COMPARISON OF SEISMIC RESISTANCE OF HIGHWAY BRIDGE IN YUNNAN BY THE SPECIFICATION OF CHINA AND JAPAN

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1. Background

Yunnan province is one of the populated areas in China where earthquakes have frequently happened especially in recent years. Meanwhile a large number of highway bridges have been designed and constructed in Yunnan, whose seismic resistance design is implemented according to the <Specifications of Earthquake Resistant Design for Highway Engineering> (JTJ004-89). Since October 1st 2008 the <Guidelines for Seismic Design of Highway Bridge> (JTG/T B02-01-2008) has been released, that has eliminated much old guiding concept and revised performance requirement for the bridge seismic design. In this paper, a representative expressway bridge in Yunnan respectively is analyzed according to the Chinese old, revised specifications and Japanese specification.

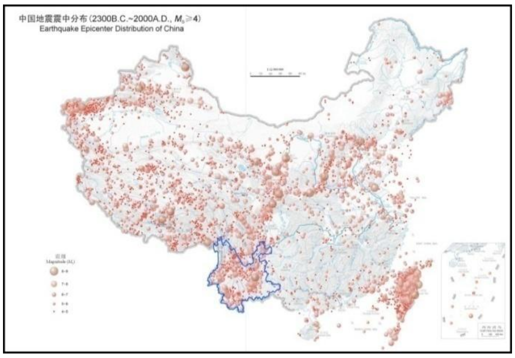

Fig.1 2300B.C.-2000A.D. epicenter distribution of over magnitude 4 earthquakes in China

2. DESCRIPTION OF SEISMIC ANALYSIS PROCEDURE

The K138+800 bridge lies in the Yuanmou~Wuding expressway as a section of the backbone highway for the Develop Western Regions Strategy. It has been open to traffic on Nov. 2008. The bridge has broadly representative as far as its span, structural components, dimension of column and geology condition concerned. In this paper the resistance in the bridge axial direction is evaluated and all columns will be looked as socle beams.

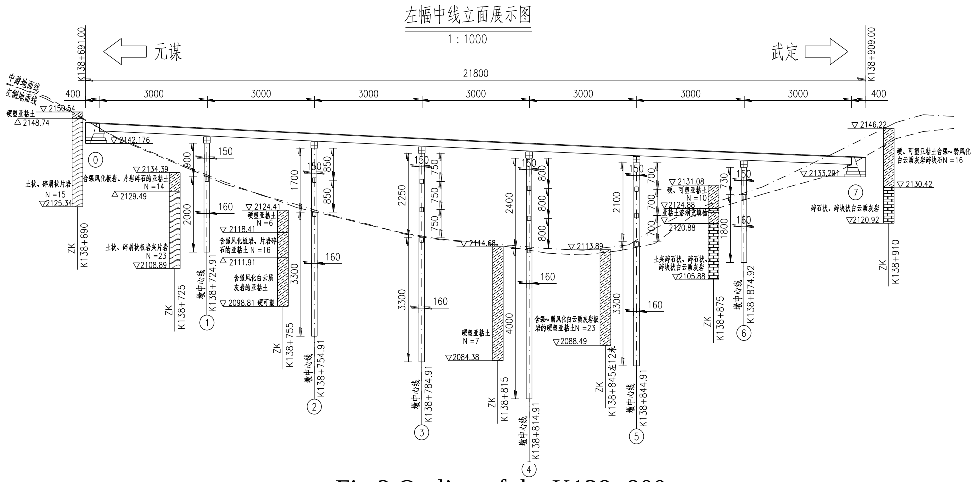

Fig.2 Outline of the K138+800

(1) The structure is considered to keep within elastic stage under the low scale earthquake and the calculation result is shown as follow.

Table 1. Calculation result under low scale earthquake

S.N. of column	E_{hp} <China JTJ044-89>		E1 <China JTG/ TB02-01-2008>		Level1 (Japan JRA-2002)	
	Moment of the bottom cross section (kN·m)	Shearing force of the bottom cross section (kN)	Moment of the bottom cross section (kN·m)	Shearing force of the bottom cross section (kN)	Moment of the bottom cross section (kN·m)	Shearing force of the bottom cross section (kN)
1	2794.2	281.8	2676.6	270.7	13007.6	1338.6
2	1993.9	114.3	1916.8	118.5	9446.9	592.0
3	1553.3	71.5	1411.5	81.5	7069.6	392.9
4	1422.3	62.8	1301.2	77.2	6565.5	359.6
5	1699.0	82.3	1549.0	90.6	7648.7	434.8
6	2400.0	291.5	2536.7	309.2	12555.2	1548.0

By the above results and the elastic resistance evaluation according to the Chinese specification related, it can be concluded that all columns are safety under the E_{hp} and the E1 defined by Chinese old and revised specification respectively. Meanwhile all columns have been beyond the limit of elastic stage under the Level 1 so that is considered has not enough seismic resistance according to the Japanese specification.

