Learning from Earthquakes

Lifelines Suffered in Kobe Quake

The Technical Council on Lifeline Earthquake Engineering (TCLEE), sent a postearthquake reconnaissance team to the Kobe area in mid-March to investigate the effects of the January 17, 1995, quake on lifeline systems. The team, which returned on April 1, 1995, consisted of Le Val Lund, Alex Tang, Bill Byers, and John Eidinger. While in the Kobe area, the team met with utility companies to obtain lifeline performance information. TCLEE will issue a detailed monograph at this summer's 4th U.S. Conference on Lifeline Earthquake Engineering (San Francisco, August 9-12, 1995), which will include information from several TCLEE-participating reconnaissance trips, including joint efforts with NIST and NCEER.

While the early reports coming out of the Kobe area in the days and weeks following the quake indicated that electric power and communications systems experienced little reduction in service, the information collected by the TCLEE team later in the recovery effort, after more systematic compilation of data was possible, indicated that the M_w 6.9 earthquake can be considered the most disruptive earthquake on lifeline systems in recent history. In almost every category, lifeline disruptions lasted ten times longer than they did in recent U.S. urban earthquakes (Northridge 1994 and Loma Prieta 1989). This summary of the findings of the TCLEE team presents some key statistics.

Telecommunications (key utility provider: NTT) — As late as 11 weeks after the earthquake, land line phone service had not yet returned to normal operating conditions. While the in-plant phone system damage was not unusual compared to that seen in recent U.S. urban earthquakes, significant outside-plant damage did occur. Current estimates by NTT of repair costs to the phone system are 250 billion yen (almost $3 billion at current exchange rates). At the peak time of restoration activities, almost 3,000 people were involved in the repair work.

Electric Power (key provider: Kansai Electric) — Estimates made by Kansai Electric at the time of the TCLEE investigation indicated that repair costs to the electric system would cost 230 billion yen (over $2.5 billion at current exchange rates). Immediately after the earthquake, power was lost to 2,600,000 customers. Within a few hours that number had been reduced to 1,000,000. Power outages due to high voltage substation damage (up to 275 kV) were restored within a day and a half, but 260,000 customers were then left without power due to distribution system damage. Extensive damage to the low voltage distribution system resulted in about five more days of repair work before power was restored to all customers (other than those customers with destroyed structures). At the peak time of restoration activities, 4,700 people were involved in repair work. About 2,500 of the repair workers were dealing with the transmission system and the remainder were working on the distribution system.

Unusual aspects of this earthquake included the extreme level of damage in the distribution system: 7,869 elevated wire support structures, mostly concrete poles, were damaged; 4,512 transformers were damaged; and 649 distribution circuits were damaged. This high level of damage is largely explained by the extensive number of building collapses. Significant damage occurred in fossil-fuel power stations (ten generating units were damaged). Some dead tank 276 kV circuit breaker bushings failed. Twenty-three high voltage transformers (77 kV to 275 kV) were damaged, and 29 more were slightly damaged largely due to anchorage and bushing failures.

Natural Gas (key provider: Osaka Gas) — Estimates made by the Osaka Gas Company at the time of the TCLEE investigation were that repairs to the gas system would total 190 billion yen (over $2.1 billion at current exchange rates). Immediately after the earthquake, gas supply was lost to about 856,000 customers. As of March 26, 1995, gas service had not been restored to two districts in the Kobe area totalling 117,400 customers. Most damage occurred in the low pressure distribution system (underground pipes). About six hours after the earthquake, gas was shut off to highly damaged areas. The basic restoration approach was to start in areas with little damage, and to prioritize restoring service to hospitals and other facilities with high public needs. At the time of peak restoration activities, there were 9,700 people involved in the repair work. Osaka Gas employees made up 1/3 of this force; another 1/3 came from other gas companies, and the rest were contractors. Obstacles to recovery included inflow of water and soil into gas pipes, damaged roads, and traffic congestion. Major gas facilities were located outside the area of strong ground shaking, and had little damage. A final tally of the number of broken gas pipelines is not yet available, but will likely be several thousand. A combination of screwed joint, polyethylene and ductile iron pipe was largely in place; the screwed joint pipe suffered 70%-80% of the damage in the low pressure system, although it compromised only 30% of the pipe inventory. There was virtually no damage to the polyethylene pipe. About 70% of the gas company's customers had "seismic" gas meters, set to be turned off at a ground motion of about 250 gal (about 0.25g). These had been installed by the gas company, and were usually attached to exterior walls of buildings. These were largely successful in terms of closing off the gas supply to the structure, but a number undoubtedly failed on the distribution main side of the meter owing to collapse or partial collapse of the structure (over 50,000 structures collapsed). Residual and leaking gas may have been a factor in providing fuel to the fires which occurred.

