{yd}	N/mmq	319
modulo elastico	E	N/mmq	210000

3.2.2 Armature per c.a.

Si utilizzano per le armature degli elementi in c.a.:

Acciaio tipo: B450 C Saldabile controllato in stabilimento

In conformità a quanto sopra, le caratteristiche meccaniche dell'acciaio d'armatura utilizzate nell'analisi/verifiche sono le seguenti:

Grandezza		u.m.	B450C
Tensione di snervamento caratteristica	f_{yk}	N/mmq	450
Tensione di progetto	f_{yd}	N/mmq	391
Tensione limite in esercizio	f_{SLE}	N/mmq	360
modulo elastico	E	N/mmq	210000

3.2.3 Pioli

Si utilizzano per le connessioni a taglio tra la struttura metallica ed il cls i seguenti:

Pioli (Secondo UNI EN ISO 13918): Pioli tipo "NELSON" Acciaio S235J2G3+C450

In conformità a quanto sopra, le caratteristiche meccaniche dei pioli usate per le verifiche sono le seguenti:

Grandezza		u.m.	Nelson
Tensione di snervamento caratteristica	f_{yk}	N/mmq	350
Tensione di rottura caratteristica	f_{uk}	N/mmq	450
Allungamento		%	>50
modulo elastico	E	N/mmq	210000

4 SOFTWARE DI CALCOLO

4.1 STRAUS 7

Il codice di calcolo utilizzato è Straus7, programma di modellazione strutturale agli elementi finiti di comprovata validità. Il codice è stato utilizzato per il calcolo delle sollecitazioni derivanti dalle analisi statiche dell'opera. I risultati delle sollecitazioni sono stati controllati manualmente a campione mediante metodi semplificati per verificare l'ordine di grandezza dei risultati.

4.2 PONTI EC4

Le verifiche sezionali delle sezioni composte acciaio-calcestruzzo dell'impalcato sono seguite utilizzando il programma Ponti EC4, sviluppato da Alhambra s.r.l.

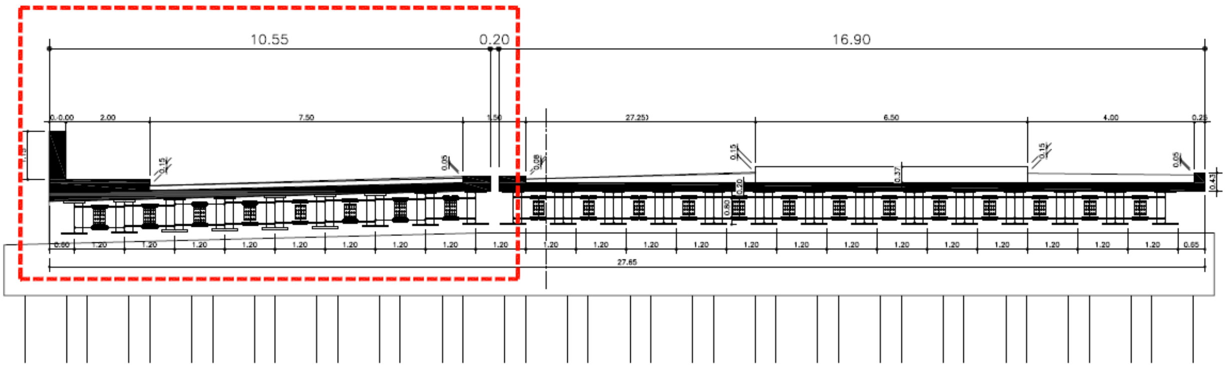
Il programma consente di eseguire tutte le verifiche connesse alla progettazione di una trave in sezione composta acciaio-calcestruzzo con riferimento alle metodologie indicate dagli Eurocodici, nei riguardi di verifiche di resistenza, verifiche di stabilità, verifiche tensionali e verifiche di fatica.

5 CRITERI DI PROGETTAZIONE

Si riportano nel presente capitolo i criteri generali e le ipotesi di base di progettazione del cavalcavia in oggetto. Per prima cosa si specifica che complessivamente il cavalcavia è composto da due parti di larghezza rispettivamente pari a 10.55m e 16.90m misurati in retto all'asse di tracciamento.

Il calcolo viene però eseguito **solo per la porzione di impalcato più stretto** (pari a 10.55m) in quanto data la minore larghezza trasversale le sollecitazioni sulle travi di impalcato risultano più onerose. Quindi sia le analisi dei carichi, che le verifiche verranno riportate solo per la porzione in oggetto.

Si riporta di seguito una schema di sezione trasversale con indicazione della parte di impalcato studiato.



5.1 METODO DI CALCOLO PER TRAVI E TRAVERSI

Il calcolo delle sollecitazioni gravanti sulle travi longitudinali e sui traversi dell'impalcato viene svolto mediante la realizzazione di diversi modelli agli elementi finiti realizzati con il software di calcolo Straus7.

Trattandosi, di un sistema misto acciaio-cls l'analisi delle azioni agenti e le verifiche vengono eseguite sulla base di una suddivisione in tre fasi del comportamento dell'impalcato, corrispondenti al grado di maturazione del getto di calcestruzzo e quindi ai diversi livelli di rigidezza e caratteristiche statiche delle sezioni.

FASE 1: Considera il peso proprio della struttura metallica, delle lastre prefabbricate e del getto della soletta che, in questa fase, è ancora inerte. La sezione resistente corrisponde alla sola parte metallica. In questo caso si tratta di un modello monofilare.

FASE 2: Ai successivi carichi permanenti applicati alla struttura (pavimentazione, barriere, ecc.) corrisponde invece una sezione resistente mista acciaio-calcestruzzo. Per tenere in considerazione i fenomeni "lenti" che accompagnano questa fase, che interagiscono con la viscosità del calcestruzzo, si adotta per il calcestruzzo un valore del modulo elastico effettivo corrispondente a quello ottenuto adottando un coefficiente di viscosità come suggerito dalla normativa, che si traduce, in fase di verifica, a considerare un valore del coefficiente di omogeneizzazione n pari a 18. Si tratta in questo caso di un modello a graticcio piano nel quale sia le travi che i traversi sono modellati come elementi beam complanari.

Anche gli effetti del ritiro sono da considerarsi "lenti" in quanto concomitanti con quelli viscosi, e vengono pertanto anch'essi valutati con le caratteristiche di resistenza della sezione della fase 2. In tale fase si tiene inoltre conto degli effetti dovuti ai cedimenti differenziali delle strutture di appoggio.

Si è inoltre tenuto conto della fessurazione trascurando il contributo del calcestruzzo alla rigidezza dell'elemento nelle zone adiacenti alla pila per una lunghezza pari al 15% della luce delle campate da ciascun lato dell'appoggio intermedio.

FASE 3: Corrisponde al transito dei carichi accidentali. Le sollecitazioni nella sezione resistente acciaio-calcestruzzo vengono calcolate considerando il rapporto tra i moduli elastici effettivi dei due materiali, che vale circa 6, per la classe di resistenza del calcestruzzo C35/45 adottata.

Particolare attenzione viene rivolta alla determinazione delle lunghezze delle stese di carico per ottenere in ciascuna sezione la condizione di massimo valore di taglio, di momento flettente o di momento torcente.

In tale fase si tiene inoltre conto degli effetti dovuti alla variazione termica differenziale e dell'azione del vento.

Si tratta in questo caso di un modello a graticcio piano come quello di Fase 2 ma con le opportune rigidezze nel quale sia le travi che i traversi sono modellati come elementi beam complanari.

Le sollecitazioni usate per le verifiche di resistenza dell'impalcato sono quelle relative alla trave maggiormente cimentata, che non necessariamente risulta essere la medesima per le varie fasi/carichi. Si veda di seguito il caso delle sollecitazioni indotte dai carichi permanenti portati per i quali la trave maggiormente carica è quella di bordo, e il caso dei carichi da traffico per i quali la trave maggiormente caricata risulta più interna rispetto quella di bordo.

La soletta d'impalcato è stata studiata in due fasi:

Una fase provvisionale in cui il getto di calcestruzzo è stato considerato solamente come peso, e la sezione resistente è stata attribuita alla sola lastra tralicciata in acciaio con funzione di cassero autoportante.

Una fase definitiva in cui si è considerato come reagente l'intero getto di calcestruzzo collaborante con la lastra tralicciata d'acciaio.

La prima fase è stata studiata manualmente con schema di trave in semplice appoggio (lastre non continue sui traversi).

La seconda fase è stata analizzata mediante il modello 3-dimensionale dell'impalcato per cogliere gli effetti flettenti globali che nascono per congruenza di deformazione con le travi principali.

5.2 MODELLO DI CALCOLO PER LA SOLETTA D'IMPALCATO.

La verifica della soletta viene condotta con riferimento a due fasi distine:

- la prima fase, provvisoria, di verifica della sezione delle sole lastre tralicciate reagenti con il peso del getto liquido;
- la seconda fase (definitiva), con la sezione in cemento armato reagente, e tutti i carichi applicati.

La prima fase è stata studiata manualmente con schema di trave in semplice appoggio (lastre non continue sui traversi).

La fase definitiva è stata studiata mediante il modello tridimensionale descritto al paragrafo precedente nel quale sono presenti le travi (elementi beam), i traversi (elementi beam) e la soletta di impalcato (elementi beam di larghezza pari ad 1m ed orditi trasversalmente). In questo modo i beam della soletta vengono direttamente caricati dai carichi da traffico, distribuiti e concentrati, e di conseguenza nascono in essi le sollecitazioni derivanti sia da comportamento locale che da comportamento globale, in funzione della rigidezza complessiva dell'impalcato.

5.3 FASI DI CALCOLO

5.3.1 Travi

Le travi sono state studiate come struttura di tipo misto acciaio-calcestruzzo, pertanto le sollecitazioni saranno legate al coefficiente di omogenizzazione acciaio-calcestruzzo i cui valori, istantanei e a lungo termine, sono calcolati come segue:

E_s = 210000 MPa	modulo elastico dell'acciaio
E_{Ct0} = 34077 MPa	modulo elastico istantaneo del calcestruzzo 35/45
$\Phi_{\infty,t0}$ = 1.89	coefficiente di viscosità
$E_{Ct\infty} = E_{Ct0}/(1+\Phi_{t0,t\infty})$ = 11791MPa	modulo elastico del calcestruzzo 35/45 a tempo ∞
$n_0 = E_s/E_{Ct0}$ = 6.16	**assunto 6**
$n_\infty = E_s/E_{Ct\infty}$ = 17.81	**assunto 18**

Il coefficiente di viscosità è stato ottenuto interpolando le tabelle 11.2.VI e 11.2.VII della norma.

I dati assunti per ottenerlo sono i seguenti:

Spessore soletta	0.20 m
Spessore lastra	0.005 m
Larghezza soletta	10.55 m
A_C	2.11 m^2
U	10.55 m
h0	4000 mm
RH umidità relativa	65%

Per tenere in considerazione le fasi costruttive dell'impalcato, che influenzano lo stato tensionale sui traversi, sono state implementate le seguenti fasi di calcolo.

FASE 1: Considera il peso proprio della struttura metallica, delle lastre di acciaio e del getto della soletta che, in questa fase, è ancora inerte. La sezione resistente corrisponde alla sola parte metallica.

FASE 2: Ai successivi carichi permanenti applicati alla struttura (pavimentazione, barriere, ecc.) corrisponde invece una sezione resistente mista acciaio-calcestruzzo. Per tenere in considerazione i fenomeni lenti legati alla viscosità del calcestruzzo che accompagnano questa fase, si adotta nella modellazione un valore del modulo elastico del calcestruzzo effettivo pari a $E_{Ct\infty}$=11791MPa. Questa scelta si traduce, in fase di verifica, nel considerare un valore del coefficiente di omogeneizzazione pari a n=18.

Anche gli effetti del ritiro sono da considerarsi lenti in quanto concomitanti con quelli viscosi, e vengono pertanto anch'essi valutati con le caratteristiche di resistenza e rigidezza della sezione nella fase 2.

FASE 3: Corrisponde al transito dei carichi accidentali. Le sollecitazioni nella sezione resistente acciaio-calcestruzzo vengono calcolate considerando il rapporto tra i moduli elastici istantanei dei due materiali n=6. Per la classe di resistenza del calcestruzzo adottata, nella modellazione sarà inserito in questa fase un modulo elastico pari a E_{Ct0}=34077 MPa.

In tale fase si tiene inoltre conto degli effetti dovuti alla variazione termica differenziale giornaliera.

5.3.2 Traversi

Per quanto riguarda i traversi, sono state estratte le sollecitazioni agenti ricavate direttamente dal modello di calcolo 3d, dovuti ai carichi portati e da traffico. Si è quindi proceduto a verificarli nel rispetto delle sollecitazioni ricavate.

Per la verifica si è considerata la sola sezione in acciaio resistente, trascurando cautelativamente il contributo resistente della soletta in c.a.. In questo modo si ha coerenza tra la determinazione delle sollecitazioni sui traversi, essendo stati modellati solo nella loro parte metallica, senza l'inerzia determinata dalla soletta superiore, e la verifica dei traversi stessi.

5.3.3 Soletta d'impalcato

Le verifiche vengono condotte con riferimento a due fasi distinte.

FASE I: PROVVISIONALE

Nella prima fase il getto non è ancora giunto a maturazione, non può quindi essere considerato efficace ai fini della resistenza, in questa fase risultano quindi efficaci le sole armature del traliccio e la lastra in acciaio. Le azioni presenti sono costituite dal peso proprio delle lastre, dal getto e da un sovraccarico accidentale dovuto al personale, ai mezzi d'opera e ad accumuli di conglomerato cementizio.

FASE II: DEFINITIVA

Nella seconda fase si fa riferimento alla sezione completa, composta cioè sia dal calcestruzzo e sia dalle armature della lastra tralicciata che quelle inserite in opera. Le sollecitazioni indotte dai carichi, sono ricavate dal modello 3d sia per gli effetti locali che per gli effetti globali.

Per quanto riguarda invece le verifiche allo stato limite ultimo e di esercizio, la verifica è svolta confrontando le resistenze di calcolo della sezione definitiva (completa) e le azioni sollecitanti (permanenti e traffico) determinate dallo schema definitivo opportunamente fattorizzate in base allo stato limite considerato.

Le coazioni legate a ritiro e variazione termica, in accordo con la UNI EN 1992-1-1 paragrafi 2.3.1.2 e 2.3.2.2, sono state tenute in conto allo stato limite di esercizio SLE come incremento di apertura delle fessure. Allo stato limite ultimo SLU, l'azione del ritiro/var. termica si considera rilassata.

6 CRITERI DI CALCOLO

6.1 CRITERI DI DEFINIZIONE DELLE AZIONI DI CALCOLO

In ottemperanza al D.M. del 17.01.2018 (Norme tecniche per le costruzioni), i calcoli sono condotti con il metodo semiprobabilistico agli stati limite.

I carichi considerati nelle verifiche sono nominati, come suggerito dalla norma, con la nomenclatura di seguito riportata

g1 Peso proprio degli elementi strutturali

g2 Peso proprio dei carichi permanenti portati (pavimentazioni, parapetti ecc.…)

g3 Altre azioni permanenti

ε1 Distorsioni e presollecitazioni di progetto

ε2 Ritiro e Viscosità

ε3 Variazioni termiche

ε4 Cedimenti vincolari

q1 Carichi variabili da traffico

q2 Incremento dinamico addizionale in presenza di discontinuità

q3 Azione longitudinale di frenamento o accelerazione

q4 Azione centrifuga

q5 Azioni di Neve e Vento

q6 Azioni Sismiche

q7 Resistenze passive dei vincoli

q8 Urto di veicolo in svio

Le combinazioni di carico sono state determinate in riferimento al par. 5.1.3.14 e 2.5.3 del D.M. 17/01/2018 e di seguito riportate:

– **Combinazione fondamentale** (SLU), generalmente impiegata per gli stati limite ultimi:

$$\sum_{i=1}^{3}\gamma_{gi}\cdot g_i+\sum_{i=1}^{4}\gamma_{\varepsilon i}\cdot\varepsilon_i+\gamma_Q\cdot q_1+\sum_{i=2}^{7}\gamma_{qi}\cdot\psi_{0i}\cdot q_i$$

– **Combinazione caratteristica** (rara), generalmente impiegata per gli stati limite di esercizio (SLE) irreversibili

$$\sum_{i=1}^{3}g_i+\sum_{i=1}^{4}\varepsilon_i+q_1+\sum_{i=2}^{7}\psi_{0i}\cdot q_i$$

– **Combinazione frequente** (SLE), generalmente impiegata per gli stati limite di esercizio (SLE) reversibili:

$$\sum_{i=1}^{3}g_i+\sum_{i=1}^{4}\varepsilon_i+\psi_{11}\cdot q_1+\sum_{i=2}^{7}\psi_{2i}\cdot q_i$$

– **Combinazione quasi permanente** (SLE), generalmente impiegata per gli effetti a lungo termine:

$$\sum_{i=1}^{3}g_i+\sum_{i=1}^{4}\varepsilon_i+\sum_{i=2}^{7}\psi_{2i}\cdot q_i$$

– **Combinazione sismica**, impiegata per gli stati limite ultimi e di esercizio connessi all'azione sismica E:

$$E+\sum_{i=1}^{3} g_i+\sum_{i=1}^{4} \varepsilon_i+\sum_{i=2}^{7} \psi_{2i} \cdot q_i$$

– **Combinazione eccezionale**, impiegata per gli stati limite ultimi connessi agli urti ed altre azioni eccezionali

$$\sum_{i=1}^{3} g_i+\sum_{i=1}^{4} \varepsilon_i+q_{8/9}+\sum_{i=2}^{7} \psi_{2i} \cdot q_i$$

Nelle quali:

Le azioni eccezionali connesse agli urti sono prese singolarmente per ogni combinazione.
L'azione sismica verticale non è significativa nel dimensionamento dell'impalcato in quanto non contemporanea al traffico.

I coefficienti di combinazione considerati nel calcolo sono di seguito riportati.

		Coefficiente	EQU[1]	A1	A2
Azioni permanenti g_1 e g_3	favorevoli sfavorevoli	γ_{G1} e γ_{G3}	0,90 1,10	1,00 1,35	1,00 1,00
Azioni permanenti non strutturali [2] g_2	favorevoli sfavorevoli	γ_{G2}	0,00 1,50	0,00 1,50	0,00 1,30
Azioni variabili da traffico	favorevoli sfavorevoli	γ_Q	0,00 1,35	0,00 1,35	0,00 1,15
Azioni variabili	favorevoli sfavorevoli	γ_{Qi}	0,00 1,50	0,00 1,50	0,00 1,30
Distorsioni e presollecitazioni di progetto	favorevoli sfavorevoli	$\gamma_{\varepsilon 1}$	0,90 1,00[3]	1,00 1,00[4]	1,00 1,00
Ritiro e viscosità, Cedimenti vincolari	favorevoli sfavorevoli	$\gamma_{\varepsilon 2}$, $\gamma_{\varepsilon 3}$, $\gamma_{\varepsilon 4}$	0,00 1,20	0,00 1,20	0,00 1,00

(1) Equilibrio che non coinvolga i parametri di deformabilità e resistenza del terreno; altrimenti si applicano i valori della colonna A2.
(2) Nel caso in cui l'intensità dei carichi permanenti non strutturali, o di una parte di essi (ad esempio carichi permanenti portati), sia ben definita in fase di progetto, per detti carichi o per la parte di essi nota si potranno adottare gli stessi coefficienti validi per le azioni permanenti.
(3) 1,30 per instabilità in strutture con precompressione esterna
(4) 1,20 per effetti locali

Tabella 6-1 Tabella dei coefficienti parziali per i ponti

Azioni	Gruppo di azioni (Tab. 5.1.IV)	Coefficiente ψ_0 di combinazione	Coefficiente ψ_1 (valori frequenti)	Coefficiente ψ_2 (valori quasi permanenti)
Azioni da traffico (Tab. 5.1.IV)	Schema 1 (carichi tandem)	0,75	0,75	0,0
	Schemi 1, 5 e 6 (carichi distribuiti	0,40	0,40	0,0
	Schemi 3 e 4 (carichi concentrati)	0,40	0,40	0,0
	Schema 2	0,0	0,75	0,0
	2	0,0	0,0	0,0
	3	0,0	0,0	0,0
	4 (folla)	--	0,75	0,0
	5	0,0	0,0	0,0
Vento	a ponte scarico SLU e SLE	0,6	0,2	0,0
	in esecuzione	0,8	0,0	0,0
	a ponte carico SLU e SLE	0,6	0,0	0,0
Neve	SLU e SLE	0,0	0,0	0,0
	in esecuzione	0,8	0,6	0,5
Temperatura	SLU e SLE	0,6	0,6	0,5

Tabella 6-2 Tabella dei coefficienti ψ per le azioni variabili per ponti stradali e pedonali.

6.2 DEFINIZIONE DELLE RESISTENZE DI CALCOLO

Le resistenze di calcolo adottate per le verifiche strutturali sono definite come segue:

$$f_d = \frac{f_k}{\gamma_m}$$

In cui:

f_d : Resistenza di calcolo

f_k : Resistenza caratteristica

γ_m: coefficiente parziale del materiale

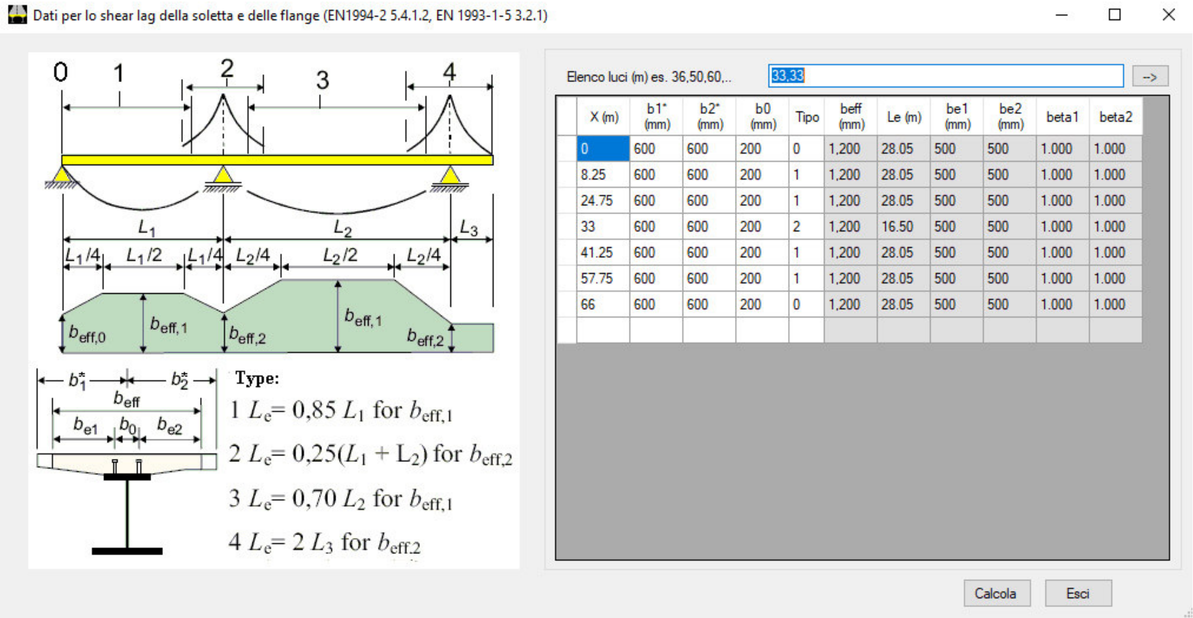
I coefficienti parziali dei materiali adottati, conformi con le NTC 18 sono riportati nella seguente tabella:

Carpenteria metallica	Resistenza delle sezioni	γ_{M0}	1.05
	Resistenza all'instabilità	γ_{M1}	1.1
	Resistenza alla rottura	γ_{M2}	1.25
	Resistenza dei pioli	γ_v	1.25
	Resistenza alla fatica	γ_f	1.35
	Resistenza a scorrimento SLE delle bullonature	γ_{M3}	1.1
Calcestruzzo e Cemento armato	Resistenza del conglomerato	γ_c	1.5
	Resistenza dell'armatura	γ_s	1.15

La resistenza del conglomerato è valutata prendendo in conto il coefficiente riduttivo della resistenza per fenomeni di lunga durata α_{cc}=0.85

6.3 SOLETTA COLLABORANTE PER ANALISI STRUTTURALE DELLE TRAVI

La larghezza collaborante di soletta da considerare per l'analisi delle travi è definita, secondo il punto 4.3.2.3 del D.M. 2018, in funzione dell'interasse delle travi e delle condizioni di vincolamento; La larghezza collaborante afferente in esame è calcolata come segue:



X (m)	b1* (mm)	b2* (mm)	b0 (mm)	Tipo	beff (mm)	Le (m)	be1 (mm)	be2 (mm)	beta1	beta2
0	600	600	200	0	1,200	28.05	500	500	1.000	1.000
8.25	600	600	200	1	1,200	28.05	500	500	1.000	1.000
24.75	600	600	200	1	1,200	28.05	500	500	1.000	1.000
33	600	600	200	2	1,200	16.50	500	500	1.000	1.000
41.25	600	600	200	1	1,200	28.05	500	500	1.000	1.000
57.75	600	600	200	1	1,200	28.05	500	500	1.000	1.000
66	600	600	200	0	1,200	28.05	500	500	1.000	1.000

7 CRITERI DI VERIFICA

7.1 TRAVI PRINCIPALI

7.1.1 Classificazione delle sezioni e calcolo delle sezioni efficaci

Nelle tabelle di verifica esposte nel seguito, sono riportate la classificazione delle sezioni trasversali in accordo con quanto espresso nel D.M.2018, in EN1993 e in EN1994.

Ove le sezioni ricadano in classe 1 o 2 è applicabile la verifica plastica, mentre per le sezioni in classe 3 si effettua la verifica di resistenza della sezione facendo riferimento allo stato limite elastico della sezione completa. Qualora la sezione venga classificata in classe 4 la verifica di resistenza della sezione fa riferimento allo stato limite elastico della sezione efficace.

Si osserva tuttavia che per studiare adeguatamente le sezioni di geometria atipica presenti sulle travi principali dell'impalcato, si farà riferimento allo stato limite elastico a prescindere dalla classificazione delle sezioni.

7.1.2 S.L.U. – Resitenza delle membrature

Le verifica di resistenza delle sezioni allo S.L.U. viene effettuata attraverso i seguenti passaggi:

- Preclassificazione della sezione

Effettuata sulla base delle caratteristiche geometriche dei singoli sotto componenti

- Analisi plastica

Tracciamento dei domini di resistenza della sezione N/M_{rd} ed $N/M_{f,rd}$ (quest'ultimo è il dominio della sezione privata dell'anima).

Per la valutazione di N_{pl} e M_{pl} si seguono i criteri contenuti in EN 1994-2, cap. 6.2.1.2. (4.3.2.1.2. delle NTC 2008).

Il calcolo di M_{pl} viene effettuato mediante semplici considerazioni di equilibrio delle forze plastiche sviluppate dai singoli elementi componenti la sezione, e della eventuale azione assiale concomitante, sotto opportune ipotesi, verificate a posteriori, riguardanti la posizione dell'asse neutro plastico.

In generale, quindi, indicato con:

$N_{abf} = t_{inf} \times b_{inf} \times f_{yinf} / \gamma_{m0}$ azione assiale plastica sviluppabile dalla piattabanda inferiore;

$N_{aweb} = t_{web} \times h_{web} \times f_{yweb} / \gamma_{m0}$ azione assiale plastica sviluppabile dalla anima;

$N_{atf} = t_{sup} \times b_{sup} \times f_{ysup} / \gamma_{m0}$ azione assiale plastica sviluppabile dalla piattabanda superiore;

$N_{c1} = 0.85 \times f_{ck} \times b_{eff} \times t_{c1} / \gamma_c$ azione assiale plastica sviluppabile dal layer di cls (di spessore pari a t_{c1}) compreso tra il layer superiore di armatura e l'estradosso della soletta (agente solo a compressione);

$N_{c2} = 0.85 \times f_{ck} \times b_{eff} \times t_{c2} / \gamma_c$ azione assiale plastica sviluppabile dal layer di cls (di spessore pari a t_{c2}) compreso tra i due layers di armatura (agente solo a compressione);

$N_{c3} = 0.85 \times f_{ck} \times b_{eff} \times t_{c3} / \gamma_c$ azione assiale plastica sviluppabile dal layer di cls (di spessore pari a t_{c3}) compreso tra la piattabanda superiore e il layer di armatura inferiore (agente solo a compressione);

$N_{layer1} = A_{slinf} \times f_{yk} / \gamma_s$ azione assiale plastica sviluppabile dal layer inferiore di armatura (di area complessiva A_{slinf});

$N_{layer2} = A_{slsup} \times f_{yk} / \gamma_s$ azione assiale plastica sviluppabile dal layer superiore di armatura (di area complessiva A_{slsup});

N_e — azione assiale esterna, agente in corrispondenza del baricentro geometrico della sezione;

f_{yinf}, f_{ysup}, f_{yweb} — resistenze caratteristiche di snervamento dell'acciaio componente rispettivamente la piattabanda inferiore, la piattabanda superiore e l'anima;

La posizione dell'asse neutro plastico, per un dato segno dell'azione flettente, è immediatamente e univocamente determinabile dall'esame di relazioni simili alla seguente, esplicitata per il caso di momento flettente negativo (soletta compressa), e asse neutro plastico disposto nell'anima:

$z_{pl} = t_{inf} + (-N_e + N_{layer1} + N_{layer2} + N_{atf} - N_{abf} + N_{aweb})/(2\ t_{web}\ f_{yweb}\ \gamma_{m0})$

Si evidenzia inoltre che:

- l'azione assiale plastica sviluppata dal calcestruzzo in compressione viene valutata sulla base di uno stress block equivalente, di altezza pari a quella effettiva, ma di intensità ridotta all'85% (cfr. EN 1994-2, cap. 6.2.1.2.(1), punto d),
- le armature in compressione vengono considerate, al fine di evitare possibili punti di discontinuità nella ricerca di a.n.p. per azione assiale variabile, rinunciando all'ipotesi semplificativa contemplata da EN 1994-2, cap. 6.2.1.2.(1), punto c
- per i medesimi motivi indicati al punto precedente, i layers di armatura vengono modellati con "strisce" di spessore equivalente.

Il tracciamento dei domini viene effettuato per punti, valutando di volta in volta la posizione dell'asse neutro plastico e il valore di M_{pl} sotto l'azione dell'azione assiale N incrementata da 0 (flessione semplice, positiva o negativa) fino a +/- N_{pl} con incrementi pari a $N_{pl}/10$.

L'operazione viene effettuata in automatico dal programma PontiEC4 per tutte le sezioni di verifica, considerando sia la sezione completa, sia la sezione formata dalle sole flange in acciaio e calcestruzzo.

- Classificazione effettiva della sezione

Effettuata sulla base dell'effettivo valore di N_{Ed}, M_{Ed} per la combinazione in esame

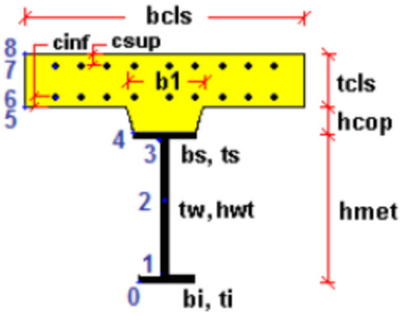
- Verifica plastica a pressoflessione (sezioni cl. 1 e 2):

Valutazione del massimo rapporto di sfruttamento plastico η_1; effettuata con riferimento a N_{Ed}, M_{Ed} agenti isolatamente, e per effetto combinato.

- Verifica elastica a pressoflessione (sezioni cl. 3-4)

Valutazione del massimo rapporto di sfruttamento elastico η_1, effettuata rispettivamente per le sezioni in classe 3 e 4 con riferimento alle caratteristiche geometriche lorde/efficaci. Le caratteristiche geometriche efficaci vengono dedotte in maniera iterativa, tenendo conto delle flessioni parassite che nascono per effetto dell'eccentricità assunta dall'azione assiale di progetto causata dallo "shift" progressivo dell'asse neutro.

Le tensioni vengono valutate in corrispondenza delle 8 fibre indicate nello schema seguente.



Nell'ambito del calcolo tensionale, la soletta viene considerata fessurata (non reagente) all'atto dell'annullamento della tensione di compressione valutata in corrispondenza della fibra media. Contestualmente all'annullamento della soletta, si annullano anche le sollecitazioni da ritiro primario.

- Verifica a taglio - sezioni non soggette a "shear buckling"

Viene effettuato il calcolo del taglio resistente plastico, ed il calcolo del rapporto di sfruttamento a taglio.

- Verifica a taglio - sezioni suscettibili di "shear buckling"

Per sezioni soggette a "shear buckling" viene valutato il coefficiente di riduzione $\chi_{w,}$ e successivamente valutato il taglio resistente $V_{b,Rd}$ come somma dei contributo resistenti dell'anima $V_{bw,Rd}$ e, se applicabile, delle flange $V_{bf,Rd}$, secondo la procedura indicata nell' EN1993-1-5.

- Verifica interazione azione assiale - flessione - taglio (tutte le classi)

Si adotta univocamente, per tutte le classi di sezione, l'approccio proposto da EN 1993-1-5, cap. 7.1, che consiste nella valutazione di un rapporto di sfruttamento modificato in funzione dei singoli rapporti di sfruttamento valutati per pressoflessione e taglio agenti separatamente. L'adozione di questa formulazione risulta a rigore solo leggermente più cautelativa di quella riservata alle sezioni di classe 1 e 2, per le quali l'interazione N-M-V si risolverebbe con la deduzione di un rapporto di sfruttamento elastico per tensioni normali valutato con riferimento ad un'anima opportunamente ridotta per tenere conto dell'influenza del taglio (cfr. EN 1994-2 cap. 6.2.2.4 (2)).

Un'ulteriore ipotesi cautelativa, riservata alla verifica di sezioni in classe 3 e 4, è l'utilizzo sistematico del rapporto di sfruttamento elastico η_1 in luogo di quello plastico $\overline{\eta}_1$, indipendentemente dall'andamento delle tensioni lungo l'anima (a rigore la EN 1993-1-5, cap. 7.1.(4) e (5) prevede tale accortezza solo qualora l'anima risulta interamente in compressione). Inoltre in EN 1993-1-5 7.1 (2) è indicato che la verifica deve essere effettuata a distanza maggiore di $h_w/2$ dalla sezione di appoggio.

Come già evidenziato relativamente al calcolo del contributo resistente a taglio delle flange, le resistenze plastiche della sezione completa e della sezione privata dell'anima sono rilevate direttamente dai rispettivi domini di interazione, per cui:

$M_{pl,Rd} = M_{pl(N),Rd}$ (sezione intera)

$M_{f,Rd} = M_{f(N),Rd}$ (sezione costituita dalle sole flange)

Si rileva che la diseguaglianza associata alla formula di interazione presentata poco sopra, evidenzia implicitamente che la formula non è applicabile (non vi è interazione) qualora il momento di progetto sia minore di quello sopportabile dalle sole flange.

Per sezioni in classe 3 e 4, il momento di progetto M_{Ed} viene valutato sulla base degli stress cumulati nella fibra più sollecitata ($M_{Ed,eq} = \max | W_{xi} * \Sigma\sigma_{x,i} |$).

7.1.3 S.L.E. - Limitazione delle tensioni

La verifica, con riferimento alle tensioni di Von Mises valutate sotto la combinazione fondamentale S.L.E. rara, richiede che sia rispettata la limitazione:

$$\sigma_{x,Ed}^2 + \sigma_{y,Ed}^2 - \sigma_{x,Ed} \cdot \sigma_{y,Ed} + 3 \cdot \tau_{Ed}^2 \leq \left(f_{yk} / \gamma_{m,ser} \right)^2$$

dove:

$\sigma_{x,Ed}$ è il valore di calcolo della tensione normale nel punto in esame, agente in direzione parallela all'asse della membratura;

$\sigma_{z,Ed}$ è il valore di calcolo della tensione normale nel punto in esame, agente in direzione ortogonale all'asse della membratura;

τ_{Ed} è il valore di calcolo della tensione tangenziale nel punto in esame, agente nel piano della sezione della membratura.

$\gamma_{m,ser}$ = 1.0 è il coefficiente da applicare al materiale in condizioni di esercizio.

Tuttavia, in accordo con quanto espresso al paragrafo 7.1.1, essendo tutte le verifiche SLU effettuate nei riguardi dello stato limite elastico delle sezioni, il controllo sulla limitazione delle tensioni allo SLE risulta implicitamente soddisfatto e quindi sulle travi principali verrà omesso.

7.1.4 S.L.E. – Web Breathing

La verifica è volta alla limitazione della snellezza dei singoli pannelli e sotto pannelli. I criteri di verifica sono contenuti nelle istruzioni a NTC-08, cap. 4.2.4.1.3.4, che rimandano a EN 1993.2, cap. 7.4.

Tra i metodi proposti, si sceglie quello più rigoroso, comprendente la verifica diretta della stabilità dei sottopannelli. Tale metodo consistente nel confronto del quadro tensionale indotto dalla combinazione S.L.E. frequente e rappresentato da $\sigma_{x,Ed,ser}$ e $\tau_{xy,Ed,ser}$, con le tensioni normali e tangenziali critiche del pannello. Si applica pertanto la relazione (cfr.1993-2 cap. 7.4.(3)):

$$\sqrt{\left(\frac{\sigma_{x,Ed,ser}}{k_\sigma \sigma_E}\right)^2 + \left(\frac{1.1 \cdot \tau_{x,Ed,ser}}{k_\tau \sigma_E}\right)^2} \leq 1.1$$

In cui:

σ_E è la tensione normale critica viene valutata a partire da quella Euleriana, tenendo conto della eventuale sovrapposizione dei fenomeni di instabilità di piastra e di colonna tramite il coefficiente ξ, seguendo i criteri contenuti in EN 1993-1-5 - 4.5.4.(1).

k_σ,k_τ sono i coefficienti di imbozzamento per tensioni normali e per taglio, funzione della geometria e dello stato di sforzo del pannello.

La verifica viene effettuata in automatico dal programma Ponti EC4, sulla base delle combinazioni S.L.E. frequenti elaborate per tutte le sezioni di verifica.

7.1.5 S.L.U. e S.L.E. - Verifica connessioni trave soletta

Le piolature adottate sono tutte a completo rispristino di resistenza. I dettagli adottati per la connessione trave-soletta sono conformi alle NTC-08 paragrafo 4.3.4.1.2 e C.4.3.4 delle relative istruzioni.

- Verifica tensionale elastica SLU e SLE

La verifica tensionale elastica viene condotta mediante la deduzione del massimo scorrimento "elastico" a taglio sul singolo piolo secondo la condizione di carico analizzata (SLU o SLE). Lo scorrimento unitario è calcolato come segue:

$$\nu_{ED} = \frac{V \cdot S}{J}$$

In cui S e J sono univocamente definite sulla base delle caratteristiche non fessurate.

Quindi si fa il confronto con la portanza del piolo valutata come:

$$P_{RD}^{1} = \frac{0.8 \cdot f_U \cdot \pi \cdot d^2}{4 \cdot \gamma_V}$$

$$P_{RD}^{2} = \frac{0.29 \cdot \alpha \cdot d^2 \sqrt{f_{ck} E_{cm}}}{\gamma_V}$$

$$\alpha = 0.2 \cdot \left(\frac{h_{sc}}{d} + 1 \right) \qquad \text{per} \quad 3 \le \frac{h_{sc}}{d} \le 4$$

$$\alpha = 1 \qquad \text{per} \quad \frac{h_{sc}}{d} > 4$$

$$P_{RD} = \min\left(P_{RD}^{1}, P_{RD}^{2}\right)$$

La verifica sarà quindi condotta come segue:

$$\nu_{ED} \le n \cdot P_{RD} \qquad \text{S.L.U. (combinazione fondamentale)}$$

$$\nu_{ED} \le K_s \cdot n \cdot P_{RD} \qquad \text{S.L.E. (combinazione caratteristica)}$$

K_s è un coefficiente riduttivo per lo S.L.E. assunto pari a 0.6

n è il numero di pioli per unità di lunghezza considerata

- Verifica concentrazione scorrimenti per effetto del ritiro e della variazione termica nelle zone di estremità trave

L'ammontare delle azioni di scorrimento per ritiro e variazione termica nelle zone di coda viene calcolato a partire dall'azione assiale indotta dalle relative deformazioni impresse nella soletta (ritiro e ΔT), assumendo una distribuzione costante del flusso per una lunghezza di trave assunta pari alla larghezza di soletta efficace (b_{eff}).

$$\nu_{L,ED,max} = \frac{V_{L,ED}}{b_{eff}}$$

$$npioli = \frac{\nu_{L,ED,max}}{P_{RD}}$$

n pioli è il numero di pioli da inserire per una lunghezza b_{eff} a partire dalla testata della trave.

7.1.6 S.L.F. - Verifiche a fatica

Le verifiche a fatica sono state condotte con gli stessi criteri sia per le travi principali che per i traversi.

Le verifiche a fatica vengono effettuate con l'impiego del metodo dei coefficienti λ, associato all'impiego del veicolo a fatica FLM3 (istruzioni NTC-18, cap. 4.2.4.1.4.6.3., ovvero EN 1993-2 cap9).

In sintesi, il metodo consente di valutare l'oscillazione di sforzo in un dato dettaglio strutturale sulla base del transito di uno specifico modello di carico (FLM3). L'azione oscillante del singolo automezzo, opportunamente calibrata mediante l'applicazione dei fattori equivalenti di danno, fornisce l'impatto del traffico reale sul dettaglio considerato.

Si ha pertanto:

$\Delta\sigma_p = \| \sigma_{p,max} - \sigma_{p,min} \|$	escursione tensionale, valutata in combinazione di progetto a fatica.
$\Delta\sigma_{E,2} = \lambda \, \Phi_2 \, \Delta\sigma p$	ampiezza equivalente allo spettro di danneggiamento per 0.5E+06 cicli

con:

$\lambda = \lambda_1 \lambda_2 \lambda_3 \lambda_4$	fattore equivalente di danno
Φ_2	fattore di amplificazione dinamica (impatto)

Verifica a fatica:

$$\gamma_{Ff} \, \Delta\sigma_{E,2} \leq \Delta\sigma_c/\gamma_{Mf}$$

In ottemperanza alla norma e nell'ottica del concetto del danneggiamento si pone:

$\gamma_{Ff} = 1$

$\gamma_{Mf} = 1.35$	alta conseguenza a seguito della rottura del dettaglio
$\gamma_{Mf} = 1.15$	bassa conseguenza a seguito della rottura del dettaglio (dettagli secondari)

7.1.6.1 *Coefficienti λ*

Il valore dei coefficienti λ_1, λ_2, λ_3, λ_4 viene determinato secondo quanto previsto in EN 1993-2 cap. 9 e EN 1994-2 § 6.8.6.2. Per l'individuazione delle caratteristiche distintive la tipologia di traffico ed il modello di carico, si fa riferimento alla tabella seguente, tratta da NTC-18 § 5.1.4.3. La strada ospitata dalla struttura in esame viene assunta di categoria 2.

Tab. 5.1.X – *Flusso annuo di veicoli pesanti sulla corsia di marcia lenta*

Categorie di traffico	Flusso annuo di veicoli di peso superiore a 100 kN sulla corsia di marcia lenta
1 - Strade ed autostrade con 2 o più corsie per senso di marcia, caratterizzate da intenso traffico pesante	$2{,}0 \times 10^6$
2 - Strade ed autostrade caratterizzate da traffico pesante di media intensità	$0{,}5 \times 10^6$
3 - Strade principali caratterizzate da traffico pesante di modesta intensità	$0{,}125 \times 10^6$
4 - Strade locali caratterizzate da traffico pesante di intensità molto ridotta	$0{,}05 \times 10^6$

- **Coefficiente λ_1**

Il coefficiente λ_1 dipende dalla lunghezza e tipologia della linea di influenza.

Per la verifica dei dettagli di carpenteria (connettori esclusi), è dedotto dai grafici di seguito riportati, rispettivamente per la zona di centro campata e per la zona in prossimità degli appoggi interni, con riferimento alla luce L calcolata secondo lo schema di cui alla EN 1993-2 cap. 9.5.2.(2).

λ_1, 9.5.2 (2) EN 1993-2, 2006(E)

			Bending moment	Shear force
at midspan		2.55 – 0.7 (L-10) / 70	L = length of span under consideration	L = 0.4 * span under consideration
at support	L< 30 m	2.00 – 0.3 (L-10) / 20	L = the mean of two adjacent spans	L = length of span under consideration
	L ≥ 30 m	1.70 + 0.5 (L-30) / 50		

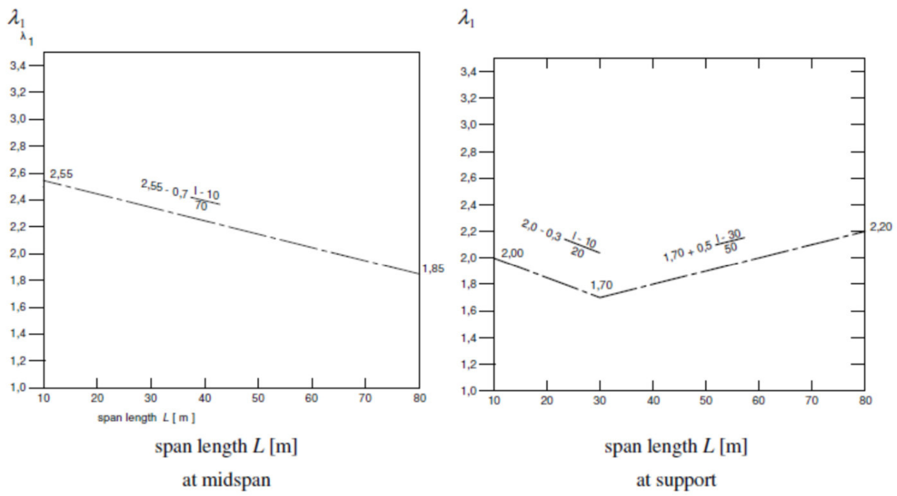


Figure 9.5: λ_1 for moments for road bridges

Per la verifica del sistema di connessione (pioli), con riferimento a EN 1994-2, cap. 6.8.6.2(4), si ha invece (valore valido per tutte le sezioni):

$$\lambda_1 = \lambda_{v1} = 1.55$$

- **Coefficiente λ_2**

Il coefficiente λ_2 dipende dalla tipologia e dal volume di traffico.

Per la valutazione dei dettagli di carpenteria, si fa riferimento a EN 1993-2 § 9.5.2.(3). il coefficiente λ_2 viene determinato in funzione del flusso atteso di veicoli pesanti (N_{Obs}), e dal peso medio degli stessi Q_{m1}, tramite la relazione (*):

$$\lambda_2 = \frac{Q_{m1}}{Q_0}\left(\frac{N_{Obs}}{N_0}\right)^{1/5}$$

Con:

N_{Obs} = 0.5e6 flusso medio veicoli pesanti/anno (strada cat 2 - cfr. tab. prec.)

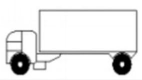
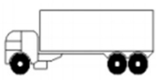
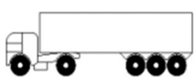
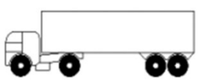
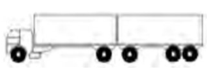
N_0 = 0.5e6 flusso di riferimento

Q_{ml} peso medio dei veicoli, dedotto secondo la composizione di traffico dei veicoli frequenti per la tipologia di strada considerata, e valutato secondo la seguente relazione:

$$Q_{m1} = \left(\frac{\sum n_i Q_i^5}{\sum n_i}\right)^{1/5}$$

Per i valori di Q_i e n_i si adotta la tabella 4.7 di EN 1991-2 cap. 4.6.5.(1), equivalente alla tabella contenuta in NTC-18 cap. 5, e di seguito riportata.

Tab. 5.1.VIII - *Modello di carico di fatica 4 – veicoli equivalenti*

				Composizione del traffico		
Sagoma del veicolo	Tipo di pneumatico (Tab.5.1-IX)	Interassi [m]	Valori equivalenti dei carichi asse [kN]	Lunga percorrenza	Media percorrenza	Traffico locale
	A B	4,50	70 130	20,0	40,0	80,0
	A B B	4,20 1,30	70 120 120	5,0	10,0	5,0
	A B C C C	3,20 5,20 1,30 1,30	70 150 90 90 90	50,0	30,0	5,0
	A B B B	3,40 6,00 1,80	70 140 90 90	15,0	15,0	5,0
	A B C C C	4,80 3,60 4,40 1,30	70 130 90 80 80	10,0	5,0	5,0

Calcolo

$$\lambda_2 = \frac{Q_{ml}}{Q_0}\left(\frac{N_{Obs}}{N_0}\right)^{1/5} \quad Q_{ml} = \left(\frac{\sum n_i Q_i^5}{\sum n_i}\right)^{1/5}$$

$$\lambda_{v2} = \frac{Q_{ml}}{Q_0}\left(\frac{N_{Obs}}{N_0}\right)^{1/8} \quad Q_{ml} = \left(\frac{\sum n_i Q_i^8}{\sum n_i}\right)^{1/8}$$

$\lambda_2 = 0.848$ $\lambda_{v2} = 0.896$

Qo = 480 kN (peso dell'FML3)

No = 0.5E6

Nobs= 5E+5 (Cfr. Tab. 4.5)

Qml= 407 kN (Cfr. Tab. 4.7)

Qmlv= 430.1 kN (Cfr. Tab. 4.7)

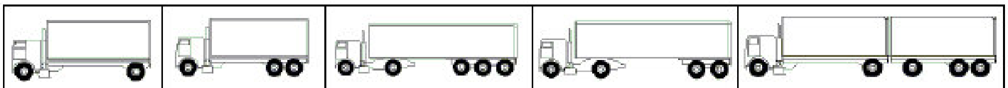
Numero di osservazioni

Table 4.5(n) - Indicative number of heavy vehicles expected per year and per slow lane. EN 1991-2:2003 (E)

		Traffic categories	N_{obs} per year and per slow lane
1	○	Roads and motorways with 2 or more lanes per direction with high flow rates of lorries	$2,0 \times 10^6$
2	◉	Roads and motorways with medium flow rates of lorries	$0,5 \times 10^6$
3	○	Main roads with low flow rates of lorries	$0,125 \times 10^6$
4	○	Local roads with low flow rates of lorries	$0,05 \times 10^6$
	○	User Calcola	

Distribuzioni del carico pesante

Table 4.7 - Set of equivalent lorries. EN 1991-2:2003 (E)



	$Q_1 = 200$ kN	$Q_2 = 310$ kN	$Q_3 = 490$ kN	$Q_4 = 390$ kN	$Q_5 = 450$ kN	
○	20%	5%	50%	15%	10%	**Long distance**
◉	40%	10%	30%	15%	5%	**Medium distance**
○	80%	5%	5%	5%	5%	**Local traffic**
○	%	%	%	%	%	**User** Calcola

$\Lambda_2 = 0.848$

$\Lambda_{v2} = 0.896$

- **coefficiente $\lambda 3$**

Il coefficiente λ_3 dipende dalla vita di progetto della struttura.

Per i dettagli di carpenteria, con riferimento a EN 1993-2 §9.5.2.(5), mediante la relazione:

$$\lambda_3 = \left(\frac{t_{Ld}}{100}\right)^{1/5}$$

dove t_{Ld} è vita di progetto prevista.

Si ottengono pertanto i valori tabellari indicati di seguito.

Table 9.2: λ_3

Design life in years	50	60	70	80	90	100	120
Factor λ_3	0,871	0,903	0,931	0,956	0,979	1,00	1,037

- **coefficiente $\lambda 4$**

Il coefficiente λ_4 dipende dall'organizzazione delle corsie di carico in direzione trasversale e dalla loro posizione relativa sulla linea di influenza trasversale di ciascuna trave.

La formulazione, tratta da EN 1993-2 § 9.5.2.(6), prevede:

$$\lambda_4 = \left[1 + \frac{N_2}{N_1}\left(\frac{\eta_2 Q_{m2}}{\eta_1 Q_{m1}}\right)^5 + \frac{N_3}{N_1}\left(\frac{\eta_3 Q_{m3}}{\eta_1 Q_{m1}}\right)^5 + \ldots + + \frac{N_k}{N_1}\left(\frac{\eta_k Q_{mk}}{\eta_1 Q_{m1}}\right)^5 \right]^{1/5}$$

Nel caso in esame si ha:

e = eccentricità FLM3 rispetto all'asse dell'impalcato

b = interasse fra le travi principali

$\eta_1 = ½ + e/b$

$\eta_2 = ½ - e/b$

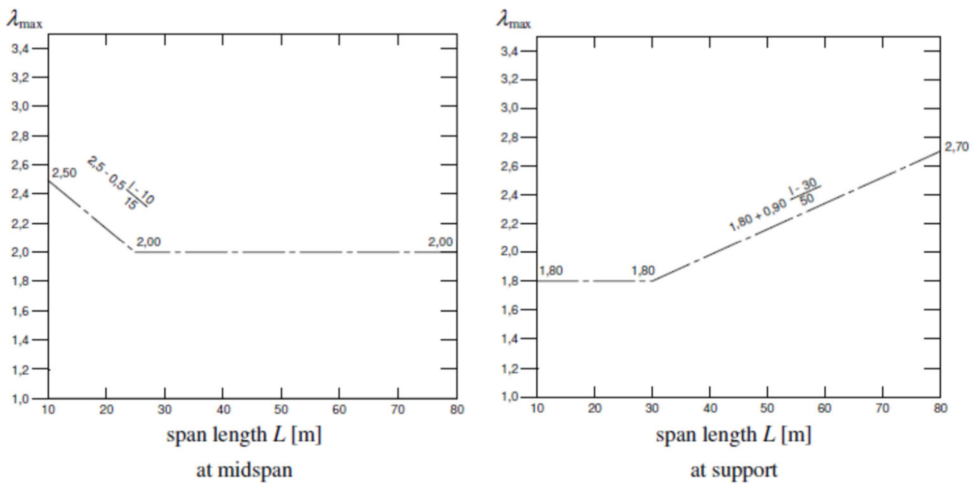
$N_1=N_2$ e $Qm_1=Qm_2$

λ_4 = 1.15 per i dettagli di carpenteria

λ_4 = 1.09 per i connettori

Coefficiente λ - λ_v

Il fattore equivalente di danno (per il momento flettente) è limitato superiormente dal fattore λ_{max}, da valutarsi secondo quanto previsto in EN 1993-2 §9.5.2.(7) in funzione della posizione della sezione verificata e della luce del ponte, con riferimento ai grafici estratti dalla norma, riportati di seguito.



7.1.6.2 *Dettagli e Coefficienti di sicurezza*

Per la verifica a fatica dei **dettagli di carpenteria**, si prendono in esame i dettagli di seguito elencati unitamente alla categoria/num. dettaglio dedotti dalle rispettive tabelle di EN 1993-1-9:

Piattabanda sup. - tensioni normali	categoria/dettaglio:	125/5	tab.8.1 EN 1993-1-9
Piattabanda inf. - tensioni normali	categoria/dettaglio:	125/5	tab.8.1 EN 1993-1-9
Anima - tensioni tangenziali	categoria/dettaglio:	100/6 (5)	tab.8.1 EN 1993-1-9
Giunz. di testa piattabande (1)	categoria/dettaglio:	90/7 (*)	tab.8.3 EN 1993-1-9
Giunz. di testa piattabande (2)	categoria/dettaglio:	112/1 (*)	tab.8.3 EN 1993-1-9
Giunz. di testa anime (1)	categoria/dettaglio:	90/7 (*)	tab.8.3 EN 1993-1-9

Giunz. di testa anime (2)	categoria/dettaglio:	112/1 (*)	tab.8.3 EN 1993-1-9
Saldatura comp. anima-piatt.	categoria/dettaglio:	125/1	tab.8.2 EN 1993-1-9
Attacco irr. vert. - piattabande	categoria/dettaglio:	80/6(**)	tab.8.4 EN 1993-1-9
Attacco irr. vert. - anima	categoria/dettaglio:	80/7(**)	tab.8.4 EN 1993-1-9

(1) per giunzioni fra piatti di spessore diverso

(2) per giunzioni fra piatti di spessore uguale

(*) si conteggia il size effect $k_s = (25/t)^{0.2}$

(**) t < 50 mm in tutti i casi

Per i ***traversi*** si considera:

Piattabanda sup. - tensioni normali	categoria/dettaglio:	90/11	tab.8.1 EN 1993-1-9
Piattabanda inf. - tensioni normali	categoria/dettaglio:	90/11	tab.8.1 EN 1993-1-9
Anima - tensioni tangenziali	categoria/dettaglio:	100/6 (5)	tab.8.1 EN 1993-1-9
Saldatura di attacco tra piatt. dei traversi ad anima travi		80/1 (a)	tab. 8.5 EN 1993-1-9

Per la verifica a fatica delle **piolature** si seguono i criteri generali contenuti in EN 1994-2. Vengono presi in esame i seguenti dettagli (EN 1993-1-9- cap. 8.):

Saldatura piolo - rottura piatt.	categoria/dettaglio:	80/9 (*)	tab.8.4 EN 1993-1-9
Saldatura piolo - rottura piolo	categoria/dettaglio:	90/10	tab.8.5 EN 1993-1-9

Il ciclo di verifica segue quanto previsto in EN 1994-2 cap. 6.8.7.2.(2), comprendendo la verifica separata per rottura del piolo e per rottura della piattabanda.

Per le piattabande in tensione si tiene conto dell'interazione dei due fenomeni, sfruttando la relazione:

$$\frac{\gamma_{Ff}\Delta\sigma_{E,2}}{\Delta\sigma_c / \gamma_{Mf}} + \frac{\gamma_{Ff}\Delta\tau_{E,2}}{\Delta\tau_c / \gamma_{Mf,s}} \leq 1.3$$

$$\frac{\gamma_{Ff}\Delta\sigma_{E,2}}{\Delta\sigma_c / \gamma_{Mf}} \leq 1 \quad \frac{\gamma_{Ff}\Delta\tau_{E,2}}{\Delta\tau_c / \gamma_{Mf,s}} \leq 1$$

Per tutti i dettagli, nell'ambito dell'approccio “vita illimitata”, si adotteranno i seguenti coefficienti di sicurezza:

$\gamma_{Mf} = 1.35$ per tutti i dettagli di carpenteria

$\gamma_{Mf} = 1.15$ per la rottura del piolo

8 ANALISI DEI CARICHI

Si riportano i carichi utilizzati nel dimensionamento dell'impalcato

8.1 CARICHI PERMANENTI (g_1 E g_2)

I carichi permanenti sull'impalcato, sono riportati nella seguente tabella.

GEOMETRIA E CARICHI IMPALCATO		
Lunghezza impalcato	66	m
Larghezza pavimentazione	7.50	m
Larghezza cordolo1	2.40	m
Larghezza cordolo2	0.65	m
Spessore soletta	0.20	m
Spessore pavimentazione	0.11	m
Spessore cordolo 1	0.26	m
Spessore cordolo 1	0.16	m
Altezza traverso	0,55	m
Incidenza in peso della struttura in acciaio	4.0	kN/m^2
Peso proprio traverso	2.0	kN/m
Peso specifico pavimentazione	23.0	kN/m^3
Peso linearizzato barriere di sicurezza	1.5	kN/m
Peso linearizzato rete parasassi	1.5	kN/m

CARICHI PROPRI	A TRAVE	
Pesi propri strutturali		
Struttura in acciaio	4.80	kN/ml
Soletta	6.00	kN/ml
TOT Pesi propri	10.80	kN/ml

Per quanto riguarda i carichi permanenti portati si riporta la somma relativa all'intero impalcato:

CARICHI PERMANENTI	A IMPALCATO	
Pesi permanenti portati		
Cordoli	28.9+2.6	kN/ml
Pavimentazione	18.98	kN/ml
Somma Barriere/rete parasassi	4,50	kN/ml
TOT Permanenti portati	54.98	kN/ml

8.2 RITIRO DIFFERENZIALE FRA TRAVE E SOLETTA (ε_2)

L'azione da ritiro è stata determinata secondo il punto 11.2.10.6 delle NTC 08. Si è considerato un calcestruzzo a ritiro compensato.

La dilatazione lineare specifica finale da ritiro per il conglomerato della soletta, sottoposto a maturazione in ambiente con umidità relativa di circa 55% e avente dimensione fittizia $h0=2A_c/u \cong 40$ (rapporto tra l'area della sezione della soletta e il perimetro della stessa a contatto con l'atmosfera), risulta:

ε_{sh} = 0.00012

in cui è stato assunto t0, età del conglomerato a partire dalla quale si considera l'effetto del ritiro, compreso tra 8 e 60 giorni.

Per le travi, essendo elementi composti acciaio-calcestruzzo, si sono valutati separatamente gli effetti primari del ritiro e gli effetti secondari (dovuti all'iperstaticità della struttura). Gli effetti primari vengono valutati con la formula:

$N_r = \varepsilon_{sh} * E_s/n_{f2b} * b_{eff} * t_{cls}$

$M_r = N_r * e$

In particolare con "e" si è indicata l'eccentricità fra il baricentro della soletta e il baricentro della sezione composta omogeneizzata. In sede di verifica tensionale, nella soletta, alle tensioni indotte da N_r e M_r si aggiunge lo stato di coazione locale di trazione $\sigma_{sh} = \varepsilon_{sh} * E_s/n_{f2b}$. Gli effetti del ritiro primario nelle verifiche sono calcolati automaticamente dal software PontiEC4 sezione per sezione, e sono ignorati nelle zone fessurate in accordo a EN1994-2, 5.4.2.2 (8); gli effetti secondari sono presi in conto dalla modellazione globale effettuata con Lusas di cui si riportano nel seguito dei paragrafi le sollecitazioni.

8.3 VARIAZIONE TERMICA DIFFERENZIALE (ε3)

Nelle strutture miste, vista la differente inerzia termica dei materiali che costituiscono l'impalcato, si considera una variazione termica uniforme sulla soletta di ±10°C, come da indicazioni in EC1 Parte 5 Cap 6.1 previsto dall'Approccio 2 per impalcati misti acciaio-calcestruzzo. Questa coazione è stata trattata in termini analoghi al ritiro: si sono cioè implementati gli effetti iperstatici nel modello Straus7, e gli effetti isostatici sono calcolati sezione per sezione in Ponti EC4 così come descritto per il ritiro.

La dilatazione termica differenziale considerata nei calcoli è la seguente:

$\varepsilon_{\Delta T} = \alpha * \Delta T$ = 1,2 E-5 x 10 = 1.2 E-4

8.4 CEDIMENTI DIFFERENZIALI DEGLI APPOGGI (ε_4)

Nelle strutture miste, vista la differente inerzia termica dei materiali che costituiscono l'impalcato, si considera una variazione termica uniforme sulla soletta di ±10°C, come da indicazioni in EC1 Parte 5 Cap 6.1 previsto dall'Approccio 2 per impalcati misti acciaio-calcestruzzo. Questa coazione è stata trattata in termini analoghi al ritiro: si sono cioè implementati gli effetti iperstatici nel modello Straus7, e gli effetti isostatici sono calcolati sezione per sezione in Ponti EC4 così come descritto per il ritiro.

La dilatazione termica differenziale considerata nei calcoli è la seguente:

$\varepsilon_{\Delta T} = \alpha * \Delta T = 1{,}2\ E\text{-}5 \times 10 = 1.2\ E\text{-}4$

8.5 CARICHI ACCIDENTALI (q1)

8.5.1 Verifiche di resistenza

Si seguono le disposizioni contenute nel D.M. 2018, cap. 5.1.3.3.5, equivalenti a quelle contenute in EN 1991-2. Si fa riferimento a ponti di I categoria.

Nel caso in esame, la carreggiata, di larghezza utile pari a 7.5 m, è in grado di ospitare 2 corsie di carico di larghezza convenzionale pari a 3.0 m. La parte rimanente è pari a 1.5 m.

Corsia di carico n.1 costituita da:

- ✓ Schema di carico n.1: n. 4 carichi concentrati da 150 kN disposti a interasse 2.00m in direzione longitudinale al viadotto e 1.2 m in direzione trasversale
- ✓ Carico uniformemente ripartito d'intensità 9.0 kN/m^2 su una larghezza di 3.00m

Corsia di carico n. 2 costituita da:

- ✓ Schema di carico n.1 ridotto: n. 4 carichi concentrati da 100 kN disposti a interasse 2.00m in direzione longitudinale al viadotto e 1.2 m in direzione trasversale
- ✓ Carico uniformemente ripartito d'intensità 2.5 kN/m^2 su una larghezza di 3.00m.

Corsia di carico n. 3 (parte rimanente) costituita da:

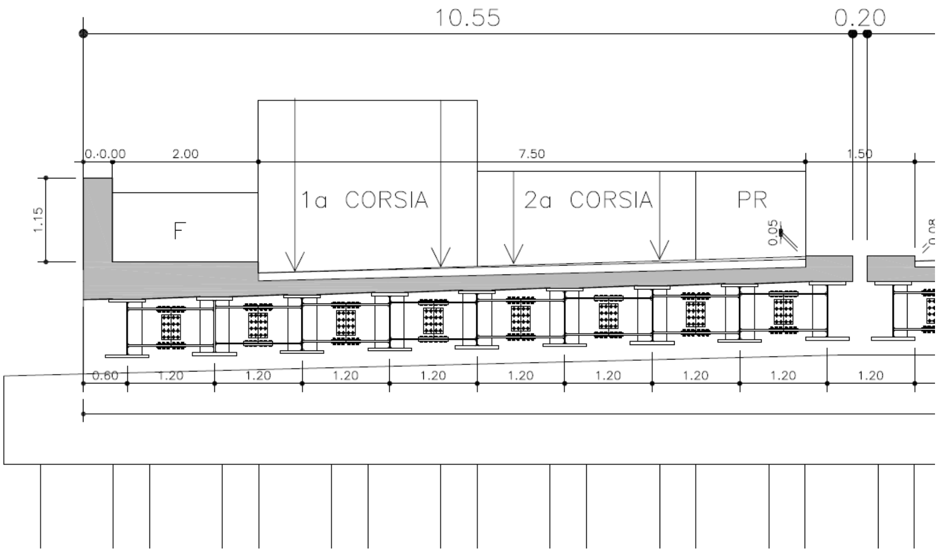
- ✓ Carico uniformemente ripartito d'intensità 2.5 kN/m^2 su una larghezza residua d'impalcato.

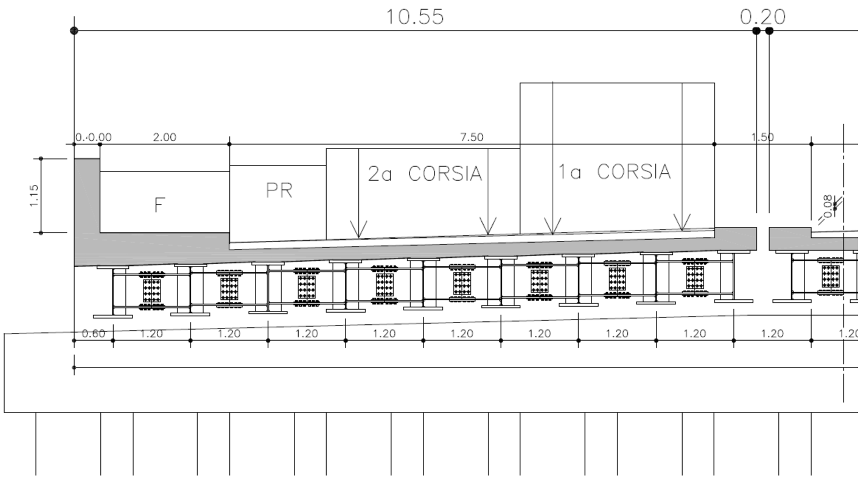
Folla costituita da:

- ✓ Carico uniformemente ripartito d'intensità 2.5 kN/m^2 sul marciapiede lato esterno impalcato di larghezza 2.00m.

Dai carichi descritti si è individuata la seguente disposizione, mirata a massimizzare gli effetti sulla travata 1, mostrata nella figura sottostante.

Nel seguito si riporta lo schema di carico 1 utilizzato:



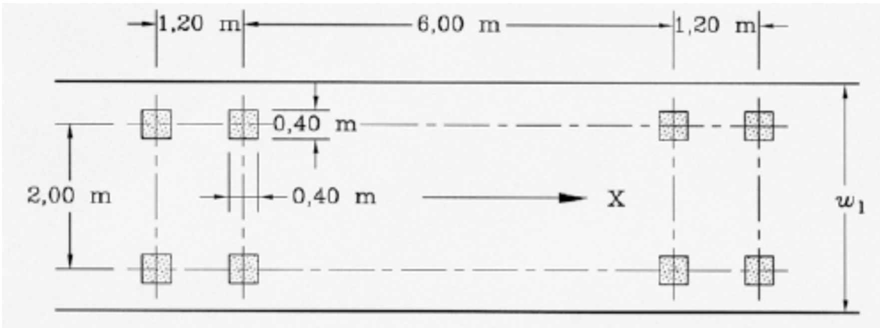


In Questi schemi si è poi provveduto ad annullare progressivamente le corsie più laterali in modo da massimizzare eventualmente le sollecitazioni sulle travi di bordo.

