Stretto di Messina

Concessionaria per la progettazione, realizzazione e gestione del collegamento stabile tra la Sicilia e il Continente Organismo di Diritto Pubblico
(Legge n° 1158 del 17 dicembre 1971, modificata dal D.Lgs. n°114 del 24 aprile 2003)

EurolinK

P O N T E S U L L O S T R E T T O D I M E S S I N A

PROGETTO DEFINITIVO

EUROLINK S.C.p.A.

IMPREGILO S.p.A. (MANDATARIA)
SOCIETÀ ITALIANA PER CONDOTTE D'ACQUA S.p.A. (MANDANTE)
COOPERATIVA MURATORI E CEMENTISTI - C.M.C. DI RAVENNA SOC. COOP. A.R.L. (MANDANTE)
SACYR S.A.U. (MANDANTE)
ISHIKAWAJIMA - HARIMA HEAVY INDUSTRIES CO. LTD (MANDANTE)
A.C.I. S.C.P.A. - CONSORZIO STABILE (MANDANTE)

IL PROGETTISTA	IL CONTRAENTE GENERALE	STRETTO DI MESSINA	STRETTO DI MESSINA
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PS0189_F0

Unità Funzionale	OPERA DI ATTRAVERSAMENTO
Tipo di sistema	SISTEMI SECONDARI
Raggruppamento di opere/attività	ARTICOLAZIONI
Opera - tratto d'opera - parte d'opera	Ammortizzatori
Titolo del documento	Relazione di progetto - Giunti d'espansione

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1 Introduzione

La presente relazione descrive la progettazione dei giunti di dilatazione stradali e ferroviari. I giunti di dilatazione stradali e ferroviari sono basati sulla progettazione illustrata nei disegni di gara e nella presentazione a 80 giorni, ma per alcuni giunti di dilatazione stradali si è ritenuto vantaggioso apportare le seguenti modifiche al progetto.

- Sui grandi giunti di dilatazione stradali E3 sono stati aggiunti due lati mobili.

I calcoli sono preparati da Mageba e VAE e sono riportati nell'Appendice.

1.1 Sommario della relazione

La presente relazione è strutturata nelle seguenti sezioni:

- La Sezione 1 contiene la presente introduzione;
- La Sezione 2 fornisce un elenco dei materiali di riferimento, comprese le specifiche di progetto, i codici di progetto, le specifiche dei materiali e i disegni di riferimento;
- La Sezione 3 fornisce le descrizioni dei materiali che vengono utilizzati per ciascun componente;
- La Sezione 4 descrive l'output di IBDAS e il modo in cui esso viene utilizzato in relazione ai giunti di dilatazione;
- Nelle appendici sono riportate le verifiche dettagliate del progetto preparate dai fornitori.

2 Riferimenti per la progettazione

2.1 Specifiche di progettazione

1 CG.10.00-P-RG-D-P-GE-00-00-00-00-00-02 - "Manuale applicativo riferito ai fondamenti progettuali" COWI 2010

2 GCG.F.05.03 "Sviluppo della Progettazione - Requisiti e Linee Guida", Stretto di Messina, 22 Ottobre 2004.

3 GCG.G.02.01 rev.0. Costruzione dei collegamenti stradali e ferroviari: Norma per l'esecuzione delle opere civili - infrastrutture stradali e ferroviarie. Stretto di Messina 6 Luglio 2004.

4 GCG.G.03.02 "Costruzioni strutturali in acciaio e rivestimenti protettivi", Stretto di Messina, 30 Luglio 2004.

2.2 Codici di progettazione

5 "Norme tecniche per le costruzioni," 2008 (NTC08).

6 EN 1993 Eurocodice 3: Progettazione di strutture in acciaio - Parte 1-1: Regole generali e regole per gli edifici

7 EN 1993 Eurocodice 3: Progettazione di strutture in acciaio - Parte 1-5: Elementi strutturali tipo piastra

8 EN 1993 Eurocodice 3: Progettazione di strutture in acciaio - Parte 1-8: Progettazione dei giunti

9 EN 1993 Eurocodice 3: Progettazione di strutture in acciaio - Parte 1-9: Fatica

10 EN 1993 Eurocodice 3: Progettazione di strutture in acciaio - Parte 1-10: Scelta dell'acciaio con riferimento alla resistenza alla frattura e alle proprietà attraverso lo spessore

11 EN 1993 Eurocodice 3: Progettazione di strutture in acciaio - Parte 2: Ponti in acciaio

12 EN 1998 Eurocodice 8: Progettazione delle strutture per la resistenza sismica

2.3 Specifiche dei materiali

13 EN 10025-1:2004 Prodotti laminati a caldo di acciai per impieghi strutturali – Parte 1: Condizioni generali di fornitura.

14 EN 10025-2:2004 Prodotti laminati a caldo di acciai per impieghi strutturali – Parte 2: Condizioni tecniche di fornitura per acciai strutturali non legati.

15 EN 10025-3:2004 Prodotti laminati a caldo di acciai per impieghi strutturali – Parte 3: Condizioni tecniche di fornitura per acciai strutturali normalizzati / normalizzati saldabili a grano fine.

16 EN 10025-4:2004 Prodotti laminati a caldo di acciai per impieghi strutturali – Parte 4: Condizioni tecniche di fornitura per acciai strutturali saldabili a grano fine ottenuti per laminazione termomeccanica.

17 EN 10164:1993 Prodotti in acciaio con aumentate proprietà di deformazione perpendicolarmente alla superficie del prodotto - Condizioni tecniche di consegna.

18 EN ISO 898-1:2001 Proprietà meccaniche degli elementi di fissaggio in acciaio al carbonio e in acciaio legato - Parte 1: Bulloni, viti e prigionieri (ISO 898-1:1999).

19 EN 20898-2:1994 Proprietà meccaniche degli elementi di fissaggio – Parte 2: Dadi con valori di carico di prova speciali - filettatura grossa (ISO 898-2:1992).

20 UNI EN 14399:2005-3 Bulloneria strutturale ad alta resistenza per pre-caricamento - Parte 3: Sistema HR - Bulloneria e dadi esagonali

21 EN 13674-1:2003. Applicazioni ferroviarie - Binario - Rotaia - Parte 1: Rotaie ferroviarie Vignole 46 kg/m e oltre

22 EN 13481-5:2002. Applicazioni ferroviarie - Binario - Rotaia - Requisiti prestazionali per i sistemi di fissaggio - Parte 5: Sistemi di fissaggio per i piastroni

2.4 Relazioni complementari

23 CG.10.00-P-RG-D-P-SV-00-00-00-00-00-01_A - "Modello globale IBDAS, Descrizione" COWI 2010

24 CG.10.00-P-SP-D-P-SS-A0-AM-00-00-00-03_A - "Specifica prestazionale - Giunto di dilatazione stradale", COWI 2010

25 CG.10.00-P-SP-D-P-SS-A0-AM-00-00-00-02_A - "Specifica prestazionale - Giunti di dilatazione ferroviari", COWI 2010

2.5 Disegni

I disegni di interesse per la presente relazione sono i seguenti:

26 CG1000-P-AX-D-P-SS-A0-00-00-00-00-01-A, Sistema di articolazione - Disposizione generale,

27 GC10.00-P-DX-D-P-SS-A0-GE-00-00-00-01-A, Sistema di articolazione - Giunti di dilatazione, Generale

28 CG1000-P-DX-D-P-SS-A0-GE-00-00-00-02-A, Sistema di articolazione - Giunti di dilatazione ferroviari (1)

29 CG1000-P-DX-D-P-SS-A0-GE-00-00-00-03-A, Sistema di articolazione - Giunti di dilatazione ferroviari (2)

30 CG1000-P-DX-D-P-SS-A0-GE-00-00-00-04-A, Sistema di articolazione - Giunti di dilatazione stradali.

3 Materiali

La progettazione dei giunti di dilatazione è effettuata dai produttori in base alle specifiche di prestazioni tecniche emesse nell'ambito del Progetto Definitivo. Le proprietà meccaniche dei materiali adottati sono riportate nella documentazione dei produttori.

