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Research Article

Assessment of the Precast Concrete Performance by using Sand with High Sludge Content

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Abstract: The use of precast concrete structural systems in the Indonesian civil engineering industry is expected to increase due to the continuous annual need of buildings and infrastructures for social and economic development. The fabrication of the precast concrete requires the use of sand with 5% suitable sludge content as one of the important raw materials but it is difficult to find a low-cost method of obtaining this sand in several regions of the country. However, the available high sludge content has been discovered to be reducing aggregate adhesion with cement paste and requires more water in the concrete mixture, thereby, causing a reduction in its compressive strength. This study tested the use of natural sand with a high sludge content of 12.7% and different variations of OPC at 2.5, 5.0, 7.5, and 10.0% in CS1, CS2, CS3, and CS4 samples, respectively, to determine the compressive strength and workability of the precast concrete structure. Moreover, two samples were used as controls and they include Ref-1 with 3.7% sludge content and Ref-2 with 12.7% sludge content without the addition of OPC. The results showed the addition of at least 2.5% OPC into concrete slurry is recommended to ensure optimal performance of the CCS samples. This means combining local natural sand, despite its high sludge content, with other materials is reliable for the fabrication of precast concrete structure in future civil engineering applications.

Keywords: Compressive strength, Precast concrete, Sludge content, Slump test.

1. INTRODUCTION

The use of precast concrete structural systems in the Indonesian civil engineering industry is expected to increase due to the continuous annual increase in the need for infrastructures such as roads, bridges, dams, airports, and several others to support social and economic development [1]. It is important to produce quality concrete using fine aggregate sand with low sludge content [2-3] but previous studies have shown it is difficult to find this natural material [4-6]. According to PT. Wijaya Karya Beton, it is very difficult to obtain natural sand with sludge content less than 5% at some sand-producing quarries in Indonesia such as in Majalengka, Kuningan, and Sumedang. This is due to the availability of sand with high sludge content causing the reduction in the workability of concrete due to absorption, thereby, requiring an increment in the cement content to achieve the standard strength [7-8]. The use of this material to produce concrete structure has been identified as a grand challenge currently facing the civil engineering industry and is expected to be the focus of further scientific research and data analysis [9-11]. This has led to the introduction of several methods such as the use of ash which was also discovered to require more cement to ensure good workability and high

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compressive strength for the concrete [12-13]. Moreover, despite the proposed of self-healing through the addition of a certain colony of bacteria in concrete to increase the compressive strength and workability [14-16], there is a need to verify the use of natural sand with high sludge content. Therefore, the objectives of this study include using four different compositions of Ordinary Portland Cement (OPC) and natural sand with high sludge content of 12.7% by weight to fabricate cylindrical concrete specimen (CCS) samples and producing two other types of CCS sample as control including one with low sludge content of 3.7% for Ref-1 and another with high sludge content of 12.7% for Ref-2 without the addition of OPC. It was also conducted to determine the optimal performance of the CCS samples using the compressive strength as the indicator of its mechanical properties and slump test for its workability in order to understand the reliability of combining natural sand with its high sludge content with other materials to fabricate the precast concrete structure.

2. MATERIAL AND METHODS

The following materials were used to fabricate the CCS samples:

Type I OPC, natural sand with 12.7% sludge content, coarse aggregate with a maximum size of 20 mm, and polycarboxylate ether-based superplasticizer (PCE) (Tamcem 60RA) delivered from PT. Normet, Jakarta, Indonesia.The common procedure was used in the production of the CCS samples and this involved blending the sand, coarse aggregate, PCE, and OPC in dry condition after which water was added in a cylindrical tube to make the mixture slurry [17-18]. The CCS produced were 15-cm diameter and 30-cm height in dimension and used to test for slump and compressive strength in four different compositions. Moreover, two references consisting of a dry mixture of OPC, sand, coarse aggregate, and PCE mixed with water at 0.22 (w/c) ratios as shown in Table 1 were also produced.

Table 1. Composition of material in the specimen

Material	Ref -1	Ref-2	CS1	CS2	CS3	CS4
OPC (kg/m^3)	498	498	511	524	536	549
Sand (kg/m^3)	710	710	710	710	710	710
Coarse aggregate (kg/m^3)	1126	1126	1126	1126	1126	1126
PCE (kg/m^3)	4.5	4.5	4.5	4.5	4.5	4.5
Sludge content (%)	3.7	12.7	12.7	12.7	12.7	12.7
w/c ratio	0.23	0.22	0.22	0.22	0.22	0.22

The four CCS samples with OPC contents were experimented as the dependent variables at the Civil Engineering Laboratory of PT. Wijaya Karya Beton. Meanwhile, the CCS sample (Ref-1) with washed sand and 3.7% sludge content was used as control and the w/c ratio of 0.23 was applied instead of the 0.22 used for all other samples due to the addition of more water to ensure the mixture forms slurry in the cylindrical tube. Moreover, the CCS sample (Ref-2) with natural sand and 12.7% sludge content without OPC was also used as control. The CCS sample with 2.5% OPC and natural sand with 12.7% sludge content was the first sample (CS1) while the OPC was varied at 5.0% for the second (CS2), 7.5% for the third (CS3), and 10.0% for the fourth (CS4).

