MECHANICAL PROPERTIES ON USING SUPPLEMENTARY MATERIALS IN CONCRETE

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Abstract - Concrete technology is developing to bring a sustainable environment with the help of many innovative materials in concrete. This can reduce the amount of cement that is usually been used in concrete to avoid its negative effects on environment. Thus, many supplementary materials are being used these days to bring up a good material than cement or equally efficient material that can be used in concrete. One such try to examine the behaviour when they are used in the concrete are studied in this paper. The supplementary materials used here are bottom ash and quartz powder replacing fine aggregate and cement respectively at various percentage combinations. The results concluded that as the bottom ash when incorporated as fine aggregate, the strength of the concrete decreases. But when it is in a combination with quartz powder its strength is equivalent to control concrete. Thus, showing that quartz powder increases the strength parameters.

1. INTRODUCTION

Concrete is a composite material which has evolved after the usage of burnt limestone and clay in ancient world which then improved over years by combining with other materials over time which is now the modern Concrete. The necessity for this evolution is the low setting period of the ancient concrete and to bring ease in workability. Therefore concrete is a versatile member suitable and can be modified in all environmental accepts. Due to its brittle nature reinforced concrete was brought to add more strength, depending upon the purpose the reinforcement is also improved by its emerging techniques. Concrete technology is emerging day by day with innovative ideas by using different constituents in the concrete over the control constituents either by fully or partially replacing it. Although fully replacement of cement or aggregates has not achieved the expected strength like the control concrete, partial replacement has achieved the desired strength or more. Later in order to increase its strength and durability additives like Chemical and Mineral admixtures came into play.

The continuous use of the control constituents in the concrete may lead to scarcity of them which in turn becomes the cause of depletion of the sources beyond its limit. Therefore, it is more significant and essential to find substitute constituents for the concrete. Thus, making concrete a sustainable and a big step towards conservation of resources which makes it preferable in today's world.

This paper presents the study on using Bottom ash and Quartz powder in replacement of fine aggregate and Cement at varying percentages to find its optimum. Bottom ash is from thermal power plants. It is a waste that gets settled in the bottom of the furnaces. Bottom ash exhibits relatively high permeability and grain size distribution which allows it to be used in impervious material. Bottom ash exhibits lower density as found in the research by Dilip Kumar, Neetesh Kumar, Ashish Gupta, (2012). The other studies made by Jawahar, Magesh, Jagen Vasugi, (2019), Kadam, Patil, (2013), Kim and Lee, (2010) shows that the strength parameters of concrete with bottom ash in it decreases beyond the optimum percentage mix. The optimum percentage varies for every bottom ash according to its nature of source.

Quartz Powder is a pozzolonic material. Bertolini, Carsana, Frassoni, Gelli,(2013) Analysed the Influence of Pozzolanic Additions on Durability of Reinforced Concrete Structures. Quartz powder occurs in most igneous and practically in all metamorphic and sedimentary rocks. Quartz is mainly made up of silica. It is highly resistant to both mechanical and chemical weathering. They primarily affect the pore structure of the concrete, which leads to higher strength and lower permeability as stated by Amirhossein Nikdel, (2014). This durability makes it the dominant mineral. Quartz has significantly improved performance in compression, flexure, impermeability, corrosion, impact and abrasion as studied by Alaa Rashad, Ahmed Hassan, Sayieda Zeedan, (2016), Amirhossein Nikdel, (2014) and Deepak, Vijay, Vinothkumar, Gokula kannan, (2017). Quartz Powder is an active member in the formation of High Performance Concrete due to its high silica content as stated by Arafa, Shihada, Karmout, (2010).

2. EXPERIMENTAL PROGRAM

2.1 Materials

Ordinary Pozzolona Cement (OPC) of 53 grade and with the specific gravity 3.15 was used for casting all the specimens. Manufactured sand (M-Sand) is used as one of the fine aggregates passing through 4.75 mm sieve as per

IS373:1970. Another material used as fine aggregate is the Bottom ash. It is a coarse, angular material of porous surface texture predominantly sand-sized. Having a specific gravity of 2.16. The course aggregate used here are according to the grading limits given in IS 383 – 1970, with specific gravity of 2.47 and passing through 20 mm sieve and retained on 12.5 mm. Casting and curing of specimens were done with the potable water as per IS 456-2000. The super plasticizer, Sika Viscocrete 20HE is used which is especially suitable for the production of concrete and mortar mixes. It gives high early strength development, powerful water reduction and excellent flow ability. The supplementary material used as a partial replacement of cement is Quartz Powder composed of silicon dioxide or silica.

2.2 Mix Proportion

Mix design guidelines provide the proper proportioning of concrete mixes as per the requirements using the materials used along with supplementary materials if any. Eight different mixes with different proportions of Quartz Powder and Bottom ash were prepared. Their combination were at 0%,5% and 10% as shown in the table. Mix design was arrived as per IS 10262-2019.

