11. EVIDENCE OF LOCALLY NONLINEAR BEHAVIOR OF STRUCTURES

A variety of structural systems showed evidence of locally nonlinear behavior during the earthquake. Such behavior typically occurred at relatively flexible connections between adjacent structures which tended to move separately under base excitation. Thus, during this moderate earthquake, the nonlinear behavior was often confined to the flexible connections themselves, or to those portions of the structures which interface with such connections.

In some cases nonlinear behavior in flexible connections was intentional and in fact intended to prevent significant structural damage. For example, some of the mechanical equipment on the UCSB campus was mounted on flexible supports which included earthquake restrainers or snubbers. Photographs of such equipment are shown in Figs. 8.14, 8.15, 8.20, and 8.21. The flexible spring mountings are provided to prevent excessive transmission of vibrational forces into the structure. However, when subjected to earthquake base motions such flexible mountings typically result in large relative motion between equipment and foundation unless snubbers are provided. The snubbers prevent excessive amplitudes of relative motion by providing an effective support stiffness which increases with the amplitude of relative motion. The resulting nonlinear behavior is confined to the flexible mountings and damage is prevented.

In other cases the intentionally flexible connections were provided for reasons other than earthquake protection, or they were intended to behave linearly. Such cases typically resulted in localized earthquake damage to the connections themselves. Examples include the many cases of damage to unsnubbed vibration mountings for equipment reported in Chapter 8, and many other cases of damage to seismic joints in buildings and expansion joints in highway bridges. Seismic joints are intentional gaps between adjacent structures to prevent structural interaction during earthquakes. The clearance between adjacent structures is typically assumed to be sufficient to prevent collisions and the associated nonlinear dynamical interaction. Many cases of relative motion at such joints were found in multistory buildings on the UCSB campus. Examples of such effects on seismic joints are shown in Figs. 11.1 to 11.4. In the majority of cases it appears that impact did not occur and that the adjacent structures probably did not interact significantly during the earthquake. It is possible however, that dynamic interaction did occur in some locations, such as the seismic joints between the Graduate Tower and the elevated walkways to the adjacent South Hall on the UCSB campus, as shown in Figs. 11.5 and 11.6. Minor damage to seismic joints was reported in most of the multistory buildings on campus. In one case this minor damage resulted in a safety hazard when a damaged seismic joint prevented the opening of a second floor emergency exit on the north side of the UCSB Library, as shown in Figs 11.7 and 11.8.

Expansion joints in highway bridges are intentional gaps between adjacent bridge sections provided to prevent excessive thermal stresses resulting from thermal expansion and contraction during changes in temperature. Evidence of minor impact at such joints was observed in

Fig. 11.1 Damage to seismic joint in South Hall, UCSB.

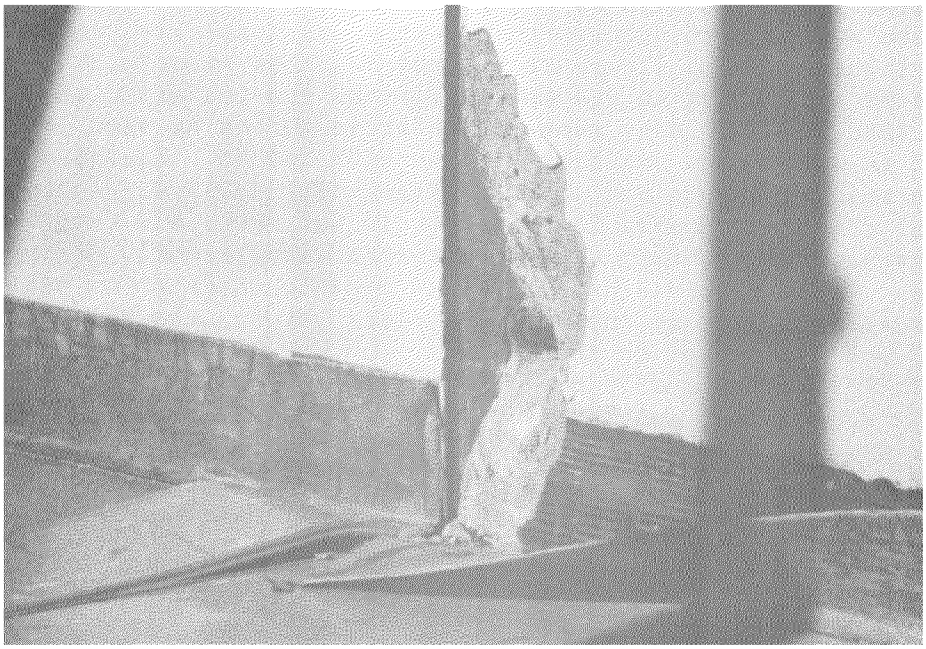

Fig. 11.2 Damage to seismic joint in South Hall, UCSB.