SEISMIC ISOLATION AND ENERGY ABSORPTION
SUPPORTING ELEMENTS FOR BRIDGE STRUCTURES

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SUMMARY

Seismic isolation is one of the oldest attempts to reduce effects of the earthquake ground motions on buildings and structures. In the past several years new ideas in modern construction have been theoretically and experimentally investigated by scientists and engineers in order to develop systems of seismic isolation supporting elements suitable for practical application.

Modern multi-span bridge structures, due to prefabricated construction of the super structure and inadequacy of the existing supporting elements, are exposed to severe damage during strong earthquakes. Particular simple connecting and supporting element has been developed and tested at IZIIS, Skopje to serve as seismic isolation and energy absorption system. Experimental results of the force-displacement characteristics of the supporting elements with testing procedure are presented and the effect of seismic isolation and energy absorption of these elements on dynamic response on the simple bridge structure is discussed.

INTRODUCTION

Considering that seismic isolation and energy absorption elements could significantly reduce transmission of earthquake energy and change amplitude and frequency content of the expected earthquake ground motion at the site, simple mechanical element of seismic isolation and energy absorption has been developed and tested at the Institute of Earthquake Engineering and Engineering Seismology at the University "Kiril and Metodij", Skopje (9). Specific force-displacement characteristics of this element are obtained for elastic and postelastic range of behaviour, working initially as seismic isolation for controlled range of displacements and in the second stage as energy absorber. This element has been introduced to a simple bridge structure in order to assess its influence on dynamic response of the structural system in the longitudinal direction.

FORCE-DISPLACEMENT CHARACTERISTICS OF SEISMIC
ISOLATION AND ENERGY ABSORPTION ELEMENT

Simple mechanical seismic isolation and energy absorption element (SIA) consists of neoprene pad under the beam and wing elements on the site of the structural beam connected with the supporting structure

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through steel bar and pair of springs (Fig. 1.). In order to obtain force-displacement characteristics of the developed element quasi-static testing has been carried out on three samples in the scale 1:3, simulating vertical load at the fixed support and force and displacements time history along the length of the beam in accordance with the test arrangement given in Fig. 2. Obtained force-displacement characteristics of the element are given in Fig. 3 (a), for the elastic range representing bilinear elastic relation, and in Fig. 3 (b), for cummulative elastic and post-elastic range, representing intensive energy absorption part before failure of the wing elements.

DYNAMIC RESPONSE OF SIMPLE BRIDGE STRUCTURE

Based on experimentally obtained force-displacement characteristics for the purpose of modeling simple bridge structure with developed SIA element, in the analysis force-displacement diagram is simplified as shown in Fig. 4 (a). In the part of bilinear elastic behaviour including neoprene pad, springs and wing elements simplified force-displacement diagram is following basically experimentally determined relationship. In the part of the postelastic behaviour of wing elements, representing energy absorption portion of the SIA element stiffness properties are modelled idealizing experimental evidence for the purpose of simplification of the analysis.

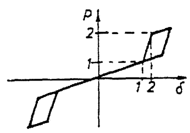
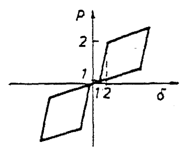
Structural elements of the simplified bridge structure are taken with the proportions usually applied in the practice and dynamic response analysis in the longitudinal direction is performed for the acceleration time history of N-S component recorded at Ulcinj, Albatros of Montenegro 1979 Earthquake, scaled at 0.1, 0.3 and 0.5 g peak ground acceleration, respectively.

Displacement earthquake response time history of the pier 2 and pier 1 are given in the upper parts of Fig. 5., considering three different levels of excitation: (a) 0.1 g, (b) 0.3 g, and (c) 0.5 g with incorporated SIA element, and case (d) 0.5 g with simulation of rigid colision of the superstructure with the abutment beam. In the case (a) with 0.1 g peak ground acceleration, the system is active within initial elastic range; in the case (b) with 0.3 g PGA, the system is completely active within bilinear elastic range and in the initial stage of nonlinear behaviour of SIA element; in the case (c) with 0.5 g PGA, the system is completely active in both linear and nonlinear range of the SIA element. In the lower part of Fig. 5. activated parts of the SIA element are given for each case separately in different scale.

COMPARISON OF THE DYNAMIC RESPONSE

Comparison of the dynamic response and sectional forces at the bottom of the piers is presented in Table 1. for all considered cases with SIA element (a, b and c) and in the case (d) considering classical solution for largest PGA.

Table 1.

