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Discussion of "Re-examination of damage distribution in Adapazari: Geotechnical considerations" [Engineering Structures 2005;27:1002–13]

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This excellent paper presents valuable data and interpretation of the distribution of damage in Adapazari during 1999 Izmit (Kocaeli) earthquake in Turkey. Contrary to the traditional views that damage is greater on "poor" ground, and consistent with similar observations in California, the Philippines, and Japan, the authors [1] show that the damaged buildings and areas with large soil deformations show remarkable separation. Their observations suggest that the structural failures occurred due to strong shaking at "stiffer" sites, where ground motion was amplified, while the buildings on the "soft" sites benefited from the natural base isolation effects, due to strong non-linear response.

These observations are in good agreement with the observed trends of damage levels relative to peak ground velocity and surficial geology, during the Northridge, California, earthquake of January 17, 1994. During this earthquake, ground velocity exceeded about 170 cm/s [6], and was high (40–90 cm/s) in broad areas where damage could be correlated with the nature of the surface deposits. In Fig. 1 we show the peak velocity versus the number of damaged buildings per 1000 housing units (hu) N^*. The solid points indicate adequate, the large open circles marginal, and the small circles very marginal numbers of data points, for the range of V_m and N^* values (Holocene: Qyf — fine-grained sediment — silt and clay; Qym — medium-grained sediment — sand; Qyc — coarse-grained sediment — gravel; Qyvc — very coarse-grained sediment — cobbles and boulders; Pleistocene: Qof — fine-grained sediment — silt and clay; Qom — medium-grained sediment — sand; Qoc — coarse-grained sediment — gravel). The solid lines show the trends through the data points for Pleistocene (Qof, Qoc and Qom) and for Holocene (Qyf, Qym, Qyc and Qyvc). It is seen that, for most of the damaged buildings on Holocene, the rate of damage growth with velocity is much slower than for the buildings situated on Pleistocene [4,5]. It will be of interest to compare these trends further with association of damage data from Adapazari, and the types of surficial geology there.

The spatial distribution of damaged buildings and of pipe breaks can further be used to determine which method of

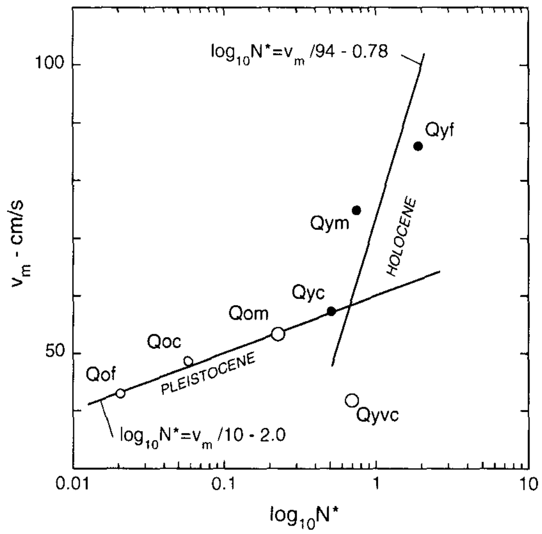

Fig. 1. Peak ground velocity versus the number of damaged (red-tagged) buildings per 1000 housing units, N^*, during the 1994 Northridge earthquake for different types of surficial geology (Qyf, Qym,...) (modified from [3]).

site characterization is most representative and correlates best with observed damage. We considered such analysis for data on buildings damaged during the Northridge, 1994, California earthquake. We analyzed (a) categories of surficial geology, (b) values of shear velocity near the ground surface, (c) liquefaction susceptibility classification according to Los Angeles County maps, and (d) liquefaction susceptibility classification according to USGS maps [2]. Correlations of the average number of damaged (red-tagged) buildings per 1000 housing units per area, with the average number of pipe breaks per 1000 housing units per area, for these four site characterizations are shown in Fig. 2. We found no clear correlations for (a)–(c), but a consistent trend for (d). That is, for sites with 'moderate', 'high', and 'very high' liquefaction susceptibility, there were proportionally fewer damaged buildings than pipe breaks (compared to the respective total area averages), by approximately a factor of two [3]. This

