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Effect of Polyester Fibers on the Mechanical Properties of Reactive Powder Concrete (RPC)

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ABSTRACT

Reactive Powder Concrete (RPC) is a type of concrete with high compressive and flexural capacity with excellent durability. It is generally prepared using cement, fine powders like quartz sand or quartz powder, silica fume and superplasticizer, with or without steel fibers. Recent studies in conventional concrete have proved that compared to steel fibers, the percentage of polyester fiber used is less to achieve the same strength. This study investigates the effect of polyester fibers on the physical properties of RPC. The mechanical (compressive strength) and durability properties (resistance to fire, acid, sulphate, alkalinity, and water absorption) were examined. RPC of 90MPa shows improved result with respect to durability and decreased performance with respect to mechanical properties.

Keywords

Reactive powder concrete, Polyester fiber, Recron 3s, Silica Fume, Durability properties.

INTRODUCTION

Reactive Powder Concrete is a developing composite material that will allow the concrete industry to optimize material use, generate economic benefits, and build structures that are strong, durable, and sensitive to the environment. RPC term has been used to describe a fibre- reinforced, superplasticized, silica fume cement mixture with very low water-cement ratio, characterized by the presence of very fine aggregates instead of ordinary aggregate. It incorporates the elimination of coarse aggregate in the cement mixture in order to maintain the homogeneity of the mix. They can be fibered and non-fibered. Fibres are incorporated in RPC in order to enhance the fracture properties of the composite material. RPC was developed by P. Richard and M. Cheyrezy in France in 1990s.

A number of research were conducted on RPC using steel fibers, PP fibers and partial replacement of cement by silica fume, fly ash, GGBS, the use of RPC as a repair material, etc. RPC specimen has a poor crack resistant behavior [11] as it is a highly densified concrete. Spalling of RPC occurred at temperatures (or time) ranges of 260–520 C (or 48–100 min). Recron 3s fiber is a polyester or polypropylene fiber used as a secondary reinforcement material. It arrests shrinkage cracks and increases resistance to water penetration, abrasion and impact [9]. Usage of Recron 3s fiber will reduce the cost of maintenance by reducing the micro cracks and permeability and increasing its durability. A cement structure free from micro cracks prevents water or moisture from entering and migrating throughout the concrete. This in turn helps prevent the corrosion of steel used for primary reinforcement in the structure, thus improving the longevity of the structure. Polyester or PP fibers melt at elevated temperature and prevents concrete from spalling [10]. This paper is a study on how these properties of recron 3s fiber can be incorporated in RPC.

EXPERIMENTAL INVESTIGATION

1. Materials

The materials used are Ordinary Portland cement, quartz sand, silica fume (white), polycarboxylic based superplasticizer (Cera Hyperplast XRW 40), Recron 3s fiber and water. Tests were conducted to determine their properties. The specific gravity of OPC is 3.09, purchased from the Heidelberg Cement Group, Zuari Cement. Silica fume with SiO_2 content greater than 97% and particle size less than 1μm was purchased from the Bison Shelter System, Ernakulum. Quartz sand has better quality, higher proportion of SiO_2, greater hardness and less impurities than natural sand. The strength of the RPC mix with natural sand were slightly smaller than quartz sand. Quartz sand passing through 600 μm IS sieve and retained in 150 μm IS sieve was used. The polyester fiber used in this present work is Recron 3s fibers with 12mm length and 280oC melting point, manufactured by Reliance Industries Ltd.

2. Mix design of RPC

The first mix ratio was taken as 1:1.1:0.25:0.016:0.15 (cement: fine aggregate: silica fume: superplasticizer: water) [21]. A total of 8 trials were done in order to achieve the appropriate mix design by using OPC, PPC, river sand, quartz sand, glenium superplasticizer, cera hyperplast XRW40 superplasticizer, silica fume and water. Each trial was done by varying the proportions of superplasticizer, fine aggregate, silica fume and water and the final mix for RPC90 was obtained. Fig. 1 is the graphical representation of the 7 days and 28 days compressive strength of trial mix specimens.

