12WCEE
2000

0890

ENSURING SEISMIC RESISTANCE OF BRIDGE CROSSINGS ON THE RAILWAY LINE IN DAGHESTAN (RUSSIA)

V SUROVTSEV[1], V SELIVERSTOV[2] And M SOKOLOV[3]

SUMMARY

The paper deals with design criteria and analysis of bridge structures in seismic region classified by a magnitude of 8-9 on the MSK-64 scale. The details of efficient structural measures controlling seismic conditions are discussed

INTRODUCTION

The design and construction of railway line in Daghestan (the North Caucausis of Russia) which provides a detour route of Chechen region were conducted in 1996-1997. This new railway line has a length of 78 km and comprises more than 50 bridges with main spans in a range of 6 – 110 m. Reference bridge structures are grouped in Table 1. One of design specifics was a high seismic activity in the region. The region is classified by a magnitude of 8-9 on the MSK-64 scale. To develop effective structural measures for bridges to control seismic conditions, detailed analyses of bridge structures on seismic load have been performed.

Table 1

#	Bridge span, m	Material	No. of bridges
1	11.5	steel	29
2	> 11.5 and < 33.6	steel	11
3	> 33.6 and < 66	steel	5
4	110	steel	1
5	6	concrete	5

STRUCTURAL MEASURES FOR BRIDGES

The limited construction schedule and economic requirements influenced a choice of standard structural solutions developed by leading Russian design firms for bridges located on seismic zones of magnitude 7-9. Since a new code of practice have recently been approved, structural details of bearings and antiseismic devices designed according to the previous design criteria have been revised. The use of non-standard structural solutions for abutments and intermediate piers required justification of seismic action analysis on these structures in conditions of high-risk seismic zones.

CODE REQUIREMENTS

The recent earthquakes happened on the territories of the former USSR (Armenia, Tadjikistan) and Russia (Sakhalin island) caused a large scale catastrophic damages and human losses. To improve the reliability of seismic action analyses, the provisions of the existing Seismic Code СНиП II-7-81 “Construction in seismic regions” were revised in 1995. These revisions have included introduction of new preliminary schemes of

[1] *Giprotransmost J.S. Co, 2 Pavla Kortchagina Str, Moscow 129278, Russian Federation*
[2] *Giprotransmost J.S. Co, 2 Pavla Kortchagina Str, Moscow 129278, Russian Federation*
[3] *Mosguiprotrans J.S. Co, 2 Pavla Kortchagina Str, Moscow 129278, Russian Federation*

seismic mapping of the territory of the former USSR, which normally have raised the magnitudes in the regions, dynamic coefficients depending on the soil category (ground motion spectra) have been defined more precisely. Fig. 1 shows the dynamic coefficient vs period of self-vibration relationships based on the previous [СНиП II-7-81, 1981] and revised [СНиП II-7-81, revised 1996] versions of the Seismic code.

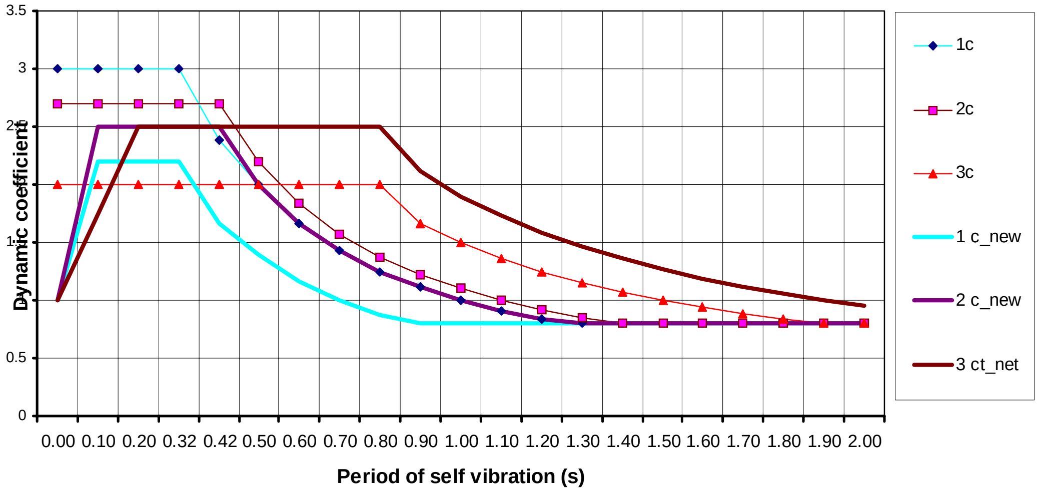
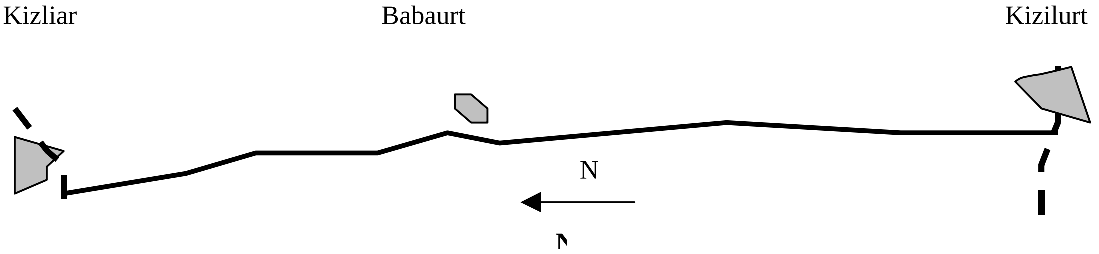