Per le verifiche locali della soletta d'impalcato si ricorre allo schema di carico globale oltre al "Modello di carico 2" (LM2), composto da un veicolo ad un solo asse, avente un peso complessivo pari a 400 kN. Dettagli riguardo alle posizioni più significative di tale carico vengono forniti nel paragrafo relativo alle verifiche locali della soletta.

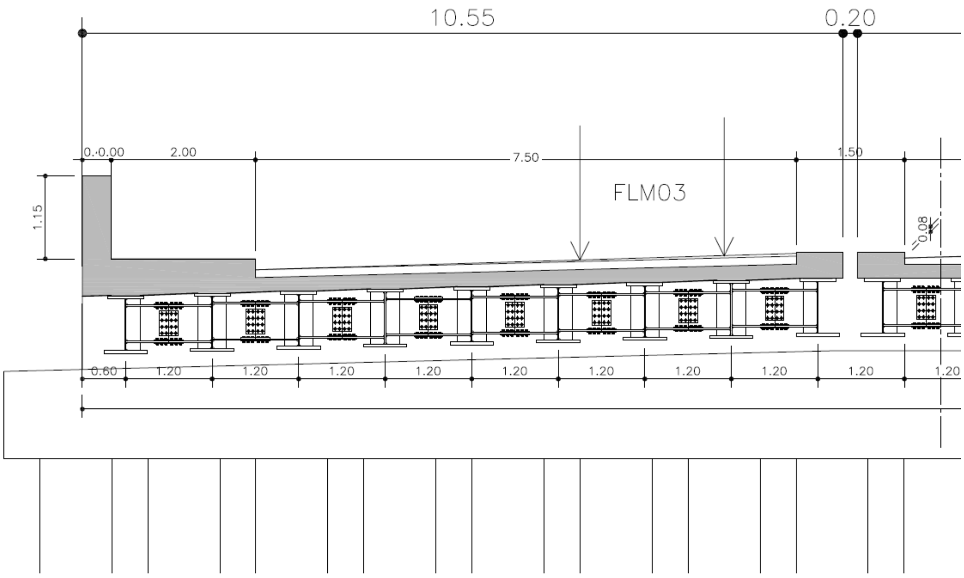
8.5.2 Verifiche a fatica

Le verifiche a fatica sono effettuate con riferimento al metodo dei coefficienti λ. Pertanto si considera il transito sulla corsia lenta del veicolo FLM3, formato da 4 assi da 120.0 kN ciascuno, ed avente la configurazione planimetrica indicata in figura.



La struttura in esame è a carreggiata unica con doppio senso di marcia e pertanto si considera la presenza di due corsie lente, posizionate nella loro collocazione reale di progetto. La presenza della doppia corsia lenta e delle rispettive posizioni, è tenuta in conto attraverso il coefficiente λ_4.

Nel seguito si riporta lo schema di carico utilizzato, mirato a massimizzare gli effetti sulla travata di bordo:



8.6 AZIONE DI FRENAMENTO DEL VEICOLO (Q_3)

Anche in merito all'azione di frenamento si rimanda a quanto prescritto dal DM 17.01.18

L'azione è stata prevista al livello della superficie stradale, come prescritto dalla stessa normativa.

$$180\text{kN} \le q_3 = 0.6 \cdot \left(2 \cdot Q_{1k}\right) + 0.10 \cdot q_{1k} \cdot w_1 \cdot L \le 900\text{kN}$$

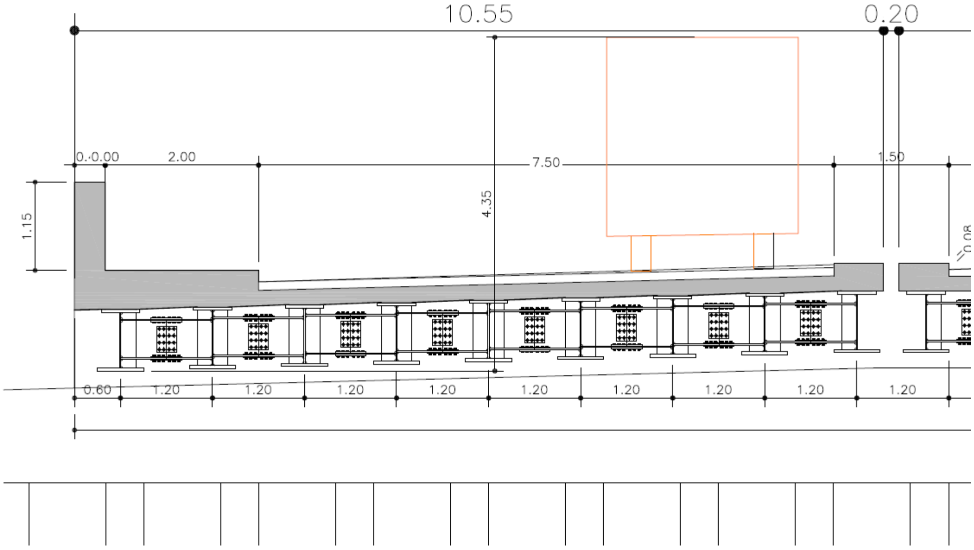
L'azione di frenamento complessiva è pari a 538 kN. Tale sollecitazione non è presa in considerazione in questo documento poiché produce sollecitazioni trascurabili sugli elementi d'impalcato.

8.7 AZIONE CENTRIFUGA (Q_4)

Essendo l'opera in rettifilo, l'azione centrifuga non è presente.

8.8 AZIONE DEL VENTO E DELLA NEVE (Q_5)

L'azione del vento perpendicolare all'impalcato viene calcolata come indicato al p.to 3.3 del DM 2018 considerando un veicolo di altezza pari a 3,00 m. Nel nostro caso verrà considerata cautelativamente un'altezza di 4.35 m.



Si assume cautelativamente una pressione del vento massima e pari a 2.50 kPa.

p_w = 2.50 kN/m^2 Pressione del vento

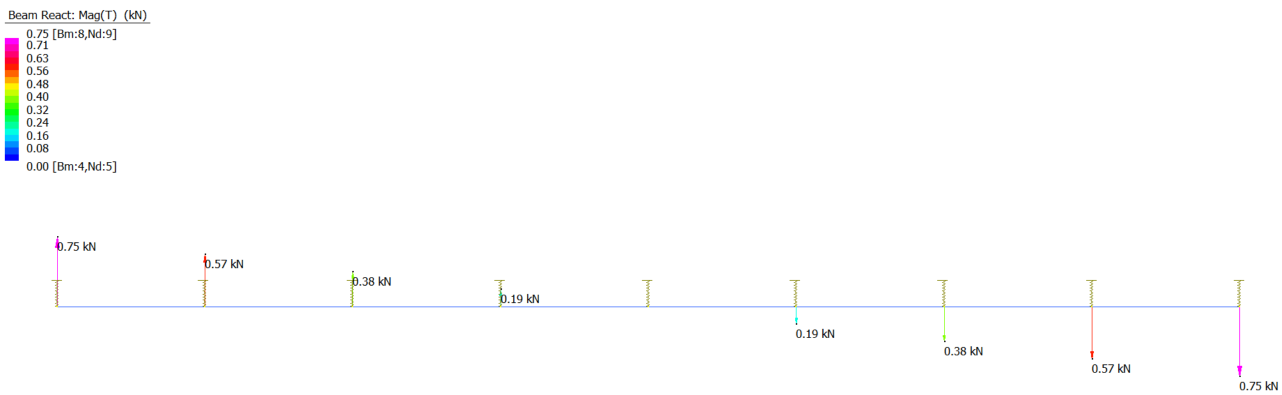
H_{tot} = 4.35 m Altezza totale della superficie esposta al vento

F_v = 2.5x4.35 = 10.88 kN/m Azione risultante del vento

l'azione del vento induce sull'impalcato un'azione torcente pari a:

M = 10.88 x 1.25 = 13.6 kNm/m

Dove 1.25m è la distanza massima dalla risultante dell'azione del vento agli appoggi della trave. Il momento torcente si traduce in un carico lineare distribuito sulla trave paria a:



Si assume cautelativamente q_v=0.75 kN/m per la singola trave.

Il carico da neve, non essendo contemporaneo al traffico, non è significativo nel dimensionamento del ponte.

8.9 AZIONE SISMICA (Q_6)

Ai fini del calcolo dell'impalcato l'azione sismica non è significativa per il dimensionamento in quanto non contemporanea ai carichi verticali e di entità inferiore.

Risulta invece significativa per lo studio del comportamento sismico dell'opera ai fini del calcolo delle sottostrutture e degli appoggi. A questo fine è stata condotta una analisi modale con spettro di risposta. Si rimanda al capitolo 12 per ulteriori dettagli dell'analisi sismica condotta.

Si riporta la definizione dell'azione sismica che verrà utilizzata per il dimensionamento degli apparecchi di appoggio (isolatori elastomerici in neoprene armato), dei giunti e delle azioni trasmesse alle sottostrutture.

Per la definizione dell'azione sismica di progetto si considerano i seguenti parametri:

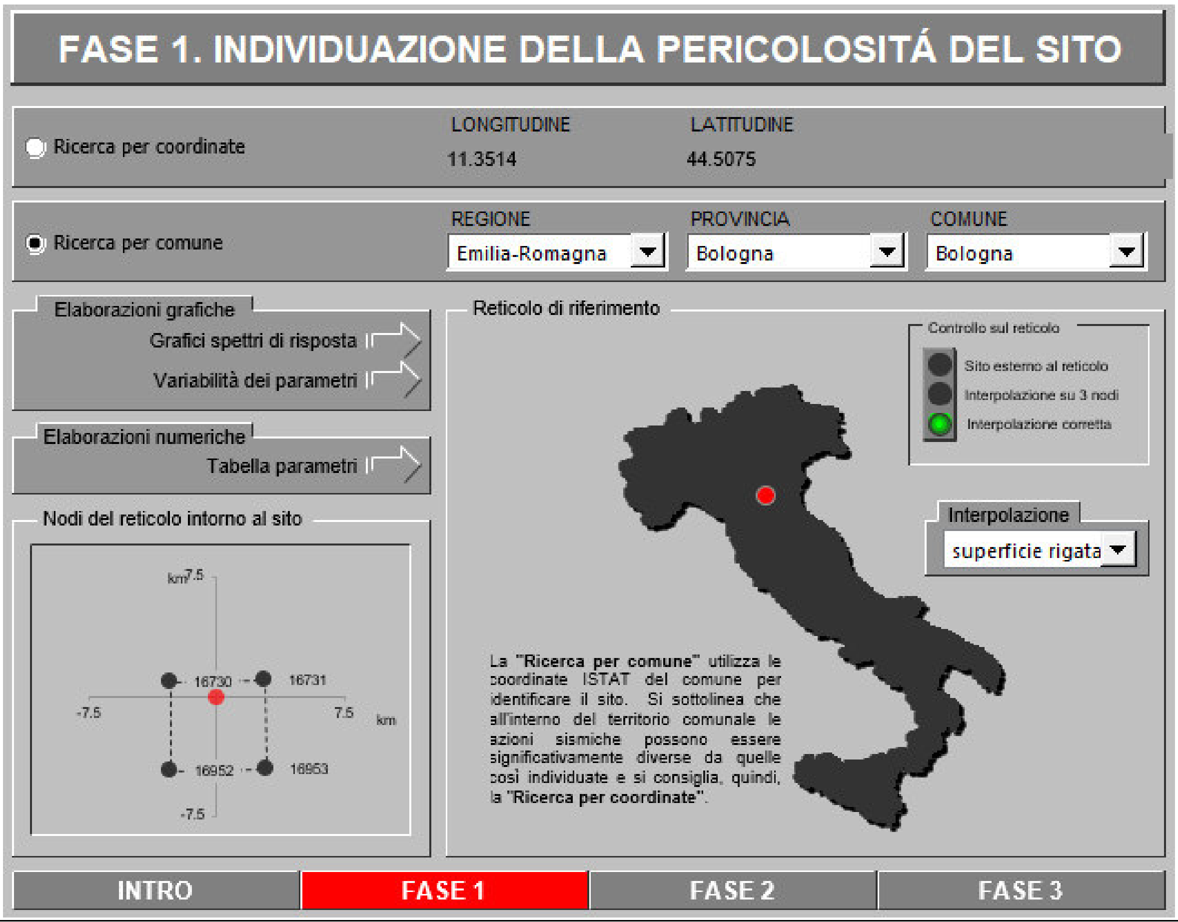
- Classe d'uso: L'opera è classificata come Classe d'uso IV e quindi un coefficiente d'uso pari a:

  $C_u = 2$
- Vita nominale: Vn = 50anni

Da cui si ricava il periodo di riferimento per l'azione sismica:

$$V_R = 50x2 = 100anni$$

A tale valore del periodo di riferimento, considerando l'ubicazione geografica dell'opera, si ricavano, a partire dalla micro-zonazione sismica del territorio nazionale, i parametri riportati nella tabella seguente per la determinazione dell'azione sismica di progetto:



Valori dei parametri a_g, F_o, T_C^* per i periodi di ritorno T_R di riferimento

SLATO LIMITE	T_R [anni]	a_g [g]	F_o [-]	T_C^* [s]
SLO	60	0.072	2.481	0.275
SLD	101	0.088	2.473	0.285
SLV	949	0.210	2.435	0.314
SLC	1950	0.263	2.451	0.321

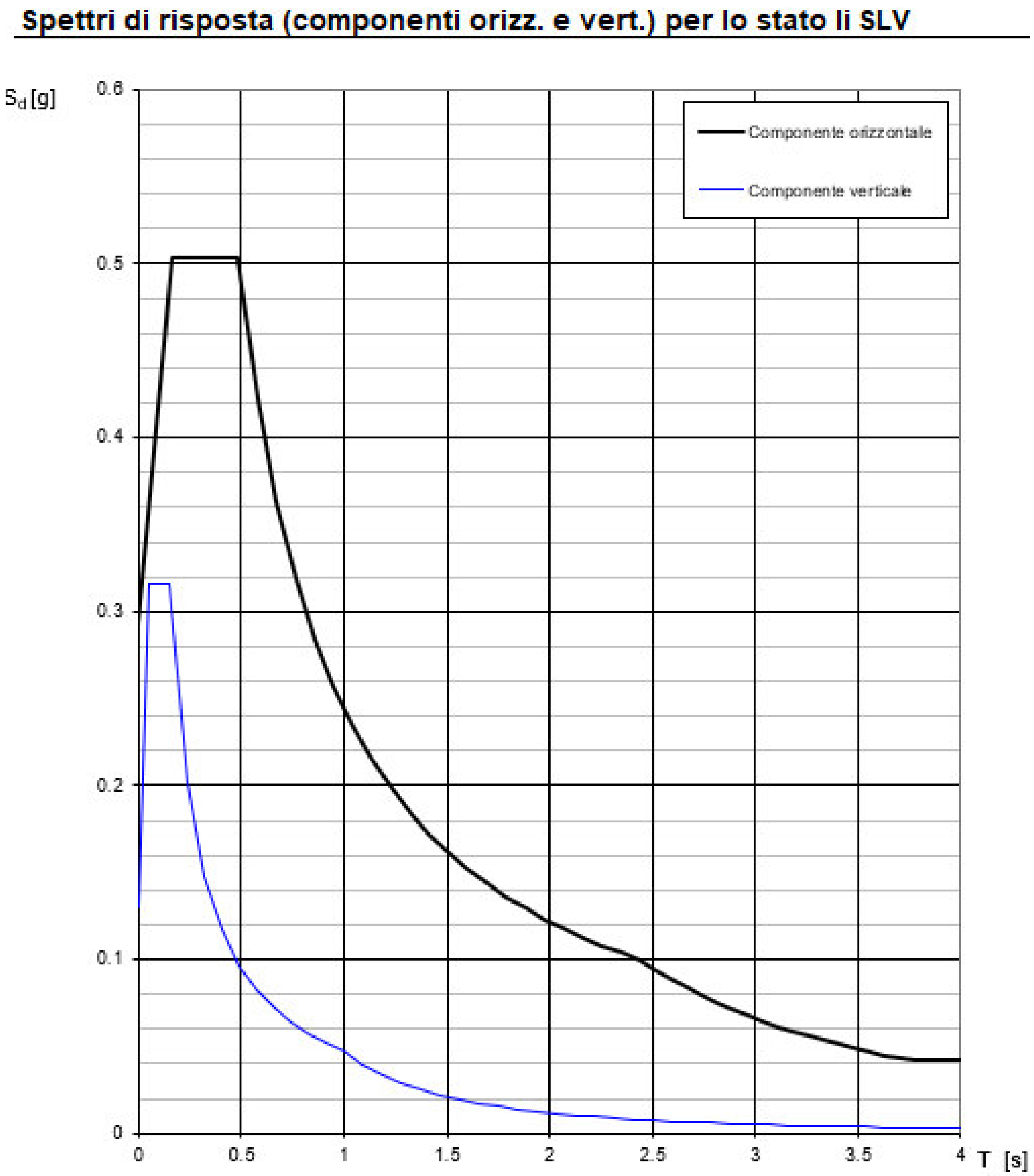
Gli altri parametri considerati ai fini del calcolo dell'azione sismica sono:

- Classificazione sismica del suolo di fondazione: C
- Categoria Topografica T1: S_T = 1.00
- Coefficiente amplificazione stratigrafica: S_s = 1.391 (SLV)

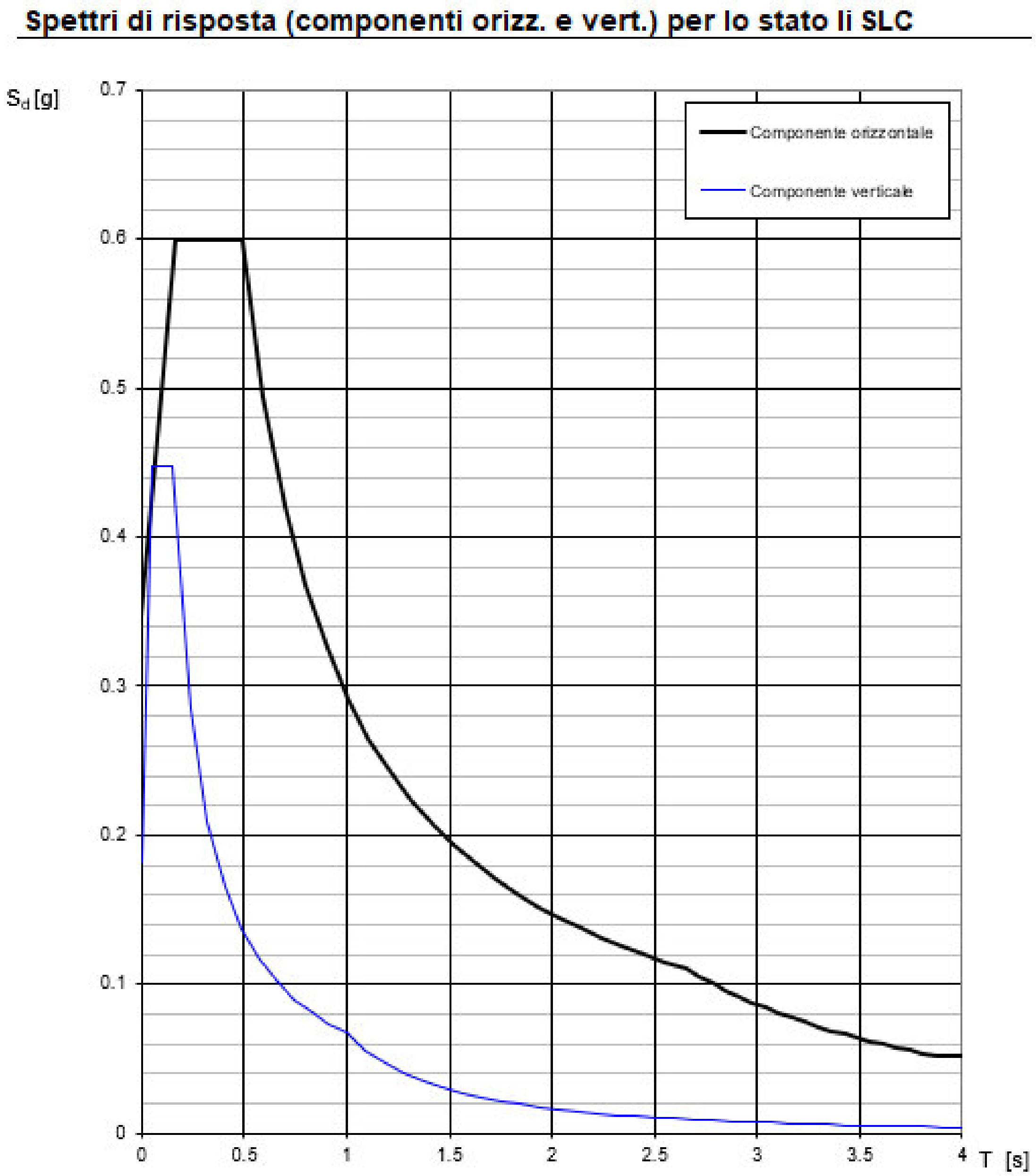
Sulla base dei parametri riportati in precedenza è possibile ricavare (mediante le funzioni riportate al 3.2.3.2.1 delle NTC'18) gli spettri di progetto in termini di accelerazione elastica per gli stati limite SLV ed SLC.

Gli spettri sono riportati nel grafico seguente considerando uno smorzamento del 15%, essendo tale valore il valore di smorzamento degli isolatori. Si precisa quindi che come da NTC18 al 7.10.5.3.1 solo il campo di periodi con T>0.8 T_{iso} andrebbe ridotto del fattore η. Ma essendo la struttura isolata è comunque accettabile ridurre tutti i periodi del valore di smorzamento, non essendo i bassi periodi significativi nell'analisi svolta.

Spettri di risposta (componenti orizz. e vert.) per lo stato limite: SLV



Spettri di risposta (componenti orizz. e vert.) per lo stato limite: SLC



8.10 RESISTENZE PASSIVE DEI VINCOLI (Q_7)

Tali valori non sono significativi nel dimensionamento delle travi d'impalcato.

9 TRAVI PRINCIPALI

Gli effetti delle azioni sono stati valutati mediante un'analisi globale elastica.

L'analisi è stata eseguita mediante l'utilizzo di un modello di calcolo agli elementi finiti come precedentemente descritto.

9.1 SEZIONI SIGNIFICATIVE DI VERIFICA

Le sezioni significative per le verifiche strutturali delle travi principali sono evidenziate nel seguito:

S1	Sezione di Spalla (Taglio massimo)	→ z=0.00m
S2a	Sezione di fine Concio A	→ z=7.00m
S2b	Sezione di inizio Concio B	→ z=7.00m
S3a	Sezione di fine Concio B	→ z=17.00m
S3b	Sezione di inizio Concio C	→ z=17.00m
S4a	Sezione di fine Concio C	→ z=27.00m
S4b	Sezione di inizio Concio D	→ z=27.00m
S5	Sezione di Pila	→ z=33.00m

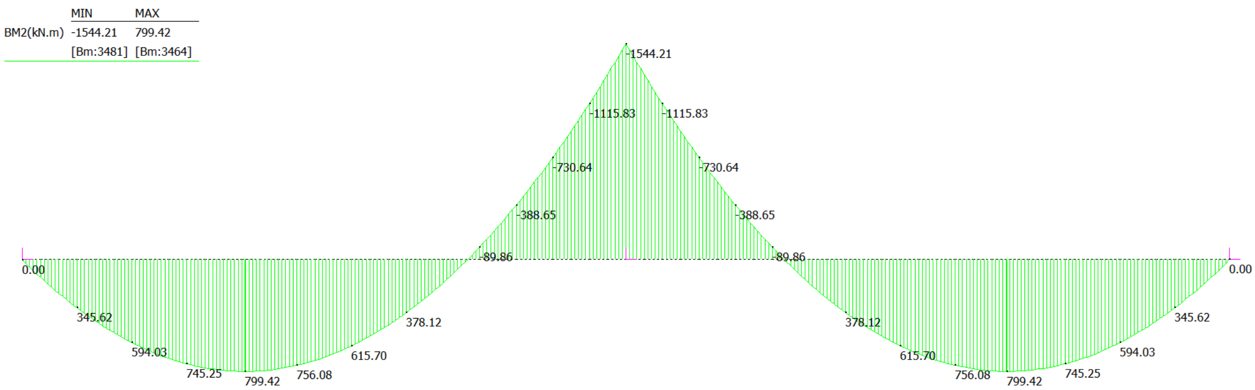
9.2 DIAGRAMMI DELLE SOLLECITAZIONI

Le unità di misura sono kN e kNm, i valori delle mappe sono relativi ai carichi nominali, quindi non fattorizzati.

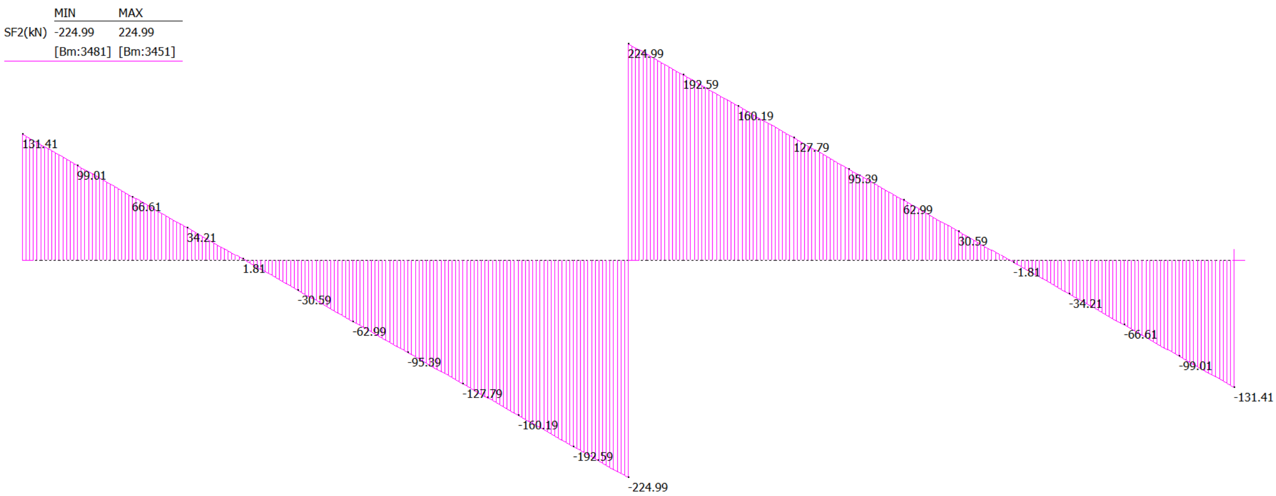
9.2.1 Pesi propri acciaio + soletta

Le sollecitazioni per questi carichi le di desumono dal modello monofilare relativo ad una sola trave.

Momento flettente:



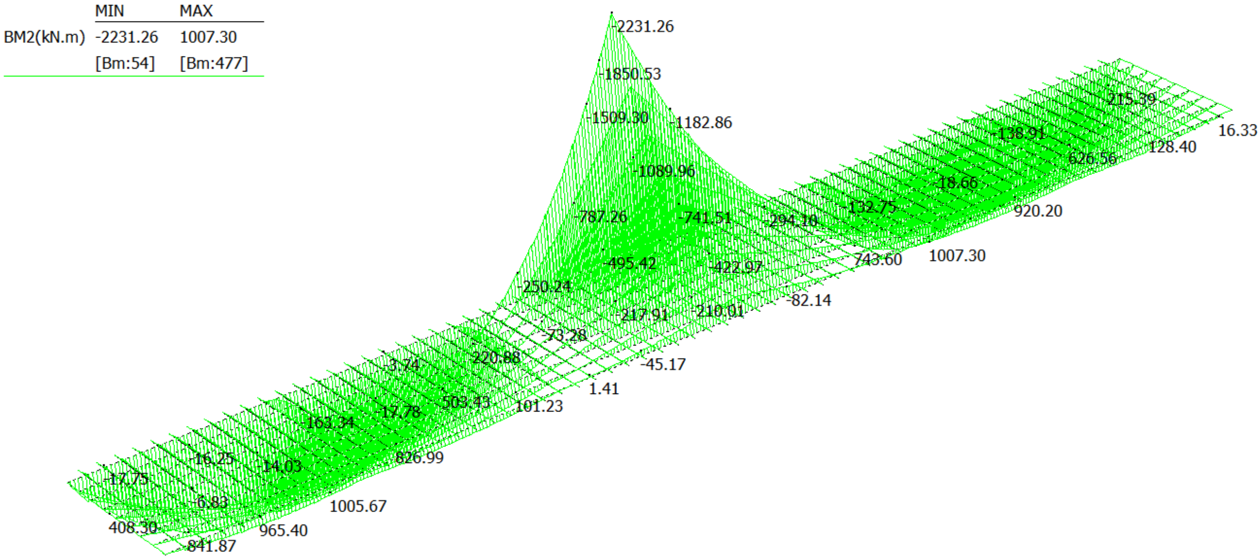
Taglio:



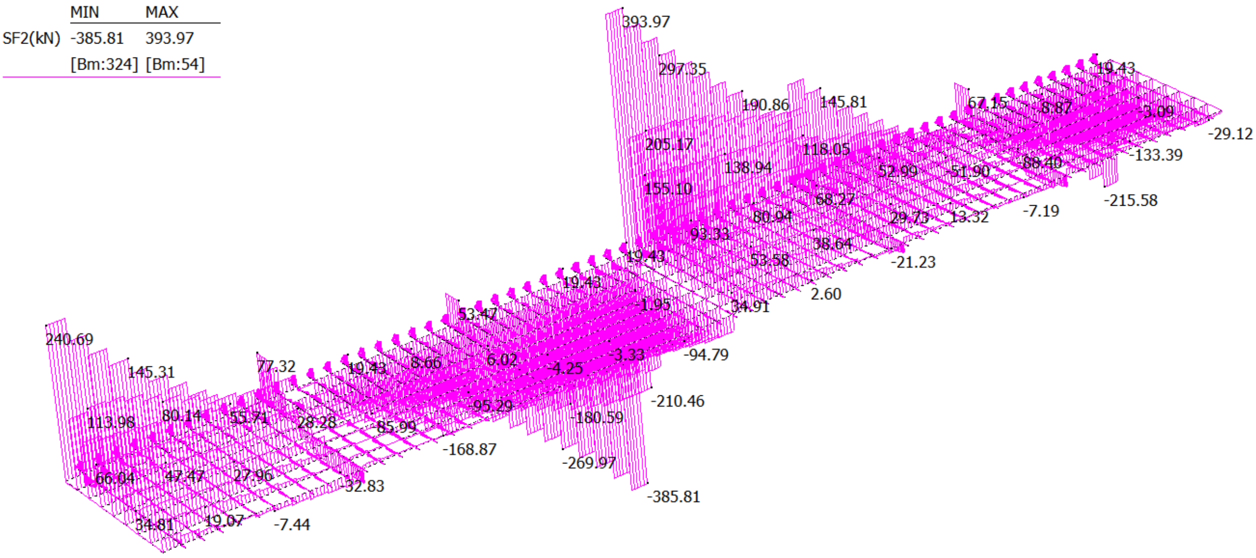
9.2.2 Pesi permanenti portati (pavimentazione, cordoli, barriere e reti)

Le sollecitazioni per questi carichi sono relative al modello di calcolo 3d.

Momento flettente:

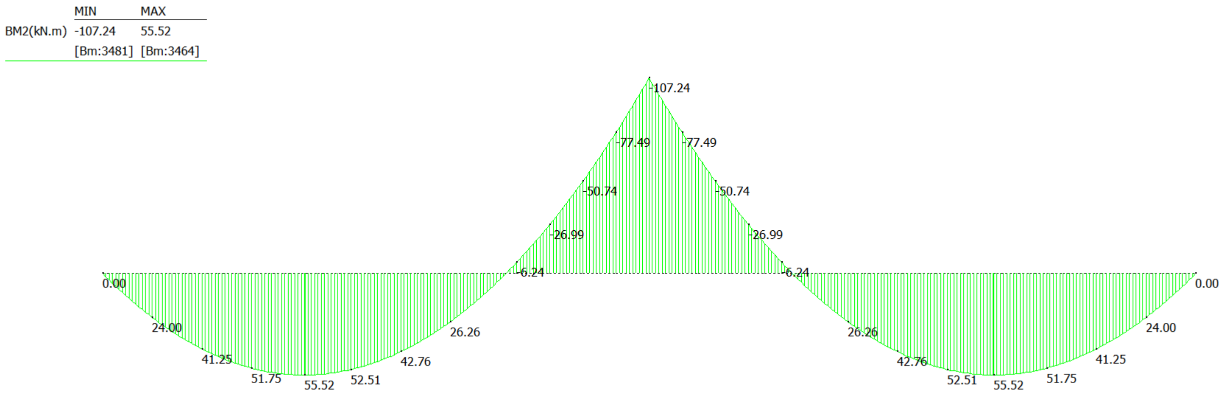


Taglio:

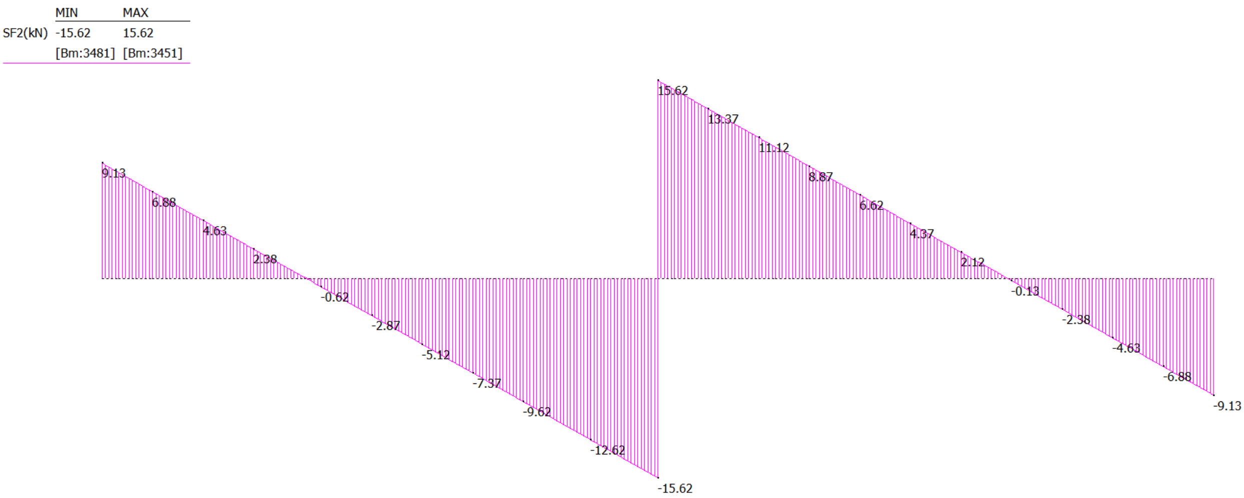


9.2.3 Azione del vento

Momento flettente:



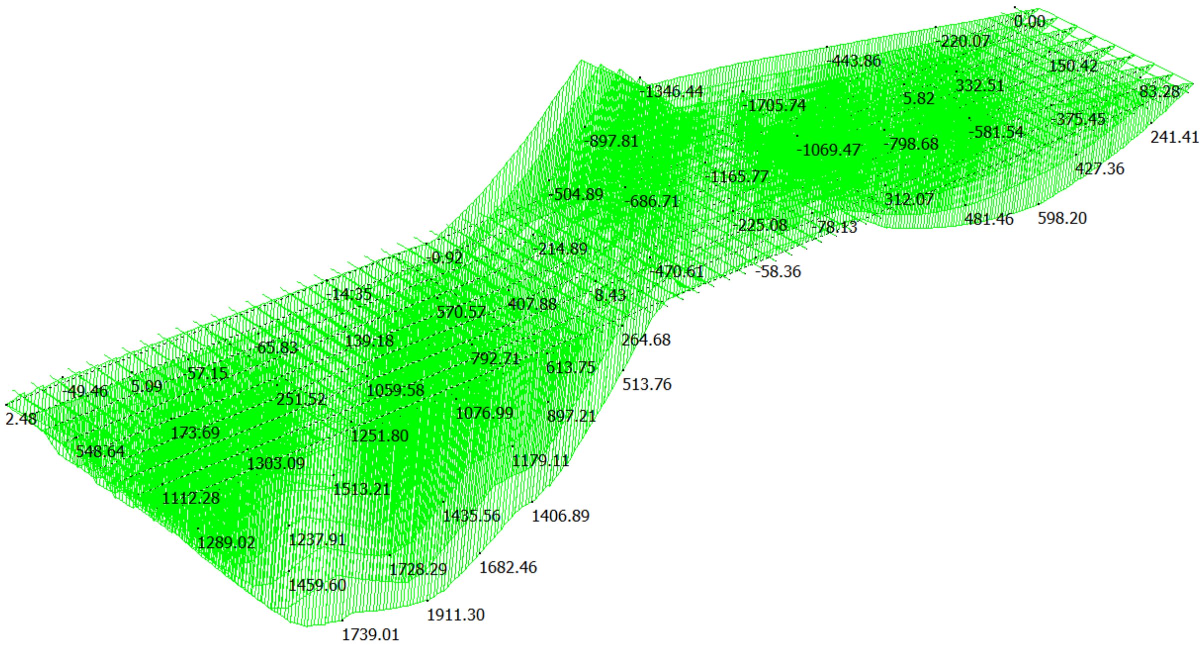
Taglio:



9.2.4 Carichi accidentali

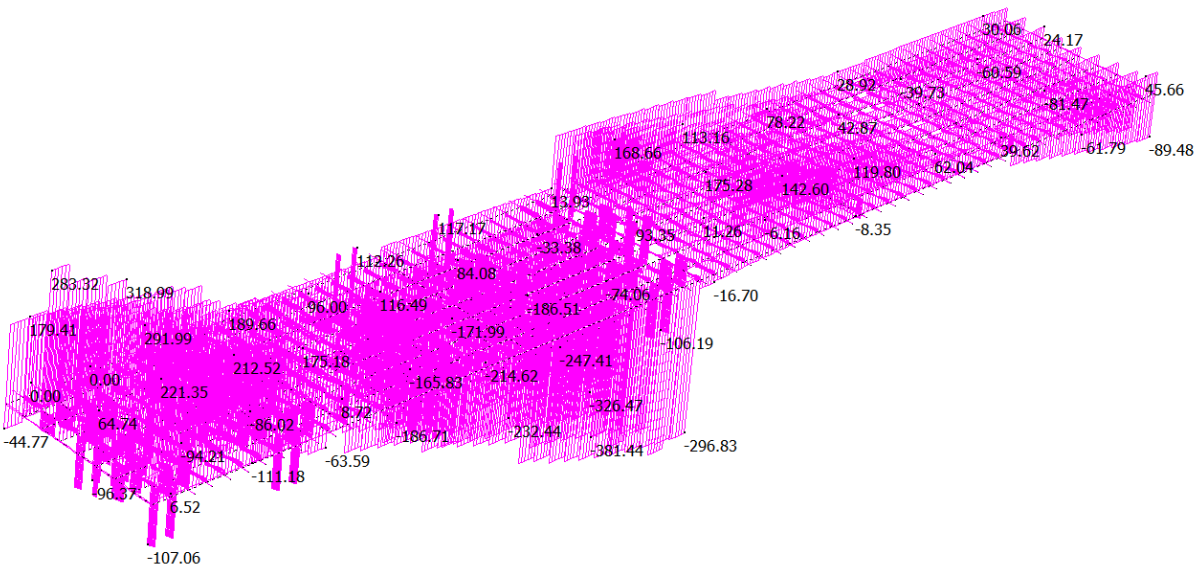
Momento flettente:

	MIN	MAX
BM2(kN.m)	-1705.74	1911.30
	[Bm:3827]	[Bm:4097]



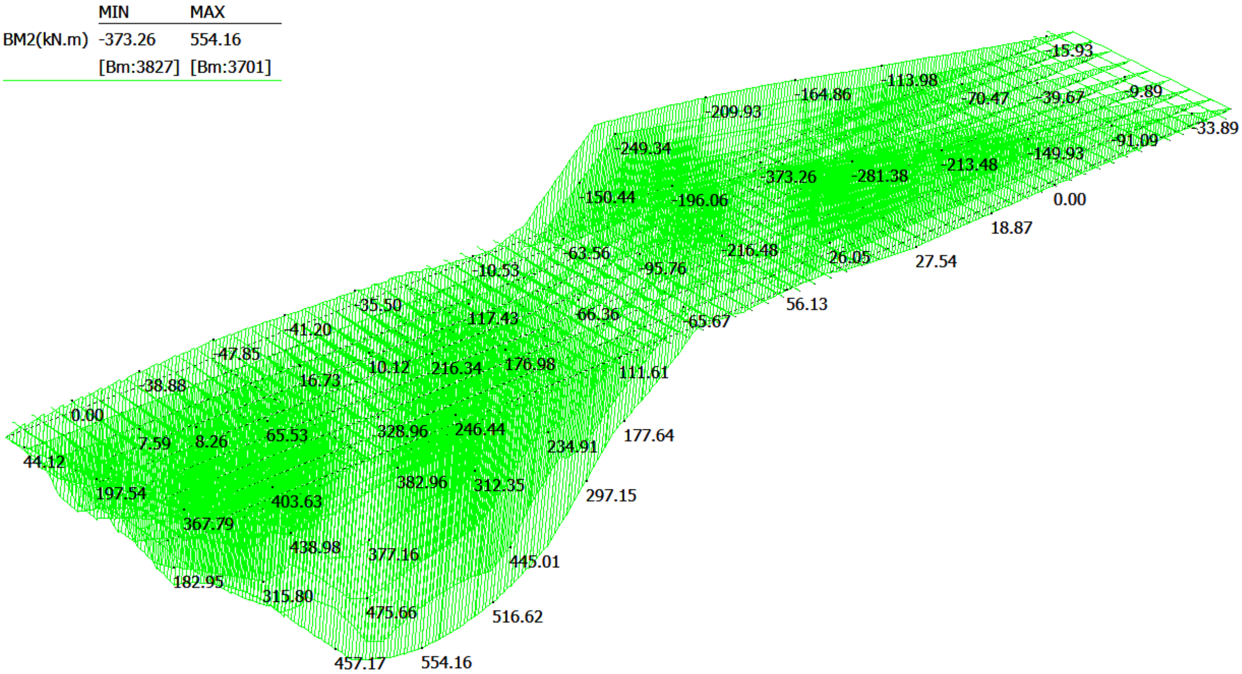
Taglio:

	MIN	MAX
SF2(kN)	-381.44	318.99
	[Bm:3831]	[Bm:3533]

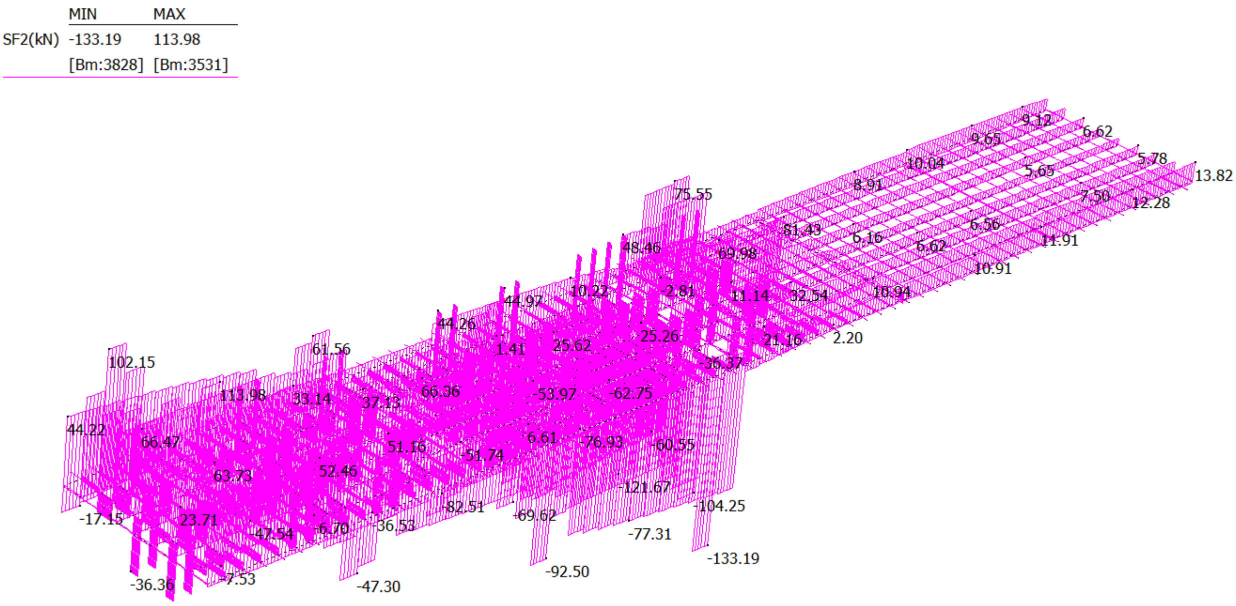


9.2.5 Carichi accidentali (Fatica FLM3)

Momento flettente:

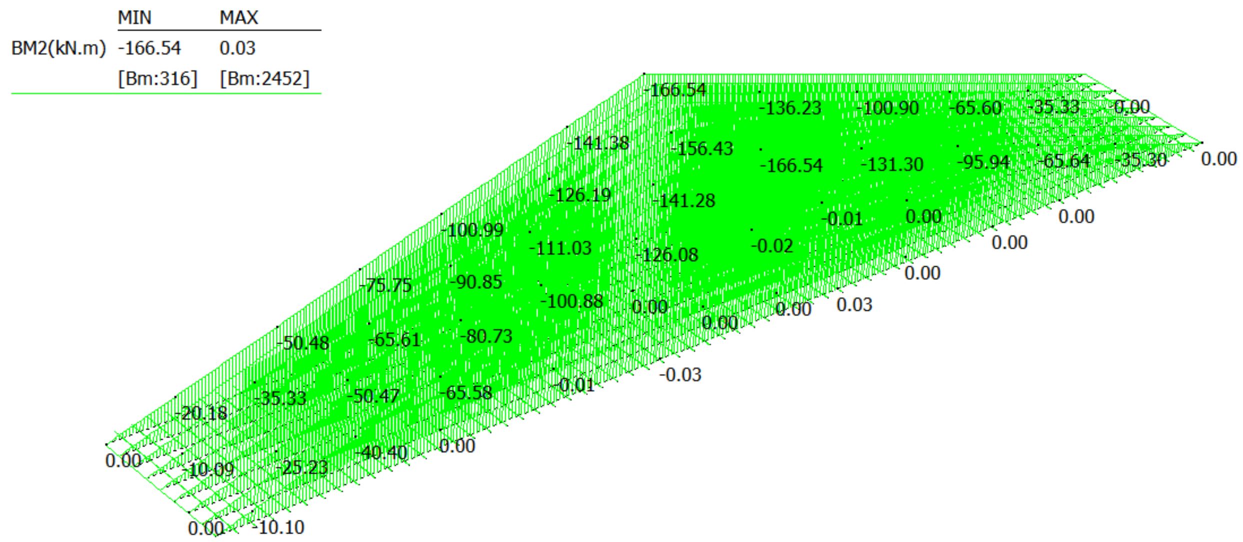


Taglio:

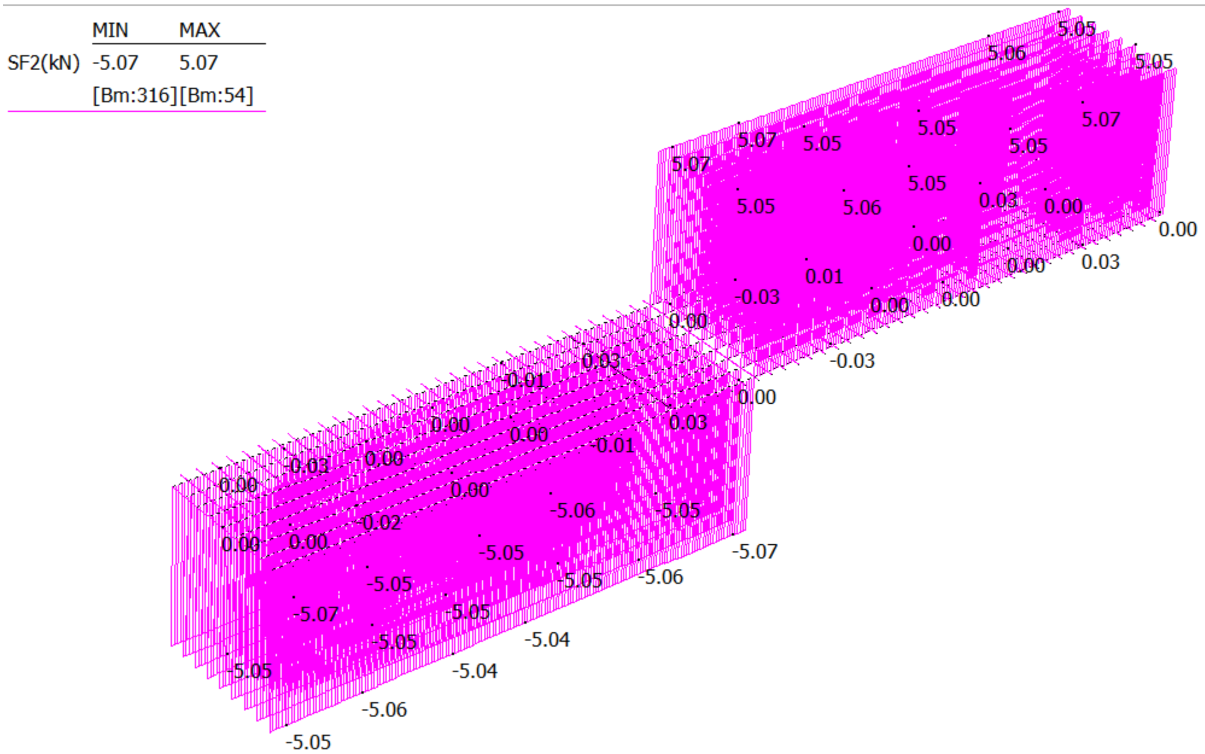


9.2.6 Ritiro

Momento flettente:



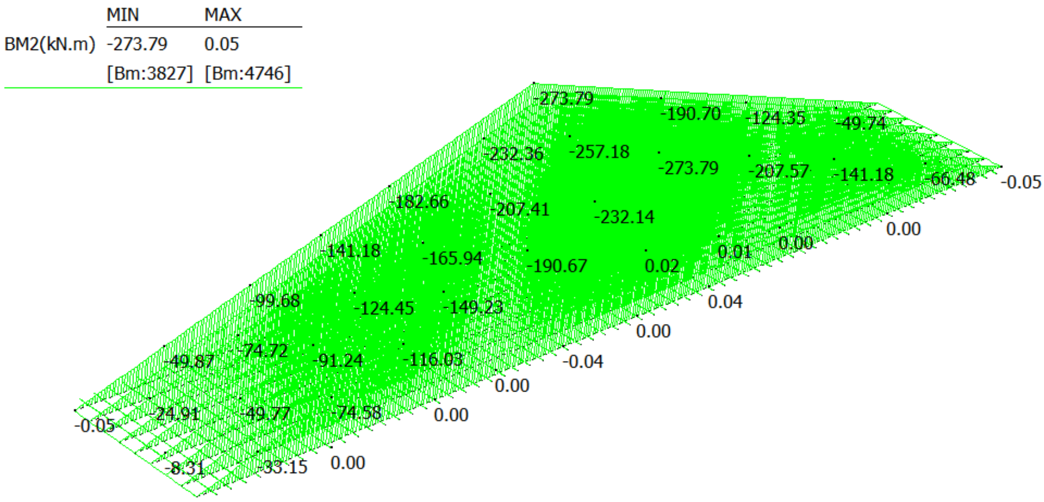
Taglio:



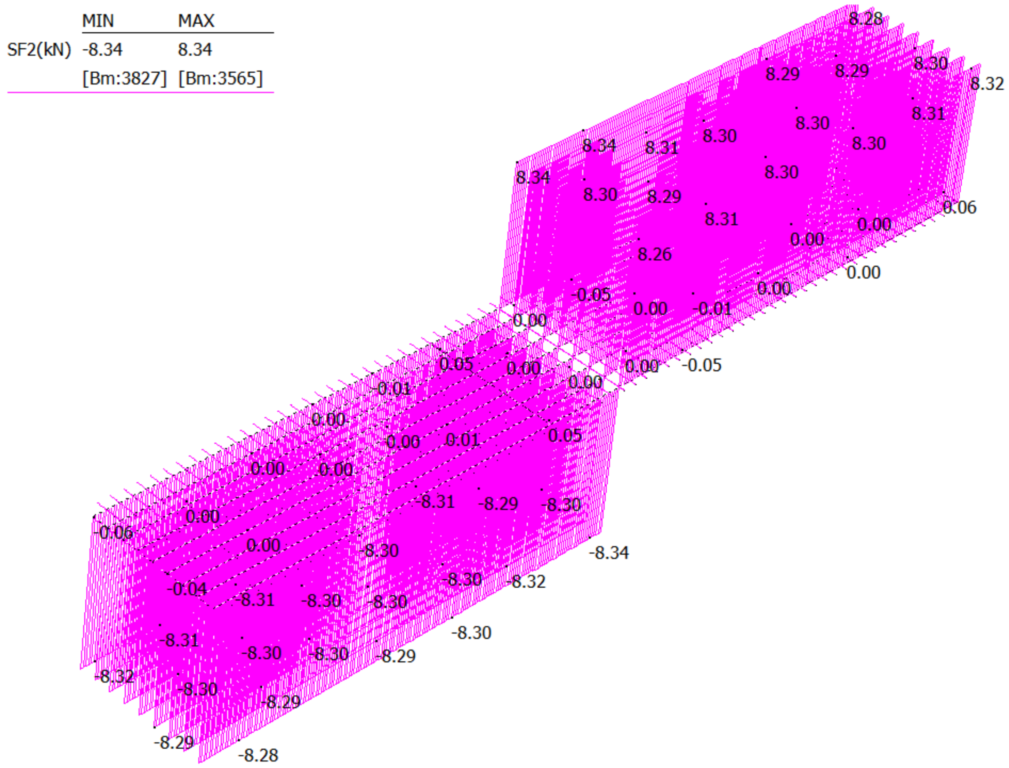
9.2.7 Variazione termica differenziale

Gli effetti della variazione termica determinano stati tensionali sugli elementi metallici delle travi principali estremamente contenuti e quindi non significativi per il dimensionamento.

Momento flettente:



Taglio:

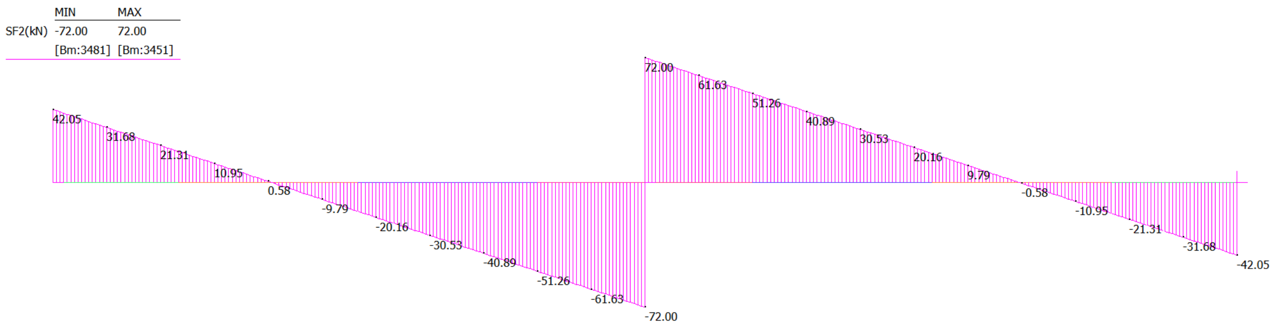


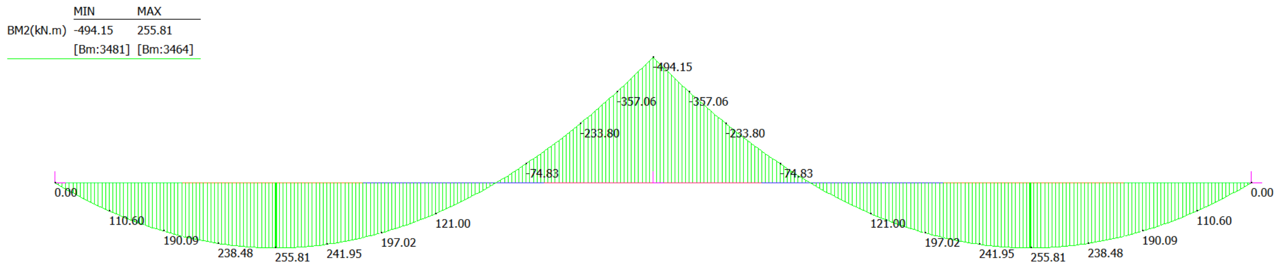
9.2.8 Sisma verticale

Si riportano di seguito le sollecitazioni sulle travi principali dovute al contributo da sisma verticale. Si specifica comunque che il sisma verticale non risulta dimensionante per la verifica delle travi di impalcato in quanto tale da determinare sollecitazioni inferiori rispetto quelle generate dagli altri carichi variabili agenti, in primis il traffico sulla piattaforma stradale (che in combinazione sismica viene annullato tramite la fattorizzazione).

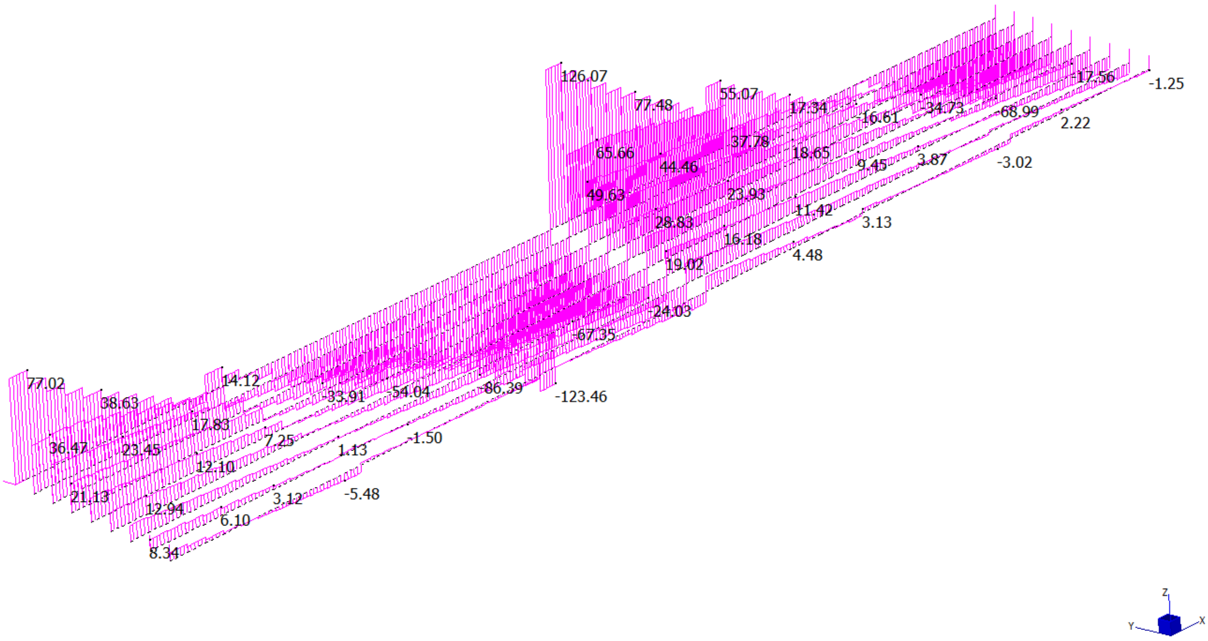
Per il sisma verticale si è considerata cautelativamente una accelerazione pari a quella del plateau e pari a 0.32g. Ciò significa che le sollecitazioni generate sono quelle tipiche dovute a pesi propri e permanenti portati moltiplicate per un fattore pari a 0.32. Si riportano di seguito le sollecitazioni cosi ricavate:

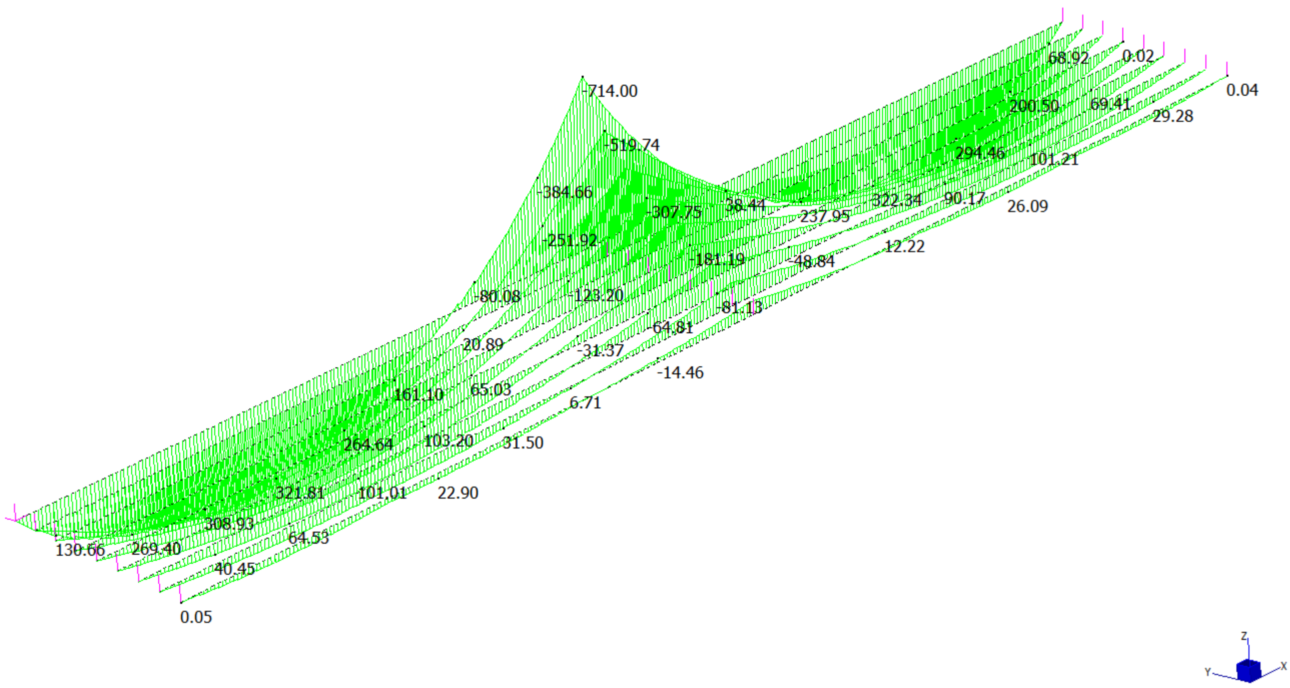
- Pesi propri:





- Permanenti portati:





9.3 VERIFICHE STRUTTURALI

Si riportano di seguito le caratteristiche geometriche dei vari conci:

	Concio A	Concio B	Concio C	Concio D
Piatt.sup	500x25	500x25	500x45	500x55
Anima	800x16	800x16	800x20	800x22
Piatt.inf	600x30	600x40	600x45	600x55

Il concio A e concio D risultano piolati con pioli Nelson φ19 h=150mm in numero pari a 15/m.

Il concio B e concio C risultano piolati con pioli Nelson φ19 h=150mm in numero pari a 10/m.

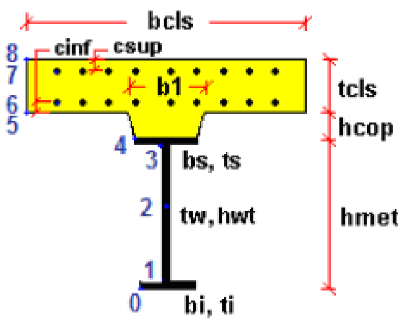
Sono poi presenti degli irrigidenti verticali piatti di dimensione 200x20 a passo 275cm.

Le proprietà geometrico-statiche delle sezioni di impalcato vengono valutate dal programma di verifica PontiEC4. Tutti i dati indicati sono espressi in mm e sono riferiti alla trave metallica singola, con relativa porzione di soletta collaborante.

Si è trascurato nel calcolo delle proprietà inerziali della sezione e quindi nelle verifiche, il contributo resistente offerto dalla predalle metallica, essendo quest'ultima non direttamente collegata alla trave in acciaio.

Per i dati relativi a ciascuna riga, si rimanda alla legenda e alla figura sottostante:

	Legenda
A	Area sezione
z_G	Distanza baricentro da intradosso
J_y	Inerzia verticale
J_z	Inerzia orizzontale
$W_{y,0}$	Modulo resistenza lembo inf. piatt. inferiore
$W_{y,1}$	Modulo resistenza lembo sup.. piatt. inferiore
$W_{y,3}$	Modulo resistenza lembo inf. piatt. superiore
$W_{y,4}$	Modulo resistenza lembo sup. piatt. superiore
$W_{y,5}$	Modulo resistenza lembo inferiore soletta in c.a.
$W_{y,6}$	Modulo resistenza layer inferiore armatura
$W_{y,7}$	Modulo resistenza layer superiore armatura
$W_{y,8}$	Modulo resistenza lembo superiore soletta in c.a.
$S_{y,1}$	Momento statico attacco anima/piatt. inferiore
$S_{y,2}$	Momento statico rispetto baricentro
$S_{y,3}$	Momento statico attacco anima/piatt. superiore
$S_{y,4}$	Momento statico interfaccia trave/soletta
e	Eccentricità tra baricentro globale e linea d'azione N



Di seguito si riportano le caratteristiche delle sezioni per ogni fase di calcolo.

Fase 1 Peso proprio

Fase 2a Permanenti

Fase 2b Ritiro

Fase 2c Coazioni e/o presollecitazioni

Fase 3a Variazione termica + Traffico

Cracked Condizione di fessurazione della soletta

A livello di armatura longitudinale in soletta si sono considerate le seguenti quantità:

- Sez 1: estradosso soletta φ16/20; intradosso soletta no;
- Sez 2a: estradosso soletta φ16/20; intradosso soletta no;
- Sez 2b: estradosso soletta φ16/20; intradosso soletta no;
- Sez 3a: estradosso soletta φ16/20; intradosso soletta no;
- Sez 3b: estradosso soletta φ16/20; intradosso soletta no;
- Sez 4a: estradosso soletta φ26/20; intradosso soletta φ16/20;
- Sez 4b: estradosso soletta φ26/20; intradosso soletta φ16/20;
- Sez 5: estradosso soletta φ26/10; intradosso soletta φ26/10.

