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EFFECT OF SEISMIC ISOLATION SYSTEMS ON DYNAMIC BEHAVIOR OF BRIDGES UNDER EARTHQUAKE LOADING

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ABSTRACT

The use of seismic isolation systems is one of the ways of aseismic designing of bridges. The dynamic modelling for analysis and design of this type of the structures is very important. The aim of this paper is to: 1) choose the suitable model for explaining the dynamic behaviour of bridges; 2) the effect of isolators locating in the structure of bridges. The paper also pay attention to analyzing the behavior of materials and isolaters which assumed to be linear and the effect of variation of some parameters such as stiffness variation of deck, piers and elastomeric bearings. The nonlinear, behaviour for isolators has been investigated too. The camparison of different isolators parameters has been studied and the results are shown by graphs.

KEYWORD

Base isolation, isolated bridge, elastomeric bearing, isolators.

INTRODUCTION

Bridges are one of the most important structures which have been used as a lifeline communicator. The applicable, lowcost and safe methods are desired for aseismic designing of bridges due to earthquake loading. One of these methods is the use of seismic isolation systems. In this method, the main parts of bridges, deck has been seperated from other parts such as piers and also the piers and abutments from the ground.

The scope of this paper is to study the effect of various isolators on the dynamic behaviour of bridges and the camparison between them.

For this purpose, the first step is to find the suitable model for explaining the dynamic behaviour of bridges. The second step is to add some parameters to this model such as isolators, and the different locations of these isolators on the bridges. These models will be analysed and will compare the results.

STUDY ON THE MODEL

3.1. Selected Model

For this study, one three span concrete bridge has been used as shown in Fig. (1). This type of bridges has some parameters such as pier, abutment, middle span and beside span which can describe in general the dynamic behaviour of bridges.

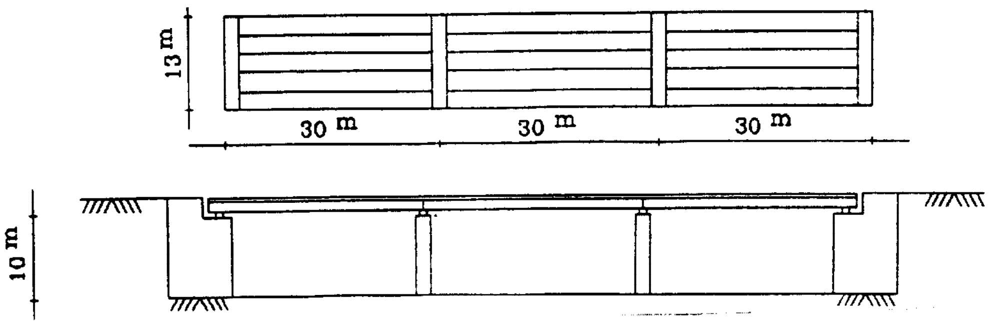


Fig (1). Plan and longitudinal section of studied bridge

3.2. Model selection

For modelling the dynamic behaviour of this bridges, following models are investigated:

- Space Model of Three Dimension (SMTD)

In this model, the deck has been modelled as a grid which contains the longitudinal and lateral girders, and piers as a row of columns. The degrees of freedom and concentrated masses are shown in Fig. 2.

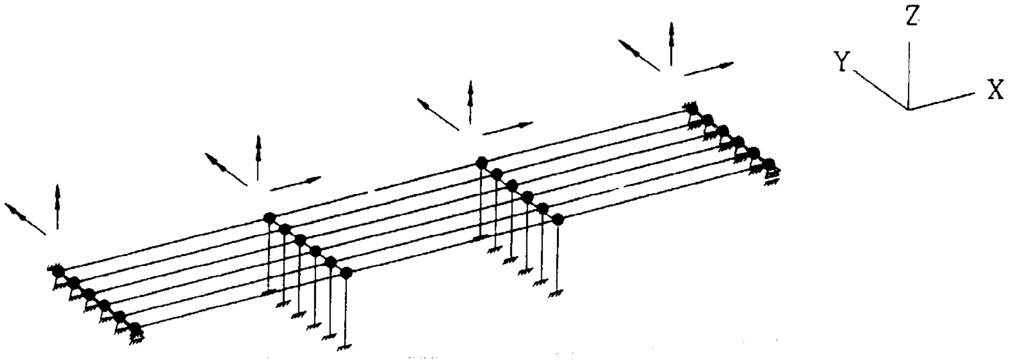


Fig (2). Three dimensional expanded model (model No. 1)

- Model of Three Dimension (MTD)

This model, infact, is the compacted form of SMTD model in the longitudinal axis of bridge. The stiffness of columns has been considered in one column as a pier. The concentrated mass has also been determined in the same way and is shown in Fig. 3.