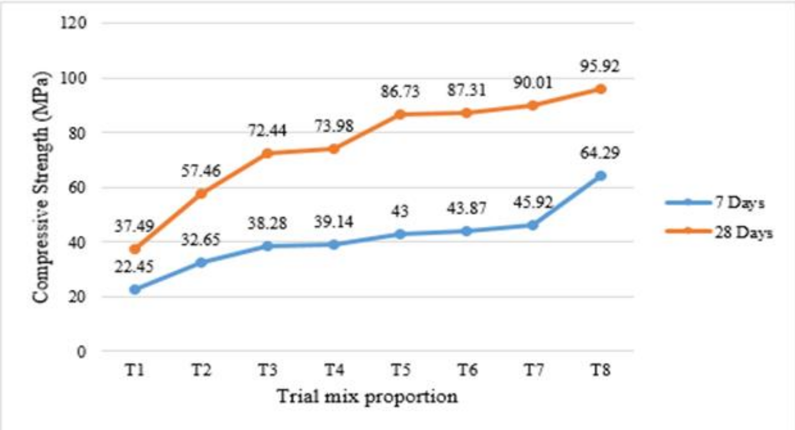

Fig 1. Compressive strength for trial mix proportions

After fixing the mix proportion, the specimens were made by varying the percentage of polyester fiber added to it. The mix designation is given in Table I.

Table 1. Mix Designation

Nomenclature	Percentage fiber (%)
P0	0.0
P1	0.2
P2	0.3
P3	0.4
P4	0.5
P5	0.6

3. Test procedure

Tests were conducted to determine the fresh and hardened properties of RPC. Flow table test was done to find the workability of the mix. Compressive strength test (mechanical property) and acid attack test, sulphate resistance test, fire resistance test, water absorption test, alkaline attack tests (durability properties) were conducted to determine the hardened properties of RPC.

3.1. Flow table test

Flow table test was conducted to determine the workability of RPC mix. The test procedure involves placing the mould (60 mm in height, internal diameter: base 100mm - top 70 mm) in the center of the flow table and filling it in two layers each layer being tamped ten times with the tamper. It was important that the mould was held firmly in place during this operation. The excess mortar was removed from the top of the mould with the trowel and the area around the base of the mould cleaned with a cloth. A period of approximately 15 seconds was allowed to elapse and the mould was then removed, the table was jolted 15 times at a rate of one jolt per second. The diameter of the spread mortar was measured in two directions at right angles to each other using calipers, both results are reported.

3.2. Compressive strength test

The compressive strength test was done to determine the compressive strength of concrete according to IS 2250-1981. The specimen of size70mm x 70mm x 70mm are taken out from the curing tank and the surface was cleaned. The dimension was measured nearest to 0.2mm and the weight was noted. The specimen was placed in the machine in such a manner that the load was applied to the opposite sides of the cubes as cast (i.e. not to the top and bottom). The load was applied without shock and was increased continuously at a rate of approximately 2-6 N/mm2 per minute. The ratio of maximum load to the cross sectional area gave the compressive strength of the specimen.

3.3. Fire resistance test

A series of fire tests was conducted on all RPC specimen using the electric furnace at three different target temperatures: 200°C, 250°C and 300°C. The heating rate was set to 10°C/ min. When the temperature inside the furnace reached the target temperature, the temperature was maintained for 2 hours to render the specimens temperature homogenous [10]. The specimens were then cooled to room temperature naturally in the furnace. After the fire tests, the specimens were visually inspected to determine whether or not explosive spalling had occurred and the compressive strength test was conducted.

3.4. Alkaline attack test

The alkaline attack test determine the resistance of various concrete mixtures to alkaline attack. After curing for 28 days the cubes of size 70mmx70mmx70mm were immersed in a solution having 5% NaOH by weight of water for 28 days. The alkalinity of water was maintained throughout the period. After 28 days the cubes were taken out and tested for compressive strength. The resistance of concrete to alkaline attack was found by the percentage loss of compressive strength on immersion of cubes on alkaline water.

