This Part II of the initial report on 23 June 2001 Atico, Peru earthquake contains the ground motion records obtained in the city of Moquegua and field observations made during 3-6 July, 2001 in the districts of Moquegua and Tacna. It was prepared by Eduardo Fierro of Wiss, Janney, Elstner Associates Inc. who was in the disaster area from June 28 to July 8, 2001.

GROUND MOTION

The Universidad Nacional de Ingenieria and the Centro Peruano Japones de Investigaciones Sismicas y Mitigacion de Desastres (CISMID) have recovered and processed the information from the only instrument that triggered in Peru, the one in the city of Moquegua. Figures 1 and 2 show the corrected ground acceleration time histories and the corresponding acceleration response spectra obtained from that instrument recording in East-West, North-South, and Vertical directions.

Figure 1. Acceleration time histories of the east-west, north-south, and vertical components of the corrected ground motion recording in the city of Moquegua. (Source: The Universidad Nacional de Ingenieria and the Centro Peruano Japones de Investigaciones Sismicas y Mitigacion de Desastres (CISMID)).
Figure 2. Acceleration response spectra obtained from the corrected ground motion along the east-west, north-south, and vertical components of the recording in the city of Moquegua. (Source: The Universidad Nacional de Ingenieria and the Centro Peruano Japones de Investigaciones Sismicas y Mitigacion de Desastres (CISMID)).
BRIDGES

Several bridges suffered damage at their approach ramps due to settlement of the roads. The most significantly damaged bridge was the Caimara bridge on the Moquegua-Tacna road. As seen in Figures 3 and 4, the approach to this bridge experienced lateral spreading of the fill and approximately 8 inches of differential settlement at the bridge interface. The abutment suffered significant damage with cracks of approximately 1 in. to 1.5 in. wide. It appears from the damage to the approach and to the abutment that the accelerations in the area were high due to amplification of accelerations by the soft soil conditions near the riverbed. Damage sustained by the abutment is shown in Figure 5.

Figure 3. Lateral spreading of the approach ramp fill of the Caimara bridge on the Moquegua-Tacna road. (Photo by E. Fierro)

Figure 4. Caimara bridge. Approach ramp settled approximately 8 inches relative to the bridge deck. (Photo by E. Fierro)

Figure 5. Caimara bridge. Diagonal cracking of the abutment wall was due to lateral loads of the soil and the bridge deck. The additional step cracking appears to be a failure that has occurred at a cold joint. (Photo by E. Fierro)

TACNA

The University Jorge Basadre in Tacna has two campuses and some damage was observed in both campuses. In the old campus building some parapet walls at the fourth floor had to be demolished since they were unstable in the out-of-plane direction. At the new campus, a 3-story building had moderate damage to the infill masonry in the form of diagonal cracking. However, the infill was strong enough to form diagonal compression struts between the beam-column joints which cracked the corner column joints in shear at the first and second floors (Figures 6, 7, and 8). The poorly detailed columns of the elevated tank located at the roof (fifth floor) had significant damage but did not collapse (Figure 9).
The Colegio Nacional Mariscal Caceres sustained extensive damage to approximately 60 short columns in the typical campus buildings. The school principal was building temporary wooden classrooms at the time of this site visit (Figures 10 and 11).
A municipality building outside Tacna suffered severe damage to the short columns and to the few masonry walls that existed. The building had typical poor short column configuration without any transverse reinforcement which caused these columns to crush and lose several inches of height. The building is not readily repairable and will be demolished (Figures 12 and 13).

Three houses collapsed and several were damaged in a non-consolidated land fill area of Tacna (Figures 14 and 15). The extent of damage and the nature of the soil imply possible amplification of the ground motion in this district.

