Research paper

Developments of the dynamic removal method for concrete pile head using the charge holder producing horizontal fracture plane

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Abstract

A dynamic removal method for concrete pile head is newly developed. The method enables us to produce the controlled horizontal fracture plane by using the charge holder with horizontal fins and a non-explosive demolition agent. The effectiveness of the presented method to produce the horizontal fracture plane was demonstrated by the model experiments with small size reinforced concrete specimens. In these experiments, the dynamic behavior of cracks propagating along the specified horizontal fracture plane was clarified by high-speed videography. The usefulness of the method on field usage was confirmed by experiments with reinforced concrete pile head of the actual size. It was shown from these experiments that the fracture plane occurred nearly horizontally at the specified position, and that the part of concrete to be removed from the pile head portion could be separated easily by lifting up action of gas pressure. It was also confirmed that smoothness of the fracture surface of the concrete pile was achieved by using the newly developed charge holders.

Keywords : fracture control, charge holder, non-explosive demolition agent

1. Introduction

As is well known, deterioration of concrete strength in cast-in-place piles used as the foundation of a building is caused by an impure ingredient such as slime into the upper part of the pile during pile driving works. The part of the pile, about 80 cm from the head, has to be removed. Such removal of the pile head is usually done by means of the hand breaking method, chipping works using manpower, but, the work is extremely hard and working efficiency is poor. Figure 1 shows chipping works by the breaker to remove the pile head. The work causes the problems such as generation of noise and vibration to the neighborhood. In order to solve the problems, the dynamic removal method for the concrete pile head of the flexural type without main bars connecting the foundation of the structure was developed by using the charge holder producing vertical fractures and a horizontal disk plate located at the boundary between the pile head and the pile body[1)-3)]. The pile body and foundation are strongly connected by main bars in the case of the pile head of the rigid type shown in Figure 2. In this case, the application of the dynamic removal method generating vertical

Figure 1 Chipping works by the breaker generating noise and vibration.

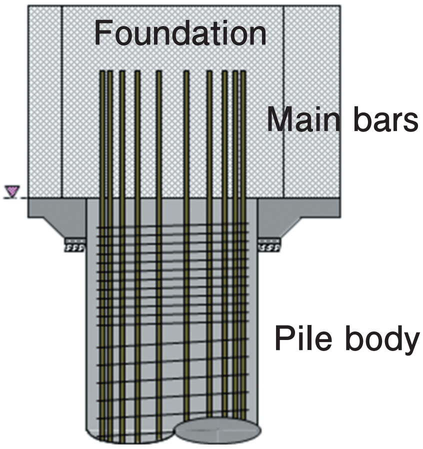


Figure 2 Pile head connected by main bars (Rigid type).

Figure 3 Fracture of the pile head by a dynamic removal method generating vertical fractures and deformation of main bars.

fractures cause deformation of main bars, as shown in Figure 3. Then, it is desirable to remove the pile head without deformation of main bars, damaging the pile body and without using the expensive horizontal plate.

In this report, a dynamic removal method by using the newly developed charge holder with horizontal fins is presented. The method enables us directly to produce the horizontal fracture plane along the boundary between the pile head, that is extra-banking concrete and the pile body without generating vertical fractures. Experiments with small size reinforced concrete specimens and actual size reinforced concrete pile head model specimens were carried out to demonstrate the effectiveness of the presented method.

2. Model experiments to demonstrate the effectiveness of the presented method[4)]

Figure 4 shows the geometry of the newly developed charge holder with horizontal fins. The fins play a role similar to a cold joint in concrete and are effective in controlling the direction of the fracture plane and in driving the controlled cracks. The horizontal length of the fin located toward center of the concrete body, that is the pile, is longer than the fin's length toward outside of the concrete body. The effectiveness of the presented method was examined by model experiments with small size reinforced concrete specimens, $\phi 200 \times 250$ mm. The specimen had four reinforcing bars, polished round bars of $\phi 8$ as used in a pile main bar. The reinforcing bars were covered with steel pipes. The pipes, 9.2 mm in inner diameter were located in the upper part above the specified horizontal fracture plane at the designed distance of 130 mm from the top surface of the specimen. After demolding, the pipes were removed from the reinforcing bars. Then, reinforcing bars are bondless condition to concrete. The charge holder used in the model experiments was fabricated from galvanized steel plate in thickness, 1.5 mm. An electric detonator and/or concrete cracker (CCR) were used as a charge in these experiments. Three experiments were performed with the electric detonator and four experiments were performed with CCR in order to confirm the reproducibility on controlled dynamic fracture processes. The inside space of the pipe attached to the holder was sealed with clay and stemming material manufactured by Asahi Kasei Chemicals Corporation. The static compressive and/or tensile strength of concrete obtained from tests based on JIS A 1108 and/or JIS A 1113 using three specimens at each test was 21.0 MPa, 1.93 MPa, respectively, at the time that the specimens were tested. These values of the static strength are mean values for