3.5. Acid attack test

3 specimens of size 70mm ×70mm ×70mm were prepared for compressive strength to take average result of the specimen. Sulphuric acid (H2SO4) solution with 2% concentration was used as the standard exposure solution [11]. The specimens were immersed in the acid solution in a tank. To prepare the solution of 2% concentration, for each 100gm of solution 98gm of water and 2gm of sulphuric acid (by weight) was added. After preparation of the solution pH value of the solution was measured by using digital pH meter. In order to maintain the concentration of throughout the test, the pH value of the solution was measured at every 15 days interval and by considering the initial pH as reference sulphuric acid or water was added and by trial and error initial pH value was achieved. The acid resistance of concrete is evaluated by measuring the residual compressive strength after acid exposure.

3.6. Sulphate resistance test

The resistance of concrete to sulphate attacks is studied by determining the loss of compressive strength or variation in compressive strength of concrete cubes immersed in sulphate water having 10% of sodium sulphate (Na2SO4) and 10% of magnesium sulphate (MgSO4) by weight of water and those which are not immersed in sulphate water [11]. The concrete cubes of 70mm x70mm x70mm size after 28days of water curing and dried for one day are immersed in solution for 28 days. After the immersion period, the concrete cubes are to be removed from the sulphate waters and after wiping out the water and girt from the surface of cubes, the compressive strength is determined

RESULTS AND DISCUSSION

1. Flow table test

The spread diameter of concrete from the flow table test is given in Fig 2.

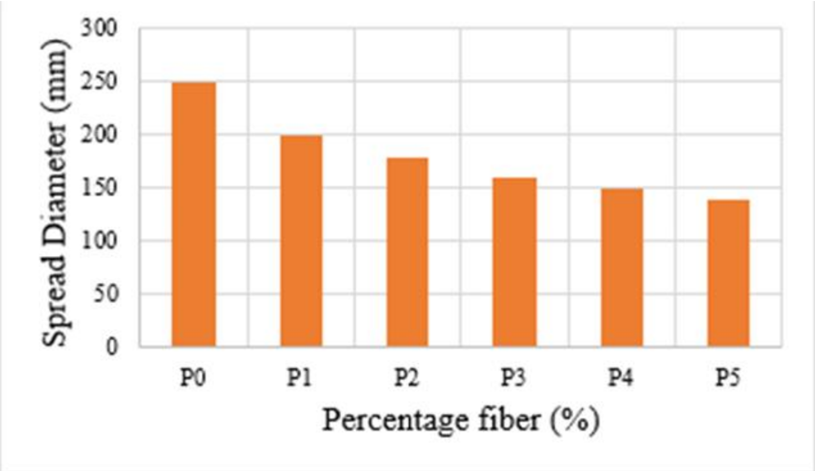

Fig 2. Flow table test results

The increase in fiber content in the concrete resulted in decrease in spread diameter of RPC. This phenomenon might be attributed to the strong fiber–matrix bond in the concrete. The bond increases the viscosity of concrete and restricts the distribution of the cement matrix; hence, a reduction in the workability was observed in RPC [8].

2. Compressive Strength Test Result

The highest 28 days strength obtained was 95.92MPa for non-fibered RPC mix as shown in Fig 3. The addition of recron 3s fibers caused a decrease in compressive strength. This might be because of the reduction in workability of the mix with the addition of fibers. Decrease in workability leads to decrease in strength.

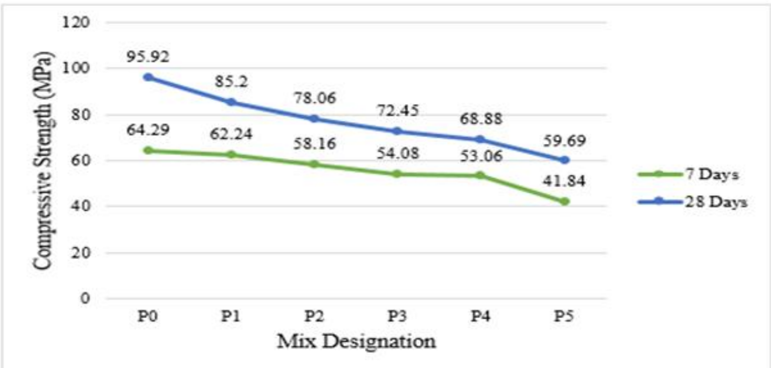

Fig 3. Compression test results

3. Water absorption test results

Fig 4 shows that the percentage weight loss for recron 3s fiber reinforced RPC specimen was more than the normal RPC specimen. The incorporation of fibers seem to increase the percentage of water absorption. It is possible that the presence of fiber leads to the creation of channels at the interface between the fiber and the paste which promotes the uptake of water.

