HIGH PERFORMANCE ECO CONCRETE BY PARTIAL REPLACEMENT OF CEMENT BY MARBLE POWDER, SAND BY TILE POWDER AND BLUE METAL BY TILE CHIPS

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Abstract

Concrete is a composite material which is comprises of blue metal and sand which are bonded together with a fluid cement which hardens over time. Concrete has been used since ancient times to build massive structures such as dams and historical monuments such as Panama Canal, The Colloseum, etc. Various researches have been carried out for a long time looking for replacement materials for the constituents of concrete to improve various properties such as strength, permeability, etc. Researches have also taken a path to reduce the cost of concrete production by use of various locally available replacement materials. The concrete industry is on the lookout for replacement materials constantly due to various ill effects in the current materials. In this experimental investigation cement is partially replaced by marble powder and sand by tile powder and blue metal by tile chips. These materials have been used as replacement in 10, 20 & 30% initially. There are very less research papers that indicate the effects of using these materials as individual replacement materials in concrete. There is no evidence of these materials being used together as replacement materials in concrete which led to the ideology of experimenting the usage of combination of replacement materials in concrete. The experimental investigation were carried out using M25 grade concrete. The replacement materials were used as to replace the conventional elements of concrete in the percentages 10, 20 & 30.The combinations of these percentages have been carried out to keenly note the results and strength variations for maximum accuracy possible.

Keywords: *Eco Concrete, Marble Powder, Tile Powder, Tile Chips*

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1. GENERAL

Concrete is one of the commonly used construction material in the industry. Concrete is a composite material composed of coarse and fine aggregate bonded together with a fluid cement which hardens over time. Most concretes used are lime-based concretes such as Portland cement concrete or concretes made with other hydraulic cements.

In Portland cement concrete (and other hydraulic cement concretes), when the aggregate is mixed together with the dry cement and water, they form a fluid mass that is easily moulded into shape. The cement reacts chemically with the water and other ingredients to form a hard matrix which binds all the materials together into a durable stone-like material that has many uses. Often, additives (such as pozzolonas or superplasticizers) are included in the mixture to improve the physical properties of the wet mix or the finished material. Most concrete is poured with reinforcing materials (such as rebar) embedded to provide tensile strength, yielding reinforced concrete.

2. OBJECTIVE

The main objective of the project is to create a concrete which is satisfying in terms of technical, economic and environmental aspects.

3. MATERIALS

Concrete is a composite material formed by combining coarse aggregate known as blue metal with fine aggregate which is commonly known as sand using a binder named cement with the right proportion of water.

Blue metal is the material which gives strength to the concrete and sand is used to fill the voids that are formed due to the angular or irregular shape of the aggregate. These materials are bonded using cement paste formed by mixing cement and water in the required proportion.

- **Cement**
  The most commonly used cement is Ordinary Portland Cement. Out of total cement production OPC accounts for 80-90%. In our study OPC of 53 grade is used, many tests were conducted on cement. Some of them are Consistency test, Setting time test, Specific gravity, etc.

- **Fine Aggregate**
  Locally available, debris free riverbed sand is used as fine aggregate. The sand particle should also be packed to give minimum void ratio. Higher void content leads to requirement of more water while mixing. In this study sand confirming to zone III as per Indian Standards has been used.

- **Coarse Aggregate**
  The crushed aggregate used are of sizes 20mm and 12.5mm and are tested as per Indian Standards and the results are within permissible limits.

4. MATERIALS FOR REPLACEMENT

Cement is a binding agent that gives hardness and binds different construction materials together and it is a major constituent of concrete. The history of cement takes us back to the Roman era when cement was used for the first time and at the time was known as hydraulic cement. In more modern times, cement became popular as Portland cement, which came into existence during the Industrial revolution in the late 1790s. It became extremely popular among engineers because of the binding and strength it would give to construction materials.The concrete industry is one of two largest producers of carbon dioxide (CO_2), creating up to 5% of worldwide man-made emissions of this gas, of which 50% is from the chemical process and 40% from burning fuel. The carbon dioxide (CO_2) produced from the manufacture of one tonne of structural concrete is estimated at 410 kg/m^3.900 kg of CO_2 are emitted for the fabrication of every ton of cement, accounting for 88% of the emissions associated with the average concrete mix. Cement manufacture contributes greenhouse gases both directly through the production of carbon dioxide when calcium carbonate is thermally decomposed, producing lime and carbon dioxide, and also through the use of energy, particularly from the combustion of fossil fuels.Emission of such greenhouse gases leads to greenhouse effect and catastrophic global warming. Due to this requirement for more economical and eco-friendly materials have extended interest in cement replacement materials. Industrial wastes such as Ground granulated blast furnace slag, pulverised fly ash, silica fume, etc. are being used as cement replacement materials.

4.1 Marble Powder

Marble powder is a product obtained from marble industry by crushing or grinding broken marble pieces. A few studies have been carried out on the use of marble powder as partial replacement material for cement, hence it is possible to use marble powder as a replacement material for cement.

