Introduction

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INTRODUCTION

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At 13h 01m (4h 01m G. M. T.) on June 16, 1964 a severe earthquake took place in the Niigata and Yamagata prefectures inflicting considerable damage to the City of Niigata and other towns and villages near the coast of the Japan Sea. This disaster occurred four months prior to the Olympiad to be held in Tokyo, and four days after the closing ceremony of the national athletic meeting which was held in the City of Niigata. In view of the severe damage to the athletic stadium in the City of Niigata, the news front of the world was keenly concerned in the possibility of an earthquake hazard during the forthcoming Olympiad, and the shocking pictures of the damaged stadium, a demolished bridge and an overturned apartment building were televised throughout the world. Even the Japanese themselves shuddered when they thought of the potential calamity of an earthquake which could strike when the Olympic stadiums were full of spectators. Another feature which attracted our keen interest was the comparatively easy destruction of modern buildings, bridges and other structures on the alluvial formation around the Shinano, the longest river in Japan, which discharges into the Japan Sea at the Niigata City.

Notwithstanding all these conspicuous destructions, the magnitude of the earthquake was less than 7.5, the intensity in the City of Niigata on consolidated ground being only 8 on the international scale. The wooden houses in the old town area which was developed in the 16th century remained almost intact, and only 3% of wooden houses were completely demolished in the whole city, while more than 25% of the modern concrete buildings on weak foundations in the new city area suffered some damage due to subsidence or inclination resulting in an extreme case to complete overturning. The geology in the old city area is not much different from the other part of the city, except for the fact that the land was formed several hundred years earlier.

However, even in the epicentral area, wooden houses on firm rocky foundations suffered only slight demolition. The intensity in such an area rarely exceeded 9 on the international scale.

It is to be stressed that, although 1960 houses were totally destroyed in the whole area, the earthquake took a toll of only 28 lives. This is very few as compared with ordinary Japanese earthquakes of comparable magnitudes. This is partly due to the fact that the earthquake was of a submarine origin, but, I think, it is mainly due to the deep focal depth of this earthquake. The depth as determined by the Japan Meteorological Agency was 40km. Owing to this fact, the intensity was not so strong as to cause many buildings to be shaken down completely. Moreover, the duration of the preliminary tremor was longer than usual in the meizoseismic area, and people had time to escape out of doors before the destruction of the houses in the principal earthquake motion. The time of occurrence, 13h 01m, which fell in the working hours in the field for farmers, must have also been helpful in preventing casualties.

The mechanism of occurrence of this earthquake was inferred from the distribution of the initial motion of the P-wave to be faulting along an almost vertical plane striking NNE, the eastern side of which was moving downward. The crustal movement, revealed from the changes of coast lines, and observed by soundings in the sea and by precise levellings on land, support the above inferrence. But no appreciable fault scarp was found even through detailed submarine inspections from a deep sea exploration vessel by a team of geologists and geophysicists, although several small abrupt topographic changes, arranging en echelon, were detected by echo soundings. At these seeming fault scarps of several metres, clearly seen on the continuous sounder record, it was found that the slopes were of one degree or so actually, and we could find no signs of disturbance of the sea bottom from closed up inspections from the deep sea exploration vessel. This may be explained by the blanketing effect of a thick soft sedimentary deposit on the sea bottom. The maximum upheaval and subsidence revealed through the soundings by the Hydrographic Department in the epicentral tract amounted to +5m and -4m respectively. The coast of an island called Awashima, which is about 10km north of the epicentre and lying on the west side of the presumed fault, upheaved about one metre and inclined 55" to N65°W, according to the study by members of the Earthquake Research Institute.

As a result of this upheaval and subsidence, tsunami waves were generated, their height observed on the main land coast reaching as high as six metres at points nearest to the central area. This source area of the tsunami, as inferred from the arrival times at places on the coast and the calculated travel times from the bathymetric chart of the sea, came out to be about 90km long in the NS direction, and 20km wide in the EW direction. This area is identical with the area of upheaval as above mentioned.

In Japan it is almost established that the source area of tsunami is identical with the area of the aftershock activity of a great earthquake. And this Niigata Earthquake offers no exception to the above theory. It might be added that the same fact was also seen in the Alaska Earthquake of 1964.