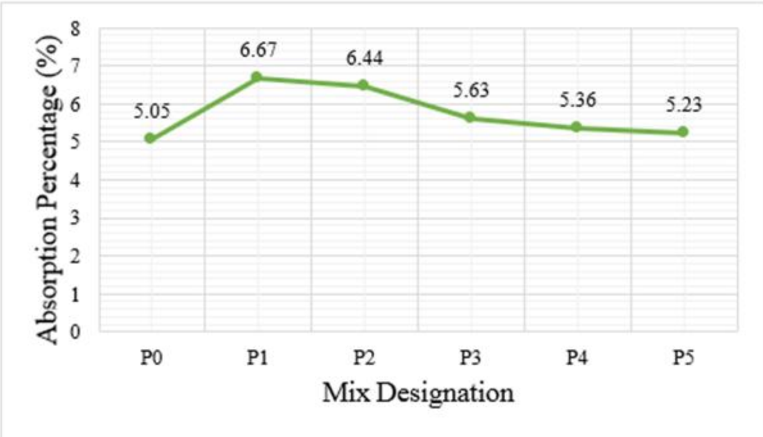

Fig 4. Water absorption test results

4. Fire resistance test results

The results of a series of fire tests indicated that the residual compressive strength of RPC decreases with the duration of fire. Compared with ordinary concrete, RPC exhibits not only a higher fire endurance temperature, but also a large residual compressive strength after a fire; as a result, RPC can be used to prevent damage to life.

From the fire resistance test conducted, the percentage strength loss was comparatively low for fiber reinforced RPC specimen at elevated temperatures. When a concrete specimen is heated, the transient moisture in the pores vaporizes and the steam pressure rises close to the surface. The pressure gradient drives the moisture out of the specimen and towards the inner colder regions. The steam will condense when it meets the inner colder concrete. The steam pressure has traditionally been used to explain the spalling of concrete under fire conditions. Non-fibered RPC were explosive in nature at high temperature whereas fibered RPC showed partial or no spalling. The studies showed that an increase in fiber content led to the prevention of spalling. From Fig 5, it can be seen that at high temperature the strength loss decreased for fibered RPC specimen compared to RPC without fiber [10].

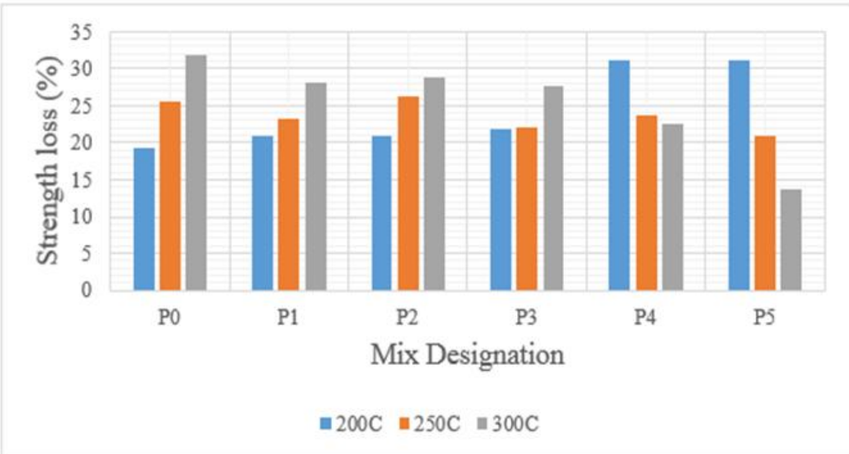

Fig 5. Percentage weight loss in fire resistance test

5. Acid attack test results

Concrete is susceptible to attack by sulphuric acid produced from either sewage or sulphur dioxide present in the atmosphere of industrial cities. Acid attack on high strength concrete, with and without silica fume, is mainly influenced by the type of acid, even though they may have the same concentration. Polyester fibers and silica fume have low resistance to sulphuric acid attack [2, 20]. Sulphuric acid removes the residual impurities in quartz sand [22]. The decrease in strength during acid attack test as shown in Fig 6 must be due to the effect of acid on silica fume and polyester fiber.