Table-1: Chemical Composition of Marble Powder

S.No.	Materials	Marble Powder (%)
1	Loss of Ignition(L.O.I)	43.63
2	CaO	43.20
3	Fe_2O_3	1.90
4	Al_2O_3	2.50
5	SiO_2	13.8
6	MgO	2.70
7	SO_3	0.07
8	K_2O	0.60
9	Na_2O	0.90
10	Cl	0.03

Advantages of using Marble

- ✓ Used more when compared to granite due to low initial cost.
- ✓ Approximately 45-65% commercial buildings are floored with marble.
- ✓ Cannot be reused due to impurities and mortar stuck in it.

Sources of Marble

- ✓ India ranks 3rd in the world in Marble production.
- ✓ India exports about 500 million tonnes of marble.
- ✓ 1300 million sq.ft of floor slabs produced per annum.
- ✓ More than 5000 trading companies are in business.
- ✓ 4000 mining leases made by private sector with the government.
- ✓ India is the leading exporter of marble to Italy, U.S.A, Canada, Japan, Singapore, UAE, etc.
- ✓ Widely available in Indian states-Rajasthan, Madhya Pradesh, Haryana, Andhra Pradesh.
- ✓ Rajasthan has 90% of the marble deposits in India.
- ✓ Indian ceramic industry is one of the most developing industry in the recent years.

4.2 Ceramic Tiles

Ceramic tile chips are used as a replacement for coarse aggregate and ceramic tile powder is used as a replacement for fine aggregate. Though the conventionally used blue metal does not harm the environment to a greater extent when compared to cement, it is being replaced to produce a concrete with greater durability and cost effectiveness.

Advantages of using Ceramic Tiles

- ✓ 15-30% goes as waste due to damage during production and transport.
- ✓ Cannot be reused.
- ✓ 60% of commercial builders prefer tile flooring due to less initial cost and easy construction.
- ✓ Debris from construction industry contributes to 30% of wastage after use.
- ✓ India ranks 3rd in tile production in the world.

Table-2: Chemical Composition of Ceramic Tiles

S.No	Materials	Ceramic Tile powder (%)
1.	SiO_2	63.29
2.	Al_2O_3	18.29
3.	Fe_2O_3	4.32
4.	CaO	4.46
5.	K_2O	2.18
6.	Na_2O	0.75
7.	MgO	0.72
8.	P_2O_5	0.16
9.	Mn_2O_3	0.05
10.	Cl	0.005
11.	SO_3	0.10
12.	Loss of Ignition (L.O.I)	1.61

Source: Geo-Test House, Baroda, Gujarat

Sources of Ceramic Tiles

- ✓ 750 million sq.m of tiles are produced per year in India.
- ✓ Global growth rate of tile industry is 11% per annum.
- ✓ Indian Tile Industry growth rate is 15% per annum.
- ✓ Industry shows a turnover of about 12,900crores per annum for the past 2 years.
- ✓ Exports 40million sq.m per annum.

5. REPLACEMENT MATERIALS

The replacement materials required to be used in concrete are available in industrial form or in the form of finished goods. These finished materials for example tiles cannot be directly used in concrete preparation. Before using these materials have to be processed to usable standards.

5.1 Marble Powder

Marble used in construction industry is in the form of square tiles or floor slabs. Marble in this form cannot be used to replace cement. So first the marble has to be processed to suitable standards so that it can be used as replacement for cement. Marble from a locally demolished building was taken in the form of pieces having irregular form. Then the marble pieces were put in abrasion machine and was made into fine powder. An approximate amount of 300 revolutions is required for making 10-15kg of marble pieces into fine powder. Then the obtained marble powder is sieved in 300micron sieve which is the same size as that of cement.

Fig-1: Source of Marbles

Fig-2: Breaking of marble into smaller pieces

Fig-3: Marble before crushing

Fig-4: Marble powder

5.2 Tile Chips

Broken tiles were collected both from a construction site as well as a demolished building as well as from a retail showroom where the pieces that were damaged during transportation were discarded.

These pieces were then further broken into smaller sizes using hammer and were sieved in IS 20mm sieve and then were used as replacement for blue metal in concrete for 10, 20 and 30 percentages.

Fig-5: Tile chips obtained after sieving in IS 20mm sieve

5.3 Tile Powder

Tile chips that passed the 20mm IS sieve were taken and were rammed with a rammer manually to obtain tile powder which was sieved in IS 2.36 sieve so that it is of the same grain size as that of the sand. After attaining such standards it was used as a replacement material for sand.

