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DISTRIBUTION OF STRUCTURAL DAMAGE AROUND THE MUKOGAWA RIVER BASIN SUFFERED FROM THE GREAT HANSHIN (HYOGOKEN NANBU) EARTHQUAKE OF JANUARY 17, 1995

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ABSTRACT

A great earthquake suddenly and severely hit the Hanshin area as well as the north of the Awajishima Island early morning on January 17, 1995. According to the violent occurrence, many human lives, building structures and lifelines suffered fatal damage from the seismic motions. The present study is concerned to evaluate the correlation between the vital disaster and the site conditions through the distributions of the damaged structures and the microtremor measurements in consideration for the topographic irregularities around the Mukogawa river basin and its neighborhood, the eastern part of the stricken area.

KEYWORDS

the Great Hanshin (Hyogoken Nanbu) earthquake; the Mukogawa river basin; the Itami river terrace; structural damage; microtremor measurements.

INTRODUCTION

For the last few decades, the Hanshin (Osaka-Kobe) region little suffered such heavy breakage as to paralyze urban lives and facilities from earthquake events. In face of this Hanshin earthquake, the elevated highways and railways were mowed down accompanied with the shearing destroy on the tips of their columns, quite a few office buildings were cracked on the feet or the middle floor levels, many wooden houses with heavy roofs were completely crashed out in the large area. Additionally, the big fires broke out incidental to the quake and engulfed the extensive quarters of Kobe City. Around the epicenter, the vertical motions were vividly recorded on the ground surface and in the structural constructions, equal or moreover to the lateral components. The most severe damage is restrictively distributed on the narrow corridors passing through the northern portion of the Awajishima Island and the continuous string of cities in the Hanshin region to the border of the Osaka prefecture, the tail of which is warped in a strange shape along the foot line of the mountains rising to the north. The corridors of the expansible damage are not always consistent with the underground trail of the seismic faults running linearly from the epicenter. The present investigation is related to the site amplification effects on the structural damage across and around the Mukogawa riversides where the suffering corridors are winding and the soil strata are composed in the topographic irregularities. To discuss the reasons the suffered areas are

partially distributed, the observed data are prepared for the demolished constructions which are researched immediately after the main shock, and furthermore the spectral results are stocked through the microtremor measurement carried out on the ground surface around there.

CHARACTERISTICS OF THE EARTHQUAKE EVENT

The several kinds of great earthquakes striking the Japanese Islands are classified in two types from a macroscopic point of view, the oceanic one caused by the subduction of the Pacific plate or the Philippine sea plate and the other associated with the tectonic compression brought about inside the plates. The present Hanshin event belongs to the tectonic inland type and broke out at 5:46 January 17, 1995 followed by the violent motions during about 11seconds. The seismic strength is publicly released to be the Richter Magnitude of 7.2, and the epicenter is located at 34°36.4' North latitude, 135°2.67' East longitude and about 14.3kilometers underneath, in correspondence with the north end of the Awajishima Island or its neighbor. The source dislocation of the main shock is expanded in a slender zone oriented to the northeast, which is simulated with the successive aftershocks distributed linearly. The aftershock cluster is interrupted by the blank spot left under the Akashi Straits between the northern cape of the Awajishima Island and its opposite shore, the singular appearance of which is explained in relation to so perfect the destruction due to the main shock as to lose the potential generating the aftershocks. The source expansion is stalled on the west-east trending Arima-Takatsuki fault line confronted still against the present shocks. The standstill manner of the tectonic line is supported on the geologic signs of the soil formation.

