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# Efficiency of Fiber Reinforced Concrete Containing Waste Marble dust and Waste Foundry Sand

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***Abstract:*** ***The study focused on the effect of marble dust 0-10% (MD) by weight of cement content, waste foundry sand 0-30% (WFS) replaced by normal river sand and inclusion of glued steel fibres 0-1.5% (GSF) by volume fraction and also 1.5% of chemical admixture(SP) by weight of binding materials produced the excellent quality of structural concrete. Conversely, the replacement level of WSF can be limited up to 30%, Further, add into the concrete will affect the strength. From the test results observed that the 10% of MP, 20 % of WFS with 1.5% of GSF along with 1.5% of SP in concrete produced the higher compressive strength was 34.20, 39.90 and 42.50 N/mm² at 7, 28 and 56 days respectively, the strength was increased up to 7.40% than compared to controlled concrete. Also, a higher amount of bending stress was measured from 3.30 to 4.57 MPa at 28 days for various mixes of concrete and the ultrasonic pulse velocity values are recorded between 3630 to 4030 m/sec for various mixes at 28 days. Finally, the durability measurement of RCPT and also material characteristics test on the modulus of elasticity of concrete were studied systematically.***

***Keywords: Concrete strength, Foundry sand, Marble dust, Rapid chloride permeability test and Steel fibre.***

## I. INTRODUCTION

Foundry sand is a by-product of industrial waste materials of ferrous and non-ferrous having more amount of silica content collecting from metal casting industries and used for structural filling in various aspects. Intended, the usage of foundry sand replaced in natural sand in building construction industries produced the quality of structural-concrete with proper curing of the specimens. Initially, setting characteristics of concrete can be affected greatly due to the presence of more amount of silt content later on the removal of silt content with help of washed the materials and thus results leads to improvement of hardening and used for fast track pavement constructions. The more dense particle available in foundry-sand cannot be used directly in conventional concrete maybe affect the workability in fresh concrete due to the presence of more voids thus resulting to increase the bleeding and segregation in fresh concrete. Also, it exhibits the lower density of concrete due to particle grains sizes is more and also increase the more water absorption than natural sand. Thiruvenkitam Manoharan et al; Bavita Bhardwaj et al; Gurumoorthy et al [1-3] concluded that the usage of foundry in various construction industries to acts as a by-product materials and produced the better strength gain properties for various structural concrete. Rafat Siddique et al [4-6] concluded that the foundry sand has stabilized the good bonding materials in concrete and it is more suitable for fine aggregate replaced in river sand thus resulting to obtained the good strength gained up to 12 to 20% than compared to the normal concrete. Also, the replacement level of fine aggregate 0 to 30% in foundry sand produced the good quality of concrete and modulus of elasticity of concrete. Hossain et al; Gireesh Mailar et al; Recep Bakis et al [7-9] advised that the foundry sand used in concrete has more flowing, passing ability with less cohesiveness in self-compacting concrete. Also, limited studies have been reported that the good packing density of concrete than compared to table vibrating concrete. It was also noted that the ratio of split tensile strength to compressive strength and also compressive strength to modulus of elasticity of concrete for various mixes. Tarun et al; Manpreet Singh, et al; Deepankar Kumar Ashish; Hanifi Binici [10-13] concluded that the concrete mixes having 0 to 20% of foundry sand replaced in river sand produced the good results. From the experimental results showed a good target strength in the case of 15% of foundry sand and also increase rate of hardening was noted in UPV. Also, the durability of concrete studied very systematically in RCPT shows less ingress of chloride ions produced the low permeability of concrete for various mixes. Gulden Cagin Ulubeyli et al; Talaha et al; Nezerka et al; [14-16] Investigated that the rich silica content of foundry sand up to 20% produced the maximum strength was increased up to 15.60% than compared to control concrete at 28 days. However, it was clearly proved that the additional C-S-H gel formation during the hydration of setting properties, which react the bonding/binding the cement with foundry sand. Ali Khodabakhshian et al; Syed Ahmed Kabeer et al; Hasan Sahan Arel; Valeria Corinaldesi et al; Muhammad Junaid Munir [17-21] concluded that the experimental test results produced the good strength improvement and also long term performace in durability studies showed a less chloride ion penetration of low permeability of averaged coulombs was noted 750 coulombs at 90-days and 365-days 500 coulombs in accordance with ASTM C1202-97.

