MIX DESIGN FOR INCORPORATING FINE AGGREGATE REPLACING MATERIALS: A REVIEW

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Abstract

One of the main ingredients of concrete is fine aggregate. The natural sand which is now in scarcity is to be replaced by the alternative material. With that concern the crushed stone known as Robo sand has been used as an alternate material. The dust particles obtained from the quarry are fine grained below 4.75 mm IS sieve or mechanically crushed stone dust by grinding the un-sized and waste rock mass at stone quarry are now being used as an alternate fine aggregate in place of natural river sand. In the concrete mix design as per code, natural river sand is being blindly replaced by manufactured sand (Robo sand). The side effects of this unscientific replacement in designed mortar or concrete mix is being reflected in the form of spalling, micro structural cracks in the work completed. Hence it is essential to have a proper mix design procedure involving manufactured sand and such other Fine Aggregate Replacing Materials [FARM]. The project is an attempt to arrive at a feasible mix design procedure involving FARM in the mortar or concrete mix. On the lines of IS code trial mix designs are developed involving FARM. The casted and cured specimens by the prepared mix are put to mechanical test for determination of designed strength. The physical tests such as (SEM) Scanning Electronic Machine and X-Ray Powder Diffraction (XRD) are analysed for the formation of crystalline structures and the density of the structural element cast. Based on the mechanical and physical test results, a mix design and an empirical formula are arrived at. These formulas are validated through repeated tests.

Keywords: *Robo Sand, Mix Design, FARM- Fine Aggregate Replacing Material, Empirical Formula, Validation*

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1. INTRODUCTION

Cement Concrete Mix Design is the determination of proportions of the concrete ingredients, i.e. cement, fine aggregate, coarse aggregate which would produce concrete possessing specified properties such as workability, durability and strength with overall maximum economy.

The concrete has been used for many amazing works throughout spanning over 5000 years from the time of Egyptian pyramids to the modern world now including the architecture, infrastructure and many more works. The developments made using concrete materials are enormous and that created the mix design concept so that the materials of concrete are used in proportions for different type of works. The formulae were developed accordingly through various experiments. The enormous developments of infrastructure and the usage of materials made the natural resources to diminish and requirements of searching of alternative materials for the cement, fine aggregate and coarse aggregate which are the materials of concrete and thus silica fume, granulated blast furnace slag etc. were used as alternative material for cement, manufactured sand (crushed stone or Robo sand) for the fine aggregate. For the usage of alternative materials various experiments has been done for which proportions the replacements can be made and still the works are being carried out. The methods of concrete mix design are I.S. Method, British Method and A.C.I. Method etc.

1.1 The Properties Desired from Concrete in Plastic Stage

- Workability-Suitable for proper placing of concrete in the member
- Cohesiveness-Better cohesiveness between the cement and aggregates to prevent segregation of concrete.
- Initial set retardation-to control the initial setting time of concrete based on requirements.

1.2 Properties Desired from Concrete in Hardened Stage

- Strength- The main objective of mix design is strength-compressive strength, split tensile strength, flexural strength etc.,
- Imperviousness- Better proportions for the protection of reinforcement from corrosion and increase the durability of concrete.
- Durability-To increase the durability of concrete.

2. INDIAN SCENARIO

In India the I.S. Method is used for mix design. The concrete mix design is of two types- nominal concrete mix and design concrete mix. Nominal mix is specified by standard codes for common construction works. This mix considers the quality control, material quality and workmanship in concrete construction. Design mix suggests the proportions of the materials based on actual material

quality, degree of quality of materials and their moisture content for give concrete compressive strength required for the project. Design mix concrete are carried out in laboratory and based on various tests and revisions in mix design, the final mix proportions are suggested. Various works has been carried out using the cement replacing materials and fine aggregate replacing materials from the past in various proportions and tests are carried out to find its workability, strength factors, durability etc.

