THE EXAMINATION REPORT ON THE 1995 HYOUGO-KEN NANBU EARTHQUAKE

A. Kodama
Chichibuonoda Co. Ltd.
Chiba, Japan

SUMMARY

An earthquake with the magnitude 7.2 hit the southern part of Hyogo prefecture in Japan at 5:46 a.m. on January 17 ,1995. Its epicenter was located at the northern part of Awaji Island. The earthquake wreaked the worst damages since the 1923 Great Kanto Earthquake. The earthquake hit modern cities directly. In Kobe city near the focus, quite a lot of structures were destroyed and fires occurred, causing many casualties. The traffic was held up all over by collapsed spans of bridges and roads, and life environment was also destroyed.
In April, the Association of Interlocking Blocks Pavement Technique undertook to examine the state of the artificial island and reclaimed land trying to grasp damages and repairs of land and road structures related mainly to interlocking blocks. This report sums up the examination.

Outline of The 1995 Hyougo-ken Nanbu Earthquake

The 1995 Hyogoken-Nanbu Earthquake heavily damaged the southern part of Hyogo-ken. The earthquake hit Kobe at 5:46 a.m. on January 17.

The Japan Meteorological Agency(JMA) announced that the epicenter was northern part of Awaji-shima Island (N34° 36' E135° 0'), that the depth was 20 kilometers and that the magnitude was 7.2. The earthquake was felt extensively. The seismic intensity announced by JMA is shown in Fig.1.
The seismic intensity of Kobe and Sumoto was designated as 6, and it was 5 for Kyoto, Hikone and Toyooka.

However, according to the examination by JMA, the seismic intensity of Kobe city, Ashiya city, Nishino-miya city, a part of Takarazuka city and northern part of Awaji-shima Island was later altered to 7.

The earthquake was characteristic in the point that it had not only horizontal quakes but also bigger longitudinal quakes than usual.

