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Effects of Cement and Polycarboxylate Ether on the Performance Concrete with High Sludge Content

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Abstract: ***The use of precast concrete structural systems in civil engineering industry in Indonesia will still increase due to the needs of buildings and infrastructure for social and economic development continuously increase from the year to year. In spite of the use of sand accompanied with its suitable sludge content has been widely used as one of the important raw materials for fabricating a precast concrete, the availability of low cost method to obtain a good quality of sand with its sludge content of less than 5% is difficult to find in many regions in the country. The aim of this study was to assess the performance of four cylindrical concrete specimen (CCS) samples by conducting the experiments of testing the natural sand with its high sludge content of 12.7% with using the different ordinary Portland cement (OPC) compositions of 2.5, 5.0, 7.5 and 10.0% and the super-plasticizer of polycarboxylate ether. Two CCS samples of the same composition (1) using the washed sand with its sludge content of 3.7% and (2) without addition of OPC were used as control. The results of compressive strength and slump test verified that the addition of OPC at least by 2.5% into concrete slurry to ensure optimal performance of the CCS samples can be recommended using the natural sand accompanied with its sludge content of 12.7%. This study concluded that the use of local natural sand with its high sludge content as long as the other material compositions used properly could be safe in the fabrication of precast concrete structure for the future civil engineering applications.***

Keywords: Compressive strength, precast concrete, sludge content, slump test

I. INTRODUCTION

The use of the precast concrete structural systems in civil engineering industry in Indonesia will still increase from the year to year due to the needs for infrastructure development such as road, bridge, dam, airport and many other infrastructures for supporting social and economic development continuously increase [1].

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As it has been set up to the government policies that the infrastructure sector remains a priority in the national development plan for the next years to come. It is well known that a good quality concrete should be made using a good quality of sand (fine aggregate) accompanied with its low sludge content [2-3].

Unfortunately, it has been discussed in many previous studies that it is difficult to find the sand as one of the most important materials frequently used to make precast concrete products coming from natural sources [4-6]. According to PT. Wijaya Karya Beton, it would have been very difficult to obtain the natural sand with its sludge content of less than 5% [7] at some sand-producing quarries such as in Majalengka, Kuningan and Sumedang [8]. The use of local natural sand accompanied with high sludge content to fabricate a good good quality of concrete structure has been identified as a grand challenge facing civil engineering industry today and must be addressed in the further scientific research and data analysis [9-11]. Using any ash to fabricate a frecast concrete structure may require more cement to having a good workability and high compressive strength of the concrete [12-13]. Even though the development of self-healing in concrte has been proposed to increase the compressive strength and workability of concrete added with a certain colony of bacteria [14-16], the use of natural sand accompanied with its high sludge content must be verified. The objectices of this study are as follows: (1) to make four different ordinary Portland cement (OPC) compositions of fabricating the cylindrical concrete specimen (CCS) samples by using the natural sand with its high sludge content of 12.7% and to make two other types of CCS sample that having low sludge content of 3.7% for Ref-1 and that adding natural sand with its high sludge content of 12.7% for Ref-2 without the addition of OPC as control and (2) to determine the optimal performance of the CCS sample verified by its compressive strength to get better understanding on its mechanical properties and by slump test to get better understanding on its workability to having an insight on the reliability of using a typical composition of the materials for the fabrication of precast concrete structure of using natural sand with its high sludge content.

II. MATERIAL AND METHODS

For the fabrication of the CCS samples, this study used the following materials: the Type I cement of OPC,

natural sand accompanied with its sludge content of 12.7%, coarse aggregate with its maximum size of 20 mm and polycarboxylate ether-based superplasticizer (PCE) (Tamcem 60RA) delivered from PT. Normet, Jakarta, Indonesia. A common procedure was used to make the CCS samples, firstly blended sand, coarse aggregate, PCE and OPC in dry condition and then added water to make slurry in a cylindrical tube such thing as conventional concrete mixture [17-18].

