Protection of structures during earthquakes

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Protection of Structures During Earthquakes

Protection des structures pendant les tremblements de terre

Vorrichtungen zum Erdbebenschutz von Tragwerken

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SUMMARY
Usefulness of application of devices for reducing earthquake induced forces on structures, especially bridges, is discussed in this paper. Use of devices which can be introduced at suitable points so as to reduce earthquake response is explained. Use of viscous dampers for this purpose has been explained in detail. Other vibration isolation systems have also been explained. Use of spring dashpot systems has been explained. Use of spring dashpot systems has been recommended as this is a superior system over other vibration isolation systems. The state of the art on damping devices for reducing earthquake forces on girder bridges has also been presented.

RÉSUMÉ
L'article examine l'utilité de dispositifs prévus en des points adéquats des ouvrages, en particular dans les éléments structuraux de ponts, en vue de réduire les efforts induits par les secousses sismiques. Il explique également le mode d'action des amortisseurs visqueux ainsi que celui d'autres types d'appareillages antivibratiles, comme par exemple les combinaisons d'amortisseurs à air et à ressort. Ces derniers semblent fournir de meilleurs résultats que les autres dispositifs et il est recommandé de les envisager. Un synoptique de l'état actuel de la technique d'amortissement des vibrations est également fourni, tout spécialement pour les ponts à poutres.

ZUSAMMENFASSUNG
Der Beitrag diskutiert den Nutzen von Vorrichtungen, die insbesondere in Brückenbauwerken, die bei Erdbeben auftretenden Kräfte begrenzen sollen. Erklärt werden die Wirkungsweise viskoser Dämpfer und anderer Schwingungsisolatoren, wie Feder-Dämpfer-Kombinationen. Letztere scheinen anderen Systemen überlegen und sind besonders zu empfehlen. Für Balkenbrücken ergibt sich ein Überblick über den Stand der Dämpfungstechniken.

INTRODUCTION

When sufficient damping is not avilable by internal hysteresis of load bearing members an external device will have to be employed to attain additional damping. There is no limit to the damping that can be achieved by external damping devices. However space limitation, financial aspect along with feasibility and flexibility of incorporating the new devices has to be seen.

The oil damper permits slow movements without resistance but develops large resistance during earthquake motions introducing substantial damping thus reducing forces introduced in the system.

By introducing external device the response of structure can be reduced to tolerable limits. Not only structure but installations are also safeguarded.

MODEL TESTS

The author fabricated, tested, fitted and used oil dampers on simply supported bridge model 2.75 m span, 0.50 m pier height K= 5 kN/cm, W= 2.5 to 5 kN. The time period varied from 0.138 to 0.2 sec. The dampers were made up of piston moving in cylinder filled with silicone oil. The length of piston as well as its nominal diameter 2.54 cm, clearance 0.127 mm to 0.508 mm, C = 15 to 50 N-s/cm. The damping introduced in the system 5 to 10%. The model was subjected to free vibration tests, steady state tests and impulse load tests. During resonant testing it was observed that for damper capacity C/C_c greater than 0.20 complete locking occurs across roller bearing. During impulse load test half sine acceleration pulse 0.132 sec duration 0.7g to 0.75g was applied. Ratio of pulse duration to natural period 0.86. Acceleration response expressed as dynamic amplification went down from 1.59 (no damping) to 1.38 with dampers installed. The results matched very well with theory.

The recommendations to use dampers are based on effectiveness of device in all the three types of model tests.

BRIEF TECHNICAL REVIEW

Provision of Hydraulic Buffers to cushion longitudinal shocks as a protection against possible earthquake attack in designing Carquinez Cantilever Bridge dates back to 1927.

The U.S. National committee for Aeronautics in technical note in 1941 gave Damping characteristics of Dashpots. In the first case the piston was assumed coaxial and in second case piston assumed eccentric. Information is also avilable for circular piston in an elliptical cylinder. It was concluded that piston is normally eccentric in cylinder.

Product Engg staff report for Dashpots in 1956 claimed"synthesizing damping factor designs on paper instead of using models requiring tests and modification".

The publication of 1968 edition of code by Japanese Society of Civil Engineers gave details of many devices including use of oil dampers on bridges to distribute horizontal seismic force caused by earthquake.

Japanese practice in Seismic design of Prestressed Concrete Bridges has been described in detail in Prestressed Concrete Institute Journal of 1972 Details of dampers using oil and grease have been described. Another device described is in which "steel rod projected from girder inserted into hole filled with viscous material on top of substructure and special steel plate springs are placed between steel rod and concrete wall to absorb braking force at one support".

For the purpose of reducing seismic force on supporting structure of massive Prestressed Concrete Bridges Professor Leonhardt [1972] suggested "Limited movement between the bridge deck and the substructure. This was achieved by using modern rubber pot bearings fixed to substructure. The bridge deck can slide on teflon pads over chromated plates". Prof Leonhardt and his associates developed this method several years ago.

On earthquake resistance of bridges while describing first application of special earthquake proof devices like S.U. dampers etc in his book on Earthquake Engineering Professor S. Okamoto said " the idea of connecting bridge girder with oil damper is idea worthy of note".

In the Fifth World Conference on Earthquake Engineeing held in Rome in 1973 Influence of permitting limited rolling or sliding at both ends to distribute loads even on both piers on aseismic design of simply supported spans of bridges was again discussed. In the same conference the shock absorber called stopper and its effect on response of bridge to the earthquake was discussed. It distributed longitudinal horizontal force acting on girder during an earthquake evenly to movable support on continuous girder bridge,and reduced maximum value of response by energy absorption. These dampers were installed at the support of prestressed concrete girder Railway bridges. The effectiveness of above device was confirmed during Miyagi Earthquake in 1978 in Japan and reported in 7th WCEE held in Istanbul Turkey by Machida and others.

Reports indicate superiority of spring-dashpot system for the support of structures over other vibration isolation systems such as rubber pads for isolation from earthquake attack. Analytical reports are avilable to confirm advantage of spring dashpot vibration isolation system over Neoprene pads. According to Tezcan, Civi and Huffman "pads are reported to be a inadequate to provide vibration for vertical and rocking motion. The spring dashpot vibration isolation system was determined to be very effective in all Horizontal,vertical and rocking motion".

The patented device Extrusion energy absorber by W.H. Robinson suitable for protection of structures during on earthquake was used for protection a bridge. A number of tests were conducted on 20 kN x 2 cm stroke to 200 kN x 26 cm extrusion energy absorbers by W.H. Robinson and Greenbank.

Robinson, Longinow and Albert [1979] in the Design manual for Retrofitting bridges to withstand Earthquakes have described several retrofit concepts that can be applied to existing bridges "which will enhance the probability of survival of the structure when it is subjected to severe earthquake environment".

Degenkolb considered deficient spiral or ties in reinforced concrete columns to be great seismic weakness in bridges. He described two methods of retrofitting round columns which have inadequate ties or spirals."First is basically a turnbuckle which develops the strength of the reinforced steel and places initial prestress in the hoop. The second method consists of welding a steel shell round the existing column. The space between column and steel shell is filled with grout.

CONCLUSIONS

Use of techniques which increase damping in the system and help in reducing earthquake induced forces is recommended. The recommendation to use oil damper is based on rigrous experimental tests on a model. Damping resistances of 1000 kN.s/m per element are reported to have been measured.

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