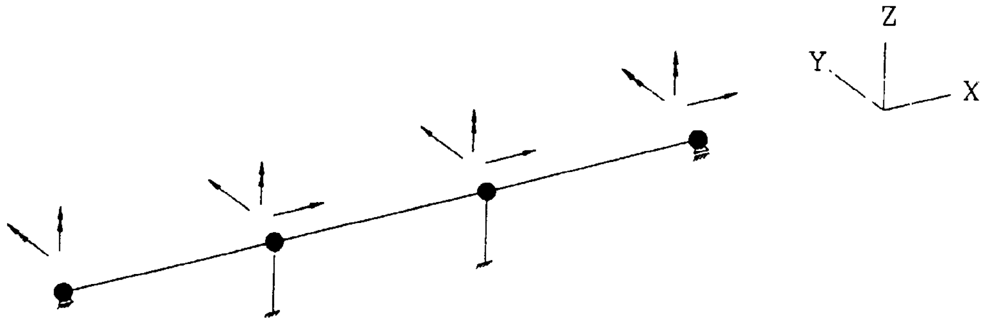


Fig (3). Three dimensional compacted model (model No. 2)

- Plane Model in lateral direction (PM)

In this model, only the stiffness of members of MTD model has been assumed in the lateral direction. This model has been proposed for simplificating the MTD Model, which is a plane model with two dimensional behaviors. Concentracted masses and degrees of freedom of this model is shown in Fig. 4.

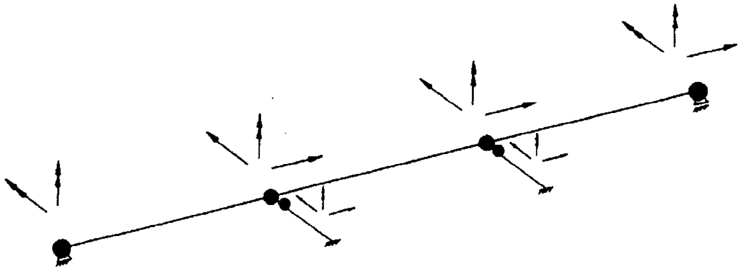


Fig (4). Two dimensional model in lateral direction (model No. 3)

- Longitudinal Plane Model (LPM)

This model is same as the PM model but in longitudinal direction. It's also same to MTD model except for the two dimensional behaviour. (Fig. 5).

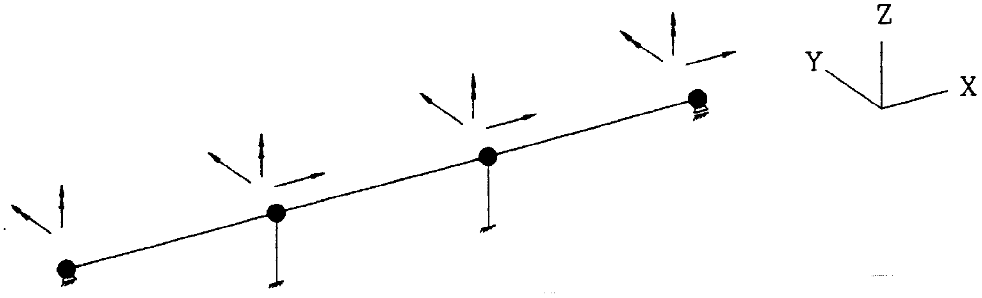


Fig (5). Two dimensional model in longitudinal direction (model No. 4)

3.3. Structure models comparison

Natural periods and mode shapes are the most important parameters in dynamic behaviour. Thus comparison between them can provide acceptable results. Comparison between these parameters in the proposed models lead to satisfactory results. Some of the comparisons are given in the table 1.