(2) The structure is considered to enter plastic stage under a strong earthquake and the calculation result is shown as follow, which is analyzed by static method:

Bridge in Yunnan, nonlinear dynamic analysis, response spectrum, seismic specification for bridge
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Table 2. Calculation result under strong scale earthquake

Specification	<China JTG/TB02-01-2008>	<Japan JRA-2002>	
Seismic effect	E2	level2	
Analysis method	Multimode response spectrum method	Ductility capacity method (push-over method)	
		Type1	Type2
Calculation result (take the No.6 column as example）	- The shearing force at the bottom of column: V_{c0}=626.7(kN)$<$$V_R$=1590.2(kN); - Maximal angle of hinge rotation: θ_p =0.0193(rad)> θ_u =0.0070(rad) - Residual displacement of the top of column: δ_R =0.207(m)>δ_{Ra} =0.130(m)	- Ductility capacity: $P_a = 529.5(kN) < k_{he}W = 2058.9(kN)$ - Shearing resistance: $P_s = 502.4(kN) < Pa < P_{so} = 704.7$ (kN) - Residual displacement of the top of column: δ_R=0.241(m)>δ_{Ra} =0.092(m)	- Ductility capacity: $P_a = 525.1(kN) < k_{he}W = 1713.4(kN)$ - Shearing resistance: P_a <Ps=604.0 (kN) - Residual displacement of the top of column: δ_R=0.126(m)>δ_{Ra} =0.092(m)
Partial safety evaluation	Shearing resistance: OK！ Brittle failure can be avoided. Maximal angle of rotation: NO! Residual displacement of the top of column: NO！	Ductility capacity: NO！ Residual displacement of the top of column: NO！ Destructional forms: shearing failure after flexural yielding.	Ductility capacity: NO！ Residual displacement of the top of column: NO！ Destructional form: flexural failure

(3) Using dynamic structural analysis by time-history method, the restriction to the displacement of superstructure by abutments will be considered seismic potential of the structure. The model is calculated by the earthquake wave of T2-III-1(1995, HYOUGOKEN_South, N12W).

When the assumptive largest displacement of the superstructure reaches 13cm (the given displacement superposed by the gaps from the expansion joint and the experiential deform of abutment), and the maximum moment of the plastic hinge at the bottom of the No.6 column is controlled within: M_{max} =4522(kN·m) < M_u =4844.8(kN·m) by the adjustment of the spring stiffness of between the superstructure and the abutments**.** The rubber supports are also kept within theirs safetylimit.

However the maximum force of the restricting spring mentioned has reach 87420 (kN) and the huge acting force (impulse) was calculated beyond the capacity for acceptance of not only the abutments but also the ends of the superstructure. So the abutments though can restrict the displacement of the superstructure and reduce the moment of column at some level, it cannot improve the seismic ability of the structure to reach safety level and the structure still is in dangerous under this kind of strong earthquake.

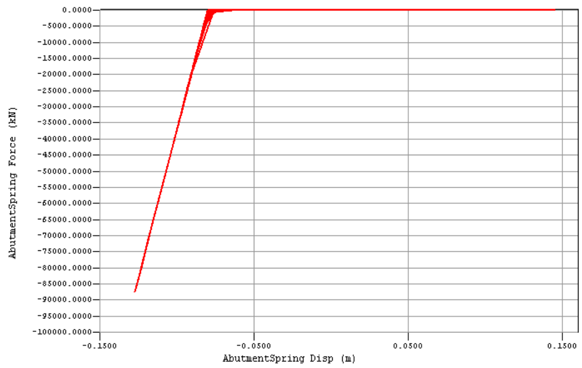

Fig.3 Time-history of the spring force between superstructure and abutment

3. CONCLUSION

1)The seismic performance level of the bridges whose seismic design was implemented before Oct 1^{st} 2008 according to the <China JT044-89> only equals to the performance for the low scale earthquake (E1) provided in the <JTG/T B02-01-2008> and cannot meet the requirement of the 3-level performance. The seismic resistance of many large highway bridges in Yunnan is not enough, including many expressway bridges accomplished not long ago and the damage is potentially predicted especially when a strong earthquake happens.

2) In strong earthquake condition, the failure pattern of the bridge mentioned is deduced as flexural failure and the brittle failure form can be avoided, that is considered is more reasonable for safety. When the plastic hinge will come into being in the bottom of some columns, at least one of them the horizontal displacement of the top and the maximum angle of rotation of the hinge will be beyond the maximum limit in the specifications and the large deformation will cause the bridge function failure.

3) The Chinese seismic structural theory and specification that is still not safety side in comparison with the Japanese one, it should widely borrow ideas from foreign advanced theory and experience and been continuously supplemented and improved. On the other hand, the bridges that have been constructed or completed to traffic should be in a planned way and with focuses seismic recalculated, checked and reinforced according to the new <JTG/T B02-01-2008> and some foreign reasonable successful experience, especially the bridges in the “lifeline” highway lie on higher seismic intensity zones.

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