Experimental Investigationon Strength Characteristics of Concrete Using Waste Materials

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Abstract: ***Concrete is a construction material consisting of cementitious material, fine aggregate, coarse aggregateand water. Now a day the cost of these materials is increased so, we need to look at a way to reduce the cost ofbuilding materials especially cement. The replacement of materials offers cost reduction, energy savings and protection ofenvironment.The quality of concrete mix is assessed through various mechanical properties likecompressive strength and split tensile strength are carried out to analyse the performance of HPC. This study helps in identifying influence of Alccofine, Fly Ash, Rice Husk ash and Marble Powder onstrength characteristics of HPC. The use of alternative material of Portland cement leads toreduction of emission gases and impact on production capacity of cement plant. This studyalso provides a strategy to reducing the cost of waste disposal and its related gains. The objective of this study is to evaluate the structural strength of high performanceconcrete by utilizing green and pozzolanic material as supplementary cementitiousmaterial and potential use of non-destructive testing devices for in-situ strength parametersof HPC during and after construction. About 720 concrete specimens of different fordifferent mix proportions were analysed in the study. This research study primarilyfocuses on the development of empirical correlations for estimating the 21 & 28days'compressive strength and split tensile strength for diverse range ofwater/binder ratio for binary and ternary concrete mixes.Results shows that the workability and compressive strengthand split tensile strengths of concrete areincreased with partial replacement of cement by Fly Ash,Metakaoline and waste marble powder between 10% to 25%.***

Keywords: High Performance Concrete, Supplementary Cementitious Material, WasteUtilization, Non-destructive Testing of Concrete, Mechanical Properties.

1. Introduction

Concrete is an extraordinary and key structural material in the human history. As writtenby Brunauer and Copeland (1964), "Man consumes no material except water in suchtremendous quantities". It is no doubt that with the development of human civilization,concrete will continue to be a dominant construction material in the future. However, thedevelopment of modern concrete industry also introduces many environmental problemssuch as pollution, waste dumping, emission of dangerous gases, depletion of naturalresources etc.

Presently, Portland cement and supplementary cementitious materials are cheapest binderswhich maintain enhance the performance of concrete. However, out of these binders,production of Portland cement is very energy exhaustive along with CO2 production.About 1 tonne of CO2 is produced in manufacturing of each tonne of Portland cement(PC). Thus, cement production accounts for about 5% of total global CO2 emissions(Tatem, 2003). On the other side of the spectrum, in order to reduce the rate of climatechange, a global resolution to an 8% reduction in greenhouse gas emissions by 2010 wasset in the Kyoto Protocol in 1997. Developed countries are much aware for its need and aclimate change tax was introduced by them. In this connection, UK Government alsointroduced same kind of tax on 1st April 2001, in order to achieve its target of a 12.5%reduction in greenhouse gas emissions which is the government's domestic goal of a 20%reduction in CO2 emissions by 2010. Therefore, it is evident that, in order to keep itsposition as a dominant material in the future, the model of concrete industry needs to beshifted towards "sustainability".

It is mistaken to bestow that supplementary cementitious materials were used in theconcrete only because of their availability and just for economic considerations. Thesematerials present some unique desirable properties which cannot be met by using OPConly. For producing high performance concrete (HPC), it is wellrecognized that the use of supplementary cementitious materials (SCMs), such as SilicaFume (SF), Alccofine (A)and Fly Ash (FA) are necessary. The concept of HPC has definitelyevolved with time. Initially it was equated to high strength concrete (HSC), whichcertainly has some merit, but it does not show a complete and true picture. There is a needto consider other properties of the concrete as well which sometimes, may even takepriority over the strength criterion. Various authors proposed different definitions forHPC. High Performance Concrete is a concrete which made with appropriate materials,combined according to a selected mix design; properly mixed, transported, placed,consolidated and cured so that the resulting concrete will give an excellent performance inthe structure in which it is placed, in the environment to which it is exposed and with theloads to which it will be subjected for its design. Thus, HPC is directly related to durableconcretes.