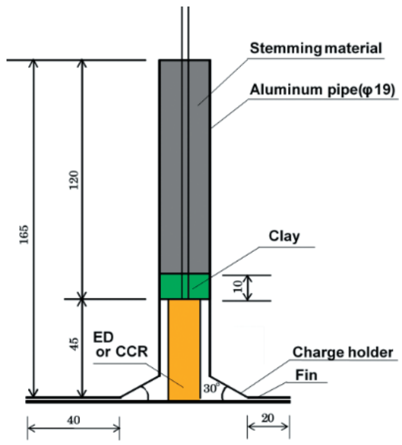
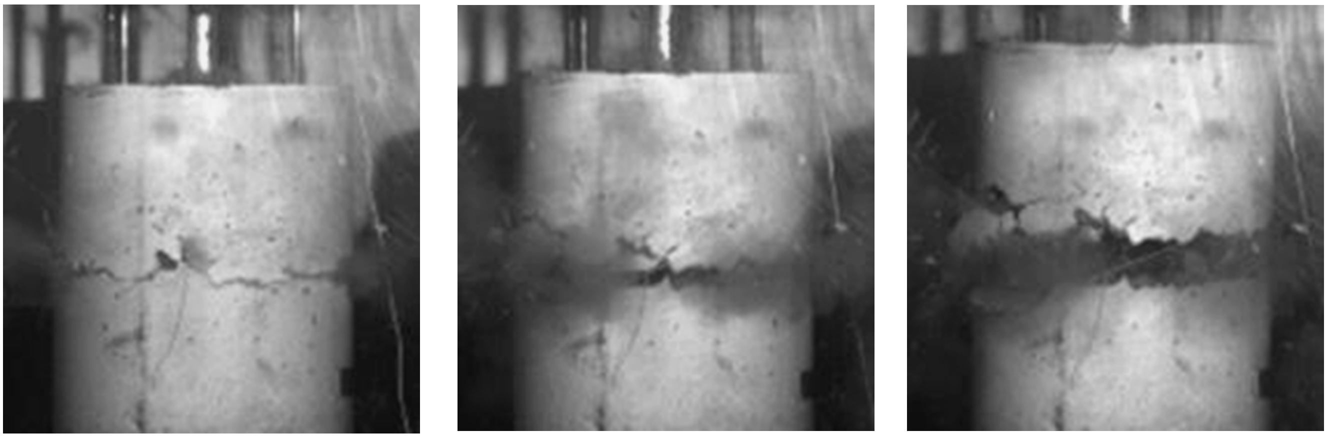


Figure 4 Geometry of the charge holder with horizontal fins used in the model experiments.



Frame No.17 Frame No.74 Frame No.208

Figure 5 High-speed video images showing crack propagation along the specified fracture surface in the model specimen, $\phi 200 \times 250$mm by using the electric detonator as a charge. Framing rates ; 18000 f/s.

Figure 6 Crack patterns in the model specimen, $\phi 200 \times 250$mm after dynamic fracture experiments using CCR as a charge.

each test.

The dynamic behavior of controlled cracks in the fracture process can be seen from the images of the high-speed video camera. The photographs from the video images are shown in Figure 5. In these experiments, an electric detonator with PETN of the main charge, 0.4 g, was used as an explosive charge. Video images were taken at the rate of 18000 frames per second (f/s). The time interval is 55.5μs for the rate of 18000 f/s. The frame number is indicated in each photograph of Figures 5. Frame No. 1 means the first frame, after the electronic pulse initiating the firing circuit of the electric detonator operated the trigger circuit of the high-speed video camera system. However, it does not mean the first frame after the explosion because of the time delay in initiating the main charge of the electric detonator. The time delay was about 100μs for the electric detonator under the experimental conditions. It can be seen from images that the controlled crack propagates along the specified horizontal fracture plane. It is also seen that the explosion gases contribute to driving forces for opening the fracture plane and lifting up the upper part of concrete body.

After these blasting experiments, the pullout test of reinforcing bars of the three specimens was carried out to examine the effects on adhesion between the reinforcing bar and concrete under dynamic action by blasting. The embedded length of the reinforcing bars in concrete specimens after blasting is 120 mm.The maximum pullout load of the three specimens, No.1, No.2 and No.3 was 1.97 kN, 2.24 kN and 1.96 kN, respectively. These values are the mean value for four reinforcing bars of each specimen. The standard mean value for four reinforcing bars with the embedded length of 120 mm of the specimen that was not used in the blasting experiments was 1.97 kN. It was seen from comparison of the maximum pullout loads of the specimens used in the blasting experiments with the standard value that adhesion between the reinforcing bars and concrete was not influenced under dynamic action by blasting.