The CCS with its dimension of 15-cm diameter and 30-cm height was used to test slump and compressive strength for four different compositions and two references consisting a dry mixture of OPC, sand, coarse aggregate and PCE and then mixed with water with 0.22 of water/cement (w/c) ratio (see Table 1).

The experiments for four CCS samples that using the OPC content as dependent variable were conducted at the Civil Engineering Laboratory of PT. Wijaya Karya Beton. The CCS sample (Ref-1) of using washed sand with its sludge content of 3.7% was used as control.

In this study, the w/c ratio should normally be set up at a proper value of 0.22 for all the CCS samples but it cannot be maintained the same value for the fabrication of CCS sample, which yields the w/c ratio of 0.23, there is due to the washed sand accompanied with its low sludge content of 3.7% may need to add a little more water for making its slurry in the cylindrical tube.

The w/c ratio can decrease from 0.23 for Ref-1 to 0.22 for the other CCS samples due to the use of natural sand with its high sludge content of 12.7% can reduce the use of water for making slurry. The CCS sample (Ref-2) of using natural sand with its sludge content of 12.7% without the addition of OPC was used also as control.

The CCS sample with the additon of 2.5% OPC of using the natural sand accompanied its sludge content of 12.7% was used for the first sample (CS1). The CCS sample with the additon of 5.0% OPC of using the natural sand accompanied its sludge content of 12.7% was used for the second sample (CS2).

The CCS sample with the additon of 7.5% OPC of using the natural sand accompanied its sludge content of 12.7% was used for the third sample (CS3). The CCS sample with the additon of 10.0% OPC of using the natural sand accompanied its sludge content of 12.7% was used for the fourth sample (CS4).

In this work, the experiments of determining the optimal performance of the CCS samples verified by compressive strength and slump test were carried out by using eight essays for each composition of the concrete materials. The slump test was performed at the age of zero day before the commencement of curing process to allow the concrete to gain a certain minimum tensile strength.

The compressive strength for every CCS sample was determined consecutively at 3, 7, 14 and 28 days of the experiment.

For the purpose of this work, the CCS samples should have a minimum compressive strength of 50 MPa and the concrete mixture should have a minimum slump of 160 ± 20 mm.

Table 1. Composition of material in the specimen

Material	Ref -1	Ref -2	CS 1	CS 2	CS 3	CS 4
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

III. RESULT AND DISCUSSION

A. Analysis of compressive strengh

The results (Fig. 1) show that compressive strengths for the CS1, CS2, CS3 and CS4 sample are all higher than 50 MPa to indicate a good performance of the CCS sample that reachs the standard quality and gradually increase with increasing the age of the concrete [19-20]. Empirical evidence shows that the values of f_c for the samples of CS3 and CS4 are almost similar higher than those for the samples of CS1 and CS2 that look like almost also similar each other (see Fig. 1). This may suggest that the increase in addition of OPC can improve the mechanical properties of CCS sample even though the contents of PCE added into concrete mixture are all constant. The addition of OPC thus acts as a glue to bind the less reactive sand of having its high sludge content additives together [21]. This study verified that the strength of CCS sample fabricated using the natural sand with its sludge content of 12.7% would be below than 50 MPa except the f_c value of such CCS sample measured at the age of 28 days. The values of f_c for the sample Ref-1 of being fabricated using the washed sand with its sludge content of 3.7% are all higher than those for the sample Ref-2 of being fabricated using the natural sand with its sludge content of 12.7% without the additon of OPC. Meaning that the compressive strength can decrease as the sludge content in CCS sample increases due to the presence of high sludge content in concrete mixture can affect the interaction between cement and sand [22-24] and thus leads to the transfer of bigger flocs into smaller ones, which has a remarkable effect on the sludge physical behaviour [25]. The compressive strength of the CCS sample can increase at a constant value with the addition of certain OPC amount as the experimental results verification shows that the increase in f_c value of the CS1 and CS2 samples caused by the additions of OPC as high as 2.5 and 5.0%, respectively, as measured at the ages of 14 and 28 days are quite similar and that of the CS3 and CS4 samples caused by the additions of OPC as high as 7.5 and 10.0%, respectively, as measured at the ages of 7, 14 and 28 days are almost similar (see Fig. 1). This suggests that more addition of OPC to make any concrete slurry can improve the mechanical characteristics and early age physical properties of the CCS sample based on the natural sand of being associated with its high sludge content [26].