4 Principi di progettazione

4.1 Modello FE

È stato creato un modello 3D computerizzato utilizzando il software interno IBDAS. L'IBDAS (Integrated Bridge Design and Analysis System - Sistema Integrato per l'Analisi e la Progettazione del Ponte) è un pacchetto software generale per l'analisi e la progettazione strutturale sviluppato da COWI. L'IBDAS è basato sulla modellazione logica solida parametrica 3D e mette a disposizione delle procedure per l'analisi e la progettazione completamente integrate delle strutture portanti.

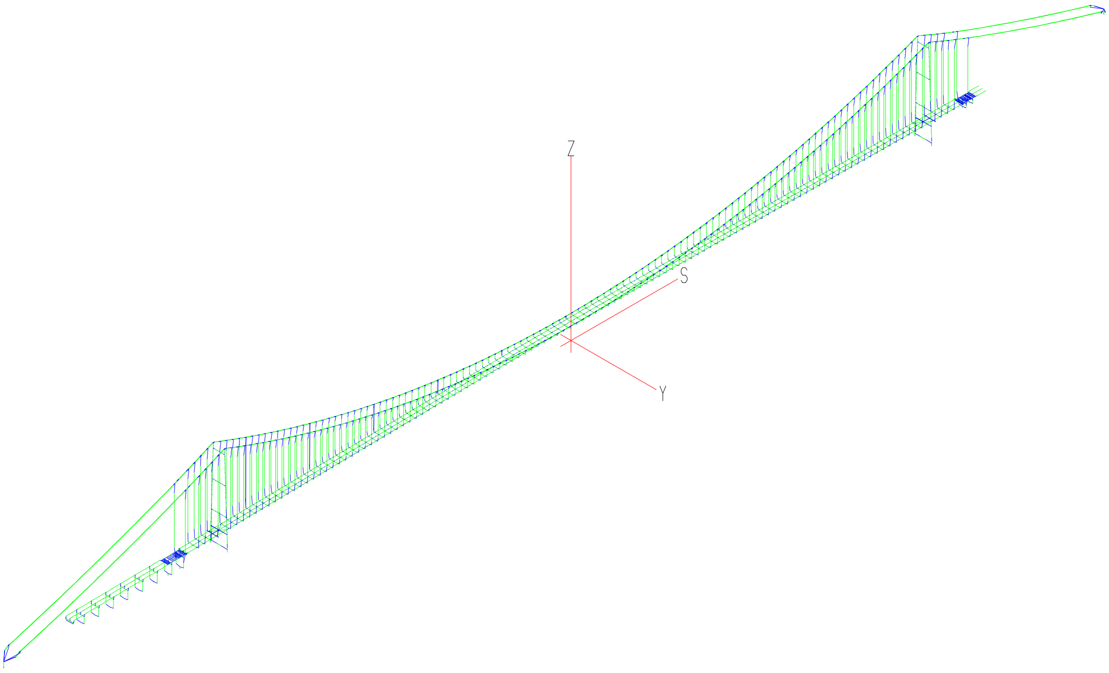

Figura 4-1: Sistema globale di coordinate in IBDAS

Con questo modello vengono determinati i movimenti e le rotazioni rilevanti per i giunti di dilatazione. Per ulteriori informazioni si rimanda a [23].

4.1.1 Output dell'IBDAS

L'IBDAS mette a disposizione i seguenti tipi di analisi:

- Analisi statica (carico fisso, carico mobile, carichi di vento e di temperatura);
- Analisi dello spettro di risposta sismica;
- Analisi dinamica del vento (analisi spettrale);
- Analisi della storia temporale sismica;

L'analisi statica, l'analisi della risposta e l'analisi spettrale sono eseguite per due sistemi statici: "libero-libero"; "fisso-fisso".

Il tipo di sistema statico si riferisce alla condizione dell'incastro longitudinale dell'impalcato sospeso in corrispondenza delle torri. Nel sistema "fisso-fisso" l'incastro longitudinale è bloccato, creando un collegamento rigido tra l'impalcato e la torre. Nel sistema "libero-libero" l'impalcato può muoversi liberamente rispetto alla torre.

Nel sistema statico "libero-libero" viene implementata una molla in direzione longitudinale corrispondente alle caratteristiche dell'ammortizzatore. La rigidità della molla è di 33 kN/m.

Nei sistemi statici "libero-libero" e "fisso-fisso" gli ammortizzatori trasversali in corrispondenza delle torri sono fissati creando un collegamento rigido trasversale.

In base al tipo di analisi e al sistema statico si hanno quattro stati limite:

- SLS1
- SLS2
- ULS
- SILS

Gli stati limite sono definiti in [1]. Per ulteriori informazioni sul modello IBDAS si rimanda a [23].

4.1.1.1 Analisi dello spettro di risposta sismica

Il movimento del suolo è definito per i quattro stati limite indicati in [1]: la differenza tra gli stati limite è l'accelerazione massima al suolo.

La risposta della struttura sottoposta al movimento del suolo è calcolata con il metodo della sovrapposizione modale con spettro di risposta. Si presuppone un movimento uniforme del suolo, vale a dire che tutti i supporti sono eccitati allo stesso modo. Il rapporto di smorzamento dell'intera struttura è assunto pari al 5% rispetto al valore critico, in considerazione del fatto che durante un terremoto si possono verificare movimenti di grande ampiezza.

Le analisi dello spettro di risposta sono eseguite per i 1760 modi di vibrazione più bassi, in modo da ottenere una massa partecipante superiore al 90%.

Sono forniti i risultati per ciascuno dei quattro stati limite. Sono applicati i principi sopra descritti per il contributo del carico di temperatura uniforme.

4.1.1.2 Analisi dinamica del vento

L'analisi dinamica del vento è costituita da otto diverse situazioni di carico per ciascuno stato limite e tra queste viene utilizzata quella più sfavorevole. Le otto situazioni di carico si basano sulla direzione del vento con riferimento al sistema globale di coordinate IBDAS, si veda la Figura 4-2:

- mw 1: y+
- mw 2: s+
- mw 3: y-
- mw 4: s-
- mw 5: s+ y+
- mw 6: s+ y-
- mw 7: s- y+
- mw 8: s- y-

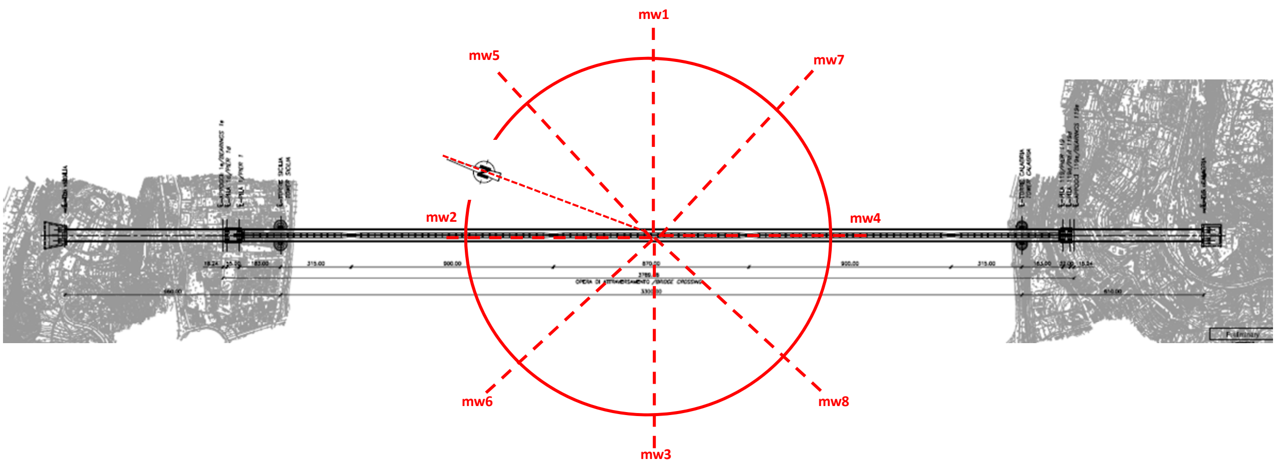

Figura 4-2: Definizione della direzione del vento

4.1.1.3 Analisi della storia temporale sismica

Le serie temporali compatibili con gli spettri di risposta di progetto ULS sono utilizzate come input sismici per l'analisi della storia temporale.

