A Brief Review on Properties of Reactive Powder Concrete

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Abstract: In the past few decades there have been many improvements in concrete technologies which lead to an impact on the structural system. Reactive powder concrete (RPC) consists of cement, fine sand, quartz, silica fume, steel fiber which is optional and superplasticizers. It is an ultra-high-strength concrete having high durability and high ductility with compressive strength up to 200Mpa – 800Mpa. The concept of RPC is to replace course aggregates with very fine ingredients like quartz powder, silica fume etc. which results in more durable and workable concrete with low permeability. It is a special concrete in the microstructure is improved through accurate gradients of all particles in a mix to produce maximum density. RPC has been used for various structures like bridges, nuclear and thermal power plants and mining engineering. In this paper we have presented the brief overview of different mechanical and others properties of RPC based on past detailed studies by different authors.

Keywords — compressive strength, flexural strength, RPC, silica fume, steel fiber, workability

I. INTRODUCTION

Over the years concrete has become more complex. Rather than its traditional method of mixing crushed stones, sand, lime and water, the use of cementitious material and additives which can enhance the various properties of concrete are used. Reactive Powder concrete (RPC) is an ultra-high strength and high-ductility cementitious composite having advance physical and mechanical properties. It comprises of cement, quartz powder, silica fume, steel fiber (optional) and super plasticizers which increases the compressive, flexural and tensile strength making it more durable, workable and low permeable concrete. RPC is a developing composite material that allows to generate the optimum material used in it which will generate economic benefits and can built structures that are strong, durable and sensitive to environment. It is one type of special concrete where the microstructure is optimized by precise gradation of all particles in the mix yields to maximum density. It uses he pozzolanic properties of silica fume and ordinary Portland cement chemistry to produce highly strength hydrates. This new type of concrete has compressive strength of 150 – 230 Mpa depending on the type and amount of fiber used. It eliminates the use of coarse aggregates for enhancement of homogeneity and the optimum usage of super plasticizers reduce w/c ratio and improves workability. Addition of steel fibers improves the ductility. RPC was first developed in early 1990s by France and the world's first Reactive Powder Concrete structure, the Sherbrooke Bridge in Canada was constructed in July 1997.Then in 1998 Aitcin defined the concrete as high strength concrete based on its compressive strength measured at specific age, but with the progress in recent studies, the concrete which was called high strength is now named as high performance concrete and this is due to not only to its strength, but because it gives enhanced performance such as durability and corrosion resistance. In the last few decades steps have been taken in the development of higher strength concrete types in the form of High Performance Concrete (HPC), Very High Performance Concrete (VHPC) and Ultra High Performance Concrete (UHPC). Later on many researches took place in 2000s leading to further improvement in RPC. This lead to development of RCC members like RPC slabs having compressive strength of around 200 Mpa or even more than that. With effective use of super plasticizers workability can be achieved and some also added brass fibers to achieve more compressive and flexural strength.

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II. LITERATURE REVIEW

A study conducted by Mahesh k Maroliya and Chetan Modhera includes the comparative study of Reactive Powder Concrete containing steel fibers and Recron 3S fibers. They compared different types of specimen of plain RPC, steel fiber reinforces RPC (SFRPC) and Recron 3S fiber reinforced RPC (RSFRPC) to test the compressive strength at 7 and 28 days and static flexural strength at 28 days. In their study they found that the addition of steel fibers at 2% volume fraction is found not to affect the workability and RPC easily gets mixed with steel fibers but addition of Recron 3S fibers at 0.039% is found to affect the workability of concrete. Further they found that the compressive strength of SFRPC is 30% higher because of more confined and dense concrete while in case of RSFRPC the strength is reducing by 19%.However, workability can be improved by readjusting the doses of super plasticizers. Split tensile strength of SFRPC and RSFRPC in comparison to plain RPC is found to increase by 50% and 30%. Flexural strength of SFRPC and RSFRPC in comparison to plain RPC is found to be 60% and 40% higher respectively.

Sarika S. studied on the properties of reactive powder concrete. The study included the material properties of cement, silica fume, polycarboxyates ether condensate (PEC) a super plasticizer, quartz powder, fine aggregates, and steel fibers. The workability of the concrete by Flow test was found to be 260mm.Compressive strength was carried out on a cubical test specimen of 100mm size in a compression testing machine of 200kN was found to be 92 MPa at 7days and 130 MPa at 28 days. 70% of the 28th day strength is attained on the 7th day.

A brief study on workability of Reactive Powder Concrete was done by Akash Patil, Vishal Patil and Aditya Patil. They studied the effect of compressive strength of the RPC by making variation to the dosage of the concrete components such as silica fume and super plasticizers. They have used Auramix400 as super plasticizer. It is a unique combination of next generation flow based on long chain polycarboxylate polymers. This significantly improves the dispensability of cement. At the beginning of the mixing process electrostatic dispersion occurs but the ability of the cement particles is to separate and disperse. This mechanism greatly reduces the amount of water that can flow into the concrete. Auramix400 combines the properties of water retention and processability. They prepared the trail mix having quartz powder as 1.5 and changed silica fume by 0.15, 0.2, 0.25 and 0.3 with varying w/c ratio by 0.2, 0.25, 0.3, 0.35 and 0.4.Also the dosage of Auramix400 was changed from 6, 8 and 10 ml.