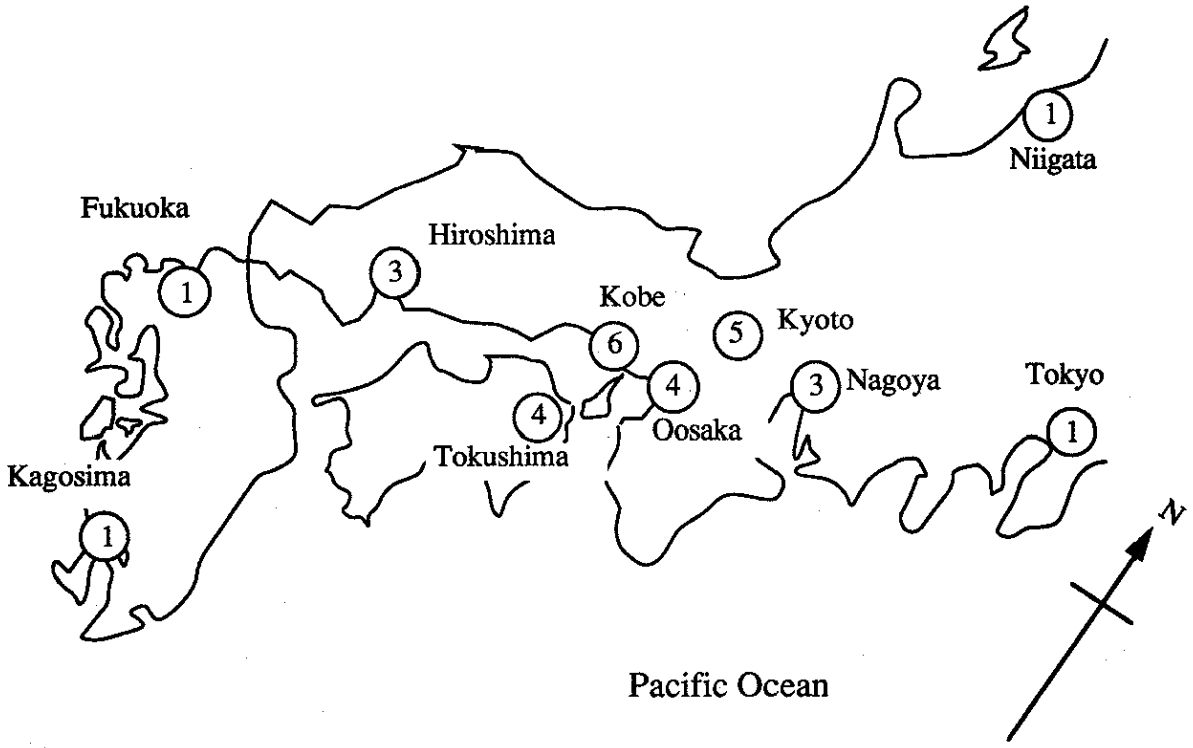


Fig.1 The seismic intensity

The damages at each district

(1) Port Island

Port Island, an artificial island, was reclaimed with soil having widely grading particle size and it is not supposed to liquefy so easily. However, the whole island was attacked by tremendous liquefaction and the maximum sinking of the ground reached approximately 60cm.

Around buildings, 50-60cm gaps were found between the level of pavement on the base concrete of the buildings and the level of pavement there around. As far as interlocking block pavement around the gaps is concerned, it was observed that many straight type blocks dropped out and moved but waving type blocks remained hanging by the interlocking effect or in the state of sloping without any cracks and chip-offs.(Photo-1) The center of the pavement looked almost undamaged because the entire ground is sunk.

The natural stone faced concrete slubs(1200×1200×150mm) with open joints were inclined in the same manner at the gaps under the pavement.(Photo-2) Some joints between slubs opened over 20cm where slubs moved horizontally, but damages, cracks, chip-offs, and peel-offs were not found on the natural stone surface.

On the coast of Port Island, many revetments moved to the seaside,(Photo-3) and apron sank over 1m in the heavily damaged place.(Photo-4) Most of revetments were reclaimed behind caissons, so caissons were pushed to the seaside due to liquefaction. In the park on the coast, cracks and sinking due to moving of revetments were observed, but where there are some underground structures like manholes did not sank heavily.(Photo-5) Wherever the ground cracked or sank, interlocking blocks also sank together with ground or were thrown around, (Photo-6) but wherever the ground did not crack or sink, joints between blocks got only slightly widened due to block movement and cracks or chip-offs of blocks were found little. The similar damage to interlocking block pavement was observed with brick pavement since it used dry method without mortar. In regard to tile pavement, they laid tiles on the mortar layer cast on 10cm thick concrete slubs.(Photo-7) The slubs have a flexible joint at the interval of about 10m. At the joints, gaps between slubs and horizontal movement took place due to cracks or peel-off were found near the joints but not in the center of the slub.

(2) Meriken Park

In the Meriken Park, damages of sinking, cracks, gaps and liquefaction were observed.(Photo-8) It was observed that the ground sank about 60cm, but interlocking blocks pavement kept the level.(Photo-9) The revetments in the Meriken Park were destroyed and sunk due to liquefaction, too.(Photo-10) Under these circumstances, we observed a lot of places where the strong interlocking effect maintained the state of interlocking block pavement hanging down from the revetments. (Photo-11)

In regard to pavement using 30mm thick natural stone, they laid the natural stone on concrete slubs with mortar. Near the flexible joint set at the interval of 10m on the concrete slubs, widening of the joint, cracks or chip-offs of the natural stone were found (Photo-12) but not in the center at all. At the Meriken Park Pier, sinking and peel-off from mortar took place to 45mm thick brick pavement using mortar. Takahama passenger terminal in Kobe Bay was built by driving piles in the ground and although slight partial local sinking and sliding of the joints were observed, damages were less than revetments with caissons.

(3) Nagata-ku(Kobe-shi)

Nagata-ku whose seismic intensity was 6 was the area in Kobe City that a lot of fires occurred. In sidewalks, damages that border blocks between a sidewalk and a roadway or pit for plants were thrown down to the roadway side were often observed.(Photo-13) In result,

interlocking blocks were pushed up or cracked. In asphalt pavement, protuberance in the center and cracks occurred.

