Scientific Journal of Impact Factor(SJIF): 3.134

e-ISSN(O): 2348-4470
p-ISSN(P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 2, Issue 11, November -2015

Use of Fly Ash and used Foundry Sand in Reactive Powder Concrete: A State of Art Review

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Abstract: *This state of art review represents the requirement of innovative cementitious material that possesses superior properties for the construction of special structure. Reactive Powder Concrete (RPC), first developed in 1990s (at Bouygues' laboratory in France by P. Richard and M. Cheyrezy, 1994) recognized as a revolutionary material, is blooming nowadays not only because of its ultra-high mechanical properties and very low porosity but it also gives excellent durability. RPC is a composite mixture of cement, silica fume, natural sand, quartz powder and steel fibers. RPC, after a specific heat treatment, has been able to achieve compressive strength ranging from 200 MPa to 800 MPa with flexural strength up to 50 MPa. Although suitable guidelines are not available to produce RPC in India, the main purpose of this state of art review is to represent the utilization of foundry sand and fly ash as the constituent of concrete. The paper summarizes conclusions of experiments conducted for the properties like strength and durability. It was observed the results have shown positive changes and improvement in strength and durability properties of the conventional cementitious concrete due to the addition or replacement of fine sand with used foundry sand in different proportions. However in couple of cases such addition has reported reduction in the values of properties. From the review of past research works it could be concluded that utilizing the used foundry sand and Fly Ash holds a great potential towards the development of environment friendly and sustainable cementitious concretes.*

Key Words: *Reactive powder concrete, Mix proportion, Silica fume, Quartz Powder, Steel Fiber, Super Plasticizer.*

I. INTRODUCTION

There is growing interest in development of innovative cementitious material that possess superior properties. A relatively new cementitious material, Reactive Powder Concrete (RPC), is recognized as a revolutionary material that provides a combination of ultrahigh strength and excellent durability. RPC is a composite mixture of cement, silica fume, natural sand, quartz powder and steel fibers. The composition of reactive powder concrete (RPC) is coarse aggregate-free, differing from that of high performance concrete (HPC).
The ultra-high mechanical performance of RPC can be explained by

(A) enhancement of homogeneity of RPC by elimination of coarse aggregate and limiting the maximum size of ingredients of RPC to be less than 600μm (Richard and Cheyrezy, 1995)

(b) Enhancement of compacted density by optimizing granular mixture (Richard and Cheyrezy, 1995)

(c) Improved matrix properties by addition of pozzolanic admixtures; that is silica fume to fill up voids among the next largest particles (cement), to enhance rheological characteristics by the lubrication effect resulting from perfect sphericity of basic particles and to produce secondary hydrates for pozzolanic reaction with lime resulting from primary hydration (Appa Rao, 2003; Behnood and Ziari, 2008; Long and Wang, 2002; Ma and Schneider, 2002; Richard and Cheyrezy, 1995; Yazici, 2007)

(d) Improved matrix properties by reducing water-to binder ratios (Ma and Schneider, 2002)

(e) Enhancement of microstructure by heat-treatment during hardening (Richard and Cheyrezy, 1995).

On the other hand, Generation of Industrial Waste and its disposal is the biggest problem all over the Globe. However, the use of waste in concrete can be a good scope. Locally available industrial waste is fly ash and used foundry sand.

Foundry sand is high quality silica sand that is a byproduct from the production of both ferrous and nonferrous metal casting Industries. Foundry sand used for the centuries as a molding casting material because it's high thermal conductivity. The physical and chemical characteristics of foundry sand will depend in great part on the type of casting process and the industry sector from which it originates. In the casting process, molding sands are recycled and reused multiple times. Eventually, however, the recycled sand degrades to the point that it can no longer be reused in the casting process. At that point, the old sand is displaced from the cycle as byproduct, new sand is introduced, and the cycle begins again.

Although there is not an enough research available and also the production of reactive powder concrete is not yet available in India, the use of two waste materials in RPC has ample scope of work.