Fig-6: Tile powder passing 2.36 IS sieve

6. BASIC TESTS & RESULTS

6.1 Specific Gravity and Water Absorption of Fine Aggregate (Sand)

The specific gravity test for fine aggregate was done based on Method 3(2.4) of IS 2386-1963 part 3. The apparatus used for conducting this experiment was a Pycnometer. This method is known as Oven Dry Method. The specific gravity of fine aggregate was found to be 2.48 & the water absorption as 3.67

6.2 Specific Gravity and Water Absorption of Coarse Aggregate (Blue Metal)-12.5mm

The specific gravity test for fine aggregate was done based on Method 2(2.3) of IS: 2386 (Part III) – 1963. This method is known as Oven Dry Method. The specific gravity of fine aggregate was found to be 2.55 & the water absorption as 0.98

6.3 Specific Gravity and Water Absorption of Coarse Aggregate (Blue Metal)-20mm

The specific gravity test for fine aggregate was done based on Method 2(2.3) of IS: 2386 (Part III) – 1963. This method is known as Oven Dry Method. The specific gravity of fine aggregate was found to be 2.84 & the water absorption as 0.603

6.4 Los Angeles Abrasion Test

Los Angeles Abrasion test is done to determine the Los Angeles abrasion value of coarse aggregates. The principle of Los Angeles abrasion test is to produce abrasive action by use of standard steel balls which when mixed with aggregates and rotated in a drum for specific number of revolutions also causes impact on aggregates. The percentage wear of the aggregates due to rubbing with steel balls is determined and is known as Los Angeles Abrasion Value. The test procedure was done based on IS: 2386 (Part IV) – 1963.The Los Angeles abrasion value was found to be 27.68

6.5 Sieve Analysis

A **sieve analysis** (or **gradation test**) is a practice or procedure used to assess the particle size distribution (also called *gradation*) of a granular material. The size distribution is often of critical importance to the way the material performs in use. A sieve analysis can be performed on any type of non-organic or organic granular materials including sands, crushed rock, clays, granite, feldspars, coal and soil, a wide range of manufactured powders, grain and seeds, down to a minimum size depending on the exact method. Being such a simple technique of particle sizing, it is probably the most common.

Sieve Analysis-20mm

Weight of sample taken = 3kg (Confirming to IS: 2386 (Part I) – 1963)

Table-3: Sieve Analysis-20mm

Sieve size	Weight retained(kg)
25mm	0
20mm	0.817
10mm	2.183
4.75mm	0
Pan	0

Sieve Analysis-12.5mm

Weight of sample taken = 3kg (Confirming to IS: 2386 (Part I) – 1963)

Table-4: Sieve Analysis-12.5mm

Sieve size	Weight retained(kg)
16mm	0
12.5mm	0.114
10mm	1.360
4.75mm	1.493
Pan	0.033

Sieve Analysis-Sand

Weight of sample taken = 1kg (Confirming to IS: 2386 (Part I) – 1963)

Table-5: Sieve Analysis-Sand

Sieve size	Weight retained(kg)
4.75mm	0.025
2.36mm	0.020
1.18mm	0.38
600u	0.416
300u	0.151
150u	0.008
Pan	0

6.6 Initial Setting Time of Cement

The initial setting time of cement was found using Vicat apparatus. The initial setting time of the cement used was found out to be 1 hour & 20mins.

6.7 Final Setting Time of Cement

The final setting time of cement was found using Vicat apparatus. The initial setting time of the cement used was found out to be 2 hour & 35mins.

6.8 pH

The pH of the portable water used was found to be 7.1 as per 10500:2012

6.9 Turbidity

The turbidity of portable water used was found to be 1 NTU as per 10500:2012

6.10 Slump Cone Test

Slump cone test was conducted to determine the workability of concrete. The basic water content was taken based on Table 2 of IS 10262: 2009 as 186kg for manufacturing $1m^3$ of concrete.
Volume of a slump cone = $0.0053m^3$
Water required for preparing 0.0053m3 of concrete = 0.986lt
When water content was increased by 3% for every desired 25mm increase in slump value
Water required for preparing 1m3 of concrete = 197lt
Water required for preparing 0.0053m3 of concrete = 1.044lt

7. MIX DESIGN (IS 10262:2009)

Stipulations for Proportioning

Grade designation: M25
Type of Cement: OPC 53 grade confirming to IS 8112: 2013
Maximum Nominal Size of Aggregate: 20mm
Minimum Cement Content: 280kg confirming to IS 456: 2000
Maximum water cement Ratio: 0.4
Workability: 100mm (Slump)
Exposure Condition: Moderate
Degree of Supervision: Good
Type of Aggregate: Crushed Angular Aggregate
Maximum Cement Content: 492.5kg

Test Data for Aggregate

Cement used: OPC 53 Grade confirming to IS 8112:2013
Brand: Ultra Tech
Specific gravity of Cement: 3.15
Specific Gravity of
Course Aggregate (20mm): 2.84
Course Aggregate (12.5mm):2.55
Fine Aggregate: 2.48
Water Absorption:
Course Aggregate (20mm): 0.603
Course Aggregate (12.5mm):0.98
Fine Aggregate: 3.67
Mix ratio obtained from mix calculations
(Cement: Sand: Blue Metal) = 1: 1.17: 2.29
Water Absorption of (20mm blue metal + 12.5mm Blue metal + Sand)
(0.603% x 705.63) + (0.98% x 422.38) + (3.67% x 577.59)
= 4.25 + 4.14 + 21.20
Total water absorbed by materials = 29.59
Water = 197 + 29.59 = $226.59lt/m^3$.

8. MIX PROPORTIONING

The quantity of concrete for various mix proportions for creating specimens for testing was calculated based on the mix design using IS 10262:2009.The specimens that were cast are cubes, cylinders and prisms. The quantity of replacement materials were calculated for using in the concrete based on the weight of conventional materials used for preparation of concrete. The replacement materials are replaced in the percentages 10, 20 & 30 percentages. These materials have been used as replacement individually and also combination of all three respective elements for these three materials have been used.