(4) Ashiya City

In Ashiya City whose Seismic intensity was 7, structures were destroyed heavily, too. Ashiya station, blocks(100×100×80mm)were used for roadway, and the blocks sank on the straight. So it is presumed that there may be some underground structures or sinking of the ground took place around the straight line. Border blocks between sidewalk and roadway were thrown down to roadway side, and blocks on sidewalk littered.

There were some places where 30mm thick waving blocks were paved on the drain and 60mm thick waving blocks around it but they scattered all over and some 30mm thick blocks showed cracking.

(5) Nishinomiya City

In Nishinomiya City whose Seismic intensity was 7, heavy and light damages of structures were mixed. In front of Nishinomiya City Office, straight type blocks were paved on the sidewalk, and waving type blocks were paved on roadway. Whole pavement sank 20～40cm, then gaps occurred between structures level and on the sidewalk. But, crack or chipped off of blocks were not found. At the joint of a bridge, gaps occurred and cracks of blocks were observed.(Photo-14)

Difference of the damages by shape and size of blocks and laying pattern

Heavily damaged interlocking block pavement is attributable to the state of the ground like cracking or sinking of the ground and not to the shape ,size or laying pattern of blocks. But, wherever gaps occurred, pavement using waving type blocks was sloped gently, and end of blocks did not stand out. However, using straight type blokes, if gaps were small, then pavement was sloped and end of blocks stood out.(Photo-15) And if gaps were large, then blocks was off and littered with the blocks. The difference of damage due to size of blocks and pattern of pavement was not found.

The Damages of Other Pavement Materials

As tile and natural stone pavement using mortar could not follow the seismic waves, a lot of cracks occurred not only around the joint but to the material itself.(Photo-16) There were

quite a few places where the pavers were laid on concrete slubs using mortar and cracks and peel-offs were often observed around the flexible joints set at the interval of 10m on the slub, but not in the center of the slub. As asphalt is paved in succession, it could not follow the seismic waves and cracks were found all over and some protuberance was seen in the center of pavement.(Photo-17)

Repairs

When the examination was undertaken, repairs were beginning in places. Wherever the gaps stemming from sinking around buildings were small, they sloped it with asphalt and where they were big, steps were built in some cases. (Photo-18,19) The roadway sunk due to liquefaction was graveled or asphalt was laid, on interlocking blocks. Full-scale repairs were carried on in some places. Scattered blocks were cleaned and reused and new blocks were used only for replacements of broken blocks and for cut blocks.

Conclusion

The circumstances commonly observed through the examination are as follows;

(1) Wherever land was destroyed suffered from heavy damages such as land subsidence and cracks blocking the traffic regardless the pavers.

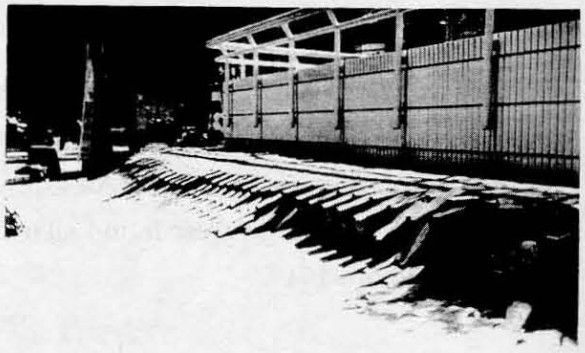
(2) Pavement with joints bound by mortar like tiles and flag stones was crushed not only in the joints but also to the materials.

(3) The interlocking block pavement did not get serious damages as it could follow the quake due to its non-continuative structure.

(4) Interlocking block pavement did not crack or chip-off so badly that the blocks can be reused for repairing.



