Mechanical Properties of DPCC using Mixture Method

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ABSTRACT

Today, the production of concrete curbs with improved properties is very important and economical. Increasing the life time and improving the mechanical properties have always been two key parameters in the production of these curbs. Since porosity is an effective parameter in the durability and life time of the structure and as the compressive strength is a parameter affecting the mechanical properties of these curbs, an attempt has been made in this study to investigate the experiments and the importance of porosity and compressive strength in dry-pressed concrete curbs (DPC). In order to this aim, 27 sample designs (DPC) were prepared based on three cement strength class as 32.5, 42.5 and 52.5 MPa. The water-cement ratio (0.2, 0.25 and 0.3) and the amount of the existing cement (300, 350, 400 kg / m 3) in the mixture design were considered along with the proportion of aggregate to cement as the main parameters of the experiment. The results of the compressive strength and the percentage of porosity in the mentioned samples were examined through data analysis and the mixture method. The results obtained by the mixture method point to the role of cement strength in the mechanical properties of concrete.

Keywords: Dry-pressed concrete curbs (DPC), Cement Classification, Compressive Strength, Porosity, Mixture model

1. INTRODUCTION

In the new construction industry, the production and use of prefabricated pieces is one of the methods for using concrete. One of the most widely used factors is the use of pressed concrete curbs which are of great interest due to the durability of this product resulting from its high porosity and the speed of production [1, 2]. In the dry-pressed method being considered in this research, the concrete with rigid and dry levels of application, also known as the non-slump concrete. One of the advantages of the dry-pressed method is the speed of manufacturing and the withdrawal of the piece from the mold immediately after the placement and accumulation which does not require a large number of molds. Furthermore, some studies have shown that the ratio of water to less amounts of cement in the concrete being used in this method leads to an improvement in the quality of the product. Porosity has been more effective than the compressive strength as a critical parameter in determining the durability of these curbs and their resistance to melting and freezing [3]. In addition, porosity is a factor with a significant impact on the mechanical properties of materials[4, 5]. Porosity depends on several factors such as the type and size of the materials, the distribution of pores, and compounds as their reduction generally leads to an increase in the solidity of matter [6-8]. It should be noted that aggregates have a significant role in the concrete properties as they constitute about three-quarters of the weight of the concrete, so that the maximum size of aggregate may directly affect the mechanical properties of the concrete. It is observed that by decreasing the maximum size of aggregates and increasing the gradation softness module, the mechanical properties of the dry-pressed concrete are improved [9]. The strength of the cement is among the other parameters that play a basic role in the compressive strength of concrete samples [10-12]. Moreover, the cement with lower porosity produces better compressive strength [7, 13, 14]. In addition to porosity, the other factor that influences the mechanical properties of cement materials is the contents or amount of the cement[15, 16]. It is worth mentioning that several parameters affecting the properties of concrete have been controlled and investigated for the first time in this study. This has been indicated in previous studies by increasing porosity based on the decrease in the resistance of cement materials. However, the present research deals with the effect of the grade and content of cement and the effect of water and the proportion of gravel to cement on compressive strength and percentage of porosity in DPC at three levels of cement strength (32.5, 42.5 and 52.5 MPa) which have not been investigated thus far. In this research, 27 different DPC mixture designs have been developed to investigate the simultaneous effect of porosity and determine the compressive strength of the DPC sample, cement rate and content in the mechanical properties of the samples by analyzing the experimental data and the diagrams derived through the mixture method.

2. The characteristics of used materials

In order to make these samples, fine aggregate and coarse aggregate and materials have been used in to the grain size curve according to the ASTM Code. The water used for the mixture design was clean and drinkable. Produced the samples using three cement strength class, 325-2, 425-2, and 525-2 MPa which were produced at Sabzevar factory. The cement has been produced according to ISIRI 389 National Standard.