The optimal performance of the samples was verified using compressive strength and slump test using eight specimens for each composition of the concrete materials. The slump test was conducted at the age of zero days before the commencement of the curing process to allow the concrete to gain a certain minimum tensile strength. Meanwhile, the compressive strength for all the CCS samples was determined consecutively at 3, 7, 14 and 28 days of the experiment. However, for the purpose of this work, the CCS was expected to have a minimum compressive strength of 50 MPa and the concrete mixture a minimum slump of 160 ± 20 mm.

3. RESULTS AND DISCUSSION

3.1. Analysis of compressive strength

The results presented in Fig. 1 show the compressive strengths for CS1, CS2, CS3, and CS4 were all higher than 50 MPa and this means the samples have a good performance reaching the standard quality and also observed to be gradually increasing with the age of the concrete [19-20]. Moreover, empirical evidence showed the values of f_c for CS3 and CS4 samples were almost similar and higher than CS1 and CS2 as shown in Fig. 1. This shows the addition of more OPC was able to improve the mechanical properties of CCS samples even though the contents of PCE is constant by acting as the glue binding the less reactive sand containing high sludge content additives together [21]. It was also discovered the compressive strength of the CCS sample with natural sand and 12.7% sludge content was below 50 MPa up to 28 days. The values of f_c Ref-1 were also observed to be higher than for Ref-2. The reduction in the compressive strength due to the increase in the sludge content is associated with its impact on the interaction between cement and sand [22-24], thereby, leading to the transfer of bigger flocs into smaller ones with remarkable effect on the sludge physical behavior [25]. However, the compressive strength of the CCS sample can increase at a constant value with the addition of certain OPC amounts as shown with the quite similar increase in f_c value of the CS1 and CS2 samples at 14 and 28 days caused by the additions of 2.5 and 5.0% OPC respectively. This was also evident with the similarity in the values obtained for CS3 and CS4 samples at 7, 14 and 28 days caused by the additions of 7.5 and 10.0% OPC respectively as shown in Fig. 1. This means the addition of more OPC in the production of concrete slurry can improve its mechanical characteristics and early age physical properties based on the high sludge content associated with the natural sand [26].

Natural sand with 12.7% sludge content, which is higher than the maximum of 5% required by the standard for precast concrete structure production, was used to fabricate the CCS samples and the increase in the OPC content of the mixture was discovered to be improving the compressive strength and subsequently other physical and mechanical properties which further led to the shrinkage of the samples [27-28]. The results presented in Fig. 1 showed despite the remarkable increase in the compressive strength for CS3 and CS4 between the 3rd and 7th day to produce a high grade of 67 MPa, a very slow improvement was recorded up to the 28th day. This was, however, better than the 66Mpa obtained for CS1 and CS2 samples at 14 and 28 days. This, therefore, means adding more than 5% of OPC can reduce the shrinkage of concrete [29] and this makes the fabrication of precast concrete structure to be uneconomical in practical applications.

3.2. Analysis of workability

The slump test results presented in Fig. 2 showed the use of natural sand with 12.7% sludge content combined with 2.5, 5.0, 7.5 and 10.0% OPC and different aggregates to produce a concrete mixture did not remarkably affect the consistency of the fresh concrete as indicated by the quite similar value of 190mm obtained in Fig. 2a and which is higher than the minimum value of 160mm recommended [30]. Moreover, the difference of 6 mm between 193mm for the Ref-1 and 187mm for CS1 presented in Fig. 2b is considered to be very small compared to a minimum tolerable error of ± 20 mm required for a slump test [31]. A minimum slump value of 160 ± 20 mm in the mixture of forecast concrete structure is reliable in the construction and civil engineering industries.