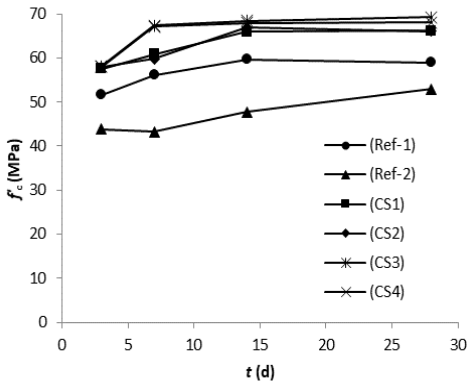

Fig. 1 Variation of compressive strength (f_c) pursuant to age (t) of the concrete

The use of natural sand with its sludge content of 12.7% higher than 5%, which is the maximum percentage of sludge to have been adopted as standard for the requirement specifications of frecast concrete structure production, can be used to fabricate the CCS samples. The increase of OPC content in concrete mixture may increase the compressive strength and affects other physical properties of the CCS sample hence this may reduce the shrinkage of CCS sample due to its mechanical properties of concrete improve [27-28]. The results (Fig. 1) show that even though the compressive strength for both the samples of CS3 and CS4 increases remarkably when the age of the concrete increases from 3 to 7 days, the early strength gained high grade of around 67 MPa for the CS3 and CS4 samples does increase, but very slowly, until the concrete age of 28 days beyond the time of the addition of OPC by 7.5 and 10.0%, respectively, while the strength gained high grade of around 66 MPa for the CS1 and CS2 samples can occur at the concrete ages of 14 and 28 days. As a conclusion, the addition of OPC higher than 5% can even reduce the shrinkage of concrete [29] and this makes the cost of fabricating the precast concrete structural systems for the purpose of civil engineering industry resulting in uneconomical practical applications.

B. Analysis of workability

The results (Fig. 2) of slump test for assessing the workability of the CCS samples show that the use of natural sand with its sludge content of 12.7% by the addition of OPC by 2.5, 5.0, 7.5 and 10.0% into a concrete mixture with its different aggregates does not remarkably affect the consistency of fresh concrete before it sets as the results (Fig 2a) of the concrete slump test verified that the values of slump are all quite similar to be around 190 mm higher than the minimum slump prerequisite of 160 mm [30]. The difference in slump value of 6 mm between the samples of Ref-1 and CS1 as it has verified by a slump value of 193 mm for Ref-1 and by that of 187 mm for CS1 (see Fig. 2b) could be very small when comparing with the minimum tolerable error of ± 20 mm for a slump test [31]. A minimum slump value of 160 ± 20 mm in the mixture of frecast concrete structure can be reliable in the construction and civil engineering industries. It is well known that sludge particles of smaller than sand, aggregates and gravel can absorb more water; therefore, the workability of the fresh concrete increases with increasing of sludge in concrete slurry as the slump of freshly prepared mixes was observed decreasing with increasing sludge content from 3.7% for the sample of Ref-1 to 12.7% the samples of Ref-2, CS1, CS2, CS3 and CS4 (see Fig. 2b). A significant change in the workability of fresh concrete verified by the slump test for all the CCS samples does not occur due to the concrete slurry mix of using the water at constant volume cannot influence them more than the amount of water used as active variable [32]. The aim of added PCE was to maintain the workability of concrete to ensure that the optimal blend of the CCS slurry mixture can be properly placed in cylindrical tube with its proper hardened strength. The addition of OPC into concrete slurry can help ensure the homogeneity of the fresh concrete and thus would likely be safe for the fabrication of the CCS samples with different compositions of the materials.

