Bull.Ind.Soc.Earth.Tech.,PaperNo.353,Vol.32,No.4,Dec.1995,pp.127- 146

THE GREAT HANSHIN EARTHQUAKE OF JANUARY 17,1995

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Abstract

Japan is located in one of the most active seismic zones of the world. It has seen great disastrous earthquakes before. An earthquake hit Kobe city and adjacent areas of Japan on January 17, 1995 at 5-48 AM which was quite different from other earthquakes. The damage caused by this earthquake surprised both the public as well as the engineering community the world over. The views of experts/public who visited Kobe are quite different from the views of people who collected information from news papers and television. This paper is intended to give information collected by authors during their visit to Kobe and from other reliable sources. This small presentation by the authors on Kobe earthquake may not give complete information about the disaster but endeavours to give an overview of the event. The authors hope that the information given will stimulate the Engineering community to think of improvements to prevent damage due to earthquakes.

SUMMARY OF GREAT HANSHIN EARTHQUAKE:

Date and time	January 17, 1995 at 5-48 AM
Magnitude of the Earthquake	7.2
Maximum intensity	11 on MMI
Epicentral distance	20 Km
Focal depth	10-20 Km (Shallow type of Earthquake)
Number of people died	5500 (approximately)
Number of people injured	28000 (approxmately)
Damaged buildings	75000 (approximately)
Reasons for damage	1.Houses, bridges, elevated tracks built to old standards 2.Fire 3.Liquefaction
Maximum peak ground acceleration recorded	833 cm/sec^2
Approximate duration of main shock	8-12 sec
Number of after shocks	about 1000

EARTHQUAKE DETAILS:

The energy released from the movement along a fault is what causes an earthquake. The cycle of pressure built up and the subsequent release of energy is often longer than 10,000 years. A fault is considered active if there has been movement in the past 1.7 million years. There are 2,000 active faults in Japan. Most major quakes in Japan had their epicenters under the ocean. These quakes occurred when two tectonic plates shifted under the ocean. However some earthquakes were caused by the movement of strata along an active fault close to the ground surface. Generally the size of an inland quake with its epicenter close to the surface is smaller than ocean-bed quakes. However, such relatively small quakes can cause disaster when the epicenter is close to big cities (Sayaka Irie, Jan 20,1995).

The great Hanshin (" Hanshin stands for the area covered by two big western cities of Osaka and Kobe. "Han" is an abbrevation of Osaka and "Shin" is that of Kobe) earthquake occurred at 5-48 AM on January 17, 1995, approximately 20 Km southeast of central Kobe city. The earthquake epicenter was located in the Osaka Bay between northern tip of Awaji Island and the mainland. This is more clear from the picture shown in Fig.1. This was an inland,

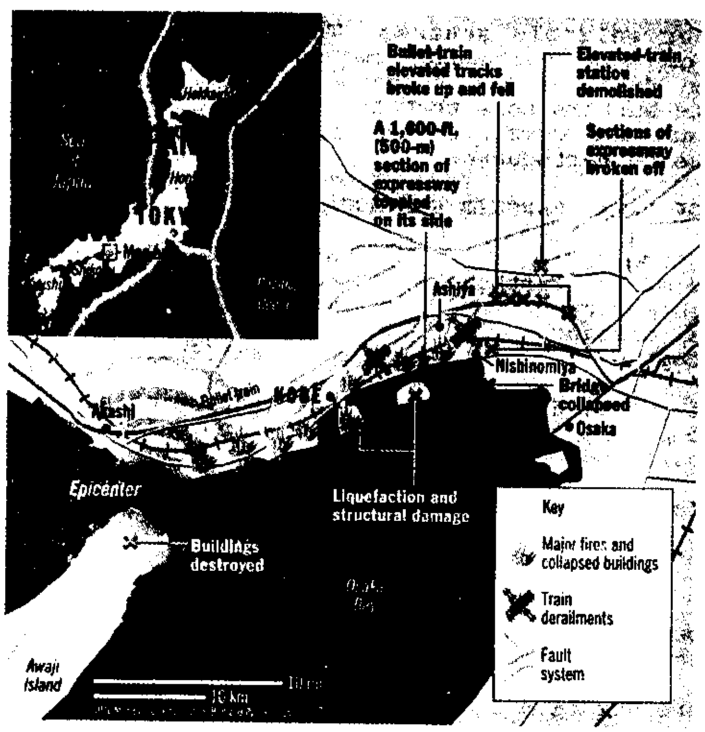


Fig.1 Epicenter location of Great Hanshin earthquake

shallow type of earthquake with focal depth of approximately 14 Km and fault rupture in this event appears to be a strike-slip motion. A strike-slip motion is characterised by two sides of the fault moving laterally with respect to each other. It appears that the length of the fault which ruptured in this event extends from the northern end of Awaji Island northeast through Kobe city. The area of greatest devastation in the event was concentrated along the fault rupture. Maximum Ground acceleration measured at Kobe weather Bureau indicates that accelerations in the central area were as high as 833 cm/sec^2, while measurements at stations 20 Km from the area of fault rupture ranged from 212 cm/sec^2 to 226 cm/sec^2 (Haresh Shah, Jan 29,1995). At faraway distances (about 150 Km) the acceleration levels are about 16 cm/sec^2 (Yoichi Koga, Feb 16, 1995).