Fig. 1 Relationship of dynamic coefficient vs period of self vibration

SEISMIC DETAILED MAPPING

Territory of Daghestan is a high seismic risk region. For the period of 19966-1996 eight disastrous earthquakes occurred, one of which had a magnitude of 9, two – 8 and five – 7 to 8. The programme of investigations and engineering surveys for design of new railway line Kizliar-Kizilurt have included seismic and geophysical investigations, which allowed seismicity to be defined more precisely. The boundaries of regions with different seismicity were determined with accuracy of 0.2 km. The review outlined that seismicity of 60% of the railway route determined according to the norms were overestimated by a unit (predominantly regions characterized by magnitude of 9 instead of 8) compared to the results of seismic detailed mapping, seismicity of 10% of the railway route were underestimated and seismicity of 30% of the railway route was estimated as equal to that

Км	0		10		20		30		40		50		60		75
N	9-8		9		9		9		9		8.5		9		9
MS	7.5-7.8		8(9)		8		8(9)-8.5		9		8.35		9.15		10



NOTES

1. N - seismicity based on norms
2. MS - seismicity based on rezults of seismic micromapping

Fig.2. Scheme of railway route.

determined in accordance with the norms. Fig. 2 shows a scheme of new railway line, distances and magnitudes obtained in accordance with normative documents and data of seismic detailed mapping [Survey report, 1997]

DESIGN BASIS

When calculating pile foundations of intermediate piers and abutments on seismic load, the standard method normally used in practice for assessment of stability of bridges and their elements in seismic conditions have been adopted [Shestoperov G.S., 1984]. Calculation of forces due to seismic action was performed in accordance with normative documents, which requires spectral analysis, and are currently in use on the territory of Russia [СНиП II-7-81*, 1996; СНиП 2.05.03-84*, 1996]. Masses due to dead loads are taken in calculations with account for coefficients of reliability and combination. When calculating bridge structure in longitudinal direction no live load was considered and the coefficients of reliability and combination was taken as 1.0; in transverse direction live load was considered and the coefficients of reliability and combination were taken as 1.0 and 0.8 respectively. The masses due to live load in calculations of seismic action in transverse direction were considered with coefficients of reliability and combination of 1.0 and 0.7 respectively [СНиП 2.05.03-84*, 1996].

When calculations were performed in longitudinal direction the mass of superstructure was applied to the centre of hinges of fixed bearings; for transverse direction – to the centre of gravity of superstructure. A mass of pilecap was increased by 25% compared to a total mass of piles. Soil pressure at abutment was determined with no account for abutment vibration. No influence of approach fill soil was considered for determination of inertial forces at abutment.

ANALYSIS OF BRIDGE STRUCTURES ON SEISMIC ACTION

To illustrate an approach to analysis of bridge structures on seismic action, an example of analysis of abutment and intermediate pier of three-span (110+110+ 100m) railway bridge over the Terek river are reviewed below. Mainly the review is concentrated on verification of seismic action on pile foundations of the abovementioned structures.

