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An investigation into the effect of earthquake on bridges

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ABSTRACT:
As the roads and bridges have significiant effects on social and economical development in a country, and because of high construction cost of such structres, it is necessary to be considered all aspects of structral design particulary earthquake effects.
In this paper, three different methods have been used to analyse the selected models: dynamic analysis, using finite element and Ray Leigh methods and proposed methods by various codes. The results have been compared, and at the end, the effects of the 1990 Gilan Earthquake on some of the bridges in the earthquake area have been explored.

Introduction:
In each highway alignment, there are many small and big bridges which their construction costs are several times higher than a road with the same width. For this reason the bridges must be designed to resist well against static and dynamic loads in short and long terms.
In a seismic region, in order to find the earthquake effects on bridges, a series of theoretical, experimental studies are made which as a series of static relationships are available in standards. In the case of bridge design, the equivalent static load is not adequate, spicially for long spans.
1. In the first phase of study, the statistical analysis was made on 3 type of bridges (fig. 1.1) which were appropriate models among the constructed bridges.
The first model was a bridge with 3 spans and rolling supports on abutments and with fixed joints between columns and beams.
The prestressed box girder have been chosen for deck's cross section. The second model was a single span frame system with reinforced concrete flat slab in deck which is often used for small spans.
The third model was a simple bridge with medium span which is used in consecutive spans and with pr-

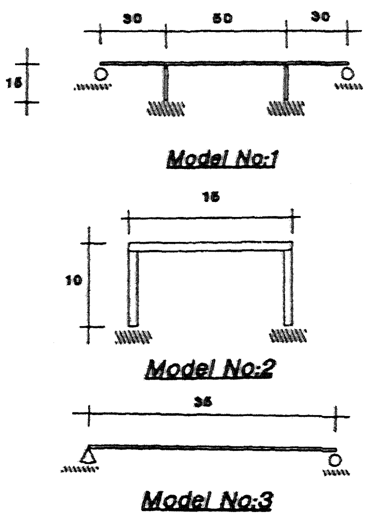

FIG. 1-1

-estressed girders in deck.
1.1: At first the three proposed models was analysed by Rayleigh method and after computing the natural frequencies, the equivalent force of earthquake was found from response spectra graphs
1.2: In second part of research, 3 proposed models of bridges was madeled with concentrated masses and analysed by finite element method according to El-Centro California response spectrum graph, and defined

5 mode shapes and natural frequencies of the first five-mode shapes . (fig. 1.2)

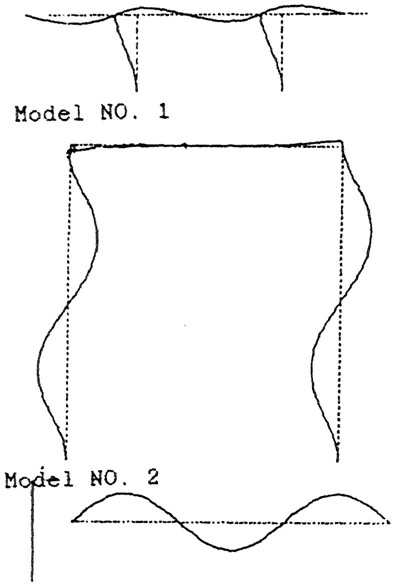

FIG.1-2 BRIDGES MODE SHAPES

All of analysies , have been made in 3 dimensions (x , y , z) . According to results of these studies the pseudo velocity was defined from the responce spectra and then the equivalent siesmic forces have been completed .
Due to the Newmark and Hall research for reinforced concrete with considarable cracks , 5 percent of damping value is used .
In general , notice that the period of the first modes in each model have maximum value , thus the max. equivalent shear force of earthquake will be in accordance with this period .

1.3 For comparing the results of relations , given in different codes with corresponding present results from dynamic analysis , the selected models are tested against proposed earthquake codes of AASHTO ,India , Japan.Results are shown in table 1.2

Conclusion

1.4 According to the dynamic studies and max. coeficients in practice codes , the following results have defined:
- In most of codes , to compute the earthquake effects, kind of structral system , geometric specificians of bridge and length of spans, natural frequencies of bridge's vibrations