Force - displacement characteristics of SIA element	Case	PGA of g	Pier ① Max. displ (cm)	Pier ① Max. shear f. (t)	Pier ① Max. b.mom. (tm)	Pier ② Max. displ. (sm)	Pier ② Max. shear f. (t)	Pier ② Max. b.mom. (tm)
	a	0.1	0.91	58.5	292.3	2.36	19.0	190.3
	b	0.3	2.70	174.0	869.8	7.19	58.0	580.0
P_1 (t): 4.2 P_2 (t): 123 δ_1 (cm): 3.0 δ_2 (cm): 5.0	c	0.5	3.01	194.2	971.0	12.22	98.6	986.0
 P_1: 0.4 P_2: 18.4 δ_1: 0.1 δ_2: 0.2	d	0.5	7.20	464.7	2323.6	8.26	66.7	667.0

From the presented data it is evident that in the case (a) there is well established control of the entire system in the elastic range, and in the case (c) there is established appropriate balance of bottom bending moments in both piers, which in comparison with case (d) of classical solution is larger more than three times in pier 1 in respect to pier 2 .Based on this simplified analysis it could be concluded that implemented simple SIA element could be suitable for efficient control of damage in small and moderate earthquakes and modification of classical structural system to more favourable one for large scale earthquakes.

CONCLUSIONS

The selected example of implementation of the seismic isolation and energy absorption elements in the case of simple bridge structure is presenting the basic idea of the efficiency of these elements in reduction of the earthquake effects on the considered structural system and creation of more favourable structural behaviour under earthquake ground motions. With the developed simple mechanical SIA element there is possibility to establish limited transfer of earthquake forces and control of displacements of the structural system by which possible control of structural and nonstructural damage in small and moderate earthquakes could be achieved and serious structural damage and failure in the strongest earthquakes could be avoided.

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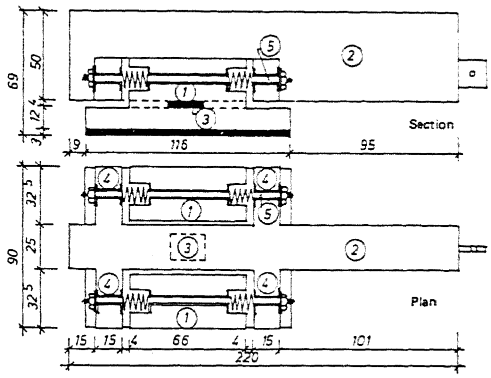

Fig. 1. Model Arrangement

(1)- Bridge pier element; (2)- beam element;
(3)- neoprene support; (4)- wing elements
(5)- steel rode with spring elements

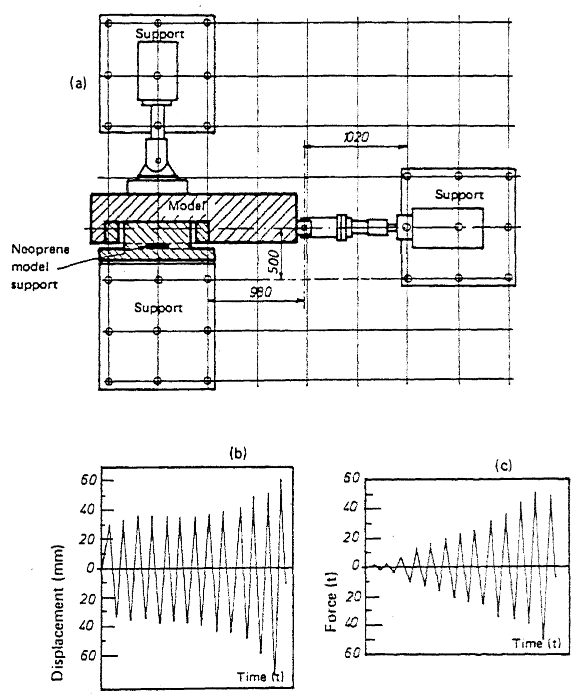

Fig. 2. Test model structure and test arrangement;