Concretes with these cementitious materials are usedextensively throughout the world. Some of the major users are power, gas, oil and nuclearindustries. The applications of such concretes are increasing with the passage of time dueto their excellent performance, low influence on energy utilisation and environmentfriendliness.

This study helps in identifying Influence of Alccofine, Fly Ash, Rice Husk Ash, Fly Ashon strength characteristics of HPC. The use of alternative material of Portland cementleads to reduction of emission gases and impact on production capacity of cement plant.This study also provides a strategy to reducing the cost of waste disposal and its relatedgains. This research work will enhance and accelerates the decision-making process in thepre, during and post construction phases of any infrastructure projects.

2. Background

According to**P. Kumar Mehta(1986)** The rapid development of construction industry has led to an increase in the demand for tall and long span concrete structures and this demand can be accomplished by high strength concrete, a type of concrete with compressive strength greater than 6,000 psi (41 MPa). It is due to the fact that high strength concrete can carry loads more efficiently than normal concrete, reduce the total amount of material needed and reduces overall cost of the structure. **Prof.Dr. Harald Justnes (2012)** Concrete can never be made sustainable since it is based on non-renewable mineral resources. However, concrete can be made more sustainable (or less unsustainable) by replacing cement with supplementary cementing materials based on industrial by-products like slag and fly ash. Larger amount of fly ash can be used if loss in early strength is counteracted by finer grinding or special grinding (mechanical activation) or accelerators.**P. Kumar Mehta.(2003)** took Class F Fly Ash, OPC Cement replacement is 15 to 60 % by Fly ash and W/B ratio is 0.30 to 0.40. At the age of 28 days 25-30 % replacement achieved good compressive strength, thermal cracking & salt resistant. Use more than 50% FA for sustainable development. **Alaa M. Rashad (2013)** partially replacing 10% MK with FA in alkali activation system gives lower porosity and higher impact strength. Other researchers believed that the inclusion of 33.3% FA in MK based geopolymer gives the highest compressive strength, but depends on the mole ratio and curing condition.**Gastaldini et. al., (2007)** Depending on produce method, the utilization of Rice Husk Ash as a pozzolanic material in cement and concrete provides several advantages, such as improved strength and durability properties. **Muhamad Ismeik (2009)** found that maximum compressive strength at 28-day obtained as 60 MPa at 15% SF replacement level with w/cm ratio of 0.30, and the minimum 35 MPa obtained at 5% SF replacement level at a w/cm ratio of 0.40. Dr.Mattur, Gopinatha, & Shridhar. (2009)60 silica fume based ternary blends, with VMA, improved the flow properties, as required for SCC and achieved target strength at 56days.**Sheng, Wan& Chen (2008)** For HPC with GGFBS at w/b of 0.30, compressive strength reaches highest value at optimum replacement of 15%. Cahit And Okan (2008)20Concrete containing 40% slag with 450 kg/m3 cement exhibits greater strength (83.8 Mpa) than that of control normal PCC Concrete. **G.Latha (2015)**Concrete is a construction material consisting of cementitious material, fine aggregate, coarse aggregateand water. The replacement of materials offers cost reduction, energy savings and protection ofenvironment. The present investigation is aimed to study the fresh and hardened properties ofconcrete when cement is partially replaced by waste marble powder. The work is focused on M20, M30, M40 grades ofconcrete. The percentage of Waste marble powder that replaced cement in this investigation are 0%,5%,10%, 15% and20%. The fresh proprieties are workability and hardened properties are compressive strength at the age of 7,28 days ofcuring, split tensile strength, and flexural strength of concrete are at the curing age of 28days are to be determined.Results shows that the workability and compressive strength, flexural, and split tensile strengths of concrete areincreased with partial replacement of cement by waste marble powder between 10% to 15%.