REASONS FOR DAMAGE/LOSS OF LIFE

1.Failure of communication network

In Japan every time there is an earthquake , seismographs at meteorological observatories or stations in each area measure the seismic activity, and automatically transmit the information to the district metereological stations via Nippon Telegraph and Telephone (NTT) corporation circuits. This information is then relayed to the National Land Agency, other central ministries and government offices and news agencies.

During the current earthquake NTT circuits got damaged and failed to relay from Kobe marine meteorological observatory to the Osaka district metereological observatory. The circuit was exclusively for transmission of such data. On an average there was a delay of 30-40 minutes in sending the information for various agencies (Metereological Agency news, Jan 29, 1995).

The effects of failure of communication system can be gauged from the activities of Osaka gas company after the earthquake. Osaka gas company divides the 5.7 million connections into eight SUPERBLOCKS and in the event of a major earthquake, the company head office stops gas flow on receiving the communication. The superblocks are further divided into medium blocks and the company employees are trained to manually stop gas supplies. In the current earthquake, company employees suspended the gas in five medium blocks (Sayaka Irie and Toru Nishijima, Jan 23, 1995) but elsewhere the decision to halt the gas supply was made at 11-50 AM, more than six hours after the earthquake. This raises doubts about the effectiveness of measures adopted by gas companies when a powerful quake strikes.

2. People were not prepared

The reason why people were not prepared is that the Kobe area had not seen a big earthquake for the last 70 years. Hanshin area has not been considered as high risk area compared with Tokyo Metropolitan area in Japan. There were no regular drills to keep people ready to face earthquakes. In sesmically risky places of

Japan education of people to face the earthquake is generally an ongoing activity.

3. Shallow earthquake and very close to a highly populated area. The focal depth was approximately 14 Km and contributed to the high level of ground shaking (Haresh Shah, Jan 29,1995).

4. Fire caused major damage

Fires broke in some of the most heavily populated residential areas in Kobe city. These may have been due to gas leak or electricity sparks. Natural gas from ruptured pipe lines was ignited by household fires in collapsed residential structures. The tightly packed old wood frame residential structures fueled the resulting great fire. In addition flammable materials used in light industrial shops in the first floor of residential cum business structures contributed to the ignition, spread and intensity of the fires. Narrow streets in these areas did nothing to stop the spread of flames throughout large sections of residential areas (Haresh shah Jan 29,1995).

5. Active faults are running through the city.

The epicenters of aftershocks (Fig.2) ranged from the southern tip of Awaji Island to areas of Kobe along a line of

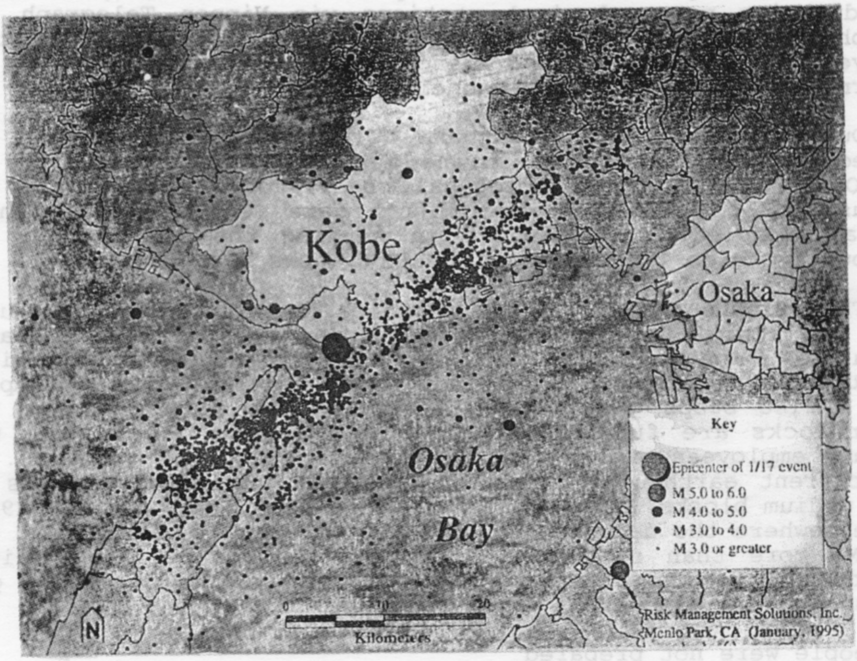


Fig.2 Foreshocks and aftershocks of the Great Hanshin earthquake, Jan 16-23,1995

about 100 Km, the meteorological agency concluded that the quake was caused by a horizontal shift along the fault which runs from Awaji Island through Akashi and Kobe cities to the Rokko mountains. The energy of the recent earthquake was transmitted along the direction of the shift and hence Kobe suffered most of the damage (Meteorological Agency news, Jan 19,1995).

6. Construction of most bridges, houses etc which collapsed had taken place around 30 years back. At that time stringent building/construction codes specifying adequacy in design were not prevailing. In particular, with regard to the residential houses, there is a question mark against the quality of the wood used. Also, Hanshin area has frequently suffered big typhoons. Therefore, roof tiles of these wooden houses were slated much more heavily than other areas to prevent the blowing off of tiles. These heavy roof houses performed badly during the earthquake.

7. Liquefaction

Liquefaction occurs in areas with poor soil and a high water table. When the ground shakes, the pore water pressure builds and water rises, causing the soil to lose its load bearing capacity. This type of ground failure was widespread in Kobe. Areas along the bay, near the line of fault rupture have some of the poorest soils in the area. In addition both Port and Rokko islands, on which many critical port facilities are located are artificial islands made of reclaimed land.