(a) Plan of test arrangement; (b) Simulated displacements;
(c) Simulated forces

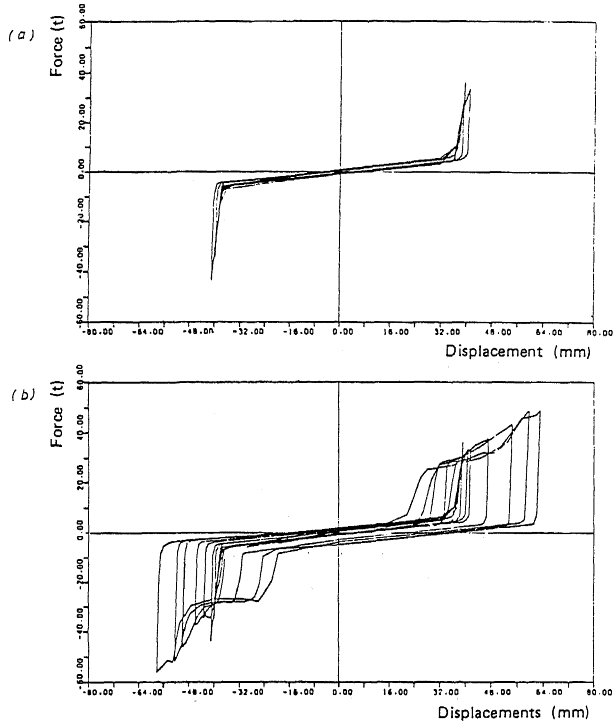

Fig. 3. Experimental force - displacement diagrams of seismic isolation and absorption element (a) Bilinear elastic response of neoprene pad, springs and wing element; (b) Nonlinear response of wing elements

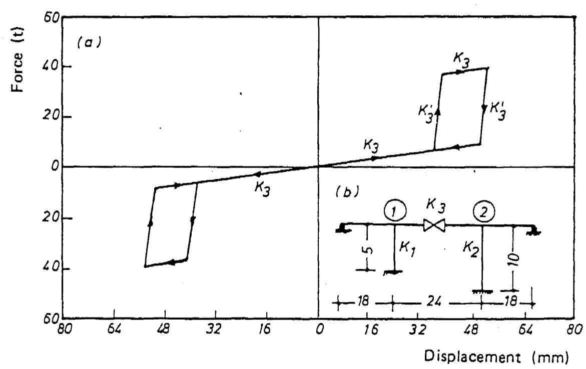

Fig. 4. Idealization of force - displacement diagram (a) of seismic isolation and absorption element (b) Scheme of bridge structure

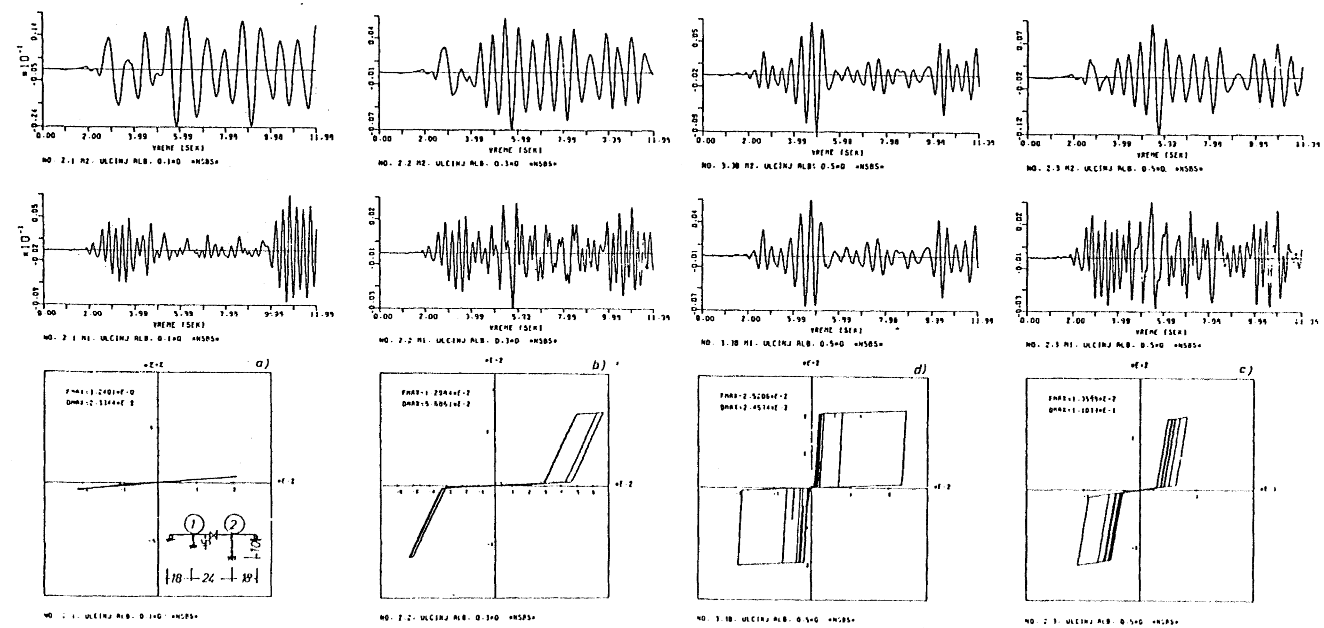

Fig. 5. Dynamic Response of Bridge Structure to Ulcinj – Albatros earthquake

(a) 0.1 g PGA – active only neoprene pad and springs ; (b) 0.3 g PGA – neoprene pad , springs and wing elements active
(c) 0.5 g PGA – neoprene pad, springs and wing elements active ; (d) 0.5 g PGA – only abutment beam active