3. Objective of Experimental Study

The main objective of the present investigation is to study the effects of marble powder on properties of fresh andhardened concrete when cement is partially replaced by concrete are Fly Ash (FA), Silica Fume (SF), Metakaoline (M), Alccofine (A), Rice Husk Ash (RHA) and Marble Powder (MP), and to compare the compressive and split tensile strength of M30 grades of concrete. We are also trying to find the percentage of Fly Ash, Metakaoline and marble powderreplaced in concrete that makes the strength of the concrete maximum. Nowadays Fly Ash, Metakaoline and marble powder has become apollutant. So, by partially replacing cement withFly Ash, Metakaoline and marble powder, we are proposing a method that can be of great use inreducing pollution to a great extent.

4. Experimental Methodology

4.1 Material Used

Concrete can be defined as a stone like material that has a cementitious medium within which aggregates are embedded. In hydraulic cement concrete, the binder is composed of a mixture of hydraulic cement and water (ACI Committee 116). Concrete has an oven-dry density greater than 2000 kg/m3 but not exceeding 2600 kg/m3 (BS EN 206-1:2000). The materials used for concrete will be briefly reviewed in the following sections.

Binder: The function of the binder in concrete is to chemically bind all the constituent materials to form a stone like material. The commonly used binders in concrete are cement, Fly Ash (FA), Silica Fume (SF), Metakaoline, Alccofine, Rice Husk Ash (RHA) and Marble Powder (MP).

Fly Ash: FA is complicated in its chemical and phase compositions. It consists of heterogeneous combinations of glassy and crystalline phases. However, wide ranges exist in the amounts of the three principal constituents- SiO2 (25 to 60%), Al2O3 (10 to 30%), and Fe2O3 (5 to 25%). FA can be categorized into two classes, i.e. Class F and Class C, according to ASTM C 618-99 (1999). If the sum of these three ingredients is 70% or greater, the FA is categorized as Class F. However, as Class C, FA generally contain significant percentages of calcium compounds reported as CaO, the sum of the three constituents just mentioned is required only to be greater than 50%. The Fly Ash used in this research work was collected from shingaji Thermal Power Station, khandwa, (M.P.).

Silica Fume: Silica Fume is an extremely reactive pozzolanic material. It is a by-product obtained from the manufacture of silicon or ferro-silicon. It is extracted from the flue gases from electric arc furnaces. SF particles are very fine with particle sizes about hundred times smaller than those of average size of OPC particles. It is a densified powder or is in the form of water slurry. The standard specifications of Silica Fume are defined in ASTM 1240. It is commonly used at a replacement level of 5% to 12%by mass of total cementitious materials.

Rice Husk Ash: Amorphous (non-crystalline) RHA was used as a supplementary cementing material (SCM). It was available in very fine powder form with a grey color. RHA was tested for relative density, Blaine specific surface area, accelerated pozzolanic activity, particle size distribution, and chemical composition. The accelerated pozzolanic activity was determined according to the procedure used for Silica Fume.

Alccofine: Alccofine is a new generation, ultrafine, low calcium silicate product, manufactured in India. It has distinct characteristics to enhance 'performance of concrete' in fresh and hardened stages. Alccofine performs in superior manner than all other mineral admixtures used in concrete within India.

Metakaoline: Metakaoline is a highly reactive pozzolanic classified as ultra-fine with an average diameter around 1-2 microns. The presence of Metakaoline has a huge effect on the hydration of cement. When Portland cement alone hydrates, typically 20-30% of the resulting paste mass is CH. However, when Metakaoline is added, it reacts rapidly with these newly forming CH compounds to produce supplementary calcium silicate hydrate. The pozzolanic reaction of Metakaoline is considered to be very effective and similar than Silica Fume. Thus, the partial replacement of cement by Metakaoline will increase the performance of concrete either in early or at long term ages. The Metkaoline used in this study was retrieved from 20 Micron (An Industry located in Kutch Region of Gujarat). The optimum cement replacement content is less than 20%. Some authors indicate 5% and for Portuguese Metakaoline report the value 15%.