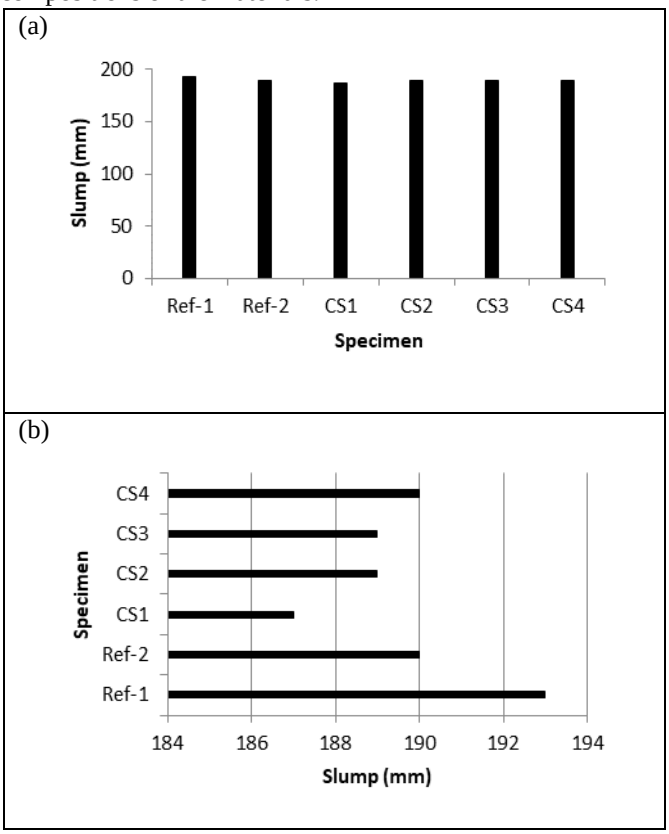

Fig. 2 Results of slump test for the different CCS samples

The addition of PCE into a concrete mixture in case of this work has similar function but differ in the treatment process of such as in case of the implantation of element into a material from which it has been reported that the implantation of nitrogen ion can improve the strength and workability of the titanium-based material [33-34]. Empirical data justification (see Fig. 1) shows that the compressive strengths are quite similar for the ages of 14 and 28 days for all specimens in spite of a decrease in the compressive strength has been verified for certain CCS samples. This means that all the CCS samples with their different amounts of OPC can have the same measured strength of the concrete, which was manifesly beyond 14 days of the experiment. The use of PCE yielding early high strength concrete is due to the effect of added PCE to a mixture concrete can stimulate the homogeneity of the PCE-modified concrete slurry.

The sludge content in natural sand can reduce the van der Waals forces of cement paste-aggregate interaction of the CCs samples [35-36] due to the presence of both alkaline and sulphate in sludge can disrupt the binding process in spite of the addition of OPC into concrete mixture has been performed to improve strength of the concrete.

IV. CONCLUSION

This study tested the CCS samples of using the natural sand with its high sludge content of 12.7% and the different amounts of OPC by adding 2.5, 5.0, 7.5 and 10.0% into the samples of CS1, CS2, CS3 and CS4, respectively, to verify the compressive strength and workability of the precast concrete structure. Two samples of Ref-1 with its sludge content of 3.7% and Ref-2 with its sludge content of 12.7% without the addition of OPC were used as control. The addition of PCE can ensure the mechanical properties and workability of the CCS samples to reach at an optimal performance. The addition of OPC by 2.5% into a concrete mixture could be reasonable when the use of natural sand with its its sludge content of higher than 5.0% could be useful for the fabrication of precast concrete structure. The use of natural sand with its sludge content of 12.7% has been verfied to be reliable for the fabrication of precast concrete structure, and this study recommends the feasibility of using the local natural sand as long as the other material compositions used properly for the future applications in civil engineering.

