

## Compressive strength of marine material mixed concrete

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**Abstract.** Many cement factories have been incorporated fly ash with clinker cement to produce blended cement. PCC is a type of blended cement incorporated fly ash that produced in Indonesia cement factories. To promote the sustainable development in the remote islands this present paper attempted to study the suitability of sea water, marine sand that available abundantly surround the remote island with Portland Composite Cement (PCC) and crushed river stone to produce concrete. Slump test was conducted to evaluate the workability of fresh concrete and also compressive strength with stress-strain relationship was carried out to evaluate the hardened concrete that cured with two curing condition (e.g. sea water curing, and tap water-wet burlap curing). Test result indicated that fresh concrete had proper workability and all hardened specimens appeared a good compaction result. Compressive strength of specimens cured which sea water was higher than the specimens which cured by tap water-wet burlap where stress-strain behavior of specimens made with sea water, marine sand, and PCC had similar behavior with specimens which made with PCC and tap water.

### 1. Introduction

In Indonesia, most of the coal used in this country is burned to generate electricity in the coal fired thermal power plant. Fly ash is the main residue from coal burning. The majority of fly ash is still disposed in landfills, which creates the environmental issue, where a landfill surcharge is needed in many areas. Hence, new recycling approaches are necessary to produce value-added products from fly ash instead of considering it as a waste material to be disposed. To obtain an environment friendly technology and to achieve material saving through the recycling of waste materials such as fly ash, then several cement factories produce and develop the blended cement containing fly ash such as Portland Composite Cement (PCC) [1-2]. Currently, most of the concrete constructions in Indonesia use PCC instead of Ordinary Portland Cement (OPC) or Portland Cement Type I. Therefore, this research attempted to use PCC containing fly ash as cementitious material. As the world's largest archipelagic state, Indonesia surrounded with 7.9 million square kilometres of sea water where many people live in the remote islands. In this concern, many serious works have been conducted enhance the sustainable infrastructure development in the remote islands. The utilization of sea water, and marine sand can reduce the consumption of fresh water and river sand, furthermore, will decrease the cost of concrete work in the low land areas and the distant-remote islands those lack of clean water and river sand. Several experimental studies have been conducted about the producing of concrete with sea water and marine sand [3-6].



This paper report for a part of the ongoing investigation which focus to study concrete made by PCC and marine material. The testing result on the workability of fresh concrete and compressive strength with stress-strain relationship of hardened concrete were discussed.

## 2. Materials and experimental methods

Table 1 shows the characteristics of sea water. The prominent compound are  $\text{Cl}^-$ , Na and Mg.

**Table 1.** Characteristics of sea water.

Density ( $\text{g/cm}^3$ )	pH	Chemical composition (mg/L)					
		Na	Ca	Mg	$\text{Cl}^-$	$\text{SO}_4$	$\text{CO}_3$
1.03	8.53	2085.22	348.35	1973.49	5303.70	134	576.58

The experiments were carried out using PCC with containing of fly ash and produced by Indonesia cement manufacture. Characteristics of PCC used in this research are shown in table 2 and meet with SNI 15-7064-2004 (Indonesia Standard for PCC).

**Table 2.** Characteristics of PCC.

Physical properties	
Initial setting time (min)	132
Final setting time (min)	224
Specific surface ( $\text{m}^2/\text{kg}$ )	341
Specific gravity ( $\text{g/cm}^3$ )	3.08
Bulk density ( $\text{kg/L}$ )	1.10
Compressive strength:	
- 3 days ( $\text{kg/cm}^2$ )	162
- 7 days ( $\text{kg/cm}^2$ )	231
- 28 days ( $\text{kg/cm}^2$ )	333
Chemical properties	
	%
MgO	0.99
$\text{SO}_3$	1.81
$\text{SiO}_2$	18.39
$\text{Al}_2\text{O}_3$	5.15
$\text{Fe}_2\text{O}_3$	3.41
CaO	61.79
LOI	4.61

Table 3 shows some physical properties of aggregates. Crushed river stone and marine sand were used as coarse aggregate and fine aggregate, respectively. Table 4 shows chemical properties of marine sand. All aggregates were used in saturated surface dry condition, and their were soaked into the sea water for 24 hours to produce saturated surface dry condition.