The results show the acceptable compatibility of the dynamic behaviour in these models. Finally, the effect of continous and concentrated masses are compared with the MTD model and the result of this comparison has been given in the table 2.

According to this results, the MTD model can be choosen in order to study the three dimensional dynamic behaviour of the assumed bridges.

Table. 1

MODEL	JOINT NO.			
	3	4	5	6
SMTD R(Z)	-1.206E-05	0	0	1.206E-05
MTD R(Z)	-1.135E-05	4E-06	-4E-06	1.135E-05

3.4. Isolators modelling

Dynamic isolation systems have many different types, but some of them are more applicable. According to this matter, types of modelling of these dynamic isolators are different, but in this paper, two types of them are considered more. These two types are shown in Fig. 6 and Fig. 7. [6].

The following parts will discuss the behaviour of these two types.

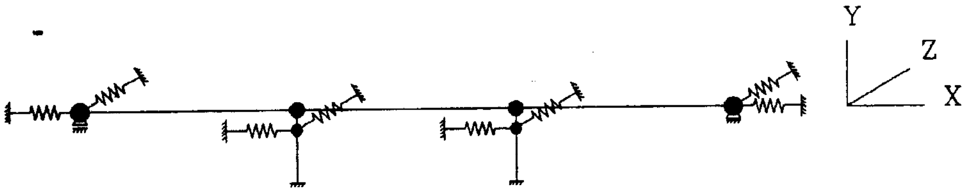


Fig (6). Dynamic model of isolated bridge

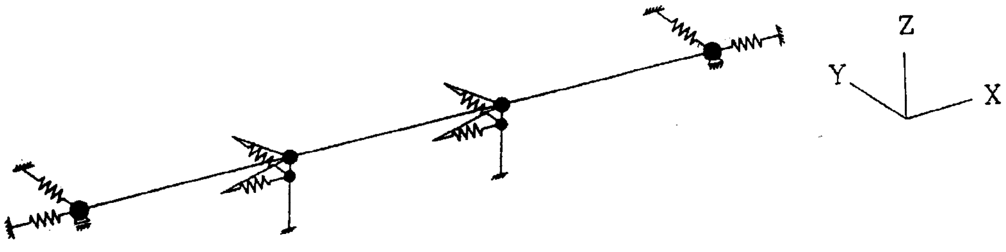


Fig (7). Dynamic model of isolated bridge

DYNAMIC ANALYSIS OF BRIDGES WITH THE ASSUMED LINEAR BEHAVIOUR OF ISOLATORS

In this part, the behavior of simplest isolators, has been investigated and they have been modelled as the linear springs. According to these considerations, following models have been studied:

a) Basic Model (nonisolated bridge), MTDH
This model is exactly same as the MTD model which has been called, as "MTDH".

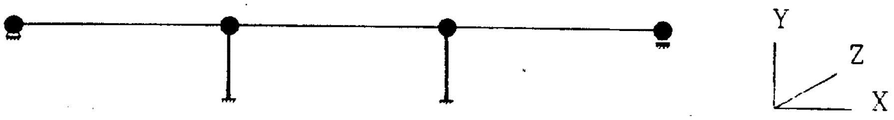


Fig (8). Nonisolated bridge model

b) Abutments isolated bridge, MTDS
This model is used for isolating abutments in two perpendicular directions. The isolators have been modelled as the linear springs.

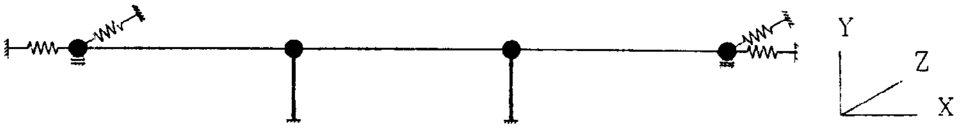


Fig (9). Dynamic model of abutment isolated bridge

c) Isolater No. 1 for under the deck isolated bridges (MTDS 1)
This model is MTDS model except for the two pair of perpendicular linear springs, at intersection of pier and deck.