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REFERENCES

1. Chou, M.C. Does tourism development promote economic growth in transition countries? A panel data analysis. *Economic Modelling* 33: 226-232 (2013).
2. Prakash, K.S., & C.H. Rao. Study on compressive strength of quarry dust as fine aggregate in concrete. *Advances in Civil Engeering* 2016: 1742769 (2016).
3. Siddique, R., G. de Schutter, & A. Noumowe. Effect of used-foundry sand on the mechanical properties of concrete. *Construction and Building Materials* 23: 976-980 (2009).
4. Gutt, W. The use of by-products in concrete. *Resources Policy* 1: 29-45 (1974).
5. Baojian, Z., P. Chisun, & S. Caijun. CO_2 curing for improving the properties of concrete blocks containing recycled aggregates. *Cement and Concrete Composites* 42: 1-8 (2013).
6. Siddique, R. Utilization of industrial by-products in concrete. *Procedia Engineering* 95: 335-347 (2014).
7. Mailar, G., N. Sujay Raghavendra, B.M. Sreedhara, D.S. Manu, H. Parameshwar, & K. Jayakesh. Investigation of concrete produced using recycled aluminium dross for hot weather concreting conditions. *Resource-efficient Technolology* 2: 68-80 (2016).
8. Omar, O.M., G.D. Abd Elhameed, M.A. Sherif, & H.A. Mohamadien. Influence of limestone waste as partial replacement material for sand and marble powder in concrete properties. *HBRC Journal* 8: 193-203 (2012).
9. Barrera-Diaz, C., G. Martinez-Barrera, O. Gencel, L.A. Bernal-Martinez, & W. Brostow. Processed wastewater sludge for improvement of mechanical properties of concretes. *Journal of Hazardous Materials* 192: 108-115 (2011).
10. Becerik-Gerber, B., M.K. Siddiqui, I. Brilakis, O. El-Anwar, N. El-Gohary, T. Mahfouz, G.M. Jog, S. Li, & A.A. Kandil. Civil engineering grand challenges: Opportunities for data sensing, information analysis, and knowledge discovery. *Journal of Computing in Civil Engineering* 28(4): 04014013 (2014).
11. Kaewunruen, S., J.M. Sussman, & A. Matsumoto. Grand challenges in transportation and transit systems. *Frontiers in Built Environement* 2:4. doi: 10.3389/fbuil.2016.00004 (2016).
12. Muhtadhi, A., & V. Dhivya. Investigating strength properties of geopolymer concrete with quarry dust. ACI Materials Journal 88: 355-363 (2017).
13. Zachar, J. Sustainable and economical precast and prestressed concrete using fly ash as a cement replacement. Journal of Materials in Civil Engineering 23, 6: (2011).
14. Omoregle, A. Impact of vibration time on compressive ctrength of hardened sandcrete building blocks. Buildings 2: 153-172 (2012).
15. Talaiekhozan, A., A. Keyvanfar, A. Shafaghat, R. Andalib, M.Z. Abd Majid, M.A. Fulazzaky, R.M. Zin, C.T. Lee, M.W. Hussin, N. Hamzah, N.F. Marwar, & H.I. Haidar. A Review of self-healing concrete research development. Journal of Environmental Treatment Techniques 2: 1-11 (2014).
16. Talaiekhozani, A., A. Keyvanfar, R. Andalib, M. Samadi, A. Shafaghat, H. Kamyab, M.Z. Abd Majid, R.M. Zin, M.A. Fulazzaky, C.T. Lee, M.W. Hussin, N. Hamzah, N.F. Marwar, & H.I. Haidar. Application of Proteus mirabilis and Proteus vulgaris mixture to design self-healing concrete. Desalination and Water Treatment 52: 3623-3630 (2014).
17. Sulaeman, A., M.A. Fulazzaky, M. Haroen, & I. Bakar. Field test results of palm oil clinker concrete pile and foamed concrete pile for floating foundation in soft soil. KSCE Journal of Civil Engineering DOI: 10.1007/s12205-017-1729-9 (2017)
18. Abd Elaty, M.A. Compressive strength prediction of Portland cement concrete with age using a new model. HBRC Journal 10: 145-155 (2014).