Section Sez. 1 Sp. A

Main properties

Main data

Steel section height	800 mm
Top flange	500x25 mm
Bottom flange	600x25 mm
Web	16x750 mm, Skew: 0
Slab	1200x200 mm
Haunch	0x0 mm (not considered in the geometric properties calculation)
Top reinforcing bars	diameter 16 mm, bar spacing 200 mm, dist. top slab face-bar centre 50 mm
Bottom reinforcing bars	diameter 0 mm, bar spacing 100 mm, dist. bottom slab face-bar centre 2 mm
Studs	diameter 19 mm, height 150 mm, number 15/m

Vertical stiffeners

Distance	2750 mm
Type	R Single sided
Plate 1	200x20 mm
Plate 2	---

Geometric properties of gross cross section

	Phase 1	*Phase 2a*	*Phase 2b*	*Phase 2c*	*Phase 3*	*Cracked*
A (mm^2)	3.95E+4	5.404E+4	5.404E+4	5.404E+4	8.071E+4	4.071E+4
z_G (mm)	375.475	517.718	517.718	517.718	644.03	392.501
J_y (mm^4)	4.669E+9	7.687E+9	7.687E+9	7.687E+9	1.039E+10	5.056E+9
$W_{y,0}$ (mm^3)	-1.244E+7	-1.485E+7	-1.485E+7	-1.485E+7	-1.613E+7	-1.288E+7
$W_{y,1}$ (mm^3)	-1.332E+7	-1.56E+7	-1.56E+7	-1.56E+7	-1.678E+7	-1.376E+7
$W_{y,3}$ (mm^3)	1.169E+7	2.988E+7	2.988E+7	2.988E+7	7.93E+7	1.322E+7
$W_{y,4}$ (mm^3)	1.1E+7	2.723E+7	2.723E+7	2.723E+7	6.659E+7	1.241E+7
$W_{y,5}$ (mm^3)	1E+300	2.723E+7	2.723E+7	2.723E+7	6.659E+7	1.241E+7
$W_{y,6}$ (mm^3)	1E+300	1E+300	1E+300	1E+300	1E+300	1E+300
$W_{y,7}$ (mm^3)	1E+300	1.778E+7	1.778E+7	1.778E+7	3.394E+7	9.069E+6
$W_{y,8}$ (mm^3)	1E+300	1.594E+7	1.594E+7	1.594E+7	2.917E+7	8.322E+6
$S_{y,1}$(mm^3)	5.445E+6	7.578E+6	7.578E+6	7.578E+6	9.473E+6	5.7E+6
$S_{y,2}$(mm^3)	6.427E+6	9.52E+6	9.52E+6	9.52E+6	1.254E+7	6.78E+6
$S_{y,3}$(mm^3)	5.15E+6	8.991E+6	8.991E+6	8.991E+6	1.24E+7	5.61E+6
$S_{y,4}$(mm^3)	-9.313E-10	5.619E+6	5.619E+6	5.619E+6	1.061E+7	6.726E+5
n_E	1E+300	18	18	18	6	1E+300

Section Sez. 2a 2a

Main properties

Main data

Steel section height	800 mm
Top flange	500x25 mm
Bottom flange	600x25 mm
Web	16x750 mm, Skew: 0
Slab	1200x200 mm
Haunch	0x0 mm (not considered in the geometric properties calculation)
Top reinforcing bars	diameter 16 mm, bar spacing 200 mm, dist. top slab face-bar centre 50 mm
Bottom reinforcing bars	diameter 0 mm, bar spacing 100 mm, dist. bottom slab face-bar centre 2 mm
Studs	diameter 19 mm, height 150 mm, number 15/m

Vertical stiffeners

Distance	2750 mm
Type	R Single sided
Plate 1	200x20 mm
Plate 2	---

Geometric properties of gross cross section

	Phase 1	*Phase 2a*	*Phase 2b*	*Phase 2c*	*Phase 3*	*Cracked*
A (mm^2)	3.95E+4	5.404E+4	5.404E+4	5.404E+4	8.071E+4	4.071E+4
z_G (mm)	375.475	517.718	517.718	517.718	644.03	392.501
J_y (mm^4)	4.669E+9	7.687E+9	7.687E+9	7.687E+9	1.039E+10	5.056E+9
$W_{y,0}$ (mm^3)	-1.244E+7	-1.485E+7	-1.485E+7	-1.485E+7	-1.613E+7	-1.288E+7
$W_{y,1}$ (mm^3)	-1.332E+7	-1.56E+7	-1.56E+7	-1.56E+7	-1.678E+7	-1.376E+7
$W_{y,3}$ (mm^3)	1.169E+7	2.988E+7	2.988E+7	2.988E+7	7.93E+7	1.322E+7
$W_{y,4}$ (mm^3)	1.1E+7	2.723E+7	2.723E+7	2.723E+7	6.659E+7	1.241E+7
$W_{y,5}$ (mm^3)	1E+300	2.723E+7	2.723E+7	2.723E+7	6.659E+7	1.241E+7
$W_{y,6}$ (mm^3)	1E+300	1E+300	1E+300	1E+300	1E+300	1E+300
$W_{y,7}$ (mm^3)	1E+300	1.778E+7	1.778E+7	1.778E+7	3.394E+7	9.069E+6
$W_{y,8}$ (mm^3)	1E+300	1.594E+7	1.594E+7	1.594E+7	2.917E+7	8.322E+6
$S_{y,1}$(mm^3)	5.445E+6	7.578E+6	7.578E+6	7.578E+6	9.473E+6	5.7E+6
$S_{y,2}$(mm^3)	6.427E+6	9.52E+6	9.52E+6	9.52E+6	1.254E+7	6.78E+6
$S_{y,3}$(mm^3)	5.15E+6	8.991E+6	8.991E+6	8.991E+6	1.24E+7	5.61E+6
$S_{y,4}$(mm^3)	-9.313E-10	5.619E+6	5.619E+6	5.619E+6	1.061E+7	6.726E+5
n_E	1E+300	18	18	18	6	1E+300

Section Sez. 2b 2b

Main properties

Main data

Steel section height	800 mm
Top flange	500x25 mm
Bottom flange	600x40 mm
Web	16x735 mm, Skew: 0
Slab	1200x200 mm
Haunch	0x0 mm (not considered in the geometric properties calculation)
Top reinforcing bars	diameter 16 mm, bar spacing 200 mm, dist. top slab face-bar centre 50 mm
Bottom reinforcing bars	diameter 0 mm, bar spacing 100 mm, dist. bottom slab face-bar centre 2 mm
Studs	diameter 19 mm, height 150 mm, number 10/m

Vertical stiffeners

Distance	2750 mm
Type	R Single sided
Plate 1	200x20 mm
Plate 2	---

Geometric properties of gross cross section

	Phase 1	*Phase 2a*	*Phase 2b*	*Phase 2c*	*Phase 3*	*Cracked*
A (mm^2)	4.826E+4	6.28E+4	6.28E+4	6.28E+4	8.947E+4	4.947E+4
z_G (mm)	313.219	450.034	450.034	450.034	584.152	328.749
J_y (mm^4)	5.513E+9	9.462E+9	9.462E+9	9.462E+9	1.334E+10	5.99E+9
$W_{y,0}$ (mm^3)	-1.76E+7	-2.103E+7	-2.103E+7	-2.103E+7	-2.284E+7	-1.822E+7
$W_{y,1}$ (mm^3)	-2.018E+7	-2.308E+7	-2.308E+7	-2.308E+7	-2.452E+7	-2.075E+7
$W_{y,3}$ (mm^3)	1.194E+7	2.912E+7	2.912E+7	2.912E+7	6.99E+7	1.342E+7
$W_{y,4}$ (mm^3)	1.133E+7	2.704E+7	2.704E+7	2.704E+7	6.181E+7	1.271E+7
$W_{y,5}$ (mm^3)	1E+300	2.704E+7	2.704E+7	2.704E+7	6.181E+7	1.271E+7
$W_{y,6}$ (mm^3)	1E+300	1E+300	1E+300	1E+300	1E+300	1E+300
$W_{y,7}$ (mm^3)	1E+300	1.893E+7	1.893E+7	1.893E+7	3.647E+7	9.642E+6
$W_{y,8}$ (mm^3)	1E+300	1.72E+7	1.72E+7	1.72E+7	3.208E+7	8.924E+6
$S_{y,1}$(mm^3)	7.037E+6	1.032E+7	1.032E+7	1.032E+7	1.354E+7	7.41E+6
$S_{y,2}$(mm^3)	7.634E+6	1.167E+7	1.167E+7	1.167E+7	1.591E+7	8.077E+6
$S_{y,3}$(mm^3)	5.929E+6	1.082E+7	1.082E+7	1.082E+7	1.562E+7	6.484E+6
$S_{y,4}$(mm^3)	9.313E-10	6.603E+6	6.603E+6	6.603E+6	1.308E+7	7.495E+5
n_E	1E+300	18	18	18	6	1E+300

Section Sez. 3a_3a

Main properties

Main data

Steel section height	800 mm
Top flange	500x25 mm
Bottom flange	600x40 mm
Web	16x735 mm, Skew: 0
Slab	1200x200 mm
Haunch	0x0 mm (not considered in the geometric properties calculation)
Top reinforcing bars	diameter 16 mm, bar spacing 200 mm, dist. top slab face-bar centre 50 mm
Bottom reinforcing bars	diameter 0 mm, bar spacing 100 mm, dist. bottom slab face-bar centre 2 mm
Studs	diameter 19 mm, height 150 mm, number 10/m

Vertical stiffeners

Distance	2750 mm
Type	R Single sided
Plate 1	200x20 mm
Plate 2	---

Geometric properties of gross cross section

	Phase 1	*Phase 2a*	*Phase 2b*	*Phase 2c*	*Phase 3*	*Cracked*
A (mm^2)	4.826E+4	6.28E+4	6.28E+4	6.28E+4	8.947E+4	4.947E+4
z_G (mm)	313.219	450.034	450.034	450.034	584.152	328.749
J_y (mm^4)	5.513E+9	9.462E+9	9.462E+9	9.462E+9	1.334E+10	5.99E+9
$W_{y,0}$ (mm^3)	-1.76E+7	-2.103E+7	-2.103E+7	-2.103E+7	-2.284E+7	-1.822E+7
$W_{y,1}$ (mm^3)	-2.018E+7	-2.308E+7	-2.308E+7	-2.308E+7	-2.452E+7	-2.075E+7
$W_{y,3}$ (mm^3)	1.194E+7	2.912E+7	2.912E+7	2.912E+7	6.99E+7	1.342E+7
$W_{y,4}$ (mm^3)	1.133E+7	2.704E+7	2.704E+7	2.704E+7	6.181E+7	1.271E+7
$W_{y,5}$ (mm^3)	1E+300	2.704E+7	2.704E+7	2.704E+7	6.181E+7	1.271E+7
$W_{y,6}$ (mm^3)	1E+300	1E+300	1E+300	1E+300	1E+300	1E+300
$W_{y,7}$ (mm^3)	1E+300	1.893E+7	1.893E+7	1.893E+7	3.647E+7	9.642E+6
$W_{y,8}$ (mm^3)	1E+300	1.72E+7	1.72E+7	1.72E+7	3.208E+7	8.924E+6
$S_{y,1}$(mm^3)	7.037E+6	1.032E+7	1.032E+7	1.032E+7	1.354E+7	7.41E+6
$S_{y,2}$(mm^3)	7.634E+6	1.167E+7	1.167E+7	1.167E+7	1.591E+7	8.077E+6
$S_{y,3}$(mm^3)	5.929E+6	1.082E+7	1.082E+7	1.082E+7	1.562E+7	6.484E+6
$S_{y,4}$(mm^3)	9.313E-10	6.603E+6	6.603E+6	6.603E+6	1.308E+7	7.495E+5
n_E	1E+300	18	18	18	6	1E+300

Section Sez. 3b 3b

Main properties

Main data

Steel section height	800 mm
Top flange	500x45 mm
Bottom flange	600x45 mm
Web	20x710 mm, Skew: 0
Slab	1200x200 mm
Haunch	0x0 mm (not considered in the geometric properties calculation)
Top reinforcing bars	diameter 16 mm, bar spacing 200 mm, dist. top slab face-bar centre 50 mm
Bottom reinforcing bars	diameter 0 mm, bar spacing 100 mm, dist. bottom slab face-bar centre 2 mm
Studs	diameter 19 mm, height 150 mm, number 10/m

Vertical stiffeners

Distance	2750 mm
Type	R Single sided
Plate 1	200x20 mm
Plate 2	---

Geometric properties of gross cross section

	Phase 1	*Phase 2a*	*Phase 2b*	*Phase 2c*	*Phase 3*	*Cracked*
A (mm^2)	6.37E+4	7.824E+4	7.824E+4	7.824E+4	1.049E+5	6.491E+4
z_G (mm)	373.332	471.977	471.977	471.977	580.778	384.05
J_y (mm^4)	7.614E+9	1.1E+10	1.1E+10	1.1E+10	1.473E+10	8.007E+9
$W_{y,0}$ (mm^3)	-2.039E+7	-2.33E+7	-2.33E+7	-2.33E+7	-2.536E+7	-2.085E+7
$W_{y,1}$ (mm^3)	-2.319E+7	-2.575E+7	-2.575E+7	-2.575E+7	-2.749E+7	-2.362E+7
$W_{y,3}$ (mm^3)	1.995E+7	3.885E+7	3.885E+7	3.885E+7	8.454E+7	2.159E+7
$W_{y,4}$ (mm^3)	1.784E+7	3.352E+7	3.352E+7	3.352E+7	6.719E+7	1.925E+7
$W_{y,5}$ (mm^3)	1E+300	3.352E+7	3.352E+7	3.352E+7	6.719E+7	1.925E+7
$W_{y,6}$ (mm^3)	1E+300	1E+300	1E+300	1E+300	1E+300	1E+300
$W_{y,7}$ (mm^3)	1E+300	2.3E+7	2.3E+7	2.3E+7	3.989E+7	1.415E+7
$W_{y,8}$ (mm^3)	1E+300	2.083E+7	2.083E+7	2.083E+7	3.513E+7	1.3E+7
$S_{y,1}$(mm^3)	9.472E+6	1.214E+7	1.214E+7	1.214E+7	1.507E+7	9.762E+6
$S_{y,2}$(mm^3)	1.055E+7	1.396E+7	1.396E+7	1.396E+7	1.794E+7	1.091E+7
$S_{y,3}$(mm^3)	9.094E+6	1.316E+7	1.316E+7	1.316E+7	1.764E+7	9.535E+6
$S_{y,4}$(mm^3)	1.863E-9	6.284E+6	6.284E+6	6.284E+6	1.321E+7	6.827E+5
n_E	1E+300	18	18	18	6	1E+300

Section Sez. 4a_4a

Main properties

Main data

Steel section height	800 mm
Top flange	500x45 mm
Bottom flange	600x45 mm
Web	20x710 mm, Skew: 0
Slab	1200x200 mm
Haunch	0x0 mm (not considered in the geometric properties calculation)
Top reinforcing bars	diameter 26 mm, bar spacing 200 mm, dist. top slab face-bar centre 50 mm
Bottom reinforcing bars	diameter 16 mm, bar spacing 200 mm, dist. bottom slab face-bar centre 13 mm
Studs	diameter 19 mm, height 150 mm, number 10/m

Vertical stiffeners

Distance	2750 mm
Type	R Single sided
Plate 1	200x20 mm
Plate 2	---

Geometric properties of gross cross section

	Phase 1	*Phase 2a*	*Phase 2b*	*Phase 2c*	*Phase 3*	*Cracked*
A (mm^2)	6.37E+4	8.143E+4	8.143E+4	8.143E+4	1.081E+5	6.809E+4
z_G (mm)	373.332	488.648	488.648	488.648	590.13	408.1
J_y (mm^4)	7.614E+9	1.157E+10	1.157E+10	1.157E+10	1.505E+10	8.824E+9
$W_{y,0}$ (mm^3)	-2.039E+7	-2.367E+7	-2.367E+7	-2.367E+7	-2.551E+7	-2.162E+7
$W_{y,1}$ (mm^3)	-2.319E+7	-2.607E+7	-2.607E+7	-2.607E+7	-2.762E+7	-2.43E+7
$W_{y,3}$ (mm^3)	1.995E+7	4.342E+7	4.342E+7	4.342E+7	9.131E+7	2.544E+7
$W_{y,4}$ (mm^3)	1.784E+7	3.715E+7	3.715E+7	3.715E+7	7.173E+7	2.252E+7
$W_{y,5}$ (mm^3)	1E+300	3.715E+7	3.715E+7	3.715E+7	7.173E+7	2.252E+7
$W_{y,6}$ (mm^3)	1E+300	3.566E+7	3.566E+7	3.566E+7	6.755E+7	2.179E+7
$W_{y,7}$ (mm^3)	1E+300	2.507E+7	2.507E+7	2.507E+7	4.183E+7	1.628E+7
$W_{y,8}$ (mm^3)	1E+300	2.262E+7	2.262E+7	2.262E+7	3.673E+7	1.491E+7
$S_{y,1}$(mm^3)	9.472E+6	1.259E+7	1.259E+7	1.259E+7	1.533E+7	1.041E+7
$S_{y,2}$(mm^3)	1.055E+7	1.455E+7	1.455E+7	1.455E+7	1.83E+7	1.173E+7
$S_{y,3}$(mm^3)	9.094E+6	1.384E+7	1.384E+7	1.384E+7	1.803E+7	1.053E+7
$S_{y,4}$(mm^3)	1.863E-9	7.346E+6	7.346E+6	7.346E+6	1.381E+7	2.215E+6
n_E	1E+300	18	18	18	6	1E+300

Section Sez. 4b 4b

Main properties

Main data

Steel section height	800 mm
Top flange	500x55 mm
Bottom flange	600x55 mm
Web	22x690 mm, Skew: 0
Slab	1200x200 mm
Haunch	0x0 mm (not considered in the geometric properties calculation)
Top reinforcing bars	diameter 26 mm, bar spacing 200 mm, dist. top slab face-bar centre 50 mm
Bottom reinforcing bars	diameter 16 mm, bar spacing 200 mm, dist. bottom slab face-bar centre 13 mm
Studs	diameter 19 mm, height 150 mm, number 15/m

Vertical stiffeners

Distance	2750 mm
Type	R Single sided
Plate 1	200x20 mm
Plate 2	---

Geometric properties of gross cross section

	Phase 1	*Phase 2a*	*Phase 2b*	*Phase 2c*	*Phase 3*	*Cracked*
A (mm^2)	7.568E+4	9.341E+4	9.341E+4	9.341E+4	1.201E+5	8.007E+4
z_G (mm)	372.929	473.531	473.531	473.531	568.245	402.517
J_y (mm^4)	8.957E+9	1.305E+10	1.305E+10	1.305E+10	1.692E+10	1.018E+10
$W_{y,0}$ (mm^3)	-2.402E+7	-2.757E+7	-2.757E+7	-2.757E+7	-2.977E+7	-2.529E+7
$W_{y,1}$ (mm^3)	-2.817E+7	-3.119E+7	-3.119E+7	-3.119E+7	-3.296E+7	-2.93E+7
$W_{y,3}$ (mm^3)	2.407E+7	4.809E+7	4.809E+7	4.809E+7	9.57E+7	2.973E+7
$W_{y,4}$ (mm^3)	2.097E+7	3.999E+7	3.999E+7	3.999E+7	7.299E+7	2.561E+7
$W_{y,5}$ (mm^3)	1E+300	3.999E+7	3.999E+7	3.999E+7	7.299E+7	2.561E+7
$W_{y,6}$ (mm^3)	1E+300	3.846E+7	3.846E+7	3.846E+7	6.911E+7	2.48E+7
$W_{y,7}$ (mm^3)	1E+300	2.74E+7	2.74E+7	2.74E+7	4.431E+7	1.86E+7
$W_{y,8}$ (mm^3)	1E+300	2.48E+7	2.48E+7	2.48E+7	3.918E+7	1.704E+7
$S_{y,1}$(mm^3)	1.14E+7	1.472E+7	1.472E+7	1.472E+7	1.784E+7	1.238E+7
$S_{y,2}$(mm^3)	1.251E+7	1.665E+7	1.665E+7	1.665E+7	2.074E+7	1.37E+7
$S_{y,3}$(mm^3)	1.099E+7	1.584E+7	1.584E+7	1.584E+7	2.04E+7	1.241E+7
$S_{y,4}$(mm^3)	-1.863E-9	7.614E+6	7.614E+6	7.614E+6	1.478E+7	2.239E+6
n_E	1E+300	18	18	18	6	1E+300

Section Sez. 5_5

Main properties

Main data

Steel section height	800 mm
Top flange	500x55 mm
Bottom flange	600x55 mm
Web	22x690 mm, Skew: 0
Slab	1200x200 mm
Haunch	0x0 mm (not considered in the geometric properties calculation)
Top reinforcing bars	diameter 26 mm, bar spacing 100 mm, dist. top slab face-bar centre 50 mm
Bottom reinforcing bars	diameter 26 mm, bar spacing 100 mm, dist. bottom slab face-bar centre 18 mm
Studs	diameter 19 mm, height 150 mm, number 15/m

Vertical stiffeners

Distance	2750 mm
Type	R Single sided
Plate 1	200x20 mm
Plate 2	---

Geometric properties of gross cross section

	Phase 1	*Phase 2a*	*Phase 2b*	*Phase 2c*	*Phase 3*	*Cracked*
A (mm^2)	7.568E+4	1.018E+5	1.018E+5	1.018E+5	1.284E+5	8.842E+4
z_G (mm)	372.929	505.991	505.991	505.991	587.806	446.578
J_y (mm^4)	8.957E+9	1.429E+10	1.429E+10	1.429E+10	1.766E+10	1.186E+10
$W_{y,0}$ (mm^3)	-2.402E+7	-2.824E+7	-2.824E+7	-2.824E+7	-3.004E+7	-2.656E+7
$W_{y,1}$ (mm^3)	-2.817E+7	-3.168E+7	-3.168E+7	-3.168E+7	-3.314E+7	-3.029E+7
$W_{y,3}$ (mm^3)	2.407E+7	5.978E+7	5.978E+7	5.978E+7	1.123E+8	3.975E+7
$W_{y,4}$ (mm^3)	2.097E+7	4.86E+7	4.86E+7	4.86E+7	8.321E+7	3.356E+7
$W_{y,5}$ (mm^3)	1E+300	4.86E+7	4.86E+7	4.86E+7	8.321E+7	3.356E+7
$W_{y,6}$ (mm^3)	1E+300	4.579E+7	4.579E+7	4.579E+7	7.67E+7	3.193E+7
$W_{y,7}$ (mm^3)	1E+300	3.218E+7	3.218E+7	3.218E+7	4.875E+7	2.356E+7
$W_{y,8}$ (mm^3)	1E+300	2.892E+7	2.892E+7	2.892E+7	4.284E+7	2.143E+7
$S_{y,1}$(mm^3)	1.14E+7	1.579E+7	1.579E+7	1.579E+7	1.849E+7	1.383E+7
$S_{y,2}$(mm^3)	1.251E+7	1.803E+7	1.803E+7	1.803E+7	2.161E+7	1.552E+7
$S_{y,3}$(mm^3)	1.099E+7	1.74E+7	1.74E+7	1.74E+7	2.134E+7	1.454E+7
$S_{y,4}$(mm^3)	-1.863E-9	1.007E+7	1.007E+7	1.007E+7	1.626E+7	5.574E+6
n_E	1E+300	18	18	18	6	1E+300

Si riportano di seguito le verifiche eseguite:

9.3.1 Section Sez. 1_Sp. A

First classification

The first classification refers to the composite section in Phase 3

Plastic characteristics of the single components

Components	N_{pl} *(N)*	z_N *(mm)*	z_{max} *(mm)*	z_{min} *(mm)*
Concrete layer above top reinforcing bars	1.515E+6	975.25	1000	950.5
Concrete layer between top and bottom reinforcing bars	4.498E+6	876	949.5	802.5
Concrete layer below top reinforcing bars	7.65E+4	801.25	802.5	800
Top reinforcing bars	4.721E+5	950	950.5	949.5
Bottom reinforcing bars	0E+00	802.5	802.5	802.5
Concrete haunch slab	0E+00	800	800	800
Top flange of steel beam	4.226E+6	787.5	800	775
Web of steel beam	4.057E+6	400	775	25
Bottom flange of steel beam	5.071E+6	12.5	25	0
Ultimate compression force for the full section	-1.992E+7			
Ultimate tension force for the full section	1.383E+7			
Ultimate compression force for the web less section	-1.586E+7			
Ultimate tensile force for the web less section	9.77E+6			

Flanges classification

	c/t	ε	*Hogging bending moment (M+)*	*Sagging bending moment (M-)*
Top flange	9.68	0.814	1	0
Bottom flange	11.68	0.814	4	1

Web classification

	c/t	ε	α	ψ	*class*
Hogging bending moment (M+)	46.875	0.814	0.454	-1.041	1
Sagging bending moment (M-)	46.875	0.814	0	-0.212	1
Compression (N)	46.875	0.814	1	1	4

U.L.S. composite section verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.77E+5	0E+00	0E+00
2a	0E+00	3.24E+5	0E+00	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	-4.03E+5	0	-1.54E+5	0
2c	0E+00	-1.2E+3	0E+00	0E+00
3a	0E+00	-7.2E+3	0E+00	0E+00
Therm.Iso	-7.56E+5	0	-1.94E+5	0
3b	0E+00	4.23E+5	0E+00	0E+00
Total	-1.16E+6	9.15E+5	-3.48E+5	0E+00

Bending resistance - Plastic analysis

Section classification (Mmax comb.)

	c/t	*z $_{pl}$ (mm)*	α	ψ	*Class*
Web	46.88	776.48	0	0	1
Top flange	9.68				1
Bottom flange	11.68				1
Section class					1
Plastic analysis: APPLICABLE					

Plastic section verification (Mmax comb.)

Axial force		*Bending moment*		*N/M interaction*	
N_{Ed} (N)	-1.159E+6	M_{Ed} (Nm)	-3.476E+5	N_{Ed} (N)	-1.159E+6
N_{Rd} (N)	-1.992E+7	M_{Rd} (Nm)	-6.279E+6	M_{Ed} (Nm)	-3.476E+5
				M_{Rd} (Nm)	-6.435E+6
N_{Ed} /N_{Rd}	0.058	M_{Ed} /M_{Rd}	0.055	M_{Ed} /M_{Rd}	0.054
CHECK PASSED					

<u>Axial force and bending moment stresses of gross cross section</u>

Stresses of gross cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	η_1
σ_8	0	0	0	0.7	0	0	0	0	0.5	0	0	0	0	0
σ_7	0	0	0	-16.1	0	0	0	0	-15.1	0	0	0	0	0
σ_6	0	0	0	-7.5	0	0	0	0	-9.4	0	0	0	0	0
σ_5	0	0	0	1	0	0	0	0	1.1	0	0	0	0	0
σ_4	0	0	0	-13.1	0	0	0	0	-12.3	0	0	0	0	0
σ_3	0	0	0	-12.6	0	0	0	0	-11.8	0	0	0	0	0
σ_2	0	0	0	-7.5	0	0	0	0	-9.4	0	0	0	0	0
σ_1	0	0	0	2.4	0	0	0	0	2.2	0	0	0	0	0
σ_0	0	0	0	2.9	0	0	0	0	2.6	0	0	0	0	0

Maximum utilization ratio:0 NOT RELEVANT CHECK
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = 0.73 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 0.95 N/mm^2
The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 1.21 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 2.06 N/mm^2
The section at the end of phase 3 is considered: Cracked (m.)

<u>Resistance to shear</u>

Evaluation of necessity to Shear buckling check
h_w / t_w =46.875 < $31/\eta * \varepsilon_w * (K_\tau)^{0.5}$ =49.905 Shear Buckling check: NOT REQUIRED

Shear Buckling resistance: $\mathbf{V_{b,Rd}}$ **=2.683E+6 N**

With:
a/h_w =3.667, η =1.2, K_τ =5.638
web contribution: $V_{bw,Rd}$ =2.683E+6 N, flanges contribution: $V_{bf,Rd}$ =1.383E+5 N
χ_w =1.2, $\bar{\lambda}_w$ =0.649, τ_{cr} =487.5, C=870.8
M_{Ed} =-3.476E+5 Nm, $M_{f,Rd}$ =-4.883E+6 Nm, M_{Ed} /$M_{f,Rd}$ =0.071

Plastic resistance: $\mathbf{V_{pl,Rd}}$ **=2.811E+6 N**

Shear resistance: $\mathbf{V_{Rd} = V_{pl,Rd}}$ **=2.811E+6 N**

Utilization ratios:

$\eta_3 = V_{Ed} / V_{Rd} = 0.326$, (=> CHECK VERIFIED)

$\bar{\eta}_3 = V_{Ed} / V_{bw,Rd} = 0.341$, $\bar{\eta}_1 = M_{Ed} / M_{Rd} = 0.054$

Interaction between shear force, bending moment and axial force

Evaluation of the interaction

$\bar{\eta}_3 < 0.5$, $M_{Ed} / M_{f,Rd} < 1$

INTERACTION NOT TO BE CHECKED

U.L.S. composite section verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.77E+5	0E+00	0E+00
2a	0E+00	3.24E+5	0E+00	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	1.2E+3	0E+00	0E+00
3a	0E+00	7.2E+3	0E+00	0E+00
Therm.Iso	7.56E+5	0	1.94E+5	0
3b	0E+00	4.23E+5	0E+00	0E+00
Total	7.56E+5	9.32E+5	1.94E+5	0E+00

Bending resistance - Plastic analysis

Section classification (Mmin comb.)

	c/t	z_{pl} *(mm)*	α	ψ	*Class*
Web	46.88	295.63	0.36	-5.45	1
Top flange	9.68				1
Bottom flange	11.68				4
Section class					4
Plastic analysis: NOT APPLICABLE					

Plastic section verification (Mmin comb.)

Axial force		*Bending moment*		*N/M interaction*	
N_{Ed} (N)	7.56E+5	M_{Ed} (Nm)	1.935E+5	N_{Ed} (N)	7.56E+5
N_{Rd} (N)	1.383E+7	M_{Rd} (Nm)	4.617E+6	M_{Ed} (Nm)	1.935E+5
				M_{Rd} (Nm)	4.38E+6
N_{Ed} / N_{Rd}	0.055	M_{Ed} / M_{Rd}	0.042	M_{Ed} / M_{Rd}	0.044
NOT RELEVANT CHECK					

Axial force and bending moment stresses of gross cross section

Stresses of gross cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	η_1
σ_8	0	0	0	0	0	0	0	0	-0.5	0	0	0	-0.5	0.019
σ_7	0	0	0	0	0	0	0	0	15.1	0	0	0	15.1	0.039
σ_6	0	0	0	0	0	0	0	0	9.4	0	0	0	9.4	0.024
σ_5	0	0	0	0	0	0	0	0	-1.1	0	0	0	-1.1	0.043
σ_4	0	0	0	0	0	0	0	0	12.3	0	0	0	12.3	0.036
σ_3	0	0	0	0	0	0	0	0	11.8	0	0	0	11.8	0.035
σ_2	0	0	0	0	0	0	0	0	9.4	0	0	0	9.4	0.028

σ_1	0	0	0	0	0	0	0	0	-2.2	0	0	0	-2.2	0.006
σ_0	0	0	0	0	0	0	0	0	-2.6	0	0	0	-2.6	0.008

Maximum utilization ratio:0.043 NOT RELEVANT CHECK
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = 0 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 0 N/mm^2
The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -0.48 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -1.1 N/mm^2
The section at the end of phase 3 is considered: Uncracked (m.)

Axial force and bending moment - effective cross section calculation

Effective area for shear lag and/or buckling of flanges(Mmin comb.)

Component	*b (mm)*	*t (mm)*	λ_p	ρ	$A_{c,eff}$ (mm^2)	β^k	$A_{c,eff} * \beta^k$ (mm^2)
Top left flange	250	25	---	---	---	1	6250
Top right flange	250	25	---	---	---	1	6250
Bottom left flange	300	25	0.792	0.963	7222	1	7222
Bottom right flange	300	25	0.792	0.963	7222	1	7222

Local buckling of web panels (Mmin comb.)

	Web
b (mm)	750
σ_{cr0E} (N/mm^2)	86.47
σ_{top} (N/mm^2)	11.8
σ_{bot} (N/mm^2)	-2.24
ψ	-5.28
K_σ	95.68
λ_p	0.21
b_c (mm)	119.46
$b_{c\ top}$(mm)	71.68
$b_{c\ top}$(mm)	47.79
ρ_{loc}	1
b_{ceff} (mm)	119.46
$b_{ceff\ top}$(mm)	71.68
$b_{ceff\ top}$(mm)	47.79
ϕ_{Hole}(mm)	0

Compressed web features, without ribs (Mmin comb.)

	A(mm^2)	z_G *(mm)*	J_y *(mm^4)*
$A_{c\ Top\ Edge}$	1.147E+3	108.6	4.91E+5
$A_{c\ 1}$	0E+00	0	0E+00
$A_{c\ 2}$	0E+00	0	0E+00
$A_{c\ Bottom\ Edge}$	7.646E+2	48.9	1.455E+5
$A_{c\ tot}$	1.911E+3	84.7	2.273E+6
A_c	0E+00		

Compressed web features, reduced for local buckling (Mmin comb.)

	A(mm^2)	z_G *(mm)*	J_y *(mm^4)*
$A_{c,eff\ Top\ Edge}$	1.147E+3	108.6	4.91E+5
$A_{c,eff\ 1}$	0E+00	0	0E+00
$A_{c,eff\ 2}$	0E+00	0	0E+00
$A_{c,eff\ Bottom\ Edge}$	7.646E+2	48.9	1.455E+5
$A_{c,eff\ tot}$	1.911E+3	84.7	2.273E+6

$A_{c,eff,loc}$	0E+00		

Partial factor for global buckling (Mmin comb.)

	Plate		Column
$\sigma_{cr,p}$ (p)	8273.56	$\sigma_{cr,c}$ (c)	1
β_{ac} (p)	1	β_{ac} (c)	7.635
λ_p	0.207	λ_c	1
ρ_p	1	χ_c	

Web reduced for local and global buckling (Mmin comb.)

	$A(mm^2)$	z_G (mm)	J_y (mm^4)
Top Edge	1.147E+3	108.6	4.91E+5
1	0E+00	0	0E+00
2	0E+00	0	0E+00
Bottom Edge	7.646E+2	48.9	1.455E+5
Total	1.911E+3	84.7	2.273E+6

Total reduction to apply to the section (Mmin comb.)

	$\Delta A(mm^2)$	z_G (mm)	ΔJ_y (mm^4)
Web	0E+00	0	0E+00
Top flange	0E+00	0	0E+00
Bottom flange	-5.559E+2	12.5	-2.896E+4

Geometric features of effective cross section (Mmin comb.)

	Phase 1	Phase 2a	Phase 2b	Phase 2c	Phase 3	Cracked
A (mm^2)	3.894E+4	5.348E+4	8.015E+4	5.348E+4	8.015E+4	4.015E+4
z_G (mm)	380.656	522.969	648.41	522.969	648.41	397.763
Δz_{Geff} (mm)	-5.18	-5.25	-4.38	-5.25	-4.38	-5.26
$J_{y,eff}$ (mm^4)	4.595E+9	7.544E+9	1.016E+10	7.544E+9	1.016E+10	4.974E+9
$W_{y,0eff}$ (mm^3)	-1.207E+7	-1.442E+7	-1.567E+7	-1.442E+7	-1.567E+7	-1.251E+7
$W_{y,1eff}$ (mm^3)	-1.292E+7	-1.515E+7	-1.63E+7	-1.515E+7	-1.63E+7	-1.334E+7
$W_{y,3eff}$ (mm^3)	1.165E+7	2.993E+7	8.028E+7	2.993E+7	8.028E+7	1.319E+7
$W_{y,4eff}$ (mm^3)	1.096E+7	2.723E+7	6.704E+7	2.723E+7	6.704E+7	1.237E+7
$W_{y,5eff}$ (mm^3)	1E+300	2.723E+7	6.704E+7	2.723E+7	6.704E+7	1.237E+7
$W_{y,6eff}$ (mm^3)	1E+300	1E+300	1E+300	1E+300	1E+300	1E+300
$W_{y,7eff}$ (mm^3)	1E+300	1.767E+7	3.37E+7	1.767E+7	3.37E+7	9.008E+6
$W_{y,8eff}$ (mm^3)	1E+300	1.581E+7	2.89E+7	1.581E+7	2.89E+7	8.26E+6
$S_{y,1eff}$ (mm^3)	5.318E+6	7.373E+6	9.185E+6	7.373E+6	9.185E+6	5.565E+6
$S_{y,2eff}$ (mm^3)	6.33E+6	9.357E+6	1.229E+7	9.357E+6	1.229E+7	6.676E+6
$S_{y,3eff}$ (mm^3)	5.086E+6	8.849E+6	1.217E+7	8.849E+6	1.217E+7	5.538E+6
$S_{y,4eff}$ (mm^3)	1.246E-292	5.542E+6	1.043E+7	5.542E+6	1.043E+7	6.662E+5

The effective geometric characteristics have been calculated in 0 iterations, with the following percentage variations of the factor ψ

$(\psi_1 - \psi_0)/\psi_0 * 100$	
$(\psi_2 - \psi_1)/\psi_1 * 100$	
$(\psi_3 - \psi_2)/\psi_2 * 100$	
$(\psi_4 - \psi_3)/\psi_3 * 100$	
$(\psi_5 - \psi_4)/\psi_4 * 100$	

Additional bending moment for neutral axis shift(Mmin comb.)

	Phase 1	Phase 2a	Phase 2b	Phase 2c	Phase 3a	Phase 3b
$\Delta M_{Cracked}$ (kNm)	0E+00	0E+00	0E+00	0E+00	0E+00	0E+00
$\Delta M_{Uncracked}$ (kNm)	0E+00	0E+00	0E+00	0E+00	-3.312E+3	0E+00

Stresses of effective cross section (Mmin comb.)

	Ph. 1	Ph. 2a Uncracked	Ph. 2a Cracked	Ph. 2b Uncracked	Ph. 2b Cracked	Ph. 2c Uncracked	Ph. 2c Cracked	Ph. 2 tot	Ph. 3a Uncracked	Ph. 3a Cracked	Ph. 3b Uncracked	Ph. 3b Cracked	Ph. 3 tot	η_1
σ_8	0	0	0	0	0	0	0	0	-0.5	0	0	0	-0.5	0.019
σ_7	0	0	0	0	0	0	0	0	15.1	0	0	0	15.1	0.039
σ_6	0	0	0	0	0	0	0	0	9.4	0	0	0	9.4	0.024
σ_5	0	0	0	0	0	0	0	0	-1.1	0	0	0	-1.1	0.043
σ_4	0	0	0	0	0	0	0	0	12.3	0	0	0	12.3	0.036
σ_3	0	0	0	0	0	0	0	0	11.8	0	0	0	11.8	0.035
σ_2	0	0	0	0	0	0	0	0	9.4	0	0	0	9.4	0.028
σ_1	0	0	0	0	0	0	0	0	-2.2	0	0	0	-2.2	0.007
σ_0	0	0	0	0	0	0	0	0	-2.7	0	0	0	-2.7	0.008

Maximum utilization ratio:0.043 CHECK PASSED
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = 0 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 0 N/mm^2
The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -0.48 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -1.11 N/mm^2
The section at the end of phase 3 is considered: Uncracked (m.)

Resistance to shear

Evaluation of necessity to Shear buckling check
$h_w / t_w = 46.875 < 31/\eta * \varepsilon_w * (K_\tau)^{0.5} = 49.905$ Shear Buckling check: NOT REQUIRED

Shear Buckling resistance: $\mathbf{V_{b,Rd} = 2.683E+6\ N}$

With:
$a/h_w = 3.667$, $\eta = 1.2$, $K_\tau = 5.638$
web contribution: $V_{bw,Rd} = 2.683E+6$ N, flanges contribution: $V_{bf,Rd} = 1.301E+5$ N
$\chi_w = 1.2$, $\bar{\lambda}_w = 0.649$, $\tau_{cr} = 487.5$, C=870.8
$M_{Ed} = M_{Ed,eq} = 8.225E+5$ Nm, $M_{f,Rd} = 3.253E+6$ Nm, $M_{Ed} / M_{f,Rd} = 0.253$

Plastic resistance: $\mathbf{V_{pl,Rd} = 2.811E+6\ N}$

Shear resistance: $\mathbf{V_{Rd} = V_{pl,Rd} = 2.811E+6\ N}$

Utilization ratios:
$\eta_3 = V_{Ed} / V_{Rd} = 0.331$, (=> CHECK VERIFIED)
$\bar{\eta}_3 = V_{Ed} / V_{bw,Rd} = 0.347$, $\eta_1 = \max(\eta_i) = 0.043$

Interaction between shear force, bending moment and axial force

Evaluation of the interaction
$\bar{\eta}_3 < 0.5$, $M_{Ed} / M_{f,Rd} < 1$
INTERACTION NOT TO BE CHECKED

SLS stresses verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	N (N)	V (N)	M (Nm)	T (Nm)
1	0E+00	1.31E+5	0E+00	0E+00
2a	0E+00	2.4E+5	0E+00	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	-3.36E+5	0	-1.28E+5	0

2c	0E+00	-1E+3	0E+00	0E+00
3a	0E+00	-4.8E+3	0E+00	0E+00
Therm.Iso	-5.04E+5	0	-1.29E+5	0
3b	0E+00	3.14E+5	0E+00	0E+00
Total	-8.4E+5	6.79E+5	-2.57E+5	0E+00

Stresses of gross cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	σ_{id}	η_1
σ_8	0	0	0	0.6	0	0	0	0	0.3	0	0	0	0	0	0
σ_7	0	0	0	-13.4	0	0	0	0	-10	0	0	0	0	0	0
σ_6	0	0	0	-6.2	0	0	0	0	-6.2	0	0	0	0	0	0
σ_5	0	0	0	0.8	0	0	0	0	0.7	0	0	0	0	0	0
σ_4	0	0	0	-10.9	0	0	0	0	-8.2	0	0	0	0	0.3	0.001
σ_3	0	0	0	-10.5	0	0	0	0	-7.9	0	0	0	0	81.4	0.229
σ_2	0	0	0	-6.2	0	0	0	0	-6.2	0	0	0	0	99	0.279
σ_1	0	0	0	2	0	0	0	0	1.4	0	0	0	0	83.4	0.235
σ_0	0	0	0	2.4	0	0	0	0	1.8	0	0	0	0	0	0
τ_4	0	0.4	0.1	0	0	0	0	0.1	0	0	0.6	0.1	0.1		
τ_3	9	17.5	16.6	0	0	-0.1	-0.1	25.6	-0.4	-0.3	23.4	21.7	47		
τ_2	11.3	18.6	20.1	0	0	-0.1	-0.1	31.3	-0.4	-0.4	23.7	26.3	57.2		
τ_1	9.5	14.8	16.9	0	0	-0.1	-0.1	26.4	-0.3	-0.3	17.9	22.1	48.1		
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Maximum utilization ratio:0.279 CHECK PASSED
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = 0.61 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 0.79 N/mm^2
The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 0.93 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 1.53 N/mm^2
The section at the end of phase 3 is considered: Cracked (m.)

SLS stresses verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.31E+5	0E+00	0E+00
2a	0E+00	2.4E+5	0E+00	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	1E+3	0E+00	0E+00
3a	0E+00	4.8E+3	0E+00	0E+00
Therm.Iso	5.04E+5	0	1.29E+5	0
3b	0E+00	3.14E+5	0E+00	0E+00
Total	5.04E+5	6.9E+5	1.29E+5	0E+00

Stresses of gross cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	σ_{id}	η_1
σ_8	0	0	0	0	0	0	0	0	-0.3	0	0	0	-0.3	0.3	0.012
σ_7	0	0	0	0	0	0	0	0	10	0	0	0	10	10	0.028
σ_6	0	0	0	0	0	0	0	0	6.2	0	0	0	6.2	6.2	0.017
σ_5	0	0	0	0	0	0	0	0	-0.7	0	0	0	-0.7	0.7	0.027

σ 4	0	0	0	0	0	0	0	0	8.2	0	0	0	8.2	8.4	0.024
σ 3	0	0	0	0	0	0	0	0	7.9	0	0	0	7.9	87.7	0.247
σ 2	0	0	0	0	0	0	0	0	6.2	0	0	0	6.2	93.7	0.264
σ 1	0	0	0	0	0	0	0	0	-1.4	0	0	0	-1.4	73.7	0.208
σ 0	0	0	0	0	0	0	0	0	-1.8	0	0	0	-1.8	1.8	0.005
τ 4	0	0.4	0.1	0	0	0	0	0.1	0	0	0.6	0.1	1		
τ 3	9	17.5	16.6	0	0	0.1	0.1	25.7	0.4	0.3	23.4	21.7	50.4		
τ 2	11.3	18.6	20.1	0	0	0.1	0.1	31.5	0.4	0.4	23.7	26.3	54		
τ 1	9.5	14.8	16.9	0	0	0.1	0.1	26.5	0.3	0.3	17.9	22.1	42.5		
τ 0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Maximum utilization ratio:0.264 CHECK PASSED

NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 2 = 0 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 0 N/mm^2
   The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -0.32 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -0.74 N/mm^2
   The section at the end of phase 3 is considered: Uncracked (m.)

SLS web breathing verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.31E+5	0E+00	0E+00
2a	0E+00	2.4E+5	0E+00	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	-3.36E+5	0	-1.28E+5	0
2c	0E+00	-1E+3	0E+00	0E+00
3a	0E+00	-4E+3	0E+00	0E+00
Therm.Iso	-4.2E+5	0	-1.08E+5	0
3b	0E+00	2.39E+5	0E+00	0E+00
Total	-7.56E+5	6.05E+5	-2.36E+5	0E+00

Stresses of effective cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*
σ 8	0	0	0	0	0	0	0	0	0	0	0	0	0
σ 7	0	0	0	0	0	0	0	0	0	0	0	0	0
σ 6	0	0	0	0	0	0	0	0	0	0	0	0	0
σ 5	0	0	0	0	0	0	0	0	0	0	0	0	0
σ 4	0	0	0	0	0	0	0	0	0	0	0	0	0
σ 3	0	0	0	0	0	0	0	0	0	0	0	0	0
σ 2	0	0	0	0	0	0	0	0	0	0	0	0	0
σ 1	0	0	0	0	0	0	0	0	0	0	0	0	0
σ 0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 2 = 0 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 0 N/mm^2
   The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 0 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 0 N/mm^2
   The section at the end of phase 3 is considered: Cracked (m.)

Web assessment (Mmax comb.)

	Web
b (mm)	750
σ_{sup} (N/mm²)	0
σ_{inf} (N/mm²)	0
σ_{Ed} (N/mm²)	0
K_{σ}	1E+50
σ_{cr0E} (N/mm²)	86.47
τ_{Ed} (N/mm²)	45.3
σ_{cr} (P) (N/mm²)	1E+300
σ_{cr} (C) (N/mm²)	6.09
ξ	1
σ_{cr} (N/mm²)	1E+300
K_{τ}	5.64
$K_{\tau\,sl}$	0
Utilization ratio	0.102
Result	CHECK VERIFIED

SLS web breathing verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.31E+5	0E+00	0E+00
2a	0E+00	2.4E+5	0E+00	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	-1E+3	0E+00	0E+00
3a	0E+00	4E+3	0E+00	0E+00
Therm.Iso	4.2E+5	0	1.08E+5	0
3b	0E+00	2.39E+5	0E+00	0E+00
Total	4.2E+5	6.13E+5	1.08E+5	0E+00

Stresses of effective cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*
σ_8	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_7	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_6	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_5	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_4	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_3	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_2	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_1	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = 0 N/mm²
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 0 N/mm²
The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 0 N/mm²
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 0 N/mm²
The section at the end of phase 3 is considered: Cracked (m.)

Web assessment (Mmin comb.)

	Web
b (mm)	750
σ_{sup} (N/mm^2)	0
σ_{inf} (N/mm^2)	0
σ_{Ed} (N/mm^2)	0
K_{σ}	1E+50
σ_{cr0E} (N/mm^2)	86.47
τ_{Ed} (N/mm^2)	43.64
σ_{cr} (P) (N/mm^2)	1E+300
σ_{cr} (C) (N/mm^2)	6.09
ξ	1
σ_{cr} (N/mm^2)	1E+300
K_{τ}	5.64
$K_{\tau sl}$	0
Utilization ratio	0.098
Result	CHECK VERIFIED

Shear connectors assessment

Main data

Number of studs for unit length, n (m^{-1})	15
Stud diameter, d (mm)	19
Stud height, h (mm)	150
Ultimate resistance of studs α	1
Partial safety factor, γ_v	1.25
Ultimate resistance of studs f_u (N/mm^2)	450
Coefficient E_{cm} (N/mm^2)	36283
Characteristic cylinder compressive strength, f_{ck} (N/mm^2)	45

Resistance of headed stud connectors

Shank shear resistance, $P_{Rd1} = 0.8\, f_u\, \pi\, d^2/4/\gamma_v$, (N)	81656.28
Concrete crushing resistance, $P_{Rd2} = 0.29\, \alpha\, d^2 (f_{ck} E_{cm})^{0.5}/\gamma_v$, (N)	107017.34
Design stud resistance P_{Rd} = Min(P_{Rd1}, P_{Rd2}), (N)	81656.28

Elastic assessment at ULS

Utilization ratio (Mmax comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\, P_{Rd}\, \kappa_s$ (N/mm)	1224.8
Reduction factor, κ_s	1.00
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	660.2
Utilization ratio ν_{Ed}/ν_{Rd}	0.539
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmax comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	3.24E+5	5.619E+6	7.687E+9	236.8
Phase 2b	0E+00	5.619E+6	7.687E+9	0
Phase 2c	-1.2E+3	5.619E+6	7.687E+9	-0.9
Phase 3a	-7.2E+3	1.061E+7	1.039E+10	-7.4
Phase 3b	4.226E+5	1.061E+7	1.039E+10	431.6
			Sum	660.2

Utilization ratio (Mmin comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\, P_{Rd}\, \kappa_s$ (N/mm)	1224.8
Reduction factor, κ_s	1.00
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	679.9
Utilization ratio ν_{Ed}/ν_{Rd}	0.555
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmin comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4eff}$ (mm^3)*	*$J_{y,eff}$ (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	3.24E+5	5.542E+6	7.544E+9	238
Phase 2b	0E+00	5.542E+6	7.544E+9	0
Phase 2c	1.2E+3	5.542E+6	7.544E+9	0.9
Phase 3a	7.2E+3	1.043E+7	1.016E+10	7.4
Phase 3b	4.226E+5	1.043E+7	1.016E+10	433.6
			Sum	679.9

Elastic assessment at ELS

Utilization ratio (Mmax comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\, P_{Rd}\, \kappa_s$ (N/mm)	734.9
Reduction factor, κ_s	0.6
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	490.1
Utilization ratio ν_{Ed}/ν_{Rd}	0.667
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmax comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	2.4E+5	5.619E+6	7.687E+9	175.4
Phase 2b	0E+00	5.619E+6	7.687E+9	0
Phase 2c	-1E+3	5.619E+6	7.687E+9	-0.7
Phase 3a	-4.8E+3	1.061E+7	1.039E+10	-4.9
Phase 3b	3.136E+5	1.061E+7	1.039E+10	320.3
			Sum	490.1

Utilization ratio (Mmin comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\, P_{Rd}\, \kappa_s$ (N/mm)	734.9
Reduction factor, κ_s	0.6
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	501.4
Utilization ratio ν_{Ed}/ν_{Rd}	0.682
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmin comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	2.4E+5	5.619E+6	7.687E+9	175.4
Phase 2b	0E+00	5.619E+6	7.687E+9	0
Phase 2c	1E+3	5.619E+6	7.687E+9	0.7
Phase 3a	4.8E+3	1.061E+7	1.039E+10	4.9
Phase 3b	3.136E+5	1.061E+7	1.039E+10	320.3
			Sum	501.4

Assesment of studs at deck ends - shrinkage and thermal influence - (ULS)

Check of minimum studs number

Characteristic shrinkage shear per unit length, $\nu_{L,k}$ (N/mm)	280
Characteristic thermal shear per unit length (-), $\nu_{L,k}$ (N/mm)	700
Total design shear per unit length, $\nu_{L,Ed}$ (N/mm)	1*280 + 1.2*700 = 1120

Minimum number of studs at deck ends, n min (m^{-1})	13.7 < 15
CHECK VERIFIED	

Fatigue limit state verification

Forces and moments for steel details and studs (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.31E+5	0E+00	0E+00
2a	0E+00	2.4E+5	0E+00	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	0E+00	0E+00	0E+00
3a	0E+00	0E+00	0E+00	0E+00
Therm.Iso	0E+00	0	0E+00	0
3b max	0E+00	1.14E+5	0E+00	0E+00
3b max	0E+00	0E+00	0E+00	0E+00

Stresses of gross cross section for steel details and studs (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked Max*	*Ph. 3b Cracked Max*	*Ph. 3b Uncracked Min*	*Ph. 3b Cracked Min*	*Total Uncracked Max*	*Total Cracked Max*	*Total Uncracked Min*	*Total Cracked Min*	$\Delta\sigma, \Delta\tau$
σ_8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	135.3
σ_6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
τ_4	0	0.4	0.1	0	0	0	0	0	0	0.2	0	0	0	0.6	0.6	0.4	0.4	0.2
τ_3	9	17.5	16.6	0	0	0	0	0	0	8.5	7.9	0	0	35.1	35.1	26.6	26.6	8.5
τ_2	11.3	18.6	20.1	0	0	0	0	0	0	8.6	9.6	0	0	38.4	38.4	29.8	29.8	8.6
τ_1	9.5	14.8	16.9	0	0	0	0	0	0	6.5	8	0	0	30.8	30.8	24.3	24.3	6.5
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 3 max = 0 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 3 max = 0 N/mm^2
The section at the end of phase 3 max is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 min = 0 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 min = 0 N/mm^2
The section at the end of phase 3 min is considered: Cracked (m.)

Forces and moments for steel details and studs (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.31E+5	0E+00	0E+00
2a	0E+00	2.4E+5	0E+00	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	0E+00	0E+00	0E+00
3a	0E+00	0E+00	0E+00	0E+00

Therm.Iso	0E+00	0	0E+00	0
3b max	0E+00	1.14E+5	0E+00	0E+00
3b max	0E+00	0E+00	0E+00	0E+00

Stresses of gross cross section for steel details and studs (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked Max*	*Ph. 3b Cracked Max*	*Ph. 3b Uncracked Min*	*Ph. 3b Cracked Min*	*Total Uncracked Max*	*Total Cracked Max*	*Total Uncracked Min*	*Total Cracked Min*	*Δσ,Δτ*
σ_8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	135.3
σ_6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
τ_4	0	0.4	0.1	0	0	0	0	0	0	0.2	0	0	0	0.6	0.6	0.4	0.4	0.2
τ_3	9	17.5	16.6	0	0	0	0	0	0	8.5	7.9	0	0	35.1	35.1	26.6	26.6	8.5
τ_2	11.3	18.6	20.1	0	0	0	0	0	0	8.6	9.6	0	0	38.4	38.4	29.8	29.8	8.6
τ_1	9.5	14.8	16.9	0	0	0	0	0	0	6.5	8	0	0	30.8	30.8	24.3	24.3	6.5
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 3 max = 0 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 3 max = 0 N/mm^2
   The section at the end of phase 3 max is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 min = 0 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 min = 0 N/mm^2
   The section at the end of phase 3 min is considered: Cracked (m.)

Main data for partial factors and damage equivalent facors

Partial factor for steel:	γ_{Ff}	1
	γ_{Mf}	1.35
Bending damage equivalent factor for steel:	$\lambda = \lambda_1 * \lambda_2 * \lambda_3 * \lambda_4 =$	2.32 x 0.848 x 1 x 1.15 = 2.262>2=>2 (Midspan)
Shear damage equivalent factor for steel:	$\lambda = \lambda_1 * \lambda_2 * \lambda_3 * \lambda_4 =$	2.518 x 0.848 x 1 x 1.15 = 2.455 (Midspan)
Data for calculation of λ_1	Section position:	(Midspan)
	L span for moment (m):	33
	L span for shear (m):	13.2
Data for calculation of λ_2, λ_{v2}	Q_0 (kN)	480
	N_0	500000
	N_{obs}	500000
	Q_{ml} (kN)	0
	Traffic category (Table 4.5n - EN 1991-2) :	Roads and motorways with medium flow rates of lorries
	Traffic distribution (Table 4.7 - EN 1991-2) :	Medium distance (40% Q1, 10% Q2, 30% Q3, 15% Q4, 5% Q5)
Data for calculation of λ_3, λ_{v3}	Design life (years):	100

Data for calculation of γ_{Mf} for steel:	Assessment method:	
	Consequence of failure:	
Damage equivalent factor for studs:	$\lambda_v = \lambda_{v1} * \lambda_{v2} * \lambda_{v3} * \lambda_{v4} =$	1.55 x 0.896 x 1 x 1.09 = 1.514
Partial factor for studs:	γ_{Ff}	1
	γ_{Mf}	1

Fatigue assessment of structural steel

Utilization ratio (Mmax comb.)

	$\gamma_{Ff}\Delta\sigma_{E,2}$	$\Delta\sigma_c/\gamma_{Mf}$	u.r.
Top flange	0	92.593	0
Bottom flange	0	92.593	0
Web	21.12	74.074	0.285
Top flange welding			
Bottom flange welding			
Web-top flange welding	0	92.593	0
Web-bottom flange welding	0	92.593	0
Vertical stiffeners - web welding	0	59.259	0
Vertical stiffeners - top flange welding	0	59.259	0
Vertical stiffeners - bottom flange welding	0	59.259	0
Longitudinal stiffener 1 - web welding			
Longitudinal stiffener 2 - web welding			

Utilization ratio (Mmin comb.)

	$\gamma_{Ff}\Delta\sigma_{E,2}$	$\Delta\sigma_c/\gamma_{Mf}$	u.r.
Top flange	0	92.593	0
Bottom flange	0	92.593	0
Web	21.12	74.074	0.285
Top flange welding			
Bottom flange welding			
Web-top flange welding	0	92.593	0
Web-bottom flange welding	0	92.593	0
Vertical stiffeners - web welding	0	59.259	0
Vertical stiffeners - top flange welding	0	59.259	0
Vertical stiffeners - bottom flange welding	0	59.259	0
Longitudinal stiffener 1 - web welding			
Longitudinal stiffener 2 - web welding			

Fatigue assessment of studs

Utilization ratio (Mmax comb.)

$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) <=1$	=1*41.45/(90/1) =0.461
$\gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <=1$	=1*0/(80/1.35) =0(*)
$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s})+\gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <=1.3$	=0.461+0=0.461(*)
CHECK PASSED	

(*) Not relevant check (Top flange in compression)

Utilization ratio (Mmin comb.)

$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) <=1$	=1*41.45/(90/1) =0.461
$\gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <=1$	=1*0/(80/1.35) =0(*)
$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s})+\gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <=1.3$	=0.461+0=0.461(*)
CHECK PASSED	

(*) Not relevant check (Top flange in compression)

Stiffeners checks

Torsional buckling of vertical stiffeners

	Vertical stiffeners
	CHECK PASSED
u.r.	0.898
Type	Vert. (R)
σ_{cr} (N/mm²)	--
6*f_y (N/mm²)	--
l_{cr} (mm)	--
I_w (mm⁶)	--
I_T (mm⁴)	5.333E+5
I_P (mm⁴)	5.347E+7
I_T /I_P	0.01
5.3 f_y /E	0.009
cθ (N)	--
E (N/mm²)	210000
f_y (N/mm²)	355
G (N/mm²)	87500
a (mm)	2750

Intermediate vertical stiffeners acting as rigid support for web panels

I_{st} = 4.247E+7 mm^4 > $I_{st\,min}$ = 0.75 h_w $t_w^{\,3}$ =2.304E+6 mm^4

CHECK PASSED

With:

t_w = 16 mm b_w = 410.5 mm A_{st} = 10568.6 mm^2 e_1 = 40.9 mm ^{2}
a = 2750 mm h_w = 750 mm a/hw = 3.667

Maximum stress and the additional deflection in the vertical stiffeners (Mmax comb.)

w = 0 < 2.5 mm

σ_{max} = 81.4 < 322.7 N/mm^2

CHECK PASSED

With:

$\Sigma N_{st,Ed} = N_{st,Ed} + \Delta N_{st,Ed}$ = 8.39E+5 + 0E+00 = 8.39E+5 N
$N_{st,Ed} = N_{st,ten} + N_{st,ex}$ = 0E+00 + 8.39E+5 = 8.39E+5 N
σ_m = 0 N/mm^2 $\sigma_{cr(C)} / \sigma_{cr(P)}$ = 6.09/1E+300 = 0=> 0.5
N_{Ed} = 0E+00 N $\bar{\lambda}_w$ = 0.649
$N_{cr,st}$ = 1.565E+8 N e_1 = 40.9 mm e_{max} = 167.1 mm w_0 = 2.5 mm
δ_m = 0

9.3.2 Section Sez. 2a_2a

First classification

The first classification refers to the composite section in Phase 3

Plastic characteristics of the single components

Components	N_{pl} *(N)*	z_N *(mm)*	z_{max} *(mm)*	z_{min} *(mm)*
Concrete layer above top reinforcing bars	1.515E+6	975.25	1000	950.5
Concrete layer between top and bottom reinforcing bars	4.498E+6	876	949.5	802.5
Concrete layer below top reinforcing bars	7.65E+4	801.25	802.5	800
Top reinforcing bars	4.721E+5	950	950.5	949.5
Bottom reinforcing bars	0E+00	802.5	802.5	802.5
Concrete haunch slab	0E+00	800	800	800
Top flange of steel beam	4.226E+6	787.5	800	775
Web of steel beam	4.057E+6	400	775	25
Bottom flange of steel beam	5.071E+6	12.5	25	0
Ultimate compression force for the full section	-1.992E+7			
Ultimate tension force for the full section	1.383E+7			
Ultimate compression force for the web less section	-1.586E+7			
Ultimate tensile force for the web less section	9.77E+6			

Flanges classification

	c/t	ε	*Hogging bending moment (M+)*	*Sagging bending moment (M-)*
Top flange	9.68	0.814	1	0
Bottom flange	11.68	0.814	4	1

Web classification

	c/t	ε	α	ψ	*class*
Hogging bending moment (M+)	46.875	0.814	0.454	-1.041	1
Sagging bending moment (M-)	46.875	0.814	0	-0.212	1
Compression (N)	46.875	0.814	1	1	4

U.L.S. composite section verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	8.91E+4	-8.84E+5	0E+00
2a	0E+00	1.19E+5	-1.22E+6	0E+00
2b	0E+00	-6E+3	4.2E+4	0E+00
Shr.Iso	-4.03E+5	0	-1.54E+5	0
2c	0E+00	-1.2E+3	8.4E+3	0E+00
3a	0E+00	-7.2E+3	5.22E+4	0E+00
Therm.Iso	-7.56E+5	0	-1.94E+5	0
3b	0E+00	2.52E+5	-1.82E+6	0E+00
Total	-1.16E+6	4.46E+5	-4.17E+6	0E+00

Bending resistance - Plastic analysis

Section classification (Mmax comb.)

	c/t	z_{pl} *(mm)*	α	ψ	*Class*
Web	46.88	776.48	0	-1.56	1
Top flange	9.68				1
Bottom flange	11.68				1
Section class					1

Plastic analysis: APPLICABLE

Plastic section verification (Mmax comb.)

Axial force		*Bending moment*		*N/M interaction*	
N_{Ed} (N)	-1.159E+6	M_{Ed} (Nm)	-4.171E+6	N_{Ed} (N)	-1.159E+6
N_{Rd} (N)	-1.992E+7	M_{Rd} (Nm)	-6.279E+6	M_{Ed} (Nm)	-4.171E+6
				M_{Rd} (Nm)	-6.435E+6
N_{Ed} /N_{Rd}	0.058	M_{Ed} /M_{Rd}	0.664	M_{Ed} /M_{Rd}	0.648
CHECK PASSED					

Axial force and bending moment stresses of gross cross section

Stresses of gross cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	η_1
σ_8	0	-4.2	0	0.9	0	0	0	-3.3	0.8	0	-10.4	0	-13	0.509
σ_7	0	-68.5	-134.3	-13.8	4.6	0.5	0.9	-81.8	-13.5	5.8	-53.7	-201.2	-149	0.381
σ_6	0	0	0	-7.5	0	0	0	-7.5	-9.4	0	0	0	-16.8	0.043
σ_5	0	-2.5	0	1	0	0	0	-1.4	1.2	0	-4.6	0	-4.8	0.187
σ_4	-80.4	-44.7	-98.1	-11.6	3.4	0.3	0.7	-136.4	-11.5	4.2	-27.4	-147	-175.3	0.518
σ_3	-75.7	-40.8	-92.1	-11.2	3.2	0.3	0.6	-127.3	-11.1	3.9	-23	-138	-161.5	0.478
σ_2	0	0	0	-7.5	0	0	0	-7.5	-9.4	0	0	0	-16.8	0.05
σ_1	66.4	78.1	88.5	-0.3	-3.1	-0.5	-0.6	143.6	-0.9	-3.8	108.7	132.6	251.4	0.744
σ_0	71.1	82	94.5	0.1	-3.3	-0.6	-0.7	152.6	-0.6	-4.1	113.1	141.6	265.2	0.784

Maximum utilization ratio:0.784 NOT RELEVANT CHECK
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -3.34 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -1.43 N/mm^2
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -12.98 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -4.76 N/mm^2
The section at the end of phase 3 is considered: Uncracked (m.)

Resistance to shear

Evaluation of necessity to Shear buckling check
h_w/t_w =46.875 < $31/\eta \cdot \varepsilon_w \cdot (K_\tau)^{0.5}$ =49.905 Shear Buckling check: NOT REQUIRED

Shear Buckling resistance: **$V_{b,Rd}$ =2.683E+6 N**

With:
a/h_w =3.667, η =1.2, K_τ =5.638
web contribution: $V_{bw,Rd}$ =2.683E+6 N, flanges contribution: $V_{bf,Rd}$ =3.756E+4 N
χ_w =1.2, $\bar{\lambda}_w$ =0.649, τ_{cr} =487.5, C=870.8
M_{Ed} =-4.171E+6 Nm, $M_{f,Rd}$ =-4.883E+6 Nm, $M_{Ed}/M_{f,Rd}$ =0.854

Plastic resistance: **$V_{pl,Rd}$ =2.811E+6 N**

Shear resistance: **V_{Rd} =$V_{pl,Rd}$ =2.811E+6 N**

Utilization ratios:
$\eta_3 = V_{Ed}/V_{Rd}$ =0.158, (=> CHECK VERIFIED)
$\bar{\eta}_3 = V_{Ed}/V_{bw,Rd}$ =0.166, $\bar{\eta}_1 = M_{Ed}/M_{Rd}$ =0.648

Interaction between shear force, bending moment and axial force

Evaluation of the interaction

$\eta_3 < 0.5$, $M_{Ed} / M_{f,Rd} < 1$

INTERACTION NOT TO BE CHECKED

U.L.S. composite section verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	8.91E+4	-8.84E+5	0E+00
2a	0E+00	1.19E+5	-1.22E+6	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	1.2E+3	-8.4E+3	0E+00
3a	0E+00	7.2E+3	-5.22E+4	0E+00
Therm.Iso	7.56E+5	0	1.94E+5	0
3b	0E+00	2.61E+5	-1.91E+6	0E+00
Total	7.56E+5	4.77E+5	-3.88E+6	0E+00

Bending resistance - Plastic analysis

Section classification (Mmin comb.)

	c/t	z_{pl} *(mm)*	α	ψ	*Class*
Web	46.88	782.14	-0.01	-2	1
Top flange	9.68				1
Bottom flange	11.68				1
Section class					1
Plastic analysis: APPLICABLE					

Plastic section verification (Mmin comb.)

Axial force		*Bending moment*		*N/M interaction*	
N_{Ed} (N)	7.56E+5	M_{Ed} (Nm)	-3.876E+6	N_{Ed} (N)	7.56E+5
N_{Rd} (N)	1.383E+7	M_{Rd} (Nm)	-6.279E+6	M_{Ed} (Nm)	-3.876E+6
				M_{Rd} (Nm)	-6.176E+6
N_{Ed}/N_{Rd}	0.055	M_{Ed}/M_{Rd}	0.617	M_{Ed}/M_{Rd}	0.628
CHECK PASSED					

Axial force and bending moment stresses of gross cross section

Stresses of gross cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	η_1
σ_8	0	-4.2	0	0	0	0	0	-4.3	-0.8	0	-10.9	0	-15.9	0.625
σ_7	0	-68.5	-134.3	0	0	-0.5	-0.9	-68.9	13.5	-5.8	-56.2	-210.3	-111.6	0.285
σ_6	0	0	0	0	0	0	0	0	9.4	0	0	0	9.4	0.024
σ_5	0	-2.5	0	0	0	0	0	-2.5	-1.2	0	-4.8	0	-8.5	0.334
σ_4	-80.4	-44.7	-98.1	0	0	-0.3	-0.7	-125.4	11.5	-4.2	-28.6	-153.7	-142.6	0.422
σ_3	-75.7	-40.8	-92.1	0	0	-0.3	-0.6	-116.7	11.1	-3.9	-24.1	-144.3	-129.6	0.383
σ_2	0	0	0	0	0	0	0	0	9.4	0	0	0	9.4	0.028
σ_1	66.4	78.1	88.5	0	0	0.5	0.6	145	0.9	3.8	113.7	138.6	259.6	0.768
σ_0	71.1	82	94.5	0	0	0.6	0.7	153.7	0.6	4.1	118.3	148.1	272.5	0.806

Maximum utilization ratio:0.806 NOT RELEVANT CHECK

NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 2 = -4.27 N/mm^2

2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -2.5 N/mm^2
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -15.95 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -8.51 N/mm^2
The section at the end of phase 3 is considered: Uncracked (m.)

