

FUNDAMENTAL STUDY ON COMPRESSION COMPONENT OF HALF PRECAST CONCRETE

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In this study, we examined the compressive component of half precast concrete. Form work is unnecessary in half precast concrete, and it is able to reduce cost of the construction. In Japan, the damage of housing by Typhoon and Tornado occurs frequently in recent years. Therefore, there is a possibility that the construction of half precast concrete house will increase in the future. The section of half precast concrete is consisted of two kinds of concrete. However, most studies of concrete engineering have focused on single layer concrete. The studies of double layer concrete are not enough. It was confirmed that the maximum compressive load of the compression member increased by making the aspect of the mortar double layer of a shell and a core by the past study. In this study, we made non-line mortar specimen (diameter: 100mm) imitated half precast concrete column. By the experiment, we examined the design formula of maximum compressive load of half precast concrete. We proposed a design formula to add ΔP (increment by sectional constitution of plural concrete, 28 kN in this experiment) to P_{ms} (maximum compressive load by calculating the product of the compressive strength, in consideration of the distortion in the specimen fracture, and cross-sectional area of the shell and core).

Keywords: Non-line mortar specimen; unreinforced mortar test specimens, mix proportioning, Superimposed strength equation.

1 INTRODUCTION

This study is an investigation of a half precast (PCa) concrete compression member. In concrete construction, the number of types of concrete that can be poured in the same area is almost always limited to one type due to problems of control. Therefore, in the field of research into construction materials, the assumption is made that, basically, members are made from one type of concrete. There is very little experimental research reported using test specimens made from two types of concrete, as in half PCa concrete. On the other hand, many researchers of the field of structure study proof stress of the half PCa concrete (Hosoya *et al.* 2001, Kubokura *et al.* 1994, Masuda *et al.* 1994, Matsufuji *et al.* 1990, Nakanishi *et al.* 1997, Nakano *et al.* 1992). However, there are few researchers of the field of materials about half PCa concrete. In a prior study, we found that the maximum yield strength of a mortar test piece increases during central compression by utilizing a two layer system, namely, a core-in-shell structure (Mukae *et al.* 2014). In this paper, we aim to propose an evaluation formula for the maximum proof stress on an unreinforced test piece imitating half PCa concrete. The

evaluation formula takes into account the difference in strain between the shell and the core during maximum stress.

2 EXPERIMENTAL PROGRAM

This experimental study was carried out using unreinforced mortar test specimens. The materials used in the mortar from which the test specimens were made are shown in Table 1. In addition, mix proportions of mortar and compressive strength are shown in Table 2. The compressive strengths shown in this table are the values measured based on JIS A 1108 using cylindrical test specimens $\Phi 100$ mm \times 200 mm. The water-cement ratio for the mortar that forms the shell and the core was made 0.55. In addition to foundation mortar preparation (M), a concrete preparation mixed with coarse aggregate (C), a preparation half mixed with coarse aggregate (hC) and a preparation quarter mixed with coarse aggregate (qC) were created with the aim of varying the strain during maximum stress. Also, a preparation with half and three quarters of the fine aggregate removed from the mortar preparation (hP and qP, respectively) was created for a total of six preparations. The core preparations were made to the above six standards. The shell preparations were made to the single standard of just the mortar preparation (M). The mortar was mixed using a uniaxial rotary mixer. The mixing time was five

Table 1. Materials.

Material	Property	Symbol
Ordinary Portland Cement	Density: 3.16g/cm ³	OPC
Water	-	W
Sea sand	Density in saturated surface-dried condition: 2.60g/cm ³ Percentage of absorption: 1.37% Solid content: 61.2% Fineness modulus: 2.43	S
Crushed stone	Density in saturated surface-dried condition: 2.69g/cm ³ Percentage of absorption: 0.60% Solid content: 56.7% Aggregate maximum particle diameter: 13mm	G

Table 2. Mix proportions.

	Water-cement ratio	Type	Unit amount, kg/m ³				Compressive strength*, N/mm ²
			W	OPC	S	G	
Core	0.55	C	175	318	881	915	35.8
		hC	211	383	1,061	551	36.4
		qC	235	427	1,183	307	38.5
		M	265	482	1,342	-	39.6
		qP	304	553	1,149	-	44.2
		hP	357	649	898	-	45.0
Shell	0.55	-	265	482	1,342	-	36.9

*Those to be used in the shell were measured to age of 28 days. Those to be used in the core were measured to age of 31 days.

minutes. After mixing was completed, it was confirmed that the mortar had sufficient fluidity to enable it to be poured, and that the air content was $6.8 \pm 1.5\%$, before the mortar was poured.