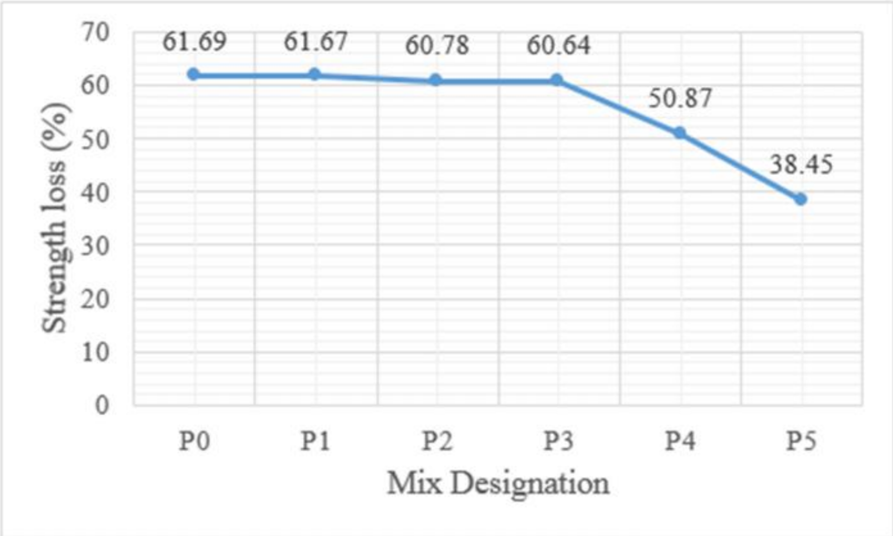

Fig 6. Strength loss in acid attack test

6. Sulphate resistance test results

Sulphate attack is a common form of concrete deterioration. It occurs when concrete comes in contact with water containing sulphates. Sulphates can be found in some soils (especially when arid conditions exist), in seawater, and in wastewater treatment plants. Sulphate attack in concrete can be external or internal. External attack is due to the penetration of sulphate in solutions. The specimen were tested after 28 days. The results are shown in Fig 7. Results showed that the inclusion of fibers showed better performance in sulphate immersion compared to the specimen without fibers.

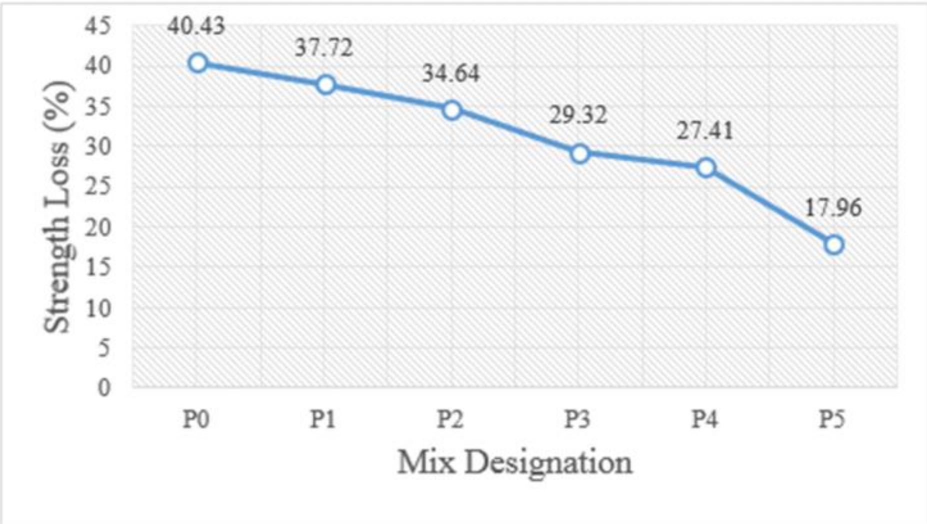

Fig 7. Strength loss in sulphate resistance test

7. Alkaline attack test results

The alkali effect on RPC was measured by determining the percentage strength loss of RPC samples after immersion in NaOH solution. Recron 3s fibers have better resistance to alkali attack. It was observed that there was a decrease in percentage strength loss with the addition of fibers as shown in Fig 8.