Waste marble powder (WMP): The Waste Marble powder was collected from the local market in Mumbai. It was sieved by IS-90-micron sieve before mixing in concrete. Tests are carried out in order to find out the properties of waste marble powder. The test results are presented here.

- Fineness of waste marble powder = 13%
- Specific gravity = 1.5

Cement: The ordinary Portland cement of 53grade manufactured by the JP Cement Company was used in the study, which is in accordance with IS 8112:1989. Properties of this cement were tested and shown in table-1.

Fine aggregate: Locally available fresh river sand, free from organic matter, was used. The result of sieve analysis confirms to zone-I (according to IS: 383-1970). The other properties of fine aggregate are determined and shown in table -2.

Coarse aggregate: Crushed aggregate of 20mm size is brought from quarry. Aggregates of more than 20mm size are separated by sieving. Tests are carried out in order to find out properties of it. The test results are presented in table- 2.

Table 1: Physical Properties of Cement

Properties	Results
Fineness	7%
specific gravity	3.16
standard consistency	31.5
initial setting time	150min
final setting time	270min

Table 2: Physical Properties of Cement

Properties	Fine aggregate	Coarse aggregate
Bulk density	1.44g/cc	1.44g/cc
Porosity	37.42%	71.11%
Void ratio	0.59	1.07
specific gravity	2.29	2.99
Fineness modulus	3.62	6.45

Water: In this investigation, fresh potable water was used for mixing as well as curing of concrete.

5. Results and Discussion

Concrete Specimens

This research observed two factors to produce high strength concrete, i.e. the use of supplementary cementitious material and variation in W/B ratio in high performance concrete. This research commenced by finding the optimum concrete mix design of HPC using SCM. HPC mixes were designed by IS 10262: 2009 for High Performance Concrete. The concrete specimens have dimensions of 150 x 150 x 150 mm cubes for compressive strength test and cylinder of dia.150 mm x 300 mm for split tensile strength. Therefore, all variations of mix proportion used in this experiment are:

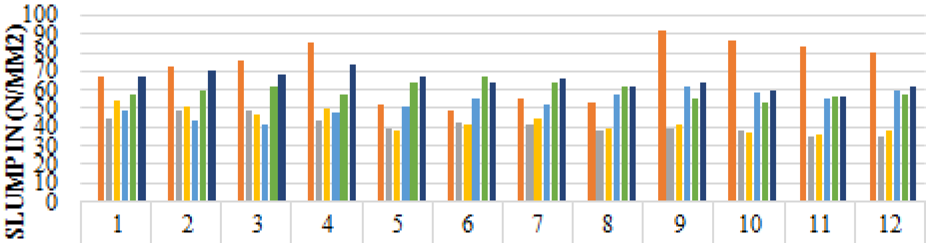
Binary Mix

a) High performance concrete comprising of Rice Husk Ash (6%, 9%, 12% and 15%) as supplementary cementitious material incorporating variation in W/B ratio from 0.3 to 0.5.
b) High performance concrete comprising of Fly Ash (15%, 20%, 25% and 30%) as supplementary cementitious material incorporating variation in W/B ratio from 0.3 to 0.5.
c) High performance concrete comprising of Alccofine (4%, 8%, 12% and 16%) as supplementary cementitious material incorporating variation in W/B ratio from 0.3 to 0.5.
d) High performance concrete comprising of Silica Fume (6%, 8%, 10% and 12%) as supplementary cementitious material incorporating variation in W/B ratio from 0.3 to 0.5.
e) High performance concrete comprising of Metakaoline (8%, 10%, 12% and 16%) as supplementary cementitious material incorporating variation in W/B ratio from 0.3 to 0.5.
f) High performance concrete comprising of Marble Powder (10%, 15%, 20% and 25%) as supplementary cementitious material incorporating variation in W/B ratio from 0.3 to 0.5.
g) Super-plasticizer content has been taken 1.00% of total binder content on all above-mentioned proportion.