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### Highlights

- This research work reports the experimental test results on high strength concrete by utilizing the industrial waste by-products and it is more economical and suitable for construction building materials in concrete
- Marble dust with waste foundry sand represents excellent characteristics in concrete.
- There is no significant delay in the gel formation during hydration in the setting properties of hardening and thus results produce the low permeability of chloride ions.

## II. Material used and Methodology

### A. Cement

The 53 Grade of Ordinary Portland cement was used in accordance with IS 12262-1970 [22]. The various test results are represented in Figure 1.

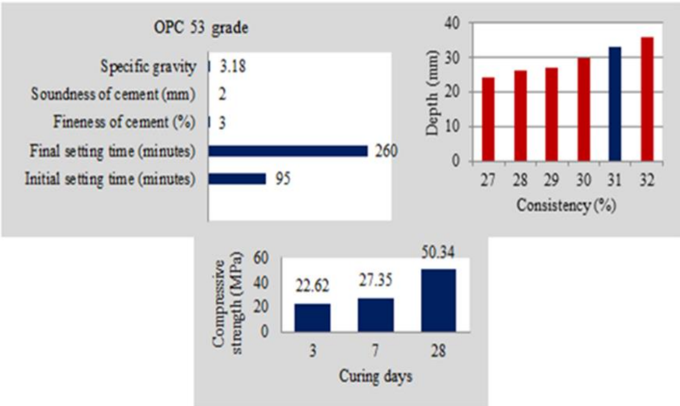


**Fig.1. Various test results for OPC (53 grade)**

### B. Marble dust

It is a by-product collected from the marble industrial plants during the cutting, shaping and polishing of marble. It's around 25 to 30% of marble turns into the powder form. Further, sieved 90 microns and used for various mixture proportions of concrete. The test values (chemical-composition) are given in Table I and physical properties of test values are given in Table II.

Table-I: Test values for marble dust

| Oxide-presents | Content (%) |
|---|---|
| $SiO_2$ | 14.28 |
| $Al_2O_3$ | 2.69 |
| $Fe_2O_3$ | 1.19 |
| CaO | 41.24 |
| MgO | 2.70 |
| $SO_3$ | 0.23 |
| $Na_2O$ | 0.11 |
| $K_2O$ | 0.62 |
| $P_2O_5$ | 0.04 |
| Cl- | 0.08 |
| SrO | 0.05 |
| L.O.I | 36.77 |

Table- II: Test values of marble powder.

| Physical-properties | Test results |
|---|---|
| Surface area | 11.4 x$10^3$ ($cm^2$/gm) |
| Bulk-density | 520 (kg/m) |
| Specific-gravity | 2.43 |

### C. Aggregates

The different percentage of river-sand replaced in foundry-sand was used and fineness modulus of river sand test was performed and confirmed to Zone-II as per guidelines are given in IS 383 2016 [23]. The comparison of natural sand and foundry sand test values as given in Table III and the gradation curve are shown in Figure 1. The crushed stone (coarse aggregate) less than 20 mm size was used and properties test values as provided in Table IV.

Table- III: Fineness modulus of natural sand vs waste foundry sand

| Sieve Size (mm) | Cumulative Percentage passing (%) | |
|---|---|---|
| | Natural sand | Foundry sand |
| 4.75 | 97.8 | - |
| 2.36 | 95.3 | - |
| 1.18 | 69 | 99.4 |
| 0.6 | 20.7 | 98.0 |
| 0.3 | 5.3 | 15.30 |
| 0.15 | 1.3 | 2.14 |
| 0.075 | 0.1 | - |
| Pan | - | - |

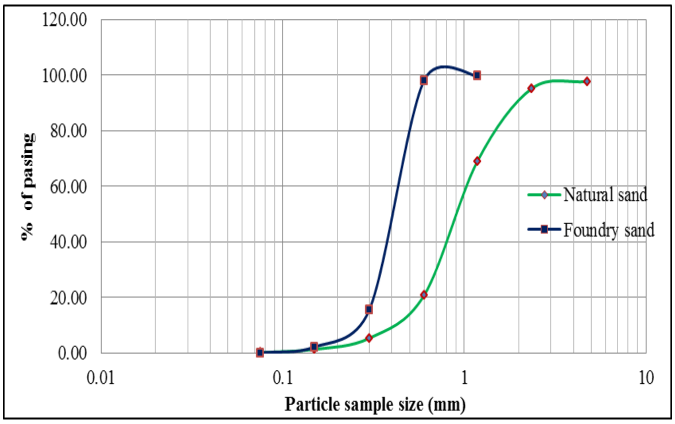


**Fig. 1. Particle sample size vs percentage of passing**

Table-IV: Test results for aggregates (physical)

| Name of the test | River-Sand | Foundry-sand | Course Aggregate |
|---|---|---|---|
| Specific-gravity | 2.63 | 2.94 | 2.94 |
| Fineness-modulus | 2.89 | 2.15 | 7.1 |
| Porosity (%) | 41.5 | 40 | 40 |
| Void ratio | 0.8 | 0.4 | 0.4 |