In totale durante la progettazione sono stati analizzati 8 set di serie temporali.

Ogni set è costituito da tre componenti ortogonali: due componenti orizzontali perpendicolari e una componente verticale. Vengono considerate le due combinazioni seguenti:

- Componente longitudinale 1.0 + componente trasversale 0.8 + componente verticale 0.75;
- Componente longitudinale 0.8 + componente trasversale 1.0 + componente verticale 0.75.

Per le due combinazioni i risultati degli 8 set di serie temporali sono mediati in conformità con [1].

Nell'analisi è incluso solamente il carico fisso. Pertanto i risultati vengono combinati con il rispettivo carico rimanente che è indicato nelle seguenti combinazioni di carico:

- Componenti strutturali primari:
  - ULS: 6903
  - SLS1: 6913
  - SLS2: 6923
  - SILS: 6933
- Componenti strutturali secondari
  - ULS: 6568
  - SLS caratteristico: 6668
  - SLS frequente: 6759

Il coefficiente di smorzamento viene attualmente determinato in base ai modi importanti per le torri.

Nell'analisi sismica basata sull'analisi della storia temporale gli ammortizzatori opereranno secondo le loro caratteristiche.

4.1.1.4 Analisi della storia temporale sismica con pre-caricamento

Dal momento che la disposizione degli ammortizzatori sulle torri produce una diversa rigidità della molla a seconda della posizione effettiva dell'ammortizzatore, la sequenza dei carichi influirà sulla risposta degli ammortizzatori. Per tener conto di questo aspetto gli ammortizzatori sono precaricati prima dell'applicazione delle serie temporali, simulando in tal modo le condizioni di temperatura e di traffico al momento dell'evento sismico. Il traffico viene collocato nella posizione più sfavorevole per un determinato elemento strutturale. Ad esempio, per quanto concerne gli ammortizzatori, il traffico può essere posizionato in modo che gli ammortizzatori ricevano la più alta tensione possibile prodotta dal carico di traffico.

4.1.1.5 Temperatura uniforme

Il contributo dei gradienti di temperatura è incluso nei rispettivi inviluppi in entrambi i sistemi statici. Il contributo della temperatura uniforme non è tuttavia incluso negli inviluppi e può essere individuato solamente come una singola situazione di carico che viene aggiunta manualmente agli inviluppi.

Il contributo della temperatura uniforme è ricavato dal sistema statico "libero-libero". Ciò è dovuto al fatto che il comportamento non lineare degli ammortizzatori può essere modellato correttamente solo nell'analisi della storia temporale. Il carico della temperatura uniforme supererà il valore di soglia degli ammortizzatori, rendendo necessaria una modifica del sistema statico.

4.1.2 Output dell'IBDAS utilizzato per i giunti di dilatazione

L'analisi sismica basata sull'analisi della storia temporale con pre-caricamento è utilizzata per determinare il movimento nei giunti di dilatazione. Il pre-caricamento è basato sulle seguenti condizioni:

- Temperatura uniforme massima;
- Fissaggio dei carichi di traffico in modo da avere la massima forza di trazione negli ammortizzatori longitudinali in corrispondenza delle torri.

5 Base per la progettazione dei giunti di dilatazione

La base per la progettazione dei giunti di dilatazione, con riferimento ai movimenti e alle rotazioni, è riportata in [27].

I movimenti e le rotazioni sono moltiplicati per un fattore di 1,10 in conformità con [2] sezione 10.5.

Appendice 1 - Mageba

Le verifiche di progetto dettagliate saranno incluse durante il Progetto Esecutivo.

Appendice 2 - VAE

Stretto di Messina

Rail Movement Joint
Preliminary Design Report

VAE GmbH
www.voestalpine.com/vae

voestalpine
ONE STEP AHEAD.

	Name	Date	Signature
Author	Rieger	12.10.10	
Checked	Rieger	14.10.10	
Approved	Ossberger	15.10.10	

Rev.	Date	Description	Author	Copies

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1 Introduction:

1.1 General:

Project : Messina Strait Bridge, Rail Expansion Joints

Customer : EUROLINK S.C.p.A., represented by IMPREGIL0 SpA, Milan

Consultant : COWI A/S, Denmark

Number of Offer: 20514504

The REJ's for the double track of the Messina Strait Bridge are designed as independent REJ's for each railway track. Each REJ is located on dedicated supporting structure and sledges. This feature allows the installation, maintenance and replacement of one track with no direct interference of the REJ of the other track.

Over the entire length of the REJ's and at any position of the Primary Bridge Structure the wheel rail interface is built to provide a continuous support (running table) and guidance (running edge) similar to the wheel transfer in a switch and stock rail assembly of a turnout. This design does not need an operational checkrail. The gauge within the REJ's does not change due to bridge and structure movements.
For safety reasons a guard rail / containment arrangement will be provided over the entire length of the defined scope of supply shown on the layout drawings.

The entire design is based on the agreed assumption that all bearings of the Primary bridge structures and viaducts are parallel to the inclination of the railway track, e.g. 1.5% at Sicilia and 1.6718% at Calabria. So due to the move of these structures no vertical displacement takes place.

1.2 Scope:

This Design description specifies the design and supply of the four rail expansion joints to each track at the Messina Bridge. The four locations
are:
- Calabria approach spans/terminal structure (E7);
- Terminal structure/suspension bridge (E4);
- Suspension bridge/terminal structure on Sicily (E4);
- Terminal structure/approach spans Sicily (E5).

Including the tracks between locations E4 and E5 as well as locations E4 and E7 and projecting tracks at the interface of terminal station to the main bridge and Terminal station to the adjacent viaduct shown on the layout drawings as scope of supply.

1.3 References:

1.3.1 Design Specifications:

1 Requirements and Guideline for the development of the Project – Expansion Joint, Rev. 1., dd. 2004-06-24
2 Performance Specification - Rail Expansion, Joints. Annex, CG.1000-P-1S-D-P-SS-A0-AM-00-00-00-00-A_A- 01_PS-Rail Expansion Joints, dd. 2010-08-16
3 GCG.G.03.02, Structural steelwork and protective treatments
4 96/48-ST13EN04 INS - part2 dd. 23/06/2006 Directive 96/48/EC - Interoperability of the trans-European high speed rail system, Draft Technical Specification for Interoperability

1.3.2 Design Specifications:

1 EN 13674-1:2008. Railway applications - Track - Rail - Part 1: Vignole railway rails 46 kg/m and above
2 EN 13674-2:2006. Railway applications - Track - Rail – Part 2: Switch and crossing rails used in conjunction with Vignole railway rails 46 kg/m and above
3 EN 13232-8:2005. Railway applications - Track - Rail – Part 8: Railway applications – Track, Switches and crossings, Part 8: Expansion devices
4 EN 13481-5:2010. Railway applications - Track - Performance requirements for fastening systems - Part 5: Fastening systems for slab track
5 EN13146:2009, relevant parts, Railway applications - Track - Test methods for fastening systems
6 EN 1991-2:2004. Eurocode 1: Actions on structures – Part 2: Traffic loads on bridges
7 EN 10025-1:2004 Hot-rolled products of structural steels
8 EN 10164:1993 Steel products with improved deformation properties perpendicular to the surface of the product – Technical delivery conditions
9 EN ISO 898-1:2001 Mechanical properties of fasteners made of carbon steel and alloy steel – Part 1: Bolts, screws and studs (ISO 898-1:1999)
10 EN 20898-2:1994 Mechanical properties of fasteners – Part 2: Nuts with special proof load values – coarse thread (ISO 898-2:1992)
11 UNI EN 14399-3:2005 High-strength structural bolting assemblies for preloading - Part 3: System HR - Hexagon bolt and nut assemblies
12 EN ISO 14555:1998 Welding-Arc stud welding of metallic materials

1.3.3 Drawings:

1 GC10.00-P-AX-D-P-CG-S5-AM-00-00-00-01-A. Articulation system - Expansion joints, Overview, except angular rotations in E4. Refer to COWI e-mail, dd. 2010-09-08.