II. LITERATURE REVIEW

Many authors throughout the world, including few from India also, has tried to investigate various properties of RPC. Amongst them, K. M. Ng, C. M. Tam and V. W. Y. Tam [1] investigated to produce reactive powder concrete using local materials under laboratory conditions. Based on their research, they adopted particular mix proportion and have experimentally conducted and compared. The results show that the compressive strength, splitting tensile strength and static modulus of elasticity are found to be significantly higher than that of high-performance concrete using the same water-to-binder ratio. The difference in strength at a later age is even bigger. They found that the Compressive strength, around 200 MPa, can be achieved even in 3 days for the reactive powder concrete samples when it is heat-treated at a Temperature of 250°C for 16 h, which they explained by the formation of xonotlite under scanning electron Microscopy investigation.

Reactive powder concrete (RPC) having high amount of cementitious materials may have high early shrinkage causing cracking of concrete. Shamsad Ahmad, Ahmed Zubair, and Mohammed Maslehuddin [2] attempted to study the simultaneous effects of three key mixture parameters on shrinkage of the RPC mixtures. For three different levels of the three key mixture factors, a total of 27 mixtures of RPC were prepared and monitored by them for shrinkage at different ages over a total period of 90 days. The experimental data pertaining to 90-day shrinkage were used. They found that the shrinkage in all the RPC mixtures was more than one-third, one-half, and two-thirds of the ultimate shrinkage occurred at the early ages of 3, 7, and 14 days. Also the increase in the total shrinkage with increase of w/b ratio from 0.15 to 0.175 is almost negligible particularly at cement content above 1000 kg/m3 because the effective w/b ratios corresponding to the intended w/b ratios of 0.15 and 0.175 were almost similar due to high requirement of superplasticizer at a w/b ratio of 0.15.

Assem Abdelalim, Mohamed Ramadan, Tarek Bahaa, Wael Halawa [3] has carried out the experimental program in two phases. In the first phase, 36 mixes were investigated and the key mixing variables were water/cement ratio, quartz, silica fume and steel balls. Out of which six optimum mixes were selected for the second phase, to evaluate the structural properties of reactive powder concrete. Reactive powder concrete has superior structural properties. A compressive strength up to 160 N/mm2 and a flexural strength up to 46 N/mm2 were achieved. The optimum value of water/cement ratio for reactive powder concrete mixes ranges from 0.17 to 0.19 based on the matrix composition. The optimum contents for silica fume and quartz are in the ranges of 15-25% and 30-40% of the cement weight, respectively. It will be more convenient to evaluate the compressive strength of RPC based on its 56 days age rather than the 28 days used for conventional concrete. Curing regime plays a dominant role in determining the strength of RPC. Air curing adversely affected the performance and did not allow the RPC to achieve its target strength level. Reactive powder concrete possesses superior durability compared to conventional concrete. It has higher resistance to sulphate attack and drying shrinkage. The presence of steel balls improves the resistance of RPC against drying shrinkage. Also, enhancement in the compressive strength was observed.

Pankaj R. Kakad [4] and his fellow mates found that by using fine steel fibers, RPC can achieve flexural strength of up to 50 MPa. They also highlighted that the energy absorption capacity of RPC is very high because only fine aggregate were used instead of course aggregate. RPC has compressive strength of 170 to 230 MPa and flexural strength of 30 to 50 MPa, depends on the type of fibers used. Replacement of fly ash to silica fume is controls the heat of hydration and cost of concrete because it affect directly to volume of silica fume which is very costlier content of RPC. Strength is decrease as the percentage of Fly Ash increase, but it is negligible as compared to other benefit. The research shows that use of fly ash replacing to silica fume achieves economy.