Table-6: Percentage of Replacement of Respective Conventional Materials by Replacement Materials

Mix	Replacement of Cement by Marble Dust	Replacement of Sand by Tile Powder	Replacement of Blue Metal by Tile Chips
C1	0	0	0
C2	10	0	0
C3	20	0	0
C4	30	0	0
C5	0	0	10
C6	0	0	20
C7	0	0	30
C8	0	10	0
C9	0	20	0
C10	0	30	0
C11	10	10	10
C12	20	20	20
C13	30	30	30
C14	10	20	10
C15	10	30	10
C16	10	10	20
C17	10	10	30
C18	20	10	10
C19	30	10	10
C20	20	10	20
C21	20	30	20
C22	20	20	10
C23	20	20	30
C24	10	20	20
C25	30	20	20
C26	30	10	30
C27	30	20	30
C28	30	30	10
C29	30	30	20
C30	10	30	30
C31	20	30	30
C32	10	20	30

9. SAMPLE PREPARATION & TESTING

9.1 Introduction

Before using concrete for any construction work the concrete has to be tested by making specimens of specific sizes. The strength of the specimens gives the strength of concrete.

9.2 Test Specimens

The test specimens were cubes, cylinders and prisms. For each ratio 9 cubes were cast and a cylinder and prism were cast. For 7^{th} day 3 cubes were tested and their average value were taken. The same procedure was followed for 14^{th} day and 28^{th} day results. Cylinder and prism were tested directly for 28 days.

The cubes were of dimension 150mm x 150mm x 150mm.The prism has a nominal dimension of 500mm x 100mm x 100mm & the cylinder has a nominal dimension of 150mm diameter and 300mm in height.

9.3 Procedure Involved In Sample Preparation

The various stages of sample preparation are: Batching, Mixing, Transporting, Placing, Compacting, Curing and Testing.

Concrete Batching or Weighing
Batching is of two types

- Volume batching
- Weight Batching

Volume Batching

Volume batching is not a good method for proportioning the material because of the difficulty it offers to measure granular material in terms of volume. Volume of moist sand in a loose condition weighs much less than the same volume of dry compacted sand. The effect of bulking should be consider for moist fine aggregate. For any small jobs, concrete may be batched by volume.

Weight Batching

Weight batching is the correct method of measuring the materials. Use of weight system in batching, facilitates accuracy, flexibility and simplicity. Large weight batching plants have automatic weighing equipment. On large work sites, the weigh bucket type of weighing equipment's are used.

Based on the mix ratio the weight of materials required for preparing specimens of each mix were found and the materials were mixed with sufficient quantity of water and the concrete was prepared. An example calculation for the nominal mix has been shown below

Volume of (9cubes + 1prism + 1cylinder +5% wastage) = $0.042m^3$

Materials required for $0.042m^3$ of concrete
Cement = 20.685kg
Sand = 24.259kg
Blue metal (20mm) = 29.636kg
Blue metal (12.5mm) = 17.740kg
Water = 9.52 litres

Preparation of Moulds

The moulds were tightened and the inner surface of the moulds were oiled and made ready before placing the fresh concrete.

Mixing

Thorough mixing of the materials is essential for the production of uniform concrete. The mixing should ensure that the mass becomes homogeneous, uniform in colour and consistency. There are two methods adopted for mixing concrete: (i) Hand mixing (ii) Machine mixing

Hand Mixing

Hand mixing is practised for small scale concrete works. As the mixing cannot be thorough and efficient, it is desirable to add 10 per cent more cement to cater for the inferior concrete produced by this method. Hand mixing should be done over an impervious concrete or brick floor of sufficiently large size to take one bag of cement. Spread out the measured quantity of coarse aggregate and fine aggregate in alternate layers. Pour the cement on the top of it, and mix them dry by shovel, turning the mixture over and over again until uniformity of colour is achieved. Water is taken in a water-can fitted with a rose-head and sprinkled over the mixture and simultaneously turned over. This operation is continued till such time a good uniform, homogeneous concrete is obtained.

Machine Mixing

It is done using portable mixers or ready mix machines. It is recommended for preparation of large quantity of concrete.
In this project hand mixing using hand shovels has been done.

Fig-7: Mixing of concrete

Transporting

The prepared concrete has to be transported to the place of placing while the concrete is still in its workable state. In case of Ready Mix Concrete the mix must be constantly rotated inside the mixer machine even while it is transported to maintain its workability.

Placing

The prepared fresh concrete was placed in the moulds in layers of 3 with placing of each layer followed by manual compaction using a tamping rod by tamping it for 25 times to remove the entrapment of air. The process of compaction can be done using machines such as needle vibrators, vibrating tables, etc.

Curing

After the placing of concrete, curing of concrete has to be done. Curing is the process in which the concrete is protected from loss of moisture and kept within a reasonable temperature range. This process results in concrete with increased strength and decreased permeability. Curing is also a key player in mitigating cracks, which can severely affect durability.