Results in dynamic fracture experiments using CCR as a charge are shown in Figure 6. In each experiment, CCR, 3 g was used. It is seen from the results that controlled cracks were initiated at specified locations and propagated along the specified horizontal fracture plane. It was confirmed that the controlled dynamic fracture process was found to be reproducible. It was also seen from these experimental results that smoothness of the fracture surface can be achieved.

3. Experiments on the applicability of the presented method to field usage[5)−8)]

Experiments were carried out using the large size specimens of reinforced concrete (RC) in order to demonstrate the applicability of the presented method. The specimens have the structure of the cast-in-place concrete pile. Dimensions of the RC specimens are 1200 mm in diameter, 1200 mm in height. Main reinforcing bars, 12−D22 were used. Compressive strength was about 39.7 MPa at the ages, 28 days. Figure 7 shows the geometry of the charge holder used in the experiments with actual size specimens. The charge holders are attached to flat bars as shown in Figure 8. The upper end of the holder pipe is located in 10 cm, the upper side from the top surface of the pile. A void form was placed to pour the stemming material around the pipe. The quick hard non-shrinkage mortar manufactured by Ube Industries, Ltd. was used as a stemming material. In these experiments, NRC (New rock cracker) was used as a non-explosive demolition agent. The non-explosive demolition agent was packed in the vinyl tube as shown in Figure 9 (a). The tube was inserted from top of the holder pipe and the stemming material was poured into the pipe and the void form as shown in Figure 9 (b). The curing time for hardening of the stemming mortar was about 1 hour.

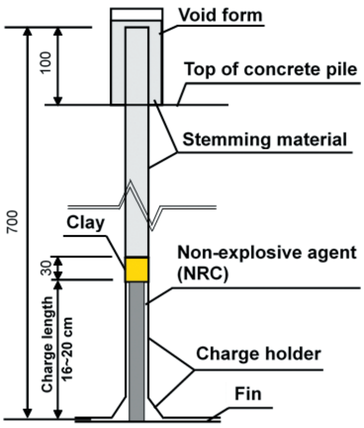


Figure 7 Geometry of the charge holder with horizontal fins used in the experiments using the large size specimens of reinforced concrete.

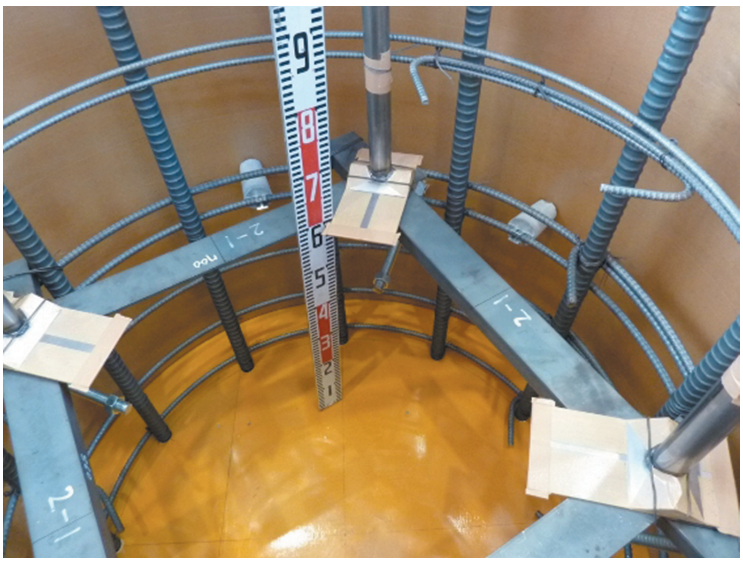
Table 1 Experimental conditions and results.

Exp. No.	N	W [g]	Crack patterns	Lifting up	P [dB]
1	4	72	horizontal fracture	feasible	113.0
2	4	54	horizontal fracture	feasible	111.2
3	4	40	horizontal fracture	feasible	104.9

N : Number of charge holders, W : Charge quantity, P : Peak value of crushing noise

In this report, experimental results are described for the case that the charge holders were placed in position as shown in Figure 8. The experimental conditions are indicated in Table 1. Three experiments, Exp. No.1~3 were performed with large-size RC specimens. The standard charge quantity, W of NRC in Exp. No.1 was determined according to the following formula : $W = K \times A/N$. where, the charge amount factor K is 256 g/m^2, the coefficient A is the crushing section area (m^2) and N is the number of charge holders. The value of K was obtained from the past experiments. In Exp. No.2 and 3, the charge quantity was determined based on the experimental results of Exp. No.1.