### D. Chemical admixture

The CONPLAST 430 type of Polycarboxylic superplasticizer having high range water reducer agent up to 40% used for the good requirements of chemical admixtures in accordance with ASTM C 494-80 [24] for various mixes of concrete.

### E. Glued Steel fibres (GSF)

Steel fibres having both ends hooked and the properties are given in Table V and image as shown in Figure 2. The different dosage levels of steel fibres 0%, 1% and 1.5% by volume fraction (Vf) were used in concrete for various mixes.

Table-V: Properties of steel fibres (GSF)

| Material | Obtained values |
|---|---|
| Relative Density (kN/m$^3$) | 7.65 |
| Length (mm) | 30 |
| l/d ratio | 60 |
| Thickness (mm) | 0.5 |
| Width (mm) | 1.25 |
| Tensile-strength (N/mm$^2$) | 1700 |

**Fig. 2. Image for GSF**

### F. Concrete mix proportions

Overall Ten different concrete mixture proportions were prepared in this study, the combination marble dust was constant up to 10% along with 0 to 30% of waste foundry sand replaced in river sand and the various components of mix constituents are represented in Table VI. The conceptual design mix was adopted and various workability of fresh concrete values are measured 70 to 80 mm, compaction factor value of 0.87 and vee bee consistometer 0.31 seconds in accordance with IS 1199-1959 [25].

Table- VI: Mix proportions details

| Mix Id | Cement | Marble | Fine aggregate | Waste foundry sand | Coarse aggregate | Water | GSF |
|---|---|---|---|---|---|---|---|
| | F/c ratio=0.6, w/b ratio= 0.35, B/TA ratio= 0.24, 1.5 % of SP was added for all mixes, (kg/m$^3$) | | | | | | (%) |
| M-1 | 425 | 0 | 670 | 0 | 1113 | 142 | 0 |
| M-2 | 382 | 43 | 603 | 67 | 1113 | 142 | 0.5 |
| M-3 | 382 | 43 | 603 | 67 | 1113 | 142 | 1 |
| M-4 | 382 | 43 | 603 | 67 | 1113 | 142 | 1.5 |
| M-5 | 382 | 43 | 536 | 134 | 1113 | 142 | 0.5 |
| M-6 | 382 | 43 | 536 | 134 | 1113 | 142 | 1 |
| M-7 | 382 | 43 | 536 | 134 | 1113 | 142 | 1.5 |
| M-8 | 382 | 43 | 469 | 201 | 1113 | 142 | 0.5 |
| M-9 | 382 | 43 | 469 | 201 | 1113 | 142 | 1 |
| M-10 | 382 | 43 | 469 | 201 | 1113 | 142 | 1.5 |

### G. Mixing-details

The ingredients materials were taken and mixed thoroughly up to 3 minutes in a tilting drum type of rotating mixture machine having a capacity of container 40 kg. Further, the addition of Polycarboxylic ether based superplasticizer was then mixed thoroughly with water up to 2 minutes before pouring into the container. After reached the good workability to shift the fresh concrete in a standard size of steel molds with table vibration required for proper compaction in concrete and next days are samples are kept in normal curing for various mixes and after reached 24-hours the same sample de-molded and tested in the laboratory.

## III. Testing Procedure

From Figure 3 shows the test set up for compressive strength-split tensile strength of concrete was carried out on cube size of 100 x 100 x100 mm and cylindrical size of 100 mm diameter by 200 mm height respectively. All the concrete samples were tested for different age of curing at 28 days in accordance with IS 5816-1999 [27].