Resistance to shear

Evaluation of necessity to Shear buckling check

$h_w / t_w = 46.875 < 31/\eta * \varepsilon_w * (K_\tau)^{0.5} = 49.905$ Shear Buckling check: NOT REQUIRED

Shear Buckling resistance: $\mathbf{V_{b,Rd} = 2.683E+6}$ **N**

With:

$a/h_w = 3.667$, $\eta = 1.2$, $K_\tau = 5.638$
web contribution: $V_{bw,Rd} = 2.683E+6$ N, flanges contribution: $V_{bf,Rd} = 4.034E+4$ N
$\chi_w = 1.2$, $\bar{\lambda}_w = 0.649$, $\tau_{cr} = 487.5$, C=870.8
$M_{Ed} = -3.876E+6$ Nm, $M_{f,Rd} = -4.601E+6$ Nm, $M_{Ed} / M_{f,Rd} = 0.842$

Plastic resistance: $\mathbf{V_{pl,Rd} = 2.811E+6}$ **N**

Shear resistance: $\mathbf{V_{Rd} = V_{pl,Rd} = 2.811E+6}$ **N**

Utilization ratios:

$\eta_3 = V_{Ed} / V_{Rd} = 0.17$, (=> CHECK VERIFIED)
$\bar{\eta}_3 = V_{Ed} / V_{bw,Rd} = 0.178$, $\bar{\eta}_1 = M_{Ed} / M_{Rd} = 0.628$

Interaction between shear force, bending moment and axial force

Evaluation of the interaction

$\bar{\eta}_3 < 0.5$, $M_{Ed} / M_{f,Rd} < 1$
INTERACTION NOT TO BE CHECKED

SLS stresses verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	6.6E+4	-6.55E+5	0E+00
2a	0E+00	8.8E+4	-9.02E+5	0E+00
2b	0E+00	-5E+3	3.5E+4	0E+00
Shr.Iso	-3.36E+5	0	-1.28E+5	0
2c	0E+00	-1E+3	7E+3	0E+00
3a	0E+00	-4.8E+3	3.48E+4	0E+00
Therm.Iso	-5.04E+5	0	-1.29E+5	0
3b	0E+00	1.87E+5	-1.35E+6	0E+00
Total	-8.4E+5	3.3E+5	-3.09E+6	0E+00

Stresses of gross cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	σ_{id}	η_1
σ_8	0	-3.1	0	0.7	0	0	0	-2.4	0.5	0	-7.7	0	-9.6	9.6	0.356
σ_7	0	-50.7	-99.5	-11.5	3.9	0.4	0.8	-61.8	-9	3.8	-39.9	-149.3	-110.7	110.7	0.308
σ_6	0	0	0	-6.2	0	0	0	-6.2	-6.2	0	0	0	-12.5	12.5	0.035
σ_5	0	-1.8	0	0.9	0	0	0	-1	0.8	0	-3.4	0	-3.5	3.5	0.131
σ_4	-59.5	-33.1	-72.7	-9.6	2.8	0.3	0.6	-102.1	-7.7	2.8	-20.3	-109.2	-130.1	130.1	0.366
σ_3	-56	-30.2	-68.2	-9.3	2.6	0.2	0.5	-95.3	-7.4	2.6	-17.1	-102.5	-119.9	126.9	0.358

σ_2	0	0	0	-6.2	0	0	0	-6.2	-6.2	0	0	0	-12.5	46.3	0.131
σ_1	49.2	57.8	65.6	-0.2	-2.5	-0.4	-0.5	106.3	-0.6	-2.5	80.7	98.4	186.4	189.7	0.534
σ_0	52.7	60.7	70	0.1	-2.7	-0.5	-0.5	113	-0.4	-2.7	84	105.1	196.6	196.6	0.554
τ_4	0	0.1	0	0	0	0	0	0.1	0	0	0.4	0	0.5		
τ_3	4.5	6.4	6.1	-0.4	-0.3	-0.1	-0.1	10.5	-0.4	-0.3	14	13	24.1		
τ_2	5.7	6.8	7.4	-0.4	-0.4	-0.1	-0.1	12	-0.4	-0.4	14.1	15.7	25.8		
τ_1	4.8	5.4	6.2	-0.3	-0.4	-0.1	-0.1	9.9	-0.3	-0.3	10.7	13.2	20.2		
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Maximum utilization ratio:0.554 CHECK PASSED
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -2.39 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -0.96 N/mm^2
   The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -9.61 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -3.53 N/mm^2
   The section at the end of phase 3 is considered: Uncracked (m.)

SLS stresses verification (Mmin comb.)

Forces and moments   (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	6.6E+4	-6.55E+5	0E+00
2a	0E+00	8.8E+4	-9.02E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	1E+3	-7E+3	0E+00
3a	0E+00	4.8E+3	-3.48E+4	0E+00
Therm.Iso	5.04E+5	0	1.29E+5	0
3b	0E+00	1.93E+5	-1.41E+6	0E+00
Total	5.04E+5	3.53E+5	-2.88E+6	0E+00

Stresses of gross cross section   (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	σ_{id}	η_1
σ_8	0	-3.1	0	0	0	0	0	-3.2	-0.5	0	-8.1	0	-11.7	11.7	0.435
σ_7	0	-50.7	-99.5	0	0	-0.4	-0.8	-51.1	9	-3.8	-41.5	-155.4	-83.6	83.6	0.232
σ_6	0	0	0	0	0	0	0	0	6.2	0	0	0	6.2	6.2	0.017
σ_5	0	-1.8	0	0	0	0	0	-1.9	-0.8	0	-3.5	0	-6.2	6.2	0.23
σ_4	-59.5	-33.1	-72.7	0	0	-0.3	-0.6	-92.9	7.7	-2.8	-21.2	-113.6	-106.4	106.4	0.3
σ_3	-56	-30.2	-68.2	0	0	-0.2	-0.5	-86.5	7.4	-2.6	-17.8	-106.6	-96.8	106.6	0.3
σ_2	0	0	0	0	0	0	0	0	6.2	0	0	0	6.2	48	0.135
σ_1	49.2	57.8	65.6	0	0	0.4	0.5	107.4	0.6	2.5	84	102.5	192.1	195.7	0.551
σ_0	52.7	60.7	70	0	0	0.5	0.5	113.9	0.4	2.7	87.4	109.4	201.7	201.7	0.568
τ_4	0	0.1	0	0	0	0	0	0.1	0	0	0.4	0.1	0.5		
τ_3	4.5	6.4	6.1	0	0	0.1	0.1	11.1	0.4	0.3	14.4	13.4	25.8		
τ_2	5.7	6.8	7.4	0	0	0.1	0.1	12.6	0.4	0.4	14.6	16.2	27.5		
τ_1	4.8	5.4	6.2	0	0	0.1	0.1	10.3	0.3	0.3	11	13.6	21.6		
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Maximum utilization ratio:0.568 CHECK PASSED
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -3.17 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -1.85 N/mm^2
   The section at the end of phase 2 is considered: Uncracked (m.)

3) Total stress at the top fibre of slab concrete at the end of phase 3 = -11.74 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -6.21 N/mm^2
The section at the end of phase 3 is considered: Uncracked (m.)

SLS web breathing verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	N (N)	V (N)	M (Nm)	T (Nm)
1	0E+00	6.6E+4	-6.55E+5	0E+00
2a	0E+00	8.8E+4	-9.02E+5	0E+00
2b	0E+00	-5E+3	3.5E+4	0E+00
Shr.Iso	-3.36E+5	0	-1.28E+5	0
2c	0E+00	-1E+3	7E+3	0E+00
3a	0E+00	-4E+3	2.9E+4	0E+00
Therm.Iso	-4.2E+5	0	-1.08E+5	0
3b	0E+00	1.42E+5	-1.04E+6	0E+00
Total	-7.56E+5	2.86E+5	-2.76E+6	0E+00

Stresses of effective cross section (Mmax comb.)

	Ph. 1	Ph. 2a Uncracked	Ph. 2a Cracked	Ph. 2b Uncracked	Ph. 2b Cracked	Ph. 2c Uncracked	Ph. 2c Cracked	Ph. 2 tot	Ph. 3a Uncracked	Ph. 3a Cracked	Ph. 3b Uncracked	Ph. 3b Cracked	Ph. 3 tot
σ_8	0	-3.1	0	0.7	0	0	0	-2.4	0.4	0	-5.9	0	-7.9
σ_7	0	-50.7	-99.5	-11.5	3.9	0.4	0.8	-61.8	-7.5	3.2	-30.5	-114.3	-99.9
σ_6	0	0	0	-6.2	0	0	0	-6.2	-5.2	0	0	0	-11.4
σ_5	0	-1.8	0	0.9	0	0	0	-1	0.7	0	-2.6	0	-2.9
σ_4	-59.5	-33.1	-72.7	-9.6	2.8	0.3	0.6	-102.1	-6.4	2.3	-15.6	-83.5	-124
σ_3	-56	-30.2	-68.2	-9.3	2.6	0.2	0.5	-95.3	-6.2	2.2	-13.1	-78.4	-114.6
σ_2	0	0	0	-6.2	0	0	0	-6.2	-5.2	0	0	0	-11.4
σ_1	49.2	57.8	65.6	-0.2	-2.5	-0.4	-0.5	106.3	-0.5	-2.1	61.8	75.3	167.6
σ_0	52.7	60.7	70	0.1	-2.7	-0.5	-0.5	113	-0.3	-2.3	64.3	80.5	177

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -2.39 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -0.96 N/mm^2
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -7.88 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -2.87 N/mm^2
The section at the end of phase 3 is considered: Uncracked (m.)

Web assessment (Mmax comb.)

	Web
b (mm)	750
σ_{sup} (N/mm^2)	-114.61
σ_{inf} (N/mm^2)	167.56
σ_{Ed} (N/mm^2)	114.61
K_σ	36.25
σ_{cr0E} (N/mm^2)	86.47
τ_{Ed} (N/mm^2)	20.37
σ_{cr} (P) (N/mm^2)	3134.36
σ_{cr} (C) (N/mm^2)	6.09
ξ	1
σ_{cr} (N/mm^2)	3134.36
K_τ	5.64
$K_{\tau sl}$	0

Utilization ratio	0.059
Result	CHECK VERIFIED

SLS web breathing verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	6.6E+4	-6.55E+5	0E+00
2a	0E+00	8.8E+4	-9.02E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	-1E+3	-7E+3	0E+00
3a	0E+00	4E+3	-2.9E+4	0E+00
Therm.Iso	4.2E+5	0	1.08E+5	0
3b	0E+00	1.42E+5	-1.04E+6	0E+00
Total	4.2E+5	3E+5	-2.52E+6	0E+00

Stresses of effective cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*
σ_8	0	-3.1	0	0	0	0	0	-3.2	-0.4	0	-5.9	0	-9.5
σ_7	0	-50.7	-99.5	0	0	-0.4	-0.8	-51.1	7.5	-3.2	-30.5	-114.3	-74.1
σ_6	0	0	0	0	0	0	0	0	5.2	0	0	0	5.2
σ_5	0	-1.8	0	0	0	0	0	-1.9	-0.7	0	-2.6	0	-5.1
σ_4	-59.5	-33.1	-72.7	0	0	-0.3	-0.6	-92.9	6.4	-2.3	-15.6	-83.5	-102.1
σ_3	-56	-30.2	-68.2	0	0	-0.2	-0.5	-86.5	6.2	-2.2	-13.1	-78.4	-93.3
σ_2	0	0	0	0	0	0	0	0	5.2	0	0	0	5.2
σ_1	49.2	57.8	65.6	0	0	0.4	0.5	107.4	0.5	2.1	61.8	75.3	169.7
σ_0	52.7	60.7	70	0	0	0.5	0.5	113.9	0.3	2.3	64.3	80.5	178.5

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -3.17 N/mm²
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -1.85 N/mm²
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -9.52 N/mm²
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -5.13 N/mm²
The section at the end of phase 3 is considered: Uncracked (m.)

Web assessment (Mmin comb.)

	Web
b (mm)	750
σ_{sup} (N/mm²)	-93.34
σ_{inf} (N/mm²)	169.73
σ_{Ed} (N/mm²)	93.34
K_σ	47.5
σ_{cr0E} (N/mm²)	86.47
τ_{Ed} (N/mm²)	21.28
σ_{cr} (P) (N/mm²)	4107.38
σ_{cr} (C) (N/mm²)	6.09
ξ	1
σ_{cr} (N/mm²)	4107.38
K_τ	5.64
$K_{\tau sl}$	0

Utilization ratio	0.053
Result	CHECK VERIFIED

Shear connectors assessment

Main data

Number of studs for unit length, n (m^{-1})	15
Stud diameter, d (mm)	19
Stud height, h (mm)	150
Ultimate resistance of studs α	1
Partial safety factor, γ_v	1.25
Ultimate resistance of studs f_u (N/mm^2)	450
Coefficient E_{cm} (N/mm^2)	36283
Characteristic cylinder compressive strength, f_{ck} (N/mm^2)	45

Resistance of headed stud connectors

Shank shear resistance, $P_{Rd1} = 0.8\ f_u\ \pi\ d^2/4/\gamma_v$, (N)	81656.28
Concrete crushing resistance, $P_{Rd2} = 0.29\ \alpha\ d^2 (f_{ck}\ E_{cm})^{0.5}/\gamma_v$, (N)	107017.34
Design stud resistance $P_{Rd} = \mathrm{Min}(P_{Rd1}, P_{Rd2})$, (N)	81656.28

Elastic assessment at ULS

Utilization ratio (Mmax comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\ P_{Rd}\ \kappa_s$ (N/mm)	1224.8
Reduction factor, κ_s	1.00
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	331.6
Utilization ratio ν_{Ed}/ν_{Rd}	0.271
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmax comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	1.188E+5	5.619E+6	7.687E+9	86.8
Phase 2b	-6E+3	5.619E+6	7.687E+9	-4.4
Phase 2c	-1.2E+3	5.619E+6	7.687E+9	-0.9
Phase 3a	-7.2E+3	1.061E+7	1.039E+10	-7.4
Phase 3b	2.52E+5	1.061E+7	1.039E+10	257.4
			Sum	331.6

Utilization ratio (Mmin comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\ P_{Rd}\ \kappa_s$ (N/mm)	1224.8
Reduction factor, κ_s	1.00
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	361.7
Utilization ratio ν_{Ed}/ν_{Rd}	0.295
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmin comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	1.188E+5	5.619E+6	7.687E+9	86.8
Phase 2b	0E+00	5.619E+6	7.687E+9	0
Phase 2c	1.2E+3	5.619E+6	7.687E+9	0.9
Phase 3a	7.2E+3	1.061E+7	1.039E+10	7.4
Phase 3b	2.61E+5	1.061E+7	1.039E+10	266.6
			Sum	361.7

Elastic assessment at ELS

Utilization ratio (Mmax comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\, P_{Rd}\, \kappa_s$ (N/mm)	734.9
Reduction factor, κ_s	0.6
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	246
Utilization ratio ν_{Ed}/ν_{Rd}	0.335
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmax comb.)

Phase	V_{Ed} *(N)*	$S_{y,4}$*(mm³)*	J_y *(mm⁴)*	V_{Ed} *(N/mm)*
Phase 2a	8.8E+4	5.619E+6	7.687E+9	64.3
Phase 2b	-5E+3	5.619E+6	7.687E+9	-3.7
Phase 2c	-1E+3	5.619E+6	7.687E+9	-0.7
Phase 3a	-4.8E+3	1.061E+7	1.039E+10	-4.9
Phase 3b	1.87E+5	1.061E+7	1.039E+10	191
			Sum	246

Utilization ratio (Mmin comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\, P_{Rd}\, \kappa_s$ (N/mm)	734.9
Reduction factor, κ_s	0.6
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	267.1
Utilization ratio ν_{Ed}/ν_{Rd}	0.363
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmin comb.)

Phase	V_{Ed} *(N)*	$S_{y,4}$*(mm³)*	J_y *(mm⁴)*	V_{Ed} *(N/mm)*
Phase 2a	8.8E+4	5.619E+6	7.687E+9	64.3
Phase 2b	0E+00	5.619E+6	7.687E+9	0
Phase 2c	1E+3	5.619E+6	7.687E+9	0.7
Phase 3a	4.8E+3	1.061E+7	1.039E+10	4.9
Phase 3b	1.93E+5	1.061E+7	1.039E+10	197.1
			Sum	267.1

Assesment of studs at deck ends - shrinkage and thermal influence - (ULS)

Check of minimum studs number

Characteristic shrinkage shear per unit length, $\nu_{L,k}$ (N/mm)	280
Characteristic thermal shear per unit length (-), $\nu_{L,k}$ (N/mm)	700
Total design shear per unit length, $\nu_{L,Ed}$ (N/mm)	1*280 + 1.2*700 = 1120
Minimum number of studs at deck ends, n min (m^{-1})	13.7 < 15
CHECK VERIFIED	

Fatigue limit state verification

Forces and moments for steel details and studs (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	6.6E+4	-6.55E+5	0E+00
2a	0E+00	8.8E+4	-9.02E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	0E+00	0E+00	0E+00
3a	0E+00	0E+00	0E+00	0E+00
Therm.Iso	0E+00	0	0E+00	0
3b max	0E+00	5.2E+4	-3.15E+5	0E+00
3b max	0E+00	-1E+4	7.2E+4	0E+00

Stresses of gross cross section for steel details and studs (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked Max*	*Ph. 3b Cracked Max*	*Ph. 3b Uncracked Min*	*Ph. 3b Cracked Min*	*Total Uncracked Max*	*Total Cracked Max*	*Total Uncracked Min*	*Total Cracked Min*	*Δσ,Δτ*
σ_8	0	-3.1	0	0	0	0	0	0	0	-1.8	0	0.4	0	-4.9	0	-2.7	0	2.2
σ_7	0	-50.7	-99.5	0	0	0	0	0	0	-9.3	-34.7	2.1	7.9	-60	-134.2	-48.6	-91.5	11.4
σ_6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_5	0	-1.8	0	0	0	0	0	0	0	-0.8	0	0.2	0	-2.6	0	-1.7	0	1
σ_4	-59.5	-33.1	-72.7	0	0	0	0	0	0	-4.7	-25.4	1.1	5.8	-97.4	-157.6	-91.6	-126.4	5.8
σ_3	-56	-30.2	-68.2	0	0	0	0	0	0	-4	-23.8	0.9	5.4	-90.2	-148.1	-85.3	-118.8	4.9
σ_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_1	49.2	57.8	65.6	0	0	0	0	0	0	18.8	22.9	-4.3	-5.2	125.8	137.6	102.7	109.5	23.1
σ_0	52.7	60.7	70	0	0	0	0	0	0	19.5	24.5	-4.5	-5.6	133	147.1	109	117.1	24
τ_4	0	0.1	0	0	0	0	0	0	0	0.1	0	0	0	0.2	0.2	0.1	0.1	0.1
τ_3	4.5	6.4	6.1	0	0	0	0	0	0	3.9	3.6	-0.7	-0.7	14.9	14.9	10.2	10.2	4.6
τ_2	5.7	6.8	7.4	0	0	0	0	0	0	3.9	4.4	-0.8	-0.8	16.4	16.4	11.7	11.7	4.7
τ_1	4.8	5.4	6.2	0	0	0	0	0	0	3	3.7	-0.6	-0.7	13.2	13.2	9.7	9.7	3.5
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 3 max = -4.94 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 3 max = -2.63 N/mm^2
   The section at the end of phase 3 max is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 min = -2.73 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 min = -1.66 N/mm^2
   The section at the end of phase 3 min is considered: Uncracked (m.)

Forces and moments for steel details and studs (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	6.6E+4	-6.55E+5	0E+00
2a	0E+00	8.8E+4	-9.02E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	0E+00	0E+00	0E+00
3a	0E+00	0E+00	0E+00	0E+00
Therm.Iso	0E+00	0	0E+00	0
3b max	0E+00	5.2E+4	-3.15E+5	0E+00
3b max	0E+00	-1E+4	7.2E+4	0E+00

Stresses of gross cross section for steel details and studs (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked Max*	*Ph. 3b Cracked Max*	*Ph. 3b Uncracked Min*	*Ph. 3b Cracked Min*	*Total Uncracked Max*	*Total Cracked Max*	*Total Uncracked Min*	*Total Cracked Min*	*Δσ,Δτ*
σ_8	0	-3.1	0	0	0	0	0	0	0	-1.8	0	0.4	0	-4.9	0	-2.7	0	2.2
σ_7	0	-50.7	-99.5	0	0	0	0	0	0	-9.3	-34.7	2.1	7.9	-60	-134.2	-48.6	-91.5	11.4

σ_6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_5	0	-1.8	0	0	0	0	0	0	0	-0.8	0	0.2	0	-2.6	0	-1.7	0	1
σ_4	-59.5	-33.1	-72.7	0	0	0	0	0	0	-4.7	-25.4	1.1	5.8	-97.4	-157.6	-91.6	-126.4	5.8
σ_3	-56	-30.2	-68.2	0	0	0	0	0	0	-4	-23.8	0.9	5.4	-90.2	-148.1	-85.3	-118.8	4.9
σ_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_1	49.2	57.8	65.6	0	0	0	0	0	0	18.8	22.9	-4.3	-5.2	125.8	137.6	102.7	109.5	23.1
σ_0	52.7	60.7	70	0	0	0	0	0	0	19.5	24.5	-4.5	-5.6	133	147.1	109	117.1	24
τ_4	0	0.1	0	0	0	0	0	0	0	0.1	0	0	0	0.2	0.2	0.1	0.1	0.1
τ_3	4.5	6.4	6.1	0	0	0	0	0	0	3.9	3.6	-0.7	-0.7	14.9	14.9	10.2	10.2	4.6
τ_2	5.7	6.8	7.4	0	0	0	0	0	0	3.9	4.4	-0.8	-0.8	16.4	16.4	11.7	11.7	4.7
τ_1	4.8	5.4	6.2	0	0	0	0	0	0	3	3.7	-0.6	-0.7	13.2	13.2	9.7	9.7	3.5
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 3 max = -4.94 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 3 max = -2.63 N/mm^2
   The section at the end of phase 3 max is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 min = -2.73 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 min = -1.66 N/mm^2
   The section at the end of phase 3 min is considered: Uncracked (m.)

Main data for partial factors and damage equivalent facors

Partial factor for steel:	γ_{Ff}	1
	γ_{Mf}	1.35
Bending damage equivalent factor for steel:	$\lambda = \lambda_1 * \lambda_2 * \lambda_3 * \lambda_4 =$	2.32 x 0.848 x 1 x 1.15 = 2.262>2=>2 (Midspan)
Shear damage equivalent factor for steel:	$\lambda = \lambda_1 * \lambda_2 * \lambda_3 * \lambda_4 =$	2.518 x 0.848 x 1 x 1.15 = 2.455 (Midspan)
Data for calculation of λ_1	Section position:	(Midspan)
	L span for moment (m):	33
	L span for shear (m):	13.2
Data for calculation of λ_2, λ_{v2}	Q_0 (kN)	480
	N_0	500000
	N_{obs}	500000
	Q_{ml} (kN)	0
	Traffic category (Table 4.5n - EN 1991-2) :	Roads and motorways with medium flow rates of lorries
	Traffic distribution (Table 4.7 - EN 1991-2) :	Medium distance (40% Q1, 10% Q2, 30% Q3, 15% Q4, 5% Q5)
Data for calculation of λ_3, λ_{v3}	Design life (years):	100
Data for calculation of γ_{Mf} for steel:	Assessment method:	
	Consequence of failure:	
Damage equivalent factor for studs:	$\lambda_v = \lambda_{v1} * \lambda_{v2} * \lambda_{v3} * \lambda_{v4} =$	1.55 x 0.896 x 1 x 1.09 = 1.514
Partial factor for studs:	γ_{Ff}	1
	γ_{Mf}	1

Fatigue assessment of structural steel

Utilization ratio (Mmax comb.)

	$\gamma_{Ff}\,\Delta\sigma_{E,2}$	$\Delta\sigma_c/\gamma_{Mf}$	u.r.
Top flange	11.62	92.593	0.126
Bottom flange	47.998	92.593	0.518
Web	11.486	74.074	0.155
Top flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c = 1 \times 90 = 90$ N/mm^2	11.624	66.667	0.174
Bottom flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c = 1 \times 90 = 90$ N/mm^2	47.998	66.667	0.72
Web-top flange welding	9.761	92.593	0.105
Web-bottom flange welding	46.135	92.593	0.498
Vertical stiffeners - web welding	46.135	59.259	0.779
Vertical stiffeners - top flange welding	9.761	59.259	0.165
Vertical stiffeners - bottom flange welding	46.135	59.259	0.779
Longitudinal stiffener 1 - web welding			
Longitudinal stiffener 2 - web welding			

Utilization ratio (Mmin comb.)

	$\gamma_{Ff}\,\Delta\sigma_{E,2}$	$\Delta\sigma_c/\gamma_{Mf}$	u.r.
Top flange	11.62	92.593	0.126
Bottom flange	47.998	92.593	0.518
Web	11.486	74.074	0.155
Top flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c = 1 \times 90 = 90$ N/mm^2	11.624	66.667	0.174
Bottom flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c = 1 \times 90 = 90$ N/mm^2	47.998	66.667	0.72
Web-top flange welding	9.761	92.593	0.105
Web-bottom flange welding	46.135	92.593	0.498
Vertical stiffeners - web welding	46.135	59.259	0.779
Vertical stiffeners - top flange welding	9.761	59.259	0.165
Vertical stiffeners - bottom flange welding	46.135	59.259	0.779
Longitudinal stiffener 1 - web welding			
Longitudinal stiffener 2 - web welding			

Fatigue assessment of studs

Utilization ratio (Mmax comb.)

$\gamma_{Ff}\,\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) <= 1$	=1*22.54/(90/1) =0.25
$\gamma_{Ff}\,\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <= 1$	=1*11.62/(80/1.35) =0.196(*)
$\gamma_{Ff}\,\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) + \gamma_{Ff}\,\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <= 1.3$	=0.25+0.196=0.447(*)
CHECK PASSED	

(*) Not relevant check (Top flange in compression)

Utilization ratio (Mmin comb.)

$\gamma_{Ff}\,\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) <= 1$	=1*22.54/(90/1) =0.25
$\gamma_{Ff}\,\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <= 1$	=1*11.62/(80/1.35) =0.196(*)
$\gamma_{Ff}\,\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) + \gamma_{Ff}\,\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <= 1.3$	=0.25+0.196=0.447(*)
CHECK PASSED	

(*) Not relevant check (Top flange in compression)

Stiffeners checks

Torsional buckling of vertical stiffeners

	Vertical

	stiffeners
	CHECK PASSED
u.r.	0.898
Type	Vert. (R)
σ_{cr} (N/mm^2)	--
6^*f_y (N/mm^2)	--
l_{cr} (mm)	--
I_w (mm^6)	--
I_T (mm^4)	5.333E+5
I_P (mm^4)	5.347E+7
I_T / I_P	0.01
5.3 f_y /E	0.009
$c\theta$ (N)	--
E (N/mm^2)	210000
f_y (N/mm^2)	355
G (N/mm^2)	87500
a (mm)	2750

Intermediate vertical stiffeners acting as rigid support for web panels

$$I_{st} = 4.247E+7\ mm^4 > I_{st\ min} = 0.75\ h_w\ t_w^{\ 3} = 2.304E+6\ mm^4$$

CHECK PASSED

With:

t_w = 16 mm b_w = 410.5 mm A_{st} = 10568.6 mm^2 e_1 = 40.9 mm ^{2}
a = 2750 mm h_w = 750 mm a/hw = 3.667

Maximum stress and the additional deflection in the vertical stiffeners (Mmax comb.)

$$w = 0 < 2.5\ mm$$

$$\sigma_{max} = 0 < 322.7\ N/mm^2$$

CHECK PASSED

With:

$\Sigma N_{st,Ed} = N_{st,Ed} + \Delta N_{st,Ed}$ = 0E+00 + 1.047E+4 = 1.047E+4 N
$N_{st,Ed} = N_{st,ten} + N_{st,ex}$ = 0E+00 + 0E+00 = 0E+00 N
σ_m = 0.184 N/mm^2 $\sigma_{cr(C)} / \sigma_{cr(P)}$ = 6.09/1E+300 = 0=> 0.5
N_{Ed} = 3.79E+5 N λ_w = 0.649
$N_{cr,st}$ = 1.565E+8 N e_1 = 40.9 mm e_{max} = 167.1 mm w_0 = 2.5 mm
δ_m = 0
(I_{vstmin} = 1.64E+4(mm^4) u = 4.77)

9.3.3 Section Sez. 2b_2b

First classification

The first classification refers to the composite section in Phase 3

Plastic characteristics of the single components

Components	*N pl (N)*	*z N (mm)*	*z max (mm)*	*z min (mm)*
Concrete layer above top reinforcing bars	1.515E+6	975.25	1000	950.5
Concrete layer between top and bottom reinforcing bars	4.498E+6	876	949.5	802.5
Concrete layer below top reinforcing bars	7.65E+4	801.25	802.5	800
Top reinforcing bars	4.721E+5	950	950.5	949.5
Bottom reinforcing bars	0E+00	802.5	802.5	802.5
Concrete haunch slab	0E+00	800	800	800
Top flange of steel beam	4.226E+6	787.5	800	775
Web of steel beam	3.976E+6	407.5	775	40
Bottom flange of steel beam	8.114E+6	20	40	0
Ultimate compression force for the full section	-2.288E+7			
Ultimate tension force for the full section	1.679E+7			
Ultimate compression force for the web less section	-1.89E+7			
Ultimate tensile force for the web less section	1.281E+7			

Flanges classification

	c/t	*ε*	*Hogging bending moment (M+)*	*Sagging bending moment (M-)*
Top flange	9.68	0.814	1	0
Bottom flange	7.3	0.814	1	1

Web classification

	c/t	*ε*	*α*	*ψ*	*class*
Hogging bending moment (M+)	45.938	0.814	0.07	-1.545	1
Sagging bending moment (M-)	45.938	0.814	0.164	-0.351	1
Compression (N)	45.938	0.814	1	1	4

U.L.S. composite section verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	8.91E+4	-8.84E+5	0E+00
2a	0E+00	1.19E+5	-1.22E+6	0E+00
2b	0E+00	-6E+3	4.2E+4	0E+00
Shr.Iso	-4.03E+5	0	-1.81E+5	0
2c	0E+00	-1.2E+3	8.4E+3	0E+00
3a	0E+00	-7.2E+3	5.22E+4	0E+00
Therm.Iso	-7.56E+5	0	-2.39E+5	0
3b	0E+00	2.52E+5	-1.82E+6	0E+00
Total	-1.16E+6	4.46E+5	-4.24E+6	0E+00

Bending resistance - Plastic analysis

Section classification (Mmax comb.)

	c/t	*z pl (mm)*	*α*	*ψ*	*Class*
Web	45.94	547.44	0.31	-1.03	1
Top flange	9.68				1
Bottom flange	7.3				1
Section class					1

Plastic analysis: APPLICABLE

Plastic section verification (Mmax comb.)

Axial force		*Bending moment*		*N/M interaction*	
N_{Ed} (N)	-1.159E+6	M_{Ed} (Nm)	-4.244E+6	N_{Ed} (N)	-1.159E+6
N_{Rd} (N)	-2.288E+7	M_{Rd} (Nm)	-8.404E+6	M_{Ed} (Nm)	-4.244E+6
				M_{Rd} (Nm)	-8.424E+6
N_{Ed} /N_{Rd}	0.051	M_{Ed} /M_{Rd}	0.505	M_{Ed} /M_{Rd}	0.504
CHECK PASSED					

Axial force and bending moment stresses of gross cross section

Stresses of gross cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	η_1
σ_8	0	-3.9	0	0.9	0	0	0	-3	0.8	0	-9.5	0	-11.7	0.46
σ_7	0	-64.3	-126.3	-13.8	4.4	0.4	0.9	-77.7	-13.6	5.4	-50	-189.2	-141.3	0.361
σ_6	0	0	0	-6.4	0	0	0	-6.4	-8.5	0	0	0	-14.9	0.038
σ_5	0	-2.5	0	1	0	0	0	-1.4	1.2	0	-4.9	0	-5.1	0.201
σ_4	-78.1	-45	-95.8	-11.6	3.3	0.3	0.7	-134.4	-11.5	4.1	-29.5	-143.5	-175.4	0.519
σ_3	-74.1	-41.8	-90.7	-11.2	3.1	0.3	0.6	-126.8	-11.1	3.9	-26.1	-135.9	-164	0.485
σ_2	0	0	0	-6.4	0	0	0	-6.4	-8.5	0	0	0	-14.9	0.044
σ_1	43.8	52.8	58.7	-0.4	-2	-0.4	-0.4	95.8	-0.8	-2.5	74.4	87.9	169.4	0.501
σ_0	50.2	57.9	66.8	0.2	-2.3	-0.4	-0.5	108	-0.3	-2.9	79.9	100.1	187.6	0.555

Maximum utilization ratio:0.555 NOT RELEVANT CHECK
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -3.03 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -1.45 N/mm^2
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -11.74 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -5.13 N/mm^2
The section at the end of phase 3 is considered: Uncracked (m.)

Resistance to shear

Evaluation of necessity to Shear buckling check
h_w/t_w =45.938 < $31/\eta * \varepsilon_w * (K_\tau)^{0.5}$ =49.853 Shear Buckling check: NOT REQUIRED

Shear Buckling resistance: **$V_{b,Rd}$ =2.629E+6 N**

With:
a/h_w =3.741, η =1.2, K_τ =5.626
web contribution: $V_{bw,Rd}$ =2.629E+6 N, flanges contribution: $V_{bf,Rd}$ =1.729E+5 N
χ_w =1.2, $\bar{\lambda}_w$ =0.636, τ_{cr} =506.5, C=1176.2
M_{Ed} =-4.244E+6 Nm, $M_{f,Rd}$ =-7.239E+6 Nm, $M_{Ed}/M_{f,Rd}$ =0.586

Plastic resistance: **$V_{pl,Rd}$ =2.755E+6 N**

Shear resistance: **V_{Rd} =$V_{pl,Rd}$ =2.755E+6 N**

Utilization ratios:
$\eta_3 = V_{Ed}/V_{Rd}$ =0.162, (=> CHECK VERIFIED)
$\bar{\eta}_3 = V_{Ed}/V_{bw,Rd}$ =0.169, $\bar{\eta}_1 = M_{Ed}/M_{Rd}$ =0.504

Interaction between shear force, bending moment and axial force

Evaluation of the interaction

$\eta_3 < 0.5$, $M_{Ed} / M_{f,Rd} < 1$
INTERACTION NOT TO BE CHECKED

U.L.S. composite section verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	8.91E+4	-8.84E+5	0E+00
2a	0E+00	1.19E+5	-1.22E+6	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	1.2E+3	-8.4E+3	0E+00
3a	0E+00	7.2E+3	-5.22E+4	0E+00
Therm.Iso	7.56E+5	0	2.39E+5	0
3b	0E+00	2.61E+5	-1.91E+6	0E+00
Total	7.56E+5	4.77E+5	-3.83E+6	0E+00

Bending resistance - Plastic analysis

Section classification (Mmin comb.)

	c/t	*z $_{pl}$ (mm)*	*α*	*ψ*	*Class*
Web	45.94	724.46	0.07	-1.33	1
Top flange	9.68				1
Bottom flange	7.3				1
Section class					1
Plastic analysis: APPLICABLE					

Plastic section verification (Mmin comb.)

Axial force		*Bending moment*		*N/M interaction*	
N_{Ed} (N)	7.56E+5	M_{Ed} (Nm)	-3.831E+6	N_{Ed} (N)	7.56E+5
N_{Rd} (N)	1.679E+7	M_{Rd} (Nm)	-8.404E+6	M_{Ed} (Nm)	-3.831E+6
				M_{Rd} (Nm)	-8.324E+6
N_{Ed} / N_{Rd}	0.045	M_{Ed} / M_{Rd}	0.456	M_{Ed} / M_{Rd}	0.46
CHECK PASSED					

Axial force and bending moment stresses of gross cross section

Stresses of gross cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	*η_1*
σ_8	0	-3.9	0	0	0	0	0	-4	-0.8	0	-9.9	0	-14.6	0.574
σ_7	0	-64.3	-126.3	0	0	-0.4	-0.9	-64.8	13.6	-5.4	-52.3	-197.8	-103.5	0.265
σ_6	0	0	0	0	0	0	0	0	8.5	0	0	0	8.5	0.022
σ_5	0	-2.5	0	0	0	0	0	-2.5	-1.2	0	-5.1	0	-8.9	0.349
σ_4	-78.1	-45	-95.8	0	0	-0.3	-0.7	-123.4	11.5	-4.1	-30.9	-150	-142.8	0.422
σ_3	-74.1	-41.8	-90.7	0	0	-0.3	-0.6	-116.2	11.1	-3.9	-27.3	-142.1	-132.3	0.391
σ_2	0	0	0	0	0	0	0	0	8.5	0	0	0	8.5	0.025
σ_1	43.8	52.8	58.7	0	0	0.4	0.4	97	0.8	2.5	77.8	91.9	175.6	0.519
σ_0	50.2	57.9	66.8	0	0	0.4	0.5	108.6	0.3	2.9	83.5	104.7	192.3	0.569

Maximum utilization ratio:0.574 NOT RELEVANT CHECK

NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 2 = -3.96 N/mm^2

2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -2.52 N/mm^2
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -14.64 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -8.9 N/mm^2
The section at the end of phase 3 is considered: Uncracked (m.)

Resistance to shear

Evaluation of necessity to Shear buckling check
$h_w / t_w = 45.938 < 31/\eta * \varepsilon_w * (K_\tau)^{0.5} = 49.853$ Shear Buckling check: NOT REQUIRED

Shear Buckling resistance: $\mathbf{V_{b,Rd} = 2.629E+6}$ **N**

With:
$a/h_w = 3.741$, $\eta = 1.2$, $K_\tau = 5.626$
web contribution: $V_{bw,Rd} = 2.629E+6$ N, flanges contribution: $V_{bf,Rd} = 1.813E+5$ N
$\chi_w = 1.2$, $\bar{\lambda}_w = 0.636$, $\tau_{cr} = 506.5$, C=1176.2
$M_{Ed} = -3.831E+6$ Nm, $M_{f,Rd} = -6.86E+6$ Nm, $M_{Ed} / M_{f,Rd} = 0.558$

Plastic resistance: $\mathbf{V_{pl,Rd} = 2.755E+6}$ **N**

Shear resistance: $\mathbf{V_{Rd} = V_{pl,Rd} = 2.755E+6}$ **N**

Utilization ratios:
$\eta_3 = V_{Ed} / V_{Rd} = 0.173$, (=> CHECK VERIFIED)
$\bar{\eta}_3 = V_{Ed} / V_{bw,Rd} = 0.182$, $\bar{\eta}_1 = M_{Ed} / M_{Rd} = 0.46$

Interaction between shear force, bending moment and axial force

Evaluation of the interaction
$\bar{\eta}_3 < 0.5$, $M_{Ed} / M_{f,Rd} < 1$
INTERACTION NOT TO BE CHECKED

SLS stresses verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	6.6E+4	-6.55E+5	0E+00
2a	0E+00	8.8E+4	-9.02E+5	0E+00
2b	0E+00	-5E+3	3.5E+4	0E+00
Shr.Iso	-3.36E+5	0	-1.51E+5	0
2c	0E+00	-1E+3	7E+3	0E+00
3a	0E+00	-4.8E+3	3.48E+4	0E+00
Therm.Iso	-5.04E+5	0	-1.59E+5	0
3b	0E+00	1.87E+5	-1.35E+6	0E+00
Total	-8.4E+5	3.3E+5	-3.14E+6	0E+00

Stresses of gross cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	σ_{id}	η_1
σ_8	0	-2.9	0	0.7	0	0	0	-2.2	0.5	0	-7	0	-8.7	8.7	0.322
σ_7	0	-47.7	-93.5	-11.5	3.6	0.4	0.7	-58.8	-9	3.6	-37.1	-140.5	-105	105	0.292
σ_6	0	0	0	-5.4	0	0	0	-5.4	-5.6	0	0	0	-11	11	0.031
σ_5	0	-1.9	0	0.9	0	0	0	-1	0.8	0	-3.7	0	-3.8	3.8	0.141
σ_4	-57.8	-33.4	-71	-9.6	2.8	0.3	0.6	-100.6	-7.6	2.7	-21.9	-106.5	-130.1	130.1	0.367
σ_3	-54.9	-31	-67.2	-9.3	2.6	0.2	0.5	-94.9	-7.4	2.6	-19.4	-100.9	-121.7	128.4	0.362

σ_2	0	0	0	-5.4	0	0	0	-5.4	-5.6	0	0	0	-11	45.7	0.129
σ_1	32.5	39.1	43.5	-0.3	-1.7	-0.3	-0.3	70.9	-0.6	-1.7	55.2	65.3	125.6	131.5	0.37
σ_0	37.2	42.9	49.5	0.2	-1.9	-0.3	-0.4	80	-0.2	-1.9	59.3	74.3	139.1	139.1	0.392
τ_4	0	0.1	0	0	0	0	0	0.1	0	0	0.4	0	0.5		
τ_3	4.4	6.3	6	-0.4	-0.3	-0.1	-0.1	10.3	-0.4	-0.3	13.7	12.7	23.6		
τ_2	5.7	6.8	7.4	-0.4	-0.4	-0.1	-0.1	12	-0.4	-0.4	13.9	15.8	25.6		
τ_1	5.3	6	6.8	-0.3	-0.4	-0.1	-0.1	10.9	-0.3	-0.4	11.9	14.5	22.4		
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Maximum utilization ratio:0.392 CHECK PASSED
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -2.16 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -0.98 N/mm^2
   The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -8.68 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -3.8 N/mm^2
   The section at the end of phase 3 is considered: Uncracked (m.)

<u>SLS stresses verification (Mmin comb.)</u>

Forces and moments   (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	6.6E+4	-6.55E+5	0E+00
2a	0E+00	8.8E+4	-9.02E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	1E+3	-7E+3	0E+00
3a	0E+00	4.8E+3	-3.48E+4	0E+00
Therm.Iso	5.04E+5	0	1.59E+5	0
3b	0E+00	1.93E+5	-1.41E+6	0E+00
Total	5.04E+5	3.53E+5	-2.85E+6	0E+00

Stresses of gross cross section   (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	σ_{id}	η_1
σ_8	0	-2.9	0	0	0	0	0	-2.9	-0.5	0	-7.3	0	-10.8	10.8	0.399
σ_7	0	-47.7	-93.5	0	0	-0.4	-0.7	-48	9	-3.6	-38.7	-146.2	-77.6	77.6	0.216
σ_6	0	0	0	0	0	0	0	0	5.6	0	0	0	5.6	5.6	0.016
σ_5	0	-1.9	0	0	0	0	0	-1.9	-0.8	0	-3.8	0	-6.5	6.5	0.241
σ_4	-57.8	-33.4	-71	0	0	-0.3	-0.6	-91.5	7.6	-2.7	-22.8	-110.9	-106.6	106.6	0.3
σ_3	-54.9	-31	-67.2	0	0	-0.2	-0.5	-86.1	7.4	-2.6	-20.2	-105	-98.8	108.1	0.304
σ_2	0	0	0	0	0	0	0	0	5.6	0	0	0	5.6	47.6	0.134
σ_1	32.5	39.1	43.5	0	0	0.3	0.3	71.9	0.6	1.7	57.5	67.9	129.9	136.3	0.384
σ_0	37.2	42.9	49.5	0	0	0.3	0.4	80.4	0.2	1.9	61.7	77.4	142.4	142.4	0.401
τ_4	0	0.1	0	0	0	0	0	0.1	0	0	0.4	0	0.5		
τ_3	4.4	6.3	6	0	0	0.1	0.1	10.8	0.4	0.3	14.1	13.1	25.3		
τ_2	5.7	6.8	7.4	0	0	0.1	0.1	12.6	0.4	0.4	14.4	16.3	27.3		
τ_1	5.3	6	6.8	0	0	0.1	0.1	11.3	0.3	0.4	12.2	14.9	23.9		
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Maximum utilization ratio:0.401 CHECK PASSED
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -2.94 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -1.87 N/mm^2
   The section at the end of phase 2 is considered: Uncracked (m.)

3) Total stress at the top fibre of slab concrete at the end of phase 3 = -10.77 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -6.49 N/mm^2
The section at the end of phase 3 is considered: Uncracked (m.)

SLS web breathing verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	6.6E+4	-6.55E+5	0E+00
2a	0E+00	8.8E+4	-9.02E+5	0E+00
2b	0E+00	-5E+3	3.5E+4	0E+00
Shr.Iso	-3.36E+5	0	-1.51E+5	0
2c	0E+00	-1E+3	7E+3	0E+00
3a	0E+00	-4E+3	2.9E+4	0E+00
Therm.Iso	-4.2E+5	0	-1.33E+5	0
3b	0E+00	1.42E+5	-1.04E+6	0E+00
Total	-7.56E+5	2.86E+5	-2.81E+6	0E+00

Stresses of effective cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*
σ_8	0	-2.9	0	0.7	0	0	0	-2.2	0.4	0	-5.4	0	-7.1
σ_7	0	-47.7	-93.5	-11.5	3.6	0.4	0.7	-58.8	-7.5	3	-28.4	-107.5	-94.7
σ_6	0	0	0	-5.4	0	0	0	-5.4	-4.7	0	0	0	-10
σ_5	0	-1.9	0	0.9	0	0	0	-1	0.7	0	-2.8	0	-3.1
σ_4	-57.8	-33.4	-71	-9.6	2.8	0.3	0.6	-100.6	-6.4	2.3	-16.8	-81.5	-123.7
σ_3	-54.9	-31	-67.2	-9.3	2.6	0.2	0.5	-94.9	-6.2	2.2	-14.8	-77.2	-115.9
σ_2	0	0	0	-5.4	0	0	0	-5.4	-4.7	0	0	0	-10
σ_1	32.5	39.1	43.5	-0.3	-1.7	-0.3	-0.3	70.9	-0.5	-1.4	42.3	50	112.7
σ_0	37.2	42.9	49.5	0.2	-1.9	-0.3	-0.4	80	-0.2	-1.6	45.4	56.9	125.2

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -2.16 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -0.98 N/mm^2
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -7.12 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -3.08 N/mm^2
The section at the end of phase 3 is considered: Uncracked (m.)

Web assessment (Mmax comb.)

	Web
b (mm)	735
σ_{sup} (N/mm^2)	-115.95
σ_{inf} (N/mm^2)	112.74
σ_{Ed} (N/mm^2)	115.95
K_σ	23.17
σ_{cr0E} (N/mm^2)	90.04
τ_{Ed} (N/mm^2)	20.81
σ_{cr} (P) (N/mm^2)	2086.38
σ_{cr} (C) (N/mm^2)	6.09
ξ	1
σ_{cr} (N/mm^2)	2086.38
K_τ	5.63
$K_{\tau sl}$	0

Utilization ratio	0.072
Result	CHECK VERIFIED

SLS web breathing verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	6.6E+4	-6.55E+5	0E+00
2a	0E+00	8.8E+4	-9.02E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	-1E+3	-7E+3	0E+00
3a	0E+00	4E+3	-2.9E+4	0E+00
Therm.Iso	4.2E+5	0	1.33E+5	0
3b	0E+00	1.42E+5	-1.04E+6	0E+00
Total	4.2E+5	3E+5	-2.5E+6	0E+00

Stresses of effective cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*
σ_8	0	-2.9	0	0	0	0	0	-2.9	-0.4	0	-5.4	0	-8.7
σ_7	0	-47.7	-93.5	0	0	-0.4	-0.7	-48	7.5	-3	-28.4	-107.5	-68.9
σ_6	0	0	0	0	0	0	0	0	4.7	0	0	0	4.7
σ_5	0	-1.9	0	0	0	0	0	-1.9	-0.7	0	-2.8	0	-5.4
σ_4	-57.8	-33.4	-71	0	0	-0.3	-0.6	-91.5	6.4	-2.3	-16.8	-81.5	-101.9
σ_3	-54.9	-31	-67.2	0	0	-0.2	-0.5	-86.1	6.2	-2.2	-14.8	-77.2	-94.7
σ_2	0	0	0	0	0	0	0	0	4.7	0	0	0	4.7
σ_1	32.5	39.1	43.5	0	0	0.3	0.3	71.9	0.5	1.4	42.3	50	114.6
σ_0	37.2	42.9	49.5	0	0	0.3	0.4	80.4	0.2	1.6	45.4	56.9	126

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -2.94 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -1.87 N/mm^2
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -8.75 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -5.35 N/mm^2
The section at the end of phase 3 is considered: Uncracked (m.)

Web assessment (Mmin comb.)

	Web
b (mm)	735
σ_{sup} (N/mm^2)	-94.73
σ_{inf} (N/mm^2)	114.6
σ_{Ed} (N/mm^2)	94.73
K_σ	29.2
σ_{cr0E} (N/mm^2)	90.04
τ_{Ed} (N/mm^2)	21.73
σ_{cr} (P) (N/mm^2)	2628.92
σ_{cr} (C) (N/mm^2)	6.09
ξ	1
σ_{cr} (N/mm^2)	2628.92
K_τ	5.63
$K_{\tau sl}$	0

Utilization ratio	0.059
Result	CHECK VERIFIED

Shear connectors assessment

Main data

Number of studs for unit length, n (m^{-1})	10
Stud diameter, d (mm)	19
Stud height, h (mm)	150
Ultimate resistance of studs α	1
Partial safety factor, γ_v	1.25
Ultimate resistance of studs f_u (N/mm^2)	450
Coefficient E_{cm} (N/mm^2)	36283
Characteristic cylinder compressive strength, f_{ck} (N/mm^2)	45

Resistance of headed stud connectors

Shank shear resistance, $P_{Rd1} = 0.8\, f_u\, \pi\, d^2/4/\gamma_v$, (N)	81656.28
Concrete crushing resistance, $P_{Rd2} = 0.29\, \alpha\, d^2 (f_{ck} E_{cm})^{0.5}/\gamma_v$, (N)	107017.34
Design stud resistance P_{Rd} = Min(P_{Rd1} , P_{Rd2}), (N)	81656.28

Elastic assessment at ULS

Utilization ratio (Mmax comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\, P_{Rd}\, \kappa_s$ (N/mm)	816.6
Reduction factor, κ_s	1.00
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	317.8
Utilization ratio ν_{Ed}/ν_{Rd}	0.389
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmax comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	1.188E+5	6.603E+6	9.462E+9	82.9
Phase 2b	-6E+3	6.603E+6	9.462E+9	-4.2
Phase 2c	-1.2E+3	6.603E+6	9.462E+9	-0.8
Phase 3a	-7.2E+3	1.308E+7	1.334E+10	-7.1
Phase 3b	2.52E+5	1.308E+7	1.334E+10	247
			Sum	317.8

Utilization ratio (Mmin comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\, P_{Rd}\, \kappa_s$ (N/mm)	816.6
Reduction factor, κ_s	1.00
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	346.6
Utilization ratio ν_{Ed}/ν_{Rd}	0.424
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmin comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	1.188E+5	6.603E+6	9.462E+9	82.9
Phase 2b	0E+00	6.603E+6	9.462E+9	0
Phase 2c	1.2E+3	6.603E+6	9.462E+9	0.8
Phase 3a	7.2E+3	1.308E+7	1.334E+10	7.1
Phase 3b	2.61E+5	1.308E+7	1.334E+10	255.8
			Sum	346.6

Elastic assessment at ELS

Utilization ratio (Mmax comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\, P_{Rd}\, \kappa_s$ (N/mm)	489.9
Reduction factor, κ_s	0.6
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	235.8
Utilization ratio ν_{Ed} / ν_{Rd}	0.481
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmax comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	8.8E+4	6.603E+6	9.462E+9	61.4
Phase 2b	-5E+3	6.603E+6	9.462E+9	-3.5
Phase 2c	-1E+3	6.603E+6	9.462E+9	-0.7
Phase 3a	-4.8E+3	1.308E+7	1.334E+10	-4.7
Phase 3b	1.87E+5	1.308E+7	1.334E+10	183.3
			Sum	235.8

Utilization ratio (Mmin comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\, P_{Rd}\, \kappa_s$ (N/mm)	489.9
Reduction factor, κ_s	0.6
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	256
Utilization ratio ν_{Ed} / ν_{Rd}	0.522
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmin comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	8.8E+4	6.603E+6	9.462E+9	61.4
Phase 2b	0E+00	6.603E+6	9.462E+9	0
Phase 2c	1E+3	6.603E+6	9.462E+9	0.7
Phase 3a	4.8E+3	1.308E+7	1.334E+10	4.7
Phase 3b	1.93E+5	1.308E+7	1.334E+10	189.2
			Sum	256

Assesment of studs at deck ends - shrinkage and thermal influence - (ULS)

Check of minimum studs number

Characteristic shrinkage shear per unit length, $\nu_{L,k}$ (N/mm)	280
Characteristic thermal shear per unit length (-), $\nu_{L,k}$ (N/mm)	700
Total design shear per unit length, $\nu_{L,Ed}$ (N/mm)	1*280 + 1.2*700 = 1120
Minimum number of studs at deck ends, n min (m^{-1})	13.7 > 10
CHECK NOT VERIFIED	

Fatigue limit state verification

Forces and moments for steel details and studs (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	6.6E+4	-6.55E+5	0E+00
2a	0E+00	8.8E+4	-9.02E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	0E+00	0E+00	0E+00
3a	0E+00	0E+00	0E+00	0E+00
Therm.Iso	0E+00	0	0E+00	0
3b max	0E+00	5.2E+4	-3.15E+5	0E+00
3b max	0E+00	-1E+4	7.2E+4	0E+00

Stresses of gross cross section for steel details and studs (Mmax comb.)

	Ph. 1	Ph. 2a Uncracked	Ph. 2a Cracked	Ph. 2b Uncracked	Ph. 2b Cracked	Ph. 2c Uncracked	Ph. 2c Cracked	Ph. 3a Uncracked	Ph. 3a Cracked	Ph. 3b Uncracked Max	Ph. 3b Cracked Max	Ph. 3b Uncracked Min	Ph. 3b Cracked Min	Total Uncracked Max	Total Cracked Max	Total Uncracked Min	Total Cracked Min	$\Delta\sigma,\Delta\tau$
σ_8	0	-2.9	0	0	0	0	0	0	0	-1.6	0	0.4	0	-4.5	0	-2.5	0	2
σ_7	0	-47.7	-93.5	0	0	0	0	0	0	-8.6	-32.7	2	7.5	-56.3	-126.2	-45.7	-86.1	10.6
σ_6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_5	0	-1.9	0	0	0	0	0	0	0	-0.8	0	0.2	0	-2.7	0	-1.7	0	1
σ_4	-57.8	-33.4	-71	0	0	0	0	0	0	-5.1	-24.8	1.2	5.7	-96.3	-153.6	-90	-123.1	6.3
σ_3	-54.9	-31	-67.2	0	0	0	0	0	0	-4.5	-23.5	1	5.4	-90.3	-145.5	-84.8	-116.7	5.5
σ_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_1	32.5	39.1	43.5	0	0	0	0	0	0	12.8	15.2	-2.9	-3.5	84.4	91.1	68.6	72.5	15.8
σ_0	37.2	42.9	49.5	0	0	0	0	0	0	13.8	17.3	-3.2	-4	93.9	104	77	82.8	16.9
τ_4	0	0.1	0	0	0	0	0	0	0	0.1	0	0	0	0.2	0.2	0.1	0.1	0.1
τ_3	4.4	6.3	6	0	0	0	0	0	0	3.8	3.5	-0.7	-0.7	14.5	14.5	10	10	4.5
τ_2	5.7	6.8	7.4	0	0	0	0	0	0	3.9	4.4	-0.7	-0.8	16.4	16.4	11.7	11.7	4.6
τ_1	5.3	6	6.8	0	0	0	0	0	0	3.3	4	-0.6	-0.8	14.6	14.6	10.6	10.6	3.9
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 3 max = -4.55 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 3 max = -2.7 N/mm^2
   The section at the end of phase 3 max is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 min = -2.54 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 min = -1.66 N/mm^2
   The section at the end of phase 3 min is considered: Uncracked (m.)

Forces and moments for steel details and studs (Mmin comb.)

Phase	N (N)	V (N)	M (Nm)	T (Nm)
1	0E+00	6.6E+4	-6.55E+5	0E+00
2a	0E+00	8.8E+4	-9.02E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	0E+00	0E+00	0E+00
3a	0E+00	0E+00	0E+00	0E+00
Therm.Iso	0E+00	0	0E+00	0
3b max	0E+00	5.2E+4	-3.15E+5	0E+00
3b max	0E+00	-1E+4	7.2E+4	0E+00

Stresses of gross cross section for steel details and studs (Mmin comb.)

	Ph. 1	Ph. 2a Uncracked	Ph. 2a Cracked	Ph. 2b Uncracked	Ph. 2b Cracked	Ph. 2c Uncracked	Ph. 2c Cracked	Ph. 3a Uncracked	Ph. 3a Cracked	Ph. 3b Uncracked Max	Ph. 3b Cracked Max	Ph. 3b Uncracked Min	Ph. 3b Cracked Min	Total Uncracked Max	Total Cracked Max	Total Uncracked Min	Total Cracked Min	$\Delta\sigma,\Delta\tau$
σ_8	0	-2.9	0	0	0	0	0	0	0	-1.6	0	0.4	0	-4.5	0	-2.5	0	2
σ_7	0	-47.7	-93.5	0	0	0	0	0	0	-8.6	-32.7	2	7.5	-56.3	-126.2	-45.7	-86.1	10.6

σ_6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_5	0	-1.9	0	0	0	0	0	0	0	-0.8	0	0.2	0	-2.7	0	-1.7	0	1
σ_4	-57.8	-33.4	-71	0	0	0	0	0	0	-5.1	-24.8	1.2	5.7	-96.3	-153.6	-90	-123.1	6.3
σ_3	-54.9	-31	-67.2	0	0	0	0	0	0	-4.5	-23.5	1	5.4	-90.3	-145.5	-84.8	-116.7	5.5
σ_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_1	32.5	39.1	43.5	0	0	0	0	0	0	12.8	15.2	-2.9	-3.5	84.4	91.1	68.6	72.5	15.8
σ_0	37.2	42.9	49.5	0	0	0	0	0	0	13.8	17.3	-3.2	-4	93.9	104	77	82.8	16.9
τ_4	0	0.1	0	0	0	0	0	0	0	0.1	0	0	0	0.2	0.2	0.1	0.1	0.1
τ_3	4.4	6.3	6	0	0	0	0	0	0	3.8	3.5	-0.7	-0.7	14.5	14.5	10	10	4.5
τ_2	5.7	6.8	7.4	0	0	0	0	0	0	3.9	4.4	-0.7	-0.8	16.4	16.4	11.7	11.7	4.6
τ_1	5.3	6	6.8	0	0	0	0	0	0	3.3	4	-0.6	-0.8	14.6	14.6	10.6	10.6	3.9
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 3 max = -4.55 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 3 max = -2.7 N/mm^2
   The section at the end of phase 3 max is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 min = -2.54 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 min = -1.66 N/mm^2
   The section at the end of phase 3 min is considered: Uncracked (m.)

Main data for partial factors and damage equivalent facors

Partial factor for steel:	γ_{Ff}	1
	γ_{Mf}	1.35
Bending damage equivalent factor for steel:	$\lambda = \lambda_1 * \lambda_2 * \lambda_3 * \lambda_4 =$	2.32 x 0.848 x 1 x 1.15 = 2.262>2=>2 (Midspan)
Shear damage equivalent factor for steel:	$\lambda = \lambda_1 * \lambda_2 * \lambda_3 * \lambda_4 =$	2.518 x 0.848 x 1 x 1.15 = 2.455 (Midspan)
Data for calculation of λ_1	Section position:	(Midspan)
	L span for moment (m):	33
	L span for shear (m):	13.2
Data for calculation of λ_2, λ_{v2}	Q_0 (kN)	480
	N_0	500000
	N_{obs}	500000
	Q_{ml} (kN)	0
	Traffic category (Table 4.5n - EN 1991-2) :	Roads and motorways with medium flow rates of lorries
	Traffic distribution (Table 4.7 - EN 1991-2) :	Medium distance (40% Q1, 10% Q2, 30% Q3, 15% Q4, 5% Q5)
Data for calculation of λ_3, λ_{v3}	Design life (years):	100
Data for calculation of γ_{Mf} for steel:	Assessment method:	
	Consequence of failure:	
Damage equivalent factor for studs:	$\lambda_v = \lambda_{v1} * \lambda_{v2} * \lambda_{v3} * \lambda_{v4} =$	1.55 x 0.896 x 1 x 1.09 = 1.514
Partial factor for studs:	γ_{Ff}	1
	γ_{Mf}	1

Fatigue assessment of structural steel

Utilization ratio (Mmax comb.)

	$\gamma_{Ff}\Delta\sigma_{E,2}$	$\Delta\sigma_c/\gamma_{Mf}$	u.r.
Top flange	12.52	92.593	0.135
Bottom flange	33.891	92.593	0.366
Web	11.345	74.074	0.153
Top flange welding $\Delta\sigma_{c,red}=\kappa_s*\Delta\sigma_c=1\times 90=90$ N/mm^2	12.523	66.667	0.188
Bottom flange welding $\Delta\sigma_{c,red}=\kappa_s*\Delta\sigma_c=0.91\times 90=81.9$ N/mm^2	33.891	60.685	0.558
Web-top flange welding	11.073	92.593	0.12
Web-bottom flange welding	31.57	92.593	0.341
Vertical stiffeners - web welding	31.57	59.259	0.533
Vertical stiffeners - top flange welding	11.073	59.259	0.187
Vertical stiffeners - bottom flange welding	31.57	59.259	0.533
Longitudinal stiffener 1 - web welding			
Longitudinal stiffener 2 - web welding			

Utilization ratio (Mmin comb.)

	$\gamma_{Ff}\Delta\sigma_{E,2}$	$\Delta\sigma_c/\gamma_{Mf}$	u.r.
Top flange	12.52	92.593	0.135
Bottom flange	33.891	92.593	0.366
Web	11.345	74.074	0.153
Top flange welding $\Delta\sigma_{c,red}=\kappa_s*\Delta\sigma_c=1\times 90=90$ N/mm^2	12.523	66.667	0.188
Bottom flange welding $\Delta\sigma_{c,red}=\kappa_s*\Delta\sigma_c=0.91\times 90=81.9$ N/mm^2	33.891	60.685	0.558
Web-top flange welding	11.073	92.593	0.12
Web-bottom flange welding	31.57	92.593	0.341
Vertical stiffeners - web welding	31.57	59.259	0.533
Vertical stiffeners - top flange welding	11.073	59.259	0.187
Vertical stiffeners - bottom flange welding	31.57	59.259	0.533
Longitudinal stiffener 1 - web welding			
Longitudinal stiffener 2 - web welding			

Fatigue assessment of studs

Utilization ratio (Mmax comb.)

$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s})<=1$	=1*32.44/(90/1) =0.36
$\gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf})<=1$	=1*12.52/(80/1.35) =0.211(*)
$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s})+\gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf})<=1.3$	=0.36+0.211=0.572(*)
CHECK PASSED	

(*) Not relevant check (Top flange in compression)

Utilization ratio (Mmin comb.)

$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s})<=1$	=1*32.44/(90/1) =0.36
$\gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf})<=1$	=1*12.52/(80/1.35) =0.211(*)
$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s})+\gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf})<=1.3$	=0.36+0.211=0.572(*)
CHECK PASSED	

(*) Not relevant check (Top flange in compression)

Stiffeners checks

Torsional buckling of vertical stiffeners

	Vertical

	stiffeners
	CHECK PASSED
u.r.	0.898
Type	Vert. (R)
σ_{cr} (N/mm^2)	--
6^*f_y (N/mm^2)	--
l_{cr} (mm)	--
I_w (mm^6)	--
I_T (mm^4)	5.333E+5
I_P (mm^4)	5.347E+7
I_T/I_P	0.01
$5.3\ f_y/E$	0.009
$c\theta$ (N)	--
E (N/mm^2)	210000
f_y (N/mm^2)	355
G (N/mm^2)	87500
a (mm)	2750

Intermediate vertical stiffeners acting as rigid support for web panels

$$I_{st} = 4.247E+7\ mm^4 > I_{st\ min} = 0.75\ h_w\ t_w^{\ 3} = 2.258E+6\ mm^4$$

CHECK PASSED

With:

$t_w = 16$ mm $b_w = 410.5$ mm $A_{st} = 10568.6\ mm^2$ $e_1 = 40.9$ mm ^{2}
a = 2750 mm $h_w = 735$ mm a/hw = 3.741

Maximum stress and the additional deflection in the vertical stiffeners (Mmax comb.)

$$w = 0 < 2.4\ mm$$

$$\sigma_{max} = 0 < 322.7\ N/mm^2$$

CHECK PASSED

With:

$\Sigma N_{st,Ed} = N_{st,Ed} + \Delta N_{st,Ed} = 0E+00 + 1.285E+4 = 1.285E+4$ N
$N_{st,Ed} = N_{st,ten} + N_{st,ex} = 0E+00 + 0E+00 = 0E+00$ N
$\sigma_m = 0.235\ N/mm^2$ $\sigma_{cr(C)}/\sigma_{cr(P)} = 6.09/1E+300 = 0 \Rightarrow 0.5$
$N_{Ed} = 4.744E+5$ N $\bar{\lambda}_w = 0.636$
$N_{cr,st} = 1.629E+8$ N $e_1 = 40.9$ mm $e_{max} = 167.1$ mm $w_0 = 2.45$ mm
$\delta_m = 0$
($I_{vstmin} = 1.965E+4(mm^4)$ u = 4.868)

9.3.4 Section Sez. 3a_3a

First classification

The first classification refers to the composite section in Phase 3

Plastic characteristics of the single components

Components	*N_{pl} (N)*	*z_N (mm)*	*z_{max} (mm)*	*z_{min} (mm)*
Concrete layer above top reinforcing bars	1.515E+6	975.25	1000	950.5
Concrete layer between top and bottom reinforcing bars	4.498E+6	876	949.5	802.5
Concrete layer below top reinforcing bars	7.65E+4	801.25	802.5	800
Top reinforcing bars	4.721E+5	950	950.5	949.5
Bottom reinforcing bars	0E+00	802.5	802.5	802.5
Concrete haunch slab	0E+00	800	800	800
Top flange of steel beam	4.226E+6	787.5	800	775
Web of steel beam	3.976E+6	407.5	775	40
Bottom flange of steel beam	8.114E+6	20	40	0
Ultimate compression force for the full section	-2.288E+7			
Ultimate tension force for the full section	1.679E+7			
Ultimate compression force for the web less section	-1.89E+7			
Ultimate tensile force for the web less section	1.281E+7			

Flanges classification

	c/t	*ε*	*Hogging bending moment (M+)*	*Sagging bending moment (M-)*
Top flange	9.68	0.814	1	0
Bottom flange	7.3	0.814	1	1

Web classification

	c/t	*ε*	*α*	*ψ*	*class*
Hogging bending moment (M+)	45.938	0.814	0.07	-1.545	1
Sagging bending moment (M-)	45.938	0.814	0.164	-0.351	1
Compression (N)	45.938	0.814	1	1	4

U.L.S. composite section verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	7.02E+4	-9.72E+5	0E+00
2a	0E+00	8.91E+4	-1.29E+6	0E+00
2b	0E+00	6E+3	1.02E+5	0E+00
Shr.Iso	-4.03E+5	0	-1.81E+5	0
2c	0E+00	-1.2E+3	2.04E+4	0E+00
3a	0E+00	-7.2E+3	1.27E+5	0E+00
Therm.Iso	-7.56E+5	0	-2.39E+5	0
3b	0E+00	1.4E+5	-2.53E+6	0E+00
Total	-1.16E+6	2.97E+5	-4.96E+6	0E+00

Bending resistance - Plastic analysis

Section classification (Mmax comb.)

	c/t	*z_{pl} (mm)*	*α*	*ψ*	*Class*
Web	45.94	547.44	0.31	-1.11	1
Top flange	9.68				1
Bottom flange	7.3				1

Section class					1
Plastic analysis: APPLICABLE					

Plastic section verification (Mmax comb.)

Axial force		*Bending moment*		*N/M interaction*	
N_{Ed} (N)	-1.159E+6	M_{Ed} (Nm)	-4.963E+6	N_{Ed} (N)	-1.159E+6
N_{Rd} (N)	-2.288E+7	M_{Rd} (Nm)	-8.404E+6	M_{Ed} (Nm)	-4.963E+6
				M_{Rd} (Nm)	-8.424E+6
N_{Ed}/N_{Rd}	0.051	M_{Ed}/M_{Rd}	0.591	M_{Ed}/M_{Rd}	0.589
CHECK PASSED					

Axial force and bending moment stresses of gross cross section

Stresses of gross cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	η_1
σ_8	0	-4.2	0	1.1	0	0.1	0	-3	1.2	0	-13.2	0	-15	0.589
σ_7	0	-67.9	-133.3	-10.6	10.6	1.1	2.1	-77.4	-11.5	13.2	-69.5	-262.9	-158.5	0.405
σ_6	0	0	0	-6.4	0	0	0	-6.4	-8.5	0	0	0	-14.9	0.038
σ_5	0	-2.6	0	1.2	0	0	0	-1.4	1.4	0	-6.8	0	-6.8	0.268
σ_4	-85.8	-47.5	-101.1	-9.4	8	0.8	1.6	-142	-10.3	10	-41	-199.4	-193.2	0.572
σ_3	-81.4	-44.1	-95.7	-9.1	7.6	0.7	1.5	-134	-10.1	9.5	-36.3	-188.8	-180.3	0.533
σ_2	0	0	0	-6.4	0	0	0	-6.4	-8.5	0	0	0	-14.9	0.044
σ_1	48.2	55.7	62	-3	-4.9	-0.9	-1	100	-3.9	-6.1	103.4	122.2	199.5	0.59
σ_0	55.2	61.1	70.5	-2.6	-5.6	-1	-1.1	112.7	-3.6	-7	111	139.1	220.2	0.651

Maximum utilization ratio:0.651 NOT RELEVANT CHECK
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -3.02 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -1.44 N/mm^2
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -15.03 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -6.83 N/mm^2
The section at the end of phase 3 is considered: Uncracked (m.)