Experimental results are shown in Figure 10 ~ 12. It can be seen that controlled cracks are initiated at the specified location and propagated along the specified horizontal fracture plane. It is also evident from observations of the fracture surface of the specimens that strength and stability of the lower side of the specimen are maintained and smoothness of the fracture surface is achieved by using the presented method. The fracture surface corresponds to the boundary between the pile body and the removal part, that is extra-banking concrete. By lifting up the removal part, it is easily separated from the pile



(a)

(b)

Figure 8 (a) The charge holders attached to flat bars in the specimen and (b) the whole of the charge holder.

(a)

(b)

Figure 9 (a) Non-explosive demolition agent, NRC packed into vinyl tube and (b) the void form located at the top surface of the specimen poured with the quick hard non-shrinkage mortar.

Figure 10 Controlled horizontal fracture along the specified location of the specimen in Exp. No.1.

body without deformation of main bars. These experiments show that the presented method is effective and applicable to field usage for dynamic removal of the pile head, extra-banking concrete.

As the movement of the pile head to the upper side in Exp. No.1 was slight larger than the predicted movement under the dynamic fracture process, it was considered that the charge quantity could be reduced. The charge quantity in Exp. No.2 and 3 indicated in Table 1 was determined based on the experimental result of Exp. No.1. It was also confirmed from these experimental results that the stemming mortar poured in the void form had

Figure 11 Controlled fracture surface indicating smoothness and stability of the specimen in Exp. No.2.

Figure 12 Lifting up of the upper side of the specimen in Exp. No.3.

sufficient effects to seal the gas pressure from the charge holder. The peak values of the crushing noise pressure under the dynamic fracture process were also listed in Table 1. These values were observed about 5 m away from the concrete specimen. The crushing noise was instantaneous and did not make persons in neighborhood uncomfortable.

4. Conclusions

The objective of this research is developments of the dynamic removal method of concrete pile head. The presented method using the charge holder with horizontal fins enables us to generate the controlled cracks along the specified fracture plane without deformation of reinforcing bars in the concrete pile head. The effectiveness of the presented method was examined by model experiments with small size reinforced concrete specimens, an electric detonator and/or concrete cracker (CCR) as a charge. The experiments on the applicability of the presented method to field usage were carried out using the large size specimens of reinforced concrete and the non-explosive demolition agent, NRC.

It was seen from high-speed video images in the model experiments that controlled cracks were initiated at specified locations and propagated along the specified fracture plane. The removal part was easily separated from the concrete body by lifting up. It was also seen from the experiments using the large size concrete specimens and the non-explosive demolition agent, NRC that the presented method is effective and applicable to field usage for dynamic removal of the pile head. The presented method is applying for patents in Japan[9]. The application of the presented method to field works was also performed and the work was recently appeared in a newspaper[10].

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References

1) Y. Nakamura, Y. Saito Y. Indo, M. Kato, and I. Yamaura, Proceeding of Japan Explosive Society, November, 27−28 (2006) (in Japanese).
2) M. Kato, Y. Nakamura, Y. Ogata, M. Yamamoto, and T. Matsuzawa, Kayaku-to-Hoan, Japan Explosive Safety Association, 39, 26−31(2007) (in Japanese).
3) I. Yamaura, M. Kato, and Y. Nakamura, Patent No.4245614, 2009.
4) Y. Nakamura, S. Nakamura, H. Takeuchi, and T. Taguchi, Proceeding of Japan Explosive Society, November, 61−62 (2012) (in Japanese).
5) H. Takeuchi, Y. Nakamura, S. Nakamura, and T. Higuchi, Proceeding of Japan Explosive Society, November, 17−20 (2012) (in Japanese).
6) S. Nakamura, H. Takeuchi, Y. Nakamura, and T. Higuchi, The 7th International Conference on Explosives and Blasting, 197−208 (2013).
7) H. Takeuchi, Y. Takahashi, and Y. Nakamura, Proceedings of the Japan Concrete Institute 35, 1339−1344 (2013) (in Japanese).
8) Y. Nakamura, H. Takeuchi and S. Nakamura, Kayaku-to-Hoan, Japan Explosive Safety Association, 46, 12−20 (2014) (in Japanese).
9) H. Takeuchi, Y. Takahashi, Y. Nakamura and Y. Kiritani, Patent Application No.2011−274654.
10) The Daily Engineering and Construction News, March 5 (2015) (in Japanese).