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

PONTE SULLO STRETTO DI MESSINA

PROGETTO DEFINITIVO

EUROLINK S.C.p.A.
IMPREGILO S.p.A. (MANDATARIA)
SOCIETÀ ITALIANA PER CONDOTTE D'ACQUA S.p.A. (MANDANTE)
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SACYR S.A.U. (MANDANTE)
ISHIKAWAJIMA - HARIMA HEAVY INDUSTRIES CO. LTD (MANDANTE)
A.C.I. S.C.P.A. - CONSORZIO STABILE (MANDANTE)

IL PROGETTISTA Ing E.M.Veje COWI Eurolink Dott. Ing. E. Pagani Ordine Ingegneri Milano n° 15408	IL CONTRAENTE GENERALE Project Manager (Ing. P.P. Marcheselli)	STRETTO DI MESSINA Direttore Generale e RUP Validazione (Ing. G. Fiammenghi)	STRETTO DI MESSINA Amministratore Delegato (Dott. P. Ciucci)

Unità Funzionale	OPERA D'ATTRAVERSAMENTO	PS0001_F0
Tipo di sistema	SOVRASTRUTTURE	
Raggruppamento di opere/attività	ELEMENTI DI CARATTERE GENERALE	
Opera - tratto d'opera - parte d'opera	General	
Titolo del documento	Serviceability Checks	

CODICE: C G 1 0 0 0 P R X D P S V 0 0 0 0 0 0 0 0 0 0 0 1 F0

REV	DATA	DESCRIZIONE	REDATTO	VERIFICATO	APPROVATO
F0	20/06/2011	EMISSIONE FINALE	LSJ	SCC	LSJ / LSJ

NOME DEL FILE: PS0001_F0.docx

INDICE

1 Introduction

1.1 Scope

The suspension bridge is checked with regard to the performance related to functionality (serviceability checks) in accordance with the Design Basis, [1]. The following serviceability checks are comprised by this report:

- Equivalent longitudinal slope for railway usage (Section 4.3.1 of [1])
- Total longitudinal slope for roadway usage (Section 4.3.2 of [1])
- Total transverse slope for roadway usage (Section 4.3.2 of [1])
- Performance relating to marine traffic (Section 4.3.3 of [1])

All the calculations are based on results from the global IBDAS model version 3.3b.

1.2 Report Outline

This report is organized into the following sections:

- Section 1 includes this introduction, provides a list of reference materials (design specifications and reference drawings) and includes the conclusion
- Section 2 describes the requirements and checks carried out regarding the equivalent longitudinal slope for railway usage
- Section 3 describes the requirements and checks carried out regarding the total longitudinal slope for roadway usage
- Section 4 describes the requirements and checks carried out regarding the total transverse slope for roadway usage
- Section 5 describes the requirements and checks carried out regarding the performance relating to marine traffic

1.3 References

1.3.1 Design Specifications

[1] CG1000-P-RG-D-P-GE-00-00-00-00-00-02-A "Basic Studies, Design Basis, Structural, Annex", COWI, 2010 October 11

1.3.2 Drawings

The project drawings relevant for this report are listed in Table 1-1.

Table 1-1 Project drawings relevant for this report

Drawing Title	Drawing Number
Roadway and Railway Alignment	CG1000-P-LX-D-P-SV-00-00-00-00-00-01_A

1.4 Conclusion

The following is concluded for the equivalent longitudinal slope for railway usage:

- The requirement to equivalent longitudinal slope for railway usage is fulfilled as the maximum slope for the situation in SLS1 with one train on one track is determined to 1.77% (below the requirement of 1.80%), for the situation in SLS1 with two trains on two different tracks is determined to 1.77% (below the requirement of 2.00%) and for the situation in SLS2 with two trains on two different tracks is determined to 1.82% (below the requirement of 2.20%).

The following is concluded for the total longitudinal slope for roadway usage:

- The requirement to total longitudinal slope for roadway usage in SLS1 is fulfilled as the maximum slope is determined to 4.94% which is below the requirement of 5%.

The following is concluded for the total transverse slope for roadway usage:

- The requirement to transverse slope for roadway usage in SLS1 is fulfilled as the maximum slope (which is at the quarter span) is determined to 6.01% which is below the requirement of 7%.