Liquefaction played a significant role in widespread damage that occured to the port facilities, surface streets, bridge abutments, under ground facilities, public parks and to commercial/industrial areas adjacent to the bay (Hresh Shah, Jan 29,1995).

EARTHQUAKE DAMAGE OBSERVATIONS

1. Failure of residential/office buildings

These failures can be divided into six categories.

(i) In Kobe a large number of buildings were structures with first floor used for commercial operations ranging from retail or restaurants to light industrial use and upper floors used for living space. However this construction creates a soft first storey (Hresh Shah, Jan 29, 1995). The residential building shown in Fig.3, though not completely collapsed has been severely damaged. This building may have failed because of weak first floor.

(ii) Some buildings failed due to a heavy roof. Heavy roofs were used in Kobe city to avoid wind problems, as explained earlier. Fig.4 shows a typical residential building which failed due to a heavy roof.

Fig.3 Typical wooden house failure

Fig.4 House failure due to heavy roof

(iii) Some buildings got damaged due to the failure of intermediate storeys. They were of medium height with about 10 stories. Damage was concentrated around 4th to 6th storey (INCEDE news letter, Jan, 1995). The reason could be high ground acceleration, reduced density of walls in a particular floor due to office space use and higher mode of structural vibration. Some experts suspect that this type of damage may take place as a result of clash effects of vertical shock waves. Fig.5 shows failure of middle floor of an office building (Haresh Shah, Jan 29,1995).

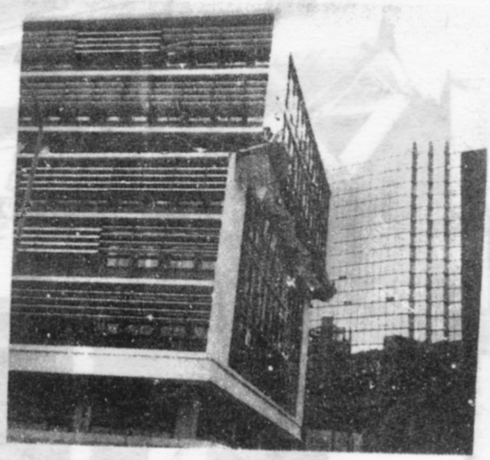


Fig.5 Failure of office building due to discontinuity in fifth floor

Fig.6 Failure of steel frame structure due to large ductile deformation

(iv) One type of steel structure failure was because of large ductile deformation due to severe ground motion and is shown in Fig.6. Another type of failure was due to shearing of bolts at joints of concrete and steel column. This failure may be due to large ground shaking or due to degrading of bolts. This type of failure is shown in Fig 7.

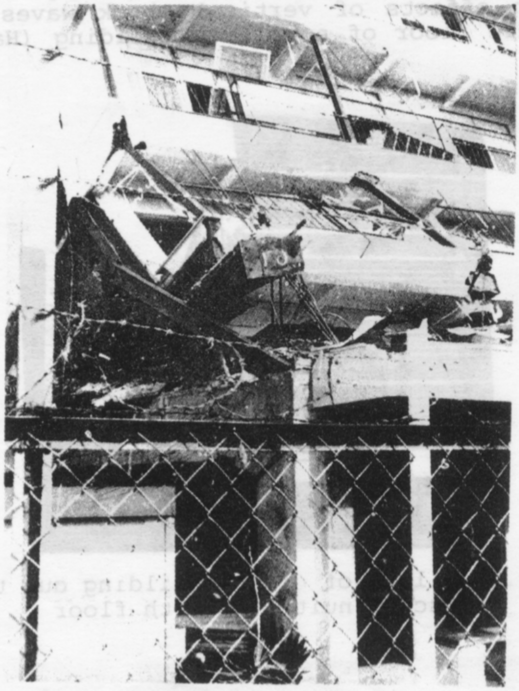
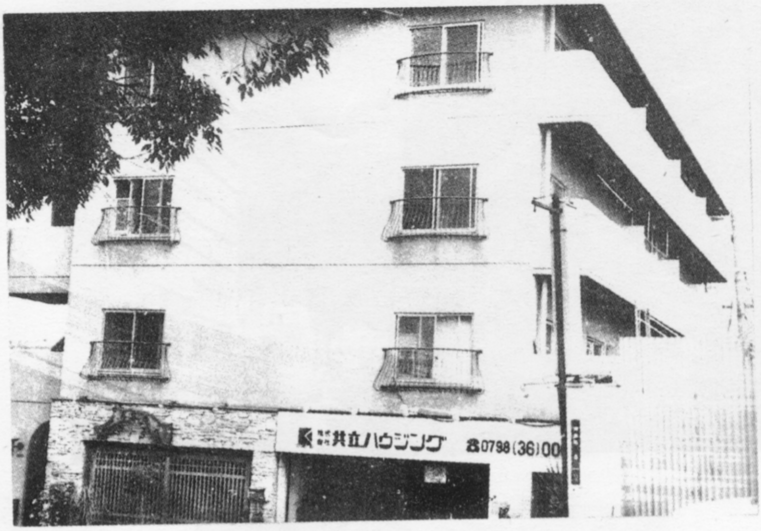


Fig.7 Failure of joint bolt of steel column and concrete column

(v) Some buildings collapsed due to failure of columns at the ground/parking area. This type of damage is shown in Fig.8. The building shown had moved about 60 cm downwards. Several vehicles parked at ground level were damaged. Fortunately, no loss of life occurred because the super structure was safe. The reasons for this type of failure appear to be due to a heavy, strong floor, strong vertical acceleration and uneven settlement of columns due to liquefaction.