TABLE 1-2

PRACTICE CODES RELATIONS

CODE	MIN. COEF.	MAX.COEF.	VERT. FORCE
JAPAN	HIGHWAY BRIDGES 0.1008	0.24	0.12
	RAILROAD BRIDGES 0.108	0.248	0.132
AASHTO	0.10	0.24	NON
INDIA 1ST METHOD	0.01	0.144	0.72
INDIA 2nd METHOD	5 PERCENT DAMPING 0.0095	0.137	CHECK OVERTURNING & SLIDING
	2 PERCENT DAMPING 0.014	0.202	

are not studied and also the earthquake effects in codes , are based on the importance of structre , kind of soil and the probability of of seismic risk .
- max.coeficients in AASHTO and Japan codes is about 0.24 and in indian code equal to 0.2 (For the social - economical programs of government)
Dynamic analysis of the first model, showed that the big span of a bridge , affects directly on the natural frequencies and mode shapes. In three dimensional analysis the max. equivalent static forces are about 2 times greater than the max. values in practice codes .
In the second model (Frame system) the responce of structre is very important and the results of dynamic analysis , specially , in the first mode are more greater than the equivalent earthquake forces in codes and in Y direction is 1.5 times greater than the max. values in codes . In prependicular direction , the effect of span's length in first and second modes are greater than 1.7 times from static values of Japanies codes , and the rigidity and shape of frame affect behavior of structre .
In isostatic bridges (model No 3) dynamic effects of earthquake in longitudinal and transversal direct--ion on deck are very low , so that, they are not computed . Vertical force of earthquake produces large forces in girders . These forces , for example , widely affect the supporting systems , so that , it may destroy all of them .

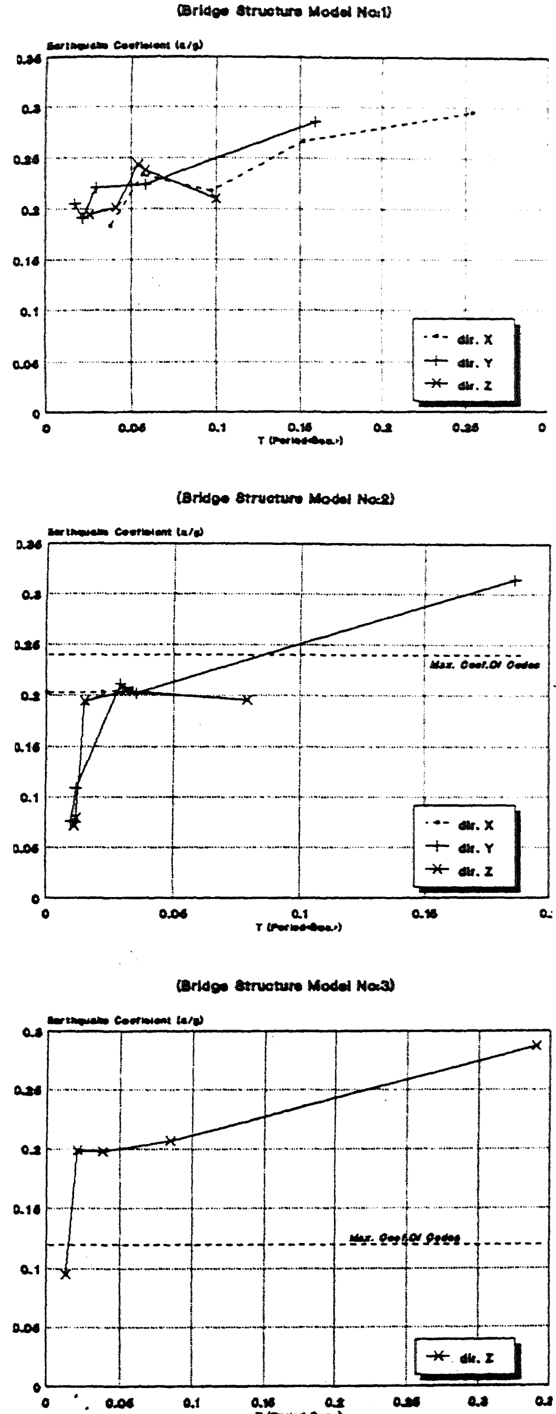

FIG 1-3

Fig. 1.3 shown the earthquake coefi--cient in the first five mode shape of each models.

The max. equivalent force of earthquake was about 2.5 times higher than Japanies code,therefore,the vertical forces of the earthquake should be computed exactly and also the structral members should be designed for it .

These studies showed that for small bridges and short columns (less than 25m), the difference between dynamic analysis and the values of codes are very low and because of instantenous effects of earthquake and using the elasto-plastic behaviour of materials it could be prevented against destruction (in ultimate limit states) , however, for bridges with long column or large length of span , it is necessary to use dynamic analysis methods and also one of the most important shortcomings of the practical codes , is that the displacements of bridges (specially) in longitudinal direction is not controlled and therefore , it may be resulted in damping the structre.