2 Nomenclature:

The following definitions shall apply:

- "Primary bridge structure" - structural load carrying elements of the suspension bridge part or the terminal structure of the Messina Bridge.
- "Railway expansion joint" - comprises rail assemblies and rail supporting structures and rail dilatation joints.
- "Rail assembly" - in a railway expansion joint, the assembly of switch rails (either cast or rolled), stock rails, running rails, guard rails, rail fastenings, base plates and base plate fastenings.
- "Rail supporting structure" - in a railway expansion joint, the structure other than primary bridge structure, which provides direct support to the rail assembly and transfers loads to the primary bridge structure, e. g. sledges and spline girder. This shall include any fixing and/or bearings required to locate and articulate the railway expansion joint.
- "Rail dilatation joint"- The joint in the rails or dilatation components like stock rails, cast expansion sleeve or rolled switch rails, where the rail can absorb movements.
- "Loads" - external forces applied to the railway expansion joint, and imposed deformations such as those caused by restraint of movement due to changes in temperature, or by rotations and movement arising from deformation of the primary bridge structure.

3 Design by manufacturer:

3.1 Design principles and performance objectives:

3.1.1 Reference

The railway expansion joint design proposed, has been used for large movements and under similar conditions with satisfactory results for a period of more than 5 years. The REJ's for E4 with similar design are used on the Tsing Ma Bridge (suspension bridge) and Kap Shui Mun Bridge (Cable Stay Bridge) and demonstrated satisfactory results since 1997 under similar extreme wear conditions as specified for this bridge. For the REJ's at E5 and E7 a design similar to the design used on the Oresund and Kap Shui Mun Bridges is proposed. On the Oresund Bridge the REJ are installed since 1999 and demonstrated satisfactory results. For more details refer to the reference list for the expansion joints supplied by VAE, enclosed in Appendix A.

3.1.2 Function and performance

The railway expansion joints are designed so as to ensure that the rotational, longitudinal or other movements of the bridge deck arising from superimposed loads, weather conditions, temperature change or any other cause, all as calculated and submitted by COWI on 2010-10-01 shall be accommodated so as not to adversely affect the safety, comfort or frequency of normal railway operations.

It is intended to provide at top of rail a smooth transition from the suspension bridge part to the terminal structure as well as from the terminal structures to the adjacent via-ducts. Therefore the belonging Rail Supporting Structure, e. g. the flexing spline girder shall provide in vertical as well as transversal direction an appropriate support and guidance for the sledges. For values of radii in vertical and transversal direction at max. closed and max. opened position of REJ's refer to the enclosed tables in Appendix B.

a) Rail Expansion Joints at E4

Location Terminal Structure / Suspension Bridge E4, ± 2000mm, Sicilia and Calabria side, 4 units for double track, VAE dwg. nos.: E03885-000-02, General layout Sicilia, E03886-000-02, General layout Calabria, E03887-000-00, Cross sections and E03869-000-00, Rail expansion Joint ± 2000.

At the location E4 of Terminal Structures / Suspension Bridge for Sicilia and Calabria 5 sledges are used to bridge the gap of ±2000m into 6 gaps. Due to this measure the spacing between baseplates is:

- 560mm at neutral position
- 560mm ±200mm at SLS1, min. 360mm, max. 760mm, trains at 120kph
- 560mm ±233mm at SLS2, min. 337mm, max. 793mm, trains at lower speed
- 560mm ±333mm at ULS, min. 227mm, max. 893mm, no trains on joints

This sledge design has been chosen in order to be able to control the gauge, cross level, profile and the alignment over the entire length of movement in the most accurate manner. At the same time simple and robust baseplates and standard fasteners already well known and used by several Railway Authorities.

The use of sledges also allows the design of simple and robust steel supporting structures underneath, which are supported and guided by suitable bearings. The vertical bearings are resting on stainless steel surfaces, the horizontal bearings are guided by up-stands with stainless steel surfaces mounted onto the spline girder top plate.

The flexible rail beam (Spline girder) under the sledges accommodate vertical and horizontal rotations as well as transverse movements as specified in drawing "GC10.00-P-AX-D-P-CG-S5-AM-00-00-00-01-A. Articulation system - Expansion joints, Overview, except angular rotations in E4 and superseded for values of angular rotations for E4 in COWI e-mail, dd. 2010-09-08. This is subject to confirmation according to COWI's design of the spline girder and the location of vertical and lateral bearings for it.

Rail Expansion Joint (REJ), Design with cast sleeve and moveable stock rail 60E1T2 (UIC60A), fixation on elastic baseplates direct on bridge deck, with 5 sledges on resilient bearings with sliding surface, containment / guard rail.

At this stage provision for further closing movement of ~160mm is given. If required, precautions for over contraction within a reasonable range can be discussed and incorporated into the design to minimize possible damages to main components in case of emergency.

b) Rail Expansion Joints at E5 & E7

At the locations of REJ's at Approach Spans and Terminal Structures E5 and E7 a 1 sledge design is suggested providing following features.

- division of vertical rotations of structures into 2 halves, e.g. 2 x 0.0025RAD(SLS1) and 2 x 0.004RAD (SLS2) according to COWI's actual design
- accommodation of transverse rotations and movements over a longer length instead of within one baseplate spacing.
- on top of the sledge and on the next baseplate locations at the adjacent locations special prestressed elastic baseplates with ±1.5mm resilience (to accommodate up and down movements of the structures) are to be installed in order to provide a smooth continuous vertical radius in the profile of the track.

Refer to VAE dwg. nos.: E05601-000-00, General layout REJ60E1 ±600 and E05605-000-00, Cross sections

At the location Terminal Structure / Approach Spans a sledge is used to bridge the gap of ±600mm at Sicilia, E5 and ±400m at Calabria, E7 into 2 gaps each. Due to this measure the spacing between baseplates is:

Location Approach Span / Terminal Structures, ± 600mm, Sicilia E5, 2 units for double track

Rail Expansion Joint (REJ), Design with switch rail 60E1A1 (Zu-1-60) and moveable stock rail 60E1 (UIC60), fixation on elastic baseplates direct on bridge deck and prestressed special elastic baseplates with approx. ±1.5mm resilience (up and down) on 1 sledge and adjacent structures, containment / guard rail.

- 520mm at neutral position
- 520mm ±125mm at SLS1 (Sicilia), min. 395mm, max. 645mm, trains at 120kph
- 520mm ±200mm at SLS2 (Sicilia), min. 320mm, max. 720mm, trains at lower speed
- 520mm ±300mm at ULS, min. 220mm, max. 820mm, no trains on joints

Location Approach Span / Terminal Structures, ± 400mm, Calabria E7, 1 unit for double track

Rail Expansion Joint (REJ), Design with switch rail 60E1A1 (Zu-1-60) and moveable stock rail 60E1 (UIC60), fixation on elastic baseplates direct on bridge deck and prestressed special elastic baseplates with approx. ±1.5mm resilience (up and down) on 1 sledge and adjacent structures, containment / guard rail.

- 530mm ±50mm at SLS1 (Calabria), min. 480mm, max. 580mm, trains at 120kph
- 530mm ±100mm at SLS2 (Calabria), min. 430mm, max. 630mm, trains at lower

speed
- 530mm ±200mm at ULS, min. 330mm, max. 730mm, no trains on joints

3.1.3 Adjustment switches and re-railing equipment

Currently there is no provision within VAE'S design and scope of supply for adjustment switches and re-railing equipment.
At the interface to the fastening system used on the main bridge provisions may be agreed to allow "breathing" of CWR. In this case adjustment switches might not be necessary.