They came to the conclusion that the compressive strength is proportional to the dosage of super plasticizer. The strength increase with the dosage of super plasticizer. Increasing the amount of super plasticizer improves the usability of the mixture. The w/c ratio of 0.3 for a ration of silica to cement of 0.2 and a super plasticizer dosage of 8-10 ml is to be used for better results.

Ahsanollah Beglarigale, Caglar Yalcinkaya and Hallit Yaziki studies the effect of steel micro fibers and silica fume dosages on the mechanical properties of RPC with autoclave method of curing. One of the curing methods to enhance the strength of this composite material is autoclaving. Autoclave curing needs additional SiO_2 to fill the micro pores and strengthen hydration products. In the scope of their study, the effect of volume fraction of steel micro-fibers and silica fume dosages as SiO_2 source on mechanical properties of RPC under autoclave curing was investigated. They prepared trail mixes of 0%, 1% and 2% volume fractions of steel micro-fibers.

Yazici investigated the mechanical properties of RPC containing mineral admixtures under different curing regimes. Their results showed that the RPC containing high volume mineral admixtures had a satisfactory mechanical performance. Though the cement and silica fume content was lower than the conventional RPC, the compressive strength exceeded 200 MPa after standard curing. They also showed that the autoclave and steam curing seems very effective to increase the compressive strength up to 234 and 250 MPa for steam and autoclave curing respectively. Cement was replaced with 0%, 10% and 20% by weight of silica fume in the mixture which has 0.18 water-to-binder ratio and 0%, 1% and 2% by volume brass coated steel fibers were used. With every 10% increase in silica fume the flow value decreased to 15 mm. The fracture energies of 1% and 2% steel fiber reinforced RPC with 20% replacement of silica fume were about 77 times and 121 times higher than the plain RPC respectively. A cementitious composite with a compressive strength of 213Mpa and a flexural strength of 30MPa can be produced by inclusion of 2%steel micro fiber and 205 silica fume. Test results indicated that the RPC has good mechanical performance after autoclaving in a short curing time.

A group of researchers from Sweden used RPC for external façade cladding thus enabling considerable reduction in the thickness of concrete element. In their study, improved RPC formulations with higher amounts of supplementary cementitious materials were developed. The results showed that even clinker replacement levels of up to ca. 40% of total binder amount, a satisfactory mechanical performance could still be achieved. The incorporation of carbon textile fiber grids proved to be highly effective in improving the post crackling behavior of the RPC. They prepared in total 3 mixes out of which one had ground granulated blast furnace. Other materials included cement, fly ash, granulated blast furnace, quartz filler, silica fume, sand 2 types (1mm,2mm), super plasticizers and water. The RPC reinforcement consists of carbon 2D grid. It has been

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shown that the use of textile reinforced reactive powder concrete has benefits concerning materials savings and sustainability. Due to extra ordinary strength and durability, façade applications in form of panels or cladding can be kept to a fraction of thicknesses of a standard concrete panel. The brittle behavior of the material can be incorporated by textile grid based on carbon fibers. The textile grid increases the load capacity of the composite material considerably while allowing for controlled cracking as a part of post peak performance.

Mujamil, Vinay, Sikandar, Shridhar and K S Kulkarni studied the mechanical properties of reactive powder concrete at different curing regimes. In this study accelerated boiled water curing and conventional water curing is adopted. The Reactive Powder Concrete is made with different proportions of silica fume varying from 0% to 50% as a partial replacement of cement. The curing of specimen was done at 100^0c for 3.5 hours and in conventional curing the specimen were cured in normal water for 28 days. Experimental results of compression strength shows that as the content of silica fume is increased up to 25%, the compressive strength also increases. Beyond 25%, the compressive strength of RPC decreases. The accelerated boiled water curing shows lesser strength as compared with the conventional water curing. Flexural strength test results shows that flexural strength increases up to 25% replacement of cement with silica fume and after that the flexural strength decreases. The difference in flexural strength for both the curing regimes is marginal as compared with the compressive strength. Hence they came to a conclusion that the optimum use of silica fume in RPC is at 25%.