A plant south of the coastal city of Ilo, suffered collapse of two cranes at the end of the pier and one rail-crane located next to the main building (Figures 16 to 26). Some of the buildings in the plant sustained damage to reinforced masonry walls (Figures 27 and 28).
Figure 16. Plant in Ilo. Rail-crane collapsed as it failed the supporting rail. (Photo by E. Fierro)

Figure 17. Plant in Ilo. Detail of the rail support in area that did not fail. (Photo by E. Fierro)

Figure 18. Plant in Ilo. Failed bolts that used to hold the rail to the support. (Photo by E. Fierro)

Figure 19. Plant in Ilo. The crane pushed the rail in the foreground which in turn failed the supporting hold-down system. (Photo by E. Fierro)

Figure 20. Plant in Ilo. Lateral support of the boiler failed in the weld and by buckling of the support. (Photo by E. Fierro)

Figure 21. Plant in Ilo. Column and diagonal brace connection; all four anchor bolts failed in tension. (Photo by E. Fierro)
Figures 22, 23, and 24. Plant in Ilo. [Clockwise starting above] Typical elongation of bolts of the 2 fuel storage tanks; relative movement of the firewater piping at the 4265 foot long pier; breakage of the pipe at a connection. Firewater was not needed after the earthquake. (Photos by E. Fierro)

Figure 25. Plant in Ilo. Remains of two cranes that collapsed at the end of the pier. (Photo by E. Fierro)

Figure 26. Plant in Ilo. View of the support of one of the collapsed cranes. No positive attachment of the crane to the supporting structure could be found. (Photo by E. Fierro)

Figures 27 and 28. Plant in Ilo. A reinforced-concrete frame building with reinforced masonry infill walls suffered damage. The light reinforcement in the masonry infill is shown above. (Photos by E. Fierro)
MOQUEGUA

The City of Moquegua was the hardest hit city by the earthquake of 23 June 2001. The records (see Figure 1) indicate that the peak ground acceleration was 0.30g and the response spectra had a plateau at approximately 0.65g-0.70g in the range from about 0.15 seconds to 1 second (see Figure 2). The damage in Moquegua is mainly to old and new adobe houses. Numerous adobe buildings collapsed in the downtown area and many others sustained heavy damage to the point of being almost unstable (Figures 29 and 30). In the area of San Francisco, the hillside was nearly totaled due to collapse of new adobe houses (Figure 31). One school had a partial collapse due to short columns (Figures 32 and 33). The cathedral lost one of its vaults, and the church of Belen sustained damage at its tower and walls (Figures 34 to 38).

Figure 29. View of an old adobe house in the main square of Moquegua. The upper story walls have collapsed and the balconies are about to collapse. (Photo by E. Fierro)

Figure 30. Typical view of streets of Moquegua where debris from collapsed houses dumped on the streets for removal. (Photo by E. Fierro)

Figure 31. View of the area of San Francisco in Moquegua. Most of the adobe houses have collapsed. (Photo by E. Fierro)
Figure 32. School building in Moquegua. Partial collapse due to failure of short columns. (Photo by E. Fierro)

Figure 33. View of the collapse of one of the short columns in the school building shown in Figure 32. (Photo by E. Fierro)

Figure 34. Cathedral in Moquegua, a stone structure with stone walls and stone vaults, sustained damage and lost one of its vaults. (Photo by E. Fierro)

Figure 35. Interior of the cathedral seen in Figure 34. The stone walls are on the verge of collapse. (Photo by E. Fierro)

Figures 36, 37, and 38. Church of Belen, Moquegua. [Clockwise starting above] Church towers are severely damaged; the dome sustained some damage but appears to be intact; lower part of the masonry wall of the church collapsed. (Photos by E. Fierro)
SUMMARY

Mr. Fierro visited the cities of Tacna, Ilo, and Moquegua during the period of July 3 to July 6, 2001. Damage patterns similar to those reported in Part I of this initial report were observed in residential, school and religious structures. Furthermore, damage to highway bridges and industrial facilities was also investigated. The only ground motion data recorded in Peru of the main event was obtained in the City of Moquegua, which, incidentally, suffered the greatest damage. The records show that significant shaking was experienced for a long duration. Response spectra analyses of the records indicate that structures in the 0.15 seconds to 1 second period range should have experienced fairly strong spectral accelerations on the order of 0.65g to 0.70g.

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