Reactive Powder Concrete with mineral admixtures

[1]Sumith Kumar K,[2] Gururaj Acharya, [3]Siddesh R Kamat Mhamai,

[1]PG Student,[2]Assistant Professor,[3]Assistant Manager
[1]PG student, Department of Civil Engineering
[1]NMAMIT Nitte, Karkala, Karnataka-574110
[2]Assistant Professor, Department of Civil Engineering
[2]NMAMIT Nitte, Karkala, Karnataka-574110
[3]Assistant Manager, Technical, RMC Readymix (India)
[3]RMC Readymix (India), Mangalore, Dakshina Kannada, Karnataka-575011

Abstract— Reactive Powder Concrete (RPC) is a developing composite material that will allow the concrete industry to optimize material utilization, produce financial advantages, and build structures that are strong, durable, and sensitive to the environment. The aim of this study is to assess the performance of RPC with different locally available cementitious materials such as metakaolin, and alccofine. Efforts for improving the performance of concrete over the past few years suggests that cement replacement materials along with Mineral admixtures can improve the strength and durability characteristics of concrete. Metakaolin and alccofine are pozzolanic materials that can be utilized to produce high strength concrete. This study investigates the performance of concrete mixture in terms of slump flow test for fresh concrete, compressive strength, split tensile strength and flexural strength test at age of 3,7, 14 and 28 days. In addition figure out the ideal composition of cement, alccofine and metakaolin from given mix proportion.

Keywords— **Alccofine, Metakaolin, Compressive Strength, Split Tensile Strength, Flexural Strength.**

I. INTRODUCTION

A. General

Original RPC can also be called as ultra-high strength concrete. Ultra-high strength concrete is not only a basic mixture of cement, coarse aggregate, fine aggregate, and water, but it has to contain mineral components and chemical admixtures with required specific characteristics which give specific properties to the concrete. Ultra- high strength concrete can achieve greatest compressive quality in its existing form of microstructure. However at such a level of quality, the coarse aggregate in the mix turns into the weakest link in concrete. The ultimate end goal of this study is to substantially increase the quality of the concrete considerably further, the required step is to wipe out the coarse aggregate. This philosophy has been used to make Reactive Powder Concrete.

B. Alccofine

ALCCOFINE 1203 is an specially prepared item in view of slag of high glass content with high reactivity got through the procedure of controlled granulation. ALCCOFINE 1203 have utilized complying with ASTM C989-99.

Table 1 Chemical Composition of Alccofine

SiO_2	33.6%
Al_2O_3	22.6%
Fe_2O_3	2.2%
CaO	31%
MgO	8.0%
SO_3	0.19%

C. Metakaolin

Metakaolin is refined kaolin dirt that is calcined under deliberately controlled conditions to make an undefined aluminosilicate that is reactive in cement. Like different pozzolans, metakaolin responds with the calcium hydroxide byproducts created amid bond hydration.

Table 2 Chemical composition of metakaolin

SiO_2	51.34%
Al_2O_3	41.95%
Fe_2O_3	0.52%
CaO	0.34%

II. LITERATURE REVIEW

A. General

In this research an attempt is being made with alccofine and metakaolin as a partial replacement of cement in the concrete mix. The main objective of this study is to present an overview of research work that has been carried out by various researchers in the past in the field of Reactive Powder Concrete, metakaolin and alccofine.

Many researchers have carried out studies on RPC in the past years to assess the properties and its behaviour. Some of the works carried out re discussed below.

