PRELIMINARY RECONNAISSANCE REPORT ON ITALIAN EARTHQUAKE OF MAY 6, 1976

by

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INTRODUCTION

Receiving news of a major earthquake in Northern Italy, the Earthquake Engineering Research Institute dispatched a Reconnaissance Team consisting of James L. Stratta and Loring A. Wyllie, Jr., to Italy to investigate the effects of the earthquake. The Reconnaissance Team arrived in Milano on May 14 and proceeded by car to Udine. The Reconnaissance Team was in the affected area through May 24.

The purpose of the reconnaissance was to make a technical investigation of the effects of the earthquake on structures of all types. Other observations of interest to the engineering community were to be noted. This preliminary report has been prepared immediately upon returning from the earthquake area in the interest of prompt dissemination of information. The comments, conclusions and recommendations are intended to be objective in nature and are in no way intended to be critical of the Codes, the design or construction represented in the area.

The earthquake occurred on Thursday, May 6, 1976, about 9:00 p.m. local time. The National Earthquake Information Center in Boulder, Colorado reported the main shock with a Richter magnitude of about 6.5 with a smaller foreshock one minute before the main shock. The epicenter was north of Udine, Italy, at latitude 46.4N and longitude 13.1E, with a shallow focal depth.

The area of damage is within Fruili area of the Venezia-Giulia sector of Italy, which is the northeastern corner of Italy. The heavy damage was located in various towns and villages north of Udine where relatively flat land meets the southern edge of the Italian Alps. The damage extended slightly into nearby Yugoslavia. At the time of writing of this report, the death toll was approximately 950.

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GENERAL OBSERVATIONS

1. Dwellings. The dwellings in the area are of different ages and construction materials. Most of the older residences, probably constructed in the last century, have walls consisting of various sizes and shapes of rocks with a low strength mortar. Floors and roofs are of wood construction and the height is generally two or three stories. Many of these structures have been expanded in later years with irregular floor plans and different construction methods including common walls with adjacent buildings. In the areas of substantial damage, these older dwellings had a very high collapse rate.

Newer construction generally had a nominal concrete frame with infilled walls of clay tile or concrete blocks. Floors and roofs were either of timber or shallow concrete joists with clay tile permanent form fillers. These structures generally performed better. However, some failures were observed. In the most heavily damaged villages, some of the newer dwellings were virtually crack-free and their constructions materials could not be observed as they were concealed by the exterior plaster finish. However, it is the general opinion of the Reconnaissance Team that the buildings with hollow block infilled walls performed better than those with clay tile infilled walls.

2. Multi-story Residential Buildings. A small group of residential buildings of five to eight stories was observed in the village of Maiano. These buildings were constructed with reinforced concrete frames, concrete joist floors with clay tile fillers, and partition and exterior walls of hollow clay tile. Two of these structures completely collapsed and the debris had been removed prior to observation by the Reconnaissance Team. Others inspected by the Reconnaissance Team had considerable damage to walls and concrete columns. A portion of a seven story building was leaning several inches in its first story. The typical structural design for these buildings provided first story columns 30 cm (12 inches) square with four bars somewhat exceeding 1% reinforcing. The building codes did not require seismic design in this area. The infilled walls in these buildings introduced rigidity and torsion effects into the structural elements which compounded damage. Concrete details, including reinforcing, tie spacing, etc., did not conform to present day ductility concepts.

3. Hospitals. Two multi-story hospitals are in the area and were visited by the Reconnaissance Team. A seven story structure is located in Tolmezzo while a ten story complex in Gemona was nearing the completion of construction. The hospital in Tolmezzo was reported to have been in a seismic zone and designed for seismic forces. The hospital in Gemona was not in a seismic zone and was not designed for seismic forces, although the two hospitals are only 17 kilometers apart.

The hospital in Tolmezzo was evacuated immediately after the earthquake. Damage consisted of cracking of clay tile infilled walls and pounding at the expansion joints. Elevator counterweights were out of their guides and some shifting of elevator equipment was observed. Only one small passenger elevator remained operational. The Reconnaissance Team visited the hospital two weeks after the earthquake and no repairs to walls, nor elevators had begun. X-ray equipment on the first floor was in use, while the remainder of the hospital was unoccupied.