TOPOGRAPHIC CONDITIONS AROUND THE MUKOGAWA RIVER BASIN

Among the regions suffered from the Hanshin earthquake, the Mukogawa river basin and its neighborhood are broadly extended and fairly complicated in the topographic arrangement, as shown in Fig.1, in comparison with the regularities of the slender Kobe area caught between the lifting Rokko Mountains to the north and the Osaka bay shore to the south. While developing the riverside deposits, the Mukogawa River streams southward from the east-west extended Hokusetsu Mountains to the Osaka Bay. The west bank is close to the alluvial fans growing firm along the east end of the Rokko Mountains standing sharply. The opposite riverside is gently continuous to the Itami river terrace, which is a low plain of hardened sand and gravel alluvium and lies in the large expanse spread northward to the foot of the Hokusetsu Mountains and falling down southward without the terrace edge under the coastal formation along the Osaka Bay shore. Beyond the terrace alluvium to the east, the Inagawa River also flows southward parallel to the Mukogawa stream, in company with the riverside deposits joined to the Osaka Plain to the east. The Arima-Takatsuki tectonic line runs east-west along the southern foot of the Hokusetsu Mountains with confronting the source advance of the Hanshin earthquake as mentioned ahead.

DISTRIBUTIONS OF STRUCTURAL DAMAGE

The most severe damage of structures is concentrated within the narrow corridors and extended straight with a little inclination to the north in the coastal alluvium of the west-east stretching Kobe and Ashiya districts along the Osaka bay shore. They are, however, swinging and fragmentary along the Rokko and Hokusetsu Mountains from the cities of Nishinomiya, Takarazuka and its east to the border of the Osaka prefecture, across the alluvial fans stuck on the mountainside as well as the soft deposits of the Mukogawa river basin. In the eastern area stricken by the quake, the swinging corridors are generally divided into three parts. The first, which trends from

west-southwest to east-northeast, passes through the southern portions of Ashiya and Nishinomiya cities and traverses the soft alluvial deposits in the lower reaches of the Mukogawa River. It is interrupted suddenly by the Itami river terrace and relatively under the little damage because these soils are much stiffer than the riverside alluvium. However, the damage associated with the first corridor surfaces again to the east, on the alluvial deposits of the Inagawa River. The second, which runs south-to-north and slightly to the east of the Rokko Mountains, starts from the downtown area of Nishinomiya City by mingling with the first corridor to the riverside zone of Takarazuka City. It is worthy of note that the severe damage is fragmentarily distributed not only on the soft deposits of the Mukogawa River but on the alluvial fans growing firmly along the Rokko mountainsides. While the third stretches west-to-east from the cross point with the second in Takarazuka City toward Kawanishi City, parallel to the southern face of the Arima-Takatsuki tectonic line or the southern foot-line of the Hokusetsu Mountains along which the Nakayama Old Highway is extended. The outward look of damaged structures is researched in the west-east section B-B' across the east end of the rocky Rokko Mountains, the mountainside fan alluvium, the soft deposits in the midstream of the Mukogawa River and the stiffened Itami terrace, as well as in the southwest-northeast section A-A' across the downtown area of Takarazuka City and the upper reaches of the Mukogawa River. As given in Fig.2(B), the severe damage is distributed on the mountainside fan alluviums in the same amount as on the riverside deposits around the western side of the middle reaches. Across the stream to the east, the damage distributions extremely decrease over the riverside formations and almost diminish when arriving at the Itami terrace. On the contrary to the condensed breakage around the westside midstream, the wrecked structures are crowded on the opposite riverbank in the upper reaches because of the winding stretches of the suffering corridors along the foot of the mountains, which is exhibited in Fig.2(A).

MICROTREMOR MEASUREMENTS

To research the spectral variations across the middle reaches of the Mukogawa river basin and its neighbor ground, the microtremor measurements were carried out during the calm nights of early August, a half year late the seismic hazard. The measuring instruments are prepared in two sets consisting of three velocity-sensitive transducers with the natural period of 1second respectively along the lateral and vertical directions, the portable amplifiers and the portable computers added in the A/D converters to digitalize the analog data in a 12-bits at the rate of 100Hz. The microscopic ground motions are caught on the twelve points at about 500meter intervals across the midstream of the Mukogawa River. The observation points are numbered from the west to the east across the midstream section and plotted in Fig.1. The measurement period is settled in 60seconds at every point and four or six segments during 20.48seconds are extracted from the recorded data without singular noises. The spectral amplitudes are analyzed through smoothing 20 times under the Hanning windows as well as averaging all the segments in the arithmetical manner, and the lateral amplitudes are especially regulated in the geometric average of the orthogonal components, as shown in Fig.3 including the lateral and vertical components. The sharp eminence is found around the period of 0.5sec at the site point No.1 of the rocky mountains with keeping the lower amplification level, which is adopted for the reference to the following spectra. The points No.2~4 are stationed on the alluvial fans beside the mountains, where the dominant properties are recognized around 0.5sec in company with the swelling at 1.0sec. The eminent disposition is extended broad from the period 0.1sec to 1.5sec with the top around 0.4sec at the site points No.5~7 arranged on the deposit formations in the western side of the Mukogawa River. The similar tendency is shown without the clear summits at the points No.8~10 over the deposits in the eastern riverside. Moreover, the remarkable prominence is exhibited at 0.5sec in the spectral characteristics from the point No.11~12 standing on the Itami terrace, the