- Richard and Cheyrezy [1995] developed an ultrahigh strength ductile concrete with the basic principles of enhancing the homogeneity by eliminating the coarse aggregate, limiting the maximum size of the aggregate less than 600µ enhancing the microstructure by post-set heat treatment and the tensile strength of concrete was increased by incorporating small, straight, high tensile microfiber. Use of pozzalonic materials like silica fume which will be able to fill up the voids between the cement particles which is next in size to the silica fume particles Two types of concretes were developed and designated as RPC200 andRPC800, which had exceptional mechanical properties. The mean compressive stress obtained for RPC200 was 218MPa and for RPC800 was exceeding 600MPa.With RPC800 strength of 810MPa has been achieved by using steel fibers in the concrete. The concrete finds its applications in industrial and nuclear waste storage silos. [1].
- Chan and Chu, [2002] has examined the impact of silica fume on the bond characteristics of steel fiber in the matrix of Reactive Powder Concrete (RPC) by bond quality, pullout energy, and so forth. Different silica fume substance ranging from 0% to 40% is utilized as a part of the mix proportions. Consequences of them demonstrate that the fuse of silica fume can successfully improve the fiber–matrix interfacial properties, particularly in fiber pullout energy. [3]
- Jianxin Ma and Marko Orgass [2004] In the present paper UHPC was created with pulverized basalt with the particle size from 2 to 5 mm. The compressive quality has come to the same magnitude as Reactive Powder Concrete (RPC) in which the maximal total size is lesser than 1.0 mm. The utilization of the coarse aggregate drove not just to the decline in cementitious paste volume fraction, additionally to a few adjustments in blending procedure and in mechanical properties. UHPC containing coarse aggregate was less demanding to be fluidised and homogenized. The blending time can be shorter than that for RPC. The fineness of quartz powder is utilized in this study to fill the voids between cement and silica fume so as to increase the packing density of the powder mix. Superplasticizer is used to ensure superior fluidity .An extra 3 minutes of mixing time was required for RPC so as to remove the floating lumps in the mixer. The cementitious paste volume fraction was found to be 20% lower in Ultra High Performance Concrete compared to RPC The both tried UHPC showed a similar conduct under compressive stresses, aside from fairly diverse modulus of elasticity and strain at peak stress, which related to the stiffness of the utilized aggregates.
- Asst. Prof. Dr. Wasan I. [2012] Khalil University of Technology Building and Construction Department has contemplated on the properties of altered Reactive Powder Concrete. In his research on altered RPC with natural sand and crushed graded natural aggregate not greater than 12.5 mm has been able to create high compressive quality of 150 MPa which can be accomplished by utilizing crushed coarse aggregate; this outcome is in contrast with the model proposed to relate the high compressive strength level of RPC to the absence of coarse aggregate. The high range water reducing agent used has resulted in gain in early and late compressive strength and reduction in the water to cement ratio. The optimum dosage of the high range water reducing agent was found to be 3% of the weight of cement. The optimum silica fume content was found to be 15% as partial replacement by weight of cement. The inclusion of hooked and crimped steel fibers has helped to increase the split tensile strength of the concrete. Altered RPC reinforced with diverse sorts (crimped and hooked) and volume portions (0%, 0.5%, and 1%) of steel fibers has a decent performance as far as high quality (Compressive strength, split tensile strength, flexural strength, impact strength) and static modulus of elasticity. [7]
- Khadiranaikar R.B. and Muranal S. M. [2012] have considered on the elements influencing the quality of Reactive Powder Concrete. They have seen from the study that water to cement ratio, silica fume content, quartz powder, high temperature curing fundamentally influences the compressive strength of RPC. Silica fume content was varied from 15% to 25% by weight of the cement to find the optimum percentage of silica content in the production of Reactive Powder Concrete. At water to powder ratio of 0.2 the compressive strength was maximum beyond which the compressive strength has

decreased. This paper suggests that the addition of quarts powder in accelerated curing condition has resulted in 20% increase in strength compared with specimens tested at ordinary room temperature curing. [8]