(vi) Some buildings failed due to asymmetry as shown in Fig.9. This might have failed due to strong ground acceleration and to some extent torsional ground motion. Torsional motion and rocking movement of monument is shown in Fig.10.



(a)

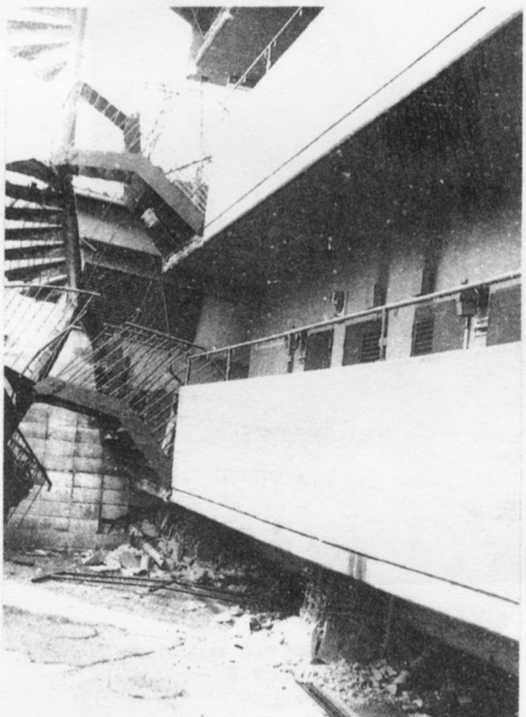
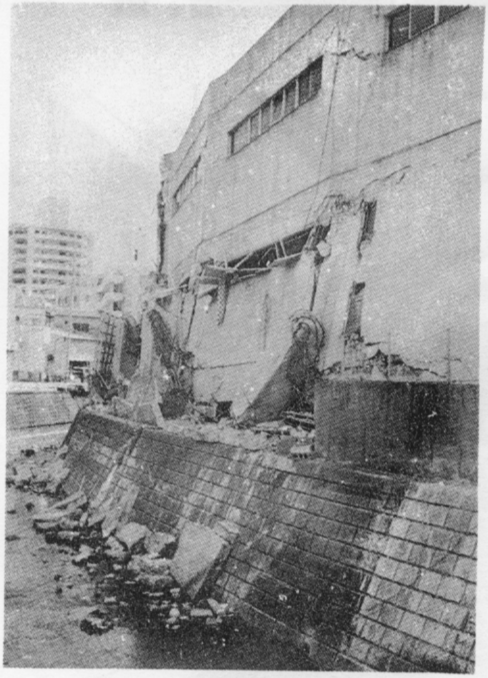


Fig.8 Failure of building due to weak columns
(a) super structure (b) failure of columns

(a)



(b)

Fig.9 Failure of asymmetric building
(a) view.1 (b) view.2

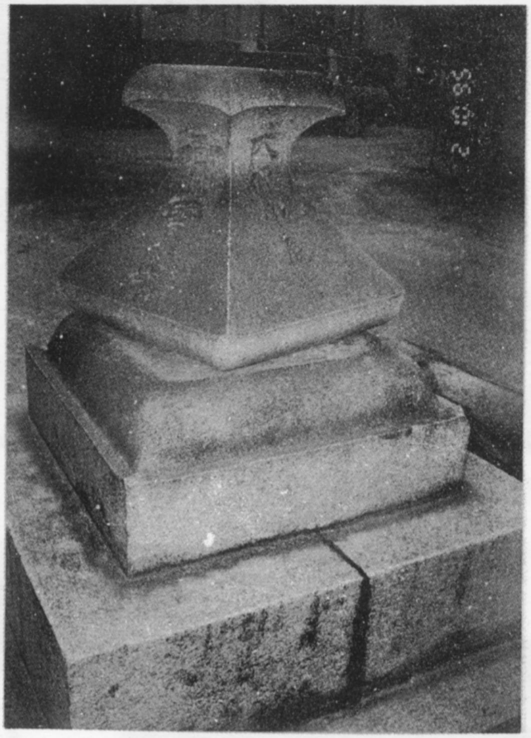


Fig.10 Rocking movement of a typical monument

2. **Failure of elevated highways/railways**

In Japan due to space shortage in cities like Kobe, Tokyo etc, railway tracks and roads were laid on elevated bridges. Generally two types of bridges are observed, one uses concrete columns and steel girders and the other uses concrete columns and concrete girders integrated into each other.

One of the surprising failures due to the earthquake was the collapse of Hanshin expressway. This was the main link between Osaka and Kobe cities. This portion of the expressway in Kobe was built about 30 years back. It is a mixture of two types of construction explained above. There were different modes of damage of the expressway. In the first type steel girders moved and slided (Fig.11) and in other places it fell down (Fig.12). There was local damage of girders at supporting points. In this situation concrete columns were generally safe. In another type the girder transmitted total load to the column with out falling/sliding and the resultant column failure is shown in Fig.12.