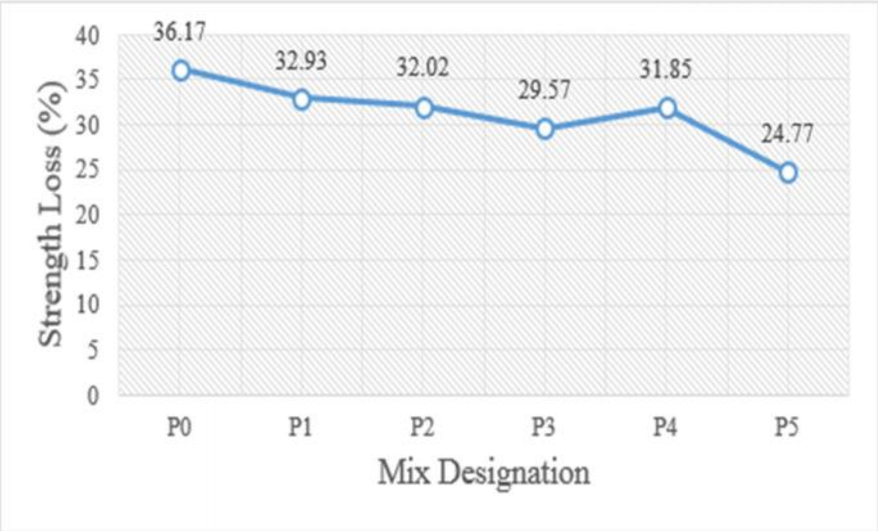

Fig 8. Strength loss in alkaline attack test

CONCLUSION

A study on the effect of recron 3s polyester fiber on the mechanical and durability properties of RPC was done. Fresh properties of RPC were determined by conducting the flow table test. The following conclusions were made based on the tests conducted.

- The spread diameter values of the matrix decreased with an increase in percentage fiber. These values indicated that the workability of RPC reduced with increase in fiber percentage.
- The compressive strength of RPC reduced with an increase in percentage of fiber.
- The addition of polyester fibers was effective in reducing the percentage strength loss in the water absorption, acid attack and alkaline attack tests.
- The fire resistance test results indicated that the strength loss decreased with an increase in fiber percentage at elevated temperature.
- Although the addition of polyester fiber did not improve the mechanical properties of RPC, it showed better durability properties with respect to fire resistance, alkaline attack, sulphate resistance tests.

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REFERENCES

[1] Agharde, A. D., and Bhalchandra, S. A. (2015). “Mechanical properties of reactive powder concrete by using fly ash.” International Journal of Advanced Technology in Engineering and Science, 3(1), 603–608.
[2] Amaro, A. M., Reis, P. N. B., Neto, M. A., and Louro, C. (2013). “Effects Of Alkaline And Acid Solutions On Glass/Epoxy Composites.” Polymer Degradation and Stability, Elsevier, Elsevier Ltd, 98(4), 853–862.
[3] Bhagyashri Sisode and Dr Sunil V Desale. (2015). “Use of Industrial Waste and Recron 3s Fiber to Improve the Mechanical Properties of Concrete .” indian journal of research, 4(7), 288–294.