Initial data included the seismicity of region, classified by a magnitude of 8; category of soil was taken as 2. A structural scheme of intermediate pier is shown in Fig.3. Foundation comprises 24 piles, having a diameter of 1.2 m, and constructed of concrete class B25. A depth of penetration is 19m; a mass of 24 piles is 1238t. Nominal mass of superstructure is 749t; nominal mass of live load is 1518.4 t.

A structural scheme of abutment is shown in Fig. 4. Foundation comprises 60 piles of square section 0.35x0.35m and constructed of concrete class B25. A depth of penetration is 10m. A mass of 60 piles is 186t. Nominal mass of superstructure and live load is the same as above.

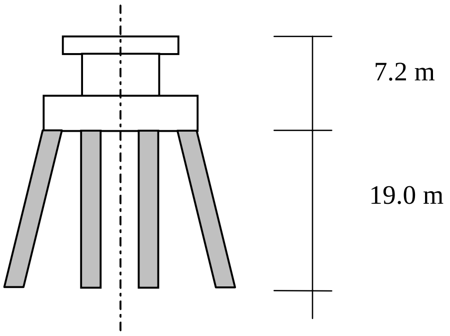


Fig. 3 Structural scheme of intermediate pier

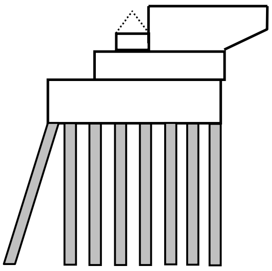


Fig. 4. Structural scheme of abutment.

Analyses of bridge structures were performed using space models by finite element method. Piles were modeled by beams, soils- by springs, corresponding to geological data with account for section dimensions and influence of a number of pile rows. Pier body was modeled by plates and beams with relevant stiffness. Masses of structure and live load reflect a real position of masses in the structure and over the structure. Three-dimensional schemes of intermediate pier and abutment are shown in Fig. 5 and 6.

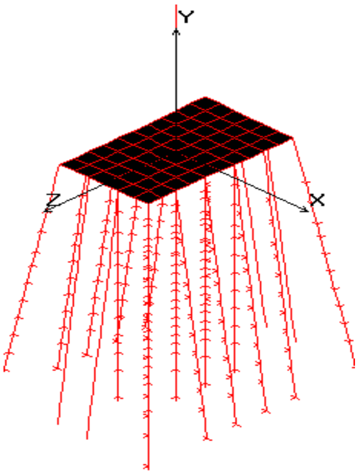


Fig. 5. Design scheme of intermediate pier

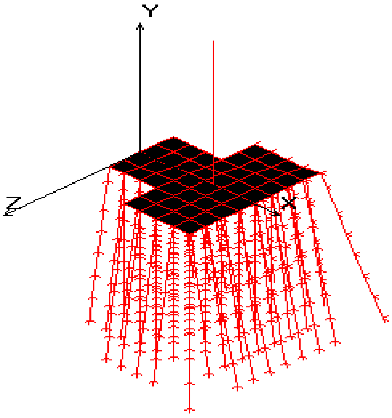


Fig. 6. Design scheme of abutment

Periods of the first modes of vibration obtained from the analyses of intermediate pier in longitudinal and transverse directions were 0.9-0.6 sec, the same for abutment – 0.68 – 0.65 sec. The obtained from the analyses seismic effects at the level of pile cap were used for calculation of piled foundation on vertical component and combined action of M, N, Q. The results of calculations are given in tables 2 and 3.

Table 2. Analysis results for intermediate pier

#	Combinations showing axes direction of seismic action	Combination of masses due to		N, t	Q, t	M, t*m
		Dead load	Live load			
1	“x” + 0.5*y	+	-	133	Q_x=128.5	M_z=714
2	“z”*1.0+”y”*0.5	+	-	133	Q_z=225	M_x=1175
3	“z”*1.0+”y”*0.5	+	(γn=1.16) +	157	Q_z=205	M_x=1578
4	“z”*1.0+”y”*0.5	+	(γn=1.23) +	203	Q_z=216	M_x=1949

Table 3. Analysis results for abutment

#	Combinations showing axes direction of seismic action	Combination of masses due to		N, t	Q, t	M, t*m
		Dead load	Live load			
1	Along the bridge “x”	+	-	30.5	Q_x=118.5	M_z=581.6
2	Transversely along “z”	+	-	-	Q_z=115.4	M_x=499.5
3	“z”*1.0+”y”*0.5	+	-	18.2	Q_z=115.4 Q_x=9.7	M_x=499.4 M_z=35.5
4	Transversely along “z”	+	+	-	Q_z=120	M_x=765
5	“z”*1.0+”y”*0.5	+	+	17.1	Q_z=120 Q_x=10.5	M_x=1949 M_z=36.6

Load combinations, which included seismic load, were governing in the calculations to strength and stability of piled foundations.