**Fig. 3. Image for concrete cubes by using compressive testing machine**

Figure 4 shows the four-point loading test set up in flexural rigidity for displacement controlled machine 1.5 mm/min and sample size 100 x 100 x 500 mm was cast and tested at 28-days as per prescribed guidelines are provided in IS 516-2008 [26]. The evaluation of bending stress can be calculated from the following equation number (1).

$$\textit{Modulus of rupture} = \frac{Pl}{bd^2} \quad (1)$$

Where $p$ is the ultimate load, l is the length of specimen, b is the breadth and $d$ is the diameter

**Fig. 4. Image for flexural testing machine**

The test specimen was placed in a compressive testing machine as shown in Figure 5 and gradually external load was applied on the specimen (cylinder size 150 x 300 mm) and every 10 kN noted it down the corresponding dial gauge reading up to 40% of the ultimate load (failure load) for each sample and calculate the modulus of elasticity by static modulus method.

**Fig. 5. Image for modulus of elasticity concrete**

The UPV techniques are to monitoring the acoustic waves from the transducer to receiver between the frequency range 45 to 54 kHz at a known distance. The pulse values are generated for each sample by direct method in terms of M/sec (as shown in Figure 6) and recorded test values as referred in accordance with IS 1311: 1992 (part 1) [28] and predicting the quality of concrete with respect to rate pulse (kM/sec).

**Fig. 6. Image for Ultrasonic pulse velocity test**

The experimental test method (RCPT) having cylindrical shape of steel mold (disc type) size of 100 mm and 50 mm height for cast and testing the sample in accordance with ASTMC 1202-1979 [29]. Initially, all the concrete samples were applied the paint/epoxy coat and then dry the sample was kept in a vacuum chamber up to 3 hours. Further, it is allowed to soak the water up to 18 hours after that the negative charge cell (left side) filled with 3% of NaCl solution and positive charge cell (right-side) filled with 0.3N of NaOH solution and test set up as shown in Figure 7. Finally, to analyze the chloride ion penetration the following Equation number 2 for various mixes in concrete.

Chloride ion permeability in Coulombs =

$$(I_0+ I_1+I_2 +I_4+I_5)\ mA \times 0.001 \times 60 \times 60 \quad (2)$$

Where $I_0$, $I_5$ are the initial and final currents (coulombs), $I_1$, $I_2$, $I_3$ and $I_4$ are the intermediate currents (coulombs)


**Fig. 7. Image for rapid chloride permeability**

The various mixes of concrete specimens were cast and de-molded after 24 hours with room temperature (27 ± 2$^0$C). Further, it was kept in normal potable water (pH value 6.7) curing tanks and all samples for necessary curing required because during the hydration process inside the concrete at the same time outside to maintain the temperature during the hardening of concrete.

## IV. DISCUSSIONS FOR TEST RESULTS

### A. Compressive strength

Figure 8 shows the maximum strength was noted up to 59.44%, 26.38% and 19.54% (M-7 F/c-0.6) in the case of natural river sand replaced in waste foundry sand up to 20% with 1.5% of super plasticizers than compared to OPC concrete. Similarly, in the case of 10% of waste foundry sand replaced in natural river sand produced the excellent performance in compressive strength. Further, the addition of 30% of foundry sand produced less strength (M-8 mix id).

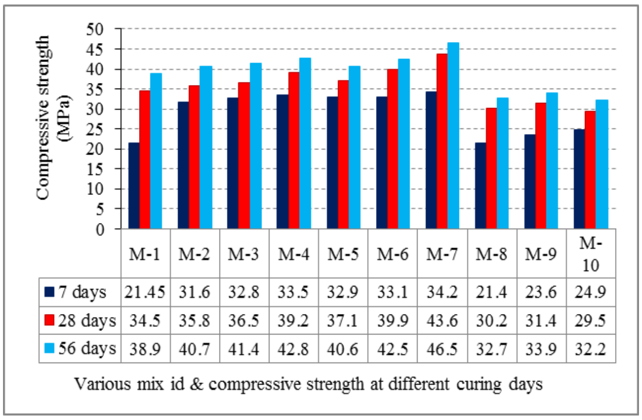


**Fig. 8. Test results for compressive strength of concrete**

### B. Split tensile strength

This method is indirect to measure the tensile strength in concrete for various mixes. The maximum strength was noted in the combination of 10% of waste marble dust with 20% of foundry sand replaced in natural sand with the addition of 1.5% of steel fibres produced the excellent strength was 3.90 N/mm$^2$ (M-7) at 28 days as shown in Figure 9. The role steel fiber addition in concrete to withstand the more tensile stress towards the downward direction of the longitudinal axis, thus resulting to produce the higher split tensile strength in concrete.