The prepared specimen after drying for 2 hours was covered with gunny bag and was made moist for initial curing. After 24 hours the specimens were removed from the mould and were placed in a curing tank. The specimens were subjected to curing with care. The cylinders were packed with smaller flat stones, so that the bottom portion also gets cured to the desirable extent.

Fig-8: Curing of specimens

9.4 Testing Procedure

The cast specimens were tested on their respective schedules of testing. Cubes were tested for compression in Compression Testing Machine. Cylinders were tested for Split tension and Prisms were tested for Flexure.

Out of many test applied to the concrete, this is the utmost important which gives an idea about all the characteristics of concrete. By this single test one judge that whether Concreting has been done properly or not.

Fig-9: Compression testing of cubes

Table-7: Compression Test Results of Cubes (Strength in N/mm^2)

Mix Combination	7^{th} Day Strength	14^{th} Day Strength	28^{th} Day Strength
C1	22	26.33	28.26
C2	20.89	28.22	31.55
C3	20.67	25.56	23.56
C4	16.89	21.11	20.22
C5	21.11	31.11	31.11
C6	20	30.67	34.44
C7	24.44	24.89	34.44
C8	24.67	30	36
C9	22.67	30.22	33.33
C10	20.44	26	28.89
C11	17.11	22.67	24
C12	18.44	24.67	28
C13	11.56	18.89	21.11
C14	17.78	25.56	31.55
C15	17.56	23.78	27.78
C16	25.11	24	31.11
C17	23.78	27.56	31.56
C18	17.78	26.89	18.22
C19	8.44	13.33	16.67
C20	15.56	21.11	25.33
C21	13.56	20.22	22.22
C22	14.44	18.67	24.22
C23	17.33	20.44	23.78
C24	24	29.56	31.11
C25	11.56	17.11	21.78
C26	12.22	16.44	20.89
C27	10.67	16	18.89
C28	9.33	14.67	19.78
C29	12.89	14.22	15.33
C30	13.33	20.89	23.56
C31	17.78	19.56	22.67
C32	25.11	26.67	33.33

Split Tension Test

Concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack. The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete

Table-8: Split Tensile Test Results (Strength in N/mm^2)

Mix Combination	28th Day Strength
C1	1.41
C2	2.62
C3	2.26
C4	1.91
C5	2.62
C6	2.76
C7	2.48
C8	2.83
C9	2.26
C10	2.48
C11	2.12
C12	2.05
C13	1.77
C14	2.55
C15	2.26
C16	2.55
C17	2.41
C18	2.05
C19	2.19
C20	2.41
C21	2.19
C22	2.33
C23	2.12
C24	2.76
C25	2.12
C26	2.12
C27	1.98
C28	2.12
C29	1.69
C30	1.84
C31	1.91
C32	2.76

Fig-10: Split Tension test

Flexural Test

Flexural strength is one measure of the tensile strength of concrete. It is a measure of an unreinforced concrete beam or slab to resist failure in bending. It is measured by loading 50cm x 10cm x 10cm concrete prisms with a span length at least three times the depth. The flexural strength is expressed as Modulus of Rupture (MR) in (N/mm^2) and is determined by standard test methods confirming to IS 516: 1959.

Fig-11: Flexural test

Table-9: Flexural Test Results (Strength in N/mm^2)

Mix Combination	28th Day Strength
C1	6.25
C2	7.25
C3	7
C4	4.75
C5	7
C6	7.5
C7	6.75
C8	7.75
C9	7.25
C10	6.5
C11	6.25

C12	6.25
C13	6
C14	8
C15	7.5
C16	8
C17	7.25
C18	5.5
C19	6.25
C20	7
C21	7.25
C22	7.25
C23	7.4
C24	8
C25	6
C26	6.25
C27	6
C28	6.28
C29	5
C30	4.5
C31	5.5
C32	8.25

10. RESULTS AND DISCUSSIONS

10.1 General

Based on the test results obtained from testing the specimens, the following ratios were found to be successful in producing both stronger and economic concrete and can be readily implemented in practice.

Table-10: Strength of Specimen on 28th Day

Mix	Cubes	Prisms	Cylinders
C1	28.26	6.25	1.41
C2	31.55	7.25	2.62
C5	31.11	7	2.62
C6	34.44	7.5	2.76
C7	34.44	6.75	2.48
C8	36	7.75	2.83
C9	33.33	7.25	2.26
C10	28.89	6.5	2.48
C14	31.55	8	2.55
C16	31.11	8	2.55
C17	31.56	7.25	2.41
C24	31.11	8	2.76
C32	33.33	8.25	2.76