Water (several key providers) — Five cities suffered major damage to their water distribution systems, resulting in widespread and long outages to customers. In Kobe (the largest system affected), four out of five areas served had initial losses of about 80%–90% of customers, with 99% restored to service within 60 days. One area was distant from the strong shaking, and had only 20% of customers without water after the earthquake and 100% service restored within eight days. In Ashiya (population 85,000), water was lost to 100% of customers for eight days due to loss of all sources of water; once transmission of water to the system was restored, it took an additional 30 days to repair pipeline damage to restore service to customers. Three other smaller cities had similar damage. The main pipeline material in the Kobe and Ashiya water systems is ductile cast iron, using a variety of joints. In the strongly shaken areas, pipeline repairs were needed at a rate of about 1 repair per kilometer of pipeline. In the area of strongest shaking, almost two repairs per kilometer were needed. In total, as of mid-March, about 4,000 distribution pipe repairs had been made and tallied; reportedly, water usage is 40% higher than normal, indicating that a number of as-yet unrepaired leaks still exist. In Kobe, 804 people (peak time) were used to deliver water to customers using 432 mobile water tank trucks; 734 people were used to repair distribution pipe breaks; 272 people were used to repair broken service connection pipes. A small percentage of ductile iron pipes used a special slip joint. These pipes fared very well (almost no reported failures). This type of joint involved initial costs about 30% higher than other pipe systems. On the customer side of the meter, the most common material used is PVP, and water companies estimate that between 70,000 and 100,000 breaks occurred. Many of these breaks can be attributed to collapse/serious damage to structures.

The Kobe water system has 199 distribution storage tanks, about 100 of which are buried rectangular reinforced concrete. The Ashiya water system has 10 tanks; half are the buried rectangular concrete type. Two of the buried concrete tanks had serious damage, leaking all water contents. No other serious damage occurred to these tanks.

The Kobe wastewater system consists of separate sanitary and storm systems. Of 3,315 km of sanitary sewers and 483 km of storm sewers, there were 1,414 repairs made. The pipeline materials are 70% concrete, 20% PVC, and 10% clay or other materials. After the earthquake, 37 cameras were used to inspect the sewers for damage. The Kobe system has seven wastewater treatment plants; three were seriously damaged. The largest plant (capacity about 150 MGD) lost primary treatment, and as of the end of March, it was estimated that repairs needed to restore primary treatment would take until the end of April. During this time, raw sewage is being chlorinated and partially treated in a makeshift settling basin, using a shipping canal. Even with the extensive damage to the sanitary sewers, there was only one reported backflow of sewage. This is, in part, attributable to the fact that there was essentially no water coming into the area after the earthquake.

Written by John Eidinger, reviewed by Anshel Schiff.

News of the Profession

ASCE Approves New Standards Activity

A new standards activity on Seismic Base Isolation Systems has been approved by ASCE. The proposal for this activity was made by Dr. Andrew W. Taylor, of the National Institute of Standards and Technology. The objective of the new activity is to develop a national consensus standard for the testing and evaluation of seismic isolation systems and components.

A call for members has been submitted for this committee. If you are interested in becoming a member please fax a brief letter of interest to Debbie Smith, Committee Coordinator, 202-289-6797, or mail it to ASCE, Suite 600, 1015 15th Street, NW, Washington, DC 20005. Once the request is received an application form will be mailed back to all who express interest.

Membership on ASCE standards committees is open to all those who might reasonably be expected to be, or who indicate they are, directly affected by the activity without dominance by any single interest group: Producer, Consumer, and General Interest, including Regulatory.