Fresh Concrete: Each batch of concrete was tested for consistency after mixing, using slump and C.F.

tests.Provided that care was taken to ensure that no water or other material was lost, the concrete used for the consistencytests was remixed with the remainder of batch before making the test specimens.

Slump test: After mixing the concrete properly, workability of concrete is determined by slump cone apparatus. Shows the slump values for different grades of concrete for various proportions of binders in concrete are cement, Fly Ash (FA), Silica Fume (SF), Metakaoline (M), Alccofine (A), Rice Husk Ash (RHA) and Marble Powder (MP)and represented in Graph-1.



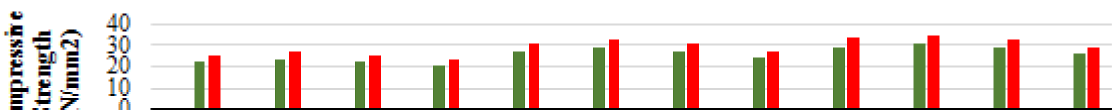
	1	2	3	4	5	6	7	8	9	10	11	12
W/B ration	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
Rice Husk Ash slump (mm)	68	73	76	86	53	49	56	54	92	87	84	81
Fly Ash slump (mm)	45	50	49	44	40	43	42	39	40	39	35	36
Alccofine slump (mm)	55	52	47	51	39	42	45	40	42	38	37	39
Silica Fume slump (mm)	49	44	42	48	52	56	53	58	62	59	56	60
Metakaoline slump (mm)	58	60	62	58	64	68	64	62	56	54	57	58
Marble Powder slump (mm)	68	71	69	74	68	64	67	62	64	60	57	62

Graph 1: Slump Test Results of Concrete Mix Incorporating all Waste Material

Hardened Concrete: After curing at 21 and 28 days in fresh water, the specimens were made dried and thentested to evaluate strength characteristics.

Compressive strength: Compressive strength of concrete is evaluated by the concrete at 21 and 28 days' cube strength. Compressive strength of concrete for various proportions of waste All materials is represented in Graph-2 & 3.

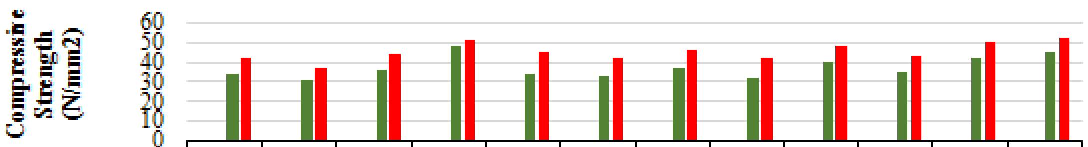
Figure 1: Compressive Strength Testing Apparatus in Laboratory



	1	2	3	4	5	6	7	8	9	10	11	12
W/B ration	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
Fly Ash (%)	15%	20%	25%	30%	15%	20%	25%	30%	15%	20%	25%	30%
21 Dyas	22	23	22	20	27	29	27	24	29	31	29	26
28Days	25	27	25	23	31	33	31	27	34	35	33	29

W/B ration Fly Ash (%) 21 Dyas 28Days

Graph 2: Compressive Strength of Concrete Mix Incorporating Fly Ash



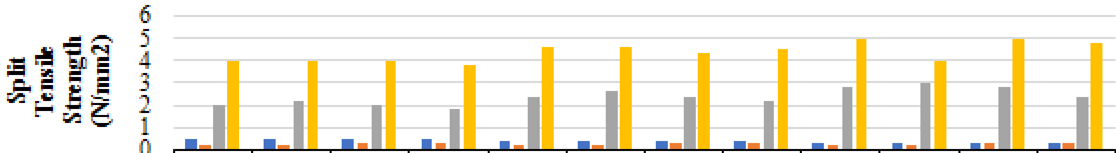
	1	2	3	4	5	6	7	8	9	10	11	12
W/B ration	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
Marble Powder (%)	10%	15%	20%	25%	10%	15%	20%	25%	10%	15%	20%	25%
21 Dyas	34	31	36	49	34	33	37	32	40	35	42	46
28Days	42	37	44	52	46	42	47	42	49	43	51	53