Test specimens are shown in Figure 1. The thickness of the shells was set to 10 mm, scaled down from an actual member. To produce the test specimens, first the mortar to form the shell was poured into cylindrical formwork. At this time a table vibrator was used because of the possibility of filling defects in the pouring method using a tamping rod. The shell was produced in advance, envisaging the actual construction sequence of half PCa concrete. After curing the shells for 3 days in a constant temperature chamber at 20°C , the formwork was removed. In order to increase the adhesion between the shell and the core, the inside of the shells after removal of formwork was scoured with a wire brush, and about 2 mL of water was sprayed using an atomizer. A tamping rod was used for pouring the mortar from which the core was formed. Thereafter the test specimens were cured for 28 days in a constant temperature chamber at 20°C , and were then supplied for the axial compression testing.

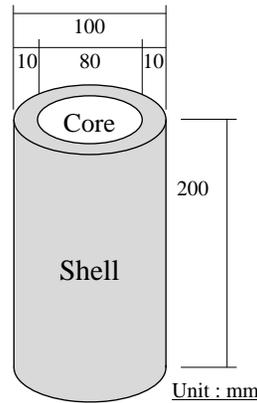


Figure 1. Blueprint of test specimens.

3 RESULTS AND DISCUSSIONS

3.1 Calculation Method for the Maximum Yield Strength according to the Superimposed Strength Equation

The following is a discussion of the ultimate strength obtained from the axial compression tests loaded over the whole surface. For this purpose the ultimate strength calculated from the accumulative strength equation was calculated for comparison with the test values. The accumulative strength equation is an equation that calculates the ultimate strength by calculating the product of the compressive strength and cross-sectional area of the shell and core that constitute the test specimen. It represented by Eq. (1).

$$P_i = \sigma_S \cdot A_S + \sigma_C \cdot A_C \quad (1)$$

P_i : Ultimate strength obtained from the accumulative strength equation (N), σ_s : Shell compressive strength (N/mm²), A_s : Shell cross-sectional area (mm²), σ_c : Core compressive strength (N/mm²), A_c : Core cross-sectional area (mm²).

In the previous section, it was confirmed that planar maintenance can be applied to the cross-section of the half PCa test sample. Accordingly, the maximum yield strength was calculated subtracting the compressive strength of the shell or the later-destroyed core, as shown in Figure 2. It represented by Eq. (2).

$$P_{ms} = \sigma'_s \cdot A_s + \sigma'_c \cdot A_c \quad (2)$$

Here, P_{ms} is the maximum yield strength (N) according to the superimposed strength equation taking into account strain during the maximum yield strength of the shell and the core., σ'_c is the stress (N/mm²) of the core due to strain equivalent to that at maximum stress of the shell plus 100×10^{-6} , which is generated when the critical stress σ_c is reached or shell failure occurs prior to destruction of the core., σ'_s is the stress (N/mm²) of the shell due to strain equivalent to that at maximum stress of the core plus 100×10^{-6} , which is generated when the critical stress σ_s is reached or core failure occurs prior to destruction of the shell.

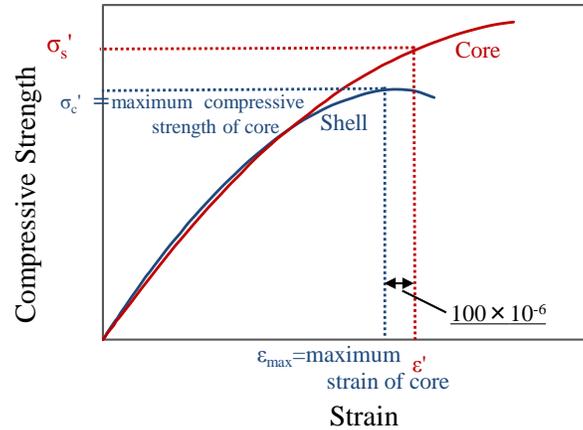


Figure 2. Calculation method of Eq. (2).

3.2 Maximum Yield Strength according to the Central Compression Test

Figure 3 shows a comparison of the calculated values P_i given by Eq. (1), the measured values P_{ms} given by Eq. (2), and the test values for the maximum yield strength of the half PCa test piece given by the central compression test. The test values for the maximum yield strength of the test pieces with the hC, qC, M and qP cores were greater than both the calculated values P_i and P_{ms} . The test value for the maximum yield strength of the test piece with the hP core was greater than the calculated value P_{ms} but smaller than the calculated value P_i . The test value for the maximum yield strength of the test piece with the C core was smaller than both the calculated values P_i and P_{ms} .

Figure 4 shows the relationship between the difference in strain at the maximum yield strength of the shell and the core and the difference in test values for maximum

yield strength and the calculated value P_i . From the approximate curve in the diagram, the range of difference in strain at maximum stress during which an increase in maximum yield strength can be expected is estimated to be approximately $\pm 550 \times 10^{-6}$.