Re-railing equipment shall be provided by others. It is not recommendable to install such devices in the vicinity of REJ's.

3.1.4 Normal railway operations

The railway expansion joints are designed including the possibility of trains on either track being operated in reverse direction and of trains approaching or passing each other at the location of the railway expansion joints or with one at the railway expansion joint while the other is at the most adverse position for movement of the primary bridge structure.

It shall be noted the area of REJ's shall not be used as parking area of trains.

3.1.5 Design life

The rail supporting structure will have a design life of 200 years except any wearing components including bearings and fixings will be designed for a service life to first major maintenance of 15 years. The rail assembly will be designed, manufactured and installed to the specified performance requirements for a service life, with normal maintenance, of not less than 15 years to track replacement.

3.1.6 Contact surfaces

The design, manufacture and installation will ensure as far as possible that excessive wear of components of the rail assembly due to fretting (repeated, small amplitude movements) does not occur. The service life for the rail assembly stated above shall apply in this respect. Contact stresses, materials, surface finishes and lubrication requirements will be defined for each sliding surface. For design purposes, a cumulative longitudinal movement at rail level as stated in Table 1 per year (average over the first 15 years) will be assumed. For the time being for E4 10km accumulated movement upper year will be considered.

3.1.7 Maintenance requirements

The maintenance requirements for the railway expansion joints shall not interfere with normal railway operations. Based on experience gained on the TMB and KSM

Bridges in Hong Kong, it can be stated that within a window of 4-5h all components of the Rail assembly, bearings of sledges or girders or parts of the lever connections can be replaced during normal scheduled maintenance.

3.1.8 Compatibility of maintenance provisions

For the time being provisions for the rail assemblies with the track work on the Messina Bridge are ensured where possible, rail head contour and steel grade of rails are identical.

3.1.9 Performance requirements

Any performance requirements of the railway authority other than already incorporated in the specifications of the project referred in 1.3.1 shall be mutually agreed between involved parties.

3.1.10 TSI conformity for high speed lines

The design of the REJ will concord with the requirement of the category II of the TSI for high speed (lines specially adapted for high speed) of the order V=200km/h, even if the design speed is speed is 120 km/h.

3.2 Loads

- The loadings for railway expansion joints shall be:

25 tons static axle load
100kN nosing force
175kN derailment force

- The partial load factors and load combinations for use in the design of railway expansion joints comply with EN 1991-2 Eurocode 1: Actions on structures – Part 2: Traffic loads on bridges

- Impact factors for use on loads on the Railway expansion joint are:

2.5 for axle load and derailment force
1.2 for derailment force defined by static axle load
1.1 for nosing

3.3 Movements and rotations of the primary bridge structure

- The railway expansion joints will be designed to accommodate movements and rotations arising from deformation of the primary bridge structure. The railway expansion joints will be designed to accommodate values of longitudinal and transverse movement and of angular rotation of up to those given in cl. 2.
- The railway expansion joints will be designed to accommodate incremental movements and accelerations due to rail live loading, occurring during the passage of a train travelling. The values to be adopted in the design are given in Table 1 of Per-

formance Specification - Rail Expansion, Joints. Annex, CG.1000-P-1S-D-P-SS-A0-AM-00-00-00-00-A_A- 01_PS-Rail Expansion Joints, dd. 2010-08-16

3.4 Performance relating to railway usage

The runability of the railway on the REJ's will be part of the runability study done by COWI for the entire bridge.

3.5 Applicability

Maximum vertical and horizontal accelerations will be evaluated for the various conditions that apply throughout the life of the railway expansion joints, including, as appropriate, the conditions at the limit of serviceability of the various components by COWI as part of there dynamic evaluation.

3.6 Existing geometry

The railway expansion joint will be fully compatible with the geometry (under permanent load and mean temperature) and structural arrangement of the primary bridge structure and with the geometry of the adjacent track work. This will be achieved for the structural arrangement of the primary bridge structure by the design of the spline girder done by COWI.

3.7 Clearances

The design will ensure that no part of the railway expansion joint, except for guard rails, projects above rail level.

3.8 Rail fastenings and support

- The running rails will be supported throughout the length of the railway expansion joint by such means and at intervals of 600mm nominal.
- Rail fastenings on the railway expansion joints shall be the elastic type and the spring element shall exert sufficient force on the foot of the rail to prevent any uplift of the rail relative to the fastening assembly. The assembly shall also prevent lateral movement of the rail relative to the fastening assembly.

At some location guiding clips with for rail free fastening will be used to guide moving stock rails through the REJ's.

As part of the interface clarification to the Rail assembly of the main bridge it has to be checked whether adjustment switches or other provisions are required.

- The resilience of the fastenings will be similar to the one of the used on the main bridge.
- The fastening system will prevent permanent longitudinal creep of the fixed rails relative to the railway expansion joint structure under braking and traction forces. Due to the function of the REJ moveable stock rails will have at defined location fas-

tening with reduced toe load or rail free fastening.

- Where angular rotations are accommodated, the fastenings will permit longitudinal movement of rails relative to the fastening assemblies, but at no time shall the axial stresses in the rails be allowed to exceed 50 N/mm^2.
- The rollover of the rail head under any combination of vertical and lateral forces specified will not exceed 1.5 mm.
- Under SLS track forces specified (not derailment or overturning conditions), track gauge under load shall not increase by more than 4 mm from the unloaded condition, measured 14 mm beneath the plane of the rails.
- Local rail deflections shall be limited so that the requirements of section 3.4 for maximum vertical accelerations are complied with. The dynamic behaviour of the rails under moving wheel loads shall be taken into account in assessing the vertical accelerations.
- Rail stresses will be within permissible limits, as determined by established methods, under all static, dynamic and fatigue loadings, Oberbauberechnung der DB AG.
- Detailing of sliding parts will be such as to minimize the ingress of objects, dirt and contaminants and to ensure the proper functioning of the joint.
- All connections on the rail assembly will be located and detailed so that inspection, adjustment and maintenance can be easily carried with a minimum of intervention to other components.

3.9 Guard rails

1 Throughout the railway expansion joints guard rails will be placed inside or outside the running rails and shall be provided to prevent derailment. The location of the guard rails will be such that they do not touch the wheel of any train whilst the train is running normally. The location of the controlling faces of the guard rail shall be compatible with the location of the controlling faces of the guard rail on the bridge structure.

2 There is no location in the railway expansion joint where the effective track gauge exceeds 1464mm. Therefore there is no need for operational check rails.

3 not used

4 The operational side of the head of inside guard rails shall be vertical. The upper surface of the head of such rails shall be up to 30 mm above the plane of the running rails when new and unworn.

5 Outside guard rails will be designed to provide protection against derailment equivalent to that provided by inner guard rails.

6 not used

7 Guard rails, check rails and their supports will be designed so that they will remain serviceable under a lateral load of 1.2 times the maximum static axle load on the rails applied to the head of the check rail at the most unfavourable location.

3.10 Wheel unloading

The action of the railway expansion joint will ensure that the wheels of a train are continuously supported throughout its length and through the transition to the adjoining track work. Effects of negative rotations to be checked by COWI during their design.

3.11 Noise and vibration

To be checked by COWI during their design

3.12 Access

The design will facilitate easy access to the whole of the railway expansion joint.

4 Materials and workmanship:

4.1 General

- All materials will be chemically, structurally and mechanically compatible with the materials specified for the works designed by the supervision. Wherever any such incompatibility could deleteriously affect the life, maintenance or operating efficiency of the works designed by the supervision, appropriate protective or isolation measures shall be included in the design wherever such compatibility would not otherwise be achieved.
- The surface treatment shall meet the requirements of corrosively category C5-M.