**Table 3.** Physical properties of aggregates.

Property		Crushed stone (diameter of 10-20 mm)	Marine sand
Specific gravity	Oven dry	2.89	2.43
	Saturated surface dry	2.91	2.47
Water absorption (%)		0.62	1.75

**Table 4.** Chemical composition of marine sand.

Chemical Composition (%)						
Mg	Fe	Ca	Al	Cl	SiO <sub>2</sub>	MgO
1.1	3.6	1.8	12	0.04	51190	1.95

Table 5 shows proportion of concrete mix. The mixture was prepared in the laboratory. The slump design was  $10 \pm 2.5$  cm. Fresh concrete was pouring into the cylindrical mold with diameter and height of 10 cm and 20 cm, respectively. All specimens were demolded after 24 hours of casting. After demolding, the specimens were divided into two sets the curing condition. Two curing condition, wet-burlap curing with tap water and sea water immersion curing were designed.

**Table 5.** Mix proportion of concrete (1 m<sup>3</sup>).

w/c	Water (kg)	Cement (kg)	(Fine aggregate) Marine sand (kg)	(Coarse aggregate) Crushed stone (kg)
0.4	204	513	477	1099

Slump test was done according to SNI 1972-1990 (Method of test for slump test). The compressive strength and static modulus were tested with according to SNI 1974-2011 (Method of test for compressive strength of concrete). Two load variable transducers displacement (LVDT) used to measure displacement and to calculate vertical strain under compressive load. The compressive load and vertical strain recorded by a computerized data logging system.

### 3. Results and discussion

#### 3.1. Slump test

Fresh concrete had a slump value of 9 cm with met the slump design of  $10 \pm 2.5$  cm. Visual observation (figure 1) revealed that fresh paste made with sea water and PCC could maintain the workability and homogeneity of the mixture without segregation, bleeding did not occur, and no coarse aggregates pilling at the bottom of specimen.

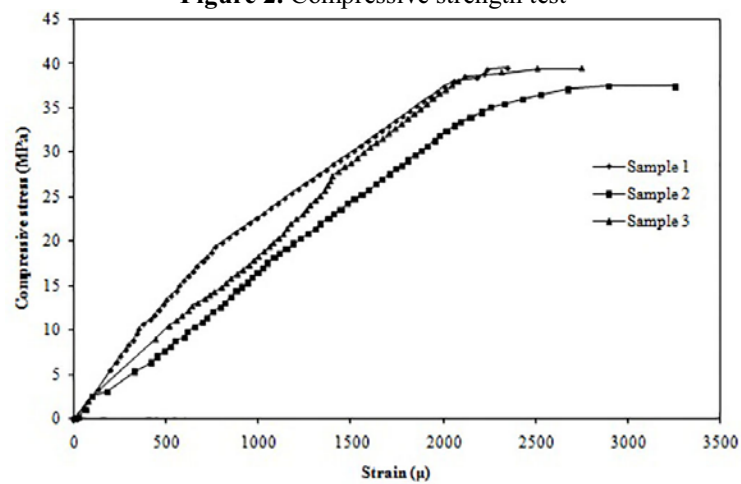
**Figure 1.** Slump Test.

#### 3.2. Compressive strength and stress strain behavior

The visual observation of the cylindrical specimens before compressive strength test shows that the surface of hardened concrete was smooth without any honey comb, and large air voids, also no pilling of coarse aggregates. This result showed that fresh concrete consisted of sea water, marine sand, PCC and crushed river stone can be poured with maintaining mixture homogeneity led to a good achievement of compaction.

