Proceedings of Ninth World Conference on Earthquake Engineering
August 2-9, 1988, Tokyo-Kyoto, JAPAN (Vol.V)

7-9-2

SEISMIC ISOLATION OF PIER BRIDGES

Lamberto BRISEGHELLA, Roberto GORI, Paolo NEGRO

Istituto di Scienza e Tecnica delle Costruzioni
Universita' degli Studi di Padova, Padua, Italy

SUMMARY

A design approach for applying base-isolation technologies to typical medium-span continuous concrete deck bridges is presented. The structural behavior corresponding to each solution is discussed. A method for constructing non-linear response spectra for rigid-plastic systems is explained: a direct strength-displacement relationship, no longer depending on the elastic period can be obtained. A dimensionless analysis for the 2DOF system is also carried on. A bridge is then analyzed for different structural solutions: both challenging and doubtful aspects of the use of rigid-plastic dampers are brought out.

INTRODUCTION

New technologies for concrete bridges in seismic areas imply continuous decks with approximately 100 meters spans, to reach a total length up to two kilometers. Exception is made in the case of bridges in mountainous areas, where the maximum length reaches 500 meters, with up to 100 meters high piers.

There are substantially three possible structural solutions: The deck can be rigidly connected to each of the piers (except for displacements due to thermal and creep effects), leading to the formation of plastic hinges at the base of the piers as an effect of a major earthquake. Another solution relies on bearing units capable of absorbing the energy of the earthquake and of permitting a controlled relative displacement between the pier tip and the deck. The third solution places, when it is possible, dampers in corrispondence of the two ends of the continuous deck, releasing the piers from any horizontal force due to the superstructure.

In this study we focus on elastic-plastic dampers (mechanic or hydraulic devices, capable of substaining forces of up to 2,000 KN and undergo displacements up to 200 mm), placed on the top of each pier (fig.1). The design scheme corresponding to this solution implies an elastic behavior of the pier and a controlled maximum relative displacement in the pier-deck interface. The relative displacement will be accomodated by the expansion joints and the serviceability of the bridge, after a major earthquake, will not be reduced, even though the deck may have to be moved back in the previous position. The use of such a kind of damping units appears to be essential in the case of big new bridges, but it could also represent a charming solution for the seismic retrofitting of existing bridges if the ductility of the piers is not adequate.

A SIMPLE MODEL: NON-LINEAR SDOF

In many cases the bridge deck can be idealized as an elastic-plastic single-degree-of-freedom system controlled by the normalized equation relating ductility, strength and period. We obtained constant-ductility spectra and energy spectra for an elastic-perfectly plastic system (fig.2). Focusing on the hysteretic cycles, one could conclude that the first range in the load-displacement relationship has little effect on the amount of dissipated energy, even though the stiffness in the elastic range is related to the sound concept of period (elastic). Moving from that conclusion, we considered the case of the rigid-perfectly plastic system. In this case the usual concept of period vanishes and it is possible to reach a simple and direct relationship between the design strength and the maximum relative displacement (fig.2, bottom). The values of the design strength which apply to the use of such kind of damping devices lie in the 0.05÷0.10 range.

A REFINED MODEL: NON-LINEAR 2DOF

The 2DOF model with a rigid-perfectly plastic damper, can be represented by the dimensionless equation:

$$f(K,F_y,M,m,\xi,A,t,D_r) = 0 ,$$

where K is the stiffness of the piers, F_y is the yielding force for the damper, M and m represent the masses of the deck and of the piers, ξ is the damping ratio of the structure, A is the maximum ground acceleration, t the time variable and D_r the relative displacement in the pier-deck interface. The spectra can be represented as design strength vs relative displacement for different values of the period of the isolated pier and for constant values of the m/M ratio (fig.3 a,b). Looking for the maximum elastic moment at the base of the pier, one has to apply the experimental relation $M_e = F_y h + M_{e,o}$,where $M_{e,o}$ is the moment given in the graph of fig.3, c).

EXAMPLES

We analized the case of the bridge in fig.1, complying with three different design hypotheses: Deck rigidly connected to the pier (fig.4), deck resting on elastic-plastic bearing units in correspondance with each of the piers (fig.6), deck hold at the two ends with released piers (fig.5), in the two cases of "stiff" and "rigid" piers (K_r/K_f=7).