W/B ration Marble Powder (%) 21 Dyas 28Days

Graph 3: Compressive Strength of Concrete Mix Incorporating Marble Powder

Split tensile strength: The split tensile strength of concrete for cylinders, all mixes at 21-28 days of curing is shown in Graph-4& 5. Three cylinders were casted for various percentage replacements of cement by All waste materials andthey are tested by placing them horizontal in CTM.

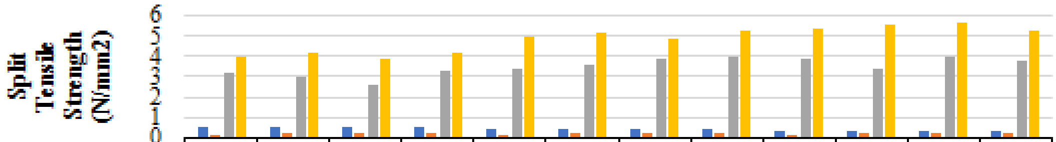
Figure 2: Split Tensile Strength Testing Apparatus in Laboratory



	1	2	3	4	5	6	7	8	9	10	11	12
W/B ration	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
Fly Ash (%)	15%	20%	25%	30%	15%	20%	25%	30%	15%	20%	25%	30%
21 Dyas	2	2.2	2	1.8	2.4	2.6	2.4	2.2	2.8	3	2.8	2.4
28Days	4	4	4	3.8	4.6	4.6	4.4	4.5	5	4	5	4.8

W/B ration Fly Ash (%) 21 Dyas 28Days

Graph 4: Split Tensile Strength of Concrete Mix Incorporating Fly Ash



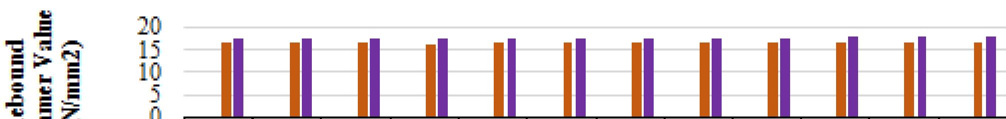
	1	2	3	4	5	6	7	8	9	10	11	12
W/B ration	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
Marble Powder (%)	10%	15%	20%	25%	10%	15%	20%	25%	10%	15%	20%	25%
21 Dyas	3.2	3	2.6	3.3	3.4	3.6	3.9	4	3.9	3.4	4	3.8
28Days	4	4.2	3.9	4.2	5	5.2	4.9	5.3	5.4	5.6	5.7	5.3

W/B ration Marble Powder (%) 21 Dyas 28Days

Graph 5: Split Tensile Strength of Concrete Mix Incorporating Marble Powder

Rebound hammer test: It is most commonly used one in India among the existing nondestructive methods. Due to its rapidity and easiness in execution, simplicity, portability, low cost and non-destructiveness it is widely used all over the world. The rebound hammer test is described in IS 13311(Part 2): 1992, BS 1881: Part 202 (1986) and TS 3260 (1978). It is usually used in comparing the concrete in various parts of a structure and indirectly as measuring concrete strength. The hammer weighs about 1.8 kg and is suitable for use both in a laboratory and in the field. The effect of carbonation on rebound hammer results. Grieb presented the effect of aggregate type on rebound hammer results.