3. Making the samples of concrete curbs and performing the experiment

used type II Portland cement in three strength class, namely 32.5, 42.5 and 52.5 MPa which were produced at Sabzevar factory in Iran. The softness modulus of aggregates in samples was calculated as 4.57. Three cement volumes of 300, 350 and 400 kg / m3 and three water-cement ratios (0.3, 0.25, and 0.20) were used to prepare and produce the DPC samples. To achieve the standard dimensions, the DPC samples were cut by the device in (10 × 10 × 50 cm and 10 × 10 × 10 cm) dimensions[17].

4. Sample test method

In this study, the measurement of compressive strength was performed according to BS 1881 Standard[18]. In order to determine the porosity, all samples (10 × 10 × 10 cm) were kept in water for 28 days. Then, three samples (10 × 10 × 10 cm) were made from each mixture for the evaluation of compressive strength based on ASTM[19]. The following equation was used to calculate porosity:

$$P = \frac{W_{SSD} - W_d}{W_{SSD} - W_W} \times 100\% \qquad (1)$$

Where P is the porosity parameter in terms of percentage, W_{SSD} is the weight of the saturated-surface dry sample, W_D is the dry weight of the samples, and W_W is the sample weight in a saturated state in water. It should be noted that this equation is a common method that can be used to measure the porosity of cement materials[20, 21].

5. Mixed design with the laboratory method and the mixture model

To determine the compressive strength and porosity, three samples of each mixture were tested in 10 × 10 × 10 cm dimensions. The given diagrams are based on the relationship between W/C, compressive strength and porosity for the cement with the resistance classifications of 32.5, 42.5 and 52.5 MPa. After obtaining the laboratory data, created the diagrams with the MINITAB 16.0TM and the extreme vertices mixture design.

Table 1: The factors and levels used in the experimental design (DOE) of the mixture study for the optimization of C 32.5, C 42.5, and C 52.5 MPa

Highest level	Lowest level	Factor
0.3	0.2	Water-cement ratio (w/c)
400	300	(kg/m^3) The amount of cement
5.8 , 6.8 , 6.87	4.5, 4.8 , 4.73	The ratio of fine-grained materials to cement (FA/C)

5.1 The experimental results and the mixture model analysis:

According to the data and diagram shown in Fig.1, the increase in the amount of cement has led to an increase in the proportion of fine aggregate materials to cement. As the water to cement ratio decreases, the amount of fine aggregate materials to cement increases as well. Additionally, by increasing the amount of cement and the proportion of gravel in each sample, a higher compressive strength can be obtained. In samples made of cement types 42.5 MPa and 52.5 MPa, this process has been completed regularly while in samples made of the cement with 32.5 MPa resistance category, it can be noted that the ratio of fine aggregate has exceeded the same proportion in the 400 of cement content in water to cement 0.2 with 300. Moreover, the 350 cement content has the highest proportion of fine-grained gravel to cement.