Straight Type Blocks



Waving Type Blocks

Photo-1 Gap around Structures



Photo-2 Damage of Precast Concrete Slubs

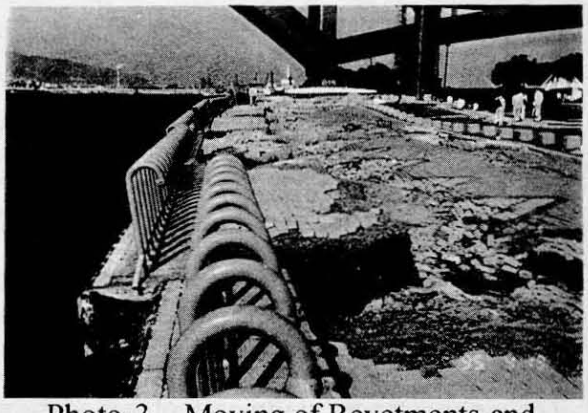


Photo-3 Moving of Revetments and Sinking of the Ground



Photo-4 Sinking of Apron



Photo-5 Sinking around Underground Structures



Photo-6 Cracks of the Ground

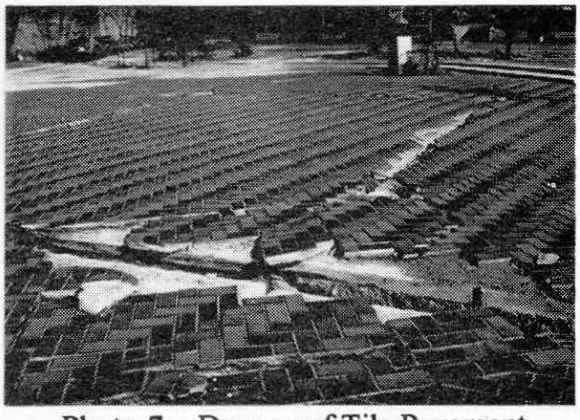


Photo-7 Damage of Tile Pavement

