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Bridge Collapse Simulation with 3-Dimensional Extended Distinct Element Method

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1. INTRODUCTION

An earthquake occurred in the northern San Fernando Valley near the city of Northridge, California, U.S.A. with an Ms=6.6 at 04:30 a.m. local time, Monday, 17, January 1994. There was a significant and costly damage over a wide area. There were collapse of reinforced concrete apartment buildings, parking structures, highway bridges, etc. A highway bridge connecting State Highway 14 and Interstate Highway 5 collapse, killing a Los Angeles motorcycle police officer who was riding on it. The location of the bridge is shown in Figure 1. We studied the collapse of this reinforced concrete bridge using the 3-Dimensional Extended Distinct Element Method (3d-EDEM).

2. ANALYTICAL METHOD

The Distinct Element Method (DEM) is an explicit time integration procedure that models assemblies of distinct elements (blocks or circles) which interact mechanically at their surfaces. The method was described initially by Cundall et. al. [1]. However, the method was applied only to discontinuous material problems. Hakuno et. al. [2] developed the Extended Distinct Element Method (EDEM) using and additional spring between elements (called pore spring) to take into account the continuity of the material. They applied the method to study reinforced concrete structures. The method was developed for 2-dimensional analysis and later for 3-dimensional [3] using pore springs in the x, y, and z direction.

The highway bridge consisted of a seat abutment and continuous spans over bents 2 and 3 (see figure 2) with a hinge near bent 4. We used a 3d-EDEM model with 5,578 elements. We calculated the necessary parameters following the procedure explained in references [2] and [3]. The loads were a sinusoidal acceleration in x, y and z directions with a frequency of 3 Hz and the effect of the gravity acting in the vertical direction. The central frequency of the ground motion recorded at CSMIP Sta. 24279 at Newhall Fire Station, which is similar to the bridge site, is about 3 Hz and the peak acceleration is more than 0.5 g for the 3 directions [4]. This was the reason to choose the load in our analysis.

There are two possible failure mechanisms: 1) the pier 2 attracted a big horizontal shear force and fail then the weight of span 1 and 2 acted on pier 3 punching the slab through the column, 2) seat loss at abutment 1 causing span 1 to collapse with subsequent failure of pier 2 followed by collapse of span 2 to pier 3 [5].

3. DISCUSSION OF THE RESULTS

The 3d-EDEM simulation showed the redistribution of the loads during the progressive collapse of the structure (see Figures 3, 4, 5, and 6). The failure of the hinge was observed followed by the non-ductile crushing of the pier 2 and finally the punching of the girder at pier 3.

4. CONCLUSION

The collapse of a reinforced concrete highway bridge was simulated. The results showed to be useful to understand the behavior of the overall structure during the rupture process.

5. REFERENCES

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[5] J. D. Goltz (1994). The Northridge, California Earthquake of January 17, 1994. Part II. *National Center for Earthquake Engineering Research. State University of New York at Buffalo.*

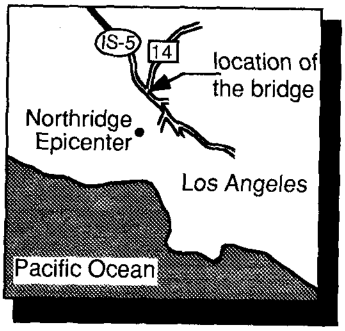

Figure 1. Location of the bridge

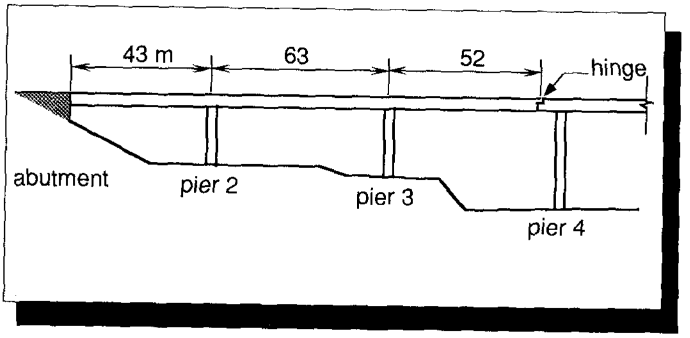

Figure 2. Bridge SR14/I-5. South-end elevation.