Resistance to shear

Evaluation of necessity to Shear buckling check
$h_w/t_w = 45.938 < 31/\eta * \varepsilon_w * (K_\tau)^{0.5} = 49.853$ Shear Buckling check: NOT REQUIRED

Shear Buckling resistance: $\mathbf{V_{b,Rd} = 2.629E+6\ N}$

With:
$a/h_w = 3.741$, $\eta = 1.2$, $K_\tau = 5.626$
web contribution: $V_{bw,Rd} = 2.629E+6$ N, flanges contribution: $V_{bf,Rd} = 1.396E+5$ N
$\chi_w = 1.2$, $\bar{\lambda}_w = 0.636$, $\tau_{cr} = 506.5$, C=1176.2
$M_{Ed} = -4.963E+6$ Nm, $M_{f,Rd} = -7.239E+6$ Nm, $M_{Ed}/M_{f,Rd} = 0.686$

Plastic resistance: $\mathbf{V_{pl,Rd} = 2.755E+6\ N}$

Shear resistance: $\mathbf{V_{Rd} = V_{pl,Rd} = 2.755E+6\ N}$

Utilization ratios:

$\eta_3 = V_{Ed}/V_{Rd} = 0.108$, (=> CHECK VERIFIED)
$\bar{\eta}_3 = V_{Ed}/V_{bw,Rd} = 0.113$, $\bar{\eta}_1 = M_{Ed}/M_{Rd} = 0.589$

Interaction between shear force, bending moment and axial force

Evaluation of the interaction

$\eta_3 < 0.5$, $M_{Ed} / M_{f,Rd} < 1$

INTERACTION NOT TO BE CHECKED

U.L.S. composite section verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	7.02E+4	-9.72E+5	0E+00
2a	0E+00	8.91E+4	-1.29E+6	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	1.2E+3	-2.04E+4	0E+00
3a	0E+00	7.2E+3	-1.27E+5	0E+00
Therm.Iso	7.56E+5	0	2.39E+5	0
3b	0E+00	1.44E+5	-2.62E+6	0E+00
Total	7.56E+5	3.11E+5	-4.79E+6	0E+00

Bending resistance - Plastic analysis

Section classification (Mmin comb.)

	c/t	*z_{pl} (mm)*	*α*	*ψ*	*Class*
Web	45.94	724.46	0.07	-1.4	1
Top flange	9.68				1
Bottom flange	7.3				1
Section class					1
Plastic analysis: APPLICABLE					

Plastic section verification (Mmin comb.)

Axial force		*Bending moment*		*N/M interaction*	
N_{Ed} (N)	7.56E+5	M_{Ed} (Nm)	-4.791E+6	N_{Ed} (N)	7.56E+5
N_{Rd} (N)	1.679E+7	M_{Rd} (Nm)	-8.404E+6	M_{Ed} (Nm)	-4.791E+6
				M_{Rd} (Nm)	-8.324E+6
N_{Ed} / N_{Rd}	0.045	M_{Ed} / M_{Rd}	0.57	M_{Ed} / M_{Rd}	0.575
CHECK PASSED					

Axial force and bending moment stresses of gross cross section

Stresses of gross cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	*η_1*
σ_8	0	-4.2	0	0	0	-0.1	0	-4.2	-1.2	0	-13.6	0	-19	0.746
σ_7	0	-67.9	-133.3	0	0	-1.1	-2.1	-69	11.5	-13.2	-72	-272.2	-129.5	0.331
σ_6	0	0	0	0	0	0	0	0	8.5	0	0	0	8.5	0.022
σ_5	0	-2.6	0	0	0	0	0	-2.7	-1.4	0	-7.1	0	-11.2	0.439
σ_4	-85.8	-47.5	-101.1	0	0	-0.8	-1.6	-134.1	10.3	-10	-42.5	-206.5	-166.3	0.492
σ_3	-81.4	-44.1	-95.7	0	0	-0.7	-1.5	-126.3	10.1	-9.5	-37.6	-195.5	-153.8	0.455
σ_2	0	0	0	0	0	0	0	0	8.5	0	0	0	8.5	0.025
σ_1	48.2	55.7	62	0	0	0.9	1	104.7	3.9	6.1	107.1	126.5	215.7	0.638
σ_0	55.2	61.1	70.5	0	0	1	1.1	117.3	3.6	7	114.9	144.1	235.8	0.697

Maximum utilization ratio:0.746 NOT RELEVANT CHECK

NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 2 = -4.22 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -2.68 N/mm^2
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -19.01 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -11.2 N/mm^2
The section at the end of phase 3 is considered: Uncracked (m.)

Resistance to shear

Evaluation of necessity to Shear buckling check

$h_w / t_w = 45.938 < 31/\eta * \varepsilon_w * (K_\tau)^{0.5} = 49.853$ Shear Buckling check: NOT REQUIRED

Shear Buckling resistance: $\mathbf{V_{b,Rd} = 2.629E+6}$ **N**

With:

$a/h_w = 3.741$, $\eta = 1.2$, $K_\tau = 5.626$
web contribution: $V_{bw,Rd} = 2.629E+6$ N, flanges contribution: $V_{bf,Rd} = 1.349E+5$ N
$\chi_w = 1.2$, $\bar{\lambda}_w = 0.636$, $\tau_{cr} = 506.5$, C=1176.2
$M_{Ed} = -4.791E+6$ Nm, $M_{f,Rd} = -6.86E+6$ Nm, $M_{Ed} / M_{f,Rd} = 0.698$

Plastic resistance: $\mathbf{V_{pl,Rd} = 2.755E+6}$ **N**

Shear resistance: $\mathbf{V_{Rd} = V_{pl,Rd} = 2.755E+6}$ **N**

Utilization ratios:

$\eta_3 = V_{Ed} / V_{Rd} = 0.113$, (=> CHECK VERIFIED)
$\bar{\eta}_3 = V_{Ed} / V_{bw,Rd} = 0.118$, $\bar{\eta}_1 = M_{Ed} / M_{Rd} = 0.575$

Interaction between shear force, bending moment and axial force

Evaluation of the interaction

$\bar{\eta}_3 < 0.5$, $M_{Ed} / M_{f,Rd} < 1$
INTERACTION NOT TO BE CHECKED

SLS stresses verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	5.2E+4	-7.2E+5	0E+00
2a	0E+00	6.6E+4	-9.52E+5	0E+00
2b	0E+00	5E+3	8.5E+4	0E+00
Shr.Iso	-3.36E+5	0	-1.51E+5	0
2c	0E+00	-1E+3	1.7E+4	0E+00
3a	0E+00	-4.8E+3	8.46E+4	0E+00
Therm.Iso	-5.04E+5	0	-1.59E+5	0
3b	0E+00	1.04E+5	-1.88E+6	0E+00
Total	-8.4E+5	2.21E+5	-3.68E+6	0E+00

Stresses of gross cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	σ_{id}	η_1
σ_8	0	-3.1	0	0.9	0	0.1	0	-2.1	0.8	0	-9.8	0	-11.1	11.1	0.412
σ_7	0	-50.3	-98.7	-8.8	8.8	0.9	1.8	-58.3	-7.7	8.8	-51.6	-195.1	-117.5	117.5	0.326
σ_6	0	0	0	-5.4	0	0	0	-5.4	-5.6	0	0	0	-11	11	0.031
σ_5	0	-2	0	1	0	0	0	-1	1	0	-5.1	0	-5.1	5.1	0.188
σ_4	-63.6	-35.2	-74.9	-7.8	6.7	0.6	1.3	-106	-6.8	6.7	-30.4	-148	-143.2	143.2	0.403

σ_3	-60.3	-32.7	-70.9	-7.6	6.3	0.6	1.3	-100	-6.7	6.3	-26.9	-140.1	-133.7	136.4	0.384
σ_2	0	0	0	-5.4	0	0	0	-5.4	-5.6	0	0	0	-11	31.9	0.09
σ_1	35.7	41.3	45.9	-2.5	-4.1	-0.7	-0.8	73.7	-2.6	-4.1	76.7	90.7	147.9	150.2	0.423
σ_0	40.9	45.3	52.2	-2.2	-4.7	-0.8	-0.9	83.2	-2.4	-4.6	82.4	103.2	163.2	163.2	0.46
τ_4	0	0.1	0	0	0	0	0	0.1	0	0	0.2	0	0.3		
τ_3	3.5	4.7	4.5	0.4	0.3	-0.1	-0.1	8.5	-0.4	-0.3	7.6	7	15.7		
τ_2	4.5	5.1	5.6	0.4	0.4	-0.1	-0.1	9.9	-0.4	-0.4	7.7	8.7	17.3		
τ_1	4.1	4.5	5.1	0.3	0.4	-0.1	-0.1	8.9	-0.3	-0.4	6.6	8	15.2		
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Maximum utilization ratio:0.46 CHECK PASSED
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -2.13 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -0.95 N/mm^2
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -11.13 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -5.07 N/mm^2
The section at the end of phase 3 is considered: Uncracked (m.)

SLS stresses verification (Mmin comb.)

Forces and moments   (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	5.2E+4	-7.2E+5	0E+00
2a	0E+00	6.6E+4	-9.52E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	1E+3	-1.7E+4	0E+00
3a	0E+00	4.8E+3	-8.46E+4	0E+00
Therm.Iso	5.04E+5	0	1.59E+5	0
3b	0E+00	1.06E+5	-1.94E+6	0E+00
Total	5.04E+5	2.3E+5	-3.56E+6	0E+00

Stresses of gross cross section   (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	σ_{id}	η_1
σ_8	0	-3.1	0	0	0	-0.1	0	-3.1	-0.8	0	-10.1	0	-14	14	0.518
σ_7	0	-50.3	-98.7	0	0	-0.9	-1.8	-51.2	7.7	-8.8	-53.2	-201.3	-96.8	96.8	0.269
σ_6	0	0	0	0	0	0	0	0	5.6	0	0	0	5.6	5.6	0.016
σ_5	0	-2	0	0	0	0	0	-2	-1	0	-5.2	0	-8.2	8.2	0.303
σ_4	-63.6	-35.2	-74.9	0	0	-0.6	-1.3	-99.4	6.8	-6.7	-31.4	-152.7	-124	124	0.349
σ_3	-60.3	-32.7	-70.9	0	0	-0.6	-1.3	-93.6	6.7	-6.3	-27.8	-144.6	-114.7	118.1	0.333
σ_2	0	0	0	0	0	0	0	0	5.6	0	0	0	5.6	31.6	0.089
σ_1	35.7	41.3	45.9	0	0	0.7	0.8	77.7	2.6	4.1	79.2	93.6	159.4	161.8	0.456
σ_0	40.9	45.3	52.2	0	0	0.8	0.9	87	2.4	4.6	85	106.5	174.4	174.4	0.491
τ_4	0	0.1	0	0	0	0	0	0.1	0	0	0.2	0	0.3		
τ_3	3.5	4.7	4.5	0	0	0.1	0.1	8.3	0.4	0.3	7.8	7.2	16.4		
τ_2	4.5	5.1	5.6	0	0	0.1	0.1	9.7	0.4	0.4	7.9	8.9	17.9		
τ_1	4.1	4.5	5.1	0	0	0.1	0.1	8.7	0.3	0.4	6.7	8.2	15.8		
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Maximum utilization ratio:0.518 CHECK PASSED
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -3.13 N/mm^2

2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -1.99 N/mm²
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -13.99 N/mm²
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -8.19 N/mm²
The section at the end of phase 3 is considered: Uncracked (m.)

SLS web breathing verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	5.2E+4	-7.2E+5	0E+00
2a	0E+00	6.6E+4	-9.52E+5	0E+00
2b	0E+00	5E+3	8.5E+4	0E+00
Shr.Iso	-3.36E+5	0	-1.51E+5	0
2c	0E+00	-1E+3	1.7E+4	0E+00
3a	0E+00	-4E+3	7.05E+4	0E+00
Therm.Iso	-4.2E+5	0	-1.33E+5	0
3b	0E+00	7.88E+4	-1.43E+6	0E+00
Total	-7.56E+5	1.97E+5	-3.22E+6	0E+00

Stresses of effective cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*
σ_8	0	-3.1	0	0.9	0	0.1	0	-2.1	0.6	0	-7.4	0	-8.9
σ_7	0	-50.3	-98.7	-8.8	8.8	0.9	1.8	-58.3	-6.4	7.3	-39.3	-148.6	-104
σ_6	0	0	0	-5.4	0	0	0	-5.4	-4.7	0	0	0	-10
σ_5	0	-2	0	1	0	0	0	-1	0.8	0	-3.9	0	-4
σ_4	-63.6	-35.2	-74.9	-7.8	6.7	0.6	1.3	-106	-5.7	5.5	-23.2	-112.8	-134.8
σ_3	-60.3	-32.7	-70.9	-7.6	6.3	0.6	1.3	-100	-5.6	5.3	-20.5	-106.8	-126.1
σ_2	0	0	0	-5.4	0	0	0	-5.4	-4.7	0	0	0	-10
σ_1	35.7	41.3	45.9	-2.5	-4.1	-0.7	-0.8	73.7	-2.2	-3.4	58.5	69.1	130
σ_0	40.9	45.3	52.2	-2.2	-4.7	-0.8	-0.9	83.2	-2	-3.9	62.8	78.7	144

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -2.13 N/mm²
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -0.95 N/mm²
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -8.93 N/mm²
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -4.02 N/mm²
The section at the end of phase 3 is considered: Uncracked (m.)

Web assessment (Mmax comb.)

	Web
b (mm)	735
σ_{sup} (N/mm²)	-126.13
σ_{inf} (N/mm²)	130.02
σ_{Ed} (N/mm²)	126.13
K_σ	24.66
σ_{cr0E} (N/mm²)	90.04
τ_{Ed} (N/mm²)	14.37
σ_{cr} (P) (N/mm²)	2220.58
σ_{cr} (C) (N/mm²)	6.09
ξ	1
σ_{cr} (N/mm²)	2220.58

K $_{\tau}$	5.63
K $_{\tau\ sl}$	0
Utilization ratio	0.065
Result	CHECK VERIFIED

SLS web breathing verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	5.2E+4	-7.2E+5	0E+00
2a	0E+00	6.6E+4	-9.52E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	-1E+3	-1.7E+4	0E+00
3a	0E+00	4E+3	-7.05E+4	0E+00
Therm.Iso	4.2E+5	0	1.33E+5	0
3b	0E+00	7.88E+4	-1.43E+6	0E+00
Total	4.2E+5	2E+5	-3.06E+6	0E+00

Stresses of effective cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*
σ_8	0	-3.1	0	0	0	-0.1	0	-3.1	-0.6	0	-7.4	0	-11.2
σ_7	0	-50.3	-98.7	0	0	-0.9	-1.8	-51.2	6.4	-7.3	-39.3	-148.6	-84.1
σ_6	0	0	0	0	0	0	0	0	4.7	0	0	0	4.7
σ_5	0	-2	0	0	0	0	0	-2	-0.8	0	-3.9	0	-6.7
σ_4	-63.6	-35.2	-74.9	0	0	-0.6	-1.3	-99.4	5.7	-5.5	-23.2	-112.8	-116.9
σ_3	-60.3	-32.7	-70.9	0	0	-0.6	-1.3	-93.6	5.6	-5.3	-20.5	-106.8	-108.5
σ_2	0	0	0	0	0	0	0	0	4.7	0	0	0	4.7
σ_1	35.7	41.3	45.9	0	0	0.7	0.8	77.7	2.2	3.4	58.5	69.1	138.3
σ_0	40.9	45.3	52.2	0	0	0.8	0.9	87	2	3.9	62.8	78.7	151.7

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -3.13 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -1.99 N/mm^2
   The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -11.22 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -6.66 N/mm^2
   The section at the end of phase 3 is considered: Uncracked (m.)

Web assessment (Mmin comb.)

	Web
b (mm)	735
σ_{sup} (N/mm^2)	-108.51
σ_{inf} (N/mm^2)	138.29
σ_{Ed} (N/mm^2)	108.51
K $_{\sigma}$	30.94
σ_{cr0E} (N/mm^2)	90.04
τ_{Ed} (N/mm^2)	14.57
σ_{cr} (P) (N/mm^2)	2785.43
σ_{cr} (C) (N/mm^2)	6.09
ξ	1
σ_{cr} (N/mm^2)	2785.43

K_{τ}	5.63
$K_{\tau\, sl}$	0
Utilization ratio	0.05
Result	CHECK VERIFIED

Shear connectors assessment

Main data

Number of studs for unit length, n (m^{-1})	10
Stud diameter, d (mm)	19
Stud height, h (mm)	150
Ultimate resistance of studs α	1
Partial safety factor, γ_v	1.25
Ultimate resistance of studs f_u (N/mm^2)	450
Coefficient E_{cm} (N/mm^2)	36283
Characteristic cylinder compressive strength, f_{ck} (N/mm^2)	45

Resistance of headed stud connectors

Shank shear resistance, $P_{Rd1} = 0.8\, f_u\, \pi\, d^2/4/\gamma_v$, (N)	81656.28
Concrete crushing resistance, $P_{Rd2} = 0.29\, \alpha\, d^2 (f_{ck} E_{cm})^{0.5}/\gamma_v$, (N)	107017.34
Design stud resistance $P_{Rd} = \mathrm{Min}(P_{Rd1}, P_{Rd2})$, (N)	81656.28

Elastic assessment at ULS

Utilization ratio (Mmax comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\, P_{Rd}\, \kappa_s$ (N/mm)	816.6
Reduction factor, κ_s	1.00
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	195.6
Utilization ratio ν_{Ed}/ν_{Rd}	0.24
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmax comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$ (mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	8.91E+4	6.603E+6	9.462E+9	62.2
Phase 2b	6E+3	6.603E+6	9.462E+9	4.2
Phase 2c	-1.2E+3	6.603E+6	9.462E+9	-0.8
Phase 3a	-7.2E+3	1.308E+7	1.334E+10	-7.1
Phase 3b	1.4E+5	1.308E+7	1.334E+10	137.2
			Sum	195.6

Utilization ratio (Mmin comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\, P_{Rd}\, \kappa_s$ (N/mm)	816.6
Reduction factor, κ_s	1.00
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	210.8
Utilization ratio ν_{Ed}/ν_{Rd}	0.258
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmin comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$ (mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	8.91E+4	6.603E+6	9.462E+9	62.2
Phase 2b	0E+00	6.603E+6	9.462E+9	0
Phase 2c	1.2E+3	6.603E+6	9.462E+9	0.8
Phase 3a	7.2E+3	1.308E+7	1.334E+10	7.1
Phase 3b	1.436E+5	1.308E+7	1.334E+10	140.7
			Sum	210.8

Elastic assessment at ELS

Utilization ratio (Mmax comb.)

Design stud resistance for unit length, $\nu_{Rd} = n P_{Rd} \kappa_s$ (N/mm)	489.9
Reduction factor, κ_s	0.6
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	145.9
Utilization ratio ν_{Ed} / ν_{Rd}	0.298
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmax comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm³)*	*J_y (mm⁴)*	*V_{Ed} (N/mm)*
Phase 2a	6.6E+4	6.603E+6	9.462E+9	46.1
Phase 2b	5E+3	6.603E+6	9.462E+9	3.5
Phase 2c	-1E+3	6.603E+6	9.462E+9	-0.7
Phase 3a	-4.8E+3	1.308E+7	1.334E+10	-4.7
Phase 3b	1.038E+5	1.308E+7	1.334E+10	101.7
			Sum	145.9

Utilization ratio (Mmin comb.)

Design stud resistance for unit length, $\nu_{Rd} = n P_{Rd} \kappa_s$ (N/mm)	489.9
Reduction factor, κ_s	0.6
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	155.5
Utilization ratio ν_{Ed} / ν_{Rd}	0.317
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmin comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm³)*	*J_y (mm⁴)*	*V_{Ed} (N/mm)*
Phase 2a	6.6E+4	6.603E+6	9.462E+9	46.1
Phase 2b	0E+00	6.603E+6	9.462E+9	0
Phase 2c	1E+3	6.603E+6	9.462E+9	0.7
Phase 3a	4.8E+3	1.308E+7	1.334E+10	4.7
Phase 3b	1.062E+5	1.308E+7	1.334E+10	104.1
			Sum	155.5

Assesment of studs at deck ends - shrinkage and thermal influence - (ULS)

Check of minimum studs number

Characteristic shrinkage shear per unit length, $\nu_{L,k}$ (N/mm)	280
Characteristic thermal shear per unit length (-), $\nu_{L,k}$ (N/mm)	700
Total design shear per unit length, $\nu_{L,Ed}$ (N/mm)	1*280 + 1.2*700 = 1120
Minimum number of studs at deck ends, n min (m^{-1})	13.7 > 10
CHECK NOT VERIFIED	

Fatigue limit state verification

Forces and moments for steel details and studs (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	5.2E+4	-7.2E+5	0E+00
2a	0E+00	6.6E+4	-9.52E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	0E+00	0E+00	0E+00
3a	0E+00	0E+00	0E+00	0E+00
Therm.Iso	0E+00	0	0E+00	0
3b max	0E+00	1.2E+4	-5.52E+5	0E+00

3b max	0E+00	-2.3E+4	1.7E+5	0E+00

Stresses of gross cross section for steel details and studs (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked Max*	*Ph. 3b Cracked Max*	*Ph. 3b Uncracked Min*	*Ph. 3b Cracked Min*	*Total Uncracked Max*	*Total Cracked Max*	*Total Uncracked Min*	*Total Cracked Min*	*Δσ,Δτ*
σ_8	0	-3.1	0	0	0	0	0	0	0	-2.9	0	0.9	0	-5.9	0	-2.2	0	3.8
σ_7	0	-50.3	-98.7	0	0	0	0	0	0	-15.1	-57.2	4.7	17.6	-65.4	-156	-45.6	-81.1	19.8
σ_6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_5	0	-2	0	0	0	0	0	0	0	-1.5	0	0.5	0	-3.4	0	-1.5	0	1.9
σ_4	-63.6	-35.2	-74.9	0	0	0	0	0	0	-8.9	-43.4	2.8	13.4	-107.7	-181.9	-96	-125.1	11.7
σ_3	-60.3	-32.7	-70.9	0	0	0	0	0	0	-7.9	-41.1	2.4	12.7	-100.9	-172.4	-90.6	-118.6	10.3
σ_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_1	35.7	41.3	45.9	0	0	0	0	0	0	22.5	26.6	-6.9	-8.2	99.5	108.2	70	73.4	29.4
σ_0	40.9	45.3	52.2	0	0	0	0	0	0	24.2	30.3	-7.4	-9.3	110.4	123.4	78.7	83.8	31.6
τ_4	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0	0	0.1
τ_3	3.5	4.7	4.5	0	0	0	0	0	0	0.9	0.8	-1.7	-1.6	9.1	9.1	6.5	6.5	2.6
τ_2	4.5	5.1	5.6	0	0	0	0	0	0	0.9	1	-1.7	-1.9	10.5	10.5	7.9	7.9	2.6
τ_1	4.1	4.5	5.1	0	0	0	0	0	0	0.8	0.9	-1.5	-1.8	9.4	9.4	7.2	7.2	2.2
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 3 max = -5.94 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 3 max = -3.44 N/mm^2
   The section at the end of phase 3 max is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 min = -2.19 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 min = -1.5 N/mm^2
   The section at the end of phase 3 min is considered: Uncracked (m.)

Forces and moments for steel details and studs (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	5.2E+4	-7.2E+5	0E+00
2a	0E+00	6.6E+4	-9.52E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	0E+00	0E+00	0E+00
3a	0E+00	0E+00	0E+00	0E+00
Therm.Iso	0E+00	0	0E+00	0
3b max	0E+00	1.2E+4	-5.52E+5	0E+00
3b max	0E+00	-2.3E+4	1.7E+5	0E+00

Stresses of gross cross section for steel details and studs (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked Max*	*Ph. 3b Cracked Max*	*Ph. 3b Uncracked Min*	*Ph. 3b Cracked Min*	*Total Uncracked Max*	*Total Cracked Max*	*Total Uncracked Min*	*Total Cracked Min*	*Δσ,Δτ*
σ_8	0	-3.1	0	0	0	0	0	0	0	-2.9	0	0.9	0	-5.9	0	-2.2	0	3.8
σ_7	0	-50.3	-98.7	0	0	0	0	0	0	-15.1	-57.2	4.7	17.6	-65.4	-156	-45.6	-81.1	19.8

σ_6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_5	0	-2	0	0	0	0	0	0	0	-1.5	0	0.5	0	-3.4	0	-1.5	0	1.9
σ_4	-63.6	-35.2	-74.9	0	0	0	0	0	0	-8.9	-43.4	2.8	13.4	-107.7	-181.9	-96	-125.1	11.7
σ_3	-60.3	-32.7	-70.9	0	0	0	0	0	0	-7.9	-41.1	2.4	12.7	-100.9	-172.4	-90.6	-118.6	10.3
σ_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_1	35.7	41.3	45.9	0	0	0	0	0	0	22.5	26.6	-6.9	-8.2	99.5	108.2	70	73.4	29.4
σ_0	40.9	45.3	52.2	0	0	0	0	0	0	24.2	30.3	-7.4	-9.3	110.4	123.4	78.7	83.8	31.6
τ_4	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0	0	0.1
τ_3	3.5	4.7	4.5	0	0	0	0	0	0	0.9	0.8	-1.7	-1.6	9.1	9.1	6.5	6.5	2.6
τ_2	4.5	5.1	5.6	0	0	0	0	0	0	0.9	1	-1.7	-1.9	10.5	10.5	7.9	7.9	2.6
τ_1	4.1	4.5	5.1	0	0	0	0	0	0	0.8	0.9	-1.5	-1.8	9.4	9.4	7.2	7.2	2.2
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 3 max = -5.94 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 3 max = -3.44 N/mm^2
   The section at the end of phase 3 max is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 min = -2.19 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 min = -1.5 N/mm^2
   The section at the end of phase 3 min is considered: Uncracked (m.)

Main data for partial factors and damage equivalent facors

Partial factor for steel:	γ_{Ff}	1
	γ_{Mf}	1.35
Bending damage equivalent factor for steel:	$\lambda = \lambda_1 * \lambda_2 * \lambda_3 * \lambda_4 =$	2.32 x 0.848 x 1 x 1.15 = 2.262>2=>2 (Midspan)
Shear damage equivalent factor for steel:	$\lambda = \lambda_1 * \lambda_2 * \lambda_3 * \lambda_4 =$	2.518 x 0.848 x 1 x 1.15 = 2.455 (Midspan)
Data for calculation of λ_1	Section position:	(Midspan)
	L span for moment (m):	33
	L span for shear (m):	13.2
Data for calculation of λ_2, λ_{v2}	Q_0 (kN)	480
	N_0	500000
	N_{obs}	500000
	Q_{ml} (kN)	0
	Traffic category (Table 4.5n - EN 1991-2) :	Roads and motorways with medium flow rates of lorries
	Traffic distribution (Table 4.7 - EN 1991-2) :	Medium distance (40% Q1, 10% Q2, 30% Q3, 15% Q4, 5% Q5)
Data for calculation of λ_3, λ_{v3}	Design life (years):	100
Data for calculation of γ_{Mf} for steel:	Assessment method:	
	Consequence of failure:	
Damage equivalent factor for studs:	$\lambda_v = \lambda_{v1} * \lambda_{v2} * \lambda_{v3} * \lambda_{v4} =$	1.55 x 0.896 x 1 x 1.09 = 1.514
Partial factor for studs:	γ_{Ff}	1
	γ_{Mf}	1

Fatigue assessment of structural steel

Utilization ratio (Mmax comb.)

	$\gamma_{Ff}\Delta\sigma_{E,2}$	$\Delta\sigma_c/\gamma_{Mf}$	u.r.
Top flange	23.36	92.593	0.252
Bottom flange	63.229	92.593	0.683
Web	6.404	74.074	0.086
Top flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c = 1 \times 90 = 90$ N/mm^2	23.363	66.667	0.35
Bottom flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c = 0.91 \times 112 = 102$ N/mm^2	63.229	75.52	0.837
Web-top flange welding	20.657	92.593	0.223
Web-bottom flange welding	58.899	92.593	0.636
Vertical stiffeners - web welding	58.899	59.259	0.994
Vertical stiffeners - top flange welding	20.657	59.259	0.349
Vertical stiffeners - bottom flange welding	58.899	59.259	0.994
Longitudinal stiffener 1 - web welding			
Longitudinal stiffener 2 - web welding			

Utilization ratio (Mmin comb.)

	$\gamma_{Ff}\Delta\sigma_{E,2}$	$\Delta\sigma_c/\gamma_{Mf}$	u.r.
Top flange	23.36	92.593	0.252
Bottom flange	63.229	92.593	0.683
Web	6.404	74.074	0.086
Top flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c = 1 \times 90 = 90$ N/mm^2	23.363	66.667	0.35
Bottom flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c = 0.91 \times 112 = 102$ N/mm^2	63.229	75.52	0.837
Web-top flange welding	20.657	92.593	0.223
Web-bottom flange welding	58.899	92.593	0.636
Vertical stiffeners - web welding	58.899	59.259	0.994
Vertical stiffeners - top flange welding	20.657	59.259	0.349
Vertical stiffeners - bottom flange welding	58.899	59.259	0.994
Longitudinal stiffener 1 - web welding			
Longitudinal stiffener 2 - web welding			

Fatigue assessment of studs

Utilization ratio (Mmax comb.)

$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) <= 1$	=1*18.32/(90/1) =0.204
$\gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <= 1$	=1*23.36/(80/1.35) =0.394(*)
$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) + \gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <= 1.3$	=0.204+0.394=0.598(*)
CHECK PASSED	

(*) Not relevant check (Top flange in compression)

Utilization ratio (Mmin comb.)

$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) <= 1$	=1*18.32/(90/1) =0.204
$\gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <= 1$	=1*23.36/(80/1.35) =0.394(*)
$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) + \gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <= 1.3$	=0.204+0.394=0.598(*)
CHECK PASSED	

(*) Not relevant check (Top flange in compression)

Stiffeners checks

Torsional buckling of vertical stiffeners

	Vertical

	stiffeners
	CHECK PASSED
u.r.	0.898
Type	Vert. (R)
σ_{cr} (N/mm^2)	--
6^*f_y (N/mm^2)	--
l_{cr} (mm)	--
I_w (mm^6)	--
I_T (mm^4)	5.333E+5
I_P (mm^4)	5.347E+7
I_T / I_P	0.01
5.3 f_y /E	0.009
$c\theta$ (N)	--
E (N/mm^2)	210000
f_y (N/mm^2)	355
G (N/mm^2)	87500
a (mm)	2750

Intermediate vertical stiffeners acting as rigid support for web panels

I_{st} = 4.247E+7 mm^4 > $I_{st\ min} = 0.75\ h_w\ t_w^{\ 3}$ =2.258E+6 mm^4

CHECK PASSED

With:

t_w = 16 mm b_w = 410.5 mm A_{st} = 10568.6 mm^2 e_1 = 40.9 mm ^{2}

a = 2750 mm h_w = 735 mm a/hw = 3.741

Maximum stress and the additional deflection in the vertical stiffeners (Mmax comb.)

w = 0 < 2.4 mm

σ_{max} = 0 < 322.7 N/mm^2

CHECK PASSED

With:

$\Sigma N_{st,Ed} = N_{st,Ed} + \Delta N_{st,Ed}$ = 0E+00 + 1.363E+4 = 1.363E+4 N

$N_{st,Ed} = N_{st,ten} + N_{st,ex}$ = 0E+00 + 0E+00 = 0E+00 N

σ_m = 0.249 N/mm^2 $\sigma_{cr(C)} / \sigma_{cr(P)}$ = 6.09/1E+300 = 0=> 0.5

N_{Ed} = 5.033E+5 N $\bar{\lambda}_w$ = 0.636

$N_{cr,st}$ = 1.629E+8 N e_1 = 40.9 mm e_{max} = 167.1 mm w_0 = 2.45 mm

δ_m = 0

(I_{vstmin} = 2.085E+4(mm^4) u = 4.868)

9.3.5 Section Sez. 3b_3b

First classification

The first classification refers to the composite section in Phase 3

Plastic characteristics of the single components

Components	N_{pl} *(N)*	z_N *(mm)*	z_{max} *(mm)*	z_{min} *(mm)*
Concrete layer above top reinforcing bars	1.515E+6	975.25	1000	950.5
Concrete layer between top and bottom reinforcing bars	4.498E+6	876	949.5	802.5
Concrete layer below top reinforcing bars	7.65E+4	801.25	802.5	800
Top reinforcing bars	4.721E+5	950	950.5	949.5
Bottom reinforcing bars	0E+00	802.5	802.5	802.5
Concrete haunch slab	0E+00	800	800	800
Top flange of steel beam	7.607E+6	777.5	800	755
Web of steel beam	4.801E+6	400	755	45
Bottom flange of steel beam	8.614E+6	22.5	45	0
Ultimate compression force for the full section	-2.758E+7			
Ultimate tension force for the full section	2.149E+7			
Ultimate compression force for the web less section	-2.278E+7			
Ultimate tensile force for the web less section	1.669E+7			

Flanges classification

	c/t	ε	*Hogging bending moment (M+)*	*Sagging bending moment (M-)*
Top flange	5.333	0.814	1	0
Bottom flange	6.444	0.838	1	1

Web classification

	c/t	ε	α	ψ	*class*
Hogging bending moment (M+)	35.5	0.814	0.444	-1.094	1
Sagging bending moment (M-)	35.5	0.814	0	-0.325	1
Compression (N)	35.5	0.814	1	1	4

U.L.S. composite section verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	7.02E+4	-9.72E+5	0E+00
2a	0E+00	8.91E+4	-1.29E+6	0E+00
2b	0E+00	6E+3	1.02E+5	0E+00
Shr.Iso	-4.03E+5	0	-1.73E+5	0
2c	0E+00	-1.2E+3	2.04E+4	0E+00
3a	0E+00	-7.2E+3	1.27E+5	0E+00
Therm.Iso	-7.56E+5	0	-2.41E+5	0
3b	0E+00	1.4E+5	-2.53E+6	0E+00
Total	-1.16E+6	2.97E+5	-4.96E+6	0E+00

Bending resistance - Plastic analysis

Section classification (Mmax comb.)

	c/t	z_{pl} *(mm)*	α	ψ	*Class*
Web	35.5	724.98	0.04	-1.4	1
Top flange	5.33				1
Bottom flange	6.44				1

Section class					1
Plastic analysis: APPLICABLE					

Plastic section verification (Mmax comb.)

Axial force		*Bending moment*		*N/M interaction*	
N_{Ed} (N)	-1.159E+6	M_{Ed} (Nm)	-4.957E+6	N_{Ed} (N)	-1.159E+6
N_{Rd} (N)	-2.758E+7	M_{Rd} (Nm)	-9.158E+6	M_{Ed} (Nm)	-4.957E+6
				M_{Rd} (Nm)	-9.355E+6
N_{Ed}/N_{Rd}	0.042	M_{Ed}/M_{Rd}	0.541	M_{Ed}/M_{Rd}	0.53
CHECK PASSED					

Axial force and bending moment stresses of gross cross section

Stresses of gross cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	η_1
σ_8	0	-3.4	0	1.2	0	0.1	0	-2.2	1.4	0	-12	0	-12.8	0.501
σ_7	0	-55.9	-90.8	-8.2	7.2	0.9	1.4	-63.2	-10.1	9	-63.5	-179.2	-136.8	0.35
σ_6	0	0	0	-5.2	0	0	0	-5.2	-7.2	0	0	0	-12.4	0.032
σ_5	0	-2.1	0	1.3	0	0	0	-0.8	1.7	0	-6.3	0	-5.4	0.213
σ_4	-54.5	-38.3	-66.8	-7.3	5.3	0.6	1.1	-99.5	-8.9	6.6	-37.7	-131.7	-146.1	0.432
σ_3	-48.7	-33.1	-59.5	-7	4.7	0.5	0.9	-88.2	-8.6	5.9	-30	-117.4	-126.8	0.375
σ_2	0	0	0	-5.2	0	0	0	-5.2	-7.2	0	0	0	-12.4	0.037
σ_1	41.9	49.9	54.4	-2.4	-4.3	-0.8	-0.9	88.6	-3	-5.4	92.2	107.3	177.8	0.557
σ_0	47.7	55.2	61.6	-2.1	-4.9	-0.9	-1	99.8	-2.7	-6.1	100	121.6	197.1	0.618

Maximum utilization ratio:0.618 NOT RELEVANT CHECK
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -2.17 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -0.82 N/mm^2
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -12.79 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -5.44 N/mm^2
The section at the end of phase 3 is considered: Uncracked (m.)

Resistance to shear

Evaluation of necessity to Shear buckling check
h_w/t_w =35.5 < $31/\eta * \varepsilon_w * (K_\tau)^{0.5}$ =49.768 Shear Buckling check: NOT REQUIRED

Shear Buckling resistance: $\mathbf{V_{b,Rd}}$ **=3.175E+6 N**

With:
a/h_w =3.873, η =1.2, K_τ =5.607
web contribution: $V_{bw,Rd}$ =3.175E+6 N, flanges contribution: $V_{bf,Rd}$ =1.8E+5 N
χ_w =1.2, $\bar{\lambda}_w$ =0.493, τ_{cr} =845.3, C=1187.9
M_{Ed} =-4.957E+6 Nm, $M_{f,Rd}$ =-7.628E+6 Nm, $M_{Ed}/M_{f,Rd}$ =0.65

Plastic resistance: $\mathbf{V_{pl,Rd}}$ **=3.326E+6 N**

Shear resistance: $\mathbf{V_{Rd} = V_{pl,Rd}}$ **=3.326E+6 N**

Utilization ratios:

$\eta_3 = V_{Ed}/V_{Rd}$ =0.089, (=> CHECK VERIFIED)
$\bar{\eta}_3 = V_{Ed}/V_{bw,Rd}$ =0.093, $\bar{\eta}_1 = M_{Ed}/M_{Rd}$ =0.53

Interaction between shear force, bending moment and axial force

Evaluation of the interaction

η_3 <0.5, $M_{Ed}/M_{f,Rd}$ <1
INTERACTION NOT TO BE CHECKED

U.L.S. composite section verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	7.02E+4	-9.72E+5	0E+00
2a	0E+00	8.91E+4	-1.29E+6	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	1.2E+3	-2.04E+4	0E+00
3a	0E+00	7.2E+3	-1.27E+5	0E+00
Therm.Iso	7.56E+5	0	2.41E+5	0
3b	0E+00	1.44E+5	-2.62E+6	0E+00
Total	7.56E+5	3.11E+5	-4.79E+6	0E+00

Bending resistance - Plastic analysis

Section classification (Mmin comb.)

	c/t	*z $_{pl}$ (mm)*	*α*	*ψ*	*Class*
Web	35.5	759.46	-0.01	-1.82	1
Top flange	5.33				1
Bottom flange	6.44				1
Section class					1
Plastic analysis: APPLICABLE					

Plastic section verification (Mmin comb.)

Axial force		*Bending moment*		*N/M interaction*	
N_{Ed} (N)	7.56E+5	M_{Ed} (Nm)	-4.788E+6	N_{Ed} (N)	7.56E+5
N_{Rd} (N)	2.149E+7	M_{Rd} (Nm)	-9.158E+6	M_{Ed} (Nm)	-4.788E+6
				M_{Rd} (Nm)	-9.024E+6
N_{Ed}/N_{Rd}	0.035	M_{Ed}/M_{Rd}	0.523	M_{Ed}/M_{Rd}	0.531
CHECK PASSED					

Axial force and bending moment stresses of gross cross section

Stresses of gross cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	*η_1*
σ_8	0	-3.4	0	0	0	-0.1	0	-3.5	-1.4	0	-12.5	0	-17.3	0.68
σ_7	0	-55.9	-90.8	0	0	-0.9	-1.4	-56.8	10.1	-9	-65.8	-185.5	-112.5	0.287
σ_6	0	0	0	0	0	0	0	0	7.2	0	0	0	7.2	0.018
σ_5	0	-2.1	0	0	0	0	0	-2.2	-1.7	0	-6.5	0	-10.3	0.405
σ_4	-54.5	-38.3	-66.8	0	0	-0.6	-1.1	-93.4	8.9	-6.6	-39.1	-136.4	-123.6	0.366
σ_3	-48.7	-33.1	-59.5	0	0	-0.5	-0.9	-82.3	8.6	-5.9	-31	-121.6	-104.8	0.31
σ_2	0	0	0	0	0	0	0	0	7.2	0	0	0	7.2	0.021
σ_1	41.9	49.9	54.4	0	0	0.8	0.9	92.6	3	5.4	95.5	111.1	191.1	0.599
σ_0	47.7	55.2	61.6	0	0	0.9	1	103.7	2.7	6.1	103.5	125.9	209.9	0.658

Maximum utilization ratio:0.68 NOT RELEVANT CHECK
NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 2 = -3.48 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -2.16 N/mm^2
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -17.34 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -10.34 N/mm^2
The section at the end of phase 3 is considered: Uncracked (m.)

Resistance to shear

Evaluation of necessity to Shear buckling check

$h_w / t_w = 35.5 < 31/\eta * \varepsilon_w * (K_\tau)^{0.5} = 49.768$ Shear Buckling check: NOT REQUIRED

Shear Buckling resistance: $\mathbf{V_{b,Rd} = 3.175E+6}$ **N**

With:

$a/h_w = 3.873$, $\eta = 1.2$, $K_\tau = 5.607$
web contribution: $V_{bw,Rd} = 3.175E+6$ N, flanges contribution: $V_{bf,Rd} = 1.762E+5$ N
$\chi_w = 1.2$, $\bar{\lambda}_w = 0.493$, $\tau_{cr} = 845.3$, $C = 1187.9$
$M_{Ed} = -4.788E+6$ Nm, $M_{f,Rd} = -7.264E+6$ Nm, $M_{Ed} / M_{f,Rd} = 0.659$

Plastic resistance: $\mathbf{V_{pl,Rd} = 3.326E+6}$ **N**

Shear resistance: $\mathbf{V_{Rd} = V_{pl,Rd} = 3.326E+6}$ **N**

Utilization ratios:

$\eta_3 = V_{Ed} / V_{Rd} = 0.094$, (=> CHECK VERIFIED)
$\bar{\eta}_3 = V_{Ed} / V_{bw,Rd} = 0.098$, $\bar{\eta}_1 = M_{Ed} / M_{Rd} = 0.531$

Interaction between shear force, bending moment and axial force

Evaluation of the interaction

$\bar{\eta}_3 < 0.5$, $M_{Ed} / M_{f,Rd} < 1$
INTERACTION NOT TO BE CHECKED

SLS stresses verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	5.2E+4	-7.2E+5	0E+00
2a	0E+00	6.6E+4	-9.52E+5	0E+00
2b	0E+00	5E+3	8.5E+4	0E+00
Shr.Iso	-3.36E+5	0	-1.44E+5	0
2c	0E+00	-1E+3	1.7E+4	0E+00
3a	0E+00	-4.8E+3	8.46E+4	0E+00
Therm.Iso	-5.04E+5	0	-1.61E+5	0
3b	0E+00	1.04E+5	-1.88E+6	0E+00
Total	-8.4E+5	2.21E+5	-3.67E+6	0E+00

Stresses of gross cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	σ_{id}	η_1
σ_8	0	-2.5	0	1	0	0	0	-1.5	0.9	0	-8.9	0	-9.5	9.5	0.351
σ_7	0	-41.4	-67.3	-6.9	6	0.7	1.2	-47.5	-6.7	6	-47.2	-132.9	-101.4	101.4	0.282
σ_6	0	0	0	-4.3	0	0	0	-4.3	-4.8	0	0	0	-9.1	9.1	0.025
σ_5	0	-1.6	0	1.1	0	0	0	-0.5	1.1	0	-4.7	0	-4	4	0.15
σ_4	-40.3	-28.4	-49.5	-6	4.4	0.5	0.9	-74.3	-5.9	4.4	-28	-97.7	-108.2	108.2	0.305

σ_3	-36.1	-24.5	-44.1	-5.8	3.9	0.4	0.8	-66	-5.7	3.9	-22.2	-87.1	-93.9	96.7	0.272
σ_2	0	0	0	-4.3	0	0	0	-4.3	-4.8	0	0	0	-9.1	26	0.073
σ_1	31	37	40.3	-2	-3.6	-0.7	-0.7	65.3	-2	-3.6	68.4	79.6	131.7	133.4	0.398
σ_0	35.3	40.9	45.7	-1.8	-4.1	-0.7	-0.8	73.7	-1.8	-4.1	74.2	90.2	146	146	0.436
τ_4	0	0.1	0	0	0	0	0	0.1	0	0	0.2	0	0.3		
τ_3	3.1	3.9	3.9	0.3	0.3	-0.1	-0.1	7.3	-0.3	-0.3	6.2	6.2	13.2		
τ_2	3.6	4.2	4.5	0.3	0.3	-0.1	-0.1	8	-0.3	-0.3	6.3	7.1	14.1		
τ_1	3.2	3.6	4	0.3	0.3	-0.1	-0.1	7.1	-0.2	-0.3	5.3	6.3	12.2		
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Maximum utilization ratio:0.436 CHECK PASSED
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -1.49 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -0.49 N/mm^2
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -9.48 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -4.04 N/mm^2
The section at the end of phase 3 is considered: Uncracked (m.)

SLS stresses verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	5.2E+4	-7.2E+5	0E+00
2a	0E+00	6.6E+4	-9.52E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	1E+3	-1.7E+4	0E+00
3a	0E+00	4.8E+3	-8.46E+4	0E+00
Therm.Iso	5.04E+5	0	1.61E+5	0
3b	0E+00	1.06E+5	-1.94E+6	0E+00
Total	5.04E+5	2.3E+5	-3.55E+6	0E+00

Stresses of gross cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	σ_{id}	η_1
σ_8	0	-2.5	0	0	0	0	0	-2.6	-0.9	0	-9.2	0	-12.7	12.7	0.471
σ_7	0	-41.4	-67.3	0	0	-0.7	-1.2	-42.1	6.7	-6	-48.7	-137.2	-84.1	84.1	0.234
σ_6	0	0	0	0	0	0	0	0	4.8	0	0	0	4.8	4.8	0.013
σ_5	0	-1.6	0	0	0	0	0	-1.6	-1.1	0	-4.8	0	-7.5	7.5	0.279
σ_4	-40.3	-28.4	-49.5	0	0	-0.5	-0.9	-69.3	5.9	-4.4	-28.9	-100.8	-92.2	92.2	0.26
σ_3	-36.1	-24.5	-44.1	0	0	-0.4	-0.8	-61	5.7	-3.9	-23	-89.9	-78.3	81.8	0.231
σ_2	0	0	0	0	0	0	0	0	4.8	0	0	0	4.8	25.8	0.073
σ_1	31	37	40.3	0	0	0.7	0.7	68.7	2	3.6	70.6	82.2	141.3	143	0.427
σ_0	35.3	40.9	45.7	0	0	0.7	0.8	76.9	1.8	4.1	76.5	93.1	155.2	155.2	0.463
τ_4	0	0.1	0	0	0	0	0	0.1	0	0	0.2	0	0.3		
τ_3	3.1	3.9	3.9	0	0	0.1	0.1	7.1	0.3	0.3	6.4	6.3	13.8		
τ_2	3.6	4.2	4.5	0	0	0.1	0.1	7.9	0.3	0.3	6.5	7.2	14.6		
τ_1	3.2	3.6	4	0	0	0.1	0.1	6.9	0.2	0.3	5.4	6.5	12.6		
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Maximum utilization ratio:0.471 CHECK PASSED
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -2.58 N/mm^2

2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -1.61 N/mm²
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -12.73 N/mm²
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -7.53 N/mm²
The section at the end of phase 3 is considered: Uncracked (m.)

SLS web breathing verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	5.2E+4	-7.2E+5	0E+00
2a	0E+00	6.6E+4	-9.52E+5	0E+00
2b	0E+00	5E+3	8.5E+4	0E+00
Shr.Iso	-3.36E+5	0	-1.44E+5	0
2c	0E+00	-1E+3	1.7E+4	0E+00
3a	0E+00	-4E+3	7.05E+4	0E+00
Therm.Iso	-4.2E+5	0	-1.34E+5	0
3b	0E+00	7.88E+4	-1.43E+6	0E+00
Total	-7.56E+5	1.97E+5	-3.21E+6	0E+00

Stresses of effective cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*
σ_8	0	-2.5	0	1	0	0	0	-1.5	0.8	0	-6.8	0	-7.5
σ_7	0	-41.4	-67.3	-6.9	6	0.7	1.2	-47.5	-5.6	5	-35.9	-101.3	-89
σ_6	0	0	0	-4.3	0	0	0	-4.3	-4	0	0	0	-8.3
σ_5	0	-1.6	0	1.1	0	0	0	-0.5	0.9	0	-3.6	0	-3.1
σ_4	-40.3	-28.4	-49.5	-6	4.4	0.5	0.9	-74.3	-4.9	3.7	-21.3	-74.5	-100.6
σ_3	-36.1	-24.5	-44.1	-5.8	3.9	0.4	0.8	-66	-4.8	3.3	-17	-66.4	-87.7
σ_2	0	0	0	-4.3	0	0	0	-4.3	-4	0	0	0	-8.3
σ_1	31	37	40.3	-2	-3.6	-0.7	-0.7	65.3	-1.7	-3	52.1	60.7	115.8
σ_0	35.3	40.9	45.7	-1.8	-4.1	-0.7	-0.8	73.7	-1.5	-3.4	56.5	68.7	128.7

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -1.49 N/mm²
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -0.49 N/mm²
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -7.51 N/mm²
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -3.12 N/mm²
The section at the end of phase 3 is considered: Uncracked (m.)

Web assessment (Mmax comb.)

	Web
b (mm)	710
σ_{sup} (N/mm²)	-87.68
σ_{inf} (N/mm²)	115.79
σ_{Ed} (N/mm²)	87.68
K_σ	32.2
σ_{cr0E} (N/mm²)	150.76
τ_{Ed} (N/mm²)	11.76
σ_{cr} (P) (N/mm²)	4855.33
σ_{cr} (C) (N/mm²)	9.52
ξ	1
σ_{cr} (N/mm²)	4855.33

K_{τ}	5.61
$K_{\tau\ sl}$	0
Utilization ratio	0.024
Result	CHECK VERIFIED

SLS web breathing verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	5.2E+4	-7.2E+5	0E+00
2a	0E+00	6.6E+4	-9.52E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	-1E+3	-1.7E+4	0E+00
3a	0E+00	4E+3	-7.05E+4	0E+00
Therm.Iso	4.2E+5	0	1.34E+5	0
3b	0E+00	7.88E+4	-1.43E+6	0E+00
Total	4.2E+5	2E+5	-3.06E+6	0E+00

Stresses of effective cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*
σ_8	0	-2.5	0	0	0	0	0	-2.6	-0.8	0	-6.8	0	-10.2
σ_7	0	-41.4	-67.3	0	0	-0.7	-1.2	-42.1	5.6	-5	-35.9	-101.3	-72.5
σ_6	0	0	0	0	0	0	0	0	4	0	0	0	4
σ_5	0	-1.6	0	0	0	0	0	-1.6	-0.9	0	-3.6	0	-6.1
σ_4	-40.3	-28.4	-49.5	0	0	-0.5	-0.9	-69.3	4.9	-3.7	-21.3	-74.5	-85.6
σ_3	-36.1	-24.5	-44.1	0	0	-0.4	-0.8	-61	4.8	-3.3	-17	-66.4	-73.2
σ_2	0	0	0	0	0	0	0	0	4	0	0	0	4
σ_1	31	37	40.3	0	0	0.7	0.7	68.7	1.7	3	52.1	60.7	122.5
σ_0	35.3	40.9	45.7	0	0	0.7	0.8	76.9	1.5	3.4	56.5	68.7	134.9

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = -2.58 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = -1.61 N/mm^2
The section at the end of phase 2 is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = -10.17 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = -6.09 N/mm^2
The section at the end of phase 3 is considered: Uncracked (m.)

Web assessment (Mmin comb.)

	Web
b (mm)	710
σ_{sup} (N/mm^2)	-73.23
σ_{inf} (N/mm^2)	122.5
σ_{Ed} (N/mm^2)	73.23
K_{σ}	42.72
σ_{cr0E} (N/mm^2)	150.76
τ_{Ed} (N/mm^2)	11.92
σ_{cr} (P) (N/mm^2)	6440.71
σ_{cr} (C) (N/mm^2)	9.52
ξ	1
σ_{cr} (N/mm^2)	6440.71

K_{τ}	5.61
$K_{\tau\,sl}$	0
Utilization ratio	0.019
Result	CHECK VERIFIED

Shear connectors assessment

Main data

Number of studs for unit length, n (m^{-1})	10
Stud diameter, d (mm)	19
Stud height, h (mm)	150
Ultimate resistance of studs α	1
Partial safety factor, γ_v	1.25
Ultimate resistance of studs f_u (N/mm^2)	450
Coefficient E_{cm} (N/mm^2)	36283
Characteristic cylinder compressive strength, f_{ck} (N/mm^2)	45

Resistance of headed stud connectors

Shank shear resistance, $P_{Rd1} = 0.8\ f_u\ \pi\ d^2/4/\gamma_v$, (N)	81656.28
Concrete crushing resistance, $P_{Rd2} = 0.29\ \alpha\ d^2 (f_{ck} E_{cm})^{0.5}/\gamma_v$, (N)	107017.34
Design stud resistance $P_{Rd} = \mathrm{Min}(P_{Rd1}, P_{Rd2})$, (N)	81656.28

Elastic assessment at ULS

Utilization ratio (Mmax comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\ P_{Rd}\ \kappa_s$ (N/mm)	816.6
Reduction factor, κ_s	1.00
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	172.8
Utilization ratio ν_{Ed}/ν_{Rd}	0.212
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmax comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$ (mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	8.91E+4	6.284E+6	1.1E+10	50.9
Phase 2b	6E+3	6.284E+6	1.1E+10	3.4
Phase 2c	-1.2E+3	6.284E+6	1.1E+10	-0.7
Phase 3a	-7.2E+3	1.321E+7	1.473E+10	-6.5
Phase 3b	1.4E+5	1.321E+7	1.473E+10	125.6
			Sum	172.8

Utilization ratio (Mmin comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\ P_{Rd}\ \kappa_s$ (N/mm)	816.6
Reduction factor, κ_s	1.00
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	186.8
Utilization ratio ν_{Ed}/ν_{Rd}	0.229
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmin comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$ (mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	8.91E+4	6.284E+6	1.1E+10	50.9
Phase 2b	0E+00	6.284E+6	1.1E+10	0
Phase 2c	1.2E+3	6.284E+6	1.1E+10	0.7
Phase 3a	7.2E+3	1.321E+7	1.473E+10	6.5
Phase 3b	1.436E+5	1.321E+7	1.473E+10	128.8
			Sum	186.8

Elastic assessment at ELS

Utilization ratio (Mmax comb.)

Design stud resistance for unit length, $\nu_{Rd} = n P_{Rd} \kappa_s$ (N/mm)	489.9
Reduction factor, κ_s	0.6
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	128.8
Utilization ratio ν_{Ed} / ν_{Rd}	0.263
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmax comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm³)*	*J_y (mm⁴)*	*V_{Ed} (N/mm)*
Phase 2a	6.6E+4	6.284E+6	1.1E+10	37.7
Phase 2b	5E+3	6.284E+6	1.1E+10	2.9
Phase 2c	-1E+3	6.284E+6	1.1E+10	-0.6
Phase 3a	-4.8E+3	1.321E+7	1.473E+10	-4.3
Phase 3b	1.038E+5	1.321E+7	1.473E+10	93.1
			Sum	128.8

Utilization ratio (Mmin comb.)

Design stud resistance for unit length, $\nu_{Rd} = n P_{Rd} \kappa_s$ (N/mm)	489.9
Reduction factor, κ_s	0.6
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	137.9
Utilization ratio ν_{Ed} / ν_{Rd}	0.281
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmin comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm³)*	*J_y (mm⁴)*	*V_{Ed} (N/mm)*
Phase 2a	6.6E+4	6.284E+6	1.1E+10	37.7
Phase 2b	0E+00	6.284E+6	1.1E+10	0
Phase 2c	1E+3	6.284E+6	1.1E+10	0.6
Phase 3a	4.8E+3	1.321E+7	1.473E+10	4.3
Phase 3b	1.062E+5	1.321E+7	1.473E+10	95.3
			Sum	137.9

Assesment of studs at deck ends - shrinkage and thermal influence - (ULS)

Check of minimum studs number

Characteristic shrinkage shear per unit length, $\nu_{L,k}$ (N/mm)	280
Characteristic thermal shear per unit length (-), $\nu_{L,k}$ (N/mm)	700
Total design shear per unit length, $\nu_{L,Ed}$ (N/mm)	1*280 + 1.2*700 = 1120
Minimum number of studs at deck ends, n min (m^{-1})	13.7 > 10
CHECK NOT VERIFIED	

Fatigue limit state verification

Forces and moments for steel details and studs (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	5.2E+4	-7.2E+5	0E+00
2a	0E+00	6.6E+4	-9.52E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	0E+00	0E+00	0E+00
3a	0E+00	0E+00	0E+00	0E+00
Therm.Iso	0E+00	0	0E+00	0
3b max	0E+00	1.2E+4	-5.52E+5	0E+00

3b max	0E+00	-2.3E+4	1.7E+5	0E+00

Stresses of gross cross section for steel details and studs (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked Max*	*Ph. 3b Cracked Max*	*Ph. 3b Uncracked Min*	*Ph. 3b Cracked Min*	*Total Uncracked Max*	*Total Cracked Max*	*Total Uncracked Min*	*Total Cracked Min*	$\Delta\sigma,\Delta\tau$
σ_8	0	-2.5	0	0	0	0	0	0	0	-2.6	0	0.8	0	-5.2	0	-1.7	0	3.4
σ_7	0	-41.4	-67.3	0	0	0	0	0	0	-13.8	-39	4.3	12	-55.2	-106.3	-37.1	-55.3	18.1
σ_6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_5	0	-1.6	0	0	0	0	0	0	0	-1.4	0	0.4	0	-2.9	0	-1.2	0	1.8
σ_4	-40.3	-28.4	-49.5	0	0	0	0	0	0	-8.2	-28.7	2.5	8.8	-77	-118.5	-66.2	-81	10.7
σ_3	-36.1	-24.5	-44.1	0	0	0	0	0	0	-6.5	-25.6	2	7.9	-67.1	-105.8	-58.6	-72.3	8.5
σ_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_1	31	37	40.3	0	0	0	0	0	0	20.1	23.4	-6.2	-7.2	88.1	94.7	61.8	64.2	26.3
σ_0	35.3	40.9	45.7	0	0	0	0	0	0	21.8	26.5	-6.7	-8.2	97.9	107.4	69.5	72.8	28.5
τ_4	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0	0	0.1
τ_3	3.1	3.9	3.9	0	0	0	0	0	0	0.7	0.7	-1.4	-1.4	7.8	7.8	5.7	5.7	2.1
τ_2	3.6	4.2	4.5	0	0	0	0	0	0	0.7	0.8	-1.4	-1.6	8.5	8.5	6.4	6.4	2.1
τ_1	3.2	3.6	4	0	0	0	0	0	0	0.6	0.7	-1.2	-1.4	7.5	7.5	5.7	5.7	1.8
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 3 max = -5.16 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 3 max = -2.95 N/mm^2
The section at the end of phase 3 max is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 min = -1.73 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 min = -1.16 N/mm^2
The section at the end of phase 3 min is considered: Uncracked (m.)

Forces and moments for steel details and studs (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	5.2E+4	-7.2E+5	0E+00
2a	0E+00	6.6E+4	-9.52E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	0E+00	0E+00	0E+00
3a	0E+00	0E+00	0E+00	0E+00
Therm.Iso	0E+00	0	0E+00	0
3b max	0E+00	1.2E+4	-5.52E+5	0E+00
3b max	0E+00	-2.3E+4	1.7E+5	0E+00

Stresses of gross cross section for steel details and studs (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked Max*	*Ph. 3b Cracked Max*	*Ph. 3b Uncracked Min*	*Ph. 3b Cracked Min*	*Total Uncracked Max*	*Total Cracked Max*	*Total Uncracked Min*	*Total Cracked Min*	$\Delta\sigma,\Delta\tau$
σ_8	0	-2.5	0	0	0	0	0	0	0	-2.6	0	0.8	0	-5.2	0	-1.7	0	3.4

σ_7	0	-41.4	-67.3	0	0	0	0	0	0	-13.8	-39	4.3	12	-55.2	-106.3	-37.1	-55.3	18.1
σ_6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_5	0	-1.6	0	0	0	0	0	0	0	-1.4	0	0.4	0	-2.9	0	-1.2	0	1.8
σ_4	-40.3	-28.4	-49.5	0	0	0	0	0	0	-8.2	-28.7	2.5	8.8	-77	-118.5	-66.2	-81	10.7
σ_3	-36.1	-24.5	-44.1	0	0	0	0	0	0	-6.5	-25.6	2	7.9	-67.1	-105.8	-58.6	-72.3	8.5
σ_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_1	31	37	40.3	0	0	0	0	0	0	20.1	23.4	-6.2	-7.2	88.1	94.7	61.8	64.2	26.3
σ_0	35.3	40.9	45.7	0	0	0	0	0	0	21.8	26.5	-6.7	-8.2	97.9	107.4	69.5	72.8	28.5
τ_4	0	0.1	0	0	0	0	0	0	0	0	0	0	0	0.1	0.1	0	0	0.1
τ_3	3.1	3.9	3.9	0	0	0	0	0	0	0.7	0.7	-1.4	-1.4	7.8	7.8	5.7	5.7	2.1
τ_2	3.6	4.2	4.5	0	0	0	0	0	0	0.7	0.8	-1.4	-1.6	8.5	8.5	6.4	6.4	2.1
τ_1	3.2	3.6	4	0	0	0	0	0	0	0.6	0.7	-1.2	-1.4	7.5	7.5	5.7	5.7	1.8
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 3 max = -5.16 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 3 max = -2.95 N/mm^2
The section at the end of phase 3 max is considered: Uncracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 min = -1.73 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 min = -1.16 N/mm^2
The section at the end of phase 3 min is considered: Uncracked (m.)

Main data for partial factors and damage equivalent facors

Partial factor for steel:	γ_{Ff}	1
	γ_{Mf}	1.35
Bending damage equivalent factor for steel:	$\lambda = \lambda_1 * \lambda_2 * \lambda_3 * \lambda_4 =$	2.32 x 0.848 x 1 x 1.15 = 2.262>2=>2 (Midspan)
Shear damage equivalent factor for steel:	$\lambda = \lambda_1 * \lambda_2 * \lambda_3 * \lambda_4 =$	2.518 x 0.848 x 1 x 1.15 = 2.455 (Midspan)
Data for calculation of λ_1	Section position:	(Midspan)
	L span for moment (m):	33
	L span for shear (m):	13.2
Data for calculation of λ_2, λ_{v2}	Q_0 (kN)	480
	N_0	500000
	N_{obs}	500000
	Q_{ml} (kN)	0
	Traffic category (Table 4.5n - EN 1991-2) :	Roads and motorways with medium flow rates of lorries
	Traffic distribution (Table 4.7 - EN 1991-2) :	Medium distance (40% Q1, 10% Q2, 30% Q3, 15% Q4, 5% Q5)
Data for calculation of λ_3, λ_{v3}	Design life (years):	100
Data for calculation of γ_{Mf} for steel:	Assessment method:	
	Consequence of failure:	
Damage equivalent factor for studs:	$\lambda_v = \lambda_{v1} * \lambda_{v2} * \lambda_{v3} * \lambda_{v4} =$	1.55 x 0.896 x 1 x 1.09 = 1.514
Partial factor for studs:	γ_{Ff}	1
	γ_{Mf}	1

Fatigue assessment of structural steel

Utilization ratio (Mmax comb.)

	$\gamma_{Ff}\Delta\sigma_{E,2}$	$\Delta\sigma_c/\gamma_{Mf}$	u.r.
Top flange	21.49	92.593	0.232
Bottom flange	56.939	92.593	0.615
Web	5.234	74.074	0.071
Top flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c = 0.889 \times 90 = 80\ N/mm^2$	21.492	59.273	0.363
Bottom flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c = 0.889 \times 112 = 99.6\ N/mm^2$	56.939	73.762	0.772
Web-top flange welding	17.081	92.593	0.184
Web-bottom flange welding	52.527	92.593	0.567
Vertical stiffeners - web welding	52.527	59.259	0.886
Vertical stiffeners - top flange welding	17.081	59.259	0.288
Vertical stiffeners - bottom flange welding	52.527	59.259	0.886
Longitudinal stiffener 1 - web welding			
Longitudinal stiffener 2 - web welding			

Utilization ratio (Mmin comb.)

	$\gamma_{Ff}\Delta\sigma_{E,2}$	$\Delta\sigma_c/\gamma_{Mf}$	u.r.
Top flange	21.49	92.593	0.232
Bottom flange	56.939	92.593	0.615
Web	5.234	74.074	0.071
Top flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c = 0.889 \times 90 = 80\ N/mm^2$	21.492	59.273	0.363
Bottom flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c = 0.889 \times 112 = 99.6\ N/mm^2$	56.939	73.762	0.772
Web-top flange welding	17.081	92.593	0.184
Web-bottom flange welding	52.527	92.593	0.567
Vertical stiffeners - web welding	52.527	59.259	0.886
Vertical stiffeners - top flange welding	17.081	59.259	0.288
Vertical stiffeners - bottom flange welding	52.527	59.259	0.886
Longitudinal stiffener 1 - web welding			
Longitudinal stiffener 2 - web welding			

Fatigue assessment of studs

Utilization ratio (Mmax comb.)

$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) <= 1$	=1*16.77/(90/1) =0.186
$\gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <= 1$	=1*21.49/(80/1.35) =0.363(*)
$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) + \gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <= 1.3$	=0.186+0.363=0.549(*)
CHECK PASSED	

(*) Not relevant check (Top flange in compression)

Utilization ratio (Mmin comb.)

$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) <= 1$	=1*16.77/(90/1) =0.186
$\gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <= 1$	=1*21.49/(80/1.35) =0.363(*)
$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) + \gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <= 1.3$	=0.186+0.363=0.549(*)
CHECK PASSED	

(*) Not relevant check (Top flange in compression)

Stiffeners checks

Torsional buckling of vertical stiffeners

	Vertical stiffeners
	CHECK PASSED
u.r.	0.898
Type	Vert. (R)
σ_{cr} (N/mm²)	--
6*f_y (N/mm²)	--
I_{cr} (mm)	--
I_w (mm⁶)	--
I_T (mm⁴)	5.333E+5
I_P (mm⁴)	5.347E+7
I_T /I_P	0.01
5.3 f_y /E	0.009
cθ (N)	--
E (N/mm²)	210000
f_y (N/mm²)	355
G (N/mm²)	87500
a (mm)	2750

Intermediate vertical stiffeners acting as rigid support for web panels

$$I_{st} = 4.84E+7\ mm^4 > I_{st\ min} = 0.75\ h_w\ t_w^{\ 3} = 4.26E+6\ mm^4$$

CHECK PASSED

With:

t_w = 20 mm b_w = 508.2 mm A_{st} = 14163.4 mm² e_1 = 31.1 mm ²
a = 2750 mm h_w = 710 mm a/hw = 3.873

Maximum stress and the additional deflection in the vertical stiffeners (Mmax comb.)

$$w = 0 < 2.4\ mm$$

$$\sigma_{max} = 0 < 322.7\ N/mm^2$$

CHECK PASSED

With:

$\Sigma N_{st,Ed} = N_{st,Ed} + \Delta N_{st,Ed}$ = 0E+00 + 9.804E+3 = 9.804E+3 N
$N_{st,Ed} = N_{st,ten} + N_{st,ex}$ = 0E+00 + 0E+00 = 0E+00 N
σ_m = 0.192 N/mm² $\sigma_{cr(C)} / \sigma_{cr(P)}$ = 9.52/1E+300 = 0=> 0.5
N_{Ed} = 3.748E+5 N $\bar{\lambda}_w$ = 0.493
$N_{cr,st}$ = 1.99E+8 N e_1 = 31.1 mm e_{max} = 178.9 mm w_0 = 2.37 mm
δ_m = 0
(I_{vstmin} = 1.525E+4(mm⁴) u = 5.395)

9.3.6 Section Sez. 4a_4a

First classification

The first classification refers to the composite section in Phase 3

Plastic characteristics of the single components

Components	*N_{pl} (N)*	*z_N (mm)*	*z_{max} (mm)*	*z_{min} (mm)*
Concrete layer above top reinforcing bars	1.489E+6	975.66	1000	951.33
Concrete layer between top and bottom reinforcing bars	4.136E+6	881.09	948.67	813.5
Concrete layer below top reinforcing bars	3.824E+5	806.25	812.5	800
Top reinforcing bars	1.247E+6	950	951.33	948.67
Bottom reinforcing bars	4.721E+5	813	813.5	812.5
Concrete haunch slab	0E+00	800	800	800
Top flange of steel beam	7.607E+6	777.5	800	755
Web of steel beam	4.801E+6	400	755	45
Bottom flange of steel beam	8.614E+6	22.5	45	0
Ultimate compression force for the full section	-2.875E+7			
Ultimate tension force for the full section	2.274E+7			
Ultimate compression force for the web less section	-2.395E+7			
Ultimate tensile force for the web less section	1.794E+7			

Flanges classification

	c/t	*ε*	*Hogging bending moment (M+)*	*Sagging bending moment (M-)*
Top flange	5.333	0.814	1	0
Bottom flange	6.444	0.838	1	1

Web classification

	c/t	*ε*	*α*	*ψ*	*class*
Hogging bending moment (M+)	35.5	0.814	0.574	-0.955	1
Sagging bending moment (M-)	35.5	0.814	0	-0.302	1
Compression (N)	35.5	0.814	1	1	4

U.L.S. composite section verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	2.16E+5	5.24E+5	0E+00
2a	0E+00	3.01E+5	6.09E+5	0E+00
2b	0E+00	6E+3	1.63E+5	0E+00
Shr.Iso	-4.03E+5	0	-1.66E+5	0
2c	0E+00	1.2E+3	1.56E+4	0E+00
3a	0E+00	7.2E+3	2.02E+5	0E+00
Therm.Iso	-7.56E+5	0	-2.34E+5	0
3b	0E+00	3.6E+5	1.28E+6	0E+00
Total	-1.16E+6	8.91E+5	2.39E+6	0E+00

Bending resistance - Plastic analysis

Section classification (Mmax comb.)

	c/t	*z_{pl} (mm)*	*α*	*ψ*	*Class*
Web	35.5	538.32	0.69	-1	1
Top flange	5.33				1
Bottom flange	6.44				1

Section class					1
Plastic analysis: APPLICABLE					

Plastic section verification (Mmax comb.)