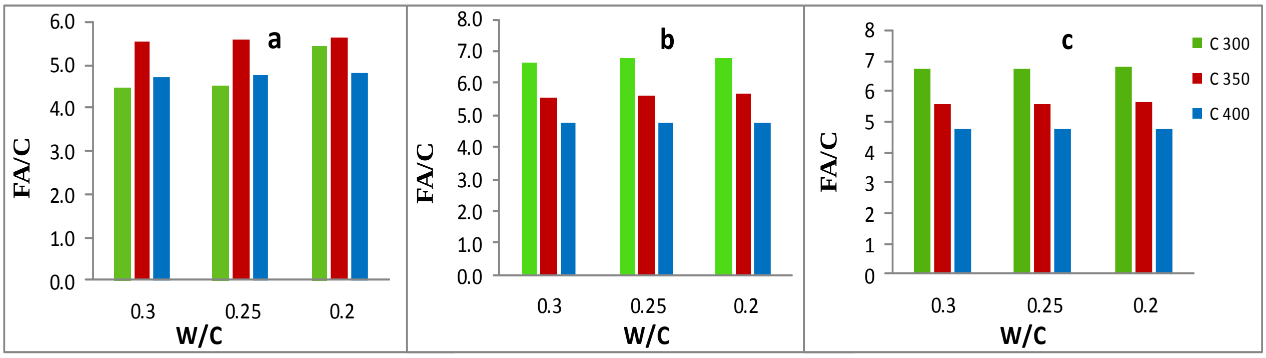

Fig.1 – The relationship between W/C and the proportion of FA/C for the cement with the strength of (a) 32.5, (b) 42.5 and (c) 52.5 (MPa)

With the help of mixture modeling as shown in Fig.2 for cement 32.5 MPa and the effect of variables on porosity, as the ratio of w/c (illustrated by the black line in the curve) increases (and the rest of the compounds decrease), the level of porosity decreases rapidly. As the proportion of FA/C (shown by the red line in the curve) increases (and the rest of the compounds decrease), the level of porosity increases. When FA/C decreases (and the rest of the compounds increase), the level of porosity increases. As the level of C (shown by the green dots in the curve) increases, the rest of the compounds decrease.

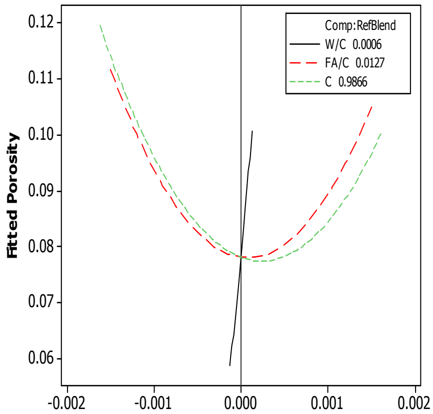

Fig. ۲ – Plot Cox Response Trace in porosity for C 32.5 (MPa)

Fig.3 shows contour plot and surface plot. In the diagram of mixture contour and the surface diagram of the mixture, the change in compressive strength has been shown as 32.5 MPa based on the formulation change. The lowest compressive strength is seen at the top of the triangle that is related to the formulation in which the ratio of W/C is maximal and the ratios of FA/C and C is minimal. From top to bottom, with the decrease in the W/C ratio, have approached the range in which the compressive strength has increased. The maximum compressive strength is within the range where the C value and the FA/C ratio are defined at the maximum level and the W/C ratio is the minimum.

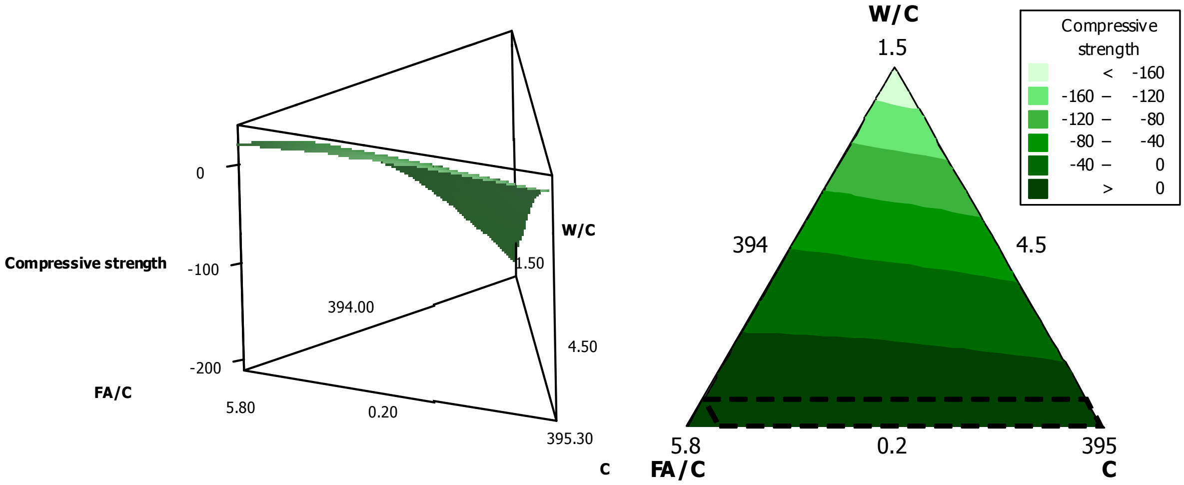

Fig. 3 The contour plot and surface plot for cement 32.5 MPa in the compressive strength