CONCLUSIONS

The employment of elastic-plastic dampers is a powerful tool to lessen the required ductility in the piers. Relative displacements between the pier and the deck could be relevant. More work in detecting the effects of the seismic environment in near field in complex situations is required.

BIBLIOGRAPHY

1. Applied Technology Council, "Seismic Retrofitting Guidelines for Highway Bridges", report ATC 6-2, november 1982.
2. Penzien, J., "Seismic Analysis of Multi-span Reinforced Concrete Bridges", Report ATC 6-1, november 1979.
3. Kelly, J.M. and Hodder, S.B., "Experimental Study of Lead and Elastomeric Dampers for Base-Isolation Systems", Report UCB-EERC 81/16, October 1981.

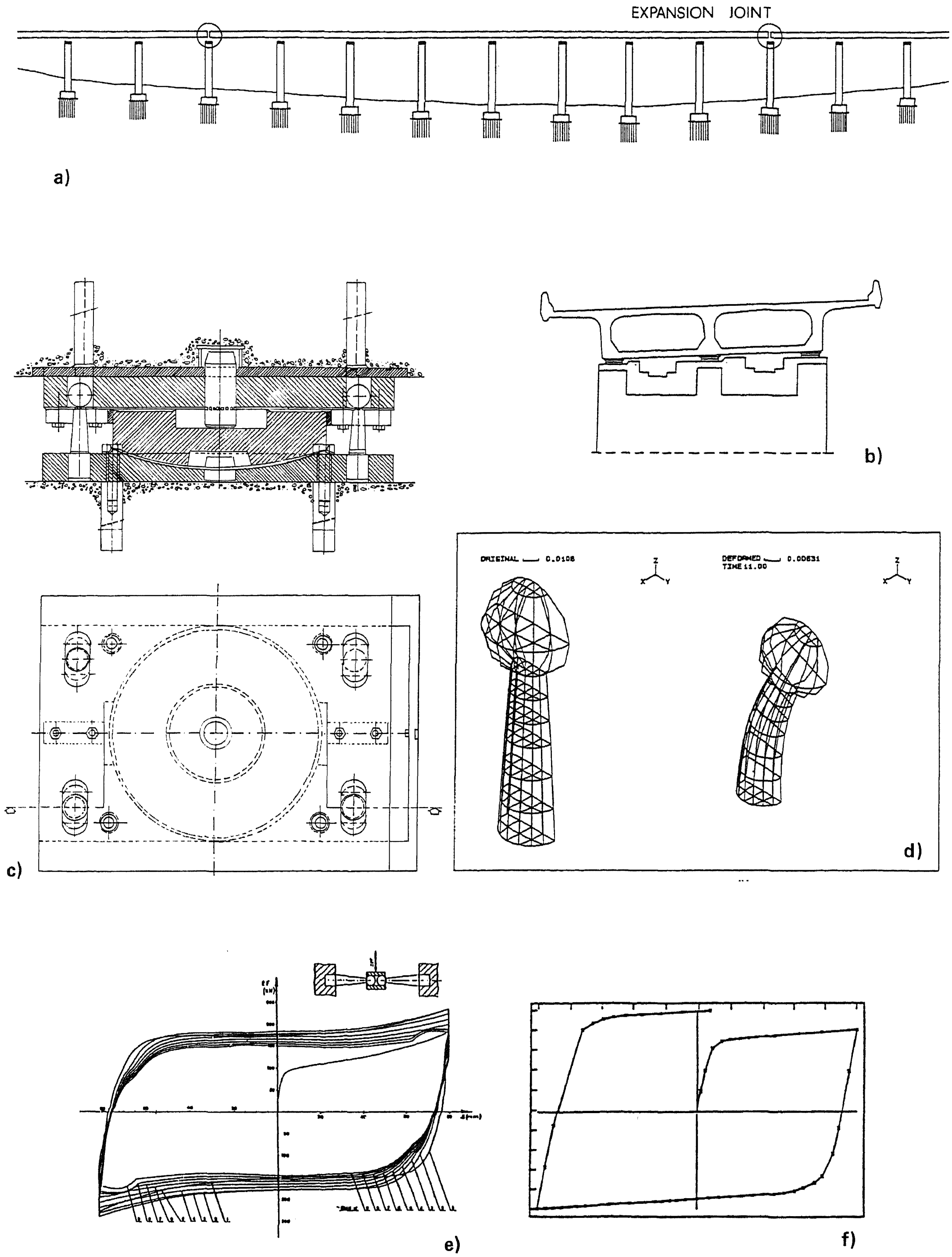

Fig. 1 Medium span concrete bridge:
a) longitudinal view b) cross section on piers
c) bearing unit, section and plan d) fem model of the damper
e) experimental hysteretic cycle f) fem hysteretic cycle.