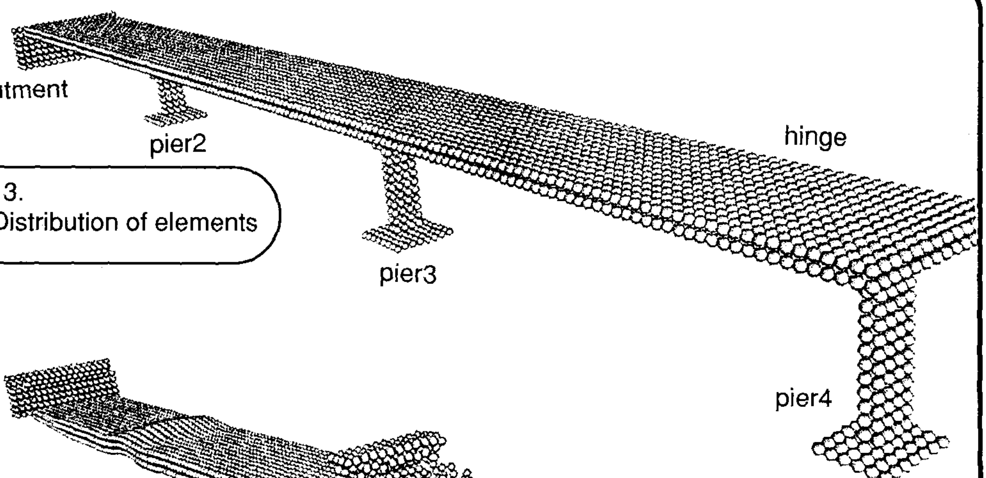

Figure 3.
Initial Distribution of elements

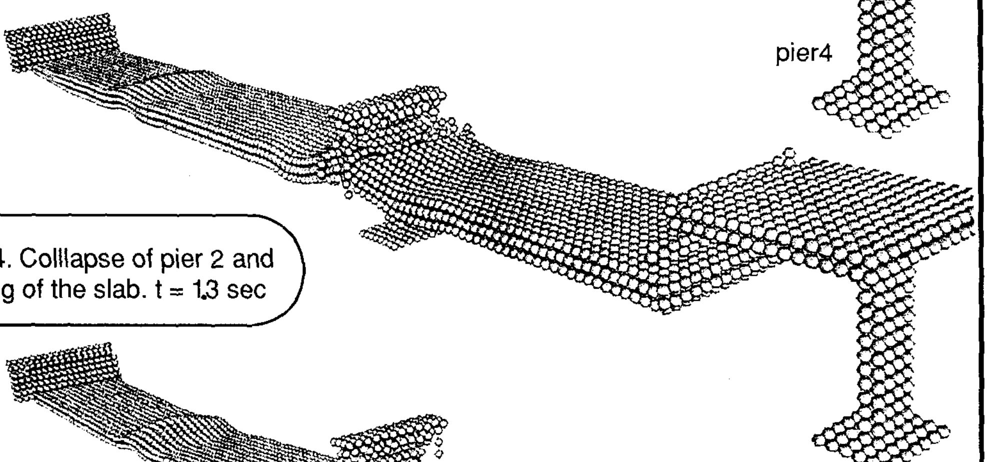

Figure 4. Colllapse of pier 2 and punching of the slab. t = 1.3 sec

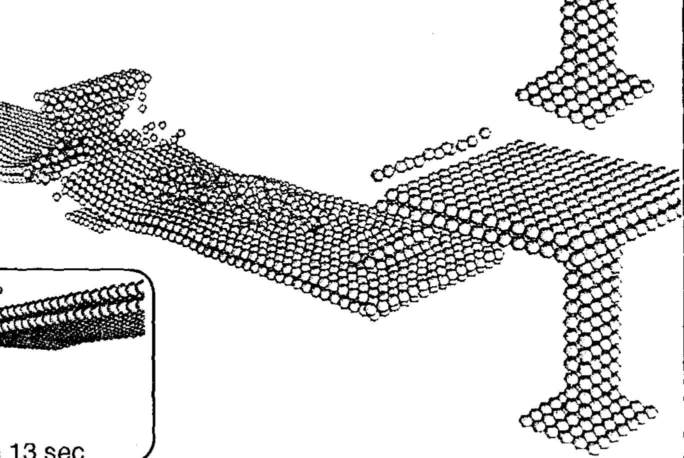

Figure 5. t = 1.5 5 sec

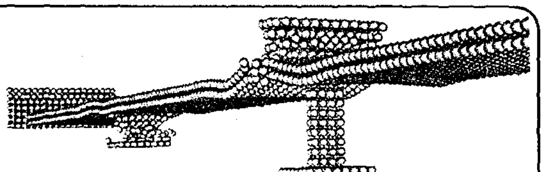

Figure 6. Crushing of pier 2. t = 1.3 sec