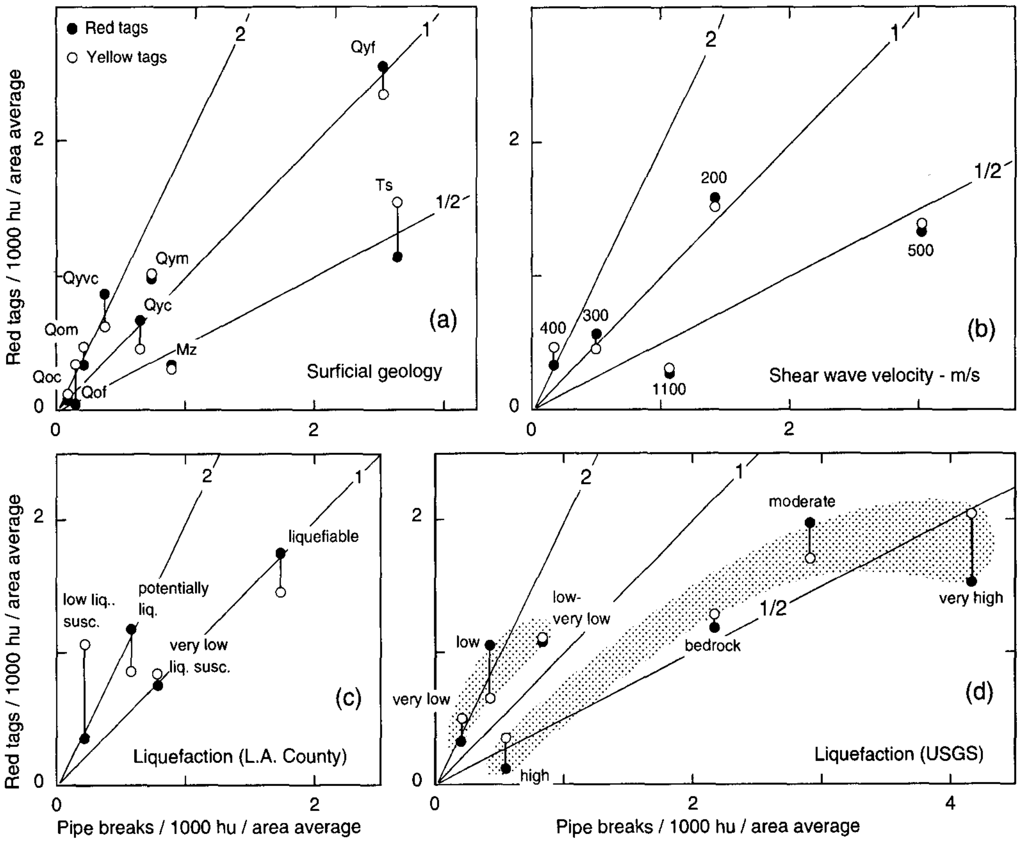

Fig. 2. Occurrence of damaged (red-tagged) buildings versus pipe breaks (both averaged to unit average for the total area of the map) relative to (a) surficial geology, (b) surface shear wave velocity, (c) liquefaction susceptibility based on Los Angeles County maps and (d) liquefaction maps based on USGS maps (modified from [3]).

trend is emphasized by the gray zones in Fig. 2(d). Again, it will be of considerable interest to find whether such trends can be seen also in the damage data in Adapazari.

Finally, having seen that the damaged buildings and areas with large soil deformations show remarkable separation, during the 1999 Izmit earthquake, the next question is how 'permanent' those areas are, and whether there is enough data from previous earthquakes to examine whether these areas recur after tens of years. If there are old records, the Adapazari earthquake of 1943 ($M = 6.6$), which produced significant damage in the city could be ideal for such an experiment, and should be analyzed further. We conducted such a study for the San Fernando, 1971, and Northridge, 1994, California earthquakes, and found that there is little or no change in the areas with damaged buildings and damaged pipelines [7]. Identification and mapping of such areas could become a valuable microzonation tool for the future.

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