Fundamental Impact Tests on Mortar Specimens for Failure Patterns of Foundation Piles due to Up-Down Vibration in Earthquakes

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ABSTRACT
This paper presents experimental investigations on particular failure patterns of foundation piles found in Hyogoken-Nambu Earthquake (1995) that were probably induced by seismic up-down vibrations. Impact tests on cylindrical mortar specimens were conducted in different loading modes. Vertical splitting failure was observed in static compression tests whereas horizontal tensile failure occurred in static tension tests and impact tension tests. Depending on the level of impact power, failure patterns in impact compression tests were found varying from cone splitting failure to X-shape shearing failure, 45-degree shearing failure, and horizontal tensile failure due to reflection of stress wave.

Key words: failure pattern, foundation pile, impact test, mortar specimen, seismic up-down vibration.

INTRODUCTION
During the 1955 Hyogoken-Nambu Earthquake a large number of structures were subjected to complicated failures which could be due to the vertical component of seismic motion (hereafter called as up-down vibration) (Ono et al,1996). The failure patterns of these pile foundations are of the type not reported in the investigation cases of pile failure patterns that occurred in other earthquakes.

To envision the cause for these failure patterns and to understand more clearly the critical conditions for failure in pile foundation, it is important to examine the relation between associated mechanical factors (for instance, ground characteristics, seismic properties, type of pile foundation, restraint conditions, surcharge load on pile head, etc.) and that related to failure patterns.

Moreover, when the developed failure patters of pile after the earthquake was observed in detail, the failure mechanism was found to be different in the static loading and impact loading. It can be said that the understanding of failure mechanism is not adequate even at the laboratory experiment level of impact compression and impact tension test on these materials of concrete and steel.

As the measurement of pure tensile strength of mortar or concrete specimen based on static phenomenon of tension test is difficult, many tension tests, instead, in general is examined by laying the cylindrical specimen in horizontal direction with pressure load applied in vertical direction. Although the experimental method of compressive strength can be easily performed, the difference in mechanical condition with pure tensile strength limits the idea of determining impact compressive strength in the earthquake from compression test.

On the other hand, the impact test experiment with a hydraulic apparatus and the experiment that uses the shaking table have been conducted as a method for impact test. The tensile stress region might be caused by the reflection and the interference with the stress wave at impact compression test, and there is an experimental method called Hopkinson method of examining this mechanical phenomenon (Kolsky,1963;Jitsu et al,1998). However, application of this experiment and measurement set up is difficult to be applied to the mortar specimen. Despite an advancement in the approach to the impact test, relatively little is known regarding the mechanism of the failure patterns of various piles that occured in Hyogoken-Nambu Earthquake.

Based on this view point, this paper focuses on the shear failure patterns of PC piles and the tensile failure patterns of Benoto piles investigated from the boring operation near Uozaki of southern reclaimed land of Hyogo prefecture. Next, the huge weight impact testing apparatus is set up for the impact compression and impact tension test and the laboratory experiments are conducted to the mortar specimen of the same shape and size. The experimental results are presented, from which the failure patterns of pile foundation in two locations of Uozaki reclaimed land are discussed.

FAILURE PATTERNS OF PILE FOUNDATION

Figure 1 shows the investigation site of pile foundation failure. The investigation point is at two locations of Uozaki reclaimed land. Fig.2 shows the profiles of subsoil and pile foundation details at the investigation sites. The soil layer at the end of pile toe of PC pile and Beneto pile consists of gravel layers of standard penetration test, N value of about 50.

The seismic motion of Hyogoken-Nambu Earthquake in the investigated location can refer to the seismic motion record of Port Island and thus shall be presumed. From the seismic record of Port Island, the water table location can refer to the seismic motion record of Port Island and thus shall be presumed. From the seismic record of Port Island, the water table position is found to be at 1.6 below the ground level; up-down acceleration is 786.6 gal; N-S horizontal acceleration: 564.7 gal and E-W horizontal acceleration as 543.5 gal are observed. The seismic motion being relatively large in vertical direction than in horizontal direction is a feature, and the possibility of the relation to the phenomenon of failure mechanics of the pile foundation is large. Liquefaction of soil was not observed during the boring operation at the investigated location in the ground in either of the two locations under the structure.

Shear failure of PC piles

The investigation carried out was in the building of three storied as shown in Fig 2. Foundation pile is PC piles of 350mm in the outside diameter, and has 8 reinforcement steel bars of 9 mm dia. The stratum in the PC pile...