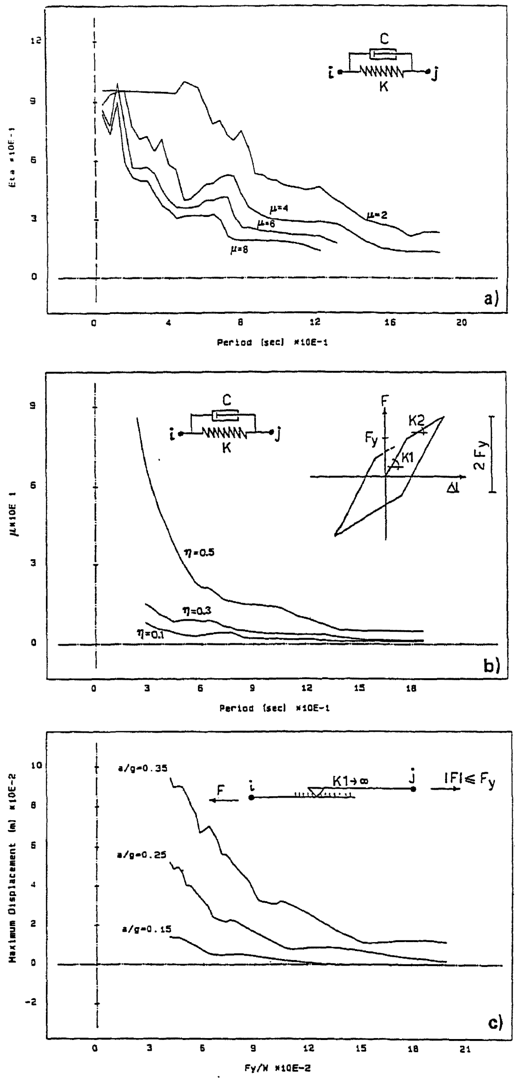

Fig. 2 Non-linear SDOF response spectra
a),b) elastic-plastic damper
c) rigid-plastic damper

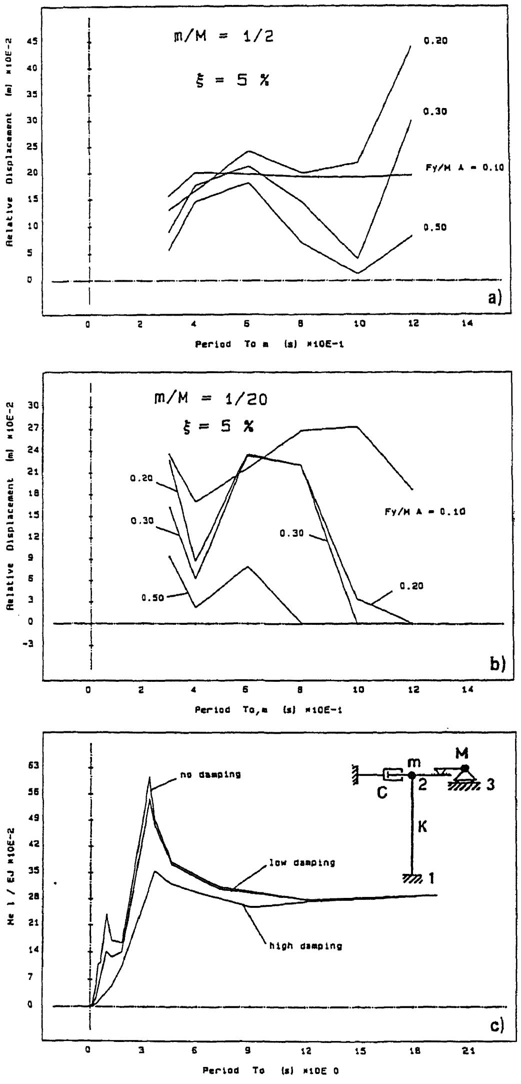

Fig. 3 Non-linear 2DOF response spectra
a) m/M=1/2, b) m/M=1/20
c) M_e design chart

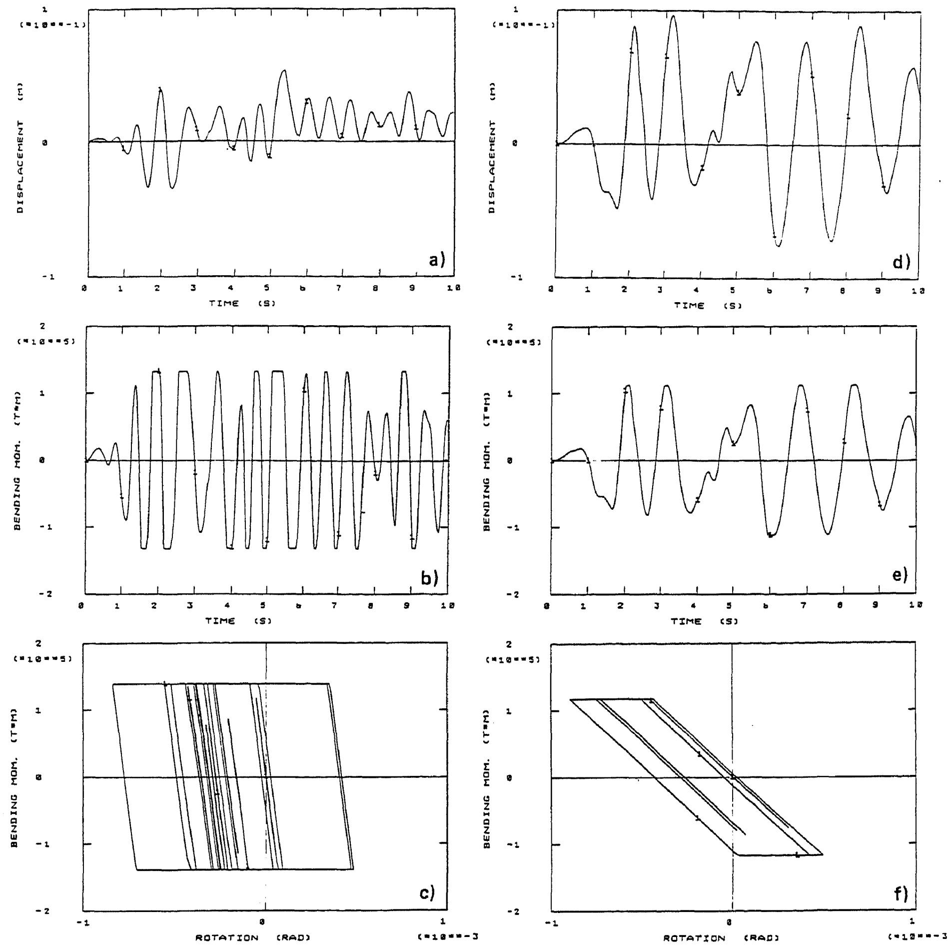

Fig.4 Response for deck rigidly connected to the pier:
a),b),c) Rigid pier d),e),f) Flexible pier

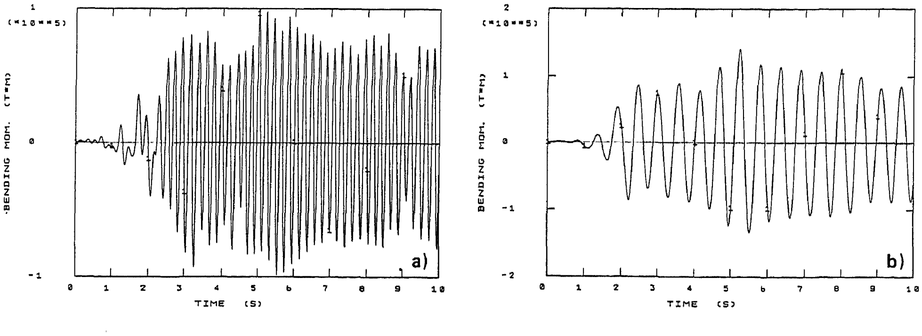

Fig.5 Response for elastic pier completely disconnected from the deck:
a) Rigid pier b) Flexible pier

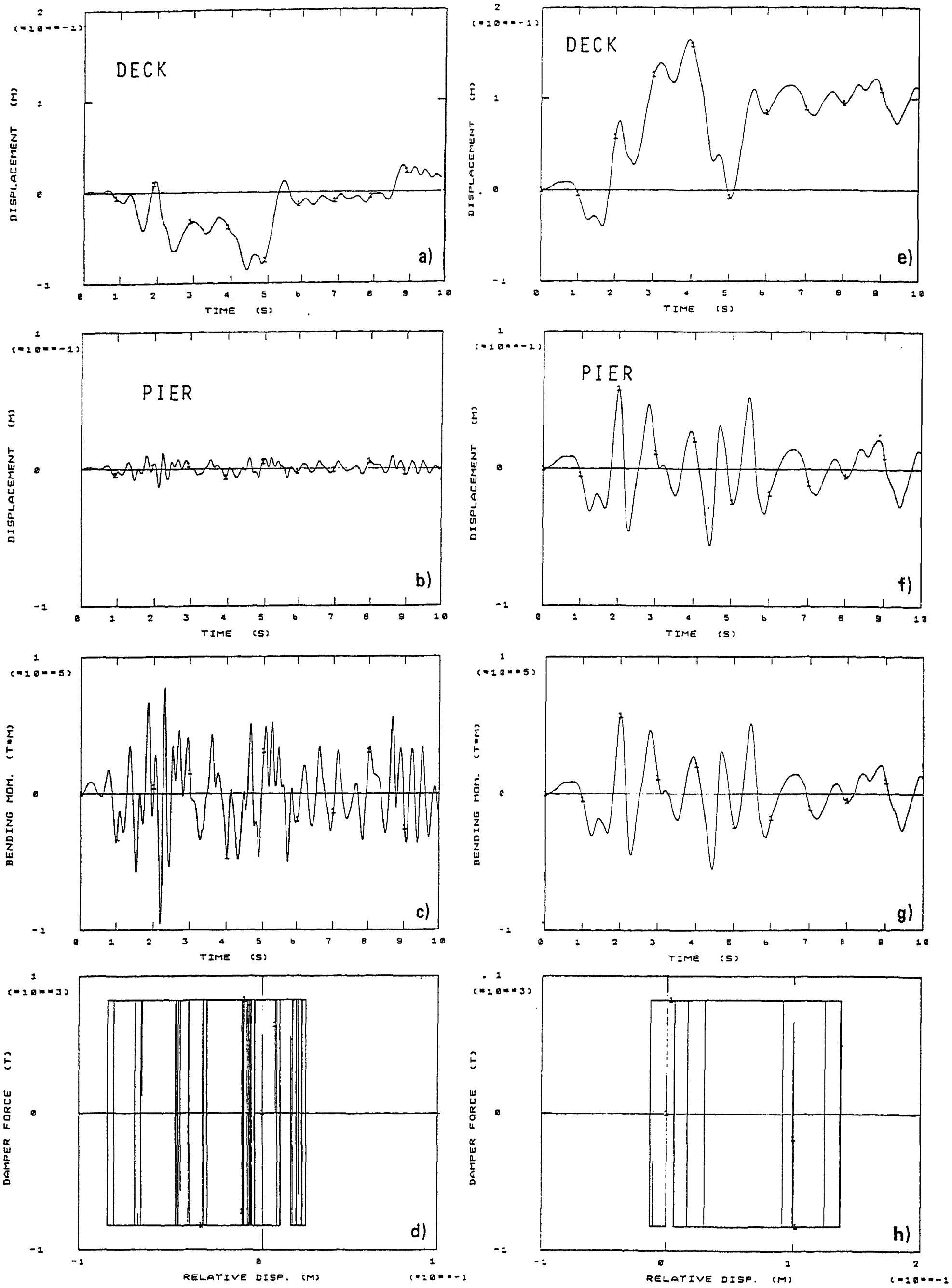

Fig. 6 Response for deck resting on dampers and elastic pier:
a),b),c),d) Rigid pier e),f),g),h) Flexible pier