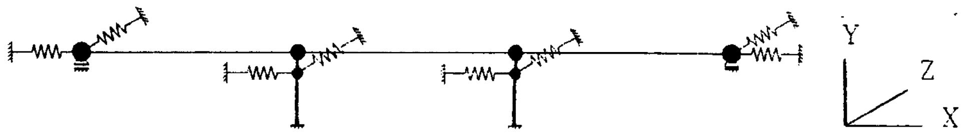


Fig (10). Dynamic model of deck isolated bridge with No. 1 isolated model

d) Isolater No. 2 for under the deck isolated bridges (MTDS 2)

This model is MTDS model except for two pair of No. 2 isolators [2] model at intersection of pier and deck. In this type of isolator modelling, each isolators modelled with two perpendicular linear springs plus three rigid bars which have been used for connecting the masses of pier to deck. These two masses can move in two different degrees of freedom which are not completely independent.

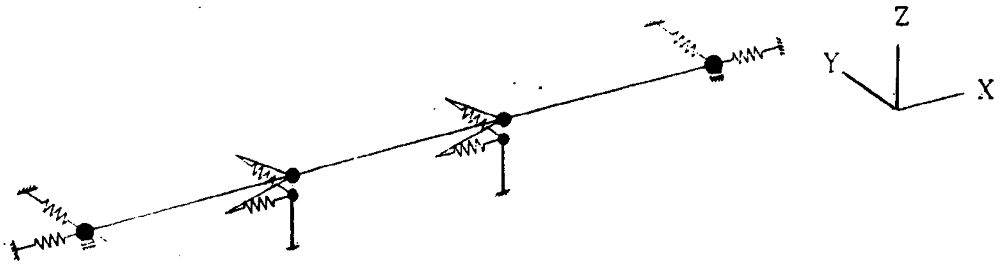


Fig (11). Dynamic model of deck isolated bridge with No. 2 isolated model

e) Base isolated bridge (MTDS B)

In this model, all of the members at abutments and under the piers, have been seperated from the ground.

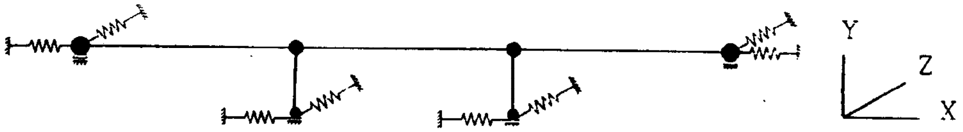


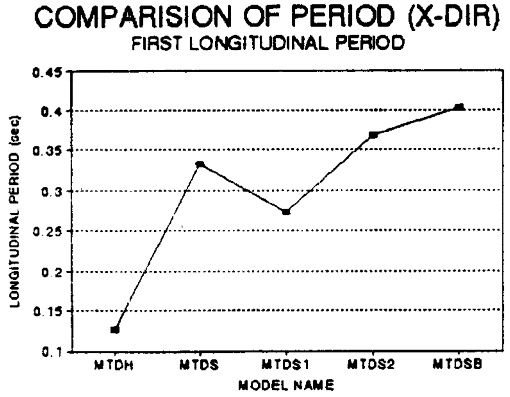
Fig (12). Dynamic model of base isolation bridge

4.1. Natural period comparison

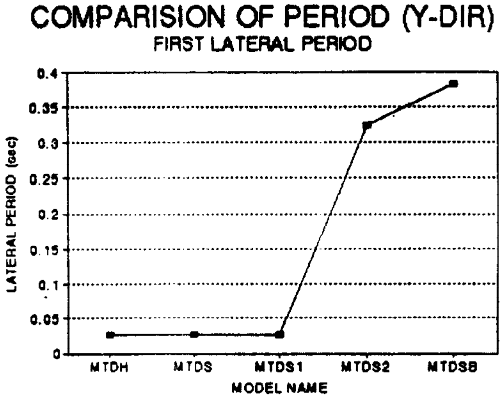
According to natural periods of these models, natural period in longitudinal direction will be increased by adding the isolators at abutments. But in lateral direction, natural periods won't change. Thus one of the aims of using the isolators will be achieved, but by adding the isolators in intersection of piers and deck and using the first type of isolator's model, longitudinal period, closely remain constant. This action is not compatible with the real. Thus this type of isolator model may not be enough suitable.