Dr. Narayana Sabhahit [5] and his group investigated reactive powder concrete without quartz powder and containing fly ash and GGBS as a replacement for cement at the percentage of 5% (RPC1), 10% (RPC2) and 15% (RPC3) by each. They compared the results of cement replaced mixture with a specimen without cement replacement (RPC). The 28 days compressive strength increased for 5% (RPC1) and 10% (RPC2) replacement of cement by fly ash and GGBS each. For 15% replacement (RPC3) the results were lower than the control mix (RPC). RPC1 with 5% cement replacement gave highest 28 days compressive strength of 128MPa as compared to RPC having 28 days strength of 126.33MPa. The 7 days and 14 days compressive strength values were lower than RPC for all mixes with cement replacement, which is because of slow hydration of cementitious matter at initial days. Flexural strength of RPC with 10% and 15% replacement of cement by fly ash and GGBS each (RPC2 and RPC3) were higher than that of control mix (RPC). For

RPC with 5% replacement of cement (RPC1), the flexure strength was lower than the strength of control mix. RPC with 15% replacement of cement by fly ash and GGBS each gave higher 28 days flexural strength of 28.525MPa.

M K Maroliya [6] studied the effects of water to cement ratio, curing conditions, compositions and the effect of mineral and chemical admixtures to achieve higher compressive strength. He found that silica fume gives better compressive strength and good flow at lower water/cement ratio. At water cement ratio as low as 0.22, polycarboxylic ether gives good workable concrete, but normal super plasticizers like SMF and SNF requires higher water/cement ratio. When circular steel fibers are used then the increment in the compressive strength is 10 to 15% of the compressive strength obtained without steel fibers. The flexural strength of the RPC obtained by using circular steel fibers has increased by 50% compared to plain RPC when hot water curing is adopted and 18% higher than plain RPC when normal curing is adopted. The hot water curing adopted at later stage is not that much beneficial as it is at the initial stage. Hot water curing for just 7-days will leads to higher compressive strength than compared to hot water curing for 2-days. However the Flexural strength obtained for 28-days continuous hot water curing is still higher. Partial replacement of silica fume by fly ash and metakaolin does not help much but from cost aspect it can be justified and composition is suggested.

Yin-Wen Chan and Shu-Hsien Chu [7] studied the Effect of silica fume on steel fiber bond characteristics in reactive powder concrete. Various silica fume contents ranging from 0% to 40% are used in the mix proportions. Fiber pullout tests are conducted to measure the bond characteristics of steel fiber from RPC matrix. From his experimental studies, it was concluded that the optimal silica fume–cement ratio is found to be in between 20% and 30%, given the conditions of this experimental program. At this silica fume dosage, the bond strength and the fiber pullout energy are the highest among all cases.

The effect of high temperature on reactive powder concrete was experimented by Mehmet Canbaz [8] from Turkey, in which he found that the Compressive strengths higher than 200 MPa were achieved after water curing at 90 _C for 3 days and after applying a pre-setting pressure of 80 MPa to the RPC. However, the addition of polypropylene fiber caused a maximum reduction in strength of 140 MPa. A strength of 165 MPa was obtained in the case of 1% fiber ratio usage.

Chetan D Modhera [9] and his colleague also studied the effect on RPC when STEEL FIBERS AND RECRON 3S FIBERS were used. Addition of steel fiber at 2% volume fraction is found not to affect the workability of RPC. RPC is easily mixed with steel fibers, however addition of 0.039 Recron 3s fibers is found to affect the workability of concrete. Even after taking utmost care balling effect of fibers was observed while casting some of the samples, workability of RSFRPC mix can be improved by using lower percentage of fibers. Addition of steel fibers does not affect the finish ability of RPC outer surface of concrete after casting was as smooth as plain RPC. While in case of Recron 3s fiber finish ability was not as good as plain and steel fiber reinforced RPC.

Anil S. Karabuluta [10]and his fellow mates have carried out experimental investigation to study the Mechanical properties (compressive strength, flexural strength, and toughness) of reactive powder concrete (RPC) produced with class C fly ash (FA) and ground granulated blast furnace slag (GGBFS) were investigated under different curing conditions (standard, autoclave and steam curing) in this study. Test results indicate that, compressive strength of RPC increased considerably after steam and autoclaving compared to the standard curing.

