A REPLY TO "COMMENTS ON 'THE SAN FERNANDO EARTHQUAKE AND PUBLIC SCHOOL SAFETY'" BY DONALD A. RODGERS

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Mr. Rodgers has properly drawn attention to the fact that ideas for limiting conditions of earthquake ground motion must inevitably involve some speculation. For purposes of the present study, however, the evidence from several lines of approach is so consistent that the practical conclusions are clear, and we welcome the opportunity to again emphasize them.

The discussion in our paper of earthquake ground motion applies to those characteristics of the motion having engineering significance for school buildings of the type involved in the San Fernando earthquake. Mr. Rodgers' statements that the amplitudes of ground motion would be expected to be greater for a magnitude 8+ shock than for the magnitude 6.4 San Fernando earthquake are correct, but the inference that this would be significant for such school structures is not correct. The important point here is that the buildings we are considering in the schoolhouse report are structures having relatively high frequencies, and that for such buildings it is the high-frequency components of ground motion that are of consequence for hazardous structural damage. These high-frequency components are more nearly proportional to ground accelerations than to ground displacements, and this is the reason why it has often been noted that high-frequency structures have undergone ground displacements of many feet near a fault with no evidence of distress. As would be expected from our knowledge of the attenuation of high-frequency waves, the extent of faulting involved in large earthquakes, and the mechanisms of rupture propagation, it is now clear that ground accelerations do not increase indefinitely with earthquake magnitude, but that above about magnitude 7 the peak ground accelerations tend to level off. The important point, therefore, is not whether "we can almost certainly expect larger ground motions from larger events," but whether the character of these larger ground motions is such that it represents an increased structural hazard. These larger motions would be for the most part long-period displacements that would have little to do with hazardous structural conditions for the relatively strong, rigid, high-frequency structures being discussed in the schoolhouse report. These ideas are borne out by experience during the magnitude 8.3 San Francisco earthquake of 1906. It is well known that surface fault displacements during that earthquake were as much as 15 to 20 feet, or approximately four times the displacements observed during the San Fernando earthquake, and that many structures in the immediate vicinity of these motions were not seriously damaged. The amplitudes of long-period waves (greater than 10 sec) were no doubt correspondingly large, but these waves were not significant motions for structures of the type we are considering.

It is true that measurements are available for so few earthquakes that ideas of "usual" or "unusual" events based on strictly quantitative analysis perhaps are not convincing. These measurements, however, can be supplemented in very important ways by a careful study of damage caused by past earthquakes. Many investigators who have studied earthquake damage at first hand for many past earthquakes have felt that the severity of the ground motions associated with the San Fernando earthquake were notably high, considering the assigned magnitude and the extent of faulting. This is of course reflected in the high values of Modified Mercalli intensity of IX to XI in the epicentral region. These intensity ratings in effect average over the impressions of many

people and involve many noninstrumental effects which could not be treated in a more quantitative way.

Although the type of thrust faulting involved in the San Fernando earthquake was not a new feature, it is a basically different mechanism than that usually postulated for "great" California earthquakes, which are ordinarily expected to be associated with the San Andreas fault system. Our current picture of the generation of earthquakes makes it seem likely that only along major, through-going fault systems of the scale of the San Andreas are the really great earthquakes of over magnitude 8 likely to occur. Given the particular crustal conditions in California, and the known characteristics of the San Andreas system, it would be expected that major events on the San Andreas would be similar in many respects to the 1906 San Francisco event, and to the 1857 Fort Tejon earthquake. A major portion of the 1906 surface faulting occurred on land in easily accessible regions occupied by many types of structures, and a very complete photographic record is fortunately available for study of the structural damage. Pictures of downtown San Francisco taken after the earthquake and before the fire are more notable for the relatively small amount of major structural damage revealed, than as examples of widespread devastation. Many well-known photographs show relatively weak structures virtually on or very close to major fault motions of many feet, without significant structural damage. Although there were undoubtedly many areas of severe ground shaking during the 1906 earthquake, the general idea that emerges from a study of the photographs is that there were widespread regions directly along the ruptured fault which had ground shaking considerably less than in the epicentral region of the San Fernando earthquake, and probably no regions in which it is clearly evident that the damaging shaking motions were greater.

A large earthquake which did have a faulting mechanism similar to that of San Fernando was the magnitude 7.7 Kern County earthquake of 1952. Here again, detailed investigations of damage in the towns of Arvin and Tehachapi did not suggest that the ground shaking in the structurally significant frequency range was appreciably more severe than in the Sylmar area during the San Fernando earthquake.

If the school buildings in the epicentral region of the San Fernando earthquake had been located along that portion of the San Andreas fault that ruptured during the 1906 earthquake and had been exposed to the ground shaking from that event, or had been located in Arvin and Tehachapi in 1952, it is our belief that they would not in general have been more seriously damaged than in San Fernando. It is in this sense that we have concluded that the San Fernando earthquake involved a ground shaking in the frequency range of importance for typical school structures that was approaching the limit for any likely earthquake.

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