Review on Reactive Powder Concrete using different ingredients

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Abstract— ***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 environment. RPC is a new ultra-high performance concrete with wide range of capabilities. RPC was developed in the 1990s by Bouygues' laboratory in France. RPC represents a new class of Portland cement-based material with compressive strengths of 200 MPa range. By introducing fine steel fibers RPC can achieve flexural strength up to 50 MPa. It has no coarse aggregates and contains small steel fibres that provide additional strength.RPC include Portland cement, silica flour, fine sand, superplastizer, water and steel fibres. The main object of this study is to check the effect of replacing silica fume fly ash and percentage variation of steel fiber on reactive powder concrete, to achieve economy without any significant change in properties of RPC.***

Keywords— ***Fly ash, Precipitated silica, Reactive Powder Concrete, RPC, Steel fibers, Silica fume.***

I. INTRODUCTION

Concrete, one of the most widely used construction materials, has been subject to major research and development over the past century. The high performance concrete (HPC) is also a new trend concrete material that enhances high strength up to 120 MPa, but Richard and Cheyrezy show that Reactive powder concrete (RPC) in which strength is obtained in excess of 200 MPa and flexural strength 30-60 MPa [1]. Physical, mechanical, and durability properties of RPC and HPC (High Performance concrete) show that RPC possesses better strength.

Reactive Powder concrete contains very fine materials such as precipitated silica, crushed sand and silica fume. The basic composition for the production of RPC has been explained by the Richard and Cheyrezy [1]. A very dense matrix is achieved by optimizing the granular packing of these powders [2]. Due to inverse effect of high cement content on the early age shrinkage behavior and decreased hardened performance by micro-cracking, supplementary cementations materials such as fly ash, blast furnace slag, and silica fume are commonly used in cement and concrete industry [3]. It is possible to modify some fresh and hardened properties of composite by utilizing these materials.In this study, it have been checked that effect of fly ash as a replacement of silica fume on the parameters of reactive powder concrete such as compressive, tensile and flexural strength.

II LITERATURE REVIEW

Dugat [4], investigated the mechanical properties of reactive powder concrete by using superplasticizers and silica fume; it was possible to reduce the water/cementitious ratio to less than 0.15. It help to reduce the total pore volume of the cement paste and the average diameter of the pores.Parameters of Characterization of RPC200 was determine from uniaxial compression and centre-point and two-point bending tests.It was necessary for development of a behavioral law for the material. These parameters were measured on three specimens per test. The addition of steel fibers to RPC200 helps increase its ductility. The effect of different fiber contents on the fracture energy has been studied. The fiber contents studied were 0, 2, 2.5 and 4%. The optimum content is between 2 and 3%. A higher fiber content causes the fracture energy.Its extremely high compactness, as a result of the rational use of silica fume, silica powders and superplasticizers, makes it possible to obtain a compressive strength of 200 MPa in the case of RPC200.

A.N Ming-zhe [5] studied the coefficient and law of the size effect of RPC through experiments and theoretical analysis.They indicate that RPC without fiber behaves quite the same as normal or high strength concrete. The size effect on compressive strength is more prominent in RPC containing fiber. A formula is given to predict the compressive strength of cubic RPC specimens 100 mm on a side where the fiber dosage ranges from 0–2%. The size effect of compressive strength of RPC is clear: the bigger the size, the lower the strength.When the size of the cubic specimen was smaller than 100 mm, the size effect showed no obvious tendency. For cubic specimens no less than 100 mm the size effect becomes more obvious: with an increase in the fiber dosage the conversion coefficient become lager. A formula to predict the compressive strength of 100 mm RPC specimens was obtained, which is valid for the range of fiber dosage of 0 to 2%. Lower size and 2% of fibre,there is large value of compressive strength.

Mahesh K Maroliya, Chetan D Modhera [6] compared compressive strength and flexural strength of plain reactive powder concrete (RPC) and RPC reinforced with corrugated steel fibres and recron 3s fibres. Composition of RPC which was optimized by trial and error method in previous work by varying different ingredient was used with a water cement ratio of 0.22.Corrugated steel fibres was used 0.4 mm dia. And 13mm long and recron 3s fiber of triangular shape and 12 mm length was incorporated in the concrete. Addition of steel fiber at 2% volume fraction was found not to affect the workability of RPC. RPC was easily mixed with steel fibers, however addition of 0.039 Recron 3s fibers was found to affect the workability of concrete.Workability of RSFRPC mix can be improved by using lower percentage of fibers. Addition of steel fibers does not affect the finishibility of RPC outer surface of concrete after casting was as smooth as plain RPC. While in case of Recron 3s fiber finishibility was not as good as plain and steel fiber reinforced RPC.