Additional isolators with second type of isolator's model will cause the increase of longitudinal period. By adding the isolators in the intersection of pier and deck, lateral period will increase, but by locating the isolators at abutments, lateral period will remain constant.

If the isolators place at the base of bridge (connected to the ground), longitudingal periods will increase proportionally. Graphs 1 and 2 show the behavior of the isolators.



Graph (1) Period comparison in longitudinal direction



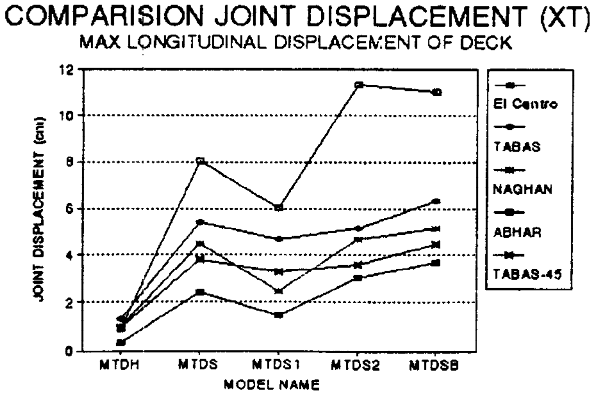
Graph (2) Period comparison in lateral direction

4.2. Time history analysis of models

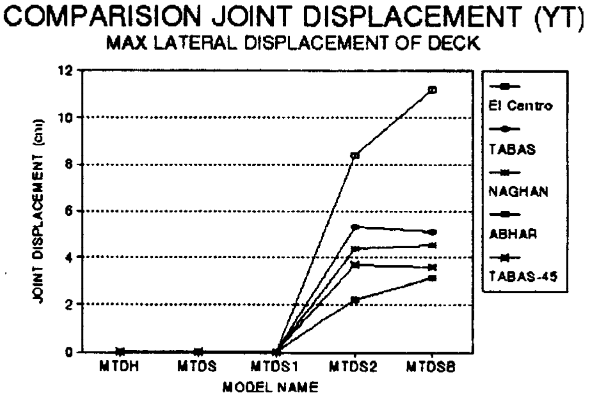
For studying the models behaviour under seismic loads, a few time history records have been applied. These records are El Centro 1940 N-S, Naghan 1977, Tabas 1978 and Manjil 1990. In order to study the interaction between longitudinal and lateral vibration, Tabas record has been applied to the models with 45° (angle between longitudinal and lateral axis) in the deck plane. Analysis of these models lead to the following results:

a) Maximum longitudinal deck displacement
This parameter has been shown in graph 3. This graph shows that by increasing the degree of isolation, this parameter can be increased and deck behaviour will step toward the rigid body motion.

b) Maximum-lateral deck displacement
The effect of isolators in the abutments on dynamic behaviour of bridge in lateral direction is very small (graph. 4).
This matter can be understood by considering the large stiffness of piers and sovereignty of first model of lateral vibration. This model will be eliminated in comparison to the MTDSI results.
The use of two dimensional models for dynamic analysis of bridges which has been shown in graphs 3 and 4 are no far from reality. The observation shows a satisfactory result.



Graph (3) Comparison of maximum deck longitudinal displacement



Graph (4) Comparison of maximum deck lateral displacement

4.3. Effect of some parameters variation on the dynamic behaviour of bridges

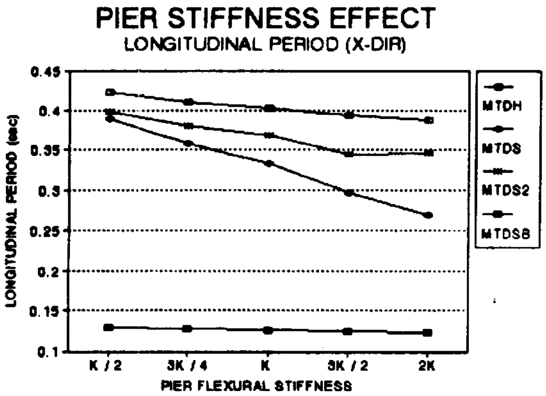
In this part, the effect of variation of some parameters such as pier stiffness, deck stiffness, and elastomeric bearings stiffness on dynamic behaviour of isolated and nonisolated bridges have been studied. In this step, only Tabas record has been applied on the different models. Nonisolated bridges parameters have been considered as a base comparison model.