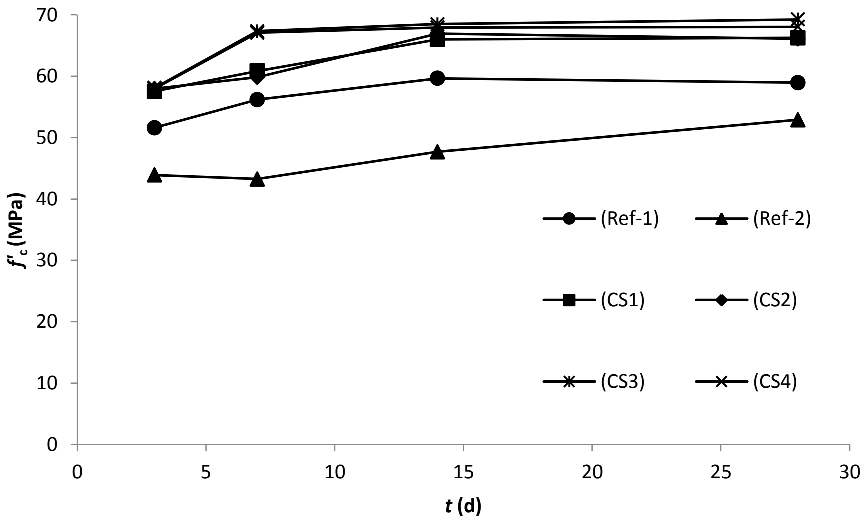

Fig. 1. Variation of compressive strength (f_c) pursuant to age (t) of the concrete

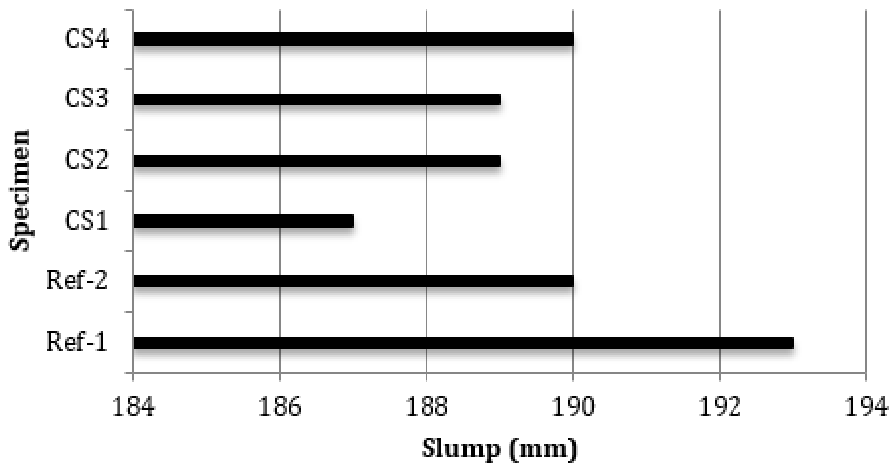

Fig. 2. Results of slump test for the different CCS samples

Sludge particles have the ability to absorb more water because they are smaller than sand, aggregates, and gravel. This, therefore, made the workability of the fresh concrete to be increasing with the content of the sludge in the concrete slurry while the slump was observed to be decreasing from 3.7% in Ref-1 to 12.7% in Ref-2, CS1, CS2, CS3 and CS4 as shown in Fig. 2b. This significant change in the workability was discovered to be due to the change in the water content [32]. Moreover, the PCE was added to maintain the workability towards ensuring the optimal blend of the CCS slurry mixture was properly placed in the cylindrical tube with adequate hardened strength. Meanwhile, the OPC was added to ensure the homogeneity of the fresh concrete and safe fabrication of the CCS samples with different compositions of the materials.

The addition of PCE into the concrete mixture performs the same function but differ in the treatment process with the implantation of element nitrogen ion to improve the strength and workability of a titanium-based material [33-34]. Furthermore, the empirical data justification in Fig. 1 shows the compressive strengths are quite similar for the ages of 14 and 28 days for all specimens despite the differences in the compositions of the CCS samples. Meanwhile, the PCE added produced an early high strength concrete due to the stimulation of the PCE-modified concrete slurry homogeneity.

4. CONCLUSIONS

This study tested the use of natural sand with a high sludge content of 12.7% and different variations of OPC at 2.5, 5.0, 7.5, and 10.0% in CS1, CS2, CS3, and CS4 samples, respectively, to determine the compressive strength and workability of the precast concrete structure. Moreover, two samples were used as controls and they include Ref-1 with 3.7% sludge content and Ref-2 with 12.7% sludge content without the addition of OPC. PCE was also added to ensure the mechanical properties and workability of the CCS samples was adequate to achieve optimal performance. The results, therefore, showed the addition of 2.5% OPC into the concrete mixture is reasonable when using natural sand with sludge content higher than 5.0% to fabricate the precast concrete structure. This means it is also reliable to use natural sand with 12.7% sludge content for future applications in civil engineering as long as other material compositions are adequate.

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