The following is concluded for the performance relating to marine traffic:

- The level to the deflected soffit of the cross girder at the edge of the 600 meter wide navigation clearance is approx. 65.41 m which is above the requirement of 65.00 m.
- The level to the deflected soffit of the cross girder at the edge of the 3,240 meter wide navigation clearance is approx. 52.17 m which is above the requirement of 50.00 m.

2 Equivalent longitudinal slope for railway usage

2.1 Technical requirements

The requirement to the equivalent longitudinal slope for railway usage is given in Clause 4.3.1, Table 10 of [1]:

- SLS1: <1.8% (one train on one track) and <2.0% (two trains on two different tracks).
- SLS2: <2.2% (two trains on two different tracks).

2.2 Serviceability check

The longitudinal slope of the bridge deck at the reference condition is bigger for the Sicily side of the main span (1.5000%) compared to the Calabria side of the main span (0.9232%). Therefore the check is carried out for the Sicily side of the main span.

The allowable equivalent longitudinal slope for variable loads is thereby limited to the following values:

- SLS1, one train on one track: 1.80% - 1.50% = 0.30%
- SLS1, two trains on two different tracks: 2.00% - 1.50% = 0.50%
- SLS2, two trains on two different tracks: 2.20% - 1.50% = 0.70%

The following loads are applied:

- Road and rail traffic loads: QR loads as defined in Clause 5.2.2 of [1].
- Wind load: SLS1/SLS2 static mean wind load as defined in Clause 5.3.1 of [1].

- Seismic load: SLS1/SLS2 seismic load as defined in Clause 5.3.2 of [1].
- Temperature load: SLS temperature load as defined in Clause 5.3.3 of [1].

The values for the equivalent longitudinal slope are calculated for the following locations of the rail traffic load (mid point of train(s), length varying between 75 m and 750 m in intervals of 75 m) - for each location the most adverse location of the road traffic load is applied:

- S = -450 (half of the train(s) is located on the section with 1.5% slope and the other half on the curved part of the alignment)
- S = -637.50 (three quarter of the train(s) is located on the section with 1.5% slope and one quarter on the curved part of the alignment)
- S = -825 (the train(s) is located at the end of the section with 1.5% slope - this is also equivalent to the quarter span)
- S = -1012.5 (the train(s) is moved a quarter of the train length further towards Sicily tower)
- S = -1200 (the train(s) is moved a quarter of the train length further towards Sicily tower)

2.2.1 Checks for SLS1

Values for the equivalent longitudinal slope for railway usage in SLS1 for the situation with two trains on two different tracks are summarised in the table below. The values are taken as the ry rotations from the global IBDAS model.

Table 2.1 Equivalent longitudinal slope for railway usage in SLS1 for the situation with two trains on two different tracks - slopes are given in % - positive values means slope in same direction as built in longitudinal slope.

Location for mid point of trains (m)	**-450**	**-637.5**	**-825**	**-1012.5**	**-1200**
QR road traffic load	0.04	0.04	0.07	0.06	0.04
QR rail traffic load	0.08	0.06	0.00	-0.05	-0.09
VV, SLS1 static mean wind load	0.02	0.01	0.01	0.01	0.02
VS, SLS1 seismic load	0.03	0.02	0.05	0.05	0.06
VT, SLS temperature load	0.08	0.11	0.15	0.18	0.21
SLS1 load comb. 4 (PP+PN+QR+VV+VT)	0.23	0.23	0.22	0.19	0.18
SLS1 load comb. 5 (PP+PN+QR+VS+VT)	0.23	0.23	0.27	0.23	0.22
Railway built in longitudinal slope	1.50	1.50	1.50	1.50	1.50
Total longitudinal slope (SLS1 - two trains)	**1.73**	**1.73**	**1.77**	**1.73**	**1.72**

The requirement to equivalent longitudinal slope for railway usage is fulfilled as the maximum value from the table above is below the requirement of 2.00%.

The figure below shows the deck deflections applying two 750 m long trains on two different tracks at the 5 locations investigated. The figure explains the negative values for the equivalent longitudinal slope obtained for the locations S = -1012.5 and -1200.