It should be specially mentioned here that a most remarkable crustal movement was revealed by precise levellings repeated many times before and after the earthquake by the Geographical Survey Institute. The plain of Niigata abounds in natural gases and petroleum resources. But the exploitation of these resources caused so considerable a subsidence around Niigata City that this grave consequence compelled us to watch the advance of subsidence by repeated precise levellings, entrusting the task to the above Institute. The changes in the relative heights, thus revealed, of the bench marks in the vicinity of the epicentre of the present earthquake, have gone on gradually in the last 70 years, while very conspicuous and abrupt changes have taken place in the last 10 years. It is known in Japan that before the great Kwanto earthquake of 1923 the ground at Aburatsubo on the Miura peninsula, very near to the epicentre, subsided gradually over about 20 years so far as observations existed, while the crustal movement at the spot changed into a slight upheaval a few years in advance of the great earthquake. This mode of crustal movement has been taken as a precursory phenomenon of the great earthquake. An exactly similar yet more marked crustal movement observed in the present earthquake is nothing but further evidence to assure the possibility of predicting an earthquake occurrence more definitely.

A minute survey of the distributions of the damage and ground fissures, sand and water vents etc. revealed clearly the actual course of the rivers Shinano and Agano which discharged in historical times through the present area of Niigata City. Many rough sketch maps of the area in old times exist, and changes of the river courses and positions of islands have been indicated, but the validity of the maps and exact positions of the land marks on each map were not known till now. However, the high earthquake intensity and the particular pattern of fissures, distributions of water and sand vents, which were particularly abundant on the soft ground, revealed the exact position of former river courses in conformity with the old maps. The most important feature of the earthquake effect on the old river course was the failure of the ground amounting to great dislocation, subsidence, effusions of large quantities of sand and water which at places left a pool of several decimetres deep and sand deposits as thick as one metre in wide areas. Large subsidence of bench marks as much as 140cm at maximum was revealed by precise levelling.

In the area along the old river courses, most of the concrete buildings with insufficient substructures (with piles less than 8m in the mean) suffered characteristic damage of inclination and subsidence as already mentioned. These features may be ascribed to the so-called quick sand effect or liquefaction of sandy deposit. To discriminate from the damage due to the effect of vibration (vibration damage), damage caused by the ground failure is named in Japan after this earthquake as "ground failure calamity (damage)". This type of damage of considerable severity is displayed at places of a particular subsoil condition even when the intensity of earthquake motion is not so strong as to cause "vibration damage". This was perfectly attested by the records of strong motion accelerographs installed at the basement and on the fourth floor of one of the apartment buildings on reclaimed land near the river Shinano. There were eight such buildings at the site, and almost all subsided or were inclined, and indeed one of them was overturned. Apartment No. 2 among them on which the accelerographs had been installed, stood the earthquake with least damage. The maximum resultant acceleration was about 190 gals at the basement, while the maximum double amplitude of the displacement at the fourth floor as calculated from the accelerogram came out to be about 80cm in the lateral direction.