T.Zdeb,J.Sliwinski[7]studied properties and microstructure of Reactive Powder Concrete (RPC), which was developed at Cracow University of Technology. The influence of three different curing conditions: water (W), steam (S) and autoclave (A) and also steel fibres content on selected properties of RPC was analyzed. The composite characterized by w/s ratio equal to 0.20 and silica fume to cement ratio 20%, depending on curing conditions and fibres content, obtained compressive strength was in the range from 200 to 315 MPa, while modulus of elasticity determined during compression was about 50 GPa.

Hydrothermal curing conditions were great importance in development of mechanical properties of reactive powder concretes.Steam curing increases both compressive and flexural strengths, but also influence on other properties like microporosity or shrinkage However,Autoclaving also improves many features of cementitious composites, especially mechanical properties. This can be attributed to enhancement of pozzolanic activity of ingredients as well as presence of crystalline forms of hydrated calcium silicates.

Yigiter et al. [8] carried out experimental research on reactive powder concrete with low cement content using with high volume fly ash. Cement was replaced with the class –c fly ash upto 60% for this purpose.The compressive strength values greater than 200 MPa was successfully accomplished with LCRPC. This study showed that it is possible to exceed the 200 MPa compressive strength level with cement content as low as 376 kg/m3. The effect of curing condition on mechanical properties is important for conventional RPC and LCPRC. Satisfactory mechanical strength values were obtained even in standard water curing. Fly ash as a pozzolanic material makes a significant contribution to performance gain. Very high mechanical performances obtained after autoclave and steam curing. Test result showed that mechanical performance of RPC composites can be reached ultimate values even in 2 days after heat treatment curing. Implementation of sintered bauxite as an aggregate in RPC mixtures resulted in greater mechanical performance than RPC containing granite aggregate. On the other hand test results indicated that both conventional Portland cement RPC and LCRPC can also be produced using with granite aggregate successfully. Compressive strength of 403 MPa was reached with the application of pressure during setting and hardening stage and then autoclaving in conventional Portland cement RPC. This value was 338 MPa for 60% fly ash incorporated LCRPC. SP conservation and denser microstructure can be ensured by pressure application process. LCRPC mixtures showed quite sufficient splitting tensile and flexural performance compared to conventional RPC (CTRL mixture) in both bauxite and granite series. Splitting tensile strengths greater than 20 MPa and flexural strengths greater than 25 MPa can be achieved by LCRPC.

Silvia Collepardi[9] studied the influence of the superplasticizer type (naphthalene, melamine and acrylic

polymer) on the RPM performance in terms of water-cement ratio and compressive strength. The acrylic polymer admixture performed better than SNF-or MSF-based
superplasticizers in terms of lower w/c, regardless of the cement and silica fume type used in manufacturing RPM mixtures. However, when a C3A-free portland cement with low specific surface area (340m2/kg) was used, the 1-day compressive strength was much lower with the AP admixture than with the SNF- and SMF-based superplasticizers particularly in the presence of white or dark silica fumes. This behavior should be related with a specific retarding effect on the early hydration of this cement caused by AP in the presence of densified silica fumes (white and dark-colored). With other portland cements, and in the presence of a loose un-densified silica fume, the AP superplasticizers did not cause any early retardation. At later ages (after 3 days) the compressive strength of RPM mixtures with the AP admixture were always higher than with SNF- or SMF-based superplasticizers independently of the cement and silica fume type.

Wang et. al. [10] carried out an experimental research on the hybrid fiber-reinforced RPC after heating for temperatures up to 900°C, the compressive properties and microstructures of RPC were investigated in this paper. They concluded that the incorporation of steel fiber can effectively improve the compressive properties of RPC after elevated temperatures. The addition of polypropylene fiber has adverse effect on the compressive strength of RPC after exposure to the lower temperature, but has active impact when RPC exposed to a higher temperature. There is no spalling occurring in the heating process due to the presence of steel fiber and polypropylene fiber. The cubic and axial compressive strength increases first and then decreases with the increasing temperature, and the critical temperatures are 400°C and 300°C respectively, but the decay rate of the axial compressive strength is faster than the cubic compressive strength. Equations to express the relationship of the compressive strength with the exposure temperatures are proposed, and they are in good agreement with the test results. Compared with normal-strength and high-strength concrete, the hybrid fiber-reinforced RPC has excellent capacity in resistance to high temperature.