Adel A. Al- Azzawi and Radhwan Abdulsattar has studied and reviewed various literature papers related to mechanical properties of RPC and RPC slab. In their study they have found that Reactive powder concrete gives improved performance like corrosion and toughness and resistance. In the heat treatment the tensile strength achieved is more at 90°c in splitting tensile strength 25 Mpa to 35 Mpa, , and compressive strength from 120 to 180 MPa. They have found that in RPC mixture the compressive and flexural strength of the brass plated fiber is more as compared to any other type of fiber. The concrete can be prepared with compressive strength equal to 132MPa, flexural strength equal to 19.1MPa, dynamic modulus 48.61GPa.The addition of fibers didn't changed the first crack load of normal concrete slabs, but the load of cracking at flexural of normal concrete increases by about (25 and 32%) and the capacity at maximum load of normal concrete increases by (20 and 34%)with the addition of fibers by volume of fraction of (0.32 and 0.48%).The compressive strength about (57-65%) is provided in 3 days by the treatment in normal water at 20°C. While the treatment of compressive strength with 80°C gives about (80-90%) in 3 days, and (93-97%) at 7 days that of 28 day. The load is ultimately increased by the steel fibers and silica fume content resulting in deflection at failure load and curvature. While the more steel content ratio causes more load at failure and curvature. Moreover, with the increase of fiber content and silica fume content, flexural toughness increases

J. Arvindhan and G. Vijayakumar studied the properties of Reactive Powder Concrete by preparing a mix having 120 Mpa strength and carried out compressive strength, split tensile test and flexural strength. They also studied rapid chloride penetration which revealed that the chloride ion penetration is negligible in RPC, hence it can be a promising construction material to use in aggressive environment. Starting from 15% addition of silica fume in the mix and till 35% with 5% increment various tests for the compressive strength, flexural strength and split tensile strength were carried out. From the results of those tests it was concluded that the compressive and split tensile strength of 30% silica fume was better than other percentages. The Flexural strength was observed higher for 25% silica fume addition and can be increased further by addition of steel fibers. RPC with 25% of silica fume was found to have lower penetration value. It represents that, RPC is more durable when corrosion resistance is considered with other class of high strength concrete. RPC exhibits excellent corrosion resistance characteristics compared to other concretes and may be effectively utilized in marine construction.

L. Jaya and Sumantha Doodala carried out a comparative study of Reactive Powder Concrete and High Performance Concrete. Comparision shows that RPC possess better both compressive and flexural results as compared to High Performance Concrete (HPC). The principle objective of their study was to compare mechanical and durable properties of M60 HPC with RPC120.In this study, performance of RPC concrete without quartz powder and containing silica fume as a replacement for cement and HPC M60 grade with silica fume as an admixture at the varying percentage of 0%, 5%, 15%, and 20% by each was investigated. Preparation of HPC was done with the addition of chemical and mineral admixtures. Also the tests for acid alkali attack was carried out by measuring % loss of weight for RPC and also for HPC of M60 grade. Slump test for RPC 120 and HPC 60 was done and maximum workability was achieved at 20% silica fume replacement with cement for both. Also it was noticed that the compressive strength of both HPC and RPC are attained more than the target strength at 20% of silica fumes replacement with cement quantity. Similarly, for the tensile strength test more than the target strength was achieved for both HPC and RPC at 20% silica fumes replacement with cement quantity. The average Flexural strength of RPC attain more than the target strength at 20% silica

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replacement but for HPC flexural strength was not achieved more than the target strength at even 20% silica fumes replacement with cement quantity but it was nearer to target strength. They came to a conclusion that for dealing with steel fibers in RPC and silica fumes in HPC there is a necessity of suitable super plasticizer to achieve workability.

III. Conclusion

From the past studies it can be concluded that:-

- The replacement of silica fume can be done up to 20% - 25% with the cement quantity will give more improved results.
- The Reactive Powder Concrete gives more strength than High Performance Concrete.
- The rapid chloride penetration test when conducted on RPC was negligible which proved RPC is low permeable and can be used for marine construction.
- RPC can also be effectively used as an element for external façade cladding by adding textile fibers.
- Appropriate quantity of super plasticizer is to be added to attain the required workability which in turns makes the concrete expensive.

References

[1] Aditya Patil, Vishal Patil and Akash Patil, "Study on the effect of Reactive Powder Concrete on the compressive strength and workability," IJIERT, Volume 4, Issue 11, Nov-2017.

[2] Prabhu K. and Jose Ravindra Raj B., "A brief review on Ultra High Performance Concrete," IJEMR, Volume 6, Issue 5, Sept-Oct 2016.

[3] L. Jaya and Sumanth Doodala, "A comparative study between Reactive Powder Concrete and High Performance Concrete," IJETER, Volume 4, Issue 8, August 2016.

[4] Mahesh K. Maroliya and Chetan D Modhera, "A comparative study of Reactive Powder Concrete containing steel fibers and Recron 3S fibers," JERS, Volume 1, Issue 1, Sept 2010.

[5] Sarika S, "A study on properties of Reactive Powder Concrete," IJERT, Volume 4, Issue 11, Nov 2015.

[6] Mujamil, Vinay, Sikandar, Shridhar and K S Kulkarni, "Mechanical properties of Reactive Powder Concrete for different curing regimes," ISSN 0974-5904, Volume 4,No.6,Dec 2015.

[7] J. Arvidhan and G. VijayaKumar, "Study on strength characteristics of Reactive Powder Concrete," ISSN 0972-768X, 2016.

[8] Abdulamir and Hussien, "Mechanical properties of Reactive Powder Concrete with various combinations of fibers and ultrafine," IJSER, Volume 9, Issue 12, Dec 2018.

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