- K. M. Ng, C. M. Tam and V. W. Y. Tam [2010] City University of Hong Kong; University of Western Sydney have studied the production process and mechanical properties of Reactive Powder Concrete. They have examined the generation process, mechanical properties and impacts of heat treatment of RPC by comparing it with HPC. Tests on concrete specimens were tentatively led. It was found that compressive strength, split tensile strength and static modulus of elasticity of the RPC are higher than those of the HPC over the whole curing period for the same water to cement ratio. The rate of quality advancement of the RPC is more prominent than that of the HPC. The constant quality advancement of the RPC can be clarified by the high silica substance of the RPC which prompts a nonstop pozzolanic response at the later age. Heat-treatment of the RPC brings about a huge increment in compressive quality attributable to the micro structural change. It was found that the compressive strength has increased rapidly with the increase in temperature from 100ºC to 250ºC. In this study it was found that the compressive strength, split tensile strength and flexural strength was found to be higher when compared to the strengths of high performance concrete. [2]
- Patel et al [2013] This paper concentrates on the performance of the concrete mixture in terms of compressive strength, chloride attack test, sea water test and accelerated corrosion test at the age of 28 and 56 days. In addition determine the optimum dosage of alccofine and fly ash from the different mix proportions. The accofine is varied from 4 to 14 % and fly ash is varied from 20 to 35 % and the above mentioned four tests were conducted in order to determine the optimum dosage of alccofine and fly ash. Here the compression test, chloride attack test, sea water test was conducted using 150X150X150mm specimen, the rapid chloride penetration test and accelerated corrosion test was conducted using 100mm diameter and 200 mm length cylinders were used. Looking into all the results the researchers have concluded that 8% alccofine and 20% fly ash is the optimum dosage among the different selected mix proportions

III. OBJECTIVES AND AIM

The main objective of the present investigation is to study and compare the behaviour of the concrete with partial replacement of cement by industrial wastes alccofine and metakaolin and finding out the optimal mix which improves strength resulting in sustainable concrete. Since one of the major environmental issues is the disposal of industrial wastes that is being dumped every day cause harmful effects to the environment. This study intends to use these industrial wastes in concrete which proves to be economical as it is a non-useful waste.

A. Aim of the work

- To determine different powder mixes with maximum packing density
- Study and compare the behavior of the concrete with partial replacement of cement with alccofine and metakaolin
- To find out the strength of the concrete when cement is replaced with alccofine and metakaolin.
- To distinguish weaknesses and recommend changes.

IV. MATERIALS AND METHODS

A. Cement

In the present work 53 grade OPC is used as the binder .Physical properties are as shown below.

Table 3 Physical properties of OPC Grade 53

Characteristics	Obtained Value	As per IS:12269-1976
Specific gravity	3.14	3.15
Normal consistency	30.4%	30% to 35%
Initial setting time	125 minutes	>30 minutes.
Final setting time	215 minutes	<600 minutes
Blaine fineness	308m^2/kg	225m^2/kg
Soundness	1.0	<10

B. Fine Aggregates

The test were conducted as per IS 2386(Part 3): 1963, fine aggregates passing through 600µ sieve and retained on 150µ sieve is used. Physical properties are shown below [6] [8].

Table 4 Physical Properties of Fine Aggregates

Characteristics	Obtained Value
Specific Gravity	2.49
Water Absorption	2.1%
Grading	Zone IV
Surface Moisture	Nil

C. Alccofine

Alccofine is an innovative product in the world of concrete. Physical properties of the powder like specific gravity 2.60 and fineness of 12000 cm^2/gm. The chemical properties of the powder obtained are shown below.

Table 5 Chemical properties of Alccofine

Chemical Present	Test Result
SiO_2	33.6%
Al_2O_3	22.6%
Fe_2O_3	2.2%
CaO	31%
MgO	8.0%

B. Metakaolin

Metakaolin is a calcined product of the clay mineral kaolinite. The particle size of metakaolin is smaller than Cement particles, but not as fine as silica fume.

Table 6 Chemical properties of metakaolin

Chemicals present	Test Result (%)
SiO_2	62.62
Al_2O_2	28.63
Fe_2O_3	1.07
Cao	0.06
MgO	0.15

C. Types of mixes

Table 7 Type of Mixes

Type of Mix	Cement	Alccofine	Metakaolin	Steel fibers
OPC	100 %	0 %	0 %	0%
Trial 1	76 %	9 %	15 %	0%
Trial 2	68 %	17 %	15 %	0%
Trial 3	59 %	26 %	15 %	0%
Trial 4	51 %	34 %	15 %	0%
Trial 1 - SF	76 %	9 %	15 %	1 %
Trial 2 - SF	68 %	17 %	15 %	1 %
Trial 3 – SF	59 %	26 %	15 %	1 %
Trial 4 - SF	51 %	34 %	15 %	1 %

V. TESTS CONDUCTED ON SPECIMENS

The testing will be done as per I.S Specifications.