Axial force		*Bending moment*		*N/M interaction*	
N_{Ed} (N)	-1.159E+6	M_{Ed} (Nm)	2.394E+6	N_{Ed} (N)	-1.159E+6
N_{Rd} (N)	-2.875E+7	M_{Rd} (Nm)	7.838E+6	M_{Ed} (Nm)	2.394E+6
				M_{Rd} (Nm)	7.947E+6
N_{Ed}/N_{Rd}	0.04	M_{Ed}/M_{Rd}	0.305	M_{Ed}/M_{Rd}	0.301
CHECK PASSED					

Axial force and bending moment stresses of gross cross section

Stresses of gross cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	η_1
σ_8	0	1.5	0	1.4	0	0	0	0	1.8	0	5.8	0	0	0
σ_7	0	24.3	37.4	-5.1	10	0.6	1	48.4	-7.8	12.4	30.6	78.7	139.4	0.356
σ_6	0	17.1	27.9	-5	7.5	0.4	0.7	36.1	-7.5	9.3	19	58.8	104.2	0.266
σ_5	0	0.9	0	1.4	0	0	0	0	1.9	0	3	0	0	0
σ_4	29.4	16.4	27	-5	7.2	0.4	0.7	64.3	-7.4	9	17.9	56.9	130.2	0.385
σ_3	26.3	14	23.9	-5	6.4	0.4	0.6	57.2	-7.4	7.9	14	50.4	115.5	0.342
σ_2	0	0	0	-5	0	0	0	0	-7	0	0	0	0	0
σ_1	-22.6	-23.4	-25.1	-4.8	-6.7	-0.6	-0.6	-55	-5.8	-8.3	-46.4	-52.7	-116	0.364
σ_0	-25.7	-25.7	-28.2	-4.8	-7.5	-0.7	-0.7	-62.1	-5.7	-9.3	-50.2	-59.3	-130.7	0.41

Maximum utilization ratio:0.41 NOT RELEVANT CHECK
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = 2.93 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 2.33 N/mm^2
The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 10.58 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 7.22 N/mm^2
The section at the end of phase 3 is considered: Cracked (m.)

Resistance to shear

Evaluation of necessity to Shear buckling check

$h_w/t_w = 35.5 < 31/\eta * \varepsilon_w * (K_\tau)^{0.5} = 49.768$ Shear Buckling check: NOT REQUIRED

Shear Buckling resistance: **$V_{b,Rd}$ =3.175E+6 N**

With:

$a/h_w = 3.873$, $\eta = 1.2$, $K_\tau = 5.607$
web contribution: $V_{bw,Rd} = 3.175E+6$ N, flanges contribution: $V_{bf,Rd} = 2.7E+5$ N
$\chi_w = 1.2$, $\bar{\lambda}_w = 0.493$, $\tau_{cr} = 845.3$, C=1187.9
$M_{Ed} = 2.394E+6$ Nm, $M_{f,Rd} = 6.555E+6$ Nm, $M_{Ed}/M_{f,Rd} = 0.365$

Plastic resistance: **$V_{pl,Rd}$ =3.326E+6 N**

Shear resistance: **$V_{Rd} = V_{pl,Rd}$ =3.326E+6 N**

Utilization ratios:

$\eta_3 = V_{Ed}/V_{Rd} = 0.268$, (=> CHECK VERIFIED)
$\bar{\eta}_3 = V_{Ed}/V_{bw,Rd} = 0.281$, $\bar{\eta}_1 = M_{Ed}/M_{Rd} = 0.301$

Interaction between shear force, bending moment and axial force

Evaluation of the interaction

$\eta_3 < 0.5$, $M_{Ed} / M_{f,Rd} < 1$
INTERACTION NOT TO BE CHECKED

U.L.S. composite section verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	2.16E+5	5.24E+5	0E+00
2a	0E+00	3.01E+5	6.09E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	-1.2E+3	-1.56E+4	0E+00
3a	0E+00	-7.2E+3	-2.02E+5	0E+00
Therm.Iso	7.56E+5	0	2.34E+5	0
3b	0E+00	3.4E+5	1.23E+6	0E+00
Total	7.56E+5	8.48E+5	2.38E+6	0E+00

Bending resistance - Plastic analysis

Section classification (Mmin comb.)

	c/t	*z_{pl} (mm)*	*α*	*ψ*	*Class*
Web	35.5	396.71	0.5	-1.01	1
Top flange	5.33				1
Bottom flange	6.44				1
Section class					1
Plastic analysis: APPLICABLE					

Plastic section verification (Mmin comb.)

Axial force		*Bending moment*		*N/M interaction*	
N_{Ed} (N)	7.56E+5	M_{Ed} (Nm)	2.382E+6	N_{Ed} (N)	7.56E+5
N_{Rd} (N)	2.274E+7	M_{Rd} (Nm)	7.838E+6	M_{Ed} (Nm)	2.382E+6
				M_{Rd} (Nm)	7.712E+6
N_{Ed}/N_{Rd}	0.033	M_{Ed}/M_{Rd}	0.304	M_{Ed}/M_{Rd}	0.309
CHECK PASSED					

Axial force and bending moment stresses of gross cross section

Stresses of gross cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	*η_1*
σ_8	0	1.5	0	0	0	0	0	0	-1.8	0	5.6	0	0	0
σ_7	0	24.3	37.4	0	0	-0.6	-1	36.4	7.8	-12.4	29.5	75.7	99.7	0.255
σ_6	0	17.1	27.9	0	0	-0.4	-0.7	27.2	7.5	-9.3	18.2	56.6	74.5	0.19
σ_5	0	0.9	0	0	0	0	0	0	-1.9	0	2.9	0	0	0
σ_4	29.4	16.4	27	0	0	-0.4	-0.7	55.7	7.4	-9	17.2	54.7	101.5	0.3
σ_3	26.3	14	23.9	0	0	-0.4	-0.6	49.6	7.4	-7.9	13.5	48.5	90.1	0.267
σ_2	0	0	0	0	0	0	0	0	7	0	0	0	0	0
σ_1	-22.6	-23.4	-25.1	0	0	0.6	0.6	-47	5.8	8.3	-44.6	-50.7	-89.4	0.28
σ_0	-25.7	-25.7	-28.2	0	0	0.7	0.7	-53.1	5.7	9.3	-48.3	-57	-100.8	0.316

Maximum utilization ratio:0.316 NOT RELEVANT CHECK
NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 2 = 1.46 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 0.89 N/mm^2
The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 5.21 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 1.84 N/mm^2
The section at the end of phase 3 is considered: Cracked (m.)

Resistance to shear

Evaluation of necessity to Shear buckling check

$h_w / t_w = 35.5 < 31/\eta * \varepsilon_w * (K_\tau)^{0.5} = 49.768$ Shear Buckling check: NOT REQUIRED

Shear Buckling resistance: $\mathbf{V_{b,Rd} = 3.175E+6}$ **N**

With:

$a/h_w = 3.873$, $\eta = 1.2$, $K_\tau = 5.607$
web contribution: $V_{bw,Rd} = 3.175E+6$ N, flanges contribution: $V_{bf,Rd} = 2.738E+5$ N
$\chi_w = 1.2$, $\bar{\lambda}_w = 0.493$, $\tau_{cr} = 845.3$, C=1187.9
$M_{Ed} = 2.382E+6$ Nm, $M_{f,Rd} = 6.845E+6$ Nm, $M_{Ed} / M_{f,Rd} = 0.348$

Plastic resistance: $\mathbf{V_{pl,Rd} = 3.326E+6}$ **N**

Shear resistance: $\mathbf{V_{Rd} = V_{pl,Rd} = 3.326E+6}$ **N**

Utilization ratios:

$\eta_3 = V_{Ed} / V_{Rd} = 0.255$, (=> CHECK VERIFIED)
$\bar{\eta}_3 = V_{Ed} / V_{bw,Rd} = 0.267$, $\bar{\eta}_1 = M_{Ed} / M_{Rd} = 0.309$

Interaction between shear force, bending moment and axial force

Evaluation of the interaction

$\bar{\eta}_3 < 0.5$, $M_{Ed} / M_{f,Rd} < 1$
INTERACTION NOT TO BE CHECKED

SLS stresses verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.6E+5	3.88E+5	0E+00
2a	0E+00	2.23E+5	4.51E+5	0E+00
2b	0E+00	5E+3	1.36E+5	0E+00
Shr.Iso	-3.36E+5	0	-1.38E+5	0
2c	0E+00	1E+3	1.3E+4	0E+00
3a	0E+00	4.8E+3	1.34E+5	0E+00
Therm.Iso	-5.04E+5	0	-1.56E+5	0
3b	0E+00	2.66E+5	9.47E+5	0E+00
Total	-8.4E+5	6.59E+5	1.78E+6	0E+00

Stresses of gross cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	σ_{id}	η_1
σ_8	0	1.1	0	1.2	0	0	0	0	1.2	0	4.3	0	0	0	0
σ_7	0	18	27.7	-4.2	8.4	0.5	0.8	36.8	-5.2	8.3	22.6	58.2	103.3	103.3	0.287
σ_6	0	12.6	20.7	-4.2	6.2	0.4	0.6	27.5	-5	6.2	14	43.5	77.2	77.2	0.214
σ_5	0	0.7	0	1.2	0	0	0	0	1.3	0	2.2	0	0	0	0
σ_4	21.7	12.1	20	-4.2	6	0.3	0.6	48.4	-5	6	13.2	42.1	96.4	96.4	0.272

σ_3	19.5	10.4	17.7	-4.2	5.3	0.3	0.5	43	-4.9	5.3	10.4	37.2	85.6	109.4	0.308
σ_2	0	0	0	-4.1	0	0	0	0	-4.7	0	0	0	0	76.7	0.216
σ_1	-16.7	-17.3	-18.6	-4	-5.6	-0.5	-0.5	-41.4	-3.9	-5.5	-34.3	-39	-85.9	109.7	0.328
σ_0	-19	-19.1	-20.9	-4	-6.3	-0.5	-0.6	-46.8	-3.8	-6.2	-37.1	-43.8	-96.8	96.8	0.289
τ_4	0	0.3	0.1	0	0	0	0	0.1	0	0	0.5	0.1	0.3		
τ_3	9.6	13.3	13.3	0.3	0.3	0.1	0.1	23.2	0.3	0.3	15.9	15.8	39.3		
τ_2	11.1	14	14.8	0.3	0.3	0.1	0.1	26.3	0.3	0.3	16.1	17.7	44.3		
τ_1	10	12.1	13.2	0.3	0.3	0.1	0.1	23.5	0.2	0.3	13.5	15.7	39.4		
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Maximum utilization ratio:0.328 CHECK PASSED

NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 2 = 2.3 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 1.86 N/mm^2
   The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 7.83 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 5.33 N/mm^2
   The section at the end of phase 3 is considered: Cracked (m.)

SLS stresses verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.6E+5	3.88E+5	0E+00
2a	0E+00	2.23E+5	4.51E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	-1E+3	-1.3E+4	0E+00
3a	0E+00	-4.8E+3	-1.34E+5	0E+00
Therm.Iso	5.04E+5	0	1.56E+5	0
3b	0E+00	2.52E+5	9.15E+5	0E+00
Total	5.04E+5	6.3E+5	1.76E+6	0E+00

Stresses of gross cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	σ_{id}	η_1
σ_8	0	1.1	0	0	0	0	0	0	-1.2	0	4.2	0	0	0	0
σ_7	0	18	27.7	0	0	-0.5	-0.8	26.9	5.2	-8.3	21.9	56.2	74.8	74.8	0.208
σ_6	0	12.6	20.7	0	0	-0.4	-0.6	20.1	5	-6.2	13.5	42	55.9	55.9	0.155
σ_5	0	0.7	0	0	0	0	0	0	-1.3	0	2.1	0	0	0	0
σ_4	21.7	12.1	20	0	0	-0.3	-0.6	41.2	5	-6	12.8	40.6	75.9	75.9	0.214
σ_3	19.5	10.4	17.7	0	0	-0.3	-0.5	36.7	4.9	-5.3	10	36	67.4	93.6	0.264
σ_2	0	0	0	0	0	0	0	0	4.7	0	0	0	0	73.3	0.206
σ_1	-16.7	-17.3	-18.6	0	0	0.5	0.5	-34.8	3.9	5.5	-33.1	-37.6	-66.9	93.4	0.279
σ_0	-19	-19.1	-20.9	0	0	0.5	0.6	-39.3	3.8	6.2	-35.9	-42.3	-75.4	75.4	0.225
τ_4	0	0.3	0.1	0	0	0	0	0.1	0	0	0.5	0.1	0.2		
τ_3	9.6	13.3	13.3	0	0	-0.1	-0.1	22.8	-0.3	-0.3	15.1	15.1	37.6		
τ_2	11.1	14	14.8	0	0	-0.1	-0.1	25.8	-0.3	-0.3	15.3	16.8	42.3		
τ_1	10	12.1	13.2	0	0	-0.1	-0.1	23	-0.2	-0.3	12.8	14.9	37.7		
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Maximum utilization ratio:0.279 CHECK PASSED

NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 2 = 1.08 N/mm^2

2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 0.66 N/mm²
   The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 4 N/mm²
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 1.51 N/mm²
   The section at the end of phase 3 is considered: Cracked (m.)

<u>SLS web breathing verification (Mmax comb.)</u>

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.6E+5	3.88E+5	0E+00
2a	0E+00	2.23E+5	4.51E+5	0E+00
2b	0E+00	5E+3	1.36E+5	0E+00
Shr.Iso	-3.36E+5	0	-1.38E+5	0
2c	0E+00	1E+3	1.3E+4	0E+00
3a	0E+00	4E+3	1.12E+5	0E+00
Therm.Iso	-4.2E+5	0	-1.3E+5	0
3b	0E+00	1.94E+5	6.98E+5	0E+00
Total	-7.56E+5	5.87E+5	1.53E+6	0E+00

Stresses of effective cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*
σ_8	0	1.1	0	1.2	0	0	0	0	1	0	3.2	0	0
σ_7	0	18	27.7	-4.2	8.4	0.5	0.8	36.8	-4.3	6.9	16.7	42.9	86.6
σ_6	0	12.6	20.7	-4.2	6.2	0.4	0.6	27.5	-4.2	5.1	10.3	32	64.7
σ_5	0	0.7	0	1.2	0	0	0	0	1.1	0	1.6	0	0
σ_4	21.7	12.1	20	-4.2	6	0.3	0.6	48.4	-4.1	5	9.7	31	84.4
σ_3	19.5	10.4	17.7	-4.2	5.3	0.3	0.5	43	-4.1	4.4	7.6	27.5	74.9
σ_2	0	0	0	-4.1	0	0	0	0	-3.9	0	0	0	0
σ_1	-16.7	-17.3	-18.6	-4	-5.6	-0.5	-0.5	-41.4	-3.2	-4.6	-25.3	-28.7	-74.8
σ_0	-19	-19.1	-20.9	-4	-6.3	-0.5	-0.6	-46.8	-3.2	-5.2	-27.4	-32.3	-84.2

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = 2.3 N/mm²
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 1.86 N/mm²
   The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 6.49 N/mm²
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 4.54 N/mm²
   The section at the end of phase 3 is considered: Cracked (m.)

Web assessment (Mmax comb.)

	Web
b (mm)	710
σ_{sup} (N/mm²)	74.89
σ_{inf} (N/mm²)	-74.76
σ_{Ed} (N/mm²)	74.76
K_σ	23.96
σ_{cr0E} (N/mm²)	150.76
τ_{Ed} (N/mm²)	36.56
σ_{cr} (P) (N/mm²)	3612.49
σ_{cr} (C) (N/mm²)	9.52
ξ	1
σ_{cr} (N/mm²)	3612.49

K_τ	5.61
$K_{\tau\ sl}$	0
Utilization ratio	0.052
Result	CHECK VERIFIED

SLS web breathing verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.6E+5	3.88E+5	0E+00
2a	0E+00	2.23E+5	4.51E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	-1E+3	-1.3E+4	0E+00
3a	0E+00	-4E+3	-1.12E+5	0E+00
Therm.Iso	4.2E+5	0	1.3E+5	0
3b	0E+00	1.94E+5	6.98E+5	0E+00
Total	4.2E+5	5.72E+5	1.54E+6	0E+00

Stresses of effective cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*
σ_8	0	1.1	0	0	0	0	0	0	-1	0	3.2	0	0
σ_7	0	18	27.7	0	0	-0.5	-0.8	26.9	4.3	-6.9	16.7	42.9	62.9
σ_6	0	12.6	20.7	0	0	-0.4	-0.6	20.1	4.2	-5.1	10.3	32	47
σ_5	0	0.7	0	0	0	0	0	0	-1.1	0	1.6	0	0
σ_4	21.7	12.1	20	0	0	-0.3	-0.6	41.2	4.1	-5	9.7	31	67.2
σ_3	19.5	10.4	17.7	0	0	-0.3	-0.5	36.7	4.1	-4.4	7.6	27.5	59.7
σ_2	0	0	0	0	0	0	0	0	3.9	0	0	0	0
σ_1	-16.7	-17.3	-18.6	0	0	0.5	0.5	-34.8	3.2	4.6	-25.3	-28.7	-58.9
σ_0	-19	-19.1	-20.9	0	0	0.5	0.6	-39.3	3.2	5.2	-27.4	-32.3	-66.4

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = 1.08 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 0.66 N/mm^2
   The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 3.22 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 1.22 N/mm^2
   The section at the end of phase 3 is considered: Cracked (m.)

Web assessment (Mmin comb.)

	Web
b (mm)	710
σ_{sup} (N/mm^2)	59.72
σ_{inf} (N/mm^2)	-58.88
σ_{Ed} (N/mm^2)	58.88
K_σ	24.26
σ_{cr0E} (N/mm^2)	150.76
τ_{Ed} (N/mm^2)	35.63
σ_{cr} (P) (N/mm^2)	3657.75
σ_{cr} (C) (N/mm^2)	9.52
ξ	1
σ_{cr} (N/mm^2)	3657.75

K_{τ}	5.61
$K_{\tau\ sl}$	0
Utilization ratio	0.049
Result	CHECK VERIFIED

Shear connectors assessment

Main data

Number of studs for unit length, n (m^{-1})	10
Stud diameter, d (mm)	19
Stud height, h (mm)	150
Ultimate resistance of studs α	1
Partial safety factor, γ_v	1.25
Ultimate resistance of studs f_u (N/mm^2)	450
Coefficient E_{cm} (N/mm^2)	36283
Characteristic cylinder compressive strength, f_{ck} (N/mm^2)	45

Resistance of headed stud connectors

Shank shear resistance, $P_{Rd1} = 0.8\ f_u\ \pi\ d^2/4/\gamma_v$, (N)	81656.28
Concrete crushing resistance, $P_{Rd2} = 0.29\ \alpha\ d^2\ (f_{ck}\ E_{cm})^{0.5}/\gamma_v$, (N)	107017.34
Design stud resistance $P_{Rd} = Min(P_{Rd1}, P_{Rd2})$, (N)	81656.28

Elastic assessment at ULS

Utilization ratio (Mmax comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\ P_{Rd}\ \kappa_s$ (N/mm)	816.6
Reduction factor, κ_s	1.00
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	532.2
Utilization ratio ν_{Ed}/ν_{Rd}	0.652
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmax comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	3.01E+5	7.346E+6	1.157E+10	191.2
Phase 2b	6E+3	7.346E+6	1.157E+10	3.8
Phase 2c	1.2E+3	7.346E+6	1.157E+10	0.8
Phase 3a	7.2E+3	1.381E+7	1.505E+10	6.6
Phase 3b	3.596E+5	1.381E+7	1.505E+10	329.8
			Sum	532.2

Utilization ratio (Mmin comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\ P_{Rd}\ \kappa_s$ (N/mm)	816.6
Reduction factor, κ_s	1.00
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	495.5
Utilization ratio ν_{Ed}/ν_{Rd}	0.607
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmin comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	3.01E+5	7.346E+6	1.157E+10	191.2
Phase 2b	0E+00	7.346E+6	1.157E+10	0
Phase 2c	-1.2E+3	7.346E+6	1.157E+10	-0.8
Phase 3a	-7.2E+3	1.381E+7	1.505E+10	-6.6
Phase 3b	3.398E+5	1.381E+7	1.505E+10	311.7
			Sum	495.5

Elastic assessment at ELS

Utilization ratio (Mmax comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\, P_{Rd}\, \kappa_s$ (N/mm)	489.9
Reduction factor, κ_s	0.6
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	393.5
Utilization ratio ν_{Ed}/ν_{Rd}	0.803
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmax comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	2.23E+5	7.346E+6	1.157E+10	141.6
Phase 2b	5E+3	7.346E+6	1.157E+10	3.2
Phase 2c	1E+3	7.346E+6	1.157E+10	0.6
Phase 3a	4.8E+3	1.381E+7	1.505E+10	4.4
Phase 3b	2.656E+5	1.381E+7	1.505E+10	243.6
			Sum	393.5

Utilization ratio (Mmin comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\, P_{Rd}\, \kappa_s$ (N/mm)	489.9
Reduction factor, κ_s	0.6
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	368.1
Utilization ratio ν_{Ed}/ν_{Rd}	0.751
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmin comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	2.23E+5	7.346E+6	1.157E+10	141.6
Phase 2b	0E+00	7.346E+6	1.157E+10	0
Phase 2c	-1E+3	7.346E+6	1.157E+10	-0.6
Phase 3a	-4.8E+3	1.381E+7	1.505E+10	-4.4
Phase 3b	2.524E+5	1.381E+7	1.505E+10	231.5
			Sum	368.1

Assesment of studs at deck ends - shrinkage and thermal influence - (ULS)

Check of minimum studs number

Characteristic shrinkage shear per unit length, $\nu_{L,k}$ (N/mm)	280
Characteristic thermal shear per unit length (-), $\nu_{L,k}$ (N/mm)	700
Total design shear per unit length, $\nu_{L,Ed}$ (N/mm)	1*280 + 1.2*700 = 1120
Minimum number of studs at deck ends, n min (m^{-1})	13.7 > 10
CHECK NOT VERIFIED	

Fatigue limit state verification

Forces and moments for steel details and studs (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.6E+5	3.88E+5	0E+00
2a	0E+00	2.23E+5	4.51E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	0E+00	0E+00	0E+00
3a	0E+00	0E+00	0E+00	0E+00
Therm.Iso	0E+00	0	0E+00	0
3b max	0E+00	1.3E+4	-2E+5	0E+00

3b max	0E+00	-7.7E+4	2.78E+5	0E+00

Stresses of gross cross section for steel details and studs (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked Max*	*Ph. 3b Cracked Max*	*Ph. 3b Uncracked Min*	*Ph. 3b Cracked Min*	*Total Uncracked Max*	*Total Cracked Max*	*Total Uncracked Min*	*Total Cracked Min*	$\Delta\sigma,\Delta\tau$
σ_8	0	1.1	0	0	0	0	0	0	0	-0.9	0	1.3	0	0.2	0	2.4	0	0
σ_7	0	18	27.7	0	0	0	0	0	0	-4.8	-12.3	6.6	17.1	13.2	15.4	24.6	44.8	51.3
σ_6	0	12.6	20.7	0	0	0	0	0	0	-3	-9.2	4.1	12.8	9.7	11.5	16.8	33.5	21.9
σ_5	0	0.7	0	0	0	0	0	0	0	-0.5	0	0.6	0	0.2	0	1.3	0	0
σ_4	21.7	12.1	20	0	0	0	0	0	0	-2.8	-8.9	3.9	12.3	31.1	32.9	37.8	54.1	21.2
σ_3	19.5	10.4	17.7	0	0	0	0	0	0	-2.2	-7.9	3	10.9	27.6	29.3	32.9	48.1	18.8
σ_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_1	-16.7	-17.3	-18.6	0	0	0	0	0	0	7.2	8.2	-10.1	-11.4	-26.8	-27.1	-44.1	-46.7	19.7
σ_0	-19	-19.1	-20.9	0	0	0	0	0	0	7.8	9.2	-10.9	-12.9	-30.2	-30.6	-49	-52.7	22.1
τ_4	0	0.3	0.1	0	0	0	0	0	0	0	0	-0.1	0	0.3	0.3	0.1	0.1	0.2
τ_3	9.6	13.3	13.3	0	0	0	0	0	0	0.8	0.8	-4.6	-4.6	23.7	23.7	18.3	18.3	5.4
τ_2	11.1	14	14.8	0	0	0	0	0	0	0.8	0.9	-4.7	-5.1	25.9	25.9	20.4	20.4	5.5
τ_1	10	12.1	13.2	0	0	0	0	0	0	0.7	0.8	-3.9	-4.5	22.7	22.7	18.2	18.2	4.6
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 3 max = 0.2 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 3 max = 0.21 N/mm^2
The section at the end of phase 3 max is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 min = 2.37 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 min = 1.32 N/mm^2
The section at the end of phase 3 min is considered: Cracked (m.)

Forces and moments for steel details and studs (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.6E+5	3.88E+5	0E+00
2a	0E+00	2.23E+5	4.51E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	0E+00	0E+00	0E+00
3a	0E+00	0E+00	0E+00	0E+00
Therm.Iso	0E+00	0	0E+00	0
3b max	0E+00	1.3E+4	-2E+5	0E+00
3b max	0E+00	-7.7E+4	2.78E+5	0E+00

Stresses of gross cross section for steel details and studs (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked Max*	*Ph. 3b Cracked Max*	*Ph. 3b Uncracked Min*	*Ph. 3b Cracked Min*	*Total Uncracked Max*	*Total Cracked Max*	*Total Uncracked Min*	*Total Cracked Min*	$\Delta\sigma,\Delta\tau$
σ_8	0	1.1	0	0	0	0	0	0	0	-0.9	0	1.3	0	0.2	0	2.4	0	0
σ_7	0	18	27.7	0	0	0	0	0	0	-4.8	-12.3	6.6	17.1	13.2	15.4	24.6	44.8	51.3
σ_6	0	12.6	20.7	0	0	0	0	0	0	-3	-9.2	4.1	12.8	9.7	11.5	16.8	33.5	21.9
σ_5	0	0.7	0	0	0	0	0	0	0	-0.5	0	0.6	0	0.2	0	1.3	0	0

σ_4	21.7	12.1	20	0	0	0	0	0	0	-2.8	-8.9	3.9	12.3	31.1	32.9	37.8	54.1	21.2
σ_3	19.5	10.4	17.7	0	0	0	0	0	0	-2.2	-7.9	3	10.9	27.6	29.3	32.9	48.1	18.8
σ_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_1	-16.7	-17.3	-18.6	0	0	0	0	0	0	7.2	8.2	-10.1	-11.4	-26.8	-27.1	-44.1	-46.7	19.7
σ_0	-19	-19.1	-20.9	0	0	0	0	0	0	7.8	9.2	-10.9	-12.9	-30.2	-30.6	-49	-52.7	22.1
τ_4	0	0.3	0.1	0	0	0	0	0	0	0	0	-0.1	0	0.3	0.3	0.1	0.1	0.2
τ_3	9.6	13.3	13.3	0	0	0	0	0	0	0.8	0.8	-4.6	-4.6	23.7	23.7	18.3	18.3	5.4
τ_2	11.1	14	14.8	0	0	0	0	0	0	0.8	0.9	-4.7	-5.1	25.9	25.9	20.4	20.4	5.5
τ_1	10	12.1	13.2	0	0	0	0	0	0	0.7	0.8	-3.9	-4.5	22.7	22.7	18.2	18.2	4.6
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 3 max = 0.2 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 3 max = 0.21 N/mm^2
The section at the end of phase 3 max is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 min = 2.37 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 min = 1.32 N/mm^2
The section at the end of phase 3 min is considered: Cracked (m.)

Main data for partial factors and damage equivalent facors

Partial factor for steel:	γ_{Ff}	1
	γ_{Mf}	1.35
Bending damage equivalent factor for steel:	$\lambda = \lambda_1 * \lambda_2 * \lambda_3 * \lambda_4 =$	2.32 x 0.848 x 1 x 1.15 = 2.262>1.854=>1.854 (Support)
Shear damage equivalent factor for steel:	$\lambda = \lambda_1 * \lambda_2 * \lambda_3 * \lambda_4 =$	2.518 x 0.848 x 1 x 1.15 = 2.455 (Support)
Data for calculation of λ_1	Section position:	(Support)
	L span for moment (m):	33
	L span for shear (m):	33
Data for calculation of λ_2, λ_{v2}	Q_0 (kN)	480
	N_0	500000
	N_{obs}	500000
	Q_{ml} (kN)	0
	Traffic category (Table 4.5n - EN 1991-2) :	Roads and motorways with medium flow rates of lorries
	Traffic distribution (Table 4.7 - EN 1991-2) :	Medium distance (40% Q1, 10% Q2, 30% Q3, 15% Q4, 5% Q5)
Data for calculation of λ_3, λ_{v3}	Design life (years):	100
Data for calculation of γ_{Mf} for steel:	Assessment method:	
	Consequence of failure:	
Damage equivalent factor for studs:	$\lambda_v = \lambda_{v1} * \lambda_{v2} * \lambda_{v3} * \lambda_{v4} =$	1.55 x 0.896 x 1 x 1.09 = 1.514
Partial factor for studs:	γ_{Ff}	1
	γ_{Mf}	1

Fatigue assessment of structural steel

Utilization ratio (Mmax comb.)

	$\gamma_{Ff} \Delta\sigma_{E,2}$	$\Delta\sigma_c / \gamma_{Mf}$	u.r.
Top flange	39.36	92.593	0.425
Bottom flange	40.987	92.593	0.443
Web	13.429	74.074	0.181

Top flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c = 0.889 \times 90 = 80\ N/mm^2$	39.36	59.273	0.664
Bottom flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c = 0.889 \times 90 = 80\ N/mm^2$	40.987	59.273	0.691
Web-top flange welding	34.84	92.593	0.376
Web-bottom flange welding	36.467	92.593	0.394
Vertical stiffeners - web welding	36.467	59.259	0.615
Vertical stiffeners - top flange welding	34.84	59.259	0.588
Vertical stiffeners - bottom flange welding	36.467	59.259	0.615
Longitudinal stiffener 1 - web welding			
Longitudinal stiffener 2 - web welding			

Utilization ratio (Mmin comb.)

	$\gamma_{Ff}\Delta\sigma_{E,2}$	$\Delta\sigma_c/\gamma_{Mf}$	u.r.
Top flange	39.36	92.593	0.425
Bottom flange	40.987	92.593	0.443
Web	13.429	74.074	0.181
Top flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c = 0.889 \times 90 = 80\ N/mm^2$	39.36	59.273	0.664
Bottom flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c = 0.889 \times 90 = 80\ N/mm^2$	40.987	59.273	0.691
Web-top flange welding	34.84	92.593	0.376
Web-bottom flange welding	36.467	92.593	0.394
Vertical stiffeners - web welding	36.467	59.259	0.615
Vertical stiffeners - top flange welding	34.84	59.259	0.588
Vertical stiffeners - bottom flange welding	36.467	59.259	0.615
Longitudinal stiffener 1 - web welding			
Longitudinal stiffener 2 - web welding			

Fatigue assessment of studs

Utilization ratio (Mmax comb.)

$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) <= 1$	=1*44.08/(90/1) =0.49
$\gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <= 1$	=1*39.36/(80/1.35) =0.664
$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) + \gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <= 1.3$	=0.49+0.664=1.154
CHECK PASSED	

Utilization ratio (Mmin comb.)

$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) <= 1$	=1*44.08/(90/1) =0.49
$\gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <= 1$	=1*39.36/(80/1.35) =0.664
$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) + \gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <= 1.3$	=0.49+0.664=1.154
CHECK PASSED	

Stiffeners checks

Torsional buckling of vertical stiffeners

	Vertical stiffeners
	CHECK PASSED
u.r.	0.898
Type	Vert. (R)
σ_{cr} (N/mm^2)	--
$6*f_y$ (N/mm^2)	--
l_{cr} (mm)	--

I_w (mm^6)	--
I_T (mm^4)	5.333E+5
I_P (mm^4)	5.347E+7
I_T / I_P	0.01
5.3 f_y /E	0.009
$c\theta$ (N)	--
E (N/mm^2)	210000
f_y (N/mm^2)	355
G (N/mm^2)	87500
a (mm)	2750

Intermediate vertical stiffeners acting as rigid support for web panels

I_{st} = 4.84E+7 mm^4 > $I_{st\ min}$ = 0.75 $h_w t_w^{\ 3}$ =4.26E+6 mm^4

CHECK PASSED

With:

t_w = 20 mm b_w = 508.2 mm A_{st} = 14163.4 mm^2 e_1 = 31.1 mm ^{2}
a = 2750 mm h_w = 710 mm a/hw = 3.873

Maximum stress and the additional deflection in the vertical stiffeners (Mmax comb.)

w = 0 < 2.4 mm

σ_{max} = 0 < 322.7 N/mm^2

CHECK PASSED

With:

$\Sigma N_{st,Ed} = N_{st,Ed} + \Delta N_{st,Ed}$ = 0E+00 + 1.08E+4 = 1.08E+4 N
$N_{st,Ed} = N_{st,ten} + N_{st,ex}$ = 0E+00 + 0E+00 = 0E+00 N
σ_m = 0.211 N/mm^2 $\sigma_{cr(C)} / \sigma_{cr(P)}$ = 9.52/1E+300 = 0=> 0.5
N_{Ed} = 4.127E+5 N λ_w = 0.493
$N_{cr,st}$ = 1.99E+8 N e_1 = 31.1 mm e_{max} = 178.9 mm w_0 = 2.37 mm
δ_m = 0
(I_{vstmin} = 1.679E+4(mm^4) u = 5.395)

9.3.7 Section Sez. 4b_4b

First classification

The first classification refers to the composite section in Phase 3

Plastic characteristics of the single components

Components	*N pl (N)*	*z N (mm)*	*z max (mm)*	*z min (mm)*
Concrete layer above top reinforcing bars	1.489E+6	975.66	1000	951.33
Concrete layer between top and bottom reinforcing bars	4.136E+6	881.09	948.67	813.5
Concrete layer below top reinforcing bars	3.824E+5	806.25	812.5	800
Top reinforcing bars	1.247E+6	950	951.33	948.67
Bottom reinforcing bars	4.721E+5	813	813.5	812.5
Concrete haunch slab	0E+00	800	800	800
Top flange of steel beam	9.298E+6	772.5	800	745
Web of steel beam	5.132E+6	400	745	55
Bottom flange of steel beam	1.053E+7	27.5	55	0
Ultimate compression force for the full section	-3.269E+7			
Ultimate tension force for the full section	2.668E+7			
Ultimate compression force for the web less section	-2.755E+7			
Ultimate tensile force for the web less section	2.154E+7			

Flanges classification

	c/t	*ε*	*Hogging bending moment (M+)*	*Sagging bending moment (M-)*
Top flange	4.345	0.814	1	0
Bottom flange	5.255	0.838	1	1

Web classification

	c/t	*ε*	*α*	*ψ*	*class*
Hogging bending moment (M+)	31.364	0.814	0.548	-0.986	1
Sagging bending moment (M-)	31.364	0.814	0	-0.344	1
Compression (N)	31.364	0.814	1	1	3

U.L.S. composite section verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	2.16E+5	5.24E+5	0E+00
2a	0E+00	3.01E+5	6.09E+5	0E+00
2b	0E+00	6E+3	1.63E+5	0E+00
Shr.Iso	-4.03E+5	0	-1.72E+5	0
2c	0E+00	1.2E+3	1.56E+4	0E+00
3a	0E+00	7.2E+3	2.02E+5	0E+00
Therm.Iso	-7.56E+5	0	-2.51E+5	0
3b	0E+00	3.6E+5	1.28E+6	0E+00
Total	-1.16E+6	8.91E+5	2.37E+6	0E+00

Bending resistance - Plastic analysis

Section classification (Mmax comb.)

	c/t	*z pl (mm)*	*α*	*ψ*	*Class*
Web	31.36	510.7	0.66	-1.02	1
Top flange	4.35				1
Bottom flange	5.25				1
Section class					1

Plastic analysis: APPLICABLE

Plastic section verification (Mmax comb.)

Axial force		*Bending moment*		*N/M interaction*	
N_{Ed} (N)	-1.159E+6	M_{Ed} (Nm)	2.371E+6	N_{Ed} (N)	-1.159E+6
N_{Rd} (N)	-3.269E+7	M_{Rd} (Nm)	9.143E+6	M_{Ed} (Nm)	2.371E+6
				M_{Rd} (Nm)	9.255E+6
N_{Ed}/N_{Rd}	0.035	M_{Ed}/M_{Rd}	0.259	M_{Ed}/M_{Rd}	0.256
CHECK PASSED					

Axial force and bending moment stresses of gross cross section

Stresses of gross cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	η_1
σ_8	0	1.4	0	1.4	0	0	0	0	1.9	0	5.4	0	0	0
σ_7	0	22.2	32.7	-4.6	8.8	0.6	0.8	42.4	-7.4	10.8	28.9	68.9	122.1	0.312
σ_6	0	15.8	24.5	-4.5	6.6	0.4	0.6	31.8	-7	8.1	18.5	51.7	91.5	0.234
σ_5	0	0.8	0	1.4	0	0	0	0	2	0	2.9	0	0	0
σ_4	25	15.2	23.8	-4.5	6.4	0.4	0.6	55.7	-7	7.9	17.6	50	113.6	0.336
σ_3	21.8	12.7	20.5	-4.5	5.5	0.3	0.5	48.3	-6.8	6.8	13.4	43.1	98.1	0.29
σ_2	0	0	0	-4.3	0	0	0	0	-6.3	0	0	0	0	0
σ_1	-18.6	-19.5	-20.8	-4	-5.6	-0.5	-0.5	-45.5	-4.8	-6.9	-38.9	-43.7	-96.1	0.301
σ_0	-21.8	-22.1	-24.1	-4	-6.5	-0.6	-0.6	-52.9	-4.6	-8	-43	-50.7	-111.6	0.35

Maximum utilization ratio:0.35 NOT RELEVANT CHECK
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = 2.82 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 2.3 N/mm^2
The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 10.16 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 7.21 N/mm^2
The section at the end of phase 3 is considered: Cracked (m.)

Resistance to shear

Evaluation of necessity to Shear buckling check
$h_w/t_w = 31.364 \quad < \quad 31/\eta * \varepsilon_w * (K_\tau)^{0.5} = 49.702$ Shear Buckling check: NOT REQUIRED

Shear Buckling resistance: **$V_{b,Rd}$ =3.394E+6 N**

With:
$a/h_w = 3.986$, $\eta = 1.2$, $K_\tau = 5.592$
web contribution: $V_{bw,Rd}$ =3.394E+6 N, flanges contribution: $V_{bf,Rd}$ =3.574E+5 N
$\chi_w = 1.2$, $\bar{\lambda}_w = 0.436$, $\tau_{cr} = 1080.1$, C=1407
M_{Ed} =2.371E+6 Nm, $M_{f,Rd}$ =7.889E+6 Nm, $M_{Ed}/M_{f,Rd} = 0.301$

Plastic resistance: **$V_{pl,Rd}$ =3.556E+6 N**

Shear resistance: **$V_{Rd} = V_{pl,Rd}$ =3.556E+6 N**

Utilization ratios:
$\eta_3 = V_{Ed}/V_{Rd} = 0.251$, (=> CHECK VERIFIED)
$\bar{\eta}_3 = V_{Ed}/V_{bw,Rd} = 0.263$, $\bar{\eta}_1 = M_{Ed}/M_{Rd} = 0.256$

Interaction between shear force, bending moment and axial force

Evaluation of the interaction

$\eta_3 < 0.5$, $M_{Ed} / M_{f,Rd} < 1$

INTERACTION NOT TO BE CHECKED

U.L.S. composite section verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	2.16E+5	5.24E+5	0E+00
2a	0E+00	3.01E+5	6.09E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	-1.2E+3	-1.56E+4	0E+00
3a	0E+00	-7.2E+3	-2.02E+5	0E+00
Therm.Iso	7.56E+5	0	2.51E+5	0
3b	0E+00	3.4E+5	1.23E+6	0E+00
Total	7.56E+5	8.48E+5	2.4E+6	0E+00

Bending resistance - Plastic analysis

Section classification (Mmin comb.)

	c/t	*z_{pl} (mm)*	*α*	*ψ*	*Class*
Web	31.36	381.96	0.47	-1.03	1
Top flange	4.35				1
Bottom flange	5.25				1
Section class					1
Plastic analysis: APPLICABLE					

Plastic section verification (Mmin comb.)

Axial force		*Bending moment*		*N/M interaction*	
N_{Ed} (N)	7.56E+5	M_{Ed} (Nm)	2.399E+6	N_{Ed} (N)	7.56E+5
N_{Rd} (N)	2.668E+7	M_{Rd} (Nm)	9.143E+6	M_{Ed} (Nm)	2.399E+6
				M_{Rd} (Nm)	9.022E+6
N_{Ed}/N_{Rd}	0.028	M_{Ed}/M_{Rd}	0.262	M_{Ed}/M_{Rd}	0.266
CHECK PASSED					

Axial force and bending moment stresses of gross cross section

Stresses of gross cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	*η_1*
σ_8	0	1.4	0	0	0	0	0	0	-1.9	0	5.2	0	0	0
σ_7	0	22.2	32.7	0	0	-0.6	-0.8	31.9	7.4	-10.8	27.8	66.3	87.3	0.223
σ_6	0	15.8	24.5	0	0	-0.4	-0.6	23.9	7	-8.1	17.8	49.7	65.5	0.167
σ_5	0	0.8	0	0	0	0	0	0	-2	0	2.8	0	0	0
σ_4	25	15.2	23.8	0	0	-0.4	-0.6	48.1	7	-7.9	16.9	48.1	88.4	0.261
σ_3	21.8	12.7	20.5	0	0	-0.3	-0.5	41.7	6.8	-6.8	12.9	41.5	76.4	0.226
σ_2	0	0	0	0	0	0	0	0	6.3	0	0	0	0	0
σ_1	-18.6	-19.5	-20.8	0	0	0.5	0.5	-38.8	4.8	6.9	-37.4	-42.1	-74	0.232
σ_0	-21.8	-22.1	-24.1	0	0	0.6	0.6	-45.3	4.6	8	-41.4	-48.7	-86	0.27

Maximum utilization ratio:0.27 NOT RELEVANT CHECK

NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 2 = 1.33 N/mm^2

2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 0.82 N/mm^2
The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 4.68 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 1.65 N/mm^2
The section at the end of phase 3 is considered: Cracked (m.)

Resistance to shear

Evaluation of necessity to Shear buckling check

$h_w / t_w = 31.364 < 31/\eta * \varepsilon_w * (K_\tau)^{0.5} = 49.702$ Shear Buckling check: NOT REQUIRED

Shear Buckling resistance: $\mathbf{V_{b,Rd} = 3.394E+6}$ **N**

With:

$a/h_w = 3.986$, $\eta = 1.2$, $K_\tau = 5.592$
web contribution: $V_{bw,Rd} = 3.394E+6$ N, flanges contribution: $V_{bf,Rd} = 3.579E+5$ N
$\chi_w = 1.2$, $\bar{\lambda}_w = 0.436$, $\tau_{cr} = 1080.1$, C=1407
$M_{Ed} = 2.399E+6$ Nm, $M_{f,Rd} = 8.046E+6$ Nm, $M_{Ed} / M_{f,Rd} = 0.298$

Plastic resistance: $\mathbf{V_{pl,Rd} = 3.556E+6}$ **N**

Shear resistance: $\mathbf{V_{Rd} = V_{pl,Rd} = 3.556E+6}$ **N**

Utilization ratios:

$\eta_3 = V_{Ed} / V_{Rd} = 0.239$, (=> CHECK VERIFIED)
$\bar{\eta}_3 = V_{Ed} / V_{bw,Rd} = 0.25$, $\bar{\eta}_1 = M_{Ed} / M_{Rd} = 0.266$

Interaction between shear force, bending moment and axial force

Evaluation of the interaction

$\bar{\eta}_3 < 0.5$, $M_{Ed} / M_{f,Rd} < 1$
INTERACTION NOT TO BE CHECKED

SLS stresses verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.6E+5	3.88E+5	0E+00
2a	0E+00	2.23E+5	4.51E+5	0E+00
2b	0E+00	5E+3	1.36E+5	0E+00
Shr.Iso	-3.36E+5	0	-1.43E+5	0
2c	0E+00	1E+3	1.3E+4	0E+00
3a	0E+00	4.8E+3	1.34E+5	0E+00
Therm.Iso	-5.04E+5	0	-1.67E+5	0
3b	0E+00	2.66E+5	9.47E+5	0E+00
Total	-8.4E+5	6.59E+5	1.76E+6	0E+00

Stresses of gross cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	σ_{id}	η_1
σ_8	0	1	0	1.2	0	0	0	0	1.3	0	4	0	0	0	0
σ_7	0	16.5	24.3	-3.9	7.3	0.5	0.7	32.3	-4.9	7.2	21.4	50.9	90.4	90.4	0.251
σ_6	0	11.7	18.2	-3.8	5.5	0.3	0.5	24.2	-4.7	5.4	13.7	38.2	67.8	67.8	0.188
σ_5	0	0.6	0	1.2	0	0	0	0	1.3	0	2.2	0	0	0	0
σ_4	18.5	11.3	17.6	-3.8	5.3	0.3	0.5	41.9	-4.6	5.2	13	37	84.2	84.2	0.237
σ_3	16.1	9.4	15.2	-3.7	4.6	0.3	0.4	36.3	-4.5	4.5	9.9	31.9	72.7	96.4	0.272

σ 2	0	0	0	-3.6	0	0	0	0	-4.2	0	0	0	0	70.5	0.199
σ 1	-13.8	-14.5	-15.4	-3.4	-4.6	-0.4	-0.4	-34.3	-3.2	-4.6	-28.7	-32.3	-71.2	95.6	0.285
σ 0	-16.2	-16.4	-17.8	-3.3	-5.4	-0.5	-0.5	-39.9	-3.1	-5.3	-31.8	-37.4	-82.6	82.6	0.247
τ 4	0	0.3	0.1	0	0	0	0	0.1	0	0	0.5	0.1	0.2		
τ 3	8.9	12.3	12.4	0.3	0.3	0.1	0.1	21.6	0.3	0.3	14.6	14.7	36.6		
τ 2	10.2	12.9	13.6	0.3	0.3	0.1	0.1	24.2	0.3	0.3	14.8	16.3	40.7		
τ 1	9.3	11.4	12.3	0.3	0.3	0.1	0.1	21.9	0.2	0.3	12.7	14.7	36.8		
τ 0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Maximum utilization ratio:0.285 CHECK PASSED

NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 2 = 2.22 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 1.83 N/mm^2
   The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 7.51 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 5.32 N/mm^2
   The section at the end of phase 3 is considered: Cracked (m.)

SLS stresses verification (Mmin comb.)

Forces and moments   (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.6E+5	3.88E+5	0E+00
2a	0E+00	2.23E+5	4.51E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	-1E+3	-1.3E+4	0E+00
3a	0E+00	-4.8E+3	-1.34E+5	0E+00
Therm.Iso	5.04E+5	0	1.67E+5	0
3b	0E+00	2.52E+5	9.15E+5	0E+00
Total	5.04E+5	6.3E+5	1.77E+6	0E+00

Stresses of gross cross section   (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	σ_{id}	η_1
σ 8	0	1	0	0	0	0	0	0	-1.3	0	3.9	0	0	0	0
σ 7	0	16.5	24.3	0	0	-0.5	-0.7	23.6	4.9	-7.2	20.6	49.2	65.5	65.5	0.182
σ 6	0	11.7	18.2	0	0	-0.3	-0.5	17.7	4.7	-5.4	13.2	36.9	49.1	49.1	0.136
σ 5	0	0.6	0	0	0	0	0	0	-1.3	0	2.1	0	0	0	0
σ 4	18.5	11.3	17.6	0	0	-0.3	-0.5	35.6	4.6	-5.2	12.5	35.7	66.1	66.1	0.186
σ 3	16.1	9.4	15.2	0	0	-0.3	-0.4	30.9	4.5	-4.5	9.6	30.8	57.1	83.2	0.234
σ 2	0	0	0	0	0	0	0	0	4.2	0	0	0	0	67.4	0.19
σ 1	-13.8	-14.5	-15.4	0	0	0.4	0.4	-28.7	3.2	4.6	-27.8	-31.2	-55.4	82.4	0.246
σ 0	-16.2	-16.4	-17.8	0	0	0.5	0.5	-33.5	3.1	5.3	-30.7	-36.2	-64.3	64.3	0.192
τ 4	0	0.3	0.1	0	0	0	0	0.1	0	0	0.4	0.1	0.2		
τ 3	8.9	12.3	12.4	0	0	-0.1	-0.1	21.2	-0.3	-0.3	13.8	14	34.9		
τ 2	10.2	12.9	13.6	0	0	-0.1	-0.1	23.7	-0.3	-0.3	14.1	15.4	38.9		
τ 1	9.3	11.4	12.3	0	0	-0.1	-0.1	21.5	-0.2	-0.3	12.1	13.9	35.2		
τ 0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Maximum utilization ratio:0.246 CHECK PASSED

NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 2 = 0.98 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 0.61 N/mm^2
   The section at the end of phase 2 is considered: Cracked (m.)

3) Total stress at the top fibre of slab concrete at the end of phase 3 = 3.61 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 1.37 N/mm^2
The section at the end of phase 3 is considered: Cracked (m.)

SLS web breathing verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.6E+5	3.88E+5	0E+00
2a	0E+00	2.23E+5	4.51E+5	0E+00
2b	0E+00	5E+3	1.36E+5	0E+00
Shr.Iso	-3.36E+5	0	-1.43E+5	0
2c	0E+00	1E+3	1.3E+4	0E+00
3a	0E+00	4E+3	1.12E+5	0E+00
Therm.Iso	-4.2E+5	0	-1.39E+5	0
3b	0E+00	1.94E+5	6.98E+5	0E+00
Total	-7.56E+5	5.87E+5	1.52E+6	0E+00

Stresses of effective cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*
σ_8	0	1	0	1.2	0	0	0	0	1.1	0	3	0	0
σ_7	0	16.5	24.3	-3.9	7.3	0.5	0.7	32.3	-4.1	6	15.8	37.5	75.8
σ_6	0	11.7	18.2	-3.8	5.5	0.3	0.5	24.2	-3.9	4.5	10.1	28.2	56.9
σ_5	0	0.6	0	1.2	0	0	0	0	1.1	0	1.6	0	0
σ_4	18.5	11.3	17.6	-3.8	5.3	0.3	0.5	41.9	-3.9	4.4	9.6	27.3	73.6
σ_3	16.1	9.4	15.2	-3.7	4.6	0.3	0.4	36.3	-3.8	3.8	7.3	23.5	63.6
σ_2	0	0	0	-3.6	0	0	0	0	-3.5	0	0	0	0
σ_1	-13.8	-14.5	-15.4	-3.4	-4.6	-0.4	-0.4	-34.3	-2.7	-3.8	-21.2	-23.8	-61.9
σ_0	-16.2	-16.4	-17.8	-3.3	-5.4	-0.5	-0.5	-39.9	-2.6	-4.4	-23.5	-27.6	-71.9

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = 2.22 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 1.83 N/mm^2
The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 6.24 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 4.53 N/mm^2
The section at the end of phase 3 is considered: Cracked (m.)

Web assessment (Mmax comb.)

	Web
b (mm)	690
σ_{sup} (N/mm^2)	63.56
σ_{inf} (N/mm^2)	-61.91
σ_{Ed} (N/mm^2)	61.91
K_σ	24.56
σ_{cr0E} (N/mm^2)	193.15
τ_{Ed} (N/mm^2)	33.92
σ_{cr} (P) (N/mm^2)	4744.03
σ_{cr} (C) (N/mm^2)	11.51
ξ	1
σ_{cr} (N/mm^2)	4744.03
K_τ	5.59
$K_{\tau\,sl}$	0

Utilization ratio	0.037
Result	CHECK VERIFIED

SLS web breathing verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.6E+5	3.88E+5	0E+00
2a	0E+00	2.23E+5	4.51E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	-1E+3	-1.3E+4	0E+00
3a	0E+00	-4E+3	-1.12E+5	0E+00
Therm.Iso	4.2E+5	0	1.39E+5	0
3b	0E+00	1.94E+5	6.98E+5	0E+00
Total	4.2E+5	5.72E+5	1.55E+6	0E+00

Stresses of effective cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*
σ_8	0	1	0	0	0	0	0	0	-1.1	0	3	0	0
σ_7	0	16.5	24.3	0	0	-0.5	-0.7	23.6	4.1	-6	15.8	37.5	55.1
σ_6	0	11.7	18.2	0	0	-0.3	-0.5	17.7	3.9	-4.5	10.1	28.2	41.3
σ_5	0	0.6	0	0	0	0	0	0	-1.1	0	1.6	0	0
σ_4	18.5	11.3	17.6	0	0	-0.3	-0.5	35.6	3.9	-4.4	9.6	27.3	58.5
σ_3	16.1	9.4	15.2	0	0	-0.3	-0.4	30.9	3.8	-3.8	7.3	23.5	50.6
σ_2	0	0	0	0	0	0	0	0	3.5	0	0	0	0
σ_1	-13.8	-14.5	-15.4	0	0	0.4	0.4	-28.7	2.7	3.8	-21.2	-23.8	-48.7
σ_0	-16.2	-16.4	-17.8	0	0	0.5	0.5	-33.5	2.6	4.4	-23.5	-27.6	-56.6

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = 0.98 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 0.61 N/mm^2
   The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 2.9 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 1.1 N/mm^2
   The section at the end of phase 3 is considered: Cracked (m.)

Web assessment (Mmin comb.)

	Web
b (mm)	690
σ_{sup} (N/mm^2)	50.57
σ_{inf} (N/mm^2)	-48.73
σ_{Ed} (N/mm^2)	48.73
K_σ	24.83
σ_{cr0E} (N/mm^2)	193.15
τ_{Ed} (N/mm^2)	33.06
σ_{cr} (P) (N/mm^2)	4796.2
σ_{cr} (C) (N/mm^2)	11.51
ξ	1
σ_{cr} (N/mm^2)	4796.2
K_τ	5.59
$K_{\tau\,sl}$	0

Utilization ratio	0.035
Result	CHECK VERIFIED

Shear connectors assessment

Main data

Number of studs for unit length, n (m^{-1})	15
Stud diameter, d (mm)	19
Stud height, h (mm)	150
Ultimate resistance of studs α	1
Partial safety factor, γ_v	1.25
Ultimate resistance of studs f_u (N/mm²)	450
Coefficient E_{cm} (N/mm²)	36283
Characteristic cylinder compressive strength, f_{ck} (N/mm²)	45

Resistance of headed stud connectors

Shank shear resistance, $P_{Rd1} = 0.8\, f_u\, \pi\, d^2/4/\gamma_v$, (N)	81656.28
Concrete crushing resistance, $P_{Rd2} = 0.29\, \alpha\, d^2 (f_{ck} E_{cm})^{0.5}/\gamma_v$, (N)	107017.34
Design stud resistance $P_{Rd} = \mathrm{Min}(P_{Rd1}, P_{Rd2})$, (N)	81656.28

Elastic assessment at ULS

Utilization ratio (Mmax comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\, P_{Rd}\, \kappa_s$ (N/mm)	1224.8
Reduction factor, κ_s	1.00
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	500.2
Utilization ratio ν_{Ed}/ν_{Rd}	0.408
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmax comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$ (mm³)*	*J_y (mm⁴)*	*V_{Ed} (N/mm)*
Phase 2a	3.01E+5	7.614E+6	1.305E+10	175.6
Phase 2b	6E+3	7.614E+6	1.305E+10	3.5
Phase 2c	1.2E+3	7.614E+6	1.305E+10	0.7
Phase 3a	7.2E+3	1.478E+7	1.692E+10	6.3
Phase 3b	3.596E+5	1.478E+7	1.692E+10	314.2
			Sum	500.2

Utilization ratio (Mmin comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\, P_{Rd}\, \kappa_s$ (N/mm)	1224.8
Reduction factor, κ_s	1.00
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	465.5
Utilization ratio ν_{Ed}/ν_{Rd}	0.38
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmin comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$ (mm³)*	*J_y (mm⁴)*	*V_{Ed} (N/mm)*
Phase 2a	3.01E+5	7.614E+6	1.305E+10	175.6
Phase 2b	0E+00	7.614E+6	1.305E+10	0
Phase 2c	-1.2E+3	7.614E+6	1.305E+10	-0.7
Phase 3a	-7.2E+3	1.478E+7	1.692E+10	-6.3
Phase 3b	3.398E+5	1.478E+7	1.692E+10	296.9
			Sum	465.5

Elastic assessment at ELS

Utilization ratio (Mmax comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\, P_{Rd}\, \kappa_s$ (N/mm)	734.9
Reduction factor, κ_s	0.6
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	369.8
Utilization ratio ν_{Ed}/ν_{Rd}	0.503
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmax comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	2.23E+5	7.614E+6	1.305E+10	130.1
Phase 2b	5E+3	7.614E+6	1.305E+10	2.9
Phase 2c	1E+3	7.614E+6	1.305E+10	0.6
Phase 3a	4.8E+3	1.478E+7	1.692E+10	4.2
Phase 3b	2.656E+5	1.478E+7	1.692E+10	232.1
			Sum	369.8

Utilization ratio (Mmin comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\, P_{Rd}\, \kappa_s$ (N/mm)	734.9
Reduction factor, κ_s	0.6
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	345.8
Utilization ratio ν_{Ed}/ν_{Rd}	0.471
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmin comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	2.23E+5	7.614E+6	1.305E+10	130.1
Phase 2b	0E+00	7.614E+6	1.305E+10	0
Phase 2c	-1E+3	7.614E+6	1.305E+10	-0.6
Phase 3a	-4.8E+3	1.478E+7	1.692E+10	-4.2
Phase 3b	2.524E+5	1.478E+7	1.692E+10	220.5
			Sum	345.8

Assesment of studs at deck ends - shrinkage and thermal influence - (ULS)

Check of minimum studs number

Characteristic shrinkage shear per unit length, $\nu_{L,k}$ (N/mm)	280
Characteristic thermal shear per unit length (-), $\nu_{L,k}$ (N/mm)	700
Total design shear per unit length, $\nu_{L,Ed}$ (N/mm)	1*280 + 1.2*700 = 1120
Minimum number of studs at deck ends, n min (m^{-1})	13.7 < 15
CHECK VERIFIED	

Fatigue limit state verification

Forces and moments for steel details and studs (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.6E+5	3.88E+5	0E+00
2a	0E+00	2.23E+5	4.51E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	0E+00	0E+00	0E+00
3a	0E+00	0E+00	0E+00	0E+00
Therm.Iso	0E+00	0	0E+00	0
3b max	0E+00	1.3E+4	-2E+5	0E+00
3b max	0E+00	-7.7E+4	2.78E+5	0E+00

Stresses of gross cross section for steel details and studs (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked Max*	*Ph. 3b Cracked Max*	*Ph. 3b Uncracked Min*	*Ph. 3b Cracked Min*	*Total Uncracked Max*	*Total Cracked Max*	*Total Uncracked Min*	*Total Cracked Min*	$\Delta\sigma,\Delta\tau$
σ_8	0	1	0	0	0	0	0	0	0	-0.9	0	1.2	0	0.2	0	2.2	0	0
σ_7	0	16.5	24.3	0	0	0	0	0	0	-4.5	-10.8	6.3	14.9	11.9	13.5	22.7	39.2	48.3
σ_6	0	11.7	18.2	0	0	0	0	0	0	-2.9	-8.1	4	11.2	8.8	10.1	15.8	29.4	19.3
σ_5	0	0.6	0	0	0	0	0	0	0	-0.5	0	0.6	0	0.2	0	1.3	0	0
σ_4	18.5	11.3	17.6	0	0	0	0	0	0	-2.7	-7.8	3.8	10.9	27	28.3	33.6	47	18.7
σ_3	16.1	9.4	15.2	0	0	0	0	0	0	-2.1	-6.7	2.9	9.4	23.4	24.6	28.4	40.6	16.1
σ_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_1	-13.8	-14.5	-15.4	0	0	0	0	0	0	6.1	6.8	-8.4	-9.5	-22.2	-22.3	-36.7	-38.7	16.3
σ_0	-16.2	-16.4	-17.8	0	0	0	0	0	0	6.7	7.9	-9.3	-11	-25.8	-26.1	-41.9	-45	18.9
τ_4	0	0.3	0.1	0	0	0	0	0	0	0	0	-0.1	0	0.3	0.3	0.1	0.1	0.2
τ_3	8.9	12.3	12.4	0	0	0	0	0	0	0.7	0.7	-4.2	-4.3	21.9	21.9	17	17	4.9
τ_2	10.2	12.9	13.6	0	0	0	0	0	0	0.7	0.8	-4.3	-4.7	23.8	23.8	18.8	18.8	5
τ_1	9.3	11.4	12.3	0	0	0	0	0	0	0.6	0.7	-3.7	-4.3	21.3	21.3	17	17	4.3
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 3 max = 0.16 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 3 max = 0.17 N/mm^2
   The section at the end of phase 3 max is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 min = 2.19 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 min = 1.26 N/mm^2
   The section at the end of phase 3 min is considered: Cracked (m.)

Forces and moments for steel details and studs (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	1.6E+5	3.88E+5	0E+00
2a	0E+00	2.23E+5	4.51E+5	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	0E+00	0E+00	0E+00
3a	0E+00	0E+00	0E+00	0E+00
Therm.Iso	0E+00	0	0E+00	0
3b max	0E+00	1.3E+4	-2E+5	0E+00
3b max	0E+00	-7.7E+4	2.78E+5	0E+00

Stresses of gross cross section for steel details and studs (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked Max*	*Ph. 3b Cracked Max*	*Ph. 3b Uncracked Min*	*Ph. 3b Cracked Min*	*Total Uncracked Max*	*Total Cracked Max*	*Total Uncracked Min*	*Total Cracked Min*	$\Delta\sigma,\Delta\tau$
σ_8	0	1	0	0	0	0	0	0	0	-0.9	0	1.2	0	0.2	0	2.2	0	0
σ_7	0	16.5	24.3	0	0	0	0	0	0	-4.5	-10.8	6.3	14.9	11.9	13.5	22.7	39.2	48.3
σ_6	0	11.7	18.2	0	0	0	0	0	0	-2.9	-8.1	4	11.2	8.8	10.1	15.8	29.4	19.3
σ_5	0	0.6	0	0	0	0	0	0	0	-0.5	0	0.6	0	0.2	0	1.3	0	0
σ_4	18.5	11.3	17.6	0	0	0	0	0	0	-2.7	-7.8	3.8	10.9	27	28.3	33.6	47	18.7
σ_3	16.1	9.4	15.2	0	0	0	0	0	0	-2.1	-6.7	2.9	9.4	23.4	24.6	28.4	40.6	16.1

σ_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_1	-13.8	-14.5	-15.4	0	0	0	0	0	0	6.1	6.8	-8.4	-9.5	-22.2	-22.3	-36.7	-38.7	16.3
σ_0	-16.2	-16.4	-17.8	0	0	0	0	0	0	6.7	7.9	-9.3	-11	-25.8	-26.1	-41.9	-45	18.9
τ_4	0	0.3	0.1	0	0	0	0	0	0	0	0	-0.1	0	0.3	0.3	0.1	0.1	0.2
τ_3	8.9	12.3	12.4	0	0	0	0	0	0	0.7	0.7	-4.2	-4.3	21.9	21.9	17	17	4.9
τ_2	10.2	12.9	13.6	0	0	0	0	0	0	0.7	0.8	-4.3	-4.7	23.8	23.8	18.8	18.8	5
τ_1	9.3	11.4	12.3	0	0	0	0	0	0	0.6	0.7	-3.7	-4.3	21.3	21.3	17	17	4.3
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 3 max = 0.16 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 3 max = 0.17 N/mm^2
The section at the end of phase 3 max is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 min = 2.19 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 min = 1.26 N/mm^2
The section at the end of phase 3 min is considered: Cracked (m.)

Main data for partial factors and damage equivalent facors

Partial factor for steel:	γ_{Ff}	1
	γ_{Mf}	1.35
Bending damage equivalent factor for steel:	$\lambda = \lambda_1 * \lambda_2 * \lambda_3 * \lambda_4 =$	1.73 x 0.848 x 1 x 1.15 = 1.687<1.854 (Support)
Shear damage equivalent factor for steel:	$\lambda = \lambda_1 * \lambda_2 * \lambda_3 * \lambda_4 =$	1.73 x 0.848 x 1 x 1.15 = 1.687 (Support)
Data for calculation of λ_1	Section position:	(Support)
	L span for moment (m):	33
	L span for shear (m):	33
Data for calculation of λ_2 , λ_{v2}	Q_0 (kN)	480
	N_0	500000
	N_{obs}	500000
	Q_{ml} (kN)	0
	Traffic category (Table 4.5n - EN 1991-2) :	Roads and motorways with medium flow rates of lorries
	Traffic distribution (Table 4.7 - EN 1991-2) :	Medium distance (40% Q1, 10% Q2, 30% Q3, 15% Q4, 5% Q5)
Data for calculation of λ_3 , λ_{v3}	Design life (years):	100
Data for calculation of γ_{Mf} for steel:	Assessment method:	
	Consequence of failure:	
Damage equivalent factor for studs:	$\lambda_v = \lambda_{v1} * \lambda_{v2} * \lambda_{v3} * \lambda_{v4} =$	1.55 x 0.896 x 1 x 1.09 = 1.514
Partial factor for studs:	γ_{Ff}	1
	γ_{Mf}	1

Fatigue assessment of structural steel

Utilization ratio (Mmax comb.)

	$\gamma_{Ff}\,\Delta\sigma_{E,2}$	$\Delta\sigma_c / \gamma_{Mf}$	u.r.
Top flange	31.48	92.593	0.34
Bottom flange	31.878	92.593	0.344
Web	8.461	74.074	0.114
Top flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c$ =0.854 x 90 = 76.9 N/mm^2	31.479	56.941	0.553

Bottom flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c$ =0.854 x 90 = 76.9 N/mm^2	31.878	56.941	0.56
Web-top flange welding	27.123	92.593	0.293
Web-bottom flange welding	27.522	92.593	0.297
Vertical stiffeners - web welding	27.522	59.259	0.464
Vertical stiffeners - top flange welding	27.123	59.259	0.458
Vertical stiffeners - bottom flange welding	27.522	59.259	0.464
Longitudinal stiffener 1 - web welding			
Longitudinal stiffener 2 - web welding			

Utilization ratio (Mmin comb.)

	$\gamma_{Ff} \Delta\sigma_{E,2}$	$\Delta\sigma_c / \gamma_{Mf}$	u.r.
Top flange	31.48	92.593	0.34
Bottom flange	31.878	92.593	0.344
Web	8.461	74.074	0.114
Top flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c$ =0.854 x 90 = 76.9 N/mm^2	31.479	56.941	0.553
Bottom flange welding $\Delta\sigma_{c,red} = \kappa_s * \Delta\sigma_c$ =0.854 x 90 = 76.9 N/mm^2	31.878	56.941	0.56
Web-top flange welding	27.123	92.593	0.293
Web-bottom flange welding	27.522	92.593	0.297
Vertical stiffeners - web welding	27.522	59.259	0.464
Vertical stiffeners - top flange welding	27.123	59.259	0.458
Vertical stiffeners - bottom flange welding	27.522	59.259	0.464
Longitudinal stiffener 1 - web welding			
Longitudinal stiffener 2 - web welding			

Fatigue assessment of studs

Utilization ratio (Mmax comb.)