S.Rukmangadhara Rao, G.HimaliKumari, and N.Vidya SagarLal P.G Student and Assistant Professors of Gokul Institute of Technology, Andhra Pradesh (Rao, 2015)studied by replacing the robosand for natural river sand in percentage of 0%, 50%, 75%and 100%. The tests have been carried out for split tensile strength, flexural strength considering the grade of concrete as M25 and M35. The results obtained are on the higher side than the natural sand. For the compressive strength it is 12% to 15% more for 50% replacement and 3% to 4% more for 100% replacement. For split tensile strength it is 7% to 9% more for 50% replacement and 3% to 4% more for 100% replacement. For flexural strength it is 20% to 22% more for 50% replacement and for 100% replacement it is 5% to 8% more.

M.D.Narendra, G.Gangha SRM University Kattankulathur (Narendra and Gangha, 2015) has considered the various percentage of GGBS and Robosand replacing the cement and fine aggregate and the experiments has been conducted on cubes, cylinders and beams to determine the compressive strength, tensile strength and flexural strength curing it for 28 days and it has been determined that the increase in Robosand decreases the workability and the average increase in the strengths has been seen by increasing the percentage of Robosand and GGBS.

Rachana M.N, Ramesh Babu.E P.G Student and Associate Professor of Ghousia College of Engineering, India (Rachana and Ramesh Babu, 2014) has used Robo Sand as a partial replacement of fine aggregate and for Mix design M30 and M40 has been used for the concrete mix and cubes, cylinders and beams are casted and tested for its compression, flexural and tensile strengths. The 75% replacement of Robo sand for fine aggregate has been found to be given good compressive strength.

Dr. S.Elavenil, B.Vijaya. Professor and Assistant Professor of Dr. MGR University, Chennai (Elavenil and Vijaya, 2013) has compared the usage of Manufactured sand as a replacing material of fine aggregate, the physical properties like bulk specific gravity, absorption capacity were determined and found the fresh properties of concrete were certainly affected by manufactured sand but the hardened properties like flexural strength and compression strength were not affected by using manufactured sand. Compared to concrete made of natural sand, high fines concrete generally had higher flexural strength, improved abrasion resistance, higher unit weight, low permeability.

Dr.P.Sri Chandana, Shaik Ahamed Mynuddi H.O.D, PG Student, Acharya Institute of Technology and Sciences, Kadapa (Chandana and Shaik, 2015) has used saw dust and RoboSand replacing Fine sand in various percentages of the probabilities were tried and the strengths like compression, split tensile strengths were tested for cubes and beams etc. considering the standard grades. The saw dust of 10% and Robosand of 40% were proved optimum mix to get M20 grade. The weight reduction of 7% and cost reduction of upto 85% per cubic meter of concrete is achieved.

S.Purushothaman, G.Harri, S.Lokesh, P.G Students Dhirajlal Gandhi College of Technology, Selam, (Purushothaman et al., 2015) has considered high strength concrete using the cement replacing material as flyash, silica fume, GGBS and the sand replacing material as M-Sand, crusher dust and Granite powder has been tried Mix design to achieve compressive Strength of M60 using the above materials were performed casting the cubes. The granite powder and flyash as replacing material of fine aggregate and cement were found economical and satisfied as the strength factor.

Ramakrishna Samanthula, Mahendra Reddy, Polim Reddy, M-Tech at Rajiv Gandhi University of Knowledge and Technology, Nuzivid (Samanthula and Polimreddy, 2015) has used 100% Robo Sand as a replacing material for natural sand and has proved that it is good enough in properties of concrete in its fresh and hardened state. The tests like compression strength, split tensile strength, flexural strength has been conducted for the ratios of 25, 50, 75 and 100% replacement of GGBS and 50% slag (GGBS) as a replacement of cement has been resulted in optimum strength compared to the conventional concrete.

M.Vijay Sekhar Reddy, M.SeshaLalitha H.O.D., Lecturer at Sri Venkateshwara University College of Engineering, Tirupathi (Reddy and Seshalalitha, 2014) has considered the High Performance Concrete M60 and the factors like workability, strength and durability has been given importance considering the alternative material for Fine Aggregate and Cement as Robo Sand and GGBS. The super plasticizer has been considered for the good workability. The compressive strength has been achieved 65.3MPa with 40% replacement of cement by GGBS and 15% replacement of Fine aggregate by Robo Sand. From the experimental results it has been found that 100% replacement for Fine Aggregate as RoboSand can be made but GGBS can only be partially replaced with cement.