- Compression Tests
- Split Tensile Tests
- Flexural Tests

The above tests are done for knowing the strength characteristics of concrete after 7 days and 28days. The table below shows results of 3days, 7days, and 14days and 28 days strength of specimens.

Table 8 Compressive strength (N/mm2) of RPC without Steel fibers

Mix Designation	Compressive Strength (N/mm^2)			
	3 days	7 days	14 days	28 days
OPC	63.9	72.6	77.1	80.7
Mix 1	69.3	74.0	75.9	86.2
Mix 2	74.6	79.7	81.9	92.8
Mix 3	77.1	82.5	83.5	96.2
Mix 4	85.2	91.0	94.9	106.0

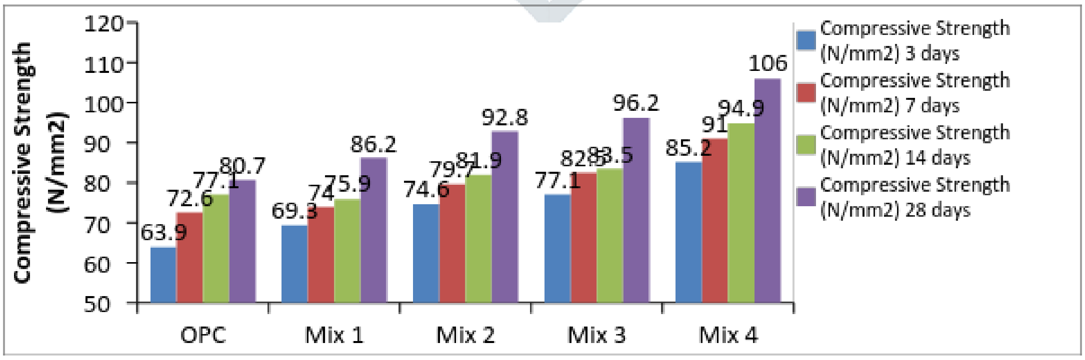

Fig 1 Compressive strength (N/mm2) of RPC without Steel fibers

Table 9 Compressive strength (N/mm2) of RPC with Steel fibers

Mix Designation	Compressive Strength (N/mm^2)			
	3 days	7 days	14 days	28 days

Mix 1 - SF	79.6	84.3	86.6	98.2
Mix 2 - SF	81.0	86.1	88.9	100.3
Mix 3 - SF	82.2	88.1	90.2	102.6
Mix 4 - SF	87.9	93.7	95.6	109.1

