Proceedings of the 9th International Conference On Civil Structural and Transportation Engineering (ICCSTE 2024)
Niagara Falls, Canada – June 13-15, 2024
Paper No. 119
DOI: 10.11159/iccste24.119

Compressive Strength and Packing Density in Conventional Concretes

Daniela Ortiz[1], Diego Jiménez[1], Andrés Restrepo[1], César Echavarría[1]
[1] Universidad Nacional de Colombia
Carrera 65 No. 9A-110 Bloque 24, Medellín, Colombia
dortizlo@unal.edu.co; djimenezz@unal.edu.co; anfrestrepora@unal.edu.co; caechavarrial@unal.edu.co

Extended Abstract

The design of a concrete mix is primarily a volumetric packing problem. The optimum proportions of fine and coarse components are a function of the aggregate and cement size distribution curve and their packing characteristics. Optimizing the design of a granular system can increase the efficiency of cementitious materials, achieve higher strengths, and reduce cement demand by increasing packing density. For this reason, it is important to relate compressive strength and packing density in a conventional and/or high performance concrete granular system.

Increasing the packing density of the particles is one of the main attributes to achieve low porosity, flowability, durability and reduction of defects in concretes [1].

Therefore, mix design procedures were developed around the central strategy of maximizing packing and ensuring proper particle size distribution to achieve high levels of strength and the desired workability of the mix [2-4]. To improve packing density, the compressive packing model (CPM) proposed by De Larrard and Sedran was used [5-11].

The objective of this research was to analyse the relationship between packing density and compressive strength in concrete mixes. In this study, 6 different concrete mixture designs were considered, and 20 cylinders (100 mm x 200 mm) were manufactured for each mixture, to analyse the relationship between compression strength and packing density of the matrix. The material used were: general purpose Portland cement Type I (ASTM C1157/C1157M-20), sand with a medium diameter of 1.85 mm, and coarse aggregate with a medium diameter of 11.40 mm.

Compression tests were performed in accordance with ASTM C39. Among the different concrete mixtures proposed, a virtual packing density of 0.68-0.87 was found. The compressive strength increased as the packing density improved.

It was found that it is possible to optimize the use of cement and aggregates in a concrete mix to obtain high packing densities and consequently high compressive strengths. The concrete was manufactured with materials common in the industry, using conventional tools, and production methods. It is possible to scale up the manufacture of the optimized concrete mix proposed in this study for in-situ use.

References

[1] M.G. Sohail, B. Wang, A. Jain, R. Kahraman, N.G. Ozerkan, B. Gencturk, M. Dawood and A. Belarbi, “Advancements in Concrete Mix Designs: High-Performance and Ultrahigh-Performance Concretes from 1970 to 2016,” *J. Mater. Civ. Eng.,* no. 30, 2018. doi.org/10.1061/(ASCE)MT.1943-5533.0002144.
[2] N.A. Soliman and A. Tagnit-Hamou, “Using glass sand as an alternative for quartz sand in UHPC,” *Constr. Build. Mater.*, no. 145, pp. 243–252, 2017. doi:10.1016/j.conbuildmat.2017.03.187.
[3] M. Shaaban and S. Ahmed, “Development of Ultra-High Performance Concrete Jointed Precast Decks and Concrete Piles in Integral Abutment Bridges,” in: *First Int. Symp. Jointless Sustain. Bridg.*, Fuzhou, Fujian, China, 2016.
[4] R. Yu, P. Tang, P. Spiesz and H.J.H. Brouwers, “A study of multiple effects of nano-silica and hybrid fibres on the properties of Ultra-High Performance Fibre Reinforced Concrete (UHPFRC) incorporating waste bottom ash (WBA) R.,” *Constr. Build. Mater.,* no. 60, pp. 98–110, 2014. doi:10.1016/j.conbuildmat.2014.02.059.
[5] F. de Larrard and T. Sedran, “Mixture-proportioning of high-performance concrete,” *Cem. Concr. Res*., vol. 32, no. 11, pp. 1699–1704, 2002. doi:10.1016/S0008-8846(02)00861-X.
[6] F. de Larrard and T. Sedran, “Optimization of ultra-high-performance concrete by the use of a packing model,” *Cem. Concr. Res*., vol. 24, no. 6, pp. 997–1009, 1994. doi:10.1016/0008-8846(94)90022-1.

[7] N.A. Soliman and A. Tagnit-Hamou, “Partial substitution of silica fume with fine glass powder in UHPC: Filling the micro gap,” *Constr. Build. Mater.*, no. 139, pp. 374–383, 2017. doi:10.1016/j.conbuildmat.2017.02.084.
[8] P. Richard and M. Cheyrezy, “Composition of reactive powder concretes,” *Cem. Concr. Res.*, vol. 25, no. 7, pp. 1501–1511, 1995. doi:10.1016/0008-8846(95)00144-2.
[9] A. Tagnit-Hamou and N. Soliman, A. Omran, “Green Ultra - High - Performance Glass Concrete,” in *First Int. Interact. Symp. on UHPC*, no. 3, pp. 1–10, 2016. doi:10.21838/uhpc.2016.35.
[10] R.D. Toledo Filho, E.A.B. Koenders, S. Formagini and E.M.R Fairbairn, “Performance assessment of Ultra High Performance Fiber Reinforced Cementitious Composites in view of sustainability,” *Mater. Des.*, no. 36, pp. 880–888, 2012. doi:10.1016/j.matdes.2011.09.022.
[11] F. de Larrard, *Concrete mixture proportioning: A scientific approach*. London, CRC Press, 1999.