B.V.Venkataram Reddy, Indian Institute of Science, Bangalore (Reddy, 2012) has used manufactured sand replacing natural sand for the mortar and concrete for mixes M15 and M20 and tests of workability (flow test) and water retention were found for mortar which worked out to be well compared to the river sand. Then for concrete compressive strength, flexural strength and bond strength were found to be higher compared to the river sand. Thus using manufactured sand was recommended for the mortar as well as concrete.

K.Eswaramma, K.Raja Sekhar PG student, Professor at Siddhartha Educational Academy Group of Institution, Tirupathi (Eswaramma and Raja Sekhar, 2015) has considered High performance concrete of M40 and M50 grades were considered using the silica fume and Robo sand as a partial replacement material for cement and fine aggregate. The tests of compressive strength, split tensile strength, flexural strength were conducted and it has been found that the maximum strength was achieved by using 15% replacement of silica fume and 10% replacement of fine aggregated by Robo sand for M40 grade. The super plasticizers have also been used for good workability.

Venkatesan M-Tech Student and Assistant Professor of Prist University Kumbakonam Campus Tamilnadu (Anbarasan and Venkatesan, 2015) has used Recycled aggregate (RCA) and Robosand as a replacement materials for natural coarse aggregate and river sand in various percentages. Different strength tests were conducted with concrete having characteristic compressive strength of $30N/mm^2$ (M30) and strength aspect, cost aspects has been determined. The replacement of RCA and Robosand for 30%-100% were shown good results for both 7days and 28days curing. With 30% RCA and 50%-100% Robosand reasonable strength has been achieved with reduced cost. Without mineral admixture the target mean strength is reduced of RCA used above 30%.

Venu Malagavelli, P.N.Rao Professor and Head of Department, BITS, Pilani, Hyderabad (Malagavelli and Rao, 2010) has partially replaced for cement and natural sand by GGBS and Robosand has been done for conventional concrete M30. 0-30% Robosand and 40-60% GGBS were added and tests like compressive strength and split tensile strength were conducted. Results showed that 50% of cement can be replaced by GGBS and 25% of sand with Robosand increased the percentage of compressive strength by 11.06% and 17.6% at the age of 7 and 28 days curing.

Bhavesh Kumar M. Kataria and Sandip U. Shah, Lecturers BVPIT (DS), Umrakh, Bardoli, Gujarat (Kataria and Shah, 2015a) has used the manufactured sand replacing the river sand and various tests has been conducted like Compressive strength test, split tensile strength test and flexural strength test and the increase of 5% in compressive strength, 9% in split tensile strength and flexural strength using manufactured sand has been observed. As all the properties has been enhanced, the usage of Manufactured sand replacing river sand has been recommended so as to protect the environment from the problems of extraction of river sand.

Dr. S. Elavenil, Professor, S.R.M.University, Kattankulathur, **B.Vijaya**, Assistant Professor, Dr. M.G.R. Educational And Research Institute University , Chennai (Elavenil and Vijaya, 2013), has conducted the experiments by using manufactured sand replacing river sand with various mix from M15 to M60 and has found that the compressive strength, flexural strength are in the higher end than using the river sand though the fresh properties of concreter are certainly affected by using manufactured sand. The Sieve analysis, water absorptiontest, soundness test results also shows the manufactured sand is almost nearer to the values obtained by river sand. The particle size distribution helps in higher packing density which enhances durability of the concrete. Thus concludes that the manufactured sand had higher flexural strength, improved abrasion resistance, higher unit weight and lower permeability due to fillings the pores with micro fines.