19. Fedorovaa, G., V. Mestnikovb, O. Matveevac, & E. Nikolayev. Features of high-strength concrete creation for concreting of monolithic constructions in the Far North conditions. Procedia Engineering 57: 264-269 (2013).
20. Bickley, J.A., & D. Mitchell, A State-of-the-Art Review of High Performance Concrete Structures Built in Canada: 1990-2000. McGill University, Montreal, Canada (2001).
21. Sobolev, K., F. Sanchez, & I.F. Vivian, The use of nanopacticle admixtures to improve the performance of concrete. The 12th International Conference on Recent Advances in Concrete Tchnology and Sustainability Issues, pp. 455-469 (2012).
22. Malliou, O., M. Katsioti, A. Georgiadis, & A. Katsiri. Properties of stabilized/ solidified admixtures of cement and sewage sludge. Cement and Concrete Composites 29: 55-61 (2007).
23. Katsioti, M., N. Katsiotis, G. Rouni, D. Bakirtzis, & M. Loizidou. The effect of bentonite/cement mortar for the stabilization/solidification of sewage sludge containing heavy metals. Cement and Concrete Composites 30: 1013-1019 (2008).
24. Liu, M., Y. Duang, & H. Li. Effect of modified sludge on the rheological properties and co-slurry mechanism of petroleum coke-sludge slurry. Powder Technology 243: 18-26 (2013).
25. Mahmoud, N., G. Zeeman, H. Gijzen, & G. Lettinga. Interaction between digestion conditions and sludge physical characteristics and behaviour for anaerobically digested primary sludge. Biochemical Engineering Journal 28: 196-200 (2006).
26. Kotwal, A.R., Y.J. Kim, J. Hu, & V. Sriraman. Characterization and early age physical properties of ambient cured geopolymer mortar based on class C fly ash International Journal of Concrete Structures and Materials 9, 35-43 (2015).
27. Hama, S.M. Improving mechanical properties of lightweight Porcelanite aggregate concrete using different waste material. International Journal of Sustainable Built Environment 6: 81-90 (2017).
28. Sellami, A., M. Merzoud, & S. Amziane. Improvement of mechanical properties of green concrete by treatment of the vegetals fibers. Construction and Building Materials 47: 1117-1124 (2013).
29. Mora-Ruacho, J., R. Gettu, & A. Aguando. Influence of shrinkage-reducing admixtures on the reduction of plastic shrinkage cracking in concrete. Cement and Concrete Research 39: 141-146 (2009).
30. Zhao, l., X. Guo, Y. Liu, C. Ge, Z. Chen, L. Guo, & X. Shu, Investigation of dispersion behavior of GO modified by different water reducing agents in cement pore solution. Carbon 127: 255-269 (2018).
31. Laskar, A.I. Correlating slump, slump flow, vebe and flow tests to rheological parameters of high-performance concrete. Materials Research 12: 75-81 (2009).
32. Park, S.-B., & Tia, M. An experimental study on the water-purification properties of porous concrete. Cement and Concrete Research 34: 177-184 (2004).
33. Fulazzaky, M.A., N. Ali, H. Samekto, & M.I. Ghazali. Assessment of CpTi surface properties after nitrogen ion implantation with various dose and energy. Metallurgical and Materials Transactions A 43: 4185-4193 (2012).
34. Ali, N., M.A. Fulazzaky, M.S. Mustapa, M.I. Ghazali, M. Ridha, & T. Sujitno. Assessment of fatigue and corrosion fatigue behaviours of the nitrogen ion implanted CpTi. International Journal of Fatigue 61: 184-190 (2014).
35. Fulazzaky, M.A. Determining the resistance of mass transfer for adsorption of the surfactant onto granular activated carbons from hydrodynamic column. Chemical Engineering Journal 166: 832-840 (2011).
36. Fulazzaky, M.A., M.H. Khamidun, M.F.M. Din, & A.R.M. Yusoff. Adsorption of phosphate from domestic wastewater treatment plant effluent onto the laterites in a hydrodynamic column. Chemical Engineering Journal 258: 10-17 (2014).