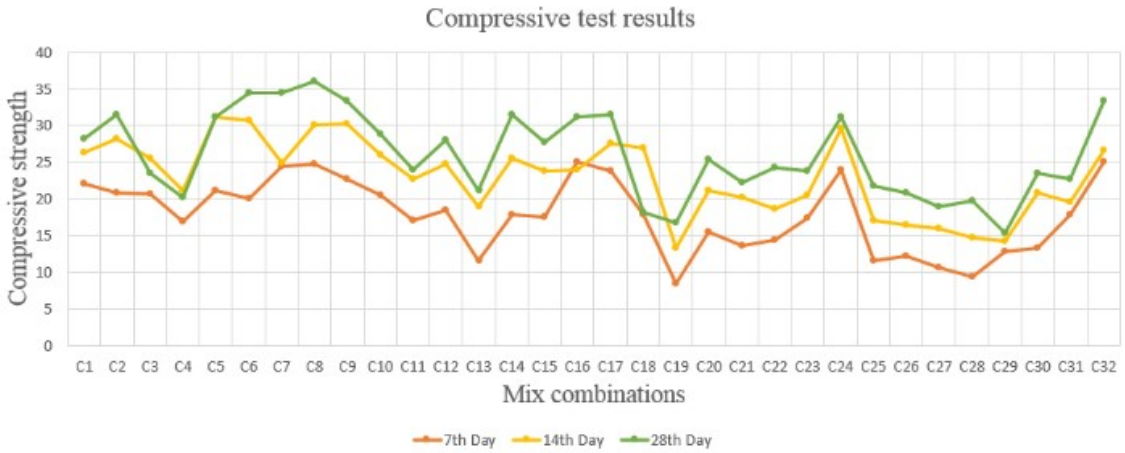

Fig-12: Compression test results of cubes

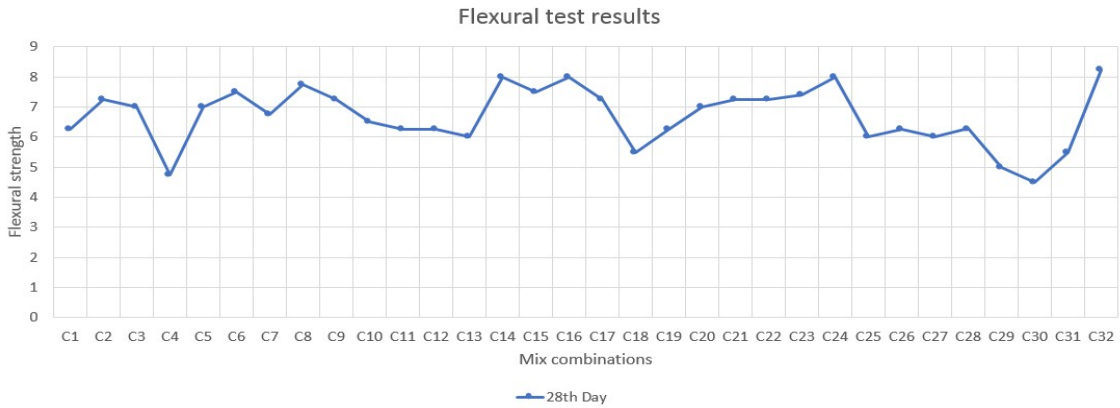

Fig-13: Flexural test results of prisms

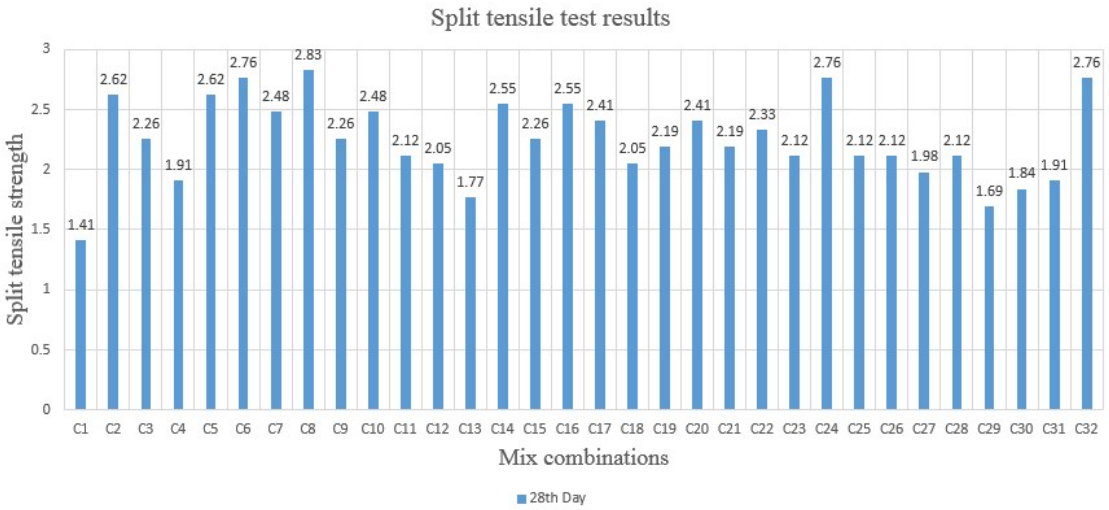

Fig-14: Split Tensile test results of cylinders

10.2 Cost Analysis

After the completion of test results the project proved to be satisfactory in terms of technical aspects like strength. But to find if the project is economic cost analysis is carried out. Any project must be cost effective so that it can be practically applicable. Hence cost analysis has been carried out for this research project also. The cost of the project is compared with the cost accrued in preparing $1m^3$ of nominal concrete.