In particular:

a) Rails, switch and stock rails, cast sleeves:

60µm DFT, Prime coat, grey
180µm DFT, Top coat, RAL code

b) baseplates:

75µm hot dip galvanizing, except vulcanized surfaces
70µm DFT, Spraying filler, grey
70µm DFT, Top coat, RAL code

c) rail fastener:

Vossloh clips, KTL, Cathodic dip painting (to be confirmed)
special K-clips, T-head bolt M22 with nut, galvanized
Uls 6 washer, hot dip galvanized

d) Sledges, lever connections, containments / guard rails and supports:

2x 50µm DFT, Prime coats, grey and red
150µm DFT, Intermediate coat, grey
150µm DFT, Top coat, RAL code

- High performance sliding materials with increased load capacity and durability will be applied in the sliding bearings.

4.2 Rail supporting structure

- Subject to section 4.1 and except where otherwise specified herein all steelwork used for Rail Supporting Structures will comply with the requirements contained in GCG.G.03.02, Structural steelwork and protective treatments.
- The Manufacturer shall propose protective treatments to the Rail Supporting Structure which will comply with GCG.G.03.02, Structural steelwork and protective treatments.

4.3 Rail assembly components

- Unless stated otherwise herein, all materials and components shall comply with the relevant railway standards, e.g. UIC, EN.
- Rails will be 60E1 (previous UIC60), grade R260 in accordance with EN13674-1
- Stock rails for REJ at location E4 will be 60E1T2 (previous A74), grade R260 in accordance with EN13674-1
- Switch rails for REJ at location E5 & E7 will be 60E1A1 (previous Zu-1-60), grade R260 in accordance with EN13674-2
- Rails will comply with], class X for profile requirements and class A for straightness, surface flatness and twist tolerances. Rails will be accompanied with certificates called up in these standards.
- Rails shall be protected from corrosion. Suitable corrosion protection to any sliding surfaces shall be provided.
- All the metallic components in rail fastenings will have a fatigue life of not less than 800 million gross tonne traffic (subject to confirmation of appointed suppliers), and shall be treated with an approved corrosion inhibitor to ensure that they remain serviceable for at least 15 years in the aggressive climatic conditions that will apply.
- Non-metallic components will be naturally resistant to the effects of heat, ultra-violet light, oil spillage and salt spray.

in particular:

a) REJ60±2000

- REJ Sleeve, casting made from Austenitic Manganese Steel acc. to UIC866-O code with 11 – 14% Mn content
- Stock rail, rail 60E1T2, R260 acc. to EN13674-1, class A and X
- Baseplates: High-elastic base plate system BWG for turnouts and special track work material like REJ's on fortified track work, high-speed turnouts and MRT-systems for

the reduction of structure-borne noise and vibrations.

- Range of resilience for 120kph and max. 25tons axle load c_{stat} 17.5 to 30.0kN/mm.
- Fastened by 2 M27 bolts with lateral adjustability of ±9mm in 1mm increments.
- Provision of ±10mm vertical adjustability by means of HDPE shims.
- rail fastener Vossloh SKL clip, clips with reduced toe load and rail free clips
- welded sledges supported and guided by resilient bearings with sliding surface on stainless steel sliding surfaces. Sliding surfaces protected by bellow.
- sledges connected by lever connections to equalize spacing between sledges and structures
- containment / guard rails from rolled section on supporting brackets
- rail inclination: at sleeves and on sledges flat, than transition to 1:40 and 1:20
- Homologation of REJ60±2000 acc. to MTRC Hong Kong requirement for 140kph and application on long suspension and cable stay bridges are available.
- Homologation of baseplates acc. to Deutsche Bahn AG requirement for high speed lines, up to 25to axle load and electrical insulation are available.

b) REJ60±600 and REJ60±400

- Switch rail, rail 60E1A1, R260 acc. to EN13674-1
- Stock rail, rail 60E1, R260 acc. to EN13674-1, class A and X
- Baseplates: High-elastic base plate system BWG for turnouts and special track work material like REJ’s on fortified track work, high-speed turnouts and MRT-systems for the reduction of structure-borne noise and vibrations.
- Range of resilience for 120kph and max. 25tons axle load c_{stat} 17.5 to 30.0kN/mm.
- Fastened by 2 M27 bolts with lateral adjustability of ±9mm in 1mm increments.
- Provision of ±10mm vertical adjustability by means of HDPE shims
- rail fastener Vossloh SKL clip, clips with reduced toe load and SKL rail free clips
- welded sledge supported and guided by resilient bearings with sliding surface PTFE on stainless steel sliding surfaces. Sliding surfaces protected by bellow.
- sledge connected by lever connection to equalize spacing between sledge and structures
- containment / guard rails from rolled section on supporting brackets
- rail inclination: at switch and stock rail assembly and on sledges flat, than transition to 1:40 and 1:20
- Homologation of REJ60±600 and REJ60±400 acc. to Deutsche Bahn AG requirement for high speed lines, up to 25to axle load are available.
- Homologation of baseplates acc. to Deutsche Bahn AG requirement for high speed lines, up to 25to axle load and electrical insulation are available.

4.4 Joints in rail assemblies

- Insulated joints are not used within the railway expansion joints.
- Running rails within the REJ’s will be made out of one piece of rail. There will be no welded joints or fish plated joints, and no drilling for fish bolts shall be undertaken in the running rails and switch and stock rails.

- Flush-butt-welding joints will be used, e.g. to join cast expansision sleeves to normal rails
- Welds will be located not less than 3 m longitudinally from any joint in the rail supporting structures.

5 Scope of supply:

From top of rail the material will be supplied down to the top of railway beam or spline girder, e.g. steel deck plate for through bolts and nuts, holes already drilled by others according to VAE design or concrete slab for drilling of anchor holes approx. Dia 40 x 140mm. On the concrete slab provisions for either keeping reinforcement out of drilling location or allowance of cutting reinforcement during drilling shall be granted by the manufacturer of the concrete slab. Concrete surface under the rails at baseplate location shall be smooth and within +0/-20mm in longitudinal and ±2mm between centrelines of rail in transverse direction.

For interface surfaces on steel structures we expect tolerances according to EN ISO 13920:1996

- linear measurements, class A
- angular measurements, class A
- straightness, flatness and parallelism, class E

VAE will supply all rails and special track work components as shown on the General Layout drawings. At interface joints of rails, VAE considers the adjacent track as continuous welded track (CWR). At these locations, VAE will not provide material for Thermit welding.

Not included in the scope of supply are:

- rail anchors
- walk ways, stairs, hand rails and cover plates
- Cables and cable connections

6 Marking and delivery:

All rails switch and stock rail, cast sleeves assemblies sledges and containment / guard rails are delivered to the side with colour coding for the installation location and marked with baseplate spacing and installation orientation.

Rails, switch and stock rails, cast sleeves assemblies and containment / guard rails are mounted on temporary wooden posts. Baseplates, lever connections and small parts are delivered in sea-worthy boxes.

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ONE STEP AHEAD.

REFERENCE LIST (excerpt)
Rail Expansion & Rail Movement Joints

customer	country	profile(s)	max. speed [km/h]	axle load [to]	expansion [mm]	track form	year of first installation
ÖBB Austrian Federal Railways	Austria	49E1 54E2 60E1 60E1	140 160 200 200	22.5	±100 ±200 ±100 ±300	ballast, wooden and concrete bearers	starting 1965
SBB Swiss Federal Railways	Switzerland	46E1 54E2 60E1	160 200	22.5	±100 ±200 ±200	ballast wooden and concrete bearers	starting 1968
BLS Swiss Private Railways	Switzerland	54E2 60E1	160 160	22.5	±100 ±200 ±300	ballast wooden and concrete bearers	starting 1987
SNTF Algerian State Railways	Algeria	54E1	160	22.5	±90 ±150	ballast wooden bearers	starting 1985
DSB Danish State Railways	Denmark	60E1	140	22	±415	direct fixation	2007

customer	country	profile(s)	max. speed [km/h]	axle load [to]	expansion [mm]	track form	year of first installation
NSB Norges Statsbaner	Norway	49E1	140	22	±100	ballast, wooden bearers	1985
CP Caminhos de Ferro Portugueses E.P.	Portugal	60E1	160	22.5	±100	ballast, wooden bearers	1998
MTRC Lantau Airport Railway	Hong Kong	60E1 including supporting structure	140	17	±1100 ±500	direct fixation	1997
MTRC Urban Line	Hong Kong	45E1	90	17	±100	direct fixation	2003
WVB Metro Vienna	Austria	49E1	80	12	±200 ±150	ballast, wooden and concrete bearers	starting 1985 2007
BR Jamuna Bridge Rail Link	Bangladesh	45E1 incl. supporting structure	60	23	+80/ -860	Direct fixation	2000