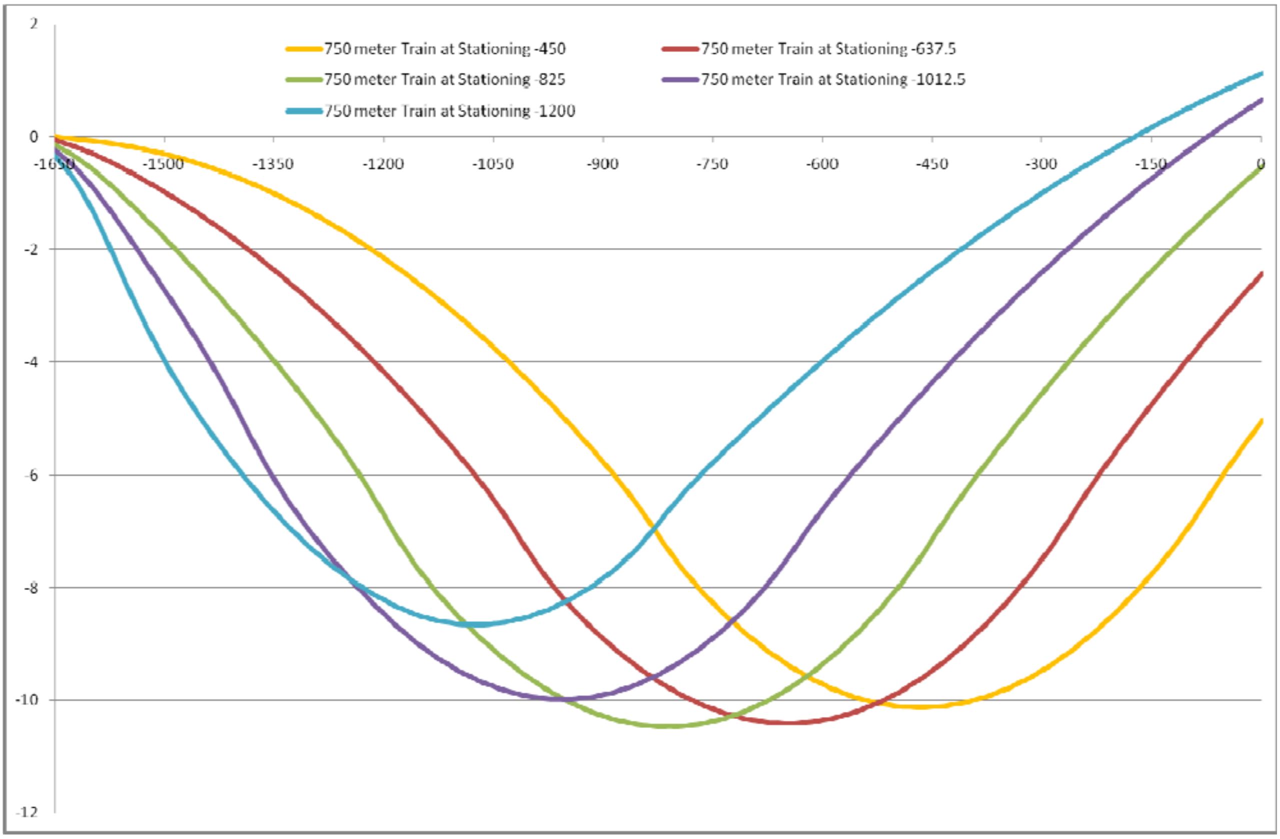

Figure 2.1: Deck deflections applying two 750 m long trains on two different tracks at the 5 locations - deflections are given in m (vertical axis).

The situation with one train in one track can be estimated by removing half of the QR railway load resulting in the following total values:

Table 2.2 Equivalent longitudinal slope for railway usage in SLS1 for the situation with one train on one track - slopes are given in % - positive values means slope in same direction as built in longitudinal slope.

Location for mid point of trains (m)	**-450**	**-637.5**	**-825**	**-1012.5**	**-1200**
Total longitudinal slope (SLS1 - one train)	1.69	1.71	1.77	1.76	1.76

The requirement to equivalent longitudinal slope for railway usage is fulfilled as the maximum value from the table above is below the requirement of 1.80%.

2.2.2 Checks for SLS2

Values for the equivalent longitudinal slope for railway usage in SLS2 for the situation with two trains on two different tracks are summarised in the table below. The values are taken as the ry rotations from the global IBDAS model.