The damage to the hospital in Gemona was considerably greater. There was extensive collapse of interior infilled clay tile walls and significant structural damage to some columns. A five story structurally separated portion of the hospital was leaning at least 15 cm (6 inches) in its second story. This story appeared to have fewer exterior walls installed, creating a discontinuity in rigidity.

4. Industrial Buildings. Numerous industrial buildings were present in the area of earthquake damage. Over ten of these structures which were visited by the Reconnaissance Team had sustained heavy damage to total collapse. Most of these buildings consisted of poured-in-place concrete columns supporting precast beams and girders or concrete tied arches. Roof slabs varied in construction but generally contained numerous skylights. The connections between precast elements relied on friction with some grout for full bearing and had no ability to transmit bending moments or tension. The structures had not been designed for seismic forces. Exterior walls were generally of precase concrete with very nominal fastenings. The mode of failure was generally a collapse of the roof system due to the lack of positive connection between the precast elements. Several of the structures had considerable damage at the base of the columns as the cantilever strength of the columns provided the sole lateral force resistance. A few of these buildings had such slender columns that even a reasonable level of calculable wind resistance appeared questionable.

A few industrial buildings in the area had minor to no damage from the earthquake These structures appeared to contain lightweight wall and roof systems with precast beams and girders thereby reducing the total mass, or they were smaller buildings with a well anchored precast wall system. The one structural steel industrial building in the area had no damage.

An interesting feature at one manufacturing facility was that all the unanchored equipment slid on the floor 0.5 to 1.0 meters in the same direction. At this same facility, collapsed precast exterior wall panels came to rest about 1.5 meters from the building. At several other plants equipment seemed to stay in place with nominal to no anchorage.

5. Churches. Most churches in the area sustained considerable damage, including partial to total collapse. These churches were basically constructed of heavy stone and masonry construction with no reinforcement. Some of the churches were several hundred years old, with the date on one church visited by the Reconnaissance Team indicating an age of nearly 500 years. All of the churches had tall campaniles and many of these were seriously damaged or had collapsed.

Old churches visited outside the heavily damaged area revealed patched cracks indicating past distress probably due to differential foundation settlement or historic earthquakes. The Reconnaissance Team could not help but speculate on the effects of this previous damage to historic structures, or the cumulative effect of damage from multiple earthquakes which continues to weaken the structural resistance.

6. Bridges. Numerous bridges were present in the damaged area. Many of the older bridges appeared to perform satisfactorily, although a few were substantially damaged. Of greatest interest to the Reconnaissance Team was a series of new freeway bridges being constructed for the autostrada. Several of these bridges were structurally complete and their damage consisted of failure of wing walls, sliding at supports and spalling of concrete at supports. Several other bridges were in the process of construction and the incomplete structures were heavily damaged from the ground shaking. Several groups of large post-tensioned bridge girders had been fabricated and were sitting on concrete blocks awaiting installation. They were toppled by the ground shaking and were so heavily damaged that they were unusable. Several small bridges which were complete except for having restraining walls poured slid considerably on their supports. Settlement of abutment fills was also observed at several bridges.

7. Landslides. Numerous landslides were observed where portions of the very steep mountains slid due to the ground shaking. In several cases these rock falls extended into villages which were built at the base of the mountain. In one village several rocks the size of two story houses fell and completely destroyed a group of homes. The majority of the landslides, however, did not affect the populated areas.

COMMENTS

The Reconnaissance Team had the opportunity to attend several meeting while in Italy with representatives of the regional government in Trieste. The meetings were held with the Director of Public Works, and members of his staff, and were arranged for the Reconnaissance Team by representatives of the United States State Department and the United States Embassy in Rome.

Based on these meetings, it is the understanding of the Reconnaissance Team that seismic design requirements will be imposed on the area where significant damage occurred during this earthquake. This new seismic zone will encompass only those areas of significant damage in this earthquake. It was mentioned at one of the meetings that the inclusion of seismic design requirements in Italy amounts to an increased construction cost of approximately 10 percent, thus there is a reluctance by government officials to expand seismic zones over large areas.