Priyanka A.Jadhav, Dilip K.Kulkarni, Research Scholar IIT Bombay and Assitant Professor, Rajarambapu Institute of Technology, Rajaramnagar, Islampur, Maharashtra (Jadhav and Kulkarni, 2013) has casted the mortars using the ratio 1:2, 1:3 and 1:6 with water cement ratio as 0.5 and 0.55 respectively and the mortar using river sand has been kept as a reference mix and using 50% and fully replaced by manufactured sand has been compared to the reference mix for its compressive strengths. The physical properties like specific gravity, fineness modulus, water absorption has also been tested which gave good values with manufactured sand. The 50% replaced mortar has the higher strengths compared to the 100% replaced mortar comparatively. Thus Manufactured sand qualifies itself as a suitable replacing material for natural sand at reasonable cost. and it also has good gradation and nice finish resulting in a good cohesive cement mortar.

Dr. T.Suresh Babu, M Avnesh Kumar Professor and Head, Visvodaya Engineering Engineering College Kavali (Babu and Anveshkumar, 2016) has used the Manufactured Sand and GGBS as a replacement material for river sand and cement in different proportions for the conventional Mix M20 and has been tested for its physical properties and its strengths- compressive strength, flexural strength and tensile strength. The optimum percentage replacement of GGBS in OPC with water cement ratio 0.45 obtained the maximum compressive strength increasing by 20% in 28 days curing and admixture used increased the workability factor. With Robo Sand the workability and strength has been increased compared to river sand without admixtures like GGBS. And also the percentage weight loss and strength loss is less in admixture concrete with robosand as compared to normal concrete showing better resistance against acidic solutions.

Dr Suresh, J.Revathi, Professor Sona College of Technology, Salem, Research Scholar, Anna University, Chennai (Suresh and Revathi, 2016) has used Manufactured sand replacing river sand and admixtures like silica fume and GGBS has been added in various percentages like 0%, 5%, 7.5%, 10% and 10%, 20%,30% respectively. Physical tests like slump for workability were conducted. The compressive strength and split tensile strengths were also determined for the conventional mix M60. The Manufactured sand showed the considerable increase in both compressive and split tensile strengths. The usage of admixture Silica fume in 5% and GGBS in 10% showed good results in both compressive and split tensile strengths in both 7 days and 28 days curing.

Mr Bhavesh Kumar M.Kataria, Mr Sandip U. Shah, Lecturers of B.V.P.I.T. (DS), Umrakh, Bardoli, Gujarat (Kataria and Shah, 2015b) has replaced the natural sand by Manufactured sand in 0%, 25%, 50% and 100%. Physical properties like fineness modulus, specific gravity, workability were found to be considerable using manufactured sand. The compressive strength increases with the increase in the ratio of Manufactured sand for both 7 days and 28 days of curing. And thus found the Manufactured sand can be used as an alternative material 100%.

3. SUMMARY

The above stated works have used alternative materials for the natural sand and cement in different percentages. The mix proportions were arrived as per IS specifications. Alternate or replacing materials were blindly used in volumetric basis equal to the ratios of the materials to be replaced. Tests were carried out for workability, strengths, durability etc.

Thus it is found very essential to evolve a mix design for incorporating FARM and derive an empirical formulae to fit the existing mix design method. This would minimize the reduction in characteristic strength of mix obtained. Which otherwise would be lesser than the target mean strength.

4. PROPOSED RESEARCH WORK

- Conventional method of Indian Standard method has been used for mix ratios. The FARM has been blindly used for the replacement materials for fine aggregate.
- Physical properties like specific weight, density etc., fresh properties like workability, water absorption etc., And hardened properties like compressive strength, durability etc., shall be determined.
- Replacing the FARM for the natural sand, the obtained strengths are determined with reference to one with natural sand. Percentage increase or decrease in strength is taken as reference for different proportion.
- The physical properties are also taken into consideration for different proportions of FARM in place of natural sand by using XRD and SEM analyis.
- Comparison is made for each proportions of FARM.
- Based on the obtained trial results an empirical formulae for the replacement of FARM would be derived.

ABBREVATIONS

SEM: Scanning Electronic Machine
XRD: X-Ray Powder Diffraction
FARM: Fine Aggregate Replacing Material
GGBS:Ground Granulated Blast Furnace Slag
RCA: Recycled Aggregate
OPC: Ordinary Portland Cement
M: Mix
IS: Indian Standar
ACI: American Concrete Institute

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