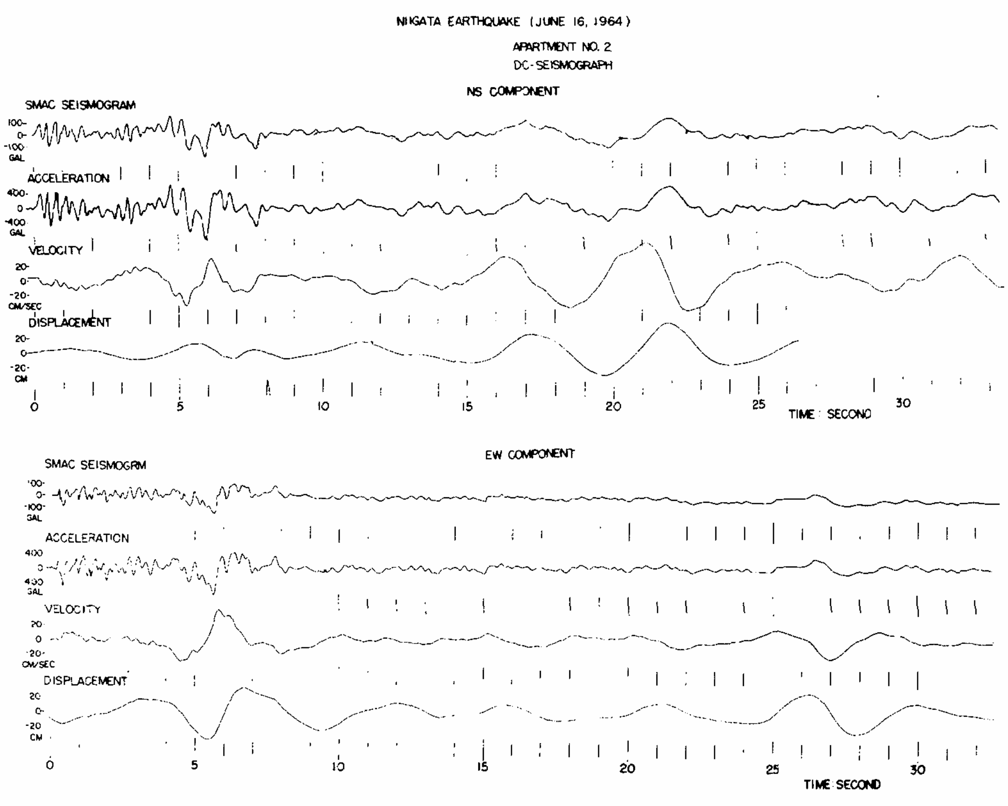

Fig. 0.1(a),(b). Accelerograms of the Niigata Earthquake observed by DC-seismographs at No. 2 Apartment, Kawagishicho, Niigata City; and calculated velocity- and displacement-seismograms. (After Yasuo Satō)

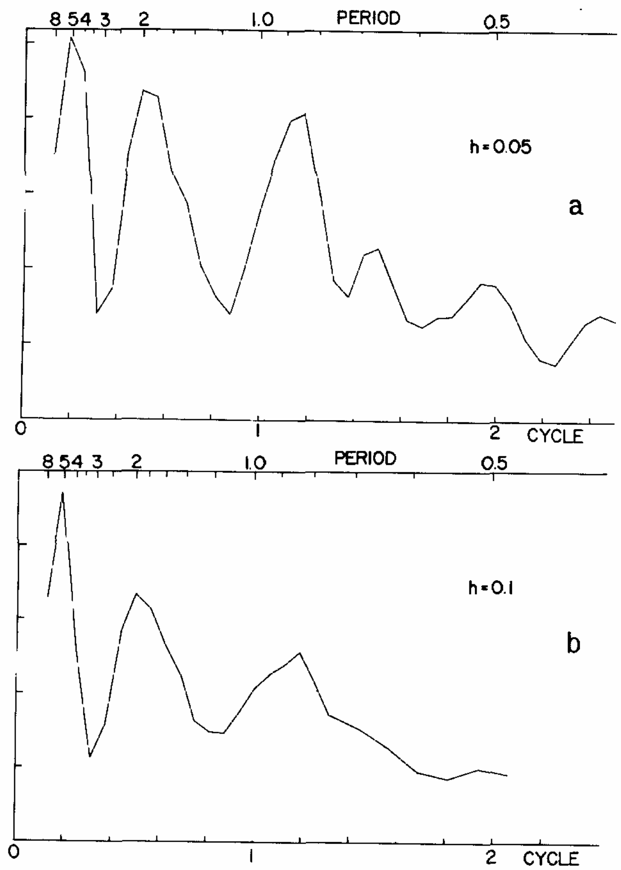

Fig. 0.2(a),(b). Response Spectra of Niigata Earthquake. (After Yasuo Satō)

The readers are referred to Part II and Part III of this report for detailed discussions and descriptions of the damage of the man-made structures and their relation to such geological conditions of their sites.

Another important consideration to the Japanese people was the menace of the earthquake fire of the facilities in the petroleum industry. The contents of a number of oil tanks in oil refineries and power plants at the mouth of the river Shinano overflowed or leaked from the breakages of tanks and pipe lines, to spread over the surface of water which spouted from underground, or inundated from the rivers over the subsided or broken banks throughout a very wide area of the city. At four points oil caught fire. It was reported that at least one of the fires was ignited by the vibration effect alone. The fissures in the ground and the breakages of roads and bridges and deep pools of water hampered the activities of the fire brigades in addition to the shortage of appropriate fire fighting facilities. Although in some factories the fire were shortly brought under control, in one factory with the largest facility, large tanks were successively brought into the blaze, many of them continuing to burn for more than a week, while one was left to burn out after 15 days.