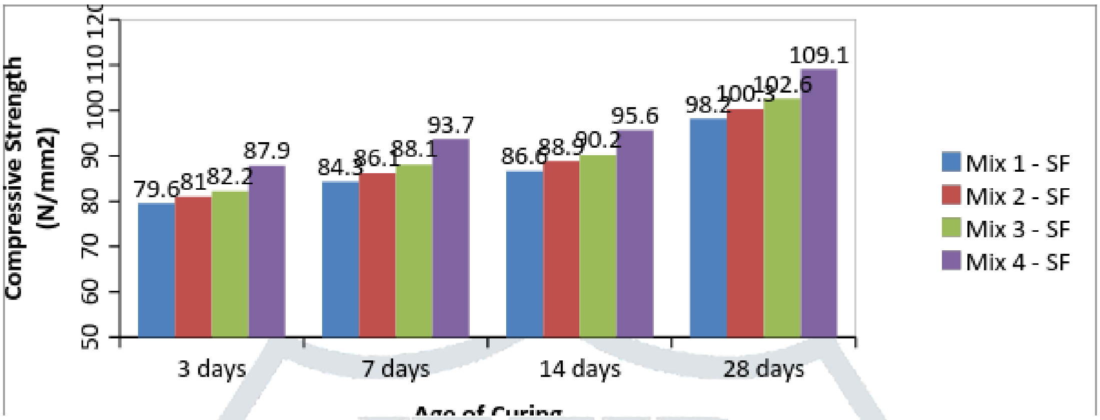

Fig 2 Compressive strength (N/mm2) of RPC with Steel fibers

Concrete mixes are prepared with different cement, alccofine and metakaolin proportions, prepared by replacing cement by alccofine and metakaolin as certain percentage. These are the graphs which show the 3 days, 7 days, 14 days and 28days strength of the concrete mix, graph also says, there is increase in strength as compared to conventional concrete. In the graphs we can see that the mix 4 without fiber and mix 4 with fiber has attained maximum compressive strength compared to other mixes.

Table 10 Split tensile strength (N/mm2) of RPC without Steel fibers

Type of mix	Split Tensile Strength (N/mm^2)
	28 Days
OPC	6.21
Mix 1	6.91
Mix 2	7.52
Mix 3	9.01
Mix 4	9.23

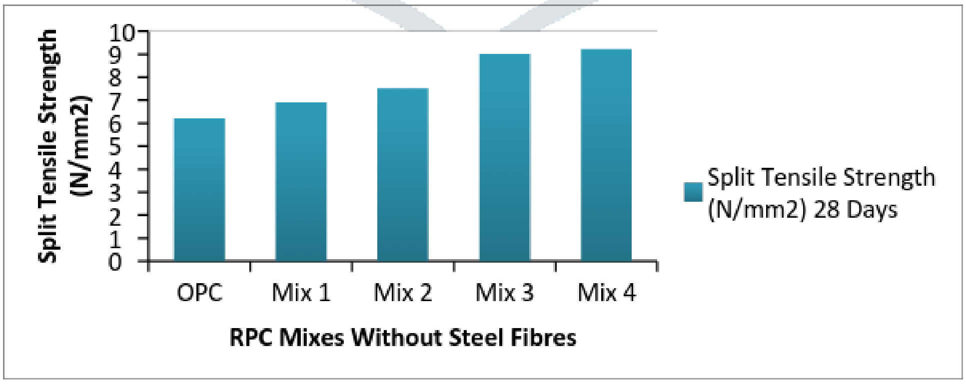

Fig 3 Split tensile strength (N/mm2) of RPC without Steel fibers

Table 11 Split tensile strength (N/mm2) of RPC with Steel fibers

Type of mix	**Split Tensile Strength (N/mm^2)**
	28 Days

Mix 1 - SF	5.22
Mix 2 - SF	5.76
Mix 3 - SF	6.05
Mix 4 - SF	6.85

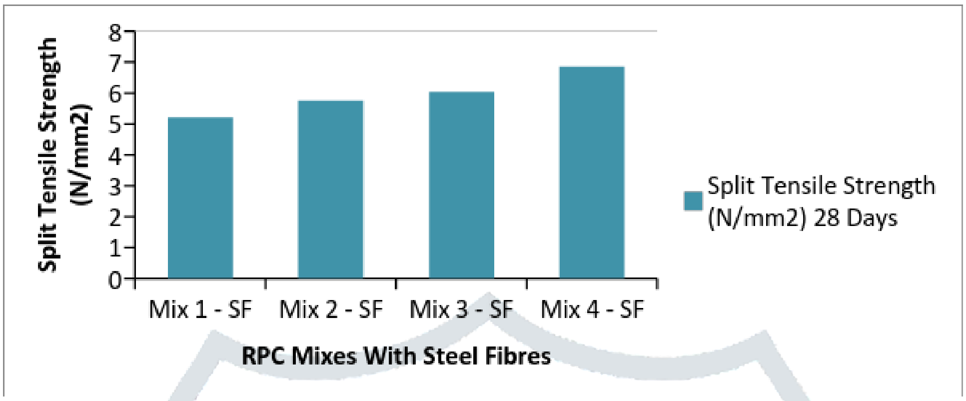

Fig 4 Split tensile strength (N/mm2) of RPC with Steel fibres

Concrete mixes are prepared with different cement, alccofine and metakaolin proportions, prepared by replacing cement by alccofine and metakaolin as certain percentage. These are the graphs which shows the 28days strength of the concrete mix, graph also says, there is increase in strength as compared to conventional concrete. In the graphs we can see that the mix 4 without fiber and mix 4 with fiber has attained maximum split tensile strength compared to other mixes.