Zhang et. al. [10] carried out an investigation programme on green reactive powder concrete with compressive strength of 200 MPa (C200 GRPC).Which was successfully prepared in this study by utilizing composite mineral admixtures consisting of 10% silica fume, 25% fly ash and 25% slag to replace 50–60 wt.% of Portland cement, using natural river sand with the maximal diameter of 3 mm to totally replace the ultra fine quartz sand with the maximam diameter of 600 µm, incorporating 3–4% volume fraction of small sized steel fibers, and employing low energy consumption curing regime-20°C and 100% RH for 90 days.They concIded that the C200 GRPC (Green Reactive Powder Concrete) has many advantages over commonly used C200 RPC such as the low production cost, less energy consumption, easier operation, which make C200 GRPC have great potentials in the fields of civil, pavement, bridge and military engineering.

Elevating temperatures and prolonging curing ages can significantly increase the hydration rate, accelerate rapid formation of hydration products, resulting in high early strength. However, too high curing temperature will lead to high energy consumption and complex operation, thus a relative gentle curing regime-20C and 100% RH for 90 days is employed to prepare C200 GRPC. The excellent static and dynamic properties of GPRC are mainly ascribed to two aspects: One is the ultra fine steel fiber involving its large numbers, small average spacing. This greatly improves the GRPC's mechanical strength, fracture energy and interfacial bonding strength. The second aspect is attributed to the particle packing and filling effect, the pozzolanic effect and micro-aggregate effect of the composite mineral admixtures, resulting in a very compacted GRPC matrix with low porosity and little macro-defects.These effects will further improve with the development of curing ages under standard curing regime.

Maroliya [11] investigated on Micro Structure Analysis of Reactive Powder Concrete and they was concluded that the scanning electron microscopy image analysis result in the present study indicate that a major influence of silica fume in concrete was associated with the densification of the microstructure at the transition zone, resulting in a much lower porosity. When the microstructure of the RPC was investigated by using SEM, it reveals that steel fiber surface was covered with densely cementatious material. The hydrated cement matrix or mortar held on side surface of steel fiber. It was clearly observed that there is a good bond between hydrated cement matrix and steel fiber in interfacial zone of RPC. Microscopic images of RPC confirmed the holding of hydrated cement matrix on side surface of steel fiber in SEM images.

SEM micrographs show that, in general, the change in microstructure in the concrete after time was mainly due to the change in the arrangement of the C-H-S compounds. From the SEM micrographs we can observed the various component of RPC also, it development with age and with different curing condition (normal and hot curried). Microstructure of hot water curried sample is much faster than the normal water curried sample.

S. Collepardi [9] summarized the comparison between Original Reactive Powder Concrete (RPC) - in form of a superplasticized cement mixture with silica fume, steel fibers and ground fine quartz (150-400 mm) with a modified RPC where a graded natural aggregate (max size 8 mm) was used to replace the fine sand and/or part of the cementitious binder. Original and modified RPC were manufactured at a plastic-fluid consistency, cast by vibration and cured at three different conditions: a) room temperature; b) steam-curing at 90°C; c) high pressure steam-curing at 160°C. The addition of the graded aggregate did not reduce the compressive strength provided that the quality of the cement matrix, in terms of its water-cement ratio, is not changed. This result was in contrast with the model proposed to relate the high compressive strength level of RPC (200 MPa) to the absence of coarse aggregate.

When the graded aggregate replaced all the fine sand and part of the cementitious binder (cement and silica fume), at a given workability level, there was an increase in the water-cement ratio, due to the reduction in the cement factor, and hence a corresponding decrease in the compressive strength. Flexural strength was lower when graded coarse aggregate replaced all the very fine sand. This effect could be explained in terms of a better homogeneity when only very fine sand is present and then to a more effective bond-strength between cement matrix and aggregate under shear stress produced in bending tests. In the presence of coarse aggregate the steel-concrete bond was increased with respect of the original RPC and this effect could be ascribed to the interlock developing between coarse aggregate and deformed reinforcing bar. Steam-curing at 90°C and specially high pressure steam-curing at 160°C gave a better performance of RPC - in terms of higher strength, lower drying shrinkage and creep strain - than the curing at room temperature. This improvement in the performance was related with a more densified microstructure of the cement matrix.