$\gamma_{Ff} \Delta\tau_{E,2} / (\Delta\tau_c / \gamma_{Mf,s}) <= 1$	=1*27.99/(90/1) =0.311
$\gamma_{Ff} \Delta\sigma_{E,2} / (\Delta\sigma_c / \gamma_{Mf}) <= 1$	=1*31.48/(80/1.35) =0.531
$\gamma_{Ff} \Delta\tau_{E,2} / (\Delta\tau_c / \gamma_{Mf,s}) + \gamma_{Ff} \Delta\sigma_{E,2} / (\Delta\sigma_c / \gamma_{Mf}) <= 1.3$	=0.311+0.531=0.842
CHECK PASSED	

Utilization ratio (Mmin comb.)

$\gamma_{Ff} \Delta\tau_{E,2} / (\Delta\tau_c / \gamma_{Mf,s}) <= 1$	=1*27.99/(90/1) =0.311
$\gamma_{Ff} \Delta\sigma_{E,2} / (\Delta\sigma_c / \gamma_{Mf}) <= 1$	=1*31.48/(80/1.35) =0.531
$\gamma_{Ff} \Delta\tau_{E,2} / (\Delta\tau_c / \gamma_{Mf,s}) + \gamma_{Ff} \Delta\sigma_{E,2} / (\Delta\sigma_c / \gamma_{Mf}) <= 1.3$	=0.311+0.531=0.842
CHECK PASSED	

Stiffeners checks

Torsional buckling of vertical stiffeners

	Vertical stiffeners
	CHECK PASSED
u.r.	0.898
Type	Vert. (R)
σ_{cr} (N/mm^2)	--
6*f_y (N/mm^2)	--
l_{cr} (mm)	--
I_w (mm^6)	--
I_T (mm^4)	5.333E+5

I_P (mm⁴)	5.347E+7
I_T / I_P	0.01
5.3 f_y /E	0.009
cθ (N)	--
E (N/mm²)	210000
f_y (N/mm²)	355
G (N/mm²)	87500
a (mm)	2750

Intermediate vertical stiffeners acting as rigid support for web panels

I_{st} = 5.098E+7 mm^4 > $I_{st\ min}$ = 0.75 $h_w t_w^3$ =5.51E+6 mm^4

CHECK PASSED

With:
t_w = 22 mm b_w = 557 mm A_{st} = 16253.7 mm^2 e_1 = 27.3 mm ^{2}
a = 2750 mm h_w = 690 mm a/hw = 3.986

Maximum stress and the additional deflection in the vertical stiffeners (Mmax comb.)

w = 0 < 2.3 mm

σ_{max} = 0 < 322.7 N/mm^2

CHECK PASSED

With:
$\Sigma N_{st,Ed} = N_{st,Ed} + \Delta N_{st,Ed}$ = 0E+00 + 9.173E+3 = 9.173E+3 N
$N_{st,Ed} = N_{st,ten} + N_{st,ex}$ = 0E+00 + 0E+00 = 0E+00 N
σ_m = 0.19 N/mm^2 $\sigma_{cr(C)} / \sigma_{cr(P)}$ = 11.51/1E+300 = 0=> 0.5
N_{Ed} = 3.608E+5 N λ_w = 0.436
$N_{cr,st}$ = 2.219E+8 N e_1 = 27.3 mm e_{max} = 183.7 mm w_0 = 2.3 mm
δ_m = 0
(I_{vstmin} = 1.412E+4(mm^4) u = 5.699)

9.3.8 Section Sez. 5_5

First classification

The first classification refers to the composite section in Phase 3

Plastic characteristics of the single components

Components	N_{pl} *(N)*	z_N *(mm)*	z_{max} *(mm)*	z_{min} *(mm)*
Concrete layer above top reinforcing bars	1.449E+6	976.33	1000	952.65
Concrete layer between top and bottom reinforcing bars	3.877E+6	884	947.35	820.65
Concrete layer below top reinforcing bars	4.696E+5	807.67	815.35	800
Top reinforcing bars	2.493E+6	950	952.65	947.35
Bottom reinforcing bars	2.493E+6	818	820.65	815.35
Concrete haunch slab	0E+00	800	800	800
Top flange of steel beam	9.298E+6	772.5	800	745
Web of steel beam	5.132E+6	400	745	55
Bottom flange of steel beam	1.053E+7	27.5	55	0
Ultimate compression force for the full section	-3.574E+7			
Ultimate tension force for the full section	2.994E+7			
Ultimate compression force for the web less section	-3.061E+7			
Ultimate tensile force for the web less section	2.481E+7			

Flanges classification

	c/t	ε	*Hogging bending moment (M+)*	*Sagging bending moment (M-)*
Top flange	4.345	0.814	1	0
Bottom flange	5.255	0.838	1	1

Web classification

	c/t	ε	α	ψ	*class*
Hogging bending moment (M+)	31.364	0.814	0.866	-0.762	1
Sagging bending moment (M-)	31.364	0.814	0	-0.295	1
Compression (N)	31.364	0.814	1	1	3

U.L.S. composite section verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	3.04E+5	2.08E+6	0E+00
2a	0E+00	5.32E+5	3.01E+6	0E+00
2b	0E+00	-6E+3	1.99E+5	0E+00
Shr.Iso	-4.03E+5	0	-1.59E+5	0
2c	0E+00	1.2E+3	1.92E+4	0E+00
3a	0E+00	7.2E+3	2.46E+5	0E+00
Therm.Iso	-7.56E+5	0	-2.36E+5	0
3b	0E+00	5.29E+5	2.4E+6	0E+00
Total	-1.16E+6	1.37E+6	7.56E+6	0E+00

Bending resistance - Plastic analysis

Section classification (Mmax comb.)

	c/t	z_{pl} *(mm)*	α	ψ	*Class*
Web	31.36	730.35	0.98	-0.87	2
Top flange	4.35				1
Bottom flange	5.25				1

Section class					2
Plastic analysis: APPLICABLE					

Plastic section verification (Mmax comb.)

Axial force		*Bending moment*		*N/M interaction*	
N_{Ed} (N)	-1.159E+6	M_{Ed} (Nm)	7.564E+6	N_{Ed} (N)	-1.159E+6
N_{Rd} (N)	-3.574E+7	M_{Rd} (Nm)	1.021E+7	M_{Ed} (Nm)	7.564E+6
				M_{Rd} (Nm)	1.009E+7
N_{Ed}/N_{Rd}	0.032	M_{Ed}/M_{Rd}	0.741	M_{Ed}/M_{Rd}	0.75
CHECK PASSED					

Axial force and bending moment stresses of gross cross section

Stresses of gross cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	η_1
σ_8	0	5.8	0	1.5	0	0	0	0	2.2	0	9.3	0	0	0
σ_7	0	93.6	127.8	-2.7	8.5	0.6	0.8	137.1	-5.7	10.4	49.2	101.8	249.3	0.637
σ_6	0	65.8	94.3	-3.1	6.2	0.4	0.6	101.2	-5.8	7.7	31.3	75.1	183.9	0.47
σ_5	0	3.4	0	1.5	0	0	0	0	2.2	0	4.8	0	0	0
σ_4	99.4	62	89.7	-3.1	5.9	0.4	0.6	195.6	-5.8	7.3	28.8	71.5	274.4	0.812
σ_3	86.6	50.4	75.8	-3.3	5	0.3	0.5	167.9	-5.8	6.2	21.3	60.3	234.4	0.693
σ_2	0	0	0	-4	0	0	0	0	-5.9	0	0	0	0	0
σ_1	-74	-95.1	-99.4	-5.2	-6.6	-0.6	-0.6	-180.6	-6.2	-8.1	-72.4	-79.2	-267.9	0.84
σ_0	-86.8	-106.7	-113.4	-5.4	-7.5	-0.7	-0.7	-208.4	-6.2	-9.3	-79.8	-90.3	-308	0.965

Maximum utilization ratio:0.965 NOT RELEVANT CHECK
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = 7.36 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 4.97 N/mm^2
The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 18.9 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 11.96 N/mm^2
The section at the end of phase 3 is considered: Cracked (m.)

Resistance to shear

Evaluation of necessity to Shear buckling check
h_w/t_w =31.364 < $31/\eta *\varepsilon_w*(K_\tau)^{0.5}$ =49.702 Shear Buckling check: NOT REQUIRED

Shear Buckling resistance: **$V_{b,Rd}$ =3.394E+6 N**

With:
a/h_w =3.986, η =1.2, K_τ =5.592
web contribution: $V_{bw,Rd}$ =3.394E+6 N, flanges contribution: $V_{bf,Rd}$ =6.545E+4 N
χ_w =1.2, $\bar{\lambda}_w$ =0.436, τ_{cr} =1080.1, C=1407
M_{Ed} =7.564E+6 Nm, $M_{f,Rd}$ =8.285E+6 Nm, $M_{Ed}/M_{f,Rd}$ =0.913

Plastic resistance: **$V_{pl,Rd}$ =3.556E+6 N**

Shear resistance: **V_{Rd} =$V_{pl,Rd}$ =3.556E+6 N**

Utilization ratios:

$\eta_3 = V_{Ed}/V_{Rd}$ =0.384, (=> CHECK VERIFIED)
$\bar{\eta}_3 = V_{Ed}/V_{bw,Rd}$ =0.403, $\bar{\eta}_1 = M_{Ed}/M_{Rd}$ =0.75

Interaction between shear force, bending moment and axial force

Evaluation of the interaction

$\eta_3 < 0.5$, $M_{Ed} / M_{f,Rd} < 1$

INTERACTION NOT TO BE CHECKED

U.L.S. composite section verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	3.04E+5	2.08E+6	0E+00
2a	0E+00	5.32E+5	3.01E+6	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	-1.2E+3	-1.92E+4	0E+00
3a	0E+00	-7.2E+3	-2.46E+5	0E+00
Therm.Iso	7.56E+5	0	2.36E+5	0
3b	0E+00	5E+5	2.21E+6	0E+00
Total	7.56E+5	1.33E+6	7.27E+6	0E+00

Bending resistance - Plastic analysis

Section classification (Mmin comb.)

	c/t	*z_{pl} (mm)*	*α*	*ψ*	*Class*
Web	31.36	601.61	0.79	-0.89	1
Top flange	4.35				1
Bottom flange	5.25				1
Section class					1
Plastic analysis: APPLICABLE					

Plastic section verification (Mmin comb.)

Axial force		*Bending moment*		*N/M interaction*	
N_{Ed} (N)	7.56E+5	M_{Ed} (Nm)	7.273E+6	N_{Ed} (N)	7.56E+5
N_{Rd} (N)	2.994E+7	M_{Rd} (Nm)	1.021E+7	M_{Ed} (Nm)	7.273E+6
				M_{Rd} (Nm)	1.024E+7
N_{Ed} / N_{Rd}	0.025	M_{Ed} / M_{Rd}	0.712	M_{Ed} / M_{Rd}	0.71
CHECK PASSED					

Axial force and bending moment stresses of gross cross section

Stresses of gross cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	*η_1*
σ_8	0	5.8	0	0	0	0	0	0	-2.2	0	8.6	0	0	0
σ_7	0	93.6	127.8	0	0	-0.6	-0.8	127	5.7	-10.4	45.2	93.6	210.2	0.537
σ_6	0	65.8	94.3	0	0	-0.4	-0.6	93.7	5.8	-7.7	28.8	69.1	155.1	0.396
σ_5	0	3.4	0	0	0	0	0	0	-2.2	0	4.4	0	0	0
σ_4	99.4	62	89.7	0	0	-0.4	-0.6	188.6	5.8	-7.3	26.5	65.7	247	0.73
σ_3	86.6	50.4	75.8	0	0	-0.3	-0.5	161.9	5.8	-6.2	19.6	55.5	211.2	0.625
σ_2	0	0	0	0	0	0	0	0	5.9	0	0	0	0	0
σ_1	-74	-95.1	-99.4	0	0	0.6	0.6	-172.8	6.2	8.1	-66.6	-72.8	-237.5	0.744
σ_0	-86.8	-106.7	-113.4	0	0	0.7	0.7	-199.5	6.2	9.3	-73.4	-83	-273.3	0.856

Maximum utilization ratio:0.856 NOT RELEVANT CHECK

NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 2 = 5.75 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 3.42 N/mm^2
   The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 12.12 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 5.65 N/mm^2
   The section at the end of phase 3 is considered: Cracked (m.)

Resistance to shear

Evaluation of necessity to Shear buckling check

$h_w/t_w = 31.364 < 31/\eta * \varepsilon_w * (K_\tau)^{0.5} = 49.702$ Shear Buckling check: NOT REQUIRED

Shear Buckling resistance: $\mathbf{V_{b,Rd} = 3.394E+6}$ **N**

With:

$a/h_w = 3.986$, $\eta = 1.2$, $K_\tau = 5.592$
web contribution: $V_{bw,Rd} = 3.394E+6$ N, flanges contribution: $V_{bf,Rd} = 1.125E+5$ N
$\chi_w = 1.2$, $\bar{\lambda}_w = 0.436$, $\tau_{cr} = 1080.1$, C=1407
$M_{Ed} = 7.273E+6$ Nm, $M_{f,Rd} = 8.609E+6$ Nm, $M_{Ed}/M_{f,Rd} = 0.845$

Plastic resistance: $\mathbf{V_{pl,Rd} = 3.556E+6}$ **N**

Shear resistance: $\mathbf{V_{Rd} = V_{pl,Rd} = 3.556E+6}$ **N**

Utilization ratios:

$\eta_3 = V_{Ed}/V_{Rd} = 0.373$, (=> CHECK VERIFIED)
$\bar{\eta}_3 = V_{Ed}/V_{bw,Rd} = 0.391$, $\bar{\eta}_1 = M_{Ed}/M_{Rd} = 0.71$

Interaction between shear force, bending moment and axial force

Evaluation of the interaction

$\bar{\eta}_3 < 0.5$, $M_{Ed}/M_{f,Rd} < 1$
INTERACTION NOT TO BE CHECKED

SLS stresses verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	2.25E+5	1.54E+6	0E+00
2a	0E+00	3.94E+5	2.23E+6	0E+00
2b	0E+00	-5E+3	1.66E+5	0E+00
Shr.Iso	-3.36E+5	0	-1.32E+5	0
2c	0E+00	1E+3	1.6E+4	0E+00
3a	0E+00	4.8E+3	1.64E+5	0E+00
Therm.Iso	-5.04E+5	0	-1.57E+5	0
3b	0E+00	3.91E+5	1.77E+6	0E+00
Total	-8.4E+5	1.01E+6	5.6E+6	0E+00

Stresses of gross cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	σ_{id}	η_1
σ_8	0	4.3	0	1.3	0	0	0	0	1.5	0	6.9	0	0	0	0
σ_7	0	69.3	94.7	-2.3	7	0.5	0.7	102.4	-3.8	7	36.3	75.1	184.5	184.5	0.512
σ_6	0	48.7	69.9	-2.6	5.2	0.3	0.5	75.6	-3.8	5.1	23.1	55.4	136.1	136.1	0.378
σ_5	0	2.6	0	1.3	0	0	0	0	1.5	0	3.5	0	0	0	0
σ_4	73.6	45.9	66.5	-2.6	4.9	0.3	0.5	145.5	-3.8	4.9	21.3	52.7	203.1	203.1	0.572

σ_3	64.1	37.3	56.1	-2.7	4.2	0.3	0.4	124.9	-3.9	4.1	15.8	44.5	173.5	199	0.561
σ_2	0	0	0	-3.3	0	0	0	0	-3.9	0	0	0	0	105.6	0.298
σ_1	-54.8	-70.4	-73.7	-4.4	-5.5	-0.5	-0.5	-134.5	-4.1	-5.4	-53.4	-58.4	-198.3	219.7	0.656
σ_0	-64.3	-79	-84	-4.5	-6.3	-0.6	-0.6	-155.1	-4.1	-6.2	-58.9	-66.6	-227.9	227.9	0.68
τ_4	0	0.6	0.4	0	0	0	0	0.4	0	0	0.7	0.4	0.7		
τ_3	12.5	21.8	21.9	-0.3	-0.3	0.1	0.1	34.3	0.3	0.3	21.5	21.8	56.3		
τ_2	14.3	22.6	23.4	-0.3	-0.3	0.1	0.1	37.5	0.3	0.3	21.7	23.2	61		
τ_1	13	19.8	20.9	-0.3	-0.3	0.1	0.1	33.7	0.2	0.3	18.6	20.7	54.6		
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Maximum utilization ratio:0.68 CHECK PASSED
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = 5.6 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 3.82 N/mm^2
The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 13.95 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 8.83 N/mm^2
The section at the end of phase 3 is considered: Cracked (m.)

SLS stresses verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	2.25E+5	1.54E+6	0E+00
2a	0E+00	3.94E+5	2.23E+6	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	-1E+3	-1.6E+4	0E+00
3a	0E+00	-4.8E+3	-1.64E+5	0E+00
Therm.Iso	5.04E+5	0	1.57E+5	0
3b	0E+00	3.71E+5	1.64E+6	0E+00
Total	5.04E+5	9.85E+5	5.39E+6	0E+00

Stresses of gross cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*	σ_{id}	η_1
σ_8	0	4.3	0	0	0	0	0	0	-1.5	0	6.4	0	0	0	0
σ_7	0	69.3	94.7	0	0	-0.5	-0.7	94	3.8	-7	33.7	69.6	156.7	156.7	0.435
σ_6	0	48.7	69.9	0	0	-0.3	-0.5	69.4	3.8	-5.1	21.4	51.4	115.6	115.6	0.321
σ_5	0	2.6	0	0	0	0	0	0	-1.5	0	3.3	0	0	0	0
σ_4	73.6	45.9	66.5	0	0	-0.3	-0.5	139.6	3.8	-4.9	19.7	48.9	183.6	183.6	0.517
σ_3	64.1	37.3	56.1	0	0	-0.3	-0.4	119.9	3.9	-4.1	14.6	41.3	157	183.5	0.517
σ_2	0	0	0	0	0	0	0	0	3.9	0	0	0	0	103	0.29
σ_1	-54.8	-70.4	-73.7	0	0	0.5	0.5	-127.9	4.1	5.4	-49.5	-54.2	-176.7	199.3	0.595
σ_0	-64.3	-79	-84	0	0	0.6	0.6	-147.7	4.1	6.2	-54.6	-61.8	-203.3	203.3	0.607
τ_4	0	0.6	0.4	0	0	0	0	0.4	0	0	0.7	0.3	0.7		
τ_3	12.5	21.8	21.9	0	0	-0.1	-0.1	34.4	-0.3	-0.3	20.4	20.7	54.9		
τ_2	14.3	22.6	23.4	0	0	-0.1	-0.1	37.7	-0.3	-0.3	20.7	22.1	59.5		
τ_1	13	19.8	20.9	0	0	-0.1	-0.1	33.8	-0.2	-0.3	17.7	19.7	53.3		
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Maximum utilization ratio:0.607 CHECK PASSED
NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = 4.25 N/mm^2

2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 2.53 N/mm²
The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 9.17 N/mm²
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 4.36 N/mm²
The section at the end of phase 3 is considered: Cracked (m.)

SLS web breathing verification (Mmax comb.)

Forces and moments (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	2.25E+5	1.54E+6	0E+00
2a	0E+00	3.94E+5	2.23E+6	0E+00
2b	0E+00	-5E+3	1.66E+5	0E+00
Shr.Iso	-3.36E+5	0	-1.32E+5	0
2c	0E+00	1E+3	1.6E+4	0E+00
3a	0E+00	4E+3	1.36E+5	0E+00
Therm.Iso	-4.2E+5	0	-1.31E+5	0
3b	0E+00	2.86E+5	1.28E+6	0E+00
Total	-7.56E+5	9.05E+5	5.11E+6	0E+00

Stresses of effective cross section (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*
σ_8	0	4.3	0	1.3	0	0	0	0	1.2	0	5	0	0
σ_7	0	69.3	94.7	-2.3	7	0.5	0.7	102.4	-3.2	5.8	26.2	54.3	162.5
σ_6	0	48.7	69.9	-2.6	5.2	0.3	0.5	75.6	-3.2	4.3	16.7	40	119.9
σ_5	0	2.6	0	1.3	0	0	0	0	1.2	0	2.6	0	0
σ_4	73.6	45.9	66.5	-2.6	4.9	0.3	0.5	145.5	-3.2	4.1	15.4	38.1	187.7
σ_3	64.1	37.3	56.1	-2.7	4.2	0.3	0.4	124.9	-3.2	3.4	11.4	32.2	160.5
σ_2	0	0	0	-3.3	0	0	0	0	-3.3	0	0	0	0
σ_1	-54.8	-70.4	-73.7	-4.4	-5.5	-0.5	-0.5	-134.5	-3.4	-4.5	-38.6	-42.2	-181.2
σ_0	-64.3	-79	-84	-4.5	-6.3	-0.6	-0.6	-155.1	-3.4	-5.1	-42.6	-48.1	-208.4

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = 5.6 N/mm²
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 3.82 N/mm²
The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 11.8 N/mm²
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 7.6 N/mm²
The section at the end of phase 3 is considered: Cracked (m.)

Web assessment (Mmax comb.)

	Web
b (mm)	690
σ_{sup} (N/mm²)	160.46
σ_{inf} (N/mm²)	-181.19
σ_{Ed} (N/mm²)	181.19
K_σ	21.05
σ_{cr0E} (N/mm²)	193.15
τ_{Ed} (N/mm²)	51.39
σ_{cr} (P) (N/mm²)	4065.87
σ_{cr} (C) (N/mm²)	11.51
ξ	1
σ_{cr} (N/mm²)	4065.87

K_{τ}	5.59
$K_{\tau\, sl}$	0
Utilization ratio	0.069
Result	CHECK VERIFIED

SLS web breathing verification (Mmin comb.)

Forces and moments (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	2.25E+5	1.54E+6	0E+00
2a	0E+00	3.94E+5	2.23E+6	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	-1E+3	-1.6E+4	0E+00
3a	0E+00	-4E+3	-1.36E+5	0E+00
Therm.Iso	4.2E+5	0	1.31E+5	0
3b	0E+00	2.86E+5	1.28E+6	0E+00
Total	4.2E+5	9E+5	5.03E+6	0E+00

Stresses of effective cross section (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 2 tot*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked*	*Ph. 3b Cracked*	*Ph. 3 tot*
σ_8	0	4.3	0	0	0	0	0	0	-1.2	0	5	0	0
σ_7	0	69.3	94.7	0	0	-0.5	-0.7	94	3.2	-5.8	26.2	54.3	142.5
σ_6	0	48.7	69.9	0	0	-0.3	-0.5	69.4	3.2	-4.3	16.7	40	105.1
σ_5	0	2.6	0	0	0	0	0	0	-1.2	0	2.6	0	0
σ_4	73.6	45.9	66.5	0	0	-0.3	-0.5	139.6	3.2	-4.1	15.4	38.1	173.7
σ_3	64.1	37.3	56.1	0	0	-0.3	-0.4	119.9	3.2	-3.4	11.4	32.2	148.6
σ_2	0	0	0	0	0	0	0	0	3.3	0	0	0	0
σ_1	-54.8	-70.4	-73.7	0	0	0.5	0.5	-127.9	3.4	4.5	-38.6	-42.2	-165.6
σ_0	-64.3	-79	-84	0	0	0.6	0.6	-147.7	3.4	5.1	-42.6	-48.1	-190.7

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 2 = 4.25 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 2 = 2.53 N/mm^2
The section at the end of phase 2 is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 = 8 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 = 3.88 N/mm^2
The section at the end of phase 3 is considered: Cracked (m.)

Web assessment (Mmin comb.)

	Web
b (mm)	690
σ_{sup} (N/mm^2)	148.61
σ_{inf} (N/mm^2)	-165.64
σ_{Ed} (N/mm^2)	165.64
K_{σ}	21.33
σ_{cr0E} (N/mm^2)	193.15
τ_{Ed} (N/mm^2)	51.11
σ_{cr} (P) (N/mm^2)	4118.98
σ_{cr} (C) (N/mm^2)	11.51
ξ	1
σ_{cr} (N/mm^2)	4118.98

K_{τ}	5.59
$K_{\tau\ sl}$	0
Utilization ratio	0.066
Result	CHECK VERIFIED

Shear connectors assessment

Main data

Number of studs for unit length, n (m^{-1})	15
Stud diameter, d (mm)	19
Stud height, h (mm)	150
Ultimate resistance of studs α	1
Partial safety factor, γ_v	1.25
Ultimate resistance of studs f_u (N/mm^2)	450
Coefficient E_{cm} (N/mm^2)	36283
Characteristic cylinder compressive strength, f_{ck} (N/mm^2)	45

Resistance of headed stud connectors

Shank shear resistance, $P_{Rd1} = 0.8\ f_u\ \pi\ d^2/4/\gamma_v$, (N)	81656.28
Concrete crushing resistance, $P_{Rd2} = 0.29\ \alpha\ d^2 (f_{ck} E_{cm})^{0.5}/\gamma_v$, (N)	107017.34
Design stud resistance $P_{Rd} = Min(P_{Rd1}, P_{Rd2})$, (N)	81656.28

Elastic assessment at ULS

Utilization ratio (Mmax comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\ P_{Rd}\ \kappa_s$ (N/mm)	1224.8
Reduction factor, κ_s	1.00
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	865.1
Utilization ratio ν_{Ed}/ν_{Rd}	0.706
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmax comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	5.319E+5	1.007E+7	1.429E+10	374.9
Phase 2b	-6E+3	1.007E+7	1.429E+10	-4.2
Phase 2c	1.2E+3	1.007E+7	1.429E+10	0.8
Phase 3a	7.2E+3	1.626E+7	1.766E+10	6.6
Phase 3b	5.288E+5	1.626E+7	1.766E+10	487
			Sum	865.1

Utilization ratio (Mmin comb.)

Design stud resistance for unit length, $\nu_{Rd} = n\ P_{Rd}\ \kappa_s$ (N/mm)	1224.8
Reduction factor, κ_s	1.00
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	827.9
Utilization ratio ν_{Ed}/ν_{Rd}	0.676
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmin comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm^3)*	*J_y (mm^4)*	*V_{Ed} (N/mm)*
Phase 2a	5.319E+5	1.007E+7	1.429E+10	374.9
Phase 2b	0E+00	1.007E+7	1.429E+10	0
Phase 2c	-1.2E+3	1.007E+7	1.429E+10	-0.8
Phase 3a	-7.2E+3	1.626E+7	1.766E+10	-6.6
Phase 3b	5E+5	1.626E+7	1.766E+10	460.5
			Sum	827.9

Elastic assessment at ELS

Utilization ratio (Mmax comb.)

Design stud resistance for unit length, $\nu_{Rd} = n P_{Rd} \kappa_s$ (N/mm)	734.9
Reduction factor, κ_s	0.6
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	639.1
Utilization ratio ν_{Ed}/ν_{Rd}	0.87
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmax comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm³)*	*J_y (mm⁴)*	*V_{Ed} (N/mm)*
Phase 2a	3.94E+5	1.007E+7	1.429E+10	277.7
Phase 2b	-5E+3	1.007E+7	1.429E+10	-3.5
Phase 2c	1E+3	1.007E+7	1.429E+10	0.7
Phase 3a	4.8E+3	1.626E+7	1.766E+10	4.4
Phase 3b	3.906E+5	1.626E+7	1.766E+10	359.8
			Sum	639.1

Utilization ratio (Mmin comb.)

Design stud resistance for unit length, $\nu_{Rd} = n P_{Rd} \kappa_s$ (N/mm)	734.9
Reduction factor, κ_s	0.6
Shear force per unit length at steel-concrete interface ν_{Ed} (N/mm)	614.6
Utilization ratio ν_{Ed}/ν_{Rd}	0.836
CHECK VERIFIED	

Shear force per unit length at steel-concrete interface (Mmin comb.)

Phase	*V_{Ed} (N)*	*$S_{y,4}$(mm³)*	*J_y (mm⁴)*	*V_{Ed} (N/mm)*
Phase 2a	3.94E+5	1.007E+7	1.429E+10	277.7
Phase 2b	0E+00	1.007E+7	1.429E+10	0
Phase 2c	-1E+3	1.007E+7	1.429E+10	-0.7
Phase 3a	-4.8E+3	1.626E+7	1.766E+10	-4.4
Phase 3b	3.714E+5	1.626E+7	1.766E+10	342.1
			Sum	614.6

Assesment of studs at deck ends - shrinkage and thermal influence - (ULS)

Check of minimum studs number

Characteristic shrinkage shear per unit length, $\nu_{L,k}$ (N/mm)	280
Characteristic thermal shear per unit length (-), $\nu_{L,k}$ (N/mm)	700
Total design shear per unit length, $\nu_{L,Ed}$ (N/mm)	1*280 + 1.2*700 = 1120
Minimum number of studs at deck ends, n min (m^{-1})	13.7 < 15
CHECK VERIFIED	

Fatigue limit state verification

Forces and moments for steel details and studs (Mmax comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	2.25E+5	1.54E+6	0E+00
2a	0E+00	3.94E+5	2.23E+6	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	0E+00	0E+00	0E+00
3a	0E+00	0E+00	0E+00	0E+00
Therm.Iso	0E+00	0	0E+00	0
3b max	0E+00	7.6E+4	-3.4E+4	0E+00

3b max	0E+00	-1.33E+5	3.73E+5	0E+00

Stresses of gross cross section for steel details and studs (Mmax comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked Max*	*Ph. 3b Cracked Max*	*Ph. 3b Uncracked Min*	*Ph. 3b Cracked Min*	*Total Uncracked Max*	*Total Cracked Max*	*Total Uncracked Min*	*Total Cracked Min*	*Δσ,Δτ*
σ_8	0	4.3	0	0	0	0	0	0	0	-0.1	0	1.5	0	4.2	0	5.7	0	0
σ_7	0	69.3	94.7	0	0	0	0	0	0	-0.7	-1.4	7.7	15.8	68.6	93.2	77	110.5	18.7
σ_6	0	48.7	69.9	0	0	0	0	0	0	-0.4	-1.1	4.9	11.7	48.3	68.8	53.6	81.5	12.7
σ_5	0	2.6	0	0	0	0	0	0	0	-0.1	0	0.7	0	2.5	0	3.3	0	0
σ_4	73.6	45.9	66.5	0	0	0	0	0	0	-0.4	-1	4.5	11.1	119.1	139.1	124	151.2	12.1
σ_3	64.1	37.3	56.1	0	0	0	0	0	0	-0.3	-0.9	3.3	9.4	101.2	119.4	104.8	129.7	10.2
σ_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_1	-54.8	-70.4	-73.7	0	0	0	0	0	0	1	1.1	-11.3	-12.3	-124.2	-127.3	-136.5	-140.8	13.4
σ_0	-64.3	-79	-84	0	0	0	0	0	0	1.1	1.3	-12.4	-14	-142.2	-147	-155.7	-162.3	15.3
τ_4	0	0.6	0.4	0	0	0	0	0	0	0.1	0.1	-0.2	-0.1	0.7	0.7	0.3	0.3	0.4
τ_3	12.5	21.8	21.9	0	0	0	0	0	0	4.2	4.2	-7.3	-7.4	38.5	38.5	27	27	11.5
τ_2	14.3	22.6	23.4	0	0	0	0	0	0	4.2	4.5	-7.4	-7.9	41.1	41.1	29.5	29.5	11.6
τ_1	13	19.8	20.9	0	0	0	0	0	0	3.6	4	-6.3	-7	36.4	36.4	26.5	26.5	9.9
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:

1) Total stress at the top fibre of slab concrete at the end of phase 3 max = 4.15 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 3 max = 2.48 N/mm^2
   The section at the end of phase 3 max is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 min = 5.74 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 min = 3.3 N/mm^2
   The section at the end of phase 3 min is considered: Cracked (m.)

Forces and moments for steel details and studs (Mmin comb.)

Phase	*N (N)*	*V (N)*	*M (Nm)*	*T (Nm)*
1	0E+00	2.25E+5	1.54E+6	0E+00
2a	0E+00	3.94E+5	2.23E+6	0E+00
2b	0E+00	0E+00	0E+00	0E+00
Shr.Iso	0E+00	0	0E+00	0
2c	0E+00	0E+00	0E+00	0E+00
3a	0E+00	0E+00	0E+00	0E+00
Therm.Iso	0E+00	0	0E+00	0
3b max	0E+00	7.6E+4	-3.4E+4	0E+00
3b max	0E+00	-1.33E+5	3.73E+5	0E+00

Stresses of gross cross section for steel details and studs (Mmin comb.)

	Ph. 1	*Ph. 2a Uncracked*	*Ph. 2a Cracked*	*Ph. 2b Uncracked*	*Ph. 2b Cracked*	*Ph. 2c Uncracked*	*Ph. 2c Cracked*	*Ph. 3a Uncracked*	*Ph. 3a Cracked*	*Ph. 3b Uncracked Max*	*Ph. 3b Cracked Max*	*Ph. 3b Uncracked Min*	*Ph. 3b Cracked Min*	*Total Uncracked Max*	*Total Cracked Max*	*Total Uncracked Min*	*Total Cracked Min*	*Δσ,Δτ*
σ_8	0	4.3	0	0	0	0	0	0	0	-0.1	0	1.5	0	4.2	0	5.7	0	0
σ_7	0	69.3	94.7	0	0	0	0	0	0	-0.7	-1.4	7.7	15.8	68.6	93.2	77	110.5	18.7

σ_6	0	48.7	69.9	0	0	0	0	0	0	-0.4	-1.1	4.9	11.7	48.3	68.8	53.6	81.5	12.7
σ_5	0	2.6	0	0	0	0	0	0	0	-0.1	0	0.7	0	2.5	0	3.3	0	0
σ_4	73.6	45.9	66.5	0	0	0	0	0	0	-0.4	-1	4.5	11.1	119.1	139.1	124	151.2	12.1
σ_3	64.1	37.3	56.1	0	0	0	0	0	0	-0.3	-0.9	3.3	9.4	101.2	119.4	104.8	129.7	10.2
σ_2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
σ_1	-54.8	-70.4	-73.7	0	0	0	0	0	0	1	1.1	-11.3	-12.3	-124.2	-127.3	-136.5	-140.8	13.4
σ_0	-64.3	-79	-84	0	0	0	0	0	0	1.1	1.3	-12.4	-14	-142.2	-147	-155.7	-162.3	15.3
τ_4	0	0.6	0.4	0	0	0	0	0	0	0.1	0.1	-0.2	-0.1	0.7	0.7	0.3	0.3	0.4
τ_3	12.5	21.8	21.9	0	0	0	0	0	0	4.2	4.2	-7.3	-7.4	38.5	38.5	27	27	11.5
τ_2	14.3	22.6	23.4	0	0	0	0	0	0	4.2	4.5	-7.4	-7.9	41.1	41.1	29.5	29.5	11.6
τ_1	13	19.8	20.9	0	0	0	0	0	0	3.6	4	-6.3	-7	36.4	36.4	26.5	26.5	9.9
τ_0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

NOTE:
1) Total stress at the top fibre of slab concrete at the end of phase 3 max = 4.15 N/mm^2
2) Total stress at the bottom fibre of slab concrete at the end of phase 3 max = 2.48 N/mm^2
   The section at the end of phase 3 max is considered: Cracked (m.)
3) Total stress at the top fibre of slab concrete at the end of phase 3 min = 5.74 N/mm^2
4) Total stress at the bottom fibre of slab concrete at the end of phase 3 min = 3.3 N/mm^2
   The section at the end of phase 3 min is considered: Cracked (m.)

Main data for partial factors and damage equivalent facors

Partial factor for steel:	γ_{Ff}	1
	γ_{Mf}	1.35
Bending damage equivalent factor for steel:	$\lambda = \lambda_1 * \lambda_2 * \lambda_3 * \lambda_4 =$	1.73 x 0.848 x 1 x 1.15 = 1.687<1.854 (Support)
Shear damage equivalent factor for steel:	$\lambda = \lambda_1 * \lambda_2 * \lambda_3 * \lambda_4 =$	1.73 x 0.848 x 1 x 1.15 = 1.687 (Support)
Data for calculation of λ_1	Section position:	(Support)
	L span for moment (m):	33
	L span for shear (m):	33
Data for calculation of λ_2, λ_{v2}	Q_0 (kN)	480
	N_0	500000
	N_{obs}	500000
	Q_{ml} (kN)	0
	Traffic category (Table 4.5n - EN 1991-2) :	Roads and motorways with medium flow rates of lorries
	Traffic distribution (Table 4.7 - EN 1991-2) :	Medium distance (40% Q1, 10% Q2, 30% Q3, 15% Q4, 5% Q5)
Data for calculation of λ_3, λ_{v3}	Design life (years):	100
Data for calculation of γ_{Mf} for steel:	Assessment method:	
	Consequence of failure:	
Damage equivalent factor for studs:	$\lambda_v = \lambda_{v1} * \lambda_{v2} * \lambda_{v3} * \lambda_{v4} =$	1.55 x 0.896 x 1 x 1.09 = 1.514
Partial factor for studs:	γ_{Ff}	1
	γ_{Mf}	1

<u>Fatigue assessment of structural steel</u>

Utilization ratio (Mmax comb.)

	$\gamma_{Ff}\Delta\sigma_{E,2}$	$\Delta\sigma_c/\gamma_{Mf}$	u.r.
Top flange	20.46	92.593	0.221
Bottom flange	25.849	92.593	0.279
Web	19.616	74.074	0.265
Top flange welding			
Bottom flange welding			
Web-top flange welding	17.273	92.593	0.187
Web-bottom flange welding	22.666	92.593	0.245
Vertical stiffeners - web welding	22.666	59.259	0.382
Vertical stiffeners - top flange welding	17.273	59.259	0.291
Vertical stiffeners - bottom flange welding	22.666	59.259	0.382
Longitudinal stiffener 1 - web welding			
Longitudinal stiffener 2 - web welding			

Utilization ratio (Mmin comb.)

	$\gamma_{Ff}\Delta\sigma_{E,2}$	$\Delta\sigma_c/\gamma_{Mf}$	u.r.
Top flange	20.46	92.593	0.221
Bottom flange	25.849	92.593	0.279
Web	19.616	74.074	0.265
Top flange welding			
Bottom flange welding			
Web-top flange welding	17.273	92.593	0.187
Web-bottom flange welding	22.666	92.593	0.245
Vertical stiffeners - web welding	22.666	59.259	0.382
Vertical stiffeners - top flange welding	17.273	59.259	0.291
Vertical stiffeners - bottom flange welding	22.666	59.259	0.382
Longitudinal stiffener 1 - web welding			
Longitudinal stiffener 2 - web welding			

Fatigue assessment of studs

Utilization ratio (Mmax comb.)

$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) <=1$	=1*68.52/(90/1) =0.761
$\gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <=1$	=1*20.46/(80/1.35) =0.345
$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s})+\gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <=1.3$	=0.761+0.345=1.107
CHECK PASSED	

Utilization ratio (Mmin comb.)

$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s}) <=1$	=1*68.52/(90/1) =0.761
$\gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <=1$	=1*20.46/(80/1.35) =0.345
$\gamma_{Ff}\Delta\tau_{E,2}/(\Delta\tau_c/\gamma_{Mf,s})+\gamma_{Ff}\Delta\sigma_{E,2}/(\Delta\sigma_c/\gamma_{Mf}) <=1.3$	=0.761+0.345=1.107
CHECK PASSED	

Stiffeners checks

Torsional buckling of vertical stiffeners

	Vertical stiffeners
	CHECK PASSED
u.r.	0.898
Type	Vert. (R)
σ_{cr} (N/mm²)	--
6*f_y (N/mm²)	--
l_{cr} (mm)	--

I_w (mm^6)	--
I_T (mm^4)	5.333E+5
I_P (mm^4)	5.347E+7
I_T /I_P	0.01
5.3 f_y /E	0.009
cθ (N)	--
E (N/mm^2)	210000
f_y (N/mm^2)	355
G (N/mm^2)	87500
a (mm)	2750

Intermediate vertical stiffeners acting as rigid support for web panels

I_{st} = 5.098E+7 mm^4 > $I_{st\ min}$ = 0.75 h_w t_w^{3} =5.51E+6 mm^4

CHECK PASSED

With:

t_w = 22 mm b_w = 557 mm A_{st} = 16253.7 mm^2 e_1 = 27.3 mm ^{2}
a = 2750 mm h_w = 690 mm a/hw = 3.986

Maximum stress and the additional deflection in the vertical stiffeners (Mmax comb.)

w = 0 < 2.3 mm

σ_{max} = 80.4 < 322.7 N/mm^2

CHECK PASSED

With:

Σ $N_{st,Ed}$ = $N_{st,Ed}$ + $\Delta N_{st,Ed}$ = 1.28E+6 + 2.757E+4 = 1.308E+6 N
$N_{st,Ed}$ = $N_{st,ten}$ + $N_{st,ex}$ = 0E+00 + 1.28E+6 = 1.28E+6 N
σ_m = 0.572 N/mm^2 $\sigma_{cr(C)}$ /$\sigma_{cr(P)}$ = 11.51/1E+300 = 0=> 0.5
N_{Ed} = 1.085E+6 N $\bar{\lambda}_w$ = 0.436
$N_{cr,st}$ = 2.219E+8 N e_1 = 27.3 mm e_{max} = 183.7 mm w_0 = 2.3 mm
δ_m = 0

9.3.9 Riassunto verifiche

Si riporta di seguito un report riassuntivo delle verifiche:

VERIFICHE SLU																		
Sezione	X (m)	Combo	Classe F1	Classe F3b	Med/Mr	σEd/fyd	Ved/Vrd	Med/Mf,Rd	Ved/Vbw,Rd	V/M/N	vEd/(n*PRd)	Pioli testata	Stiff. Long. LTB	Stiff, vert, LTB	Stiff. Vert Istmin/Ist	Stiff. Vert σ/fyd	Stiff. Vert w/(hw/300)	Sezione
Sez. 1_Sp. A	0	SLU fond., Mmax	4	1	0.06	()	0.326	0.07	0.341	No int.	0.49	0.914	0	0.898	0.054	0.252	0.005	Sez. 1_Sp. A
Sez. 1_Sp. A	0	SLU fond., Mmin	4	4	-0.05	0.043	0.331	0.25	0.347	No int.	0.505	0.914	0	0.898	0.054	0.252	0.005	Sez. 1_Sp. A
Sez. 1_Sp. A	0	SLU fond., Vmax	4	4	()	0	0	0	0	No int.	V=0	0.914	0	0.898	0.054	0.252	0.005	Sez. 1_Sp. A
Sez. 1_Sp. A	0	SLU fond., Vmin	4	4	()	0	0	0	0	No int.	V=0	0.914	0	0.898	0.054	0.252	0.005	Sez. 1_Sp. A
Sez. 2a_2a	7	SLU fond., Mmax	3	1	0.66	-0.784	0.158	0.85	0.166	No int.	0.246	0	0	0.898	0.054	0	0	Sez. 2a_2a
Sez. 2a_2a	7	SLU fond., Mmin	3	1	0.63	-0.806	0.17	0.84	0.178	No int.	0.268	0	0	0.898	0.054	0	0	Sez. 2a_2a
Sez. 2a_2a	7	SLU fond., Vmax	4	4	()	0	0	0	0	No int.	V=0	0	0	0.898	0.054	0	0	Sez. 2a_2a
Sez. 2a_2a	7	SLU fond., Vmin	4	4	()	0	0	0	0	No int.	V=0	0	0	0.898	0.054	0	0	Sez. 2a_2a
Sez. 2b_2b	7	SLU fond., Mmax	3	1	0.5	-0.555	0.162	0.59	0.169	No int.	0.354	0	0	0.898	0.053	0	0	Sez. 2b_2b
Sez. 2b_2b	7	SLU fond., Mmin	3	1	0.46	-0.574	0.173	0.56	0.182	No int.	0.386	0	0	0.898	0.053	0	0	Sez. 2b_2b
Sez. 2b_2b	7	SLU fond., Vmax	3	1	0	()	0	0	0	No int.	V=0	0	0	0.898	0.053	0	0	Sez. 2b_2b
Sez. 2b_2b	7	SLU fond., Vmin	3	1	0	()	0	0	0	No int.	V=0	0	0	0.898	0.053	0	0	Sez. 2b_2b
Sez. 3a_3a	17	SLU fond., Mmax	3	1	0.59	-0.651	0.108	0.69	0.113	No int.	0.218	0	0	0.898	0.053	0	0	Sez. 3a_3a
Sez. 3a_3a	17	SLU fond., Mmin	3	1	0.58	-0.746	0.113	0.7	0.118	No int.	0.235	0	0	0.898	0.053	0	0	Sez. 3a_3a
Sez. 3a_3a	17	SLU fond., Vmax	3	1	0	()	0	0	0	No int.	V=0	0	0	0.898	0.053	0	0	Sez. 3a_3a
Sez. 3a_3a	17	SLU fond., Vmin	3	1	0	()	0	0	0	No int.	V=0	0	0	0.898	0.053	0	0	Sez. 3a_3a
Sez. 3b_3b	17	SLU fond., Mmax	1	1	0.54	-0.618	0.089	0.65	0.093	No int.	0.192	0	0	0.898	0.088	0	0	Sez. 3b_3b
Sez. 3b_3b	17	SLU fond., Mmin	1	1	0.53	-0.68	0.094	0.66	0.098	No int.	0.208	0	0	0.898	0.088	0	0	Sez. 3b_3b
Sez. 3b_3b	17	SLU fond., Vmax	1	1	0	()	0	0	0	No int.	V=0	0	0	0.898	0.088	0	0	Sez. 3b_3b
Sez. 3b_3b	17	SLU fond., Vmin	1	1	0	()	0	0	0	No int.	V=0	0	0	0.898	0.088	0	0	Sez. 3b_3b
Sez. 4a_4a	27	SLU fond., Mmax	1	1	0.31	-0.41	0.268	0.37	0.281	No int.	0.593	0	0	0.898	0.088	0	0	Sez. 4a_4a
Sez. 4a_4a	27	SLU fond., Mmin	1	1	0.31	-0.316	0.255	0.35	0.267	No int.	0.552	0	0	0.898	0.088	0	0	Sez. 4a_4a
Sez. 4a_4a	27	SLU fond., Vmax	1	1	0	()	0	0	0	No int.	V=0	0	0	0.898	0.088	0	0	Sez. 4a_4a
Sez. 4a_4a	27	SLU fond., Vmin	1	1	0	()	0	0	0	No int.	V=0	0	0	0.898	0.088	0	0	Sez. 4a_4a
Sez. 4b_4b	27	SLU fond., Mmax	1	1	0.26	-0.35	0.251	0.3	0.263	No int.	0.371	0	0	0.898	0.108	0	0	Sez. 4b_4b
Sez. 4b_4b	27	SLU fond., Mmin	1	1	0.27	-0.27	0.239	0.3	0.25	No int.	0.345	0	0	0.898	0.108	0	0	Sez. 4b_4b
Sez. 4b_4b	27	SLU fond., Vmax	1	1	0	()	0	0	0	No int.	V=0	0	0	0.898	0.108	0	0	Sez. 4b_4b
Sez. 4b_4b	27	SLU fond., Vmin	1	1	0	()	0	0	0	No int.	V=0	0	0	0.898	0.108	0	0	Sez. 4b_4b
Sez. 5_5	33	SLU fond., Mmax	1	2	0.75	-0.965	0.384	0.91	0.403	No int.	0.642	0	0	0.898	0.108	0.249	0.006	Sez. 5_5
Sez. 5_5	33	SLU fond., Mmin	1	1	0.71	-0.856	0.373	0.84	0.391	No int.	0.614	0	0	0.898	0.108	0.249	0.006	Sez. 5_5
Sez. 5_5	33	SLU fond., Vmax	1	1	0	()	0	0	0	No int.	V=0	0	0	0.898	0.108	0.249	0.006	Sez. 5_5
Sez. 5_5	33	SLU fond., Vmin	1	1	0	()	0	0	0	No int.	V=0	0	0	0.898	0.108	0.249	0.006	Sez. 5_5

VERIFICHE SLE Caratt				
Sezione	X (m)	Combo	σid / σamm	vEd/(ksn Prd)
Sez. 1_Sp. A	0	SLS caratt., Mmax	0.279	0.667
Sez. 1_Sp. A	0	SLS caratt., Mmin	0.264	0.682
Sez. 1_Sp. A	0	SLS caratt., Vmax	0	V=0
Sez. 1_Sp. A	0	SLS caratt., Vmin	0	V=0
Sez. 2a_2a	7	SLS caratt., Mmax	0.554	0.335
Sez. 2a_2a	7	SLS caratt., Mmin	0.568	0.363
Sez. 2a_2a	7	SLS caratt., Vmax	0	V=0
Sez. 2a_2a	7	SLS caratt., Vmin	0	V=0
Sez. 2b_2b	7	SLS caratt., Mmax	0.392	0.481
Sez. 2b_2b	7	SLS caratt., Mmin	0.401	0.522
Sez. 2b_2b	7	SLS caratt., Vmax	0	V=0
Sez. 2b_2b	7	SLS caratt., Vmin	0	V=0
Sez. 3a_3a	17	SLS caratt., Mmax	0.46	0.298
Sez. 3a_3a	17	SLS caratt., Mmin	0.518	0.317
Sez. 3a_3a	17	SLS caratt., Vmax	0	V=0
Sez. 3a_3a	17	SLS caratt., Vmin	0	V=0
Sez. 3b_3b	17	SLS caratt., Mmax	0.436	0.263
Sez. 3b_3b	17	SLS caratt., Mmin	0.471	0.281
Sez. 3b_3b	17	SLS caratt., Vmax	0	V=0
Sez. 3b_3b	17	SLS caratt., Vmin	0	V=0
Sez. 4a_4a	27	SLS caratt., Mmax	0.328	0.803
Sez. 4a_4a	27	SLS caratt., Mmin	0.279	0.751
Sez. 4a_4a	27	SLS caratt., Vmax	0	V=0
Sez. 4a_4a	27	SLS caratt., Vmin	0	V=0
Sez. 4b_4b	27	SLS caratt., Mmax	0.285	0.503
Sez. 4b_4b	27	SLS caratt., Mmin	0.246	0.471
Sez. 4b_4b	27	SLS caratt., Vmax	0	V=0
Sez. 4b_4b	27	SLS caratt., Vmin	0	V=0
Sez. 5_5	33	SLS caratt., Mmax	0.68	0.87
Sez. 5_5	33	SLS caratt., Mmin	0.607	0.836
Sez. 5_5	33	SLS caratt., Vmax	0	V=0

VERIFICHE SLE Frequente			
Sezione	X (m)	Combo	C.S. Web Breathing
Sez. 1_Sp. A	0	SLS freq., Mmax	0.102
Sez. 1_Sp. A	0	SLS freq., Mmin	0.098
Sez. 1_Sp. A	0	SLS freq., Vmax	0
Sez. 1_Sp. A	0	SLS freq., Vmin	0
Sez. 2a_2a	7	SLS freq., Mmax	0.059
Sez. 2a_2a	7	SLS freq., Mmin	0.053
Sez. 2a_2a	7	SLS freq., Vmax	0
Sez. 2a_2a	7	SLS freq., Vmin	0
Sez. 2b_2b	7	SLS freq., Mmax	0.072
Sez. 2b_2b	7	SLS freq., Mmin	0.059
Sez. 2b_2b	7	SLS freq., Vmax	0
Sez. 2b_2b	7	SLS freq., Vmin	0
Sez. 3a_3a	17	SLS freq., Mmax	0.065
Sez. 3a_3a	17	SLS freq., Mmin	0.05
Sez. 3a_3a	17	SLS freq., Vmax	0
Sez. 3a_3a	17	SLS freq., Vmin	0
Sez. 3b_3b	17	SLS freq., Mmax	0.024
Sez. 3b_3b	17	SLS freq., Mmin	0.019
Sez. 3b_3b	17	SLS freq., Vmax	0
Sez. 3b_3b	17	SLS freq., Vmin	0
Sez. 4a_4a	27	SLS freq., Mmax	0.052
Sez. 4a_4a	27	SLS freq., Mmin	0.049
Sez. 4a_4a	27	SLS freq., Vmax	0
Sez. 4a_4a	27	SLS freq., Vmin	0
Sez. 4b_4b	27	SLS freq., Mmax	0.037
Sez. 4b_4b	27	SLS freq., Mmin	0.035
Sez. 4b_4b	27	SLS freq., Vmax	0
Sez. 4b_4b	27	SLS freq., Vmin	0
Sez. 5_5	33	SLS freq., Mmax	0.069
Sez. 5_5	33	SLS freq., Mmin	0.066
Sez. 5_5	33	SLS freq., Vmax	0

VERIFICHE SL FATICA																			
Sezione	X (m)	Combo	Pioli η_1	Pioli η_2	Pioli η_3	Psup	Pinf	Web	Fltop-Fltop	Pinf-Pinf	Web-Psup	Web-Pinf	IrrV-Web	IrrV-Sup	IrrV-Pinf	IrrrL1-Web	IrrrL2-Web	Barre	Sezione
Sez. 1_Sp. A	0	SL fatica., Mmax	0.461	0	0.354	0	0	0.29	--	--	0	0	0	0	0	--	--	0	Sez. 1_Sp. A
Sez. 1_Sp. A	0	SL fatica., Mmin	0.461	0	0.354	0	0	0.29	--	--	0	0	0	0	0	--	--	0	Sez. 1_Sp. A
Sez. 1_Sp. A	0	SL fatica., Vmax	0	0	0	0	0	0	--	--	0	0	0	0	0	--	--	0	Sez. 1_Sp. A
Sez. 1_Sp. A	0	SL fatica., Vmin	0	0	0	0	0	0	--	--	0	0	0	0	0	--	--	0	Sez. 1_Sp. A
Sez. 2a_2a	7	SL fatica., Mmax	0.25	0.196	0.344	0.13	0.52	0.16	0.174	0.72	0.105	0.498	0.779	0.165	0.779	--	--	0	Sez. 2a_2a
Sez. 2a_2a	7	SL fatica., Mmin	0.25	0.196	0.344	0.13	0.52	0.16	0.174	0.72	0.105	0.498	0.779	0.165	0.779	--	--	0	Sez. 2a_2a
Sez. 2a_2a	7	SL fatica., Vmax	0	0	0	0	0	0	0	0	0	0	0	0	0	--	--	0	Sez. 2a_2a
Sez. 2a_2a	7	SL fatica., Vmin	0	0	0	0	0	0	0	0	0	0	0	0	0	--	--	0	Sez. 2a_2a
Sez. 2b_2b	7	SL fatica., Mmax	0.36	0.211	0.44	0.14	0.37	0.15	0.188	0.558	0.12	0.341	0.533	0.187	0.533	--	--	0	Sez. 2b_2b
Sez. 2b_2b	7	SL fatica., Mmin	0.36	0.211	0.44	0.14	0.37	0.15	0.188	0.558	0.12	0.341	0.533	0.187	0.533	--	--	0	Sez. 2b_2b
Sez. 2b_2b	7	SL fatica., Vmax	0	0	0	0	0	0	0	0	0	0	0	0	0	--	--	0	Sez. 2b_2b
Sez. 2b_2b	7	SL fatica., Vmin	0	0	0	0	0	0	0	0	0	0	0	0	0	--	--	0	Sez. 2b_2b
Sez. 3a_3a	17	SL fatica., Mmax	0.204	0.394	0.46	0.25	0.68	0.09	0.35	0.837	0.223	0.636	0.994	0.349	0.994	--	--	0	Sez. 3a_3a
Sez. 3a_3a	17	SL fatica., Mmin	0.204	0.394	0.46	0.25	0.68	0.09	0.35	0.837	0.223	0.636	0.994	0.349	0.994	--	--	0	Sez. 3a_3a
Sez. 3a_3a	17	SL fatica., Vmax	0	0	0	0	0	0	0	0	0	0	0	0	0	--	--	0	Sez. 3a_3a
Sez. 3a_3a	17	SL fatica., Vmin	0	0	0	0	0	0	0	0	0	0	0	0	0	--	--	0	Sez. 3a_3a
Sez. 3b_3b	17	SL fatica., Mmax	0.186	0.363	0.422	0.23	0.62	0.07	0.363	0.772	0.184	0.567	0.886	0.288	0.886	--	--	0	Sez. 3b_3b
Sez. 3b_3b	17	SL fatica., Mmin	0.186	0.363	0.422	0.23	0.62	0.07	0.363	0.772	0.184	0.567	0.886	0.288	0.886	--	--	0	Sez. 3b_3b
Sez. 3b_3b	17	SL fatica., Vmax	0	0	0	0	0	0	0	0	0	0	0	0	0	--	--	0	Sez. 3b_3b
Sez. 3b_3b	17	SL fatica., Vmin	0	0	0	0	0	0	0	0	0	0	0	0	0	--	--	0	Sez. 3b_3b
Sez. 4a_4a	27	SL fatica., Mmax	0.49	0.664	0.888	0.43	0.44	0.18	0.664	0.691	0.376	0.394	0.615	0.588	0.615	--	--	0	Sez. 4a_4a
Sez. 4a_4a	27	SL fatica., Mmin	0.49	0.664	0.888	0.43	0.44	0.18	0.664	0.691	0.376	0.394	0.615	0.588	0.615	--	--	0	Sez. 4a_4a
Sez. 4a_4a	27	SL fatica., Vmax	0	0	0	0	0	0	0	0	0	0	0	0	0	--	--	0	Sez. 4a_4a
Sez. 4a_4a	27	SL fatica., Vmin	0	0	0	0	0	0	0	0	0	0	0	0	0	--	--	0	Sez. 4a_4a
Sez. 4b_4b	27	SL fatica., Mmax	0.311	0.531	0.648	0.34	0.34	0.11	0.553	0.56	0.293	0.297	0.464	0.458	0.464	--	--	0	Sez. 4b_4b
Sez. 4b_4b	27	SL fatica., Mmin	0.311	0.531	0.648	0.34	0.34	0.11	0.553	0.56	0.293	0.297	0.464	0.458	0.464	--	--	0	Sez. 4b_4b
Sez. 4b_4b	27	SL fatica., Vmax	0	0	0	0	0	0	0	0	0	0	0	0	0	--	--	0	Sez. 4b_4b
Sez. 4b_4b	27	SL fatica., Vmin	0	0	0	0	0	0	0	0	0	0	0	0	0	--	--	0	Sez. 4b_4b
Sez. 5_5	33	SL fatica., Mmax	0.761	0.345	0.851	0.22	0.28	0.27	--	--	0.187	0.245	0.382	0.291	0.382	--	--	0	Sez. 5_5
Sez. 5_5	33	SL fatica., Mmin	0.761	0.345	0.851	0.22	0.28	0.27	--	--	0.187	0.245	0.382	0.291	0.382	--	--	0	Sez. 5_5
Sez. 5_5	33	SL fatica., Vmax	0	0	0	0	0	0	--	--	0	0	0	0	0	--	--	0	Sez. 5_5
Sez. 5_5	33	SL fatica., Vmin	0	0	0	0	0	0	--	--	0	0	0	0	0	--	--	0	Sez. 5_5

10 TRAVERSI

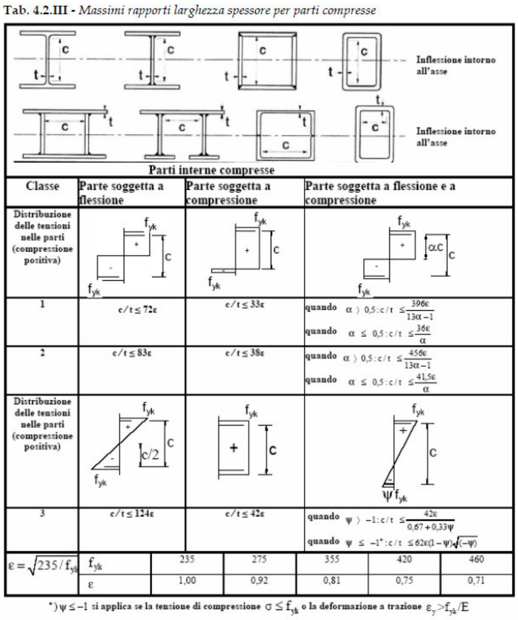
Tutti i traversi vengono connessi alla soletta mediante piolatura, l'interasse dei traversi è di 11.0m. I traversi sono costituiti da travi in parete piena colleganti alle travi principali tramite saldatura e collegati tra loro mediante bullonatura.

Le caratteristiche geometriche della sezione dei traversi sono riportate nella tabella che segue.

Traverso	Piattabanda sup. (mm)	Anima (mm)	Piattabanda inf. (mm)	Altezza ferro (mm)
Diaframmi a parete piena	350 x 25	14	350 x 25	550

Per prima cosa si procede a determinare la classe della sezione ai sensi di NTC18 4.2.3.1:

Tab. 4.2.III - *Massimi rapporti larghezza spessore per parti compresse*

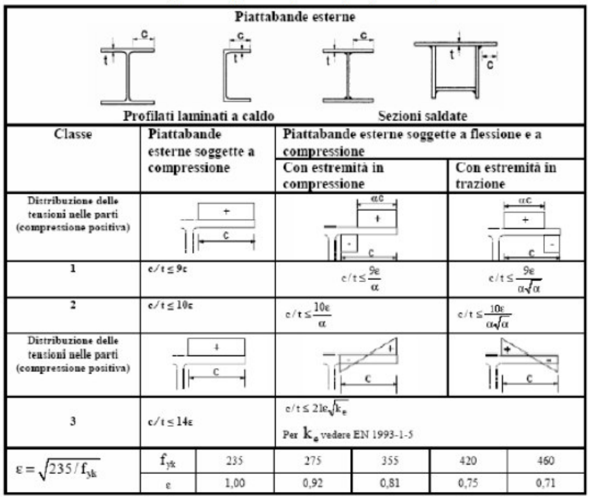


Classe	Parte soggetta a flessione	Parte soggetta a compressione	Parte soggetta a flessione e a compressione
Distribuzione delle tensioni nelle parti (compressione positiva)			
1	$c/t \le 72\varepsilon$	$c/t \le 33\varepsilon$	quando $\alpha > 0,5$: $c/t \le \frac{396\varepsilon}{13\alpha-1}$; quando $\alpha \le 0,5$: $c/t \le \frac{36\varepsilon}{\alpha}$
2	$c/t \le 83\varepsilon$	$c/t \le 38\varepsilon$	quando $\alpha > 0,5$: $c/t \le \frac{456\varepsilon}{13\alpha-1}$; quando $\alpha \le 0,5$: $c/t \le \frac{41,5\varepsilon}{\alpha}$
Distribuzione delle tensioni nelle parti (compressione positiva)			
3	$c/t \le 124\varepsilon$	$c/t \le 42\varepsilon$	quando $\psi > -1$: $c/t \le \frac{42\varepsilon}{0,67+0,33\psi}$; quando $\psi \le -1$*: $c/t \le 62\varepsilon(1-\psi)\sqrt{(-\psi)}$

$\varepsilon = \sqrt{235/f_{yk}}$	f_{yk}	235	275	355	420	460
	ε	1,00	0,92	0,81	0,75	0,71

*) $\psi \le -1$ si applica se la tensione di compressione $\sigma \le f_{yk}$ o la deformazione a trazione $\varepsilon_y > f_{yk}/E$

Tab. 4.2.IV - *Massimi rapporti larghezza spessore per parti compresse*



Classe	Piattabande esterne soggette a compressione	Piattabande esterne soggette a flessione e a compressione: Con estremità in compressione	Con estremità in trazione
Distribuzione delle tensioni nelle parti (compressione positiva)			
1	$c/t \le 9\varepsilon$	$c/t \le \frac{9\varepsilon}{\alpha}$	$c/t \le \frac{9\varepsilon}{\alpha\sqrt{\alpha}}$
2	$c/t \le 10\varepsilon$	$c/t \le \frac{10\varepsilon}{\alpha}$	$c/t \le \frac{10\varepsilon}{\alpha\sqrt{\alpha}}$
Distribuzione delle tensioni nelle parti (compressione positiva)			
3	$c/t \le 14\varepsilon$	$c/t \le 21\varepsilon\sqrt{k_\sigma}$ Per k_σ vedere EN 1993-1-5	

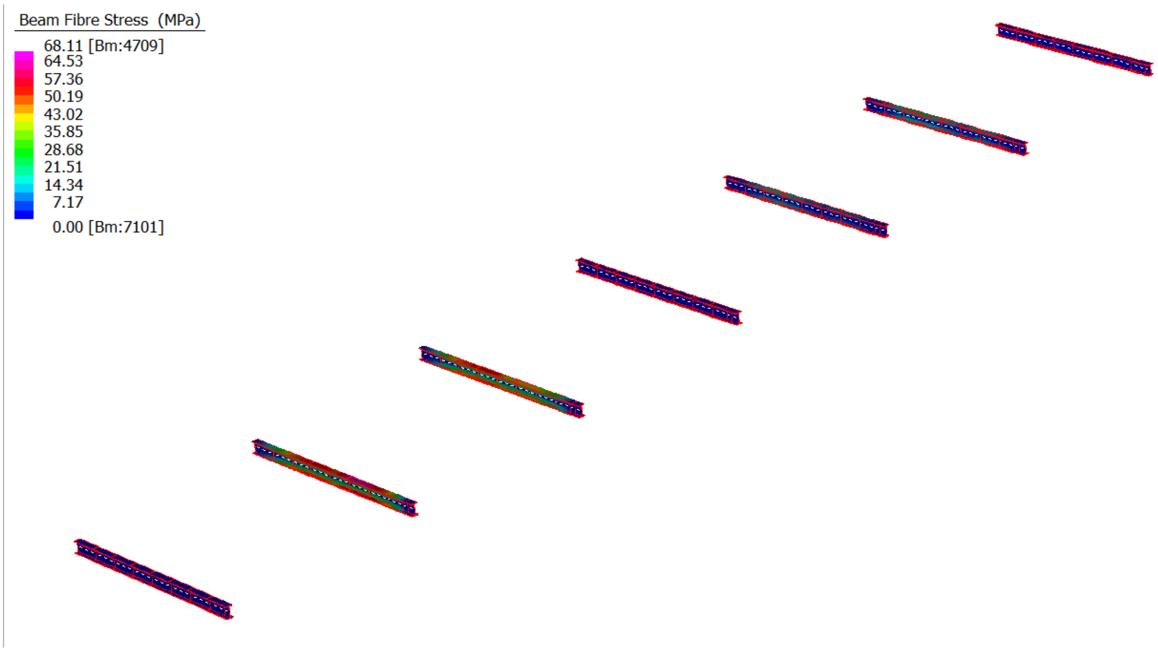
$\varepsilon = \sqrt{235/f_{yk}}$	f_{yk}	235	275	355	420	460
	ε	1,00	0,92	0,81	0,75	0,71

- Piattabanda superiore/inferiore compressa: c/t = 168/25 = 6.72 < 9 ε = 6.72 → CLASSE 1
- Anima compressa: c/t = 500/14 = 35.7 < 72 ε = 58.3 → CLASSE 1

La sezione è quindi complessivamente in classe 1. Essendo quindi la sezione in classe 1 è lecito leggere direttamente le tensioni σ dal modello di calcolo.

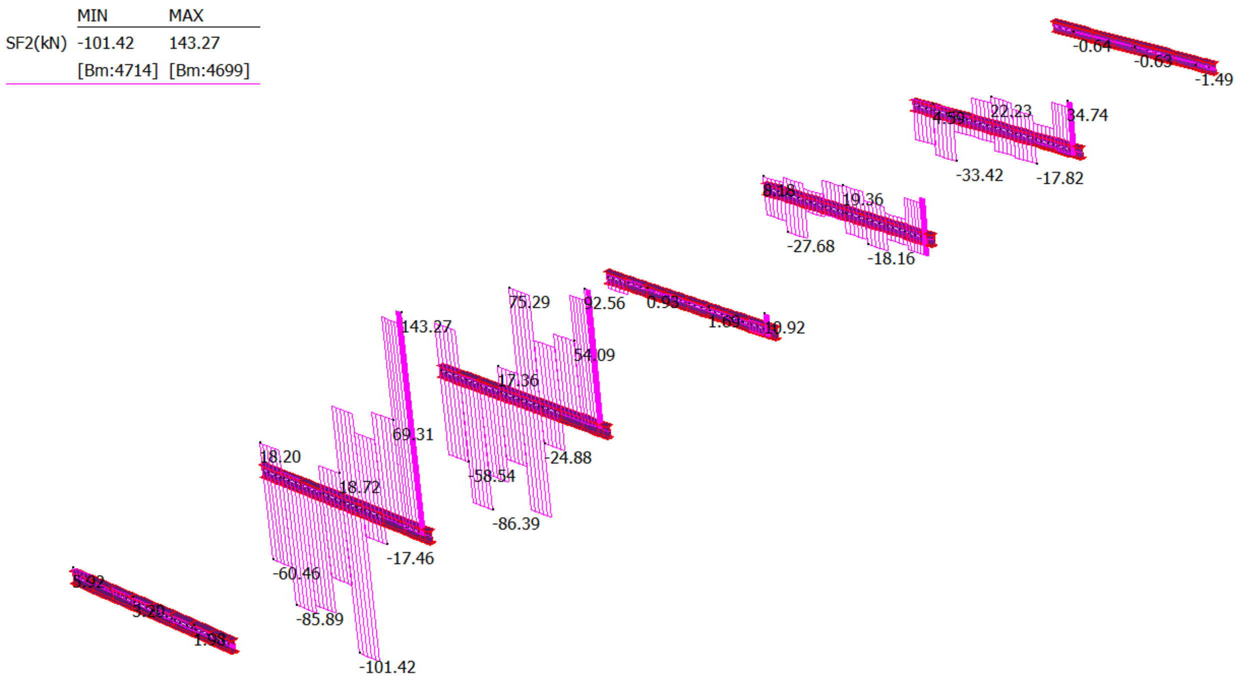
Si riportano di seguito le tensioni assiali nei traversi, soggetti ai carichi permanenti portati e alle massime sollecitazioni traffico.