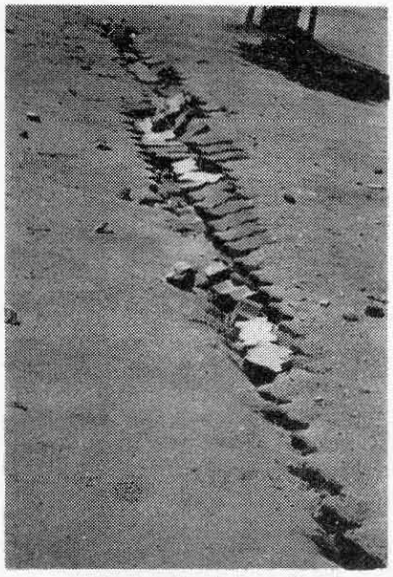


Photo-8 Liquefaction



Photo-9 Sinking of the Ground

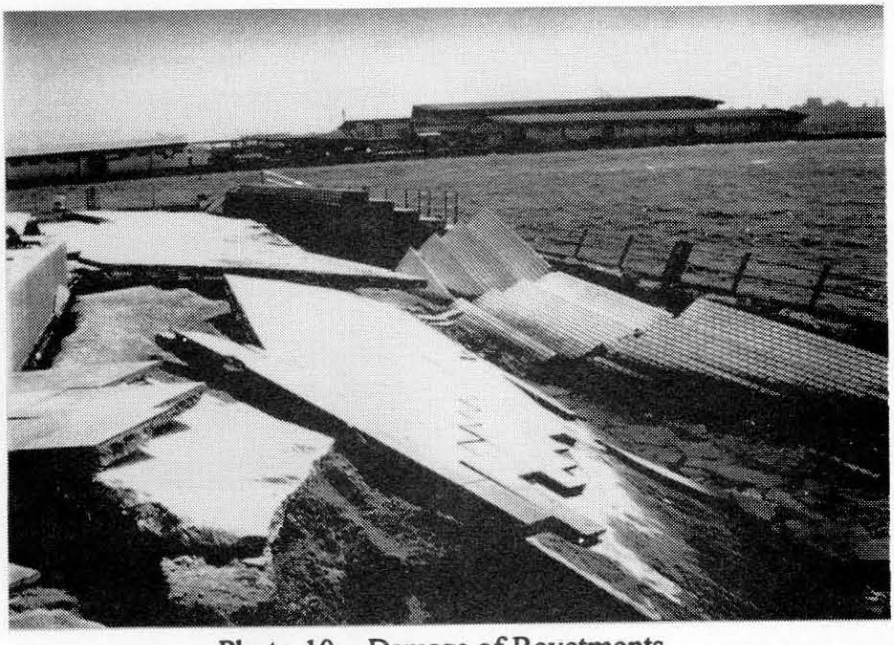


Photo-10 Damage of Revetments

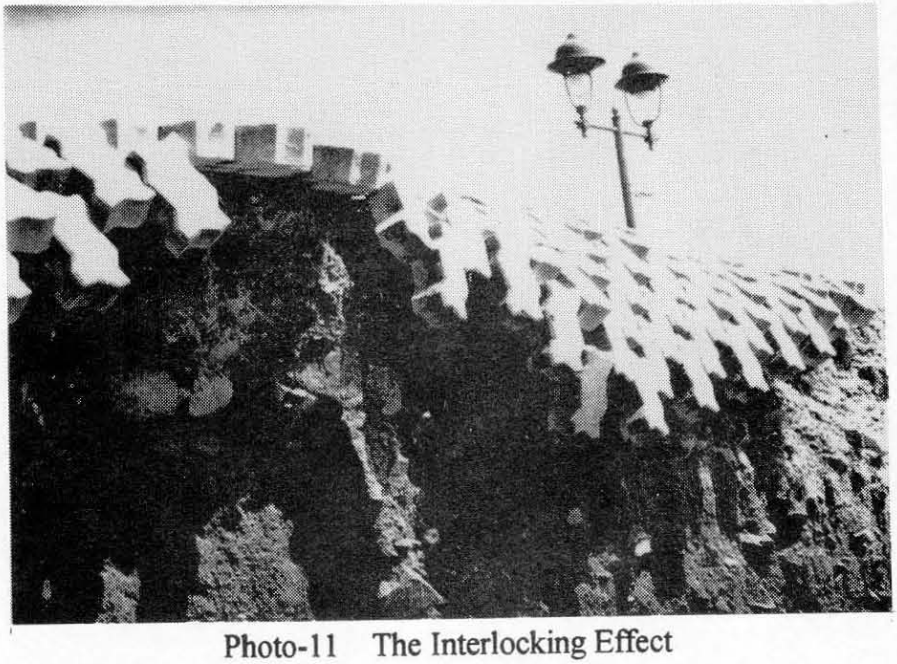


Photo-11 The Interlocking Effect

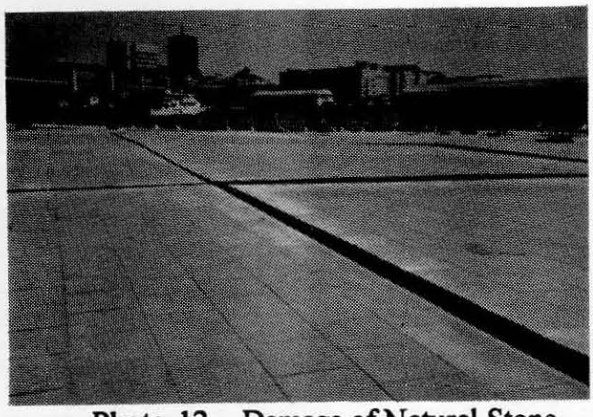


Photo-12 Damage of Natural Stone Faced Precast Concrete Slubs

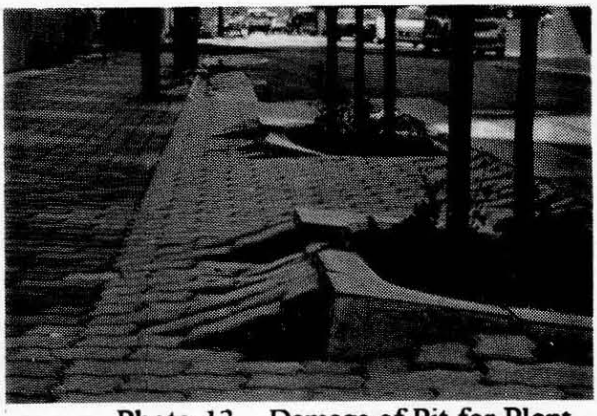


Photo-13 Damage of Pit for Plant