a) Effect of pier stiffness variation

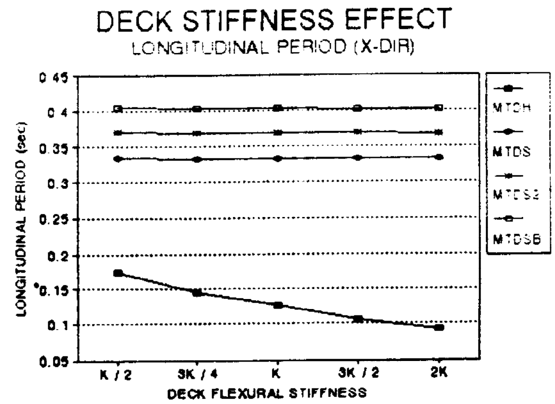
Variation of this parameter can show the variation of pier's height and stiffness variation of piers on the collapse procedure or retrofitting activities. This is more perceptible in longitudinal direction.

b) Effect of deck stiffness variation

Variation of this parameter can show the variation of deck stiffness in the retrofitting or collapse procedure in the existing bridges. Increase of deck stiffness cause no perceptible change on longitudinal period of isolated bridges whereas increase of this parameter in the nonisolated bridges may cause decrease of periods. In lateral direction period, the variation is not perceptible.



Graph (5) deck stiffness effect on longitudinal period



Graph (6) deck stiffness effect on lateral period

c) Effect of elastomeric bearings variation

This effect in two independent cases has been studied. Base stiffness in this section is required for bridges which have current bearings.

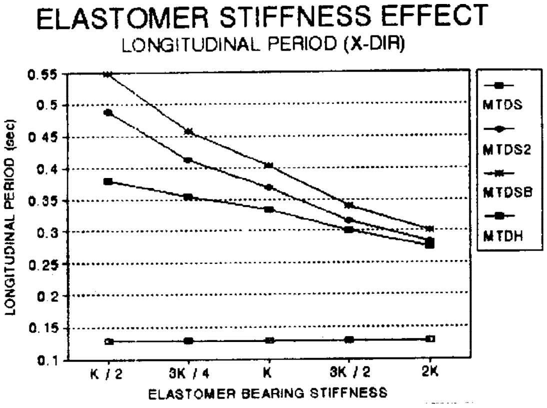
c-1) Bearings stiffness variation

In this part, three models, (MTDS, MTDS 2, MTDSB) are compared.

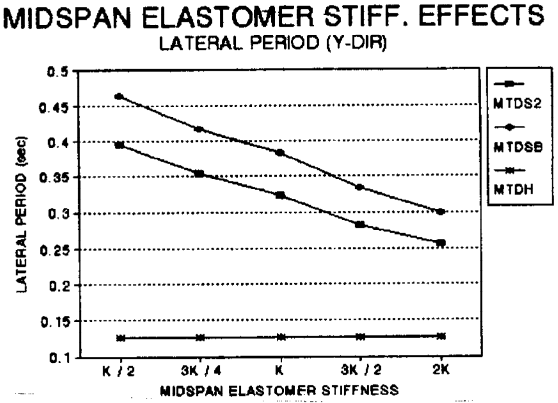
If bearings stiffness increases, longitudinal period will reduce. This reduction is same for all models. In the lateral direction, complete isolated models, (MTDS 2, MTDSB) have a perceptibility decrement procedure. Lateral periods in other models are closely constant.

c-2) Middle bearings stiffness varation

Increasing of this parameter in two models (MTDS 2, MTDSB), cause decrease of main period likely in longitudinal and lateral directions.



Graph (7) Pier stiffness effect on longitudinal period



Graph (8) Pier stiffness effect on lateral period

DYNAMIC ANALYSIS OF BRIDGES WITH THE ASSUMED NONLINEAR BEHAVIOUR OF ISOLATORS

In this section, it is assumed that all of members behaviour in the linear range and isolators can have nonlinear behaviour. Three main cases of isolator's behaviour have been studied. These three cases are:

Linear behaviour (such as elastomeric bearing pads), bilinear behaviour (such as lead rubber bearings), and perfect plastic behaviour (such as pure friction systems). Two dimensional models have been derived from MTD and the adding isolators (Fig. 13). In this part, Elastic behaviour has been presented by (E group), bilinear by (L group), and perfect plastic behaviour by (F group).