TABLE1

MIXPROPORTIONS

Mix	Cement (Kg/m³)	Quartz Powder (Kg/m³)	Water (Kg/m³)	Fine Aggregate (Kg/m³)	Bottom Ash (Kg/m³)	Coarse Aggregate (Kg/m³)	Superplasticizer (Kg/m³)
CC	350	-	140	694.5	-	1257.1	-
B10Q10	346.5	38.5	140	615	60	1238	-
B10Q5	365.75	19.25	135.61	615.8	59.8	1238.4	4.389
B10Q0	385	-	134.61	619.2	60.16	1245.2	5.39
B5Q10	346.5	38.5	135.842	649.1	29.87	1236.7	4.158
B0Q10	346.5	38.5	135.84	683.3	-	1236.7	4.158
B15Q0	385	-	134.225	592.7	91.47	1262.2	5.775
B0Q15	327.25	57.75	140	682.3	-	1235	-

2.3 Casting and Curing

The specimens of cube, cylinder and prism were casted for the required Mix of M30 using the mould sizes of 150mmx150mmx150mm for cube, 150mm diameter and 300mm height for cylinder and 100mmx100mmx500mm for prism as per IS 10262 at the required percentages. After casting, the specimens were de-moulded from put for curing for 7 and 28 days. It is important to cure the concrete to control the loss of moisture in it. This ensures hydration in the cement and enables strength and durability. After the curing process the specimens are allowed to dry and tested to know its mechanical properties. Fresh concrete properties like slump cone test were determined according to Indian Standard Specifications.

2.4 Test procedures

2.4.1 Compressive Strength For compressive strength test, cube specimens of dimensions 150 mm x 150 mm x 150 mm were casted for M30 grade of concrete. The concrete incorporated with varying percentages of bottom ash and quartz powder replacing fine aggregate and cement were casted. After 24 hours the specimens were demoulded and transferred to the curing tank where they are kept for 7days and 28 days curing. After curing the respective days the specimens are tested in the compression testing machine to find their compressive strength where load is applied as per IS 5161964.Compression testing machine with 2000kN dial is used for loading. In each percentage 2 cubes were casted. The observed readings are then used in the following formula to know the compressive strength possessed by each specimen.

Fig. 1. Compressive Strength test

2.4.2 Split Tensile test

The tensile strength of the concrete plays its role in the extent and size of cracking in structures. As concrete is weak in tension, its maximum resistance to direct tension must be known. In order to find its resistance in tension, this split tensile test on is carried out. The split tensile is carried out to determine the tensile strength of concrete. It is experimented according to IS: 5816-1999. The cylindrical specimen of 100mm diameter and 300mm height were casted in all required percentages and put for curing for 7 and 28 days. The testing is done in the compression testing machine having 2000kN dial. Load at a constant stoke rate, is applied through two steel bearing strips at the top and bottom of the horizontal cylinder. The load was then applied until the needle cylinder splits across the diametric plane connecting the loading strips.

Fig. 2. Split Tensile Test

2.4.1 Flexural Strength Test

Flexure strength is the measure of concrete beam or slab to resist failure in bending. The flexural strength of concrete prism was determined based on IS: 516 –1959. Beam specimens of size 100x100x500 mm were casted and placed in UTM and tested for flexural strength. The specimens are placed on two point loading setup and rollers above the specimens. Place the specimen in the machine in such a manner that the load is applied to the upper most surface in the mould along two lines spaced 5cm from both the edges. The load was applied without shock and increased continuously at a constant rate and it is increased until the specimen fails. Measure the distance between the line of fracture and nearest support.

Fig. 3. Flexural Strength Test

3. RESULTS AND DISCUSSION

3.1 Slump Cone Test

Table II

SLUMP VALUE

Mix	Slump with 1% of Superplasticizer	Percentage of superplasticizer increased (%)	Slump Value
BOQO	75	0	75
BOQ10	74	1.2	75
B10Q0	71	1.4	75
B0Q15	75	0	75
B15Q0	69	1.5	75
B5Q10	74	1.2	75
B10Q5	74	1.2	75
B10Q10	75	0	75

The Water cement Ratio is taken as 0.4. The observation shows that the slump value decreased as the bottom ash increased in the concrete mix with 1% of superplasticizer whereas, quartz powder did not affect the workability. In order to fix the workability of the concrete, the dosage of superplasticizer was increased and decreased to get the desired workability.

3.2 Compressive Strength

Table III

COMPRESSIVE READINGS OF THE 7 DAYS AND 28 DAYS READINGS

Mix	7 days (MPa)	28 days(MPa)
BOQO	22.2	31.6
BOQ10	25.7	33.78
B10Q0	21.7	28.8
B0Q15	26.2	34.2
B15Q0	21.3	29.3
B5Q10	22.67	29.7
B10Q5	24.8	32
B10Q10	21.7	29.3