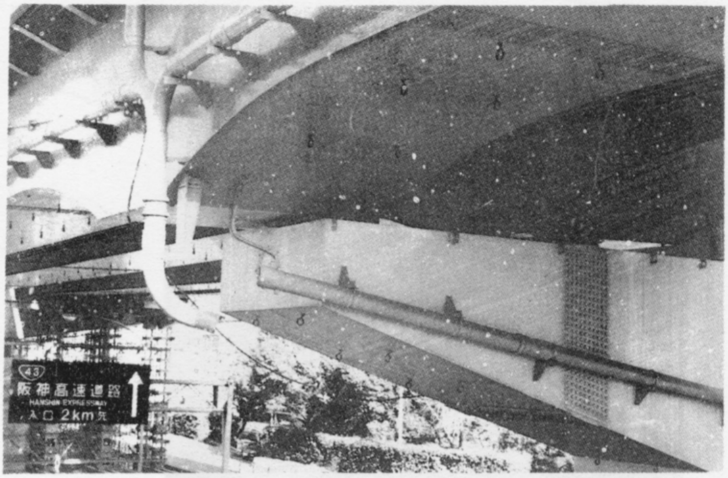


Fig.11 Slided girder of Hanshin highway

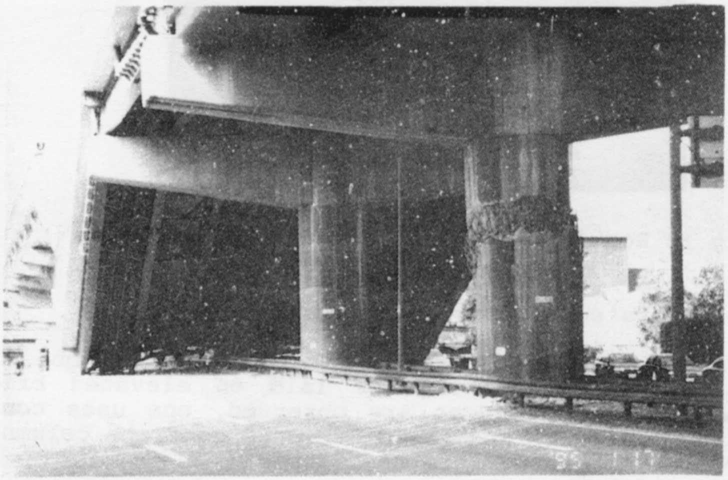


Fig.12 Collapsed bridge girder and typical column failure of Hanshin highway

In Hagishinada ward of Kobe city about 500 m span portion of the expressway toppled down as shown in Fig.13. In another place columns were damaged badly as shown in Fig.14 (INCEDE news letter, Jan, 1995). This may be due to weak columns and strong girders, strong ground shaking or uneven settlement of columns due to liquefaction.

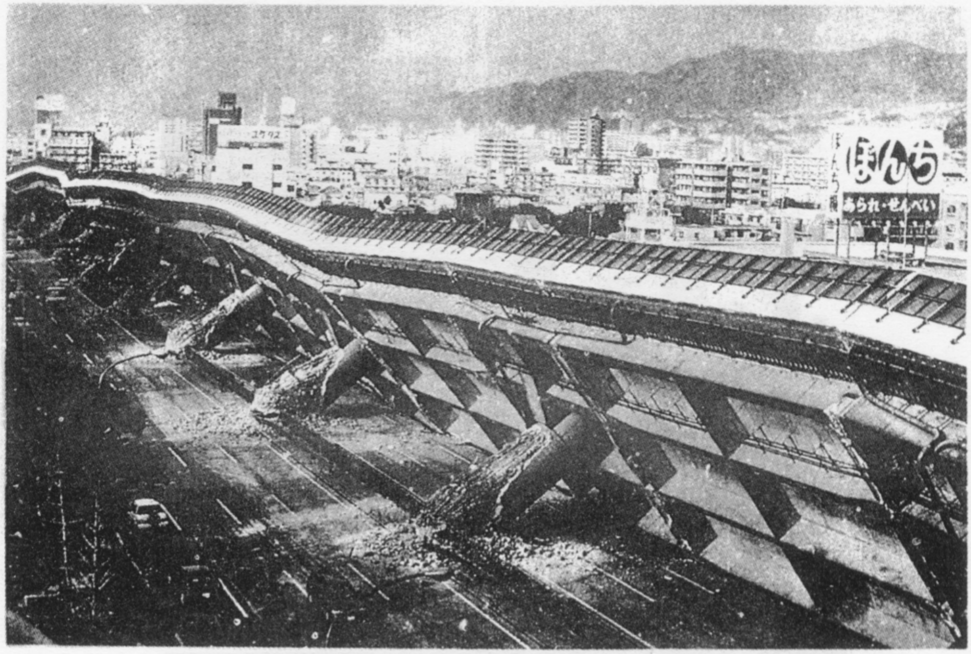


Fig.13 Toppled Hanshin highway (Kobe city, Higashinada ward)