trend of which is not a little common to the one at the rocky site No.1. The spectral site characteristics surface more remarkably in Fig.4 to drop out the source peculiarities by making the ratios between the reference spectra at No.1 and those at the following numbers.

CONCLUDING REMARKS

The distributions of the structural damage are fairly affected by the physical performance of structures, the ground arrangement and the seismic source conditions. In regard to the Hanshin earthquake, the severe damage is concentrated within the narrow corridors running through the soft deposits or the alluvial formations along the mountainside, which is not always consistent with the underground trails of the seismic faults drawn linearly. In the present study to examine the site amplification effects under the earthquake, the distributions of the structural damage are surveyed and the spectral properties are researched through the microtremor measurement around and across the Mukogawa river basin, the eastern part of the stricken area. By referring the observed or analyzed data, the damage distributions are wholly classified with the ground topography such as the rocky site, the fan or terrace alluvium and the deposit formation. Their detail is, however, complicated because of the short distance between the suffered area and the seismic trails and the spectral eminence marked around the natural periods of standard structures. It is necessary to examine carefully the distribution of damaged structures and the site amplification properties under the consideration of the topographic irregularities around the Hanshin region suffered from the present quake.

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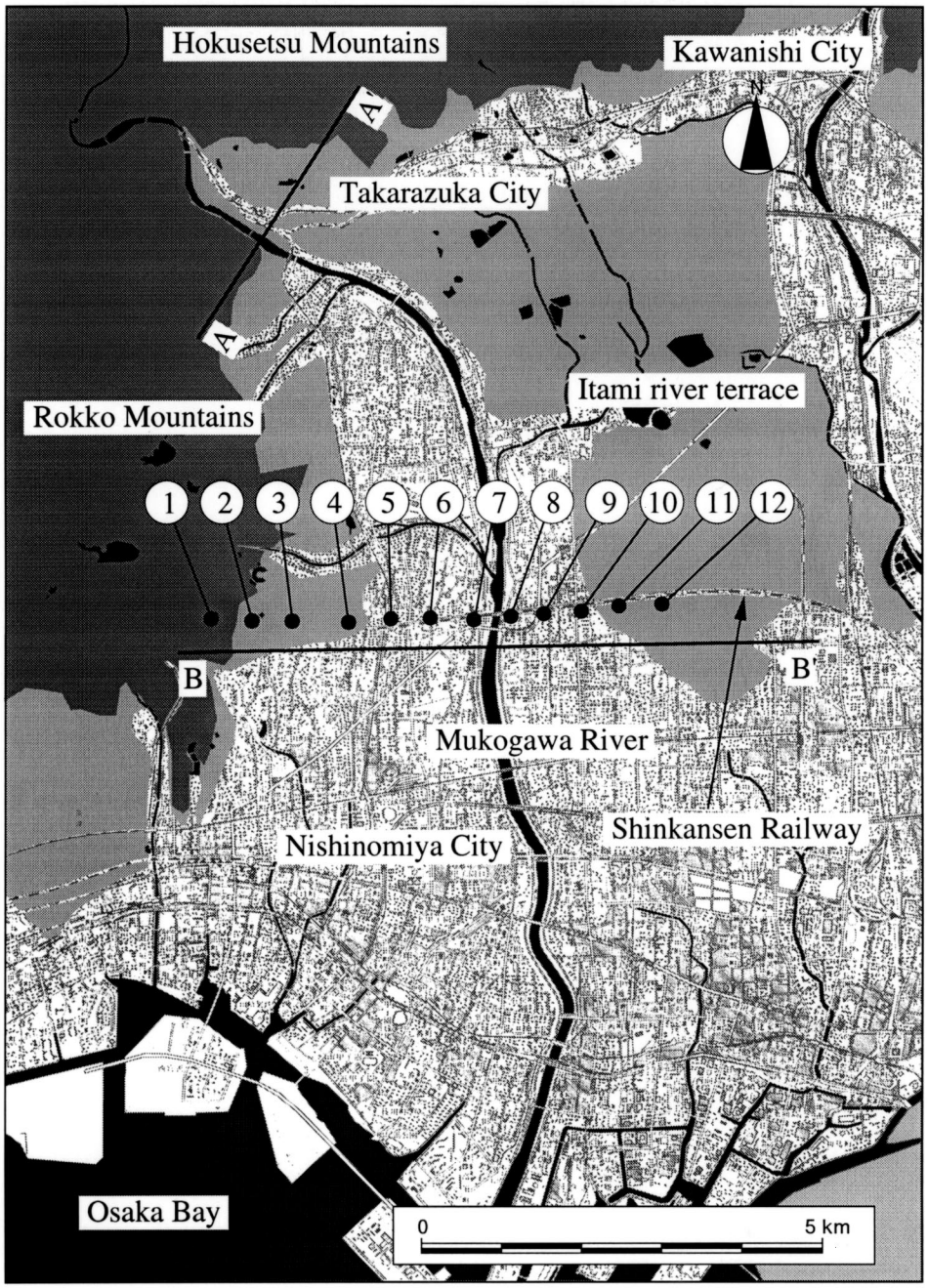
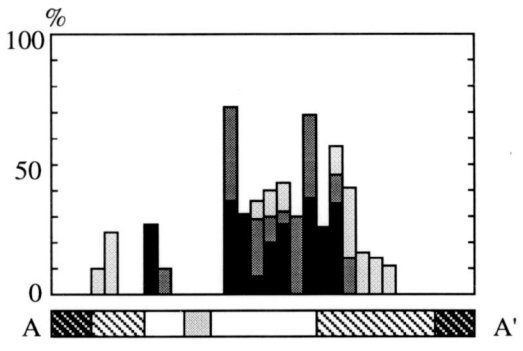
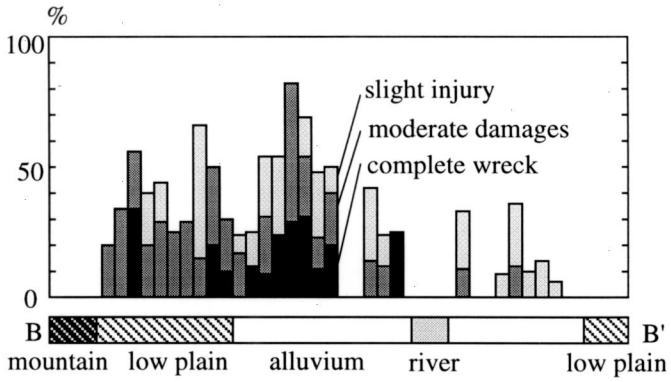


Fig.1 Topographic conditions around the Mukogawa river basin encompassed with the Hokusetsu Mountains to the north, the Rokko Mountains to the west, Osaka Bay to the south and the Osaka Plain to the east.



(A) the southwest-northeast section across the upper reach.



(B) the west-east section across the middle reach.

Fig.2 Distributions of wrecked structures across the Mukogawa River.