Table-11: Cost of Preparation of Nominal Concrete

Material	Qty	Qty/' Units	Cost of 1 unit (Rs)	Total Cost (Rupees)
Cement	50 Bags (Say 500kg)	10	400	4000
Sand	600kg	15cft	60	900
Blue Metal	1150kg	29cft	30	870
Total Cost				5770

Ratio of Maximum strength = (Cement: Sand: Blue metal) = (10:20:30)

- If cement alone is replaced by marble powder
  Cost of cement required for preparation of nominal concrete = Rs.4000
  Cost of cement required if eco concrete is used = Rs.3600

  Savings in cost of cement = Rs.400

  Savings % = (400/4000) x 100 = 10%

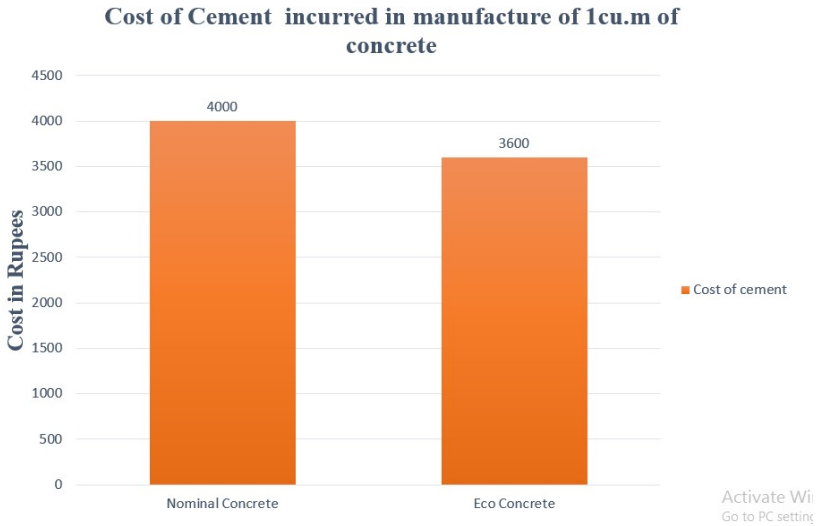

Fig-15: Cost of Cement incurred in manufacture of 1cu.m of concrete

- If sand alone is replaced by tile powder
  Cost of sand required for preparation of nominal concrete = Rs.900

  Cost of sand required if eco concrete is used = Rs.720

  Savings in cost of sand = Rs.180

  Savings % = (180/900) x 100 = 20%

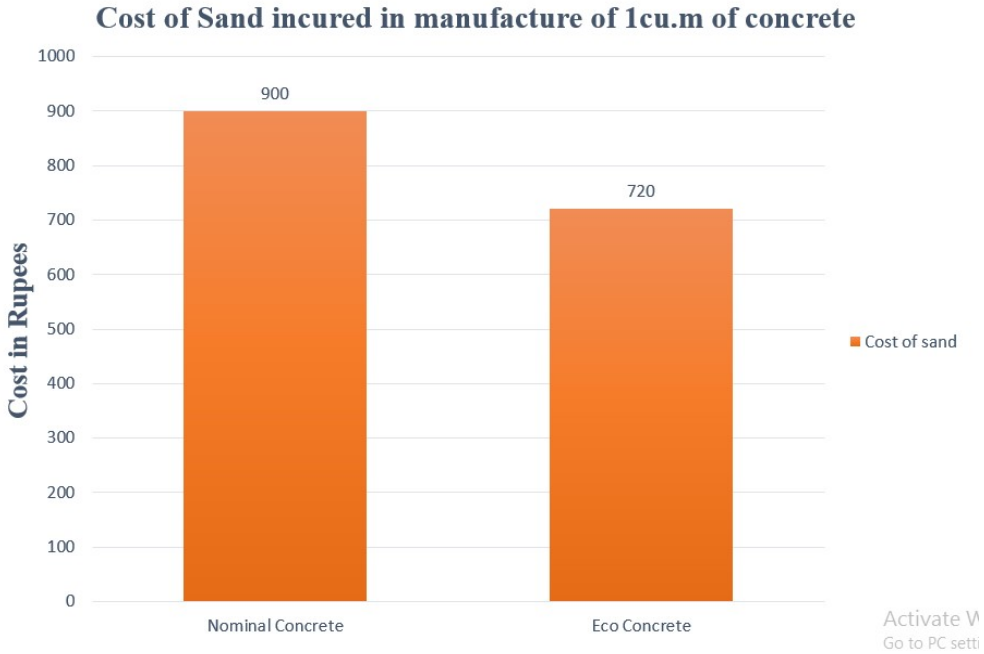

Fig-16: Cost of sand incurred in manufacture of 1cu.m of concrete

- If blue metal alone is replaced by tile chips
  Cost of blue metal required for preparation of nominal concrete = Rs.870