2.The country of Iran is on Alpayed fault . History of the last 80 years has shown that in average an signifant earthquake has occured in Iran where at least two of them has had intensity of higher than seven on Richter scale. The last earthquake occured on thursday , June 22 , 1990 in north-west of Iran at 21h ,13s(UT) ,with approximatly 7.3, magnitude on Richter scale .The epicenter was near the south coast ,at the bottom of caspian sea ,about 200 kilometers north west of Tehran in Deylaman area.

In Gillan region , many small masonry bridges have collapsed,however modern bridges , which had been designed on the basis of engineering standards , sustained less damages .

In following,two of these later bridg--es are analysed.

2.1 Rostam-Abad bridge :This bridge has 15 spans with 30 meters length , was built in Rostam - Abad area . The average length of column is 4.5meters and the circular columns have 2.5 meter in diameter . Each column has been built on a pile . Deck of bridge have 4 prestressed girder with 2.75 meter distance between them , and are sit on neoprene bearings .

deformation and by siesmic vibrations , large displacements were applied .

a) longitudinal displacement of girders filled the consturction joints about 3 to 5 Cm,because,Girders were not kept by suitable resisting system b) In transversed direction ,because of non lateral Supporting system deck of bridge have large displacements and 12,13,14 and15 internal spans have eccentricity from center line of bridge and some cases the girders are displaced from bearings.

C)Because of vertical force of earthquaks. The deck (with 600 TON weight)was jumped and after falling ,the bearings was damaged and also the shear force of this impact produced shear cracks in girders . For study these phenomena a model of simple span bridge was analysed by dynamic methods(Fig2.1) and the results showed the importance of vertical earthquake component therefore ,it is necessary to use the vertical and lateral supports to protect the deck and bearings and also the neoprene bearings should calculated exactly for horizontal displacements of girders .

2.2 Bala-Bala bridge:This bridge who has twenty three spans with 30 meter

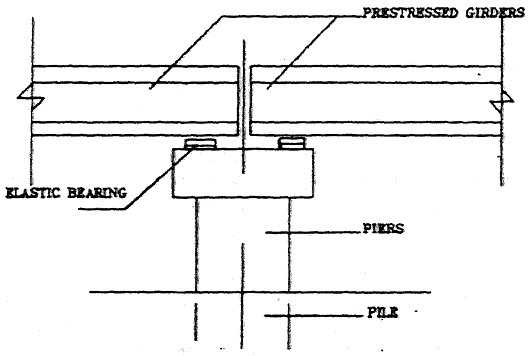

FIG.2.1 TYPICAL DETAIL FOR GIRDERS SUPPORT

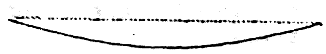

FIG.2.2 FIRST MODE SHAPE OF BRIDGE

length which has built in 1976 on loashan river.The deck of this bridge has prestrssed concrete beams and other specifications are similar to Rostam - Abad bridge.The main damages in this bridge and the reasons of damaging were studied by dynamic analy--sis method .

Fig.2.2 shown the first mode shape of this bridge.

The results are as follows:

2.3 The river bed is sandy soil and liquifaction produced the displacements of piers and the lateral displacements of soil near the columns is about 30 to 70 Cm .

2.4 In this bridge bearings with 20x50x1 (Cm) dimensions (as fig 2.3) were damaged due to the large distorsion and buckling therefore , because of the high pressure of impact of the deck to the base plates the elastic part of the base plate was buckled .

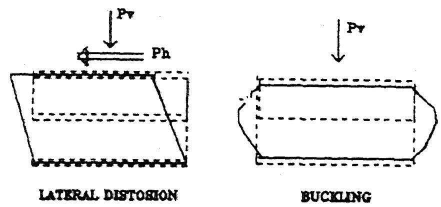

FIG.2-3 DISTORSION OF ELSTIC BEARINGS

Min thickness of the bearings should be computed by the following relation : $a/10<T<a/5$

$a=20$, $T=1$: $T<a/10=2$ Cm

2.5 In each bridge and for each girder the lateral supports should be designed for both lateral and vertic--al effect of earthquake specially for vertical force and also min.stress on bearings should be greater than:

(min. stress) > $(P-Fv)/Abp$

Where P:vertical force (weight)
Fv:negative earthquake force (vertical force)
Abp:area of bearing

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