Table 12 Flexural strength (N/mm2) of RPC without Steel fibres

Type of mix	**Flexural Strength (N/mm^2)**
	28 Days
OPC	13
Mix 1	13.8
Mix 2	15.8
Mix 3	16.8
Mix 4	17.8

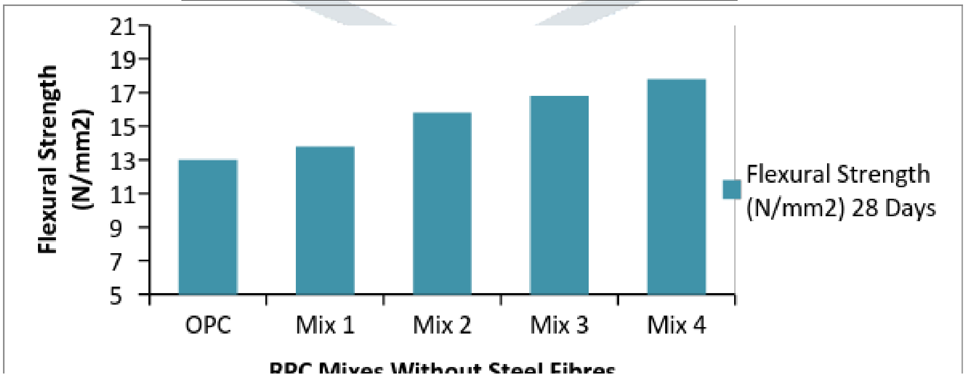

Fig 5 Flexural strength (N/mm2) of RPC without Steel fibres

Table 13 Flexural strength (N/mm2) of RPC with Steel fibres

Type of mix	**Flexural Strength (N/mm^2)**

	28 Days
Mix 1 - SF	12
Mix 2 - SF	13.8
Mix 3 - SF	14.4
Mix 4 - SF	15.2

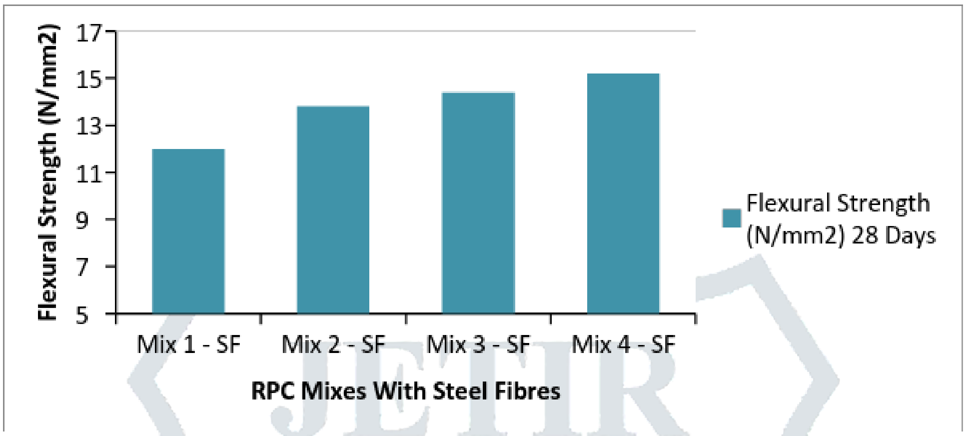

Fig 6 Flexural strength (N/mm2) of RPC with Steel fibres

Concrete mixes are prepared with different cement, alccofine and metakaolin proportions, prepared by replacing cement by alccofine and metakaolin as certain percentage. These are the graphs which shows the 28days strength of the concrete mix, graph also says, there is increase in strength as compared to conventional concrete. In the graphs we can see that the mix 4 without fiber and mix 4 with fiber has attained maximum flexural strength compared to other mixes.