Reconstruction plans are being developed by the Regional Director of Public Works. It appears that a thorough field reconnaissance will be necessary to determine which buildings may be reconstructed and which structures will be completely demolished and then rebuilt. Seismic codes for the area are being developed and forms and check lists are being finalized to facilitate the detailed field reconnaissance. The first priority of the reconstruction will be the replacement of homes, followed by the reconstruction of schools.

CONCLUSIONS - LESSONS LEARNED AND RELEARNED

The following are the preliminary conclusions reached by the Reconnaissance Team:

1. The buildings in the damaged area had not been designed to resist earthquake effects. This lack of seismic resistance was the primary cause of damage to structures.

2. Many low rise residential buildings of recent construction with substantial concrete or infilled masonry walls performed reasonably well in the earthquakes.

3. Reinforced concrete members were not detailed for ductility considerations and they exhibited damage consistent with past observations.

4. Bridge spans tend to slide on their supports while abutments tend to move independently of each other. Support details and restrainers must be designed for these considerations.

5. Steep mountain slopes are susceptible to earthquake induced landslides. The potentially disastrous effects of these landslides on villages at the base of the mountains should be recognized.

RECOMMENDATIONS

The following recommendations are based on observations by the Reconnaissance Team while in Italy plus judgment based on observation of past earthquakes throughout the world. The recommendations are directed at steps which the Reconnaissance Team feels should be considered in the reconstruction program due to the many requests for this type of recommendation. It must be emphasized that these recommendations are offered in a constructive manner and are not an attempt to be critical in any way.

1. Structures in the area should be designed for seismic forces. Design for seismic forces includes not only the calculation of lateral forces but also the selection of a building concept, materials and details that are appropriate for seismic resistance. The design should be performed by an engineer knowledgeable in the practical aspects of earthquake engineering. The construction must be properly inspected to insure that design details are followed. The practical knowledge and judgment of the design engineer cannot be overemphasized.

2. Repairs to damaged structures should consider the cumulative effects of damage from multiple earthquakes or other factors. Any reinforcement or changing of stiffness of a structure must include a consideration of the effect of that change on the remainder of the structure in future earthquakes.

3. One or two story structures should be designed for a lateral force coefficient as required by Italian law for seismic zones. Critical members should be properly detailed for ductility and the structure should be properly tied together. Designs should contain provisions for torsion, relative rigidities, infilled walls in addition to the ductility of the resisting elements.

4. The earthquake appeared to create pockets of damage indicating microzonation within the area. Thorough documentation of such effects is beyond the scope of this report.

5. The landslide potential should be evaluated prior to reconstruction of villages immediately below the steep faces of mountains.

6. New homes should be constructed of local materials best suited for earthquake resistance structures. The Reconnaissance Team would recommend properly reinforced masonry structures or concrete frames with properly anchored infilled walls. Clay tile should not be used for load bearing walls and should be used only sparingly for non-structural partitions and infilled walls. Floor and roof diaphragms should be properly detailed to provide ties and transmit lateral forces at each level.

7. Damaged structures which are to be repaired should be properly strengthened by an appropriate method. Such methods might include the addition of reinforced gunite walls, epoxy repairs of damaged members, the addition of poured-in-place concrete or new reinforced masonry walls acting as shear walls. Proper anchorage of all floor and roof systems to exterior walls must be provided.

8. Multi-story buildings (four floors or more) should be properly detailed such that all critical members will have adequate ductility. The effects of infilled masonry walls must be considered in these structures during the design stage. Seismic provisions should approximate provisions of the Uniform Building Code or the Recommendations of the Structural Engineers Association of California.

9. Industrial buildings of precast concrete should be properly detailed and tied together for seismic forces. A complete stress path should be provided which does not rely on friction between members.

10. Special design requirements may be appropriate for facilities which should be kept operational after an earthquake. These facilities might include hospitals, emergency operation facilities, firehouses, etc.

11. Villages which will have considerable replacement of structures should have the effects of these structures on utility systems, traffic flow, etc., considered in the planning process.

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