Saeed Ahmari, Xin Ren, Vahab Toufigh and Lianyang Zhang [11] from USA have tried to produce the geopolymeric binder from blended waste concrete powder and fly ash in which he experimented to completely recycle and utilize waste concrete in a sustainable and environmentally- friendly way. A method that does not need re-clinkering at high temperature shall be used. This paper studies the production of geopolymeric binder from ground waste concrete (GWC) powder mixed with class F fly ash (FA), which can then be used with recycled concrete aggregates to produce new concrete. The results indicate that utilization of GWC together with FA can increase the UCS of the geopolymeric binder up to 50% GWC content. Further increase of GWC decreases the UCS of the geopolymeric binder. So with proper combination of GWC and FA, the geopolymeric binder with required strength can be produced.

Halit Yazici [12] and his group from Turkey tried to find out the possibility of producing a reactive powder concrete (RPC) with low cement content. Cement was replaced with class-C fly ash (FA) up to 60% for this purpose. Three different curing conditions (standard water curing, autoclave curing and steam curing) were applied to specimens. Two series of RPC composites were prepared with bauxite and granite aggregates. Mechanical properties such as compressive strength, splitting tensile strength, flexural strength and fracture energy of composites were investigated. Test results showed that, compressive strength of 200 MPa can be reached with low cement by using high-volume fly ash. Thermally treated specimens showed compressive strength beyond 250 MPa and high volume fly ash RPC have superior performance.

Khatib and Baig [13, 14] investigated fresh and hardened properties of concrete containing waste foundry sand (WFS) replaced with 0 to 100% with fine aggregate. The water to cement for all mixes was kept constant. Testing on hardened properties was mainly conducted at 14, 28 and 56 days. The results show that the incorporation of waste foundry sand in concrete causes a systematic decreases in workability, ultrasonic pulse velocity and strength and an increase in water absorption and shrinkage of concrete. They also reported that an acceptable concrete strength can be achieved using foundry sand.

Kumbhar [15] investigated the various mechanical properties of normal concrete containing used foundry sand. Concrete was produced by replacing natural sand with UFS in various percentages (10%, 20%, 30% and 40%). Based on the test results they concluded that (i) workability goes on reducing with increase in UFS content; (ii) At 28-days, Compressive strength, splitting tensile strength and flexural tensile strength for different replacement levels of UFS is increased whereas flexural tensile strength goes on reducing for UFS content more than 20%; (iii) At 28-days, the modulus of elasticity values increases with replacement of UFS up to 20%. They also concluded that the UFS can be utilized as a replacement to regular sand in concrete up to about 20%.

III. DISCUSSION

Based on various researchers, it is observed that there isn't any paper available for RPC in which there is combination of used foundry sand and fly ash. Even for RPC, the paper with only used foundry sand is also not available. However, the researchers for normal concrete noticed that the fresh concrete behavior with foundry sand was decreasing the workability with the increase of foundry sand content by slump test or flow table test. It could also be noted that the effects of concrete containing foundry sand shall be differs as the foundry sand changes its characteristics according to its manufacturing process and source. The research shows that use of fly ash replacing to silica fume achieves economy as silica fume is the one of the costliest material.

IV. CONCLUSION

Although suitable guidelines are not available to produce RPC in India, the main purpose of this experimental investigation will be, to study the strength and durability of RPC produced using locally available waste materials.

Although suitable guidelines are not available to produce RPC in India, the individual ingredients content of RPC can be concluded from the review of the above research papers. They are as follows:-

1) The cement content of the RPC mixes ranged from 800 kg/m3 to 1000 kg/m3.
2) The optimum contents for silica fume and quartz are in the ranges of 15-25% and 30-40% of the cement weight, respectively.
3) It will be more convenient to evaluate the compressive strength of RPC based on its 56 days age rather than the 28 days used for conventional concrete.
4) Curing regime plays a dominant role in determining the strength of RPC.
5) When circular steel fibers are used then the increment in the compressive strength is 10 to 15% of the compressive strength obtained without steel fibers.
6) Strength is decrease as the percentage of Fly Ash increase, but it is negligible as compared to other benefit
7) Test results indicate that, compressive strength of RPC increased considerably after steam and autoclaving compared to the standard curing.