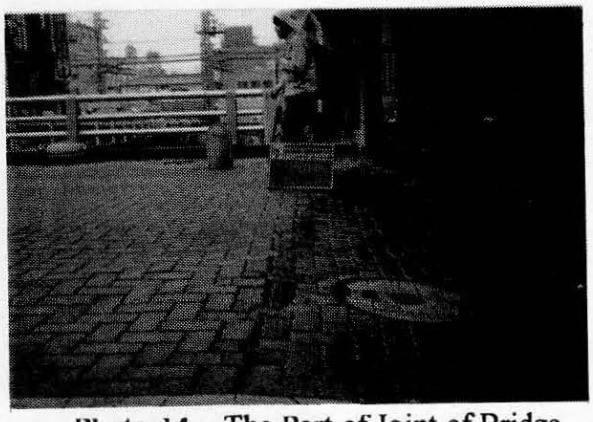


Photo-14 The Part of Joint of Bridge

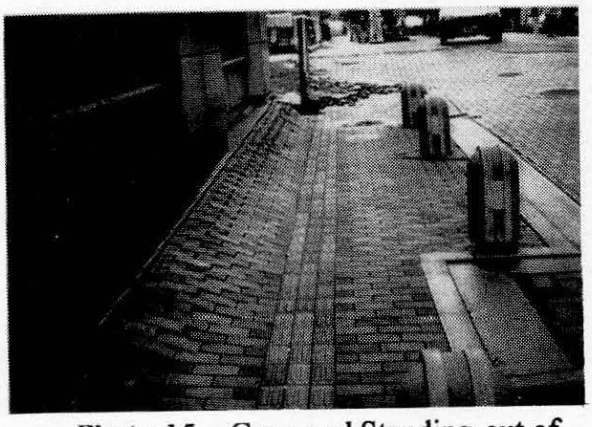


Photo-15 Gaps and Standing-out of the End of Blocks



Photo-16 Damage of Natural Stone Pavement



Photo-17 Damage of Asphalt Pavement

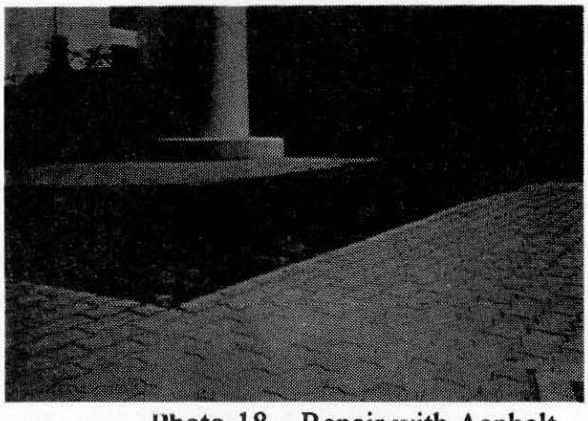


Photo-18 Repair with Asphalt

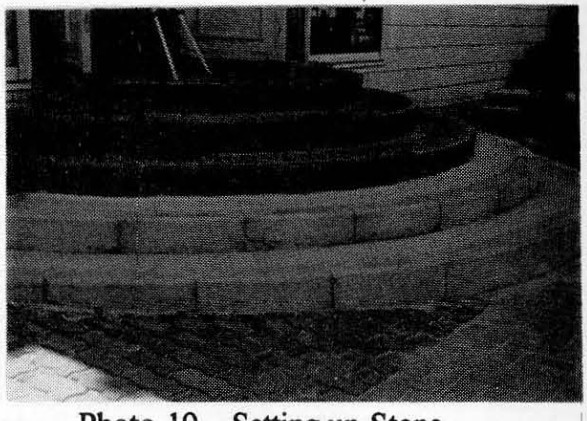


Photo-19 Setting up Steps