As shown in Fig.4, for all three content of cement that received similarly, porosity variations are shown in the mixture contour and the surface diagram of the mixture based on the formulation change. As shown above, the highest level of porosity is seen at the top of the triangle that is related to the formulation in which the W/C ratio is maximal and the ratios of FA/C and C are minimal. From top to bottom, with the decrease in W/C ratio, approach the range within which the porosity is minimum. The maximum amount of porosity is within the range where C and FA/C ratios are defined by the minimum amount while the proportion of W/C is maximal.

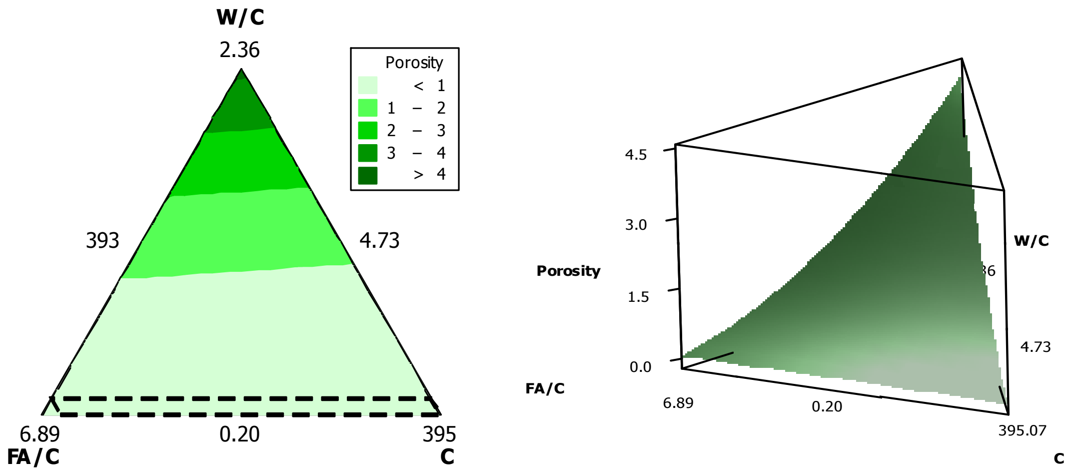

Fig.4 – Contour plot and surface plot diagrams for cement 52.5 MPa at the level of porosity

6. Conclusion

In this research, the effect of experimental parameters on the compressive strength and porosity of dry-pressed concrete curbs (DPC) was investigated. Based on laboratory studies, the obtained results are as follows:

- Based on experimental and laboratory results, DPC resistance increases commensurate with the increase in the strength and amount of the cement. In addition, increasing the strength and contents of the cement leads to a decrease in porosity.
- The cement with a strength class of 52.5 MPa and 400 grades has a higher compressive strength. Furthermore, for compressive strength, the amount of cement is one of the main parameters in determining the amount of compressive strength.
- With the help of modeling with mixture, found that samples made of cement with the resistance class of 52.5 MPa and the cement content of 400 have a higher compressive strength and the amount of cement is a key parameter in determining the amount of compressive strength.

- It can also be asserted that there is no accurate and simultaneous prediction based on the variations in the parameters of any mixture in obtaining the output from the software analyses. Regardless, by examining the minimum and maximum outputs obtained based on the diagram, it can be said that the increase in the strength of cement is effective in reaching the maximum compressive strength and the minimum percentage of porosity.