  Cost of blue metal required if eco concrete is used = Rs.600

  Savings in cost of blue metal = Rs.270

  Savings % = (270/870) x 100 = 31%

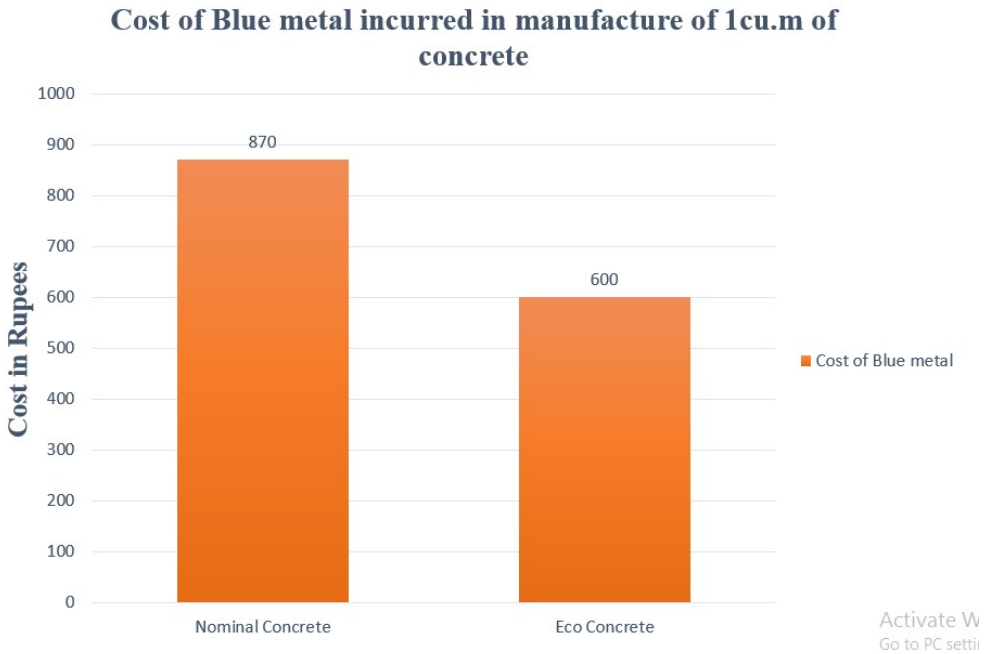

Fig-17: Cost of Blue metal incurred in manufacture of 1cu.m of concrete

Table-12: Total Saving in Cost Due to Use of Eco Concrete

Material	%	Quantity/ Units	Cost of Units(Rupees)
Cement	10	1 Bag	400
Sand	20	3cft	180
Blue Metal	30	9cft	270
Total Savings			850

Cost of preparing $1m^3$ of nominal concrete = 5770

Total Savings for $1m^3$ of Eco concrete = 850

Cost of preparing $1m^3$ of Eco Concrete = 4920

Savings % = (850/5770) x 100 = 15%

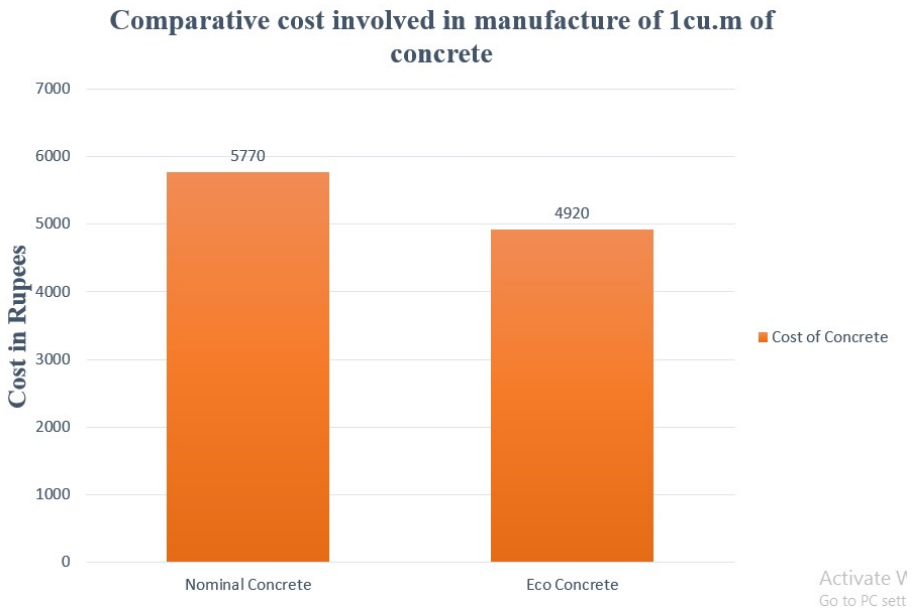

Fig-18: Cost incurred in manufacture of 1cu.m of concrete

Hence it is a much cost effective research as it brings in a savings about 15% of the cost of nominal concrete.

11. CONCLUSION

From the above test results it has been found that cement can be successfully replaced by marble dust up to 10% and sand can be replaced by tile powder up to 20% and blue metal can be replaced by tile chips up to 30% individually. The mixes C2,C5,C6,C7,C8,C9,C10,C14,C16,C17,C24 & C32 gives an increase in strength for the concrete. Mixes C24 & C32 are combination mixes which involves replacement of all 3 conventional materials of concrete. Thus it provides a more economical and stronger concrete mix which is environment friendly.

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