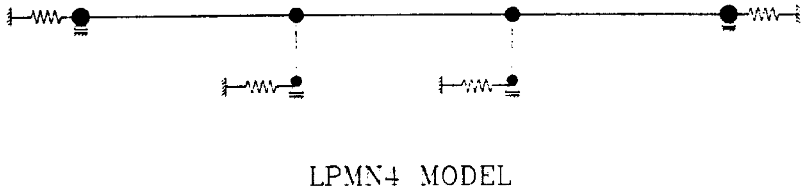


Fig (13). Nonlinear behavior of isolators in different model

a) Longitudinal direction comparison

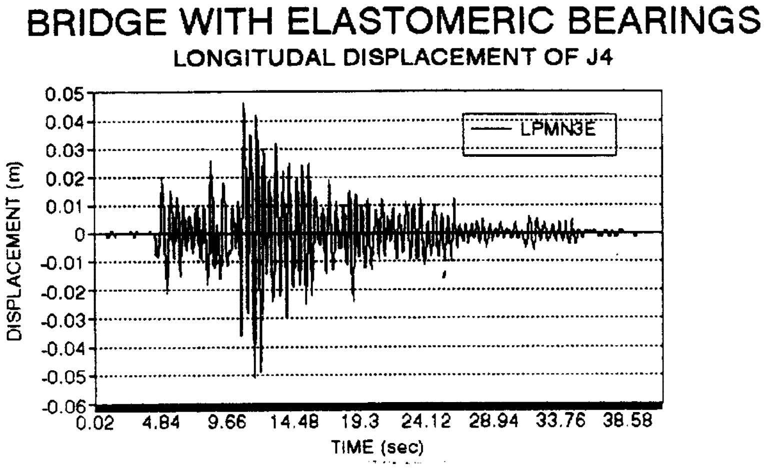
According to isolators modelling assumption in comparison models, maximum deck displacement in L and F groups decrease more propotionally to E group. This decrease is more perceptible, in F group. Initial period in isolated bridges with nonlinear isolators are in the same range in all models, just because of their large initial stiffness.

b) Isolation systems comparison

The energy dissipation of nonlinear systems is more greater than the linear systems and the behaviour of nonlinear systems under the service loading is more desirable. By concentration on variation of displacement response record in different systems, the following results can be made:

Maximum displacement of L systems will be damped quickly whereas in E systems, this parameter continued until the many cycles have been reached the maximum response.

The use of this procedure in F systems is not the same. It means that maximum displacement during the alternative cycles has been repeated.



Graph (9) Force-displacement diagram for different isolated bridges

Tabel. 2

MODEL	MODE NO.				
	1	2	3	4	5
SMTDC	0.126855	0.047825	0.03483	0.025623	0.025614
SMTD	0.126814	0.047811	0.034813	0.025622	0.02561
MTDC	0.126625	0.047739	0.03476	0.025538	0.024927
MTD	0.126724	0.04776	0.034788	0.025543	0.024908
PMC	0.131105	0.047982	0.034837	0.025481	0.024628
PM	0.131167	0.048004	0.034857	0.025489	0.024636
LPMC	0.297555	0.130753	0.106669	0.047853	0.034764
LPM	0.298761	0.131176	0.107101	0.048004	0.034857

CONCLUSION

1- In dynamic analysis of structures, modelling is very important for analysing the structures, especially bridges.

2- Because of the importance of bridges as one of the lifelines in natural disasters, dynamic analysis of bridges, specially bridges which have elastomeric pads, is highly recommended.

3- The use of the nonlinear isolation systems, will be provided in order to obtain a elastomeric better and more desirable result in propotion of linear systems. In this direction, the use of lead rubber bearings, seems more applicable.

4- Seismic isolation systems may be used as one of the best variant for retrofitting the existing bridges and also for designing of new bridges.

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