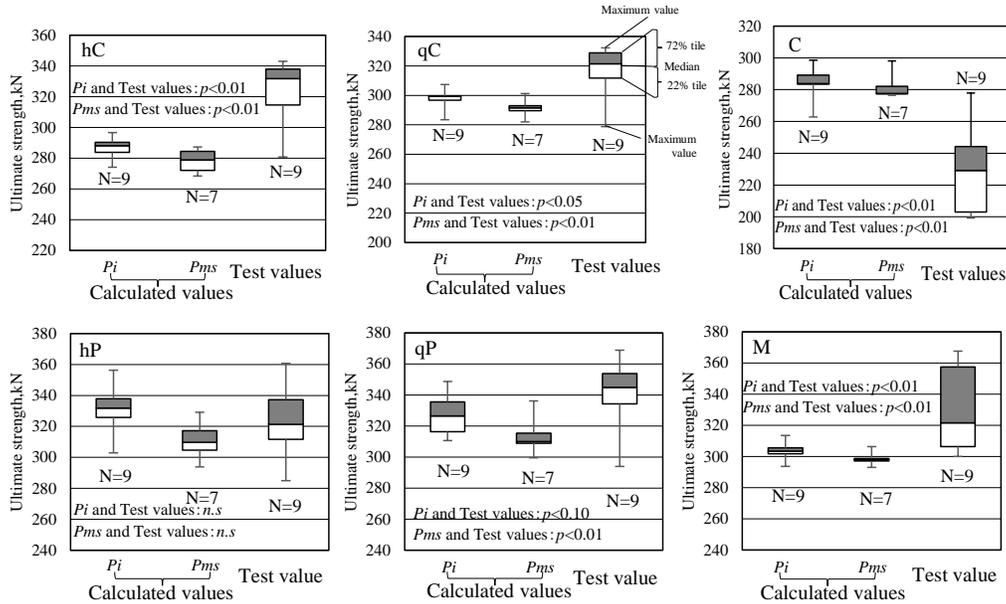


Figure 3. The test values for the maximum yield strength of the half PCa test piece given by the central compression test.

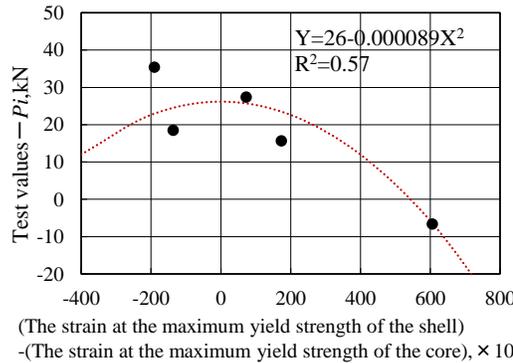


Figure 4. The relationship between the difference in test values and the calculated value P_i .

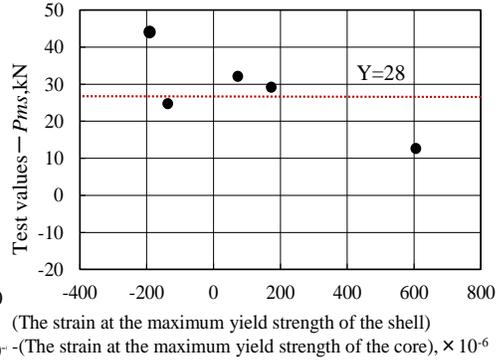


Figure 5. The relationship between the difference in test values and the calculated value P_{ms} .

3.3 Proposal of an Evaluation Equation for Maximum Yield Strength

In this section, we investigate an evaluation equation for maximum yield strength in the case where a half PCa test sample undergoes a central compression test. The equation proposed takes into account a drop in yield strength in the case the strain during

maximum stress of the shell and the core differs. Figure 5 shows the relationship between the difference in strain at the maximum yield strength of the shell and the core and the difference in test values for maximum yield strength and the calculated value P_{ms} . The test values for maximum yield strength were large in comparison to the calculated value P_{ms} at an average of 28 kN. Because of this, the following equation is proposed as the evaluation equation for maximum yield strength.

$$P'_{ms} = \sigma'_S \cdot A_S + \sigma'_C \cdot A_C + \Delta P \quad (3)$$

Here, P'_{ms} is the estimated value of maximum yield strength for the test piece in this test (N) and ΔP is the amount of increase in maximum yield strength (approx. 28 kN in the range of this test).

This equation applies to only the test pieces of this test, and so a new investigation will be necessary concerning an equation for test pieces of differing dimensions and cross-sectional forms in the future.

4 CONCLUSIONS

- In the scope of this experiment, the range of difference in strain at the maximum stress during which an increase in maximum yield strength can be expected was estimated to be approximately $\pm 550 \times 10^{-6}$.
- An equation in which ΔP was added to the maximum yield strength P_{ms} according to a superimposed strength equation taking into account the strain at the maximum yield strength of the shell and the core was proposed as an evaluation equation for the maximum yield strength of a half PCa test piece.

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