ANTISEISMIC DEVICES

To prevent against seismic action, the following antiseismic devices were adopted:

- for steel superstructure - hinged and no-hinged vertical anchor devices;

- for reinforced concrete superstructures - side reinforced concrete curbs (to prevent against transverse seismic action)

A hinged anchor device developed for steel superstructures, having a single span system of 33-110m is shown in Fig. 7. In this structural solution the superstructure is fixed at both ends over transverse beams at junctions of stringers and transverse beams. Where sliding bearings are installed, the structural details of this anchor device allow displacement of superstructure due to live load and temperature. Where standard precast prestressed reinforced concrete railway superstructures, having spans in a range of 16.5-27.6 m, for seismic regions with magnitude of 7-8, reinforced curbs were adopted. Bearing upstands of intermediate piers and abutments are additionally reinforced. The curbs are concreted when the superstructure is erected.

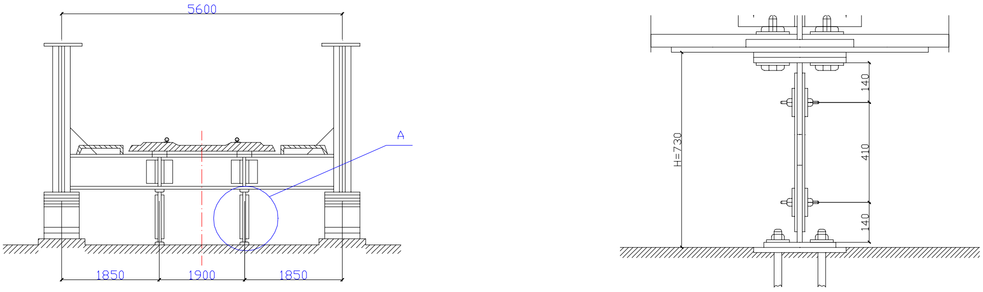


Fig.7. Antiseismic device (span system of 33 ÷ 110m)

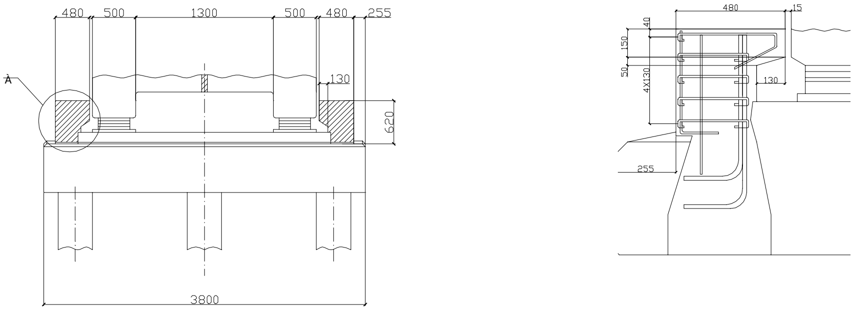


Fig. 8. Antiseismic device (span system of 16.5 ÷ 27.6m)

CONCLUSION

The performed analyses of bridge structures on seismic loads allowed to verify their structural form, to improve the reliability of pier and abutment foundations behaviour, to develop effective structural measures against seismic action conforming to the new requirements of the Seismic code.

REFERENCES

1. CHuП II-7-81* (Building norms and regulations). Construction in seismic regions. Minstroy of Russia, M, 1996.(in Russian).
2. Report on “Surveys of the route of railway line Kizliar-Karlanurt for purposes of detailed seismic mapping”. Enterprise “CKOH”, Mahachkala, 1997.(in Russian)
3. Shestoperov G.S. Stability of bridges against seismic, Transport, Moscow, 1984.(in Russian)
4. CHuП 2.05.03-84* (Building norms and regulations). Bridges and culverts. Minstroy of Russia, M, 1996.(in Russian)