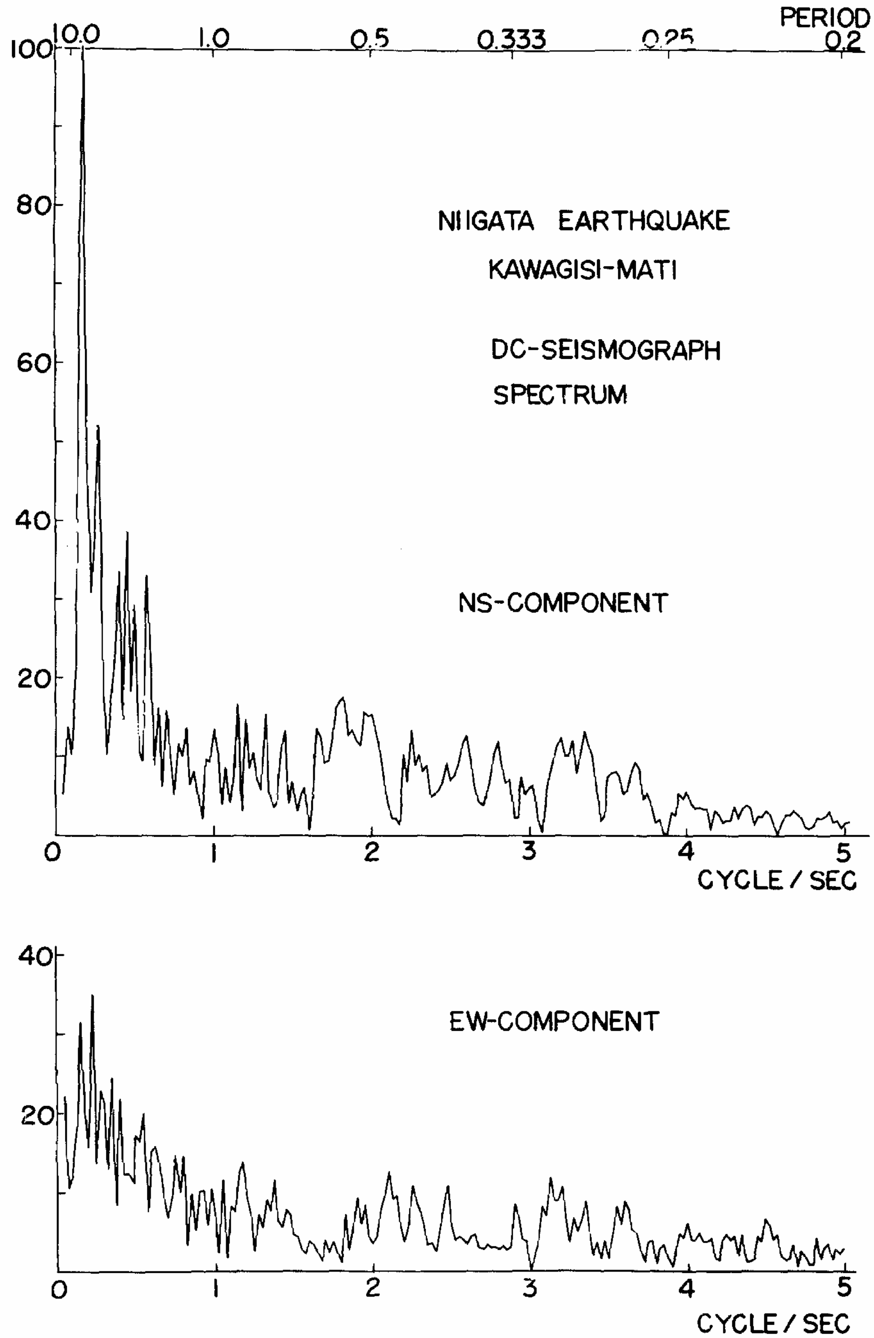

Fig. 0. 3. (After Yasuo Satō)