Table 2.3 Equivalent longitudinal slope for railway usage in SLS2 for the situation with two trains on two different tracks - slopes are given in % - positive values means slope in same direction as built in longitudinal slope.

Location for mid point of trains (m)	**-450**	**-637.5**	**-825**	**-1012.5**	**-1200**
QR road traffic load	0.04	0.04	0.07	0.06	0.04
QR rail traffic load	0.08	0.06	0.00	-0.05	-0.09
VV, SLS2 static mean wind load	0.03	0.02	0.01	0.01	0.02
VS, SLS2 seismic load	0.06	0.05	0.10	0.11	0.14
VT, SLS temperature load	0.08	0.11	0.15	0.18	0.21
SLS2 load comb. 4 (PP+PN+QR+VV+VT)	0.23	0.23	0.23	0.19	0.18
SLS2 load comb. 5 (PP+PN+QR+VS+VT)	0.26	0.26	0.32	0.30	0.29
Railway built in longitudinal slope	1.50	1.50	1.50	1.50	1.50
Total longitudinal slope (SLS2)	**1.76**	**1.76**	**1.82**	**1.80**	**1.79**

The requirement to equivalent longitudinal slope for railway usage is fulfilled as the maximum value from the table above is below the requirement of 2.20%.

3 Total longitudinal slope for roadway usage

3.1 Technical requirements

The requirement to the longitudinal slope for roadway usage is given as <5% in Clause 4.3.2, Table 12 of [1] for the functionality level CF (complete functionality). It appears from Table 9 of [1] that CF refers to SLS1. Therefore the SLS1 load combinations are applied for this check.

3.2 Serviceability check

The longitudinal slope of the bridge deck at the reference condition is bigger for the Sicily side of the main span (1.5000%) compared to the Calabria side of the main span (0.9232%). Therefore the check is carried out for the Sicily side of the main span.

The allowable total longitudinal slope for variable loads is thereby limited to 5.0% - 1.5% = 3.5% for SLS1.

The following loads are applied:

- Road and rail traffic loads: QR loads as defined in Clause 5.2.2 of [1].
- Wind load: SLS1 static mean wind load as defined in Clause 5.3.1 of [1].
- Seismic load: SLS1 seismic load as defined in Clause 5.3.2 of [1].
- Temperature load: SLS temperature load as defined in Clause 5.3.3 of [1].

The values for the total longitudinal slope are calculated using the most adverse location of the road and rail traffic loads.

Values for the total longitudinal slope are summarised in the table below for 5 locations. The values are taken as the ry rotations from the global IBDAS model.

Values in general for SLS1 load combination 5 are shown in the figure below for the Sicily part of the main span.

Table 3.1 Total longitudinal slope of roadway girder in SLS1 - slopes are given in % - positive values means slope in same direction as built in longitudinal slope.

Location for mid point of trains (m)	**-1560**	**-1185**	**-810**	**-435**	**-60**
QR road traffic load	0.19	0.15	0.14	0.16	0.16
QR rail traffic load	2.90	2.14	1.85	1.85	1.93
VV, SLS1 static mean wind load	0.06	0.04	0.03	0.03	0.04
VS, SLS1 seismic load	0.09	0.06	0.05	0.05	0.03
VT, SLS1 temperature load	0.26	0.20	0.14	0.08	0.01
SLS1 load comb. 4 (PP+PN+QR+VV+VT)	3.41	2.53	2.16	2.12	2.14
SLS1 load comb. 5 (PP+PN+QR+VS+VT)	3.44	2.55	2.18	2.14	2.13
Roadway built in longitudinal slope	1.50	1.50	1.50	1.50	1.50
Total longitudinal slope	**4.94**	**4.05**	**3.68**	**3.64**	**3.64**