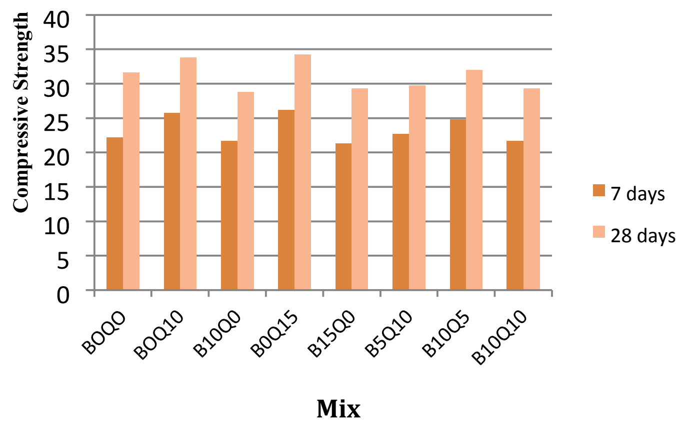

Fig. 4. Graph Plotting the Compressive Strength

The compressive strength test shows that the mix with 0% of bottom ash and 15% of quartz powder gave the higher strength of 8% than the conventional concrete. The mixes replacing the bottom ash alone shows that the increase of bottom ash decreases the compressive strength. With the increasing percentages of quartz powder along with bottom ash the compressive strength increases. But their increasing percentage is more or less equal to the conventional concrete.

3.3 Split Tensile Strength

Table III

TENSILE READINGS OF 7 DAYS AND 28 DAYS READINGS

Mix	7 days (MPa)	28 days(MPa)
BOQO	1.8	3.1
BOQ10	2.1	3.3
B10Q0	1.6	2.9
B0Q15	2.2	3.5
B15Q0	2.1	3.3
B5Q10	1.9	2.8
B10Q5	2.4	3.6
B10Q10	2.1	3.2

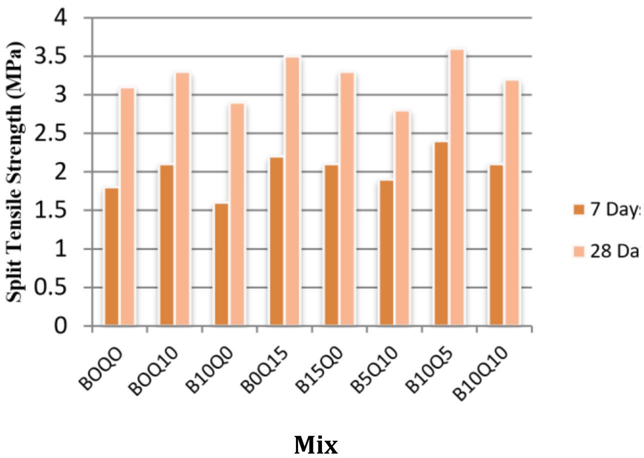

Fig. 5. Graph Plotting the Tensile Strength

The Split Tensile again proves that the replacement of the quartz powder alone at 15% showed the greater resistance to split tensile of about 16% than conventional. This describes that the addition of bottom ash decreases the tensile strength.

3.1 Flexural Strength

Table III

TABLE FLEXURAL READINGS OF THE 7 DAYS AND 28 DAYS

Mix	7 days (Mpa)	28 days(MPa)
BOQO	2.6	3.8
BOQ10	7.3	8.64
B10Q0	7.15	8.08
B0Q15	6.8	7.08
B15Q0	6.52	7.2
B5Q10	6.1	6.52
B10Q5	7.92	8.84
B10Q10	5.9	6.84

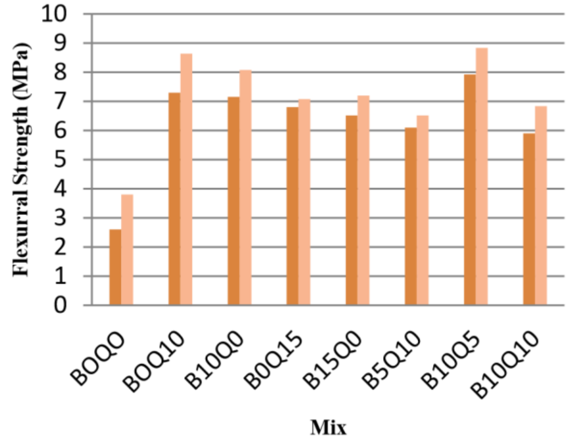

Fig. 6. Graph Plotting the Flexural Strength

The flexural readings show a higher increase in flexural strength of 27% than the conventional concrete. This indicates that the addition of bottom ash and quartz powder increases the flexural strength.

4. CONCLUSIONS

- It can be concluded that using bottom ash and quartz powder increases the strength parameters comparing the conventional concrete.
- The greater strength is attained in 15% replacement of quartz powder and 0% of bottom ash at 8%,16% and 27% increase in compressive, tensile and flexural strengths.
- This least strength gain was in replacing 0% quartz powder and 15% of bottom ash reduced at7%.
- This clearly shows that the addition of bottom ash decreases the strength. This ma be due to the porosity nature of the bottom ash.
- The other percentages show that adding quartz powder along with bottom ash can bring the strength nearer to the conventional concrete. This may be due to the fineness of quartz powder about 100 mesh which binds with the porous bottom ash.
- Thus, using these materials controls the use of cement upto 15% which plays a major role in sustainable environment.

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