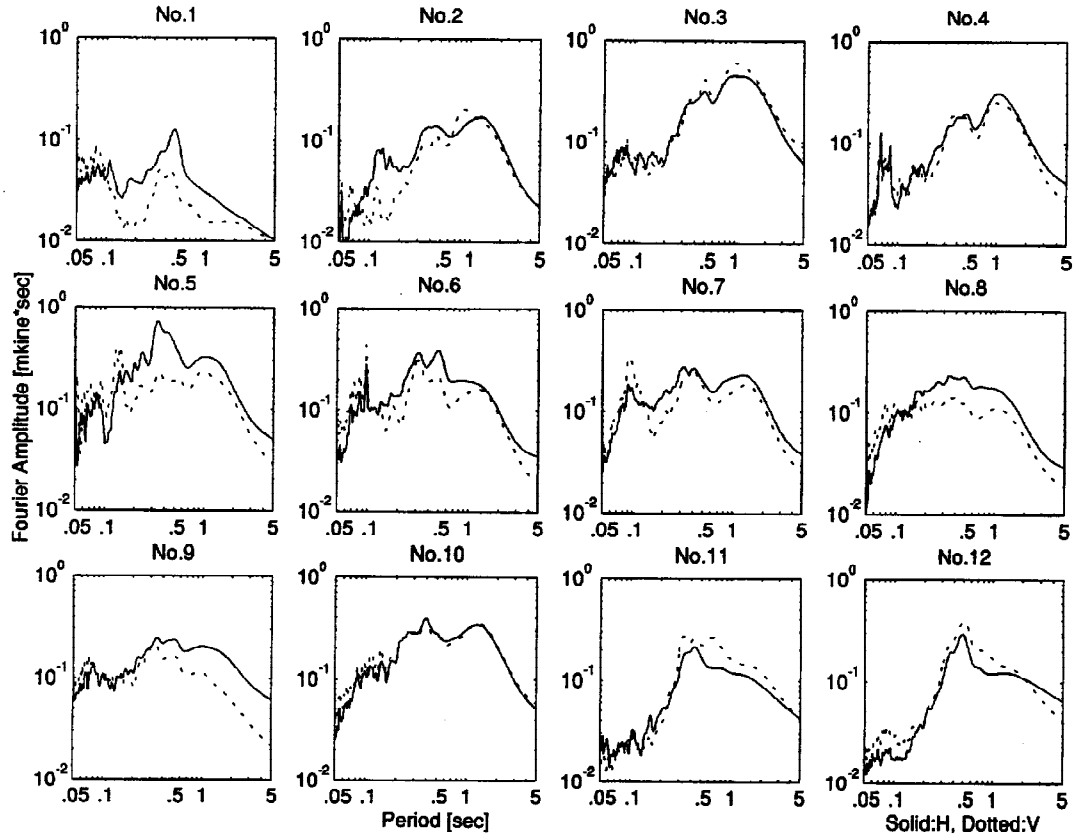


Fig.3. Fourier spectral amplitudes through the micrometer measurement across the midstream of the Mukogawa River.
The solid lines correspond to the lateral components and the dotted lines to the vertical ones.

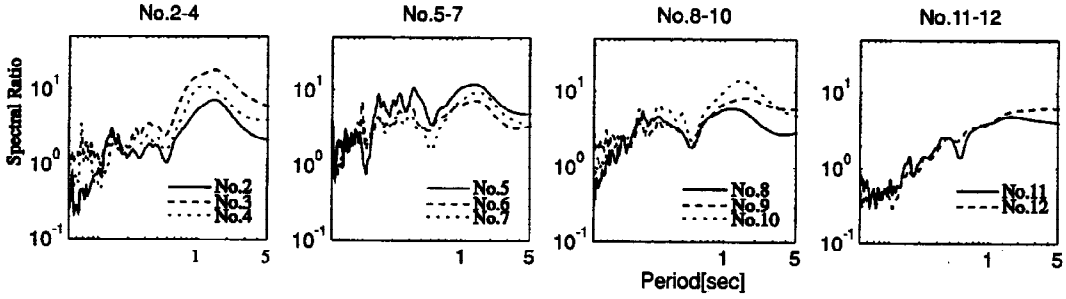


Fig.4 Spectral amplitudes ratios referred to the lateral components at the site No.1 around the Rokko Mountains.