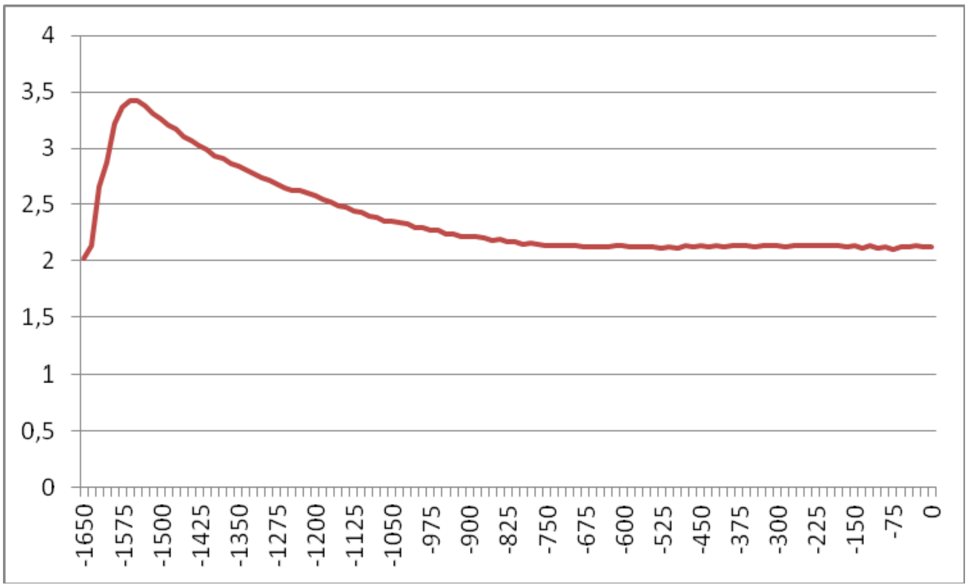

Figure 3.1: Total longitudinal slope of roadway girder in SLS1 load combination 5 for Sicily part of the main span - slopes are given in % - positive values means slope in same direction as built in longitudinal slope.

The requirement to total longitudinal slope for roadway usage is fulfilled as the maximum value from the table above is below the requirement of 5%.

4 Total transverse slope for roadway usage

4.1 Technical requirements

The requirement to the total transverse slope for roadway usage is given as <7% in Clause 4.3.2, Table 12 of [1] for the functionality level CF (complete functionality). It appears from Table 9 of [1] that CF refers to SLS1. Therefore the SLS1 load combinations are applied for this check.

As the roadway deck has a built-in cross fall of 2%, the allowable total transverse slope for variable loads is <5%.

4.2 Serviceability check

The following loads are applied:

- Road and rail traffic loads: QR loads as defined in Clause 5.2.2 of [1].
- Wind load: SLS1 static mean wind load as defined in Clause 5.3.1 of [1].
- Seismic load: SLS1 seismic load as defined in Clause 5.3.2 of [1].
- Temperature load: SLS temperature load as defined in Clause 5.3.3 of [1]

The maximum total transverse slope appears at the quarter span. The values for the total transverse slope are calculated using the most adverse location of the road and rail traffic loads.

Values for the total transverse slope are summarised in the table below. The values are taken as the rs rotations from the global IBDAS model.

Table 4.1 Total transverse slope of roadway girder in SLS1 - wind is blowing from Y+ direction - slopes are given in %.

	Y- roadway girder		**Y+ roadway girder**	
	Max rs	Min rs	Max rs	Min rs
QR road traffic load	1.56	-1.56	1.56	-1.56
QR rail traffic load	1.61	-2.01	2.01	-1.61
VV, SLS1 static mean wind load	0.76 1)	-0.39 1)	0.77 1)	-0.38 1)
VS, SLS1 seismic load	0.04	-0.04	0.04	-0.04
VT, SLS temperature load	0.08	-0.03	0.03	-0.08
SLS1 load comb. 2 (PP+PN+QR+VT)	3.25	-3.60	3.60	-3.25
SLS1 load comb. 4 (PP+PN+QR+VV+VT)	4.01	-3.99	4.37	-3.63
SLS1 load comb. 5 (PP+PN+QR+VS+VT)	3.29	-3.64	3.64	-3.29
Roadway built in cross fall	2.00	2.00	-2.00	-2.00
Total transverse slope	**6.01**	**-1.99**	**2.37**	**-5.63**

1) These slopes are conservatively based on dynamic wind without traffic

The requirement to total transverse slope for roadway usage is fulfilled as the maximum value from the table above is below the requirement of 7%.