VI. CONCLUSION

- Here we have found that the blend 3 containing 59% cement, 15% metakaolin and 26% alccofine has achieved maximum packing density.
- In this study compressive strength of specimens is increased with the increase in the percentage of alccofine in mixes with both with and without steel fibers when the results are compared with the OPC mix which contains 100% cement.
- The study suggests that the split tensile strength of specimens has increased with the increase in the percentage of alccofine compared to the OPC mix.
- Flexural strength of the cast beam has increased with the increase in the percentage of alccofine percentage in both the mixes with steel fibers and without steel fibers.
- But the strength gained is slightly less compared to the RPC 200[ ] which can be achieved by using silica fume or quartz sand in the mixes.
- Finally we can reason that the Mix 4 without fiber is the optimum mix which contains 51% cement, 15% metakaolin and 26% alccofine.
- We have taken up simple methods to reduce the cost of construction with use of waste material, which is freely or cheaply available.
- This study also has an aim of controlling the environmental pollution.

VII. ACKNOWLEDGEMENT

The authors are thankful to our beloved HOD Dr. Srinath Shetty K, Principal Dr. N Chiplunkar and faculty members Department of Civil Engineering NMAMIT, Nitte for their continuous support to carry out this research work.

REFERENCES

[1] Richard, P.; Cheyrezy, M.: composition of reactive powder concrete. In: Cement and Concrete Research 25, No. 7, S. 1501-1511, 1995.
[2] K. M. Ng*, C. M. Tam* and V. W. Y. Tam†: Studying the production process and mechanical properties of reactive powder concrete. In: Magazine of Concrete Research, 2010, 62, No. 9, September, 647–654
[3] Yin-Wen Chan and Shu-Hsien Chu (2004), “Effect of silica fume on steel fiber bond characteristics in reactive powder concrete,” Cement and Concrete Research, No- 34, pp.1167–1172.
[4] Mohammad Panjehpour, Abang Abdullah Abang Ali, Ramazan Demirboga.:
[5] A REVIEW FOR CHARACTERIZATION OF SILICA FUME AND ITSEFFECTS ON CONCRETE PROPERTIES. In: International Journal of Sustainable Construction Engineering & Technology (ISSN: 2180-3242) Vol 2, Issue 2, December 2011

[6] Ma, J.; Orgass, M.; Tue, N.V.; Dehn, F.; Schmidt, D., 'Comparative investigations on ultra high performance concrete with and without coarse aggregates',), Kassel, Germany, September 2004
[7] Dr. Wasan I. Khalil.: Some Properties of Modified Reactive Powder Concrete. In: Journal of Engineering and Development, Vol. 16, No.4, Dec. 2012 ISSN 1813- 7822
[8] Khadiranaikar R.B. and Muranal S. M.: FACTORS AFFECTING THE STRENGTH OF REACTIVE POWDER CONCRETE (RPC). In: INTERNATIONAL JOURNAL OF CIVIL ENGINEERING AND TECHNOLOGY (IJCIET), Volume 3, Issue 2, July- December (2012), pp. 455-464
[9] Yatin H Patel, P.J.Patel, Prof. Jignesh M Patel and Dr. H S Patel : "STUDY ON DURABILITY OF HIGH PERFORMANCE CONCRETE WITH ALCCOFINE AND FLY ASH", IJAERS/Vol. II/ Issue III/April-June, 2013/154-157
[10] Mr.Anjan Kumar M U, Dr. Asha Udaya Rao and Dr. Narayana Sabhahit :"Reactive Powder Concrete Properties with Cement Replacement Using Waste Material" In: International Journal of Scientific & Engineering Research, Volume 4, and Issue 5, May-2013 (ISSN 2229-5518).
[11] IS: 383 (1970), Specifications for Coarse and Fine Aggregates from Natural Sources for Concrete. Bureau of Indian Standards, New Delhi
[12] IS: 2386(1963), Indian standard "code of practice for methods of test for aggregates for concrete" Bureau of Indian standards, New Delhi
[13] M.S.SHETTY.,"CONCRETE TECHNOLOGY Theory and Practice", Ram Nagar, New Delhi, pp 1-118.