DSB / BV State Railways	Öresund, Denmark/ Schweden	60E1	200 90	22,5 25,0	±600	ballast, concrete bearers	1999

Stretto di Messina
Support Spacing between Sledges and Terminal E4(S)-SLS1

Movement	Number of sledes	distance between CL of supports	
E4	5	325	Reference TMB dwg. no.:104371, 596mm - 275mm = ~325mm
Movement		12800	
1200	200,0	760	max. distance between centre lines of supports
0		560,0	neutral distance between centre lines of supports
-1200	-200,0	360	min. distance between centre lines of supports

vertical rotation [Rad]		12800	Proposal for E4, distance between supports on concrete structures in neutral position
		14000	
0,001	0,057295828	14000	max. Radius [m] due to vertical rotation, max. opening
		11600	min. Radius [m] due to vertical rotation, max. closing
0,001	0,057295828	14000	max. Radius [m] due to vertical rotation, max. opening
		11600	min. Radius [m] due to vertical rotation, max. closing
horizontal rotation [Rad]		12800	Proposal for A1, distance between supports on concrete structures in neutral position
		11600	
0,002	0,114591656	7000	max. Radius [m] due to horizontal rotation, max. opening
		5800	min. Radius [m] due to horizontal rotation, max. closing
0,002	0,114591656	7000	max. Radius [m] due to horizontal rotation, max. opening
		5800	min. Radius [m] due to horizontal rotation, max. closing
track inclination relative to bridge bearing [%]			Bridge & Spline girder bearerings parallel to track inclination
1,500	0,015	0,0	[mm] vertical displacement, when max. open
		0,0	[mm] vertical displacement, when max. closed

Legend:
Base plates spacing on sledges shall be 600mm
values for SLS1 movements
max. vertical rotation up = +mrad, down -mrad
max. horzontal rotation clockwise +mrad, counter clockwise -mrad
reviced vertical rotations received by e-mail on 1.10.10

Stretto di Messina
Support Spacing between Sledges and Terminal E4(S)-SLS2

Movement	Number of sledes	distance between CL od supports	
E4	5	325	Reference TMB dwg. no.:104371, 596mm - 275mm = ~325mm
Movement		12800	
1400	233,3	793	max. distance between centre lines of supports
0		560,0	neutral distance between centre lines of supports
-1400	-233,3	327	min. distance between centre lines of supports

vertical rotation [Rad]		12800	Proposal for E4, distance between supports on concrete structures in neutral position
		14200	
0,002	0,114591656	7100	max. Radius [m] due to vertical rotation, max. opening
		5700	min. Radius [m] due to vertical rotation, max. closing
0,002	0,114591656	7100	max. Radius [m] due to vertical rotation, max. opening
		5700	min. Radius [m] due to vertical rotation, max. closing
horizontal rotation [Rad]		12800	Proposal for A1, distance between supports on concrete structures in neutral position
		11400	
0,0025	0,14323957	5680	max. Radius [m] due to horizontal rotation, max. opening
		4560	min. Radius [m] due to horizontal rotation, max. closing
0,0025	0,14323957	5680	max. Radius [m] due to horizontal rotation, max. opening
		4560	min. Radius [m] due to horizontal rotation, max. closing
track inclination relative to bridge bearing [%]			Bridge & Spline girder bearerings parallel to track inclination
1,500	0,015	0,0	[mm] vertical displacement, when max. open
		0,0	[mm] vertical displacement, when max. closed

Legend:
Base plates spacing on sledges shall be 600mm
values for SLS2 movements
max. vertical rotation up = +mrad, down -mrad
max. horzontal rotation clockwise +mrad, counter clockwise -mrad
reviced vertical & horizontal rotations received by e-mail on 1.10.10

Stretto di Messina
Support Spacing between Sledges and Terminal E4(S)-ULS

Movement	Number of sledes	distance between CL od supports	
E4	5	325	Reference TMB dwg. no.:104371, 596mm - 275mm = ~325mm
Movement		12800	
2000	333,3	893	max. distance between centre lines of supports
0		560,0	neutral distance between centre lines of supports
-2000	-333,3	227	min. distance between centre lines of supports

vertical rotation [Rad]		12800	Proposal for E4, distance between supports on concrete structures in neutral position
		14800	
0,004	0,229183312	3700	max. Radius [m] due to vertical rotation, max. opening
		2700	min. Radius [m] due to vertical rotation, max. closing
0,004	0,229183312	3700	max. Radius [m] due to vertical rotation, max. opening
		2700	min. Radius [m] due to vertical rotation, max. closing
horizontal rotation [Rad]		12800	Proposal for A1, distance between supports on concrete structures in neutral position
		10800	
0,003	0,171887484	4933	max. Radius [m] due to horizontal rotation, max. opening
		3600	min. Radius [m] due to horizontal rotation, max. closing
0,003	0,171887484	4933	max. Radius [m] due to horizontal rotation, max. opening
		3600	min. Radius [m] due to horizontal rotation, max. closing
track inclination relative to bridge bearing [%]			Bridge & Spline girder bearerings parallel to track inclination
1,500	0,015	0,0	[mm] vertical displacement, when max. open
		0,0	[mm] vertical displacement, when max. closed

Legend:
Base plates spacing on sledges shall be 600mm
values for ULS movements
max. vertical rotation up = +mrad, down -mrad
max. horzontal rotation clockwise +mrad, counter clockwise -mrad
reviced vertical & horizontal rotations received by e-mail on 1.10.10

Stretto di Messina
Support Spacing between Sledges and Terminal E5(S)-SLS1

Movement	Number of sledes	distance between CL of supports	
E5	1	325	Reference TMB dwg. no.:104371, 596mm - 275mm = ~325mm
Movement		3460	
250	125,0	655	max. distance between centre lines of supports
0		530,0	neutral distance between centre lines of supports
-250	-125,0	405	min. distance between centre lines of supports

vertical rotation [Rad]		3460	Proposal for E5, distance between supports on concrete structures in neutral position
		3710	
0,002	0,114591656	1855	max. Radius [m] due to vertical rotation, max. opening
		1605	min. Radius [m] due to vertical rotation, max. closing
0,002	0,114591656	1855	max. Radius [m] due to vertical rotation, max. opening
		1605	min. Radius [m] due to vertical rotation, max. closing
horizontal rotation [Rad]		3460	Proposal for E5, distance between supports on concrete structures in neutral position
		3210	
0,002	0,114591656	1855	max. Radius [m] due to horizontal rotation, max. opening
		1605	min. Radius [m] due to horizontal rotation, max. closing
0,002	0,114591656	1855	max. Radius [m] due to horizontal rotation, max. opening
		1605	min. Radius [m] due to horizontal rotation, max. closing
track inclination relative to bridge bearing [%]			Bridge & Spline girder bearerings parallel to track inclination
1,500	0,015	0,0	[mm] vertical displacement, when max. open
		0,0	[mm] vertical displacement, when max. closed

Legend:
Base plates spacing on sledges shall be 600mm
values for SLS1 movements
max. vertical rotation up = +mrad, down -mrad
max. horzontal rotation clockwise +mrad, counter clockwise -mrad