REFERENCES

[1] K. M. Ng, C. M. Tam and V. W. Y. Tam, Studying the production process and mechanical properties of reactive powder concrete: a Hong Kong study, Magazine of Concrete Research, 2010, 62, No. 9, September, 647–654. Doi: 10.1680/macr.9.00063

[2] Shamsad Ahmad. Ahmed Zubair and Mohammed Maslehuddin, Research Article Effect of the Key Mixture Parameters on Shrinkage of Reactive Powder Concrete, Hindawi Publishing Corporation, The Scientific World Journal, Volume 2014, Article ID 426921, 8 pages, http://dx.doi.org/10.1155/2014/426921

[3] Assem Abdelalim, Mohamed Ramadan, Tarek Bahaa and Wael Halawa, PERFORMANCE OF REACTIVE POWDER CONCRETE PRODUCED USING LOCAL MATERIALS, HBRC Journal VOL. 4 No. 3 December 2008

[4] Pankaj R. Kakad, Ganesh B. Gaikwad, Rajesh R. Hetkale, Dattatray S. Kolekar and Prof. Yogesh Paul, Reactive Powder Concrete Using Fly Ash, International Journal of Engineering Trends and Technology (IJETT) – Volume 22 Number 8-April 2015

[5] Mr. Anjan kumar M U, Dr. Asha Udaya Rao and Dr. Narayana Sabhahit, Reactive Powder Concrete Properties with Cement Replacement Using Waste Material, International Journal of Scientific & Engineering Research Volume 4, Issue 5, May-2013, ISSN 2229-5518

[6] M K Maroliya, An Investigation on Reactive Powder Concrete containing Steel Fibers and Fly- Ash, International Journal of Emerging Technology and Advanced Engineering Website: www.ijetae.com (ISSN 2250-2459, Volume 2, Issue 9, September 2012)

[7] Yin-Wen Chan, Shu-Hsien Chu, Effect of silica fume on steel fiber bond characteristics in reactive powder concrete, Cement and Concrete Research 34 (2004) 1167–1172,

[8] Mehmet Canbaz, The effect of high temperature on reactive powder concrete, Construction and Building Materials 70 (2014) 508–513

[9] Mahesh K Maroliya, Chetan D Modhera, A COMPARATIVE STUDY OF REACTIVE POWDER CONCRETE CONTAINING STEEL FIBERS AND RECRON 3S FIBERS, Journal of Engineering Research and Studies

[10] Halit Yazici, Mert Yucel Yardimci, Serdar Aydın, Anıl S. Karabulut, Mechanical properties of reactive powder concrete containing mineral admixtures under different curing regimes, Construction and Building Materials Volume 23, Issue 3, March 2009, Pages 1223–1231.

[11] Saeed Ahmari, Xin Ren, Vahab Toufigh, Lianyang Zhang, Production of geopolymeric binder from blended waste concrete powder and fly ash, Construction and Building Materials 35 (2012) 718–729

[12] Huseyin Yigister, Serdar Aydın, Halit Yazici, Mert Yucel Yardimci, Mechanical performance of low cement reactive powder concrete (LCRPC), Composites: Part B 43 (2012) 2907–2914

[13] J. M. Khatib, S. Baig, A Bougara and C Booth, "Foundry sand utilization in concrete production", Second International Conference on Sustainable Construction Materials and Technologies, ISBN 978-1-4507-1490-7, June 28-30, 2010.

[14] Khatib.J.M, Baig.B, Menadi.B, Kenai.S, "Waste foundry sand usage in concrete", INVACO2, Morocco-Rabat, November 23-25, 2011.

[15] Kumbhar P. D. and Usharani S. Sangar, "Experimental study of mechanical properties of concrete blended with used foundry sand", Global Journal Engineering and Applied Sciences, ISSN 2249-2631, Pg.122-126, 2011.

BIOGRAPHIES

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