[4] Bhosale, P. A., and Kawade, U. R. (2015). "Effect of Recron 3s Fibers on GGBS Replaced Cement Concrete." International Journal of Science and Research, 4(9).
[5] Canbaz, M. (2014). "The effect of high temperature on reactive powder concrete." Construction and Building Materials, Elsevier Ltd, 70, 508–513.
[6] Cwirzen et. al. (2008). "Reactive powder based concretes : Mechanical properties , durability and hybrid use with OPC." Cement and Concrete Research, Elsevier, 38, 1217–1226.
[7] Dharani.N, Ashwini.A, Pavitha.G, P. . (2013). "Experimental investigation on mechanical properties of recron 3s fiber reinforced hyposludge concrete." International Journal of Civil Engineering and Technology, 4, 182–189.
[8] Faizan Akbar, Fawad Bilal, Z. S. (2015). "Optimizing mix proportions for Reactive Powder Concrete (RPC) and investigating the compressive strength ." International Journal of Advanced Structures and Geotechnical Engineering, 4(2).
[9] Husain, M. N., and Aggarwal, P. (2015). "Application of Recron 3S Fibre in Improving Silty Subgrade Behaviour." Journal of Mechanical and Civil Engineering, 12(2), 51–55.
[10] Jang, H., So, H., and So, S. (2016). "The properties of reactive powder concrete using PP fiber and pozzolanic materials at elevated temperature." Journal of Building Engineering, Elsevier, (October), 0–1.
[11] Ji, T., Chen, C., and Zhuang, Y. (2012). "Evaluation method for cracking resistant behavior of reactive powder concrete." Construction and Building Materials, Elsevier Ltd, 28(1), 45–49.
[12] Kawamura, K. T. and M. (1994). "Effects of fly ash and silica fume on the resistance of mortar to sulfuric acid and sulfate attack." 24(2), 361–370.
[13] Kushartomo, W., Bali, I., and Sulaiman, B. (2015). "Mechanical behavior of reactive powder concrete with glass powder substitute." Procedia Engineering, Elsevier B.V., 617–622.
[14] M K Maroliya. (2012). "An Investigation on Reactive Powder Concrete containing Steel Fibers and Fly- Ash." International journal of emerging technology and advanced engineering, 2(9).
[15] Maroliya, M. (2012). "BOND STRENGTH OF REACTIVE POWDER CONCRETE CONTAINING STEEL FIBRE AND SILICA FUME ." International journal of emerging technology and advanced engineering, 2(10), 66–69.
[16] Mostofinejad, D., Nikoo, M. R., and Hosseini, S. A. (2016). "Determination of optimized mix design and curing conditions of reactive powder concrete (RPC)." Construction and Building Materials, Elsevier Ltd, 123, 754–767.
[17] N. Roux, C. A. and M. A. S. (1996). "Experimental study of durability of reactive powder concretes." 8(February), 1–6.
[18] Patel, H., Patel, C., Patel, K., Manjurali, P., Prof, I. B., and Patel, V. A. (2015). "Performance Evaluation of Polymer Fiber ' RECRON -3S ' i n Pavement Quality Concrete Sankalchand Patel College of Engineering , Visnagar , Gujarat , India." 2(11), 457–461.
[19] Rafat Siddique, Kushal Kapoor, El-Hadj Kadri, R. B. (2016). "Effect of polyester fibres on the compressive strength and abrasion resistance of HVFA concrete." ELSEVIER.
[20] Ravindrarajah, R. S. (2015). "Acids attack on silica fume high-strength concrete." (September).
[21] Richard, P., Cheyrezy, M., Bouygues, S. D., and Quentin, S. (1995). "Composition of Reactive powder concretes." Cement and concrete research, 25(7), 1501–1511.
[22] Tam, C. M., Tam, V. W. Y., and Ng, K. M. (2012). "Assessing drying shrinkage and water permeability of reactive powder concrete produced in Hong Kong." 26, 79–89.
[23] Yanzhou, P., Jun, Z., Jiuyan, L., Jin, K., and Fazhou, W. (2015). "Properties and microstructure of reactive powder concrete having a high content of phosphorous slag powder and silica fume." CONSTRUCTION & BUILDING MATERIALS, Elsevier Ltd, 101, 482–487.
[24] Zdeb, T. (2015). "Influence of the physicochemical properties of Portland cement on the strength of reactive powder concrete." Procedia Engineering, Elsevier B.V., 108, 419–427.
[25] Zheng, W., Luo, B., and Wang, Y. (2013). "Compressive and tensile properties of reactive powder concrete with steel fibres at elevated temperatures." Construction and Building Materials, 41, 844–851.
[26] Zhu, P., Mao, X., Qu, W., Li, Z., and John, Z. (2016). "Investigation of using recycled powder from waste of clay bricks and cement solids in reactive powder concrete." Construction and Building Materials, Elsevier Ltd, 113, 246–254.