Effect of In-Situ Curing on Compressive Strength of Reactive Powder Concrete

Ika Bali[1,a*], Widodo Kushartomo[2,b] and Jonathan[2,c]

[1]Dept. of Construction Engineering & Management, Podomoro University, Jl. Letjen. S. Parman Kav.28, Jakarta 11470, Indonesia
[2]Dept. of Civil Engineering, Tarumanagara University, Jl. Letjen. S. Parman No.1, Jakarta 11440, Indonesia

[a]ikabali@yahoo.com, [b]widodo@untar.ac.id, [c]jonathanjapri@gmail.com

Abstract. A development of Reactive Powder Concrete (RPC) currently is the use of quartz powder as a stabilizing agent with the content to cement ratio of 30% and steam curing method in an autoclave temperature of 250ºC which produced a high compressive strength of 180 MPa. That RPC can be generated due to one reason for using the technique of steam curing in an autoclave in the laboratory. This study proposes in-situ curing method in order the curing can be applied in the field and with a reasonable compressive strength results of RPC. As the benchmarks in this study are the curing methods in laboratory that are steam curing of 90°C for 8 hours (C1), and water curing for 28 days (C2). For the in-situ curing methods that are covering with tarpaulins and flowed steam of 3 hours per day for 7 days (C3), covering with wet sacks for 28 days (C4), and covering with wet sacks for 28 days for specimen with unwashed sand as fine aggregate (C5). The comparison of compressive strength of the specimens in this study showed compressive strength of RPC with in-situ steam curing (101.64 MPa) close to the compressive strength of RPC with steam curing in the laboratory with 8.2% of different. While in-situ wet curing compared with the water curing in laboratory has the different of 3.4%. These results indicated that the proposed in-situ curing methods are reasonable good in term of the compressive strength that can be achieved.
Keywords: reactive powder concrete, in-situ curing, steam curing, compressive strength.

1 Introduction

In general, the Reactive Powder Concrete (RPC) with its very high compressive strength can be made by precast in laboratory or factory. For this purpose, steam curing can be carried out in conditions that can be controlled with a certain temperature for a few hours. Thus the

*Corresponding author: ikabali@yahoo.com

hydration process can take place properly and compressive strength of concrete is expected to be achieved.

Unlike the case of RPC with the application on road pavement for example, it is casted directly on the ground or casted in-situ. In this case, the method of RPC curing after casting should be taken into account carefully. In-situ curing is usually done in the field by covering the concrete with wet sacks for several days. This study propose the in-situ steam curing by covering the RPC by a tarp and then flow the steam of 3 hours a day for 7 days. The objective of this study is to investigate the effect of the in-situ steam curing on the compressive strength of the RPC.

2 Development of RPC

The RPC can be specified on the composition of its constituent materials and calcium-silicate- hydrates (CSH). It is formed by very fine powder materials such as cement, fine aggregate, water, high reactive pozzolan, admixture materials, quartz powder, and often also added steel fiber. High reactive pozzolan as silica fume is an important constituent in the RPC in order to fill the cavity in the mortar and to react with the reaction results of cement hydration. The quartz powder in this case is used for the stabilization of the RPC strength.

The stabilization of RPC strength using the quartz powder as one of the main constituent components is reported that can reach a high compressive strength of 180 MPa [1]. In this RPC, quartz powder content to cement ratio is 30% and using the steam curing technique in an autoclave temperature of 250ºC.

Quartz powder in the RPC can be substituted by the glass particle since it demonstrated quite good technical properties, i.e. compressive strength, flexural strength, and modulus of elasticity [2]. The other advantage is that the glass particles have an active pozzolanic material due to the amorphous silica as the glass-making material. If it is combined with calcium from portlandite (Ca(OH)2), it will form a second form of CSH, which upgrades the properties of concrete.

Glass particle from glass waste has an increasing importance as a new alternative source of pozzolanic addition for concrete materials. Using 20% of waste glass powder to substitute the cement content in the concrete and with 28 days of water curing, the compressive strength of 36 MPa can be reached. The concrete is suitable for the application in concrete pavement of highway [3].

The glass powder as a substitution material of the quartz powder in RPC was also studied as concerning the use of local and recycled material. The quartz powder was grinded to micron meter size from the waste glass shards material of housing industry. The RPC that used glass powder with the content as much as 20% of cement mass, and the maximum temperature of steam curing of 95ºC has the maximum compressive strength of 136 MPa [4]. For this study, the RPC materials use the glass powder as a substitution of quartz powder with the amount of 20% of the cement content. In order to apply the RPC in the field as the road pavement, the in-situ steam curing is introduced.

3 Methodology

The RPC in this study uses glass powder from the waste glass shards material that grained to smaller than 0.15 mm size with the content as much as 20% of cement mass. Proportion of mix design of RPC with glass powder content of 20% is shown in Table 1. The main materials are used included PCC (Portland Composite Cement), water, glass powder (sieve passing of 0.15 mm), silica fume, superplasticizer (type F), sand (sieve passing of 1.2 mm), and straight steel fiber (Ø = 0.15 mm, and length of 15.0 mm).