7. REFERENCE

1. Dowson, A.J. *Back-to-Basics-Measuring the Progress of Understanding of Over 35 Years of the Use of Concrete Block Paving in the UK*. in *9th International Conference on Concrete Block Paving. Buenos Aires, Argentina*. 2009.
2. EN, B., *1340," Concrete kerb units–Requirements and test methods.* British Standards Institution, London, 2003.
3. Delatte, N. and C. Storey, *Effects of density and mixture proportions on freeze-thaw durability of roller-compacted concrete pavement.* Transportation Research Record: Journal of the Transportation Research Board, 2005(1914): p. 45-52.
4. Ghosh, S., *Advances in cement technology: critical reviews and case studies on manufacturing, quality control, optimization and use*. 2014: Elsevier.
5. Li, Y.-X., et al., *A study on the relationship between porosity of the cement paste with mineral additives and compressive strength of mortar based on this paste.* Cement and concrete research, 2006. **36**(9): p. 1740-1743.
6. Kumar, R. and B. Bhattacharjee, *Porosity, pore size distribution and in situ strength of concrete.* Cement and concrete research, 2003. **33**(1): p. 155-164.
7. Tjaronge, M.W. and U.R. Irfan, *Porosity, pore size and compressive strength of self compacting concrete using sea water.* Procedia Engineering, 2015. **125**: p. 832-837.
8. Mindess, S., *Relation between the compressive strength and porosity of autoclaved calcium silicate hydrates.* Journal of the American Ceramic Society, 1970. **53**(11): p. 621-624.
9. FAMILI, H., M. TADAYON, and M. KHOSHSIMA, *THE EFFECT OF CASTING TEMPERATURE ON SOME MECHANICAL PROPERTIES AND DURABILITY OF DRY PRESSED PRECAST CONCRETE KERBS.* 2013.
10. Auskern, A. and W. Horn, *Capillary porosity in hardened cement paste.* Journal of Testing and Evaluation, 1973. **1**(1): p. 74-79.
11. Diamond, S. and W. Dolch, *Generalized log-normal distribution of pore sizes in hydrated cement paste.* Journal of Colloid and Interface Science, 1972. **38**(1): p. 234-244.
12. Neville, A.M., *Properties of concrete*. 1995.
13. Chen, X., S. Wu, and J. Zhou, *Influence of porosity on compressive and tensile strength of cement mortar.* Construction and Building Materials, 2013. **40**: p. 869-874.
14. Chindaprasirt, P. and S. Rukzon, *Strength, porosity and corrosion resistance of ternary blend Portland cement, rice husk ash and fly ash mortar.* Construction and Building Materials, 2008. **22**(8): p. 1601-1606.
15. Mosquera, M., et al., *Addition of cement to lime-based mortars: effect on pore structure and vapor transport.* Cement and Concrete Research, 2006. **36**(9): p. 1635-1642.
16. Li, Z., K. Afshinnia, and P.R. Rangaraju, *Effect of alkali content of cement on properties of high performance cementitious mortar.* Construction and Building Materials, 2016. **102**: p. 631-639.
17. Eskandari-Naddaf, H. and M. Azimi-Pour, *Performance evaluation of dry-pressed concrete curbs with variable cement grades by using Taguchi method.* Ain Shams Engineering Journal, 2016.
18. Standard, B., *Testing concrete.* Recommendations for the, 1881.
19. ASTM, C., *Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading).* Philadelphia, PA: American Society for Testing and Materials, 1999.
20. Matusinović, T., J. Šipušić, and N. Vrbos, *Porosity–strength relation in calcium aluminate cement pastes.* Cement and concrete research, 2003. **33**(11): p. 1801-1806.
21. Papayianni, I. and M. Stefanidou, *Strength–porosity relationships in lime–pozzolan mortars.* Construction and Building Materials, 2006. **20**(9): p. 700-705.