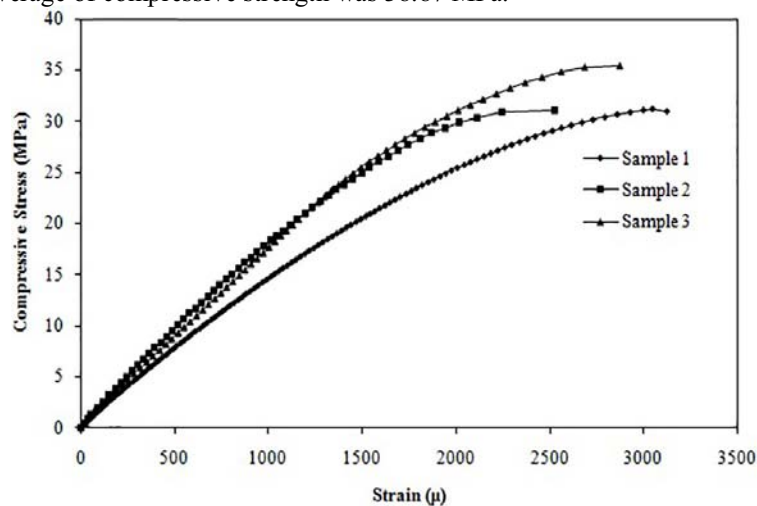


**Figure 2.** Compressive strength test



**Figure 3.** Stress-strain curve of concrete cured in the sea water

Figure 3 shows the stress-strain behavior curves of the three hardened concrete specimens with cured in sea water until 28 days. The concrete specimens attained the fracture strain from 2755  $\mu$  to 2900  $\mu$ . The average of compressive strength was 38.87 MPa.



**Figure 4.** Stress-strain curve of cured with tap water-wet burlap

Figure 4 illustrates the stress-strain behavior curves of the three hardened concrete specimens that cured with tap water-wet burlap until 28 days. The normal concrete specimens attained the fracture strain from 2500  $\mu$  to 3100  $\mu$ . The average compressive strength of normal concrete specimen was 32.46 MPa.

Based on compressive strength test result, it can be noticed that an interaction between all materials through the bond between the paste made with sea water and PCC and the aggregates can achieve a good capability of concrete made with sea water, marine sand, PCC, and river coarse aggregate to load transfer mechanism from paste to aggregates and vice versa. Such attributes ensure the capability to withstand the compressive load.

Based on figure 3 and figure 4, it was observed that 19.74% higher in compressive strength by using sea water curing when compared with the concrete cured with tap water-wet burlap. This phenomenon showed that the presence of salt in sea water and marine sand did not affect hydration process and sea water can be used to cure concrete and the proper hydration process of concrete can take place to obtain a good compressive strength.

Furthermore, it can be seen that based on the literature review [7], the strain value of concrete made with sea water, marine sand, PCC and crushed river stone similar to the ordinary concrete made with OPC and fresh water.

#### 4. Conclusions

1. The slump test result showed that fresh concrete had a proper workability while the hardened specimen exhibited that the mixture can maintain its homogeneity during pouring process into the mold and compaction process led to achieving a good compaction result without honeycombs, and large void appeared on the surface of specimens.
2. Compressive strength test showed that the specimens that cured in the sea water had a higher 28 days compressive strength as compared with the specimens cured with tap water-wet burlap while based on the literature review, the strain value of concrete made with sea water, marine sand, PCC and crushed river stone similar to the ordinary concrete made with OPC and fresh water.

#### 5. References

- [1] Antiohos S and Tsimas S 2005 Investigating the role of reactive silica in the hydration mechanism of high-calcium fly ash/cement systems, *Cement and Concrete Composites* **27**(2) 171-181.
- [2] Uddin M A, Jameel M, Sobuz H R, Islam M S and Hasan N M S 2012 Experimental study on strength gaining characteristics of concrete using PCC *KSCE Journal of Civil Engineering* **17**(4) 789-796.
- [3] Tjaronge M W, Irmawaty R, Adisasmita S A 2014 Compressive strength and hydration process of self compacting Concrete (SCC) mixed with sea water, marine sand, and PCC, *Advance Material Research* **935** 242-246.
- [4] Wegian F M 2010 Effect of sea water for mixing and curing on structural concrete, *The IES Journal Part A: Civil & Structural Engineering* **3**(4) 235-243.
- [5] Otsuki N, Furuya D, Saito T and Tadokoro Y 2011 Possibility of sea water as mixing water in concrete, *Proceedings of 36<sup>th</sup> Conference on Our World in Concrete & Structures (Singapore)* vol 1 pp 14-16.
- [6] Katano K, Takeda N, Ishizeki Y and Iriya K 2013 Properties and application of concrete made with sea water and un-washed sea sand, *Third International Conference on Sustainable Construction Materials and Technologies (Japan)* vol 3 pp e172.
- [7] Neville A M and Brooks J J 1987 *Concrete Technology* (New York: Longman Scientific & Technical).

#### Acknowledgments

Authors wishing to acknowledge all members of Eco-material laboratory Hasanuddin University.