5 Performance relating to marine traffic

5.1 Technical requirements

The requirement is given in Clause 4.3.3 of [1]: the navigational clearance shall be satisfied by the deflected bridge deck starting from the basic design profile at the reference temperature under road traffic load QR (as defined in Clause 5.2.2 of [1]) and rail traffic load taken as the worst of:

- 2 real trains RFI 5, having a length of 400 m each
- 1 real train RFI 5, having a length of 750 m

5.2 Serviceability check

The distance between the navigational clearance profile and the bridge deck at the reference condition is smaller for the Sicily side of the main span compared to the Calabria side of the main span. Therefore the deflection is checked at the following locations in the Sicily side of the main span:

- At the edge of the 600 m wide navigational clearance in the centre of the main span (s=-300)
- At the edge of the 3,240 meter wide navigational clearance near the Sicily tower (s=-1620)

The values for the deflection are calculated using the most adverse location of the traffic loads. The values are taken as the uz displacements from the global IBDAS model.

The deflection at the lower corner of the cross girder 8.75 m from the centre line of the bridge deck are summarised in the table below. The values are taken as the uz displacements from the global IBDAS model.

Table 5.1 Performance relating to marine traffic - deflections are given in m.

Distance from centre main span (m)	**-300**	**-1,620**
Vertical clearance	65	50
Reference level for railway (top of rail)	+77.500	+58.075
Distance top of rail to top of cross girder at CL-bridge	0.200	0.200
Depth of cross girder at CL-bridge	4.680	4.680
Thickness of cross girder bottom flange	0.023	0.036
Deflection, 2 nos. RFI5 having L=400 m	6.412	0.912
Deflection, 1 no. RFI5 having L=750 m	5.027	0.622
Deflection, QR road traffic load	0.772	0.079
Level to deflected soffit of cross girder	**+65.413m**	**+52.168 m**

It is noted that the deflections for rail and road traffic are based on 1st order calculations. A 2nd order calculation would reduce the deflections by approx. 5%.

Values in general for the total deflection for 2 nos. RFI5 trains having a length of 400 m each and QR roadway load for the Sicily part of the main span are shown in the figure below.

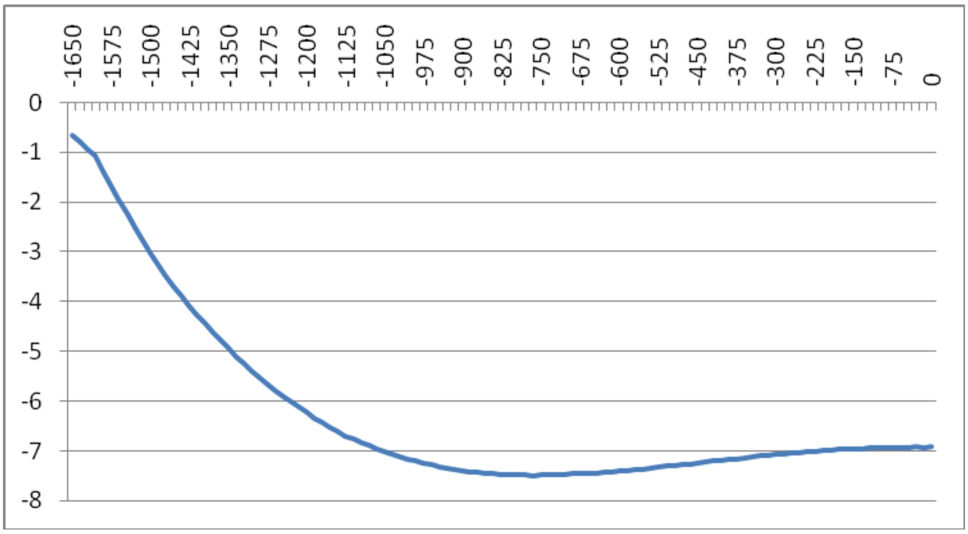

Figure 5.1: Deflection in m for 2 nos. RFI5 trains having a length of 400 m each and QR roadway load for Sicily part of the main span.

The level to the deflected soffit of the cross girder at the edge of the 600 meter wide navigation clearance is 65.413 m which is above the requirement of 65.000 m.

The level to the deflected soffit of the cross girder at the edge of the 3,240 meter wide navigation clearance is 52.168 m which is above the requirement of 50.000 m.