Le sollecitazioni sono caratteristiche:



$\sigma_{max\ SLU}$ = 68x1.35 = 92 MPa

mentre per la verifica a taglio si riportano i massimi tagli dati da carichi permanenti portati e inviluppo traffico:

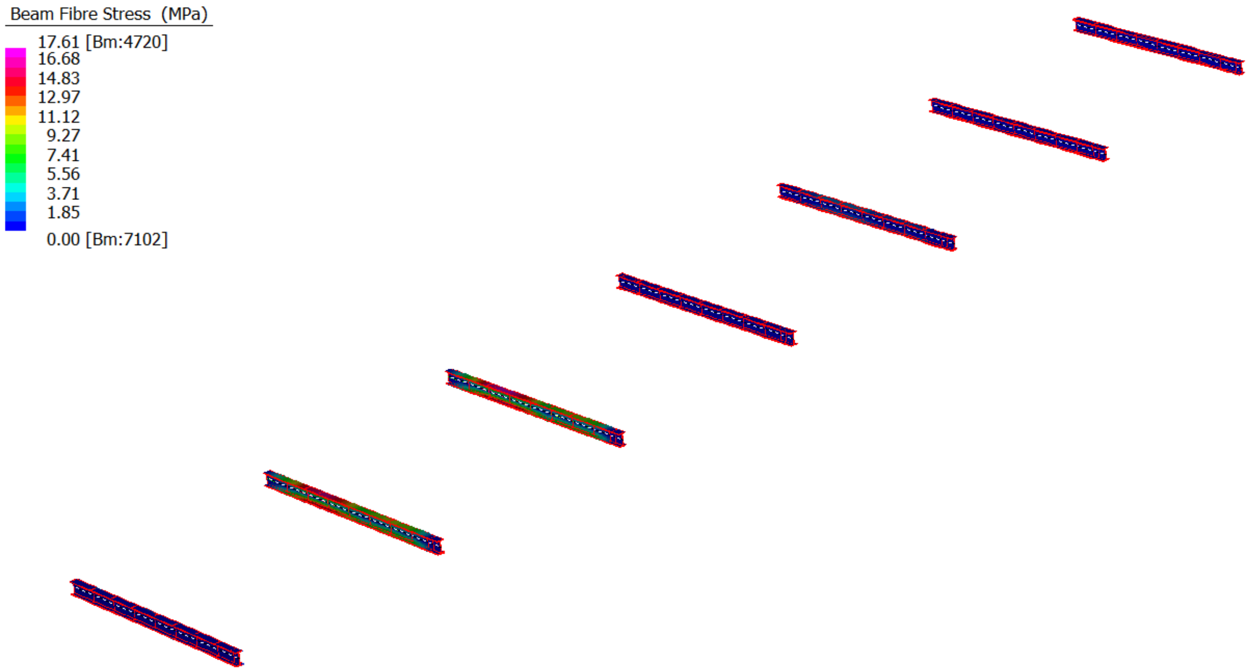


Il taglio massimo SLU è pari a V_{SLU} = 1.35x143 = 193 kN, e quindi nell'anima del traverso la verifica diventa:

V_{Rd} = 14x500x355/1.05/√3 = 1366 kN

La verifica è quindi abbondantemente soddisfatta.

Si riporta di seguito anche la verifica a fatica del traverso. La mappa delle tensioni diventa:



La massima escursione tensionale è quindi pari a 17 MPa.

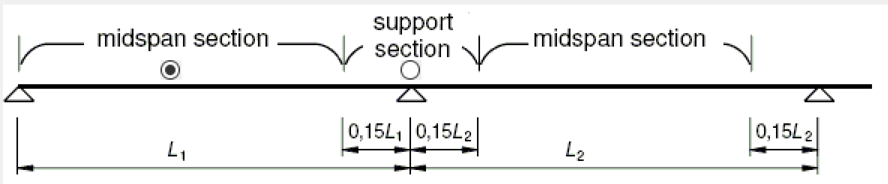
La verifica diventa:

$$\Delta\sigma = \gamma \cdot \lambda_1 \cdot \lambda_2 \cdot \lambda_3 \cdot \lambda_4 \cdot .....\cdot \lambda \cdot \varphi \cdot \Delta\sigma = \gamma \cdot \lambda \cdot \varphi \cdot \Delta\sigma_p$$

- λ_1 :

Fattore equivalente di danno LAMBDA1 per ponti stradali

Figure 9.7: Location of midspan or support



λ_1 , 9.5.2 (2) EN 1993-2, 2006(E)

			Bending moment	Shear force
at midspan		2.55 – 0.7 (L-10) / 70	L = length of span under consideration	L = 0.4 * span under consideration
at support	L< 30 m	2.00 – 0.3 (L-10) / 20	L = the mean of two adjacent spans	L = length of span under consideration
	L ≥ 30 m	1.70 + 0.5 (L-30) / 50		

Luce per i momenti (m) 1.2 $\lambda_1 =$ 2.638

Luce per i tagli (m) 0.48 $\lambda_1 =$ 2.645

OK Esci

- λ_2:

Vedi capitolo 7.1.6.1, pari a 0.848.

- λ_3 :

Vedi capitolo 7.1.6.1, pari a 1.0.

- λ_4 :

Vedi capitolo 7.1.6.1, pari a 1.15

Si ottiene:

$\Delta\sigma_{Ed}$ = 1x2.64x0.848x1x1.15x17 = 44 MPa < $\Delta\sigma_{Rd}$ = 80/1.35 = 59 MPa

Si riporta infine a verifica del giunto bullonato, considerando che nella piattabanda superiore agisce una forza di N_{SLU} = 350x25x92 = 805 kN e nell'anima un taglio SLU di V_{SLU} = 193 kN.

Si ricorda che la verifica di giunti di categoria B avviene a a taglio allo SLU e ad attrito allo SLE:

- Verifica SLU piattabande:

Sollecitazioni esterne					
σ4	92.0	Mpa	Piattabanda sup.	350	25
σ3	92.0	Mpa	Anima (incluse ali)	550	14
σ1	-92.0	Mpa	Piattabanda inf.	350	25
σ0	-92.0	Mpa	yg baricentro	275.00	
τ anima	27.6	MPa			

Bullone		
Classe bullone	10.9	
ftb	1000	Mpa
fyb	900	MPa
γM2	1.25	
γM3_SLU	1.25	
γM7	1.10	

Verifica SLU_NTC 4.2.8.1		
Piattabanda superiore		
Base	350	mm

Altezza	25	mm
N° bulloni	18	
Criterio di Verifica	A Taglio	
n° piani di taglio	2	
µ coeff. Di attrito	0.3	
Bullone M	16	
Ares	157	mm2
Gioco foro-bullone	A) Normale	
ks	1	
Ned piattabanda sup.	805	kN
Fp,Cd	99.9	kN
Fv,Rd	**62.8**	**kN**
Fv,Ed	**22.4**	**kN**
FS	**2.81**	
Piattabanda inferiore		
Base	350	mm
Altezza	25	mm
N° bulloni	18	
Criterio di Verifica	A Taglio	
n° piani di taglio	2	
µ coeff. Di attrito	0.3	
Bullone M	16	
Ares	157	mm2
Gioco foro-bullone	A) Normale	
ks	1	
Ned piattabanda inf.	-805	kN
Fp,Cd	99.9	kN
Fv,Rd	**62.8**	**kN**
Fv,Ed	**22.4**	**kN**
FS	**2.81**	

- Verifica SLE piattabande:

Sollecitazioni esterne					
σ4	68.1	Mpa	Piattabanda sup.	350	25
σ3	68.1	Mpa	Anima (incluse ali)	550	14
σ1	-68.1	Mpa	Piattabanda inf.	350	25
σ0	-68.1	Mpa		275.00	
τ anima	20.4	MPa			

Bullone		
Classe bullone	10.9	
ftb	1000	Mpa
fyb	900	MPa
γM2	1.25	
γM3_SLE	1.10	
γM7	1.10	

Varifica SLE_NTC 4.2.8.1		
Piattabanda superiore		
Base	350	mm
Altezza	25	mm
N° bulloni	18	
Criterio di Verifica	A Scorrimento	
n° piani di taglio	2	
μ coeff. Di attrito	0.3	
Bullone M	16	
Ares	157	mm2
Gioco foro-bullone	A) Normale	
ks	1	
Ned piattabanda sup.	596.2962963	kN
Fp,Cd	99.9	kN
Fs,Rd	**27.2**	**kN**
Fv,Ed	**16.6**	**kN**
FS	**1.65**	
Piattabanda inferiore		
Base	350	mm
Altezza	25	mm
N° bulloni	18	
Criterio di Verifica	A Scorrimento	
n° piani di taglio	2	
μ coeff. Di attrito	0.3	
Bullone M	16	

Ares	157	mm2
Gioco foro-bullone	A) Normale	
ks	1	
Ned piattabanda sup.	-596.2962963	kN
Fp,Cd	99.9	kN
Fs,Rd	**27.2**	**kN**
Fv,Ed	**16.6**	**kN**
FS	**1.65**	

- Verifica SLU anime:

Geometria Bullonatura								
	Xi [mm]	Xg [mm]		Yi [mm]	Yg [mm]	di [mm]	Ved [kN]
X1	-30.000	-46.875	Y1	135.000	882.250	883.5	10.4
X2	30.000	13.125	Y2	135.000	882.250	882.3	10.4
X3	-30.000	-46.875	Y3	45.000	792.250	793.6	9.3
X4	30.000	13.125	Y4	45.000	792.250	792.4	9.3
X5	-30.000	-46.875	Y5	-45.000	702.250	703.8	8.3
X6	30.000	13.125	Y6	-45.000	702.250	702.4	8.3
X7	-30.000	-46.875	Y7	-135.000	612.250	614.0	7.2
X8	30.000	13.125	Y8	-135.000	612.250	612.4	7.2

Dati Generali:		
N° bulloni	8	
Sp. Anima	14	mm
τ Ed,anima	27.57	MPa
Syy	135.000	mm
Sxx	-5,978.000	mm
Xg bulloni d'anima	16.875	mm
Yg bulloni d'anima	-747.250	mm
htot	550	mm
σ4	92.0	Mpa
σ3	92.0	Mpa
σ1	-92.0	Mpa
σ0	-92.0	Mpa
Y sup	275.0	mm
Y inf	275.0	mm
R1 (sup.)	161.0	kN
R2 (inf.)	-161.0	kN

Sollecitazioni globali sul collegamento:		
Med,anima	53.7	kNm
Ned,anima	0.0	kN
Ved,anima	193	kN
Sollecitazioni globali per bullone:		
F(M),Ed	10.4	kN
N(N),Ed	0.0	kN
V(V),Ed	24.1	kN
Sollecitazioni per asse per bullone:		
F(M),x,Ed	10.4	kN
F(M),y,Ed	0.6	kN
N(N),x,Ed	0.0	kN
V(V),y,Ed	24.1	kN
Fv,Ed	**26.77**	**kN**
Verifica SLU		
Criterio di Verifica	A Taglio	
n° piani di taglio	2	
μ coeff. Di attrito	0.3	
Bullone M	16	
Ares	157	mm2
Gioco foro-bullone	A) Normale	
ks	1	
Classe bullone	10.9	
ftb	1000	Mpa
fyb	900	MPa
γM2	1.25	
γM3	1.25	
γM7	1.10	
Fp,Cd	99.9	kN
Fv,Rd	**62.8**	**kN**
Fv,Ed	**13.4**	**kN**
FS	**4.69**	

- Verifica SLE anime:

Dati Generali:		
N° bulloni	8	
Sp. Anima	14	mm
τ Ed,anima	20.42	MPa
Syy	135.000	mm
Sxx	-5,978.000	mm
Xg bulloni d'anima	16.875	mm
Yg bulloni d'anima	-747.250	mm
htot	550	mm
σ4	68.1	Mpa
σ3	68.1	Mpa
σ1	-68.1	Mpa
σ0	-68.1	Mpa
Y sup	275.0	mm
Y inf	275.0	mm
R1 (sup.)	119.3	kN
R2 (inf.)	-119.3	kN
Sollecitazioni globali sul collegamento:		
Med,anima	39.8	kNm
Ned,anima	0.0	kN
Ved,anima	143	kN
Sollecitazioni globali per bullone:		
F(M),Ed	7.7	kN
N(N),Ed	0.0	kN
V(V),Ed	17.9	kN
Sollecitazioni per asse per bullone:		
F(M),x,Ed	7.7	kN
F(M),y,Ed	0.4	kN
N(N),x,Ed	0.0	kN
V(V),y,Ed	17.9	kN
Fv,Ed	**19.83**	**kN**
Verifica SLE		
Criterio di Verifica	A Scorrimento	
n° piani di taglio	2	
µ coeff. Di attrito	0.3	
Bullone M	16	
Ares	157	mm2
Gioco foro-bullone	A) Normale	
ks	1	

Classe bullone	10.9	
ftb	1000	Mpa
fyb	900	MPa
γM2	1.25	
γM3	1.25	
γM7	1.10	
Fp,Cd	99.9	kN
Fs,Rd	**24.0**	**kN**
Fv,Ed	**9.9**	**kN**
FS	**2.42**	

- Verifica trave depurata dai fori:

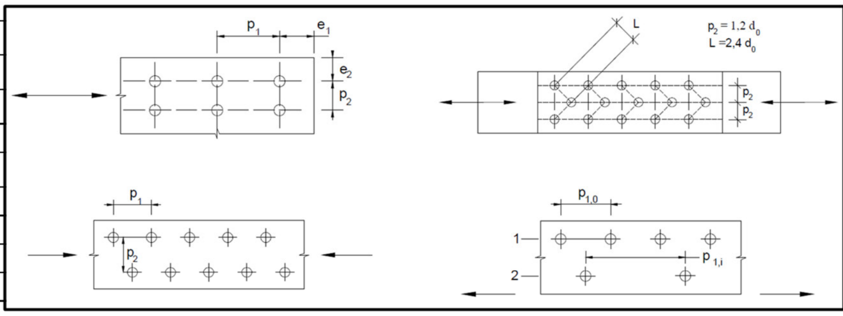
		n° bulloni	N_{Ed}	$A_{piattabanda,\ depurata}$	$\sigma_{piattabanda,\ depurata}$	$N_{pl,Rd}$	$N_{u,Rd}$	Verifica
			[kN]	[mm²]	[N/mm²]	[kN]	[kN]	Rd/Ed
Piattabanda Sup.	Sezione senza fori	-	805.0	8750	92.0	2958.3	3213.0	3.67
	1° fila di bulloni	6	805.0	6200	129.8	2958.3	2276.6	2.83
	2° fila di bulloni	6	536.67	6200	86.6	2958.3	2276.6	4.24
	3° fila di bulloni	6	268.33	6200	43.3	2958.3	2276.6	8.48
	4° fila di bulloni	0	0	8750	0.0	2958.3	3213.0	#DIV/0!

		n° bulloni	N_{Ed}	$A_{piattabanda,\ depurata}$	$\sigma_{piattabanda,\ depurata}$	$N_{pl,Rd}$	$N_{u,Rd}$	Verifica
			[kN]	[mm²]	[N/mm²]	[kN]	[kN]	Rd/Ed
Piattabanda Inf.	Sezione senza fori	-	805.0	8750	92.0	2958.3	3213.0	3.67
	1° fila di bulloni	6	805.0	6200	129.8	2958.3	2276.6	2.83
	2° fila di bulloni	6	536.7	6200	86.6	2958.3	2276.6	4.24
	3° fila di bulloni	6	268.3	6200	43.3	2958.3	2276.6	8.48
	4° fila di bulloni	0	0.0	8750	0.0	2958.3	3213.0	#DIV/0!

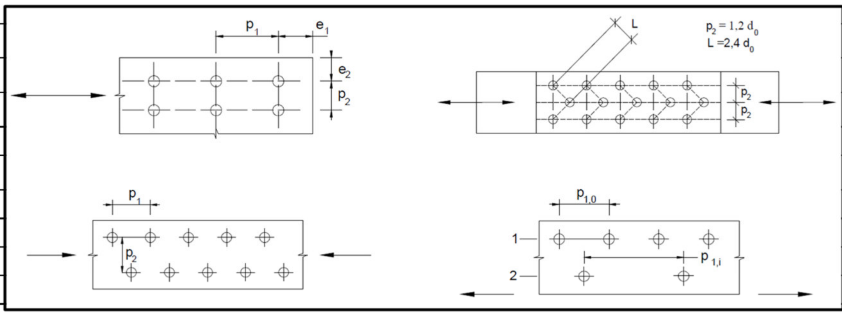
		n° bulloni	N_{Ed}	M_{Ed}	V_{Ed}	$A_{anima,\ depurata}$	$J_{anima,\ depurata}$	$W_{anima\ inf,\ depurata}$	$W_{anima\ sup,\ depurata}$	$\sigma_{SLU\ anima\ inf\ depurata.}$	$\sigma_{SLU\ anima\ sup\ depurata.}$	$\tau_{SLU\ anima\ depurata}$	$\sigma_{id,anima\ depurata.}$	Verifica
			[kN]	[kNm]	[kN]	[mm²]	[mm⁴]	[mm³]		[N/mm²]	[N/mm²]	[N/mm²]	[N/mm²]	Rd/Ed
Anima	Sezione senza fori	-	0.0	53.7	193.0	7,000.00	145,833,333.33	583,333.33	583,333.33	-92.0	92.0	27.6	103.7	3.26
	1° fila di bulloni	4	0.0	53.7	193.0	6,048.00	73,000,000.00	292,000.00	292,000.00	-183.8	183.8	31.9	191.9	1.76

- Rifollamento coprigiunti:

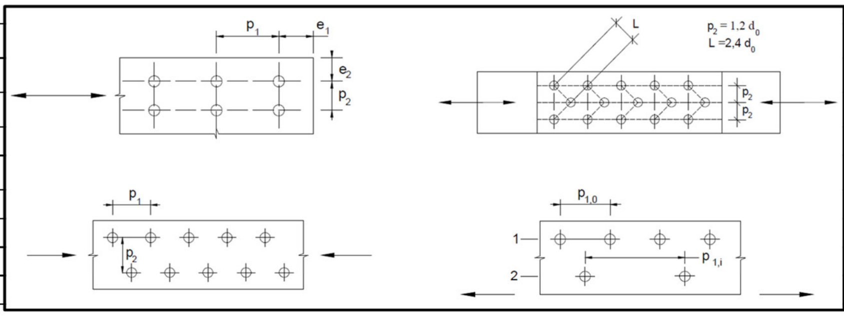
COPROGIUNTO PIATTABANDA SUPERIORE		
Acciaio	S355	
f_{tk}	510	Mpa
f_{tb}	1000	
γ_{M2}	1.25	
d	16.00	mm
$\phi_{foro} = d_0$	17	mm
Spess. Coprigiunto	15	mm
e1	40	Ok
e2	40	Ok
p1	60	Ok
p2	50	Ok
α1	0.784	Bullone di bordo nella direzione parallela al carico applicato
α2	0.926	Bullone interno nella direzione parallela al carico applicato
k1	2.500	Bullone di bordo nella direzione perpendicolare al carico applicato
k2	2.418	Bullone interno nella direzione perpendicolare al carico applicato
$F_{b,Rd,1}$	192.0	kN - Bulloni di bordo
$F_{b,Rd,2}$	219.3	kN - Bulloni interni
$F_{v,Ed}$	22.36111	kN
FS	8.59	



COPROGIUNTO PIATTABANDA INFERIORE		
Acciaio	S355	
f_{tk}	510	Mpa
f_{tb}	1000	
γ_{M2}	1.25	
d	16	mm
$\phi_{foro} = d_0$	17	mm
Spess. Coprigiunto	15	mm
e1	40	Ok
e2	40	Ok
p1	60	Ok
p2	50	Ok
α1	0.784	Bullone di bordo nella direzione parallela al carico applicato
α2	0.926	Bullone interno nella direzione parallela al carico applicato
k1	2.500	Bullone di bordo nella direzione perpendicolare al carico applicato
k2	2.418	Bullone interno nella direzione perpendicolare al carico applicato
$F_{b,Rd,1}$	192.0	kN - Bulloni di bordo
$F_{b,Rd,2}$	219.3	kN - Bulloni interni
$F_{v,Ed}$	22.36	kN
FS	8.59	



COPROGIUNTO ANIMA		
Acciaio	S355	
f_{tk}	510	Mpa
f_{tb}	1000	
γ_{M2}	1.25	
d	16	mm
$\phi_{foro} = d_0$	17	mm
Spess. Coprigiunto	10	mm
e1	40	Ok
e2	60	Ok
p1	0	NO!
p2	0	NO!
α1	0.784	Bullone di bordo nella direzione parallela al carico applicato
α2	-0.250	Bullone interno nella direzione parallela al carico applicato
k1	2.500	Bullone di bordo nella direzione perpendicolare al carico applicato
k2	-1.700	Bullone interno nella direzione perpendicolare al carico applicato
$F_{b,Rd,1}$	128.0	kN - Bulloni di bordo
$F_{b,Rd,2}$	27.7	kN - Bulloni interni
$F_{v,Ed}$	13.39	kN
FS	2.07	



11 SOLETTA

I criteri di calcolo, di progettazione e la fasistica della soletta d'impalcato sono descritti al paragrafo 5 del presente documento. La soletta è costituita da una lastra in acciaio dello spessore di 5mm, alla quale vengono saldati i tralicci elettrosaldati h = 12.5 cm posti ad interasse di 40 cm. Le lastre vengono posizionate isostaticamente sui traversi in semplice appoggio con luce tipica in prima fase pari a 0.70m. Le lastre vengono inoltre saldate tra loro in direzione longitudinale. Successivamente viene eseguito in opera il getto di calcestruzzo.

Come descritto precedentemente, la soletta è analizzata in due fasi distinte:

- una prima fase, detta "provvisionale", in cui il getto integrativo è ancora in fase fluida e risultano efficaci le sole armature del traliccio e la lastra in acciaio. Le azioni presenti sono costituite dal peso proprio delle lastre, dal getto integrativo e da un temporaneo sovraccarico accidentale dovuto al personale, ai piccoli mezzi d'opera e ad accumuli di conglomerato cementizio;

- una seconda fase, detta "definitiva", in cui nella soletta monolitica risultano efficaci anche le armature inserite in opera. Il calcolo delle sollecitazioni indotte dai carichi accidentali e permanenti verrà effettuato adottando una schematizzazione monodimensionale della sezione trasversale della soletta assumendo una striscia di larghezza unitaria. Lo schema statico adottato è quello di trave continua su ventinove appoggi.

11.1 CALCOLO DI FASE I

Si considera una soletta larga 0.4 m pari all'interasse del traliccio. Di seguito si riporta una rappresentazione schematica del traliccio.

Altezza totale del traliccio: h'0 =12.5 cm

Corrente superiore: 1 ϕ12

Corrente inferiore: 2 ϕ8

Staffe: 2 ϕ8

Carichi agenti:

- PESO PROPRIO:

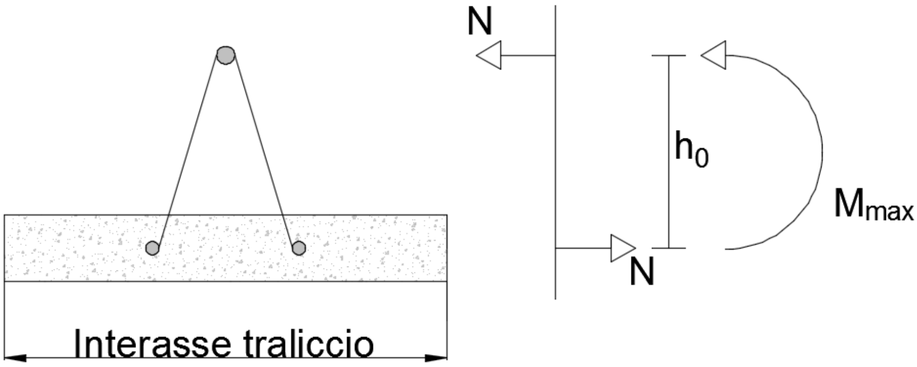
q = 0.005X78.50 + 0.20X25x0.20 = 5.39 kN/m

-MEZZI D'OPERA:

q = 1 kN/m^2

La lastra viene calcolata con uno schema statico di trave su 2 appoggi, considerando una luce di calcolo pari a 0.70 m (luce libera tra due piattabande dei traversi). Nel seguito si riporta il calcolo.

Il momento flettente è equilibrato da una coppia interna costituita dal corrente superiore compresso e dalla armatura inf. tesa come illustrato nella seguente figura.



	Carichi		
Carichi	peso proprio predalle in acc	0.39	kN/mq
	getto integrativo cls	5.00	kN/mq
	sovraccarico	1.00	kN/mq
	Geometria tralicci		
	numero di tralicci nella lastra	1	m
Corrente Superiore	ø corrente superiore traliccio	12	mm
	area corrente sup.	113	mmq
	area correnti sup. / lastra	113	mmq
	momento di inerzia corrente sup.	1018	mmq x mmq
	raggio di inerzia corrente sup.	3.00	mm
	lunghezza libera di inflessione	20	cm
	lambda correnti sup.	67	
Corrente Inferiore	ø corrente inferiore traliccio	8	mm
	area corrente inf.	50	mmq
	numero di ferri inf. aggiuntivi	0	
	ø ferri inf. aggiuntivi	0	mm
	area ferri aggiuntivi	0	mmq
	altezza totale traliccio	12.50	cm
	altezza utile traliccio	11.50	cm
staffe	ø staffa traliccio	8	mm
	area staffa	50	mmq
	area staffe / lastra	101	mmq
	momento di inerzia staffa	201	mmq x mmq

	raggio di inerzia correnti inf.	2.00	mmc
	lunghezza libera di inflessione	14.07	cm
	lambda staffe	70	
	alfa	1.04	rad
	beta	0.32	rad
	larghezza piattabanda	0	m
	lunghezza sbalzo	0	m
	lunghezza campata	0.7	m
	Momento indotto dagli sbalzi	0.00	kNm/m
	Sollecitazioni unitarie		
	M=	0.39	kNm/m
	T=	2.24	KN/m
	Sollecitazioni sulla lastra		
	larghezza lastra	0.40	m
	M SLU=	0.21	kNm/lastra
	T SLU=	1.21	kN/lastra
	S SLU staffe	2.00	kN/lastra
	Tensioni sugli elementi		
	Trazione sui correnti inf.	18.29	N/mmq
	Compressione nei correnti sup.	16.26	N/mmq
	Compressione nelle staffe	19.85	N/mmq
	Instabilità compressione (ferro sup)		
	Ned	1.84	kN
	A	113.10	mmq
	J	1017.876	mmc
	fyk	450	N/mmq
	γM1	1.1	
	E	210000	N/mmq
	l	200	mm
	β	1	

l0	200	mm
Ncr	52741.68	N
λ	0.98	
α	0.49	
ϕ	1.174	
χ	0.55	
Nb,Rd	25.46	kN
Coeff sicurezza	13.85	

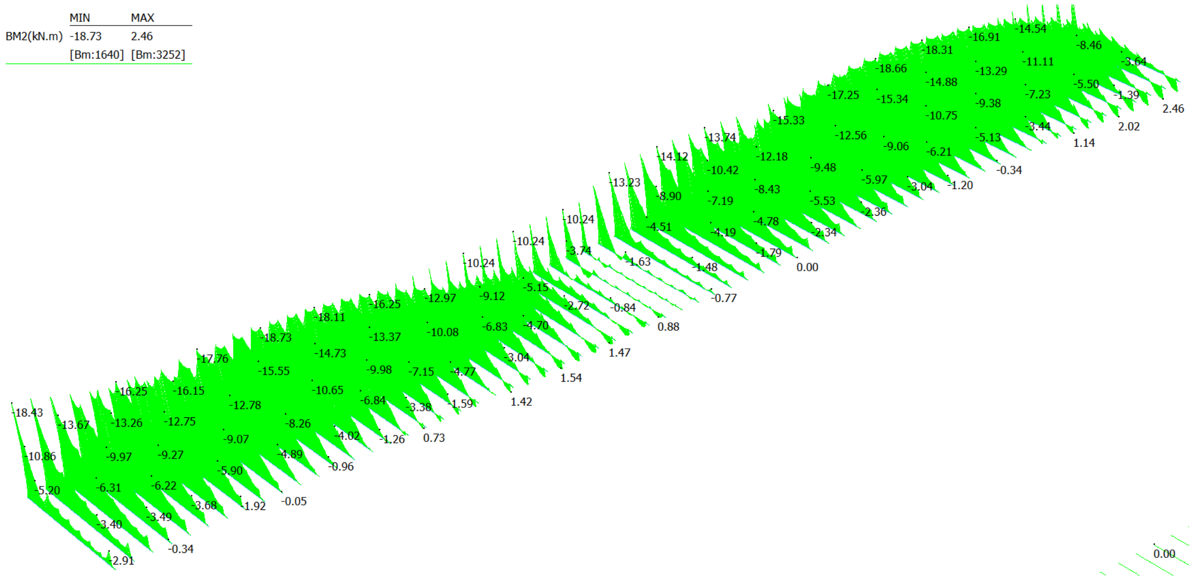
Instabilità staffa		
Ned	1.00	kN
A	50.27	mmq
J	201.06	mmc
fyk	450	N/mmq
γM1	1.1	
E	210000	N/mmq
l	140.70	mm
β	1	
l0	140.70	mm
Ncr	21048.937	
λ	1.04	
α	0.49	
ϕ	1.242	
χ	0.519	
Nb,Rd	10.67	kN
Coeff sicurezza	10.70	

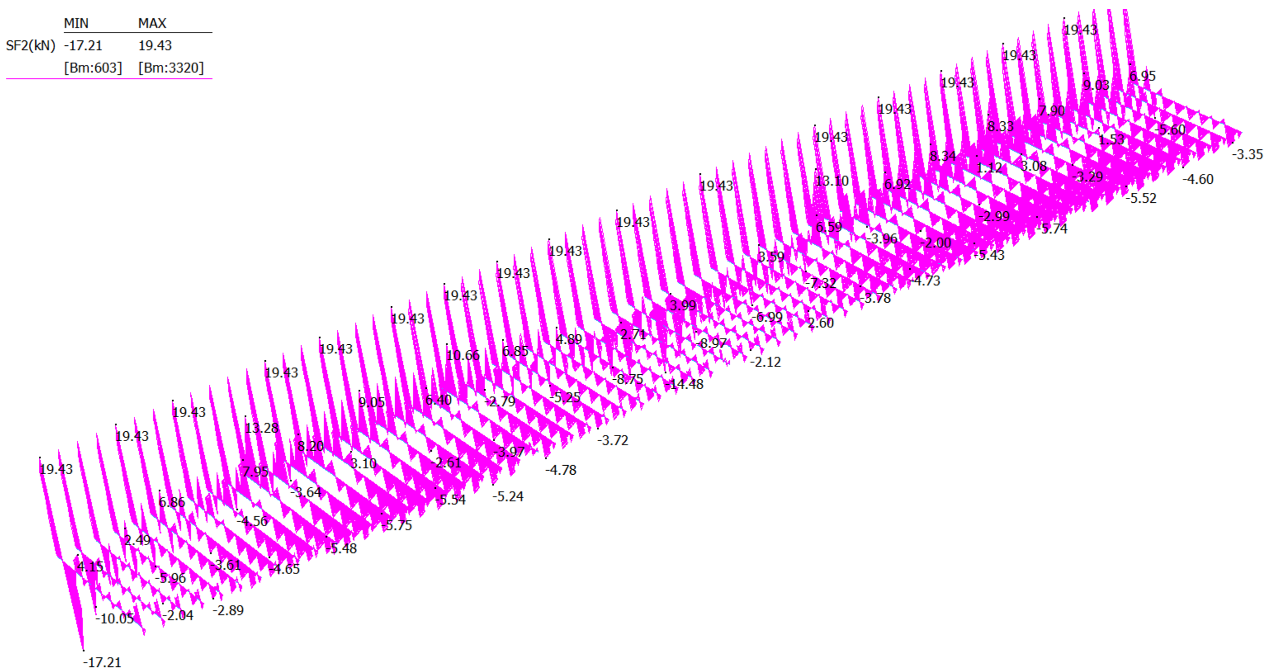
11.2 CALCOLO DI FASE II

La soletta è soggetta ai carichi permanenti ed ai carichi mobili. In questa fase si sono considerati anche ritiro e variazione termica per le verifiche allo stato limite di esercizio come richiesto dalla UNI EN 1992-1 -1 paragrafi 2.3.1.2 e 2.3.2.2. Per la valutazione delle sollecitazioni si è utilizzato il modello di calcolo 3d nel quale la soletta è schematizzata come beam di larghezza 1m.

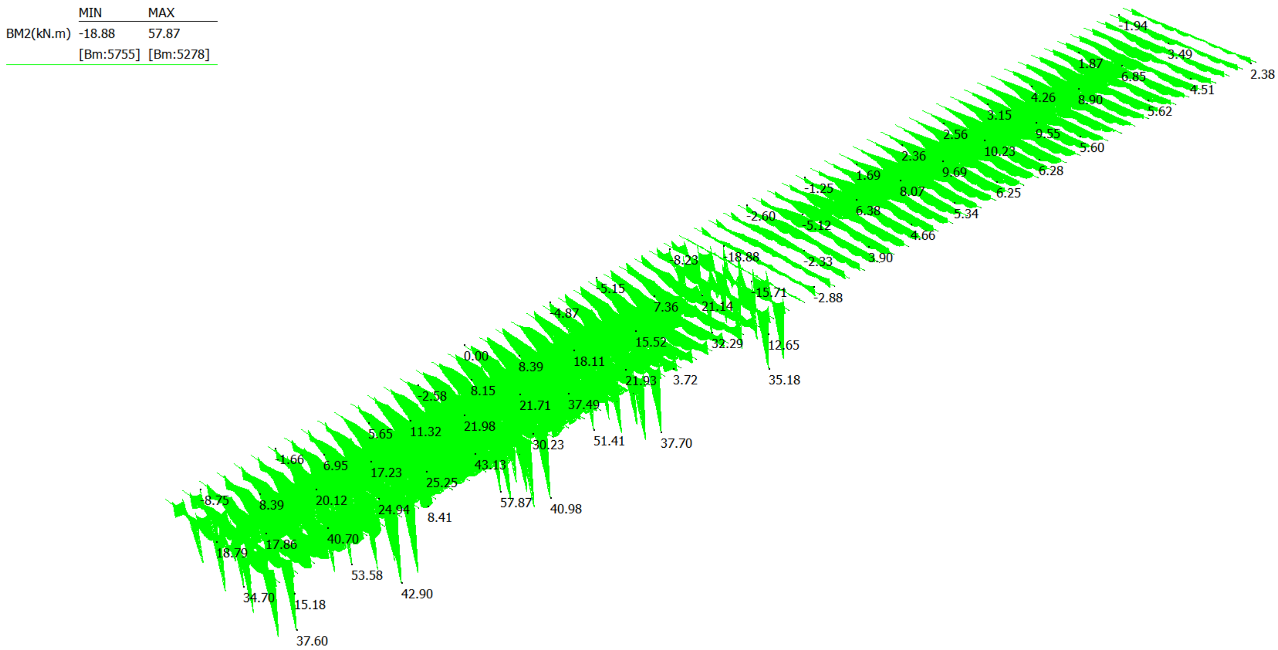
Di seguito vengono riportati gli inviluppi delle sollecitazioni.

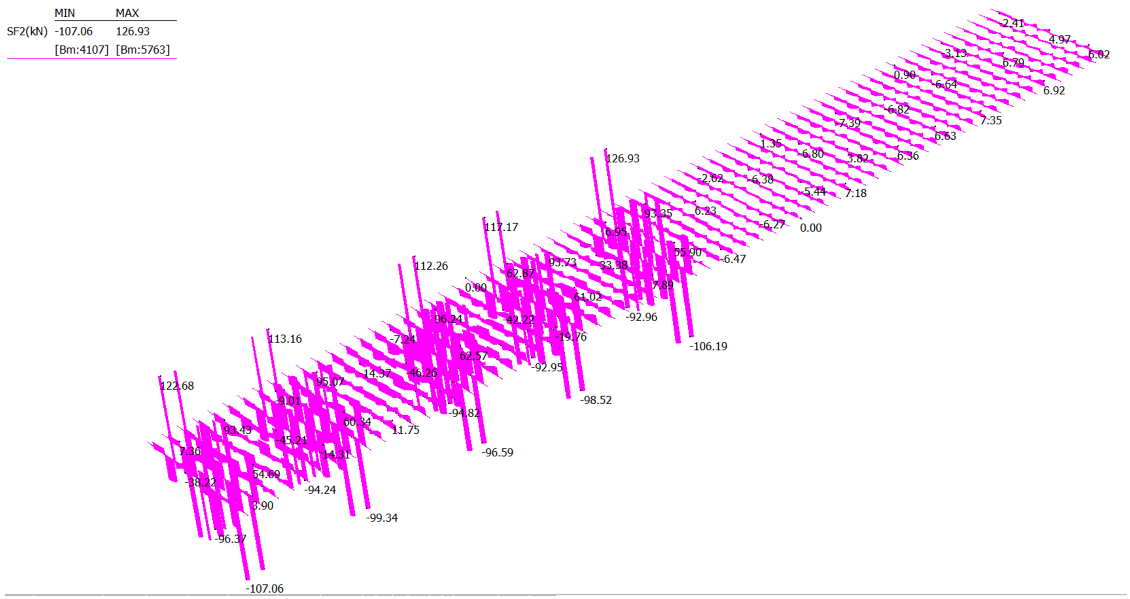
- Permanenti portati SLE:





- Inviluppo traffico SLE:





Si ottiene quindi una sollecitazione SLU pari a:

$M_{SLU,+}$ = 3x1.35+58x1.35 = 82 kNm/m

$M_{SLU,-}$ = 19x1.35+19x1.35 = 51 kNm/m

V_{SLU} =19x1.35+127x1.35 = 197 kN/m

$M_{SLE\ Fr,+}$ = 3+58x0.75 = 47 kNm/m

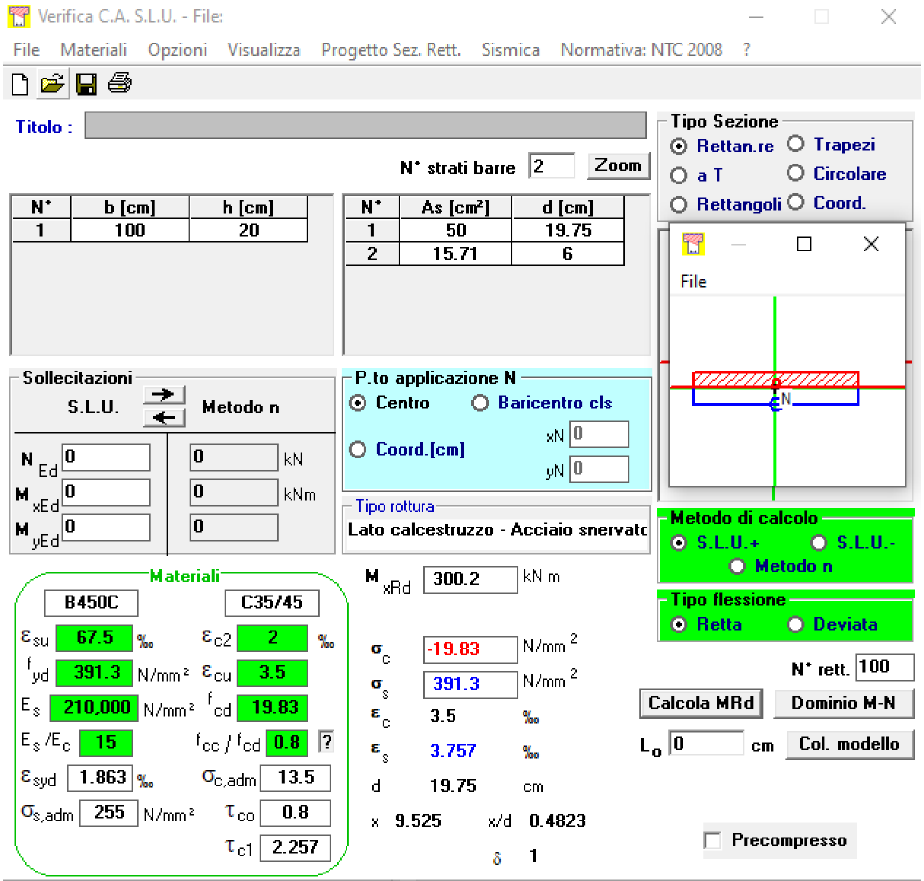
$M_{SLE\ Fr,-}$ = 19+19x0.75 = 33 kNm/m

11.2.1 Verifica SLU

11.2.2 Verifiche a flessione SLU

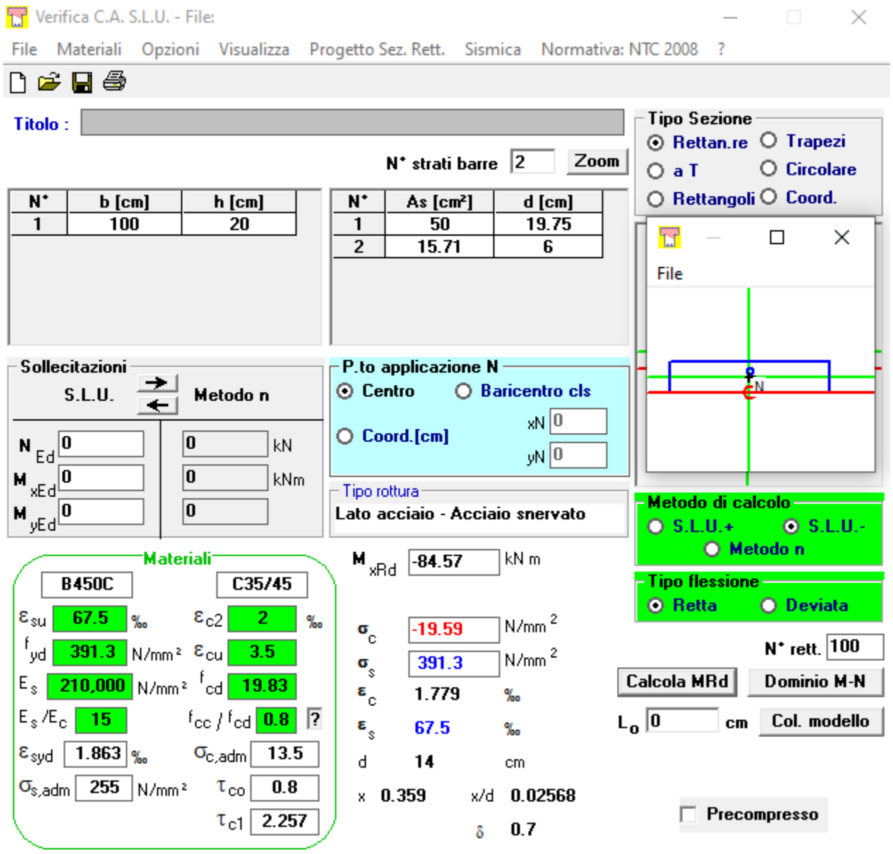
La soletta viene armata in direzione trasversale, superiormente con ferri Ø20/20cm, inferiormente si assume collaborante la piastra sp 5 mm. La verifica viene svolta considerando una sezione della larghezza di 1 metro e di spessore pari a 20 cm.

M+:



Verifica soddisfatta.

M-:



Verifica soddisfatta.

11.2.3 Verifica a taglio SLU

Il taglio massimo è pari a:

$V_{sd} = 197\ kN$

La verifica viene svolta considerando collaboranti le staffe del traliccio, in misura di staffe φ10/20 a 2 bracci a passo trasversale 40cm:

V_{sdu}	197	kN
M_{sdu}	-	kNm
N_{sdu}	0	kN
R_{ck}	45	N/mm²
f_{ck}	35	N/mm²
γ_c=	1.5	
fyk	450	N/mm²
bw	100	cm
d	15.00	cm

Asl	15.71	cm^2
c	5.00	cm
α	60	gradi
α	1.05	rad
θ	21.80	gradi
ctgθ	2.50	
$\theta_{imposto}$	21.80	gradi
Asw	3.93	cm^2
passo staffe	20.00	cm
Precompresso	no	
A_{lorda}	0.99	m^2
τ	1.877	N/mm^2
σ	1.877	N/mm^2
cotgθI	1.00	
θ_{min}	45.00	°
Check $\theta > \theta_I$	Non soddisfatto!!!	
f_{cd}	19.833	N/mm^2
$fctd_{0,05}$	1.877	N/mm^2
fyd	391.304	N/mm^2
σ_{cp}	0.0000	N/mm^2
verifica senza armatura resistente a taglio		
V_{Rd}	119.588	kN
$V_{Rd,min}$	87.849	kN
$\rho_{sw,min}$	0.001052	
$s_{l,max}$	17.75	cm
$A_{sw,min}$	1.616	$cm^2/s_{l,max}$
verifica con armatura resistente a taglio (staffe)		
V_{Rcd}	568.212	kN
V_{Rsd}	276.306	kN
V_{Rd}	276.306	kN

La verifica risulta soddisfatta.

11.2.4 Verifiche SLE a fessurazione

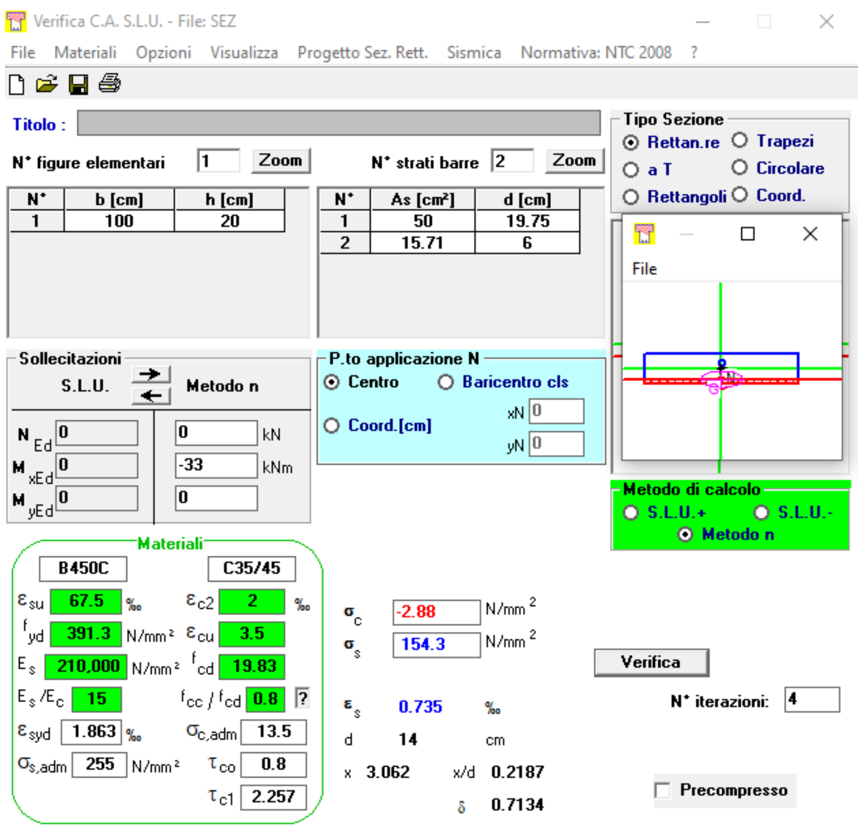
In accordo con il par. 5.1.4.4 del DM 17/01/18 nel caso di struttura in calcestruzzo ordinario si rispettano le limitazioni di tab. 4.1.IV relative al caso di armature poco sensibili. Si verificano unicamente le combinazioni di carico delle sezioni correnti.

Tab. 4.1.IV - *Criteri di scelta dello stato limite di fessurazione*

Gruppi di Esigenze	Condizioni ambientali	Combinazione di azioni	Armatura			
			Sensibile		Poco sensibile	
			Stato limite	w_k	Stato limite	w_k
A	Ordinarie	frequente	apertura fessure	$\leq w_2$	apertura fessure	$\leq w_3$
		quasi permanente	apertura fessure	$\leq w_1$	apertura fessure	$\leq w_2$
B	Aggressive	frequente	apertura fessure	$\leq w_1$	apertura fessure	$\leq w_2$
		quasi permanente	decompressione	-	apertura fessure	$\leq w_1$
C	Molto aggressive	frequente	formazione fessure	-	apertura fessure	$\leq w_1$
		quasi permanente	decompressione	-	apertura fessure	$\leq w_1$

Essendo, in accordo con il par. 4.1.2.2.4:
combo freq → w_1 = 0.2 mm
combo q.p. → w_1 = 0.2 mm

Tali verifiche vengono eseguite in corrispondenza dell'appoggio, in quanto a momento positivo essendo presente la lastra metallica non è significativa la verifica a fessurazione.



La tensione sulle barre è pari a 154 MPa.

Nella verifica si somma alla deformazione della barra dovuta alle azione esterne, la deformazione dovuta alle coazioni quali ritiro e variazione termica., pari a:

$$\varepsilon_{ritiro} = 1 \cdot 10^{-4} \qquad \varepsilon_{\Delta t} = 1.2 \cdot 10^{-4}$$

La verifica risulta quindi:

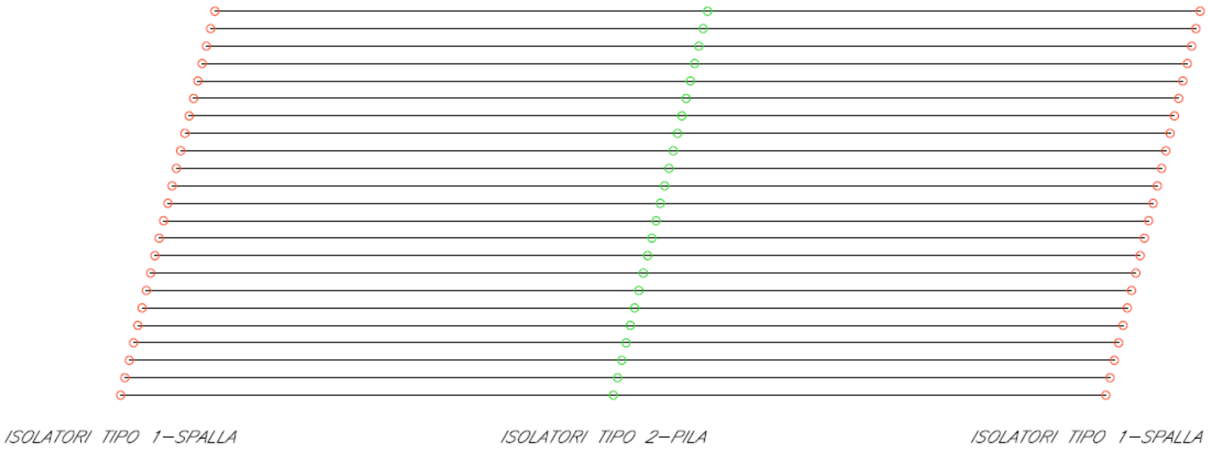
Combinazione FREQUENTE			
Caratteristiche dei materiali			
Coefficiente di omogeneizzazione cls teso-compr.	n'=	0.6	
Coefficiente di omogeneizzazione acc.-cls	n =	15	
Classe cls	R_{ck} =	45	N/mm^2
Modulo elastico acciaio	E_s =	2.1E+05	N/mm^2
Modulo elastico cls	E_{cm} =	34625	N/mm^2
Caratteristiche geometriche della sezione			
Altezza	H =	20	cm
Larghezza	B =	100	cm
Area acciaio teso	A_s =	15.71	cm^2
Copriferro baricentro acciaio teso	cs =	5.00	cm
Area acciaio compresso	A'_s =	0	cm^2
Copriferro acciaio compresso	c's =	0	cm
Ricoprimento barre esterne tese	c =	4.0	cm
Ricoprimento barre interne tese	c+S =	0.0	cm
Diametro massimo barre tese	Φ =	2	cm
Sezione non fessurata: formazione fessure			
Momento flettente in condizioni di esercizio	M_{es} =	33.00	kNm
Sforzo assiale in condizioni di esercizio	N_{es} =	0.00	kN
Resistenza media a trazione semplice del cls	f_{ctm} =	3.35	N/mm^2
Resistenza a trazione per fless. del cls	σ_{ct} =	2.79	N/mm^2
Tensione al lembo teso cls (cls reagente a traz.)	σ_c =	2.37	N/mm^2
Sezione fessurata: apertura fessure			
Momento flettente in condizioni di fessurazione	M =	33.00	kNm
Sforzo assiale in condizioni di fessurazione	N =	0.00	kN
Distanza asse neutro da lembo compresso	x =	3.06	cm
Tensione cls compresso	σ_c =	-2.88	N/mm^2
Tensione barra esterna tesa	σ_s =	154.00	N/mm^2
Distanza media fra due fessure attigue			
Coefficiente k_2	k_2 =	0.5	
Tensioni nel calcestruzzo teso	σ_1=	2.84	N/mm^2
	σ_2=	-0.51	N/mm^2
Coefficiente k_3	k_3 =	3.400	
Larghezza efficace	b_{eff} =	100.0	cm
Altezza efficace	d_{eff} =	5.6	cm
Area efficace	A_{ceff} =	564.7	cm^2
Diametro equivalente	Φ_{eq} =	2.000	cm
Area armature poste in A_{ceff}	A_s =	15.71	cm^2
Distanza media fra due fessure attigue	Δ_{smax} =	25.821	cm
Deformazione unitaria media			
Coefficiente kt	k_t =	0.4	0.4 per caric
Coefficiente k_1	k_1 =	0.8	
Coefficiente k_4	k_4 =	0.425	
Deformazione unitaria media	e_{sm} =	6.85E-04	
Ampiezza fessura	w_d =	0.177	mm
Apertura massima fessura	$w_{amm} = w_1$	0.2	mm

La verifica è quindi soddisfatta.

12 APPARECCHIATURE DI APPOGGIO E GIUNTI

Il sistema di vincolo dell'impalcato su spalle è costituito da isolatori elastomerici a elevato smorzamento.

Si riporta di seguito una pianta dell'impalcato con indicazione degli isolatori:



Gli isolatori di spalla hanno:

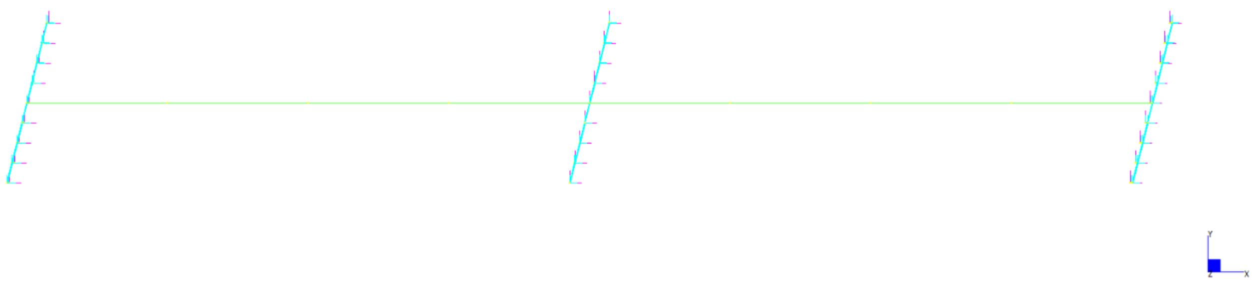
- Rigidezza per elevati spostamenti (fase sismica) pari a 0.74 kN/mm
- Rigidezza per bassi spostamenti (fase statica) pari a 1.48 kN/mm

Gli isolatori di pila hanno:

- Rigidezza per elevati spostamenti (fase sismica) pari a 1.80 kN/mm
- Rigidezza per bassi spostamenti (fase statica) pari a 3.60 kN/mm

Sulla base delle rigidezze sopra esposte è stato realizzato un modello di calcolo monofilare con il quale è stato indagato il comportamento sismico dell'opera.

Si riporta di seguito una immagine in pianta del modello di calcolo:

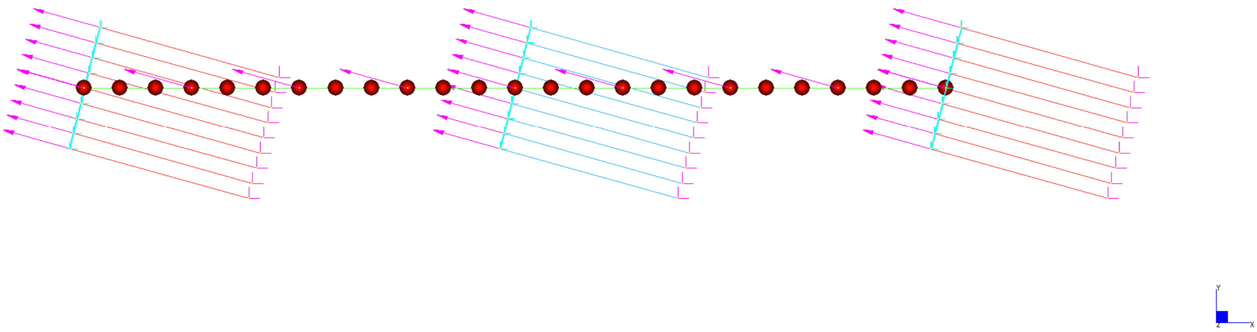


L'analisi sismica condotta è del tipo modale con spettro di risposta, che si articola nei seguenti passaggi:

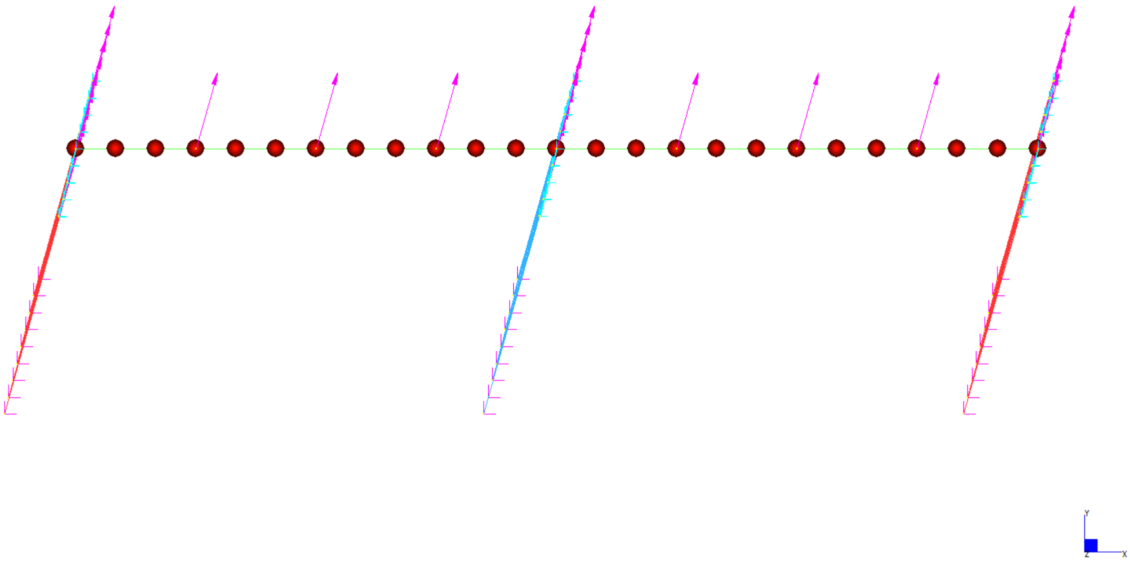
12.1 Analisi delle principali frequenze di vibrazione fondamentali tali da attivare almeno l'85% della massa sismica
12.2 Analisi modale con spettro di risposta per determinare le massime azioni sugli appoggi
12.3 Analisi statica per combinare le azioni sismiche spettrali alle azioni statiche quali pesi e variazioni termiche, da combinare opportunamente tra loro.

Di seguito si riportano le deformate delle principali frequenze di oscillazione dell'impalcato ed una tabella finale riassuntiva con i modi di vibrare e relative frequenze e masse sismiche eccitate:

1° MODO:



2° MODO:



MODE PARTICIPATION FOR TRANSLATIONAL EXCITATION

Mode	Frequency (Hz)	Modal Mass (Eng)	Modal Stiff (Eng)	PF-X (%)	PF-Y (%)	PF-Z (%)
1	8.6675E-01	1.0712E+06	3.1769E+07	92.755	7.242	0.000
2	8.6725E-01	1.0706E+06	3.1790E+07	7.243	92.757	0.000
3	1.0032E+00	3.1912E+05	1.2678E+07	0.000	0.000	0.001
4	1.7699E+00	4.9686E+05	6.1442E+07	0.001	0.000	0.000
5	2.7401E+00	4.7715E+05	1.4144E+08	0.000	0.000	69.371
TOTAL TRANSLATIONAL MASS PARTICIPATION FACTORS				99.999	100.000	69.372

Nell'analisi condotta è stato considerato, oltre che il contributo del sisma nel piano orizzontale, anche il sisma nel piano verticale. Nelle tabelle del paragrafo successivo, si ritrovano infatti i contributi elementari V), L), T) che corrispondono al sisma verticale, longitudinale e trasversale.

12.4 AZIONI APPOGGI

Si riporta la tabella appoggi riassuntiva per ogni apparecchio di appoggio.

Il dimensionamento degli apparecchi di appoggio è svolto rispetto allo SLC, poiché il sistema d'isolamento deve essere in grado di sopportare gli spostamenti previsti in tale stato limite.

Vengono riportate sia le sollecitazioni elementari sia le sollecitazioni combinate secondo i coefficienti da normativa.

SPALLA A - App.1 (Esterno)				
	N max [kN]	N min [kN]	Hlong [kN]	Htrasv [kN]
Pesi Propri	131	131		
Permanenti Portati	242	16		
Vento	7	-7	4	17
Traffico	320	-48		
Frenatura			13	
Centrifuga				
Azione termica			14	
Ritiro			3	
Alzaggio				
Cedimenti	1	-1		
V) 0.3Ex + 0.3Ey + Ez ± DT	37	-26	23	23
L) Ex + 0.3Ey + 0.3*Ez ± DT	20	-4	65	33
T) 0.3Ex + Ey + 0.3*Ez ± DT	36	-6	33	65

	COMBINAZIONI A1 STR Tab 5.1.V NTC08							
	Appoggio	COMBO	N max compr [kN]	N max traz [kN]	H long [kN]	H trasv [kN]	Hcombinato [kN]	Spostamento [mm]
SPALLA A - SLU	App. 1	*SLU 1*	839	87	20	26	32	22
		SLU 2	943	75	17	15	23	16
		SLU 3	835	91	35	15	38	26
		SLU 4	835	91	17	15	23	16
		SLU5	835	91	24	15	28	19
SPALLA A - SLC	App. 1	*SLC 1*	411	120	33	23	40	54
		SLC 2	394	142	75	33	82	111
		SLC 3	410	140	43	65	78	105
			943	**0**	**75**	**65**	**82**	**111**

Sulla base di questi risultati si riportano di seguito le caratteristiche richieste agli isolatori di spalla:

SPALLE		
DIMENSIONI DELLA GOMMA	ϕ300	mm
ALTEZZA TOTALE GOMMA E LAMIERINI (ESCLUSE PIASTRE DI ANCORAGGIO)	152	mm
CARICO VERTICALE STATICO MASSIMO (SLU)	1000	kN
TAGLIO LONGITUDINALE MASSIMO (SLU)	40	kN
TAGLIO TRASVERSALE MASSIMO (SLU)	30	kN
DEFORMAZIONE LONGITUDINALE TERMICA MASSIMA (CARATTERISTICA)	10	mm
CARICO VERTICALE SISMICO MASSIMO (SLC)	500	kN
AZIONE LONGITUDINALE SISMICA MASSIMA (SLC)	100	kN
AZIONE TRASVERSALE SISMICA MASSIMA (SLC)	70	kN
RIGIDEZZA ORIZZONTALE ELASTICA IN CONDIZIONI DINAMICHE	0.74	kN/mm
RIGIDEZZA ORIZZONTALE AL 10% DELLO SMORZAMENTO	1.48	kN/mm
SMORZAMENTO EQUIVALENTE	15	%

Essendo l'impalcato simmetrico le sollecitazioni agenti sugli appoggi della spalla A sono i medesimi agenti sulla spalla B.

Per quanto riguarda gli isolatori di pila si ottiene:

PILA - App.1 (Esterno)				
	N max [kN]	N min [kN]	Hlong [kN]	Htrasv [kN]
Pesi Propri	450	450		
Permanenti Portati	814	65		
Vento	18	-18	11	42
Traffico	535	-28		
Frenatura			32	
Centrifuga				
Azione termica				
Ritiro				
Alzaggio				
Cedimenti	2	-2		
V) 0.3Ex + 0.3Ey + Ez ± DT	105	-86	55	55
L) Ex + 0.3Ey + 0.3*Ez ± DT	45	-26	158	80
T) 0.3Ex + Ey + 0.3*Ez ± DT	88	-26	80	158

	COMBINAZIONI A1 STR Tab 5.1.V NTC08							
	Appoggio	COMBO	N max compr [kN]	N max traz [kN]	H long [kN]	H trasv [kN]	Hcombinato [kN]	Spostamento [mm]
PILA - SLU	App. 1	*SLU 1*	2277	457	17	63	65	18
		SLU 2	2447	459	10	38	39	11
		SLU 3	2267	468	53	38	65	18
		SLU 4	2267	468	10	38	39	11
		SLU5	2267	468	10	38	39	11
PILA - SLC	App. 1	*SLC 1*	1371	427	55	55	78	43
		SLC 2	1311	487	158	80	177	98
		SLC 3	1354	487	80	158	177	98
			2447	**0**	**158**	**158**	**177**	**98**

Agli isolatori di pila sono quindi richieste le seguenti caratteristiche:

PILE		
DIMENSIONI DELLA GOMMA	ϕ350	mm
ALTEZZA TOTALE GOMMA E LAMIERINI (ESCLUSE PIASTRE DI ANCORAGGIO)	143	mm
CARICO VERTICALE STATICO MASSIMO (SLU)	2500	kN
TAGLIO LONGITUDINALE MASSIMO (SLU)	60	kN
TAGLIO TRASVERSALE MASSIMO (SLU)	70	kN
DEFORMAZIONE LONGITUDINALE TERMICA MASSIMA (CARATTERISTICA)	0	mm
CARICO VERTICALE SISMICO MASSIMO (SLC)	1400	kN
AZIONE LONGITUDINALE SISMICA MASSIMA (SLC)	230	kN
AZIONE TRASVERSALE SISMICA MASSIMA (SLC)	160	kN
RIGIDEZZA ORIZZONTALE ELASTICA IN CONDIZIONI DINAMICHE	1.8	kN/mm
RIGIDEZZA ORIZZONTALE AL 10% DELLO SMORZAMENTO	3.6	kN/mm
SMORZAMENTO EQUIVALENTE	15	%

12.5 VARCO E GIUNTI

Dimensionamento varco di giunto

Lo spostamento massimo dell’impalcato atteso in corrispondenza delle spalle (in SLC+0.5*DT) è pari a:

Δ_y = 90 mm (in direzione longitudinale)

Δ_x = 85 mm (in direzione trasversale)

Si sceglie un varco sulle spalle pari a **160 mm misurato in retto all’impalcato**: tale valore è assunto per problemi geometrici ed è sufficiente a garantire lo spostamento all’SLC.

Dimensionamento giunti

Lo spostamento massimo dell’impalcato atteso in corrispondenza dei giunti sulle spalle (in SLD) è pari a:

Δ_y = 30 mm (in direzione longitudinale)

Δ_x = 30 mm (in direzione trasversale)

L’azione termica genera uno spostamento longitudinale su ogni giunto pari a:

Δ_T = 0.00001*66000mm*(30°) / 2 = 10 mm

Considerando anche il massimo eventuale spostamento dovuto alla temperatura uniforme (ridotta del 50%), si ottiene lo spostamento massimo di progetto del giunto strutturale:

Δ_d = 30+0.5*10 = 35 mm

Si scegli quindi un giunto strutturale sulle spalle con escursione massima pari a:

Δ_y = ± 40 mm (longitudinale)

Δ_x = ± 40 mm (trasversale)