Stretto di Messina
Support Spacing between Sledges and Terminal E5(S)-SLS2

Movement	Number of sledes	distance between CL of supports	
E5	1	325	Reference TMB dwg. no.:104371, 596mm - 275mm = ~325mm
Movement		3460	
400	200,0	730	max. distance between centre lines of supports
0		530,0	neutral distance between centre lines of supports
-400	-200,0	330	min. distance between centre lines of supports

vertical rotation [Rad]		3460	Proposal for E5, distance between supports on concrete structures in neutral position
		3860	
0,003	0,171887484	1287	max. Radius [m] due to vertical rotation, max. opening
		1020	min. Radius [m] due to vertical rotation, max. closing
0,003	0,171887484	1287	max. Radius [m] due to vertical rotation, max. opening
		1020	min. Radius [m] due to vertical rotation, max. closing
horizontal rotation [Rad]		3460	Proposal for E5, distance between supports on concrete structures in neutral position
		3060	
0,003	0,171887484	1287	max. Radius [m] due to horizontal rotation, max. opening
		1020	min. Radius [m] due to horizontal rotation, max. closing
0,003	0,171887484	1287	max. Radius [m] due to horizontal rotation, max. opening
		1020	min. Radius [m] due to horizontal rotation, max. closing
track inclination relative to bridge bearing [%]			Bridge & Spline girder bearerings parallel to track inclination
1,500	0,015	0,0	[mm] vertical displacement, when max. open
		0,0	[mm] vertical displacement, when max. closed

Legend:
Base plates spacing on sledges shall be 600mm
values for SLS2 movements
max. vertical rotation up = +mrad, down -mrad
max. horzontal rotation clockwise +mrad, counter clockwise -mrad

Stretto di Messina
Support Spacing between Sledges and Terminal E5(S)-ULS

Movement	Number of sledes	distance between CL of supports	
E5	1	325	Reference TMB dwg. no.:104371, 596mm - 275mm = ~325mm
Movement		3460	
600	300,0	830	max. distance between centre lines of supports
0		530,0	neutral distance between centre lines of supports
-600	-300,0	230	min. distance between centre lines of supports

vertical rotation [Rad]		3460	Proposal for E5, distance between supports on concrete structures in neutral position
		4060	
0,004	0,229183312	1015	max. Radius [m] due to vertical rotation, max. opening
		715	min. Radius [m] due to vertical rotation, max. closing
0,004	0,229183312	1015	max. Radius [m] due to vertical rotation, max. opening
		715	min. Radius [m] due to vertical rotation, max. closing
horizontal rotation [Rad]		3460	Proposal for E5, distance between supports on concrete structures in neutral position
		2860	
0,004	0,229183312	1015	max. Radius [m] due to horizontal rotation, max. opening
		715	min. Radius [m] due to horizontal rotation, max. closing
0,004	0,229183312	1015	max. Radius [m] due to horizontal rotation, max. opening
		715	min. Radius [m] due to horizontal rotation, max. closing
track inclination relative to bridge bearing [%]			Bridge & Spline girder bearerings parallel to track inclination
1,500	0,015	0,0	[mm] vertical displacement, when max. open
		0,0	[mm] vertical displacement, when max. closed

Legend:
Base plates spacing on sledges shall be 600mm
values for ULS movements
max. vertical rotation up = +mrad, down -mrad
max. horzontal rotation clockwise +mrad, counter clockwise -mrad

Stretto di Messina
Support Spacing between Sledges and Terminal E7(C)-SLS1

Movement	Number of sledes	distance between CL of supports	
E7	1	325	Reference TMB dwg. no.:104371, 596mm - 275mm = ~325mm
Movement		3460	
100	50,0	580	max. distance between centre lines of supports
0		530,0	neutral distance between centre lines of supports
-100	-50,0	480	min. distance between centre lines of supports

vertical rotation [Rad]		3460	Proposal for E7, distance between supports on concrete structures in neutral position
		3560	
0,002	0,114591656	1780	max. Radius [m] due to vertical rotation, max. opening
		1680	min. Radius [m] due to vertical rotation, max. closing
0,002	0,114591656	1780	max. Radius [m] due to vertical rotation, max. opening
		1680	min. Radius [m] due to vertical rotation, max. closing
horizontal rotation [Rad]		3460	Proposal for E7, distance between supports on concrete structures in neutral position
		3360	
0,002	0,114591656	1780	max. Radius [m] due to horizontal rotation, max. opening
		1680	min. Radius [m] due to horizontal rotation, max. closing
0,002	0,114591656	1780	max. Radius [m] due to horizontal rotation, max. opening
		1680	min. Radius [m] due to horizontal rotation, max. closing
track inclination relative to bridge bearing [%]			Bridge & Spline girder bearerings parallel to track inclination
1,6718	0,016718	0,0	[mm] vertical displacement, when max. open
		0,0	[mm] vertical displacement, when max. closed

Legend:
Base plates spacing on sledges shall be 600mm
values for SLS1 movements
max. vertical rotation up = +mrad, down -mrad
max. horzontal rotation clockwise +mrad, counter clockwise -mrad

Stretto di Messina
Support Spacing between Sledges and Terminal E7(C)-SLS2

Movement	Number of sledes	distance between CL of supports	
E7	1	325	Reference TMB dwg. no.:104371, 596mm - 275mm = ~325mm
Movement		3460	
200	100,0	630	max. distance between centre lines of supports
0		530,0	neutral distance between centre lines of supports
-200	-100,0	430	min. distance between centre lines of supports

vertical rotation [Rad]		3460	Proposal for E7, distance between supports on concrete structures in neutral position
		3660	
0,003	0,171887484	1220	max. Radius [m] due to vertical rotation, max. opening
		1087	min. Radius [m] due to vertical rotation, max. closing
0,003	0,171887484	1220	max. Radius [m] due to vertical rotation, max. opening
		1087	min. Radius [m] due to vertical rotation, max. closing
horizontal rotation [Rad]		3460	Proposal for E7, distance between supports on concrete structures in neutral position
		3260	
0,003	0,171887484	1220	max. Radius [m] due to horizontal rotation, max. opening
		1087	min. Radius [m] due to horizontal rotation, max. closing
0,003	0,171887484	1220	max. Radius [m] due to horizontal rotation, max. opening
		1087	min. Radius [m] due to horizontal rotation, max. closing
track inclination relative to bridge bearing [%]			Bridge & Spline girder bearerings parallel to track inclination
1,6718	0,016718	0,0	[mm] vertical displacement, when max. open
		0,0	[mm] vertical displacement, when max. closed

Legend:
Base plates spacing on sledges shall be 600mm
values for SLS2 movements
max. vertical rotation up = +mrad, down -mrad
max. horzontal rotation clockwise +mrad, counter clockwise -mrad

Stretto di Messina
Support Spacing between Sledges and Terminal E7(C)-ULS

Movement	Number of sledes	distance between CL of supports	
E7	1	325	Reference TMB dwg. no.:104371, 596mm - 275mm = ~325mm
Movement		3460	
400	200,0	730	max. distance between centre lines of supports
0		530,0	neutral distance between centre lines of supports
-400	-200,0	330	min. distance between centre lines of supports

vertical rotation [Rad]		3460	Proposal for E7, distance between supports on concrete structures in neutral position
		3860	
0,004	0,229183312	965	max. Radius [m] due to vertical rotation, max. opening
		765	min. Radius [m] due to vertical rotation, max. closing
0,004	0,229183312	965	max. Radius [m] due to vertical rotation, max. opening
		765	min. Radius [m] due to vertical rotation, max. closing
horizontal rotation [Rad]		3460	Proposal for E7, distance between supports on concrete structures in neutral position
		3060	
0,004	0,229183312	965	max. Radius [m] due to horizontal rotation, max. opening
		765	min. Radius [m] due to horizontal rotation, max. closing
0,004	0,229183312	965	max. Radius [m] due to horizontal rotation, max. opening
		765	min. Radius [m] due to horizontal rotation, max. closing
track inclination relative to bridge bearing [%]			Bridge & Spline girder bearerings parallel to track inclination
1,6718	0,016718	0,0	[mm] vertical displacement, when max. open
		0,0	[mm] vertical displacement, when max. closed

Legend:
Base plates spacing on sledges shall be 600mm
values for ULS movements
max. vertical rotation up = +mrad, down -mrad
max. horzontal rotation clockwise +mrad, counter clockwise -mrad