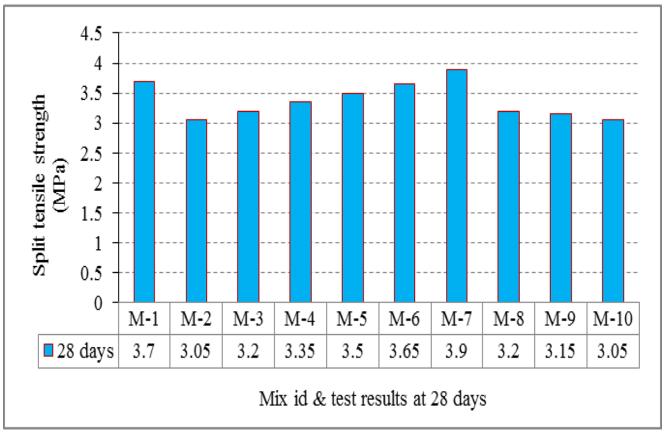


**Fig. 9. Split tensile strength of concrete**

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### C. Flexural Strength using third point loading methods

Figure 10 shows the various mixes of flexural rigidity of concrete for different curing days. It was noted that the synergistic effects on the marble dust due to the pozzolanic reaction in concrete and produced the higher bending stress up to 4.57 MPa at 28-days (M-7 mix id) around11.46% was increased than the controlled concrete. Similarly, the mix M-4 noted the bending stress was 4.35 MPa at 28-days in the case of 10% replacement of marble as well as quarry stone dust, when compared to OPC concrete. The effect of steel fibre addition in concrete beams proved the good bonding the composite materials as well as the bridging the gap before and after the failure of the structures and also improved the post-peak toughness.

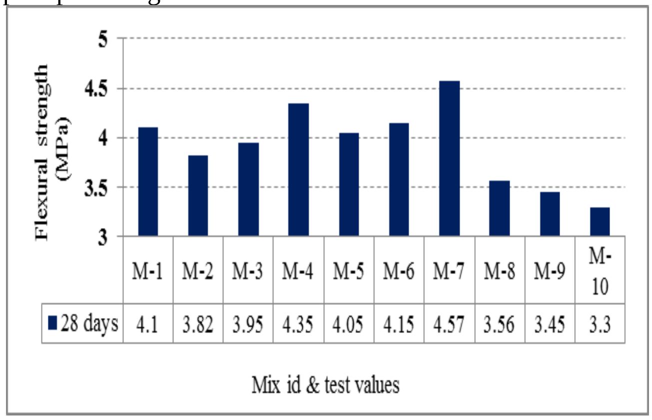


**Fig. 10. Flexural strength of concrete for various mixes**

### D. Modulus of Elasticity of concrete using stress strain curve

The secant modulus of elasticity of concrete at 28 days tested for various mix proportions of concrete. From the test results for conventional concrete at 28 days strength was 35.48 GPA and similarly for 20% of marble dust with 1.5% steel fibres the strength was calculated up to 40.45 GPA showed a better improvement in concrete when compared to controlled concrete was increased up to 14.01 %. Similarly, for all the test values were noted and graphically plotted for various mixes as shown in Figure 11.

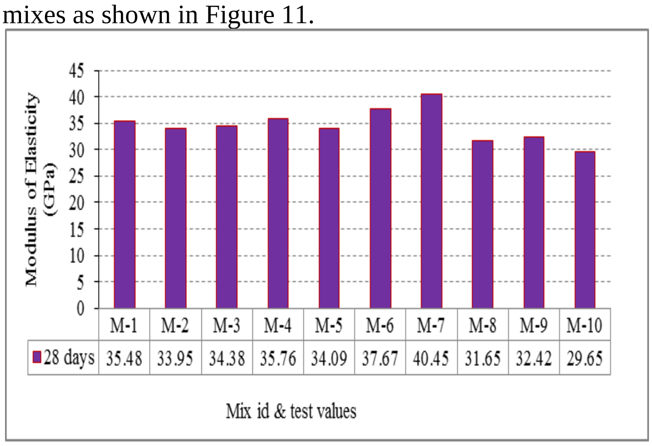


**Fig. 11. Modulus of Elasticity of concrete for various mixes**

### E. Ultrasonic pulse velocity

Figure 12 shows that the Non-destructive techniques very essentially to measure the pