Prepared Discussion : 1A

For No.6

Design Implications of Damage Observed in the Olive View Medical Center Buildings by V.V. Bertero, B. Bresler, L.G. Selna, A.K. Cbopra, and A.V. Koretsky

From Aoyama, Japan

1. The reason for failure of the exhaust pairlion was the torsional failure of cantilever beams which could be due to the presence of high torsional moment under gravity loading intensified by vertical flattering of slabs and horizontal swaying as a frame. Column bar detailing may not be the basic reason.

2. I think stairtowers A,B and D fell primarily because of large story drift in the first story of the main building. The second floor of the main building pushed the tozer, imposing large rotation of wall and prohibitive axial deformation of ground story columns below the wall. I think these columns failed in compression and tension, not in shear.

REPLY TO PREPARED DISCUSSIONS ON PAPER NO. 6

DESIGN IMPLICATIONS OF DAMAGE OBSERVED IN THE OLIVE VIEW MEDICAL CENTER BUILDINGS

by

V.V. Bertero[I], B. Bresler[I], L.G. Selna[II], A.K. Chopra[III], A.V. Koretsky[IV]

2. AOYAMA: I think stairtowers A, B and D fell primarily because of large story drift in the first story of the main building. The second floor of the main building pushed the tower, imposing large rotation of wall and prohibitive axial deformation of ground story columns below the wall. I think these columns failed in compression and tension, not in shear.

AUTHORS: While the tilting of the tower C was due to the banging of the main building against it, the collapse of the towers A, B and D was due to lack of adequate shear strength capacity in the ground story columns. As shown in Fig. 7(a) the upper six stories of towers A, B and D were separated from the main building by seismic joints which had an effective width of 4 in. throughout. Reference 15 of this paper presents the results of dynamic analyses of these towers. From evaluation of these results and those obtained from similar analyses of the whole building, considering the stiffness, ultimate strength and ductility built in the actual construction of the ground story columns, it becomes clear that:

1. A relative displacement of the first floor with respect to the ground of about 0.5 in. induced shear forces larger than the concrete shear capacity of the ground story columns. (Note that the lateral reinforcement consisting of #3 ties at 18 in. spacing could not contribute to shear resistance of the columns).

2. This relative displacement of 0.5 in. occurred very early in the time history of the ground motion and before the lateral displacement of the main building reached values close to that required for the upper 5 stories of this building to come in contact with the tower.

From above considerations it is clear that the collapse of the tower was triggered by the shear failure of the columns. Any interaction between the upper 5 stories of the main building and the towers A, B and D occurred after the shear failure of the columns. This has also been corroborated by the observed damage.

YAMADA: (see Prepared Discussion)

AUTHORS: The main objectives of this paper were to summarize the possible causes and design implications of the observed damage. Due to space limitations the authors decided to focus attention on the important problems related to all the significant aspects that are involved in the seismic design of a structure, and on the improvements needed in their solution to minimize earthquake damage, excluding detailed specific methods for the rational design of reinforced concrete structures. Some practical recommendations for improvement of seismic design have been offered by the authors in the references given in the paper, particularly, references 9 through 15.

The authors thank Professor Yamada and Kawamura for their contribution to the paper. The discussion and information given is of special interest for developing a more rational approach to seismic design for reinforced concrete buildings composed of certain types of members.

1. <u>AOYAMA</u>:

The reply to this question will be sent directly by Professor Selna.

Discussion Closure: Session 1A, Paper 6

DESIGN IMPLICATIONS OF DAMAGE OBSERVED IN THE OLIVE VIEW MEDICAL CENTER(1)

L.G. Selna(2) - The observation by Prof. Aoyama regarding the principal failure mode of the exhaust pavilion is an alternate to the one made by the authors. This is most interesting because it shows that even for this seemingly uncomplicated structure many opinions can arise. The authors contend that the failure was due to poor detailing of column bar anchorage while Prof. Aoyama claims that the failure was due to high torsional moment exerted by the sunshade slab on the edge beam. Other reports(3,4) also have stressed that torsion was significant in the failure.

The issue is whether the edge beam failed due to torsion or that the joint failed due to poor bar detailing. In the prototype flexural and torsional force components were present in the edge beam during the earthquake. These components change to biaxial moments when they go from the edge beam through the joint to the column. A structural dynamics math model(5) which used the Pacoima Dam accelerogram(3) as input showed that the maximum flexural component was 5.5 times greater than the torsional component in the edge beam.

Using ACI318-71 capacity studies were performed for the edge beam considering flexure and combined shear and torsion. The capacity forces exceeded the corresponding forces found from the structural dynamics math model thereby indicating that failure should not have occurred in the edge beam.

A capacity study was also performed on the edge beam - column joint using a plane stress finite element analysis; in this study joint failure due to edge beam flexure was considered. The effect of poor column bar detailing on joint moment and shear capacity was considered in the analysis. The joint capacity

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[1] June 1973 by V.V. Bertero, B.B. Bresler, L.G. Selna, A.K. Chopra, and A.V. Koretsky.

[2] Discussion of question by Prof. Aoyama regarding failure of exhaust pavilion prepared by L.G. Selna.

[3] Jennings P.C. (Editor), "Engineering Features of the San Fernando Earthquake, February 9, 1971," California Institute of Technology, Earthquake Engineering Research Laboratory Report, EERL 71-02, June 1971.

[4] Lew, H.S., Leyendecker, E.V., and Dikkers, R.D., "Engineering Aspects of the 1971 San Fernando Earthquake," U.S. Department of Commerce Publication, Building Science Series 40, National Bureau of Standards, December, 1971.

[5] Ogawa, Y. and Selna, L., "Behavior of the Olive View Hospital Exhaust Pavilion during the San Fernando Earthquake: a Study on Effect of Vertical Acceleration," UCLA-ENG-7226 Report, UCLA Earthquake Engineering and Structures Laboratory, April, 1972.

found by this method was nearly equal to the maximum moment and shear found from the structural dynamics model thereby indicating that failure should have occurred in the joint. The math model studies confirm that the joint should have failed due to poor detailing before the edge beam failed due to torsion.

Field studies also confirm that moment in the joint was the principal cause of the failure. The sequence of the failure can be reconstructed by study of one of the damaged joints (Fig. 1). The failure started at the top left hand side of the column due to flexural tension. The tension crack then propagated to tne right hand side of the column where a tension failure was initiated in that part of the edge beam protruding below the shade slab. There was no reinforcing steel at that elevation in the edge beam to resist the tension so that a complete failure ensued. Note that the #6 bars at the bottom of the edge beam popped out. It can be seen in Fig.1 that the direction of the diagonal failure which resulted as concrete dropped away from the inside face of the edge beam is opposite to a crack which would result from torsion due to gravity plus dynamic vertical load.

Based on these analytical and field studies it was concluded that the poor bar detailing was the principal cause of the failure.

The authors sincerely appreciate Prof. Aoyama's searching question.

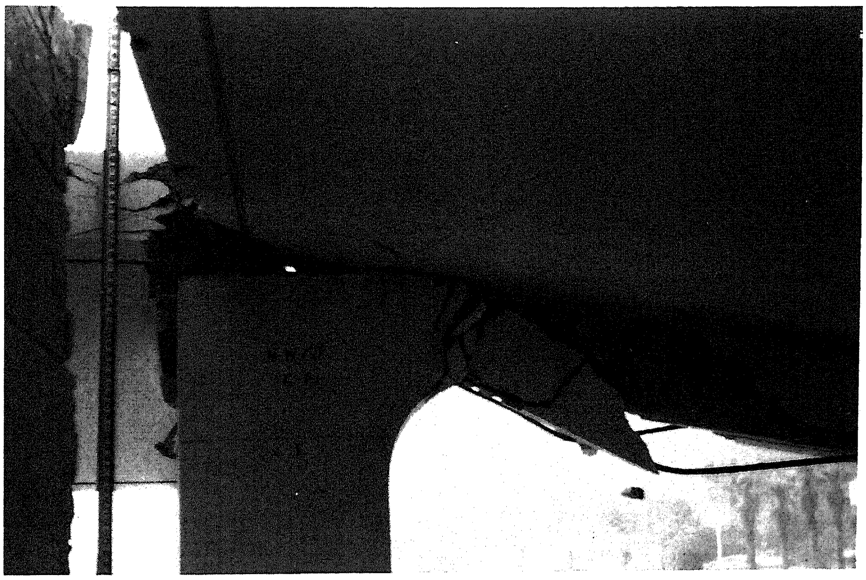

Fig. 1 Exhaust Pavilion Joint Damage