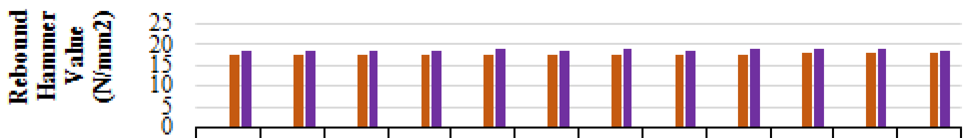
Figure 3: Rebound Hammer Testing in Laboratory



	1	2	3	4	5	6	7	8	9	10	11	12
W/B ration	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
Fly Ash (%)	15%	20%	25%	30%	15%	20%	25%	30%	15%	20%	25%	30%
21 Dyas	16.7	16.8	16.6	16.5	16.9	16.9	16.9	16.8	16.9	16.9	16.8	16.7
28Days	17.8	17.8	17.7	17.6	17.7	17.9	17.9	17.9	17.8	18	18	18

W/B ration Fly Ash (%) 21 Dyas 28Days

Graph 6: Rebound Hammer Test Results of Concrete Mix Incorporating Fly Ash



	1	2	3	4	5	6	7	8	9	10	11	12
W/B ration	0.5	0.5	0.5	0.5	0.4	0.4	0.4	0.4	0.3	0.3	0.3	0.3
Marble Powder (%)	10%	15%	20%	25%	10%	15%	20%	25%	10%	15%	20%	25%
21 Dyas	17.8	17.7	17.8	17.7	17.8	17.7	17.6	17.8	17.6	17.9	18	17.9
28Days	18.8	18.7	18.8	18.6	19	18.8	18.9	18.8	19.1	19	18.9	18.8

W/B ration Marble Powder (%) 21 Dyas 28Days

Graph 7: Rebound Hammer Test Results of Concrete Mix Incorporating Marble Powder

6. Summary of Results

Series of tests were carried out on the concrete cubes to evaluate the mechanical properties of Ultra High Performance Concrete (UHPC). This chapter presented the results obtained from the testing program. The results are the slump test, compressive strength, split tensile strength and Rebound hammer Test. The results obtained from utilization alccofine and Fly Ash as SCM in ternary mix has given effective results and there is substantial improvement in strength of high performance concrete. Such integrated approach of utilization of industrial waste and low cost cementitious product will lead to cost and environment effective production of HPC.

7. Conclusion

Laboratory investigations are performed covering the almost all aspects of high performance concrete. The major experimental outcomes of this thesis as follows;

1) Compressive strength testing of various mix proportions by considering all available supplementary cementitious materials, it was depicted that for binary mix incorporating rice husk ash has given good results as compare to others. The compressive strength of concrete is increased with increase in Alccofine content up to 8% & Silica content up to 11% & Marble Powder content up to 25%. It was observed that there is possibility of production of concrete having compressive strength more than 78 MPa from ternary mix incorporating Alccofine, Marble Powder or Silica Fume as SCM. The optimum proportion is obtained from combination of 13% of Metakaoline, 25% Fly Ash, 30% Marble Powder and 0.3W/B ratio based on experimental investigation. The utilization Metakaoline, Fly Ash and Marble Powder in binary has shown substantial improvement in strength characteristics of HPC.
2) Compared to fly ash concrete, Marble Powder and Metakaoline concrete had slightly higher early strength as well as late strength.
3) The results obtained from the present study shows that there is great potential for the utilization of best Marble powder, Fly Ash and Metakaoline add mixture in concrete.
4) High durable concrete achieved through the use of supplementary cementitious materials will decrease the maintenance cost of structure. Thus, life cycle cost will decrease.
5) Empirical correlations are developed by carrying out multivariate linear parametric regression analysis using MS excel tool for estimating concrete strength parameters such as 21 & 28 days' compressive strength and split tensile strength from non-destructive testing devices like rebound hammer Test for diverse range of water/binder ratio for binary and ternary concrete mixes of SCM's.

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