Table 1. Proportion Of Mix Design (1 M^3)

No.	Material	Content (kg)
1.	Water	140.60
2.	Cement (PCC)	703.00
3.	Sand	1054.5
4.	Silica Fume	175.75
5.	Superplasticizer	21.09
6.	Glass Powder	140.60
7.	Steel Fiber (volume of 1.5%)	117.75

For the curing method, it consists of the curing methods in laboratory and the in-situ curing methods. The curing methods in laboratory are steam curing with temperature of 90°C for 8 hours in 1 day after casting (C1), and water curing for 28 days (C2) as seen in Fig.1. In order to simulate the in-situ steam curing method (Fig. 2), the specimens are covered by tarpaulins and flowed steam with temperature of 90°C through a pipe in 3 hours per day for 7 days (C3). Fig. 3 shows the in-situ wet curing method namely covering with wet sacks for 28 days (C4), and covering with wet sacks for 28 days for specimen with unwashed sand as fine aggregate (C5). Each curing method is represented by 5 cylinder specimens with diameter (Ø) of 10 cm and height of 20 cm. The test of specimens is conducted using the compressive strength test (Fig. 4).

Fig. 1. The steam and water curing (in laboratory).

Fig. 2. Simulation of the in-situ steam curing.

Fig. 3. Simulation of the in-situ wet curing.

Fig. 4. Compressive strength test.

4 Results and Discussions

The test results of average compressive strength on Reactive Powder Concrete (RPC) with the steam curing in laboratory (C1), the water curing (C2), the in-situ steam curing (C3), the in-situ wet curing (C4), and the in-situ wet curing for the specimen with unwashed sand (C5) are respectively, 110.73 MPa, 102.36 MPa, 101.64 MPa, 98.88 MPa, and 73.47 MPa (Fig. 5).

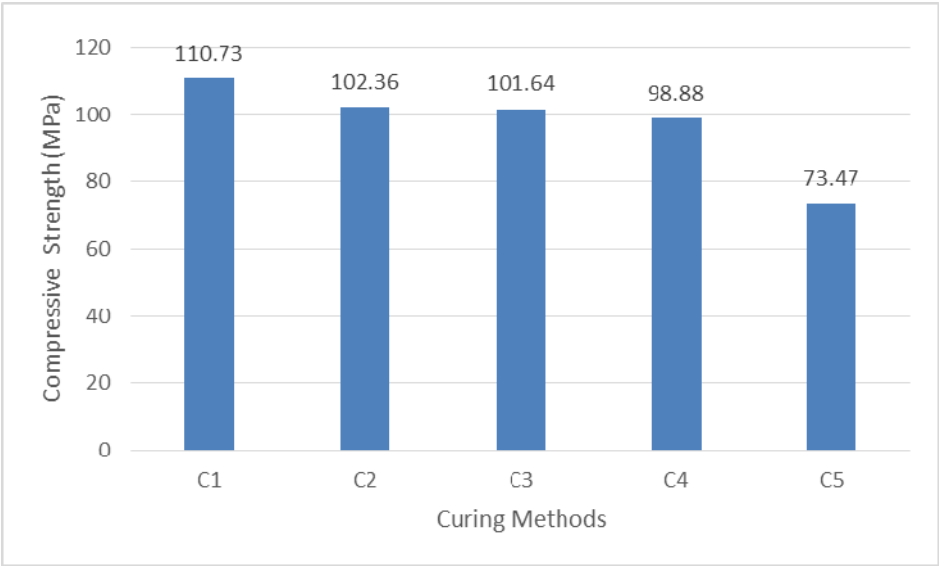

Fig. 5. Average compressive strength of the specimens with various curing methods

As reported in the previous research report [1], the steam-curing of 90°C for 24 hours and the water curing of 20°C for 28 days both curing methods showed detectable presence of cement, ettringite (rigid gel), and Ca $(OH)_2$. However, the RPC that treated with steam curing of 90°C for 24 hours was also detected tobermorite (crystals) are more dense than ettringite, while the RPC that treated by water curing of 20°C for 28 days was not detected tobermorite. This possibly causes the value of the compressive strength of RPC treated with steam curing of 90°C for 8 hours (C1) in this study that have a greater value than the other curing methods. Tobermorite is the result of continued reaction from the cement hydration namely calcium hydroxide with SiO_2.

The average compressive strength of the in-situ steam curing is different by 8.2% from the average compressive strength of the steam curing in laboratory. In the other hand, the average compressive strength of the in-situ wet curing is different only 3.4% from the water curing in laboratory. Based on these results, this study showed that the in-situ steam curing and the in-situ wet curing are quite good to be applied to the RPC. The average compressive strength of the in-situ wet curing for specimen with unwashed sand exhibited 28.2% lower than the specimen of water curing in laboratory due to the presence of the mud in unwashed sand that blocking the bonding between the cement paste and aggregate.

5 Conclusion

Comparing the test results of compressive strength in Reactive Powder Concrete (RPC) of the various methods of curing, the conclusion can be described as follows. The average compressive strength of the in-situ steam curing (C3) in this study can reach 101.64 MPa. The average compressive strength of C3 is close to the average compressive strength of the steam curing in laboratory (C1) with the different of 8.2%. The average compressive strength of the in-situ wet curing (C4) is lower only 3.4% compared with the water curing in laboratory (C2). This study indicated that the in-situ steam curing and the in-situ wet curing are reasonable good and can be applied for the RPC.

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