Rachael A. Price [14] investigated with High strength concrete has been in use for many years although serves little purpose in structural applications due to its brittle nature. Reactive Powder Concrete (RPC) has been produced with strengths ranging from 100 to 800MPa while maintaining fracture energies of 1200 to 40,000 J/m2 although an optimised mixture suitable for structural applications in Australia does not exist. This thesis work was intended to further test for an optimised mixture of RPC 200 without the use of traditional passive reinforcement and also to investigate the mechanical and chemical properties of this mix design using finite element analysis models in ANSYS and additional models in MATLAB. The desired outcome of this thesis was to aid in the development of an optimised mix design for RPC 200 that will someday be used in the concrete construction industry in Australia. They found that the fracture energies varied from 15,000 J/m2 to 40,000 J/m2 depending on the amount of steel fibre added to the mix. The maximum stress encountered was approximately ten times greater than the displacement at the opening of the first crack.

Mahesh Maroliya[11]summarized the evaluation of composite material has to take in to consideration the mechanical behavior of each component as well as their interaction with often governs the mechanical behavior at the macro level interaction of Steel reinforcement with RPC.This Study was determined the structural performance at the composite level. RPC has been studied in direct pull out test of reinforcement specimen. Results showed that Pull out behavior of plain matrix is perfectly of brittle nature where as RPC with fibres

maintained the load carrying capacity with large deformation and prevented splitting cracking and disintegration of matrix.
Pull out behavior of the plain RPC matrix is perfectly of brittle nature where as RPC with fibres maintained the load carrying capacity with large deformation and prevented splitting cracking and disintegration of the composite. Being a dense microstructure and packing density along with hot curing make the interface denser, increase the compressive strength and shear strength of composite there for bond strength of RPCF4 is found to be the greatest among all.

3.2. Remarks on literature review

1.Steam curing increases both compressive and flexural strengths, but also influence on other properties like microporosity or shrinkage However, primary setting time in natural condition has to be suitable.Autoclaving also improves many features of cementitious composites, especially mechanical properties. This can be attributed to enhancement of pozzolanic activity of ingredients as well as presence of crystalline forms of hydrated calcium silicates.

2. The bigger the size, the lower the strength.When the size of the cubic specimen was smaller than 100 mm, the size effect showed no obvious tendency.

3. Workability of RSFRPC mix can be improved by using lower percentage of fibers. Addition of steel fibers does not affect the finishibility of RPC outer surface of concrete after casting was as smooth as plain RPC. While in case of Recron 3s fiber finishibility was not as good as plain and steel fiber reinforced RPC.

4. The experimental results of thermogravimetric analyses on RPC, HPC and OC specimens suffered from the same fire temperature and duration indicate that the total weight loss of RPC is lower than others. Besides excellent workability and high compressive strength, the studied RPC could provide better fire resistance than HPC and OC, and thus is applicable to building materials.

5. in the heating process due to the presence of steel fiber and polypropylene fiber. The cubic and axial compressive strength increases first and then decreases with the increasing temperature, and the critical temperatures are 400°C and 300°C respectively, but the decay rate of the axial compressive strength is faster than the cubic compressive strength.

6. The excellent static and dynamic properties of GPRC are mainly ascribed to two aspects: One is the ultra fine steel fiber involving its large numbers, small average spacing. This greatly improves the GRPC's mechanical strength, fracture energy and interfacial bonding strength. The second aspect is attributed to the particle packing and filling effect, the pozzolanic effect and micro-aggregate effect of the composite mineral admixtures, resulting in a very compacted GRPC matrix with low porosity and little macro-defects.These effects will further improve with the development of curing ages under standard curing regime.

7. The scanning electron microscopy image analysis result in the present study indicate that a major influence of silica fume in concrete is associated with the densification of the microstructure at the transition zone, resulting in a much lower porosity.

8. There is a good bond between hydrated cement matrix and steel fiber in interfacial zone of RPC. Microscopic images of RPC confirmed the holding of hydrated cement matrix on side surface of steel fiber in SEM images.

9. AP superplasticizers did not cause any early retardation. At later ages (after 3 days) the compressive strength of RPM mixtures with the AP admixture were always higher than with SNF- or SMF-based superplasticizers independently of the cement and silica fume type.

From the literature survey,it can be concluded that, Reactive powder concrete have lower production cost when we replace cement by cheap composite mineral such as fly ash, slag. Due to this, it can give sufficient compressive strength than by using sufficient quantity of Portland sand, fine quartz sand. Reactive powder concrete with steel fiber gives the better compressive strength, tensile strength and flexural strength than the normal concrete. Compressive strength,split tensile strength and flexural strength of steel fiber reinforced reactive powder concrete increases with respect to the increase in the percentage volume fraction.Therefore it is beneficial to use steel fiber and replacement of silica fume by fly ash in RPC to enhanced its mechanical properties.

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