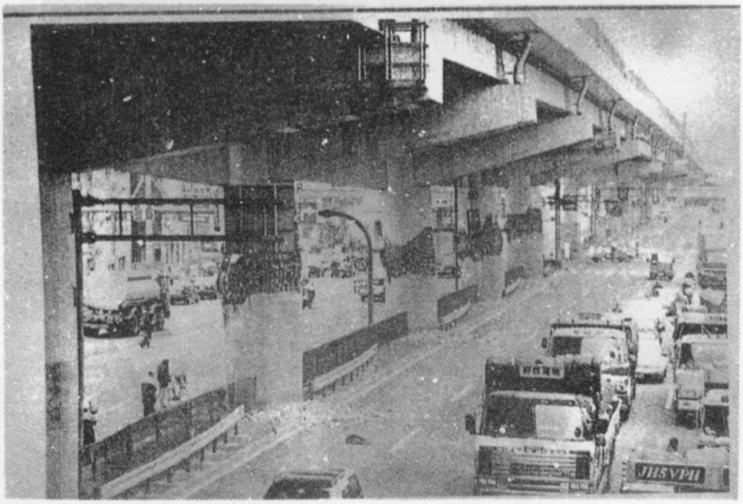
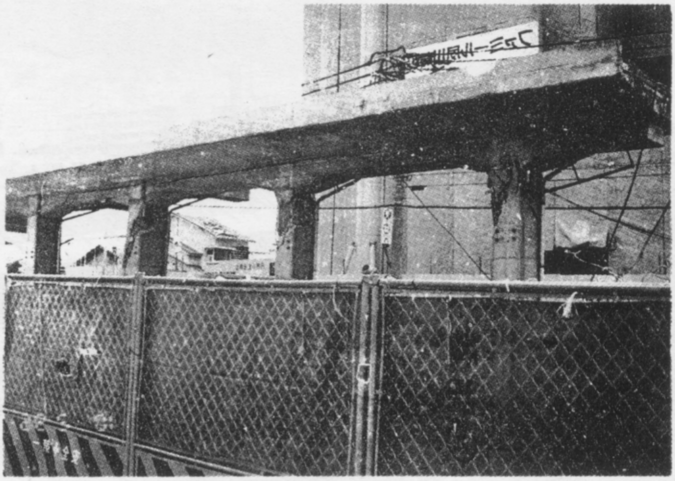
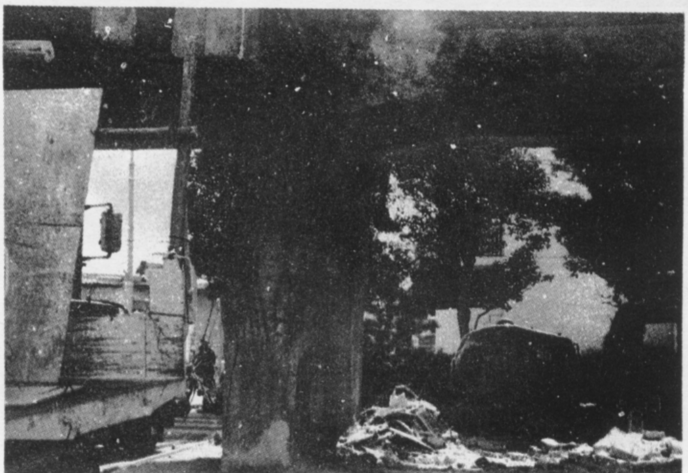


Fig.14 Failure of columns of highway due to compression

Similar types of failures were observed in the case of elevated railway lines including the famous Shinkansen line, shown in Fig.15.



(a)



(b)

Fig.15 Failure of columns in Hankyu-Kobe railway line
(a) shear failure (b) compression failure

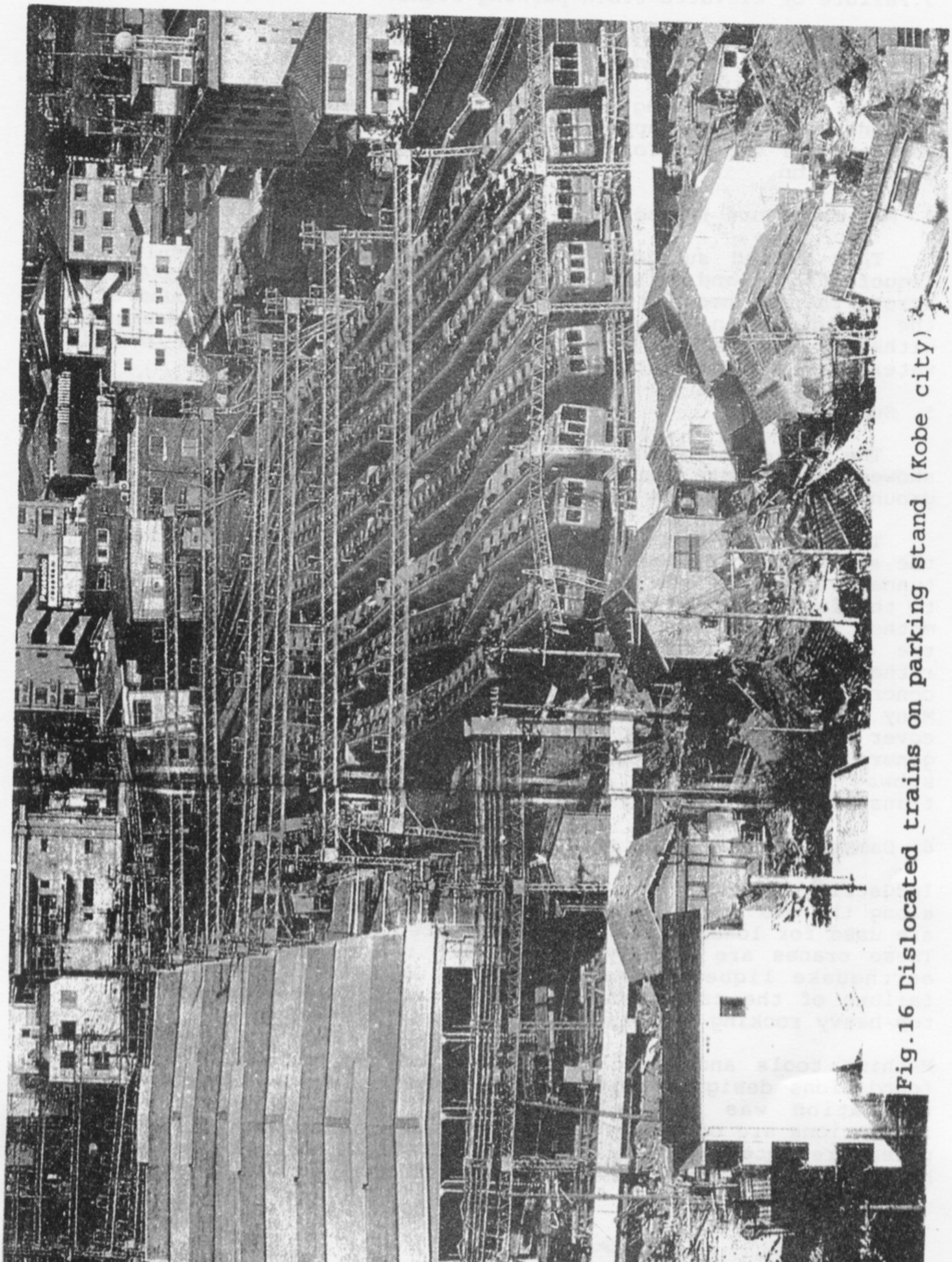


Fig.16 Dislocated trains on parking stand (Kobe city)

3. Failure of elevated train parking stand.

To save space, train parking area was provided on elevated platforms. The area under the platform was provided for shops. Dislocated trains in the parking area are shown in Fig.16. Failure of the parking stand columns are shown in Fig.17. The reasons for failure appear to be a strong floor weak column, asymmetry of the platform and uneven settlement of columns due to liquefaction.

4. Man made Port island

This island subsidised as much as 60 cm as a result of liquefaction. Land subsidence which ranged in depth from 5-60 cm across the 440 hectare island was found on all roads, around all the buildings in the island. Buildings on the island designed to withstand liquefaction sustained no damage. However, Under ground water, gas and electricity lines were damaged.

5. Subway damage

The survey of Transport Ministry's railway transport bureau showed that damage was due to difference in the firmness of the ground above and below of the tunnels.

The bureau also suspects that the strong vertical jolt due to the earthquake damaged the supports because soil on top of the tunnel was not of the same firmness as that below. This is due to the fact that the tunnels are built mostly using cut-and-cover method. In this, tunnels were built by digging large trenches in the ground and then covering over the finished subway tubes, rather than horizontally drilling passage ways. Once a section of concrete subway is finished, it is covered with earth and sand. Many of the 36 subways of Japan have been built by the cut-and-cover method. Horizontal tunnelling, known as shield method, is generally used in residential districts and on stretches where a subway is bored below a river (Transport Ministry's railway transport bureau news, Jan 28,1995).

6. Damage to industrial structures

Industrial cranes: In Japan many huge industries are located along the sea coast and equipped with large sized cranes. These are used for loading and unloading material to and from ships. These cranes are usually located on rails. Due to the recent earthquake liquefaction displaced the rails and resulted in failure of the cranes. Also several cranes were damaged due to top-heavy rocking vibration of the jib of cranes.

Machine tools and foundations: Most of the machine tools and foundations designed to withstand liquefaction were safe. Pile foundation was adopted to support machine tools. Pile foundations are of two types, in one case foundation base and the piles are integrated into each other and in another foundation base is laid on the piles. The piles used in industry were

Fig.17 Failure of columns of train parking stand due to compression (Kobe city)

driven into the ground to a depth of about 30 meters. In some industries type one foundations were used and in such situations failures at the foundation bolts were noticed. In another type of industry, tilting of foundation along with the machine was observed. In this case it is suspected that the piles and the foundation base were not integrated to each other.

Failure of industrial pipelines: Pipe line supports failed causing large ductile deformation in the pipe lines (Fig.18).

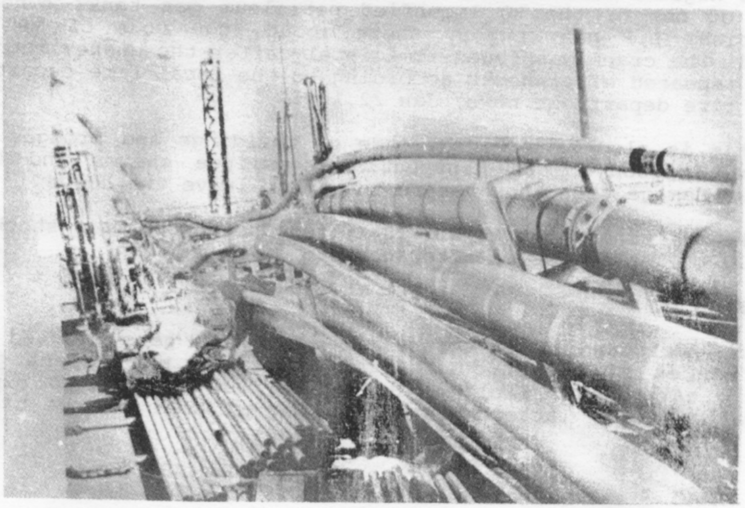


Fig.18 Large ductile deformation of pipes due to failure of supports

This large deformation did not interrupt their function. Brittle pipe joints had failed as shown in Fig.19. In another kind of system pipes connecting tanks failed because of uneven settlement of the ground below the tank and below the pipe supports.

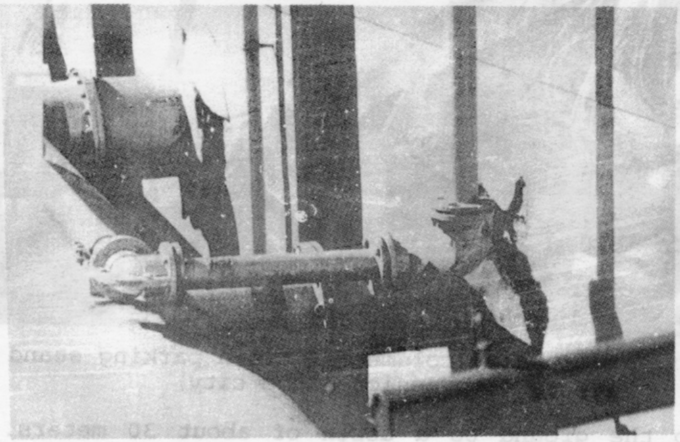


Fig.19 Brittle failure of pipe bends

EFFECTS OF AFTERSHOCKS

Between 935 to 1000 aftershocks rocked Kobe and adjacent areas as of 5 PM 21,Jan 1995. Of these100 were strong enough to be felt.

In Higashi-Nada ward of Kobe, inspectors found a crack in a valve of one of the 30 liquefied petroleum gas tanks owned by Mitsubishi L.P gas company where about 2000 tons of LPG was stored. The crack was found immediately after the quake, but grew after repeated aftershocks according to the local fire department (Kobe fire department news, Jan 22,1995).

This is also true in the case of buildings and bridges. Due to this reason if the inspection committee checks and finds similar damage then they ask residents to leave the house.

The building shown in Fig.20 tilted due to the main shock and totally collapsed due to aftershocks.

REMARKS

An understanding of structural behavior gets updated with experiences of disastrous earthquakes like the recent great Hanshin earthquake. Pooling the experiences of various experts generally yields acceptable methodologies which can be brought into the codes . Based on these methodologies/procedures a kind of retrofitting should be suggested for various structures built long ago and for new constructions. During Hanshin earthquake the structures built to current standards were safe. Therefore updated codal methodologies/procedures can eliminate, to a great extent, the great damage and loss of life due to earthquakes.

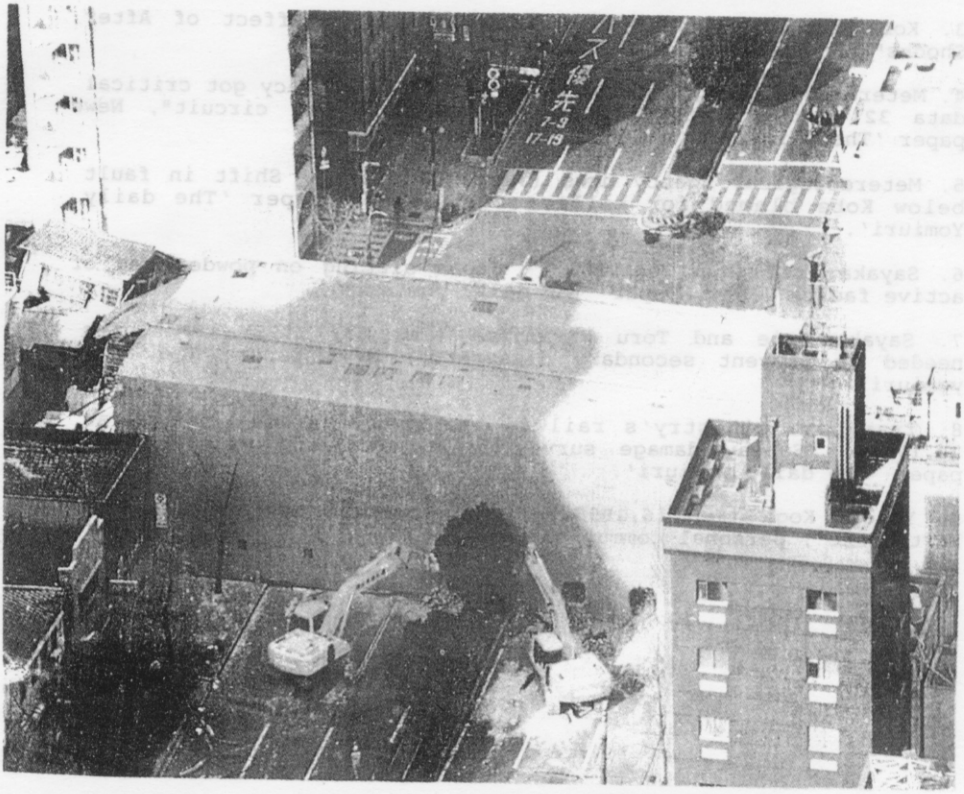


Fig.20 Collapsed building due to aftershocks

ACKNOWLEDGEMENTS

We would like to acknowledge all the authors/publishers of references given in this paper for making the information available to us. Also thanks are due to Mr. T.Mitsumori, Mr. T.Watanabe of Mechanical Engineering Department, Tokyo Metropolitan University, Tokyo, Japan for their help in collecting some of the information presented in this paper.

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