CALCULATED INELASTIC STRUCTURAL RESPONSE TO UNIAXIAL AND BIAXIAL EARTHQUAKE MOTIONS

by

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SYNOPSIS

Inelastic dynamic response analyses of the Olive View Medical Center were carried out for four different ground motions: The 1971 Pacoima Dam record scaled to two different maximum accelerations; the El Centro 1940 record; and an artificially generated earthquake. Several of the analyses included the effects of biaxial interaction due to two horizontal components of ground motion acting simultaneously. For all cases studied there was a significant increase in maximum story drifts due to biaxial interaction effects.

OBJECT AND SCOPE

Calculations of inelastic dynamic structural response are often carried out by subjecting a planar mathematical model of the structure to a single component of ground motion. In this paper, the significance of biaxial inelastic interaction is investigated with particular reference to the Olive View Medical Center, which suffered severe damage in the 1971 San Fernando earthquake. Despite the choice of a particular structure, the emphasis is intended to be on the general problem of interaction rather than on the specifics of the OVMC response. Impact of the first story with a retaining wall, and accidental stiffness eccentricity are briefly investigated as possible causes of torsional motion.

DESCRIPTION OF ANALYSIS

Two facts, drawn from post-earthquake damage studies and confirmed by preliminary elastic analyses, influenced the structural idealization of the OVMC. These were: (1) the upper four stories moved essentially as a rigid block due to the shear walls in these upper stories. (2) Considerable torsional motion took place, as evidenced by the measured permanent displacements. The OVMC was therefore idealized as a two-story rigid-floor structure with columns of two types: the first, ductile elastoplastic shear resisting elements, intended to simulate spirally reinforced concrete columns; and the second elastic-brittle shear resisting elements, intended to simulate tied columns failing prematurely and suddenly in shear. Figure 1 shows the resulting story shear vs. story relative displacement relations for uniaxial loading. To reduce computational cost, column groups were represented as single shear resisting elements. This idealization is not adequate for cases in which torsional motion takes place, since the torsional stiffness is not properly reduced in the inelastic range.

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Response calculations were carried out for the first 12 seconds of four ground motions: 1) the two components of the 1971 Pacoima Dam record, full scale (max. acc. 1.25g) 2) the two components of Pacoima scaled to 0.5g maximum acceleration 3) the two components of El Centro 1940, and 4) an artificially generated earthquake[III]. The second component of ground motion for the artificially generated earthquake is the same as the first, but delayed by 0.25 sec. All analyses included the elastic-brittle columns.

RESULTS

Table 1 provides a brief summary of some of the results of the analyses. These results, although admittedly restricted in scope, show several clear trends:

(1) Two dimensional interaction substantially increased the story drifts. The reason for this is that column stiffness is reduced considerably when motion is taking place in the perpendicular direction, as is demonstrated by the results for the artificial ground motion, in which large drifts take place in the direction of the delayed motion (Fig. 2). Maximum responses to the Pacoima motion for the elastic and most of the uniaxial inelastic cases occur at 3-4 sec. when a sustained acceleration pulse of about 0.5g acts. For the biaxial inelastic systems, however, the large story drifts take place as a result of the high acceleration peaks of 1.25g at about 8-9 sec. acting on the already damaged and softened structure. It is also interesting to note that the relative effect of interaction is greater for the Pacoima record scaled to 0.5g max. than for the full scale record.

(2) It is significant to note that if this model was being used in design, results based on uniaxial motion might have been acceptable (inelastic story drifts less than 4 times column yield), while those based on biaxial motion would have caused concern even for El Centro.

(3) It appears from these results that impact of the first story with the retaining wall may not have had a large effect. These results are somewhat inconclusive since a rather arbitrary clearance of 1" between the building and the wall was assumed. The effect of a stiffness eccentricity of 25' in each story was slight. However, an improved idealization of column arrangement, which would allow proper reduction of torsional stiffness in the inelastic range could significantly alter the results for both impact and stiffness eccentricity cases.

ACKNOWLEDGEMENT

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[III] A. K. Chopra, private communication.

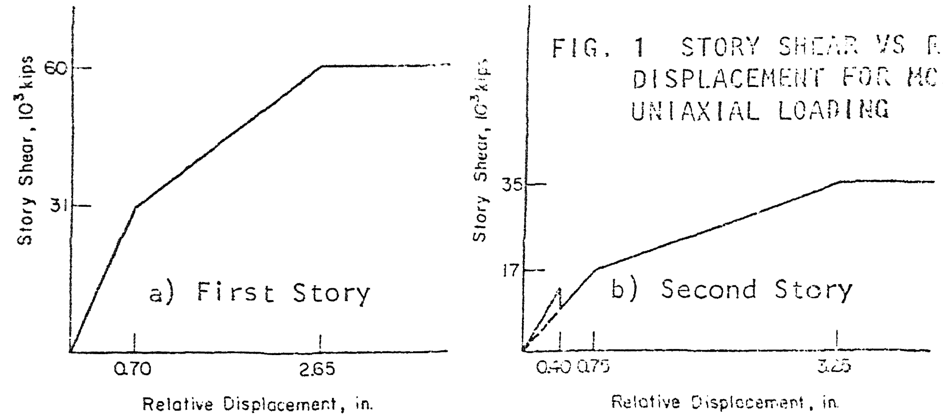

FIG. 1 STORY SHEAR VS RELATIVE DISPLACEMENT FOR MONOTONIC UNIAXIAL LOADING

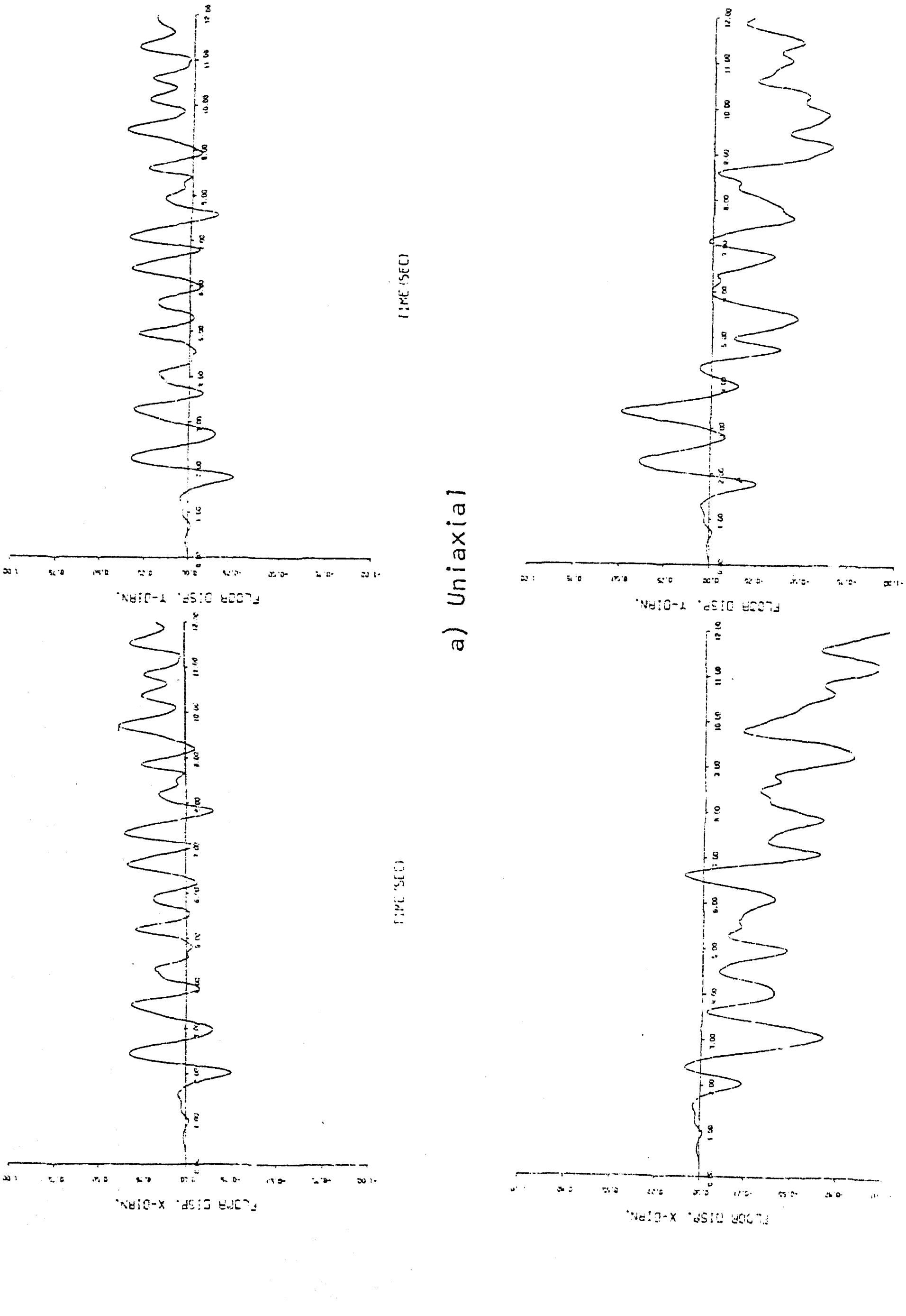

FIG. 2 SECOND STORY DISPLACEMENT RESPONSE TO ARTIFICIAL EARTHQUAKE

TABLE 1. MAXIMUM SECOND STORY DRIFTS

GROUND MOTION	ELASTIC		INELASTIC							
			UNIAXIAL		BIAXIAL					
							IMPACT		STIFFNESS ECCENTRICITY	
	1-1	2-2	1-1	2-2	1-1	2-2	1-1	2-2	1-1	2-2
PACOIMA Full Scale	3.7 (3.4)	4.6 (3.3)	7.8 (8.8)	7.7 (3.7)	-5.9* (3.1)	-10.3 (9.0)	6.7 (5.2)	-9.1 (3.1)	-7.4 (8.1)	-10.8 (9.0)
PACOIMA 0.5g Max. Acc.			1.5 (3.5)	2.0 (3.4)	5.7 (8.8)	8.5 (9.3)				
EL CENTRO	-1.9 (2.7)	-3.0 (11.8)	-2.3 (5.4)	-2.3 (11.8)	4.8 (11.7)	-4.8 (11.8)				
ARTIFICIAL 0.5g Max. Acc.	6.4 (10.4)	6.3 (10.2)	4.2 (9.7)	4.2 (9.5)	-10.1 (11.2)	6.4 (3.4)				

*First story drift -9.4" at 10.0 sec.

Notes
(1) Entries in table are: maximum drifts, inches (time), seconds.
(2) All analyses included the elastic-brittle columns
(3) The ground motion components used are as follows:

	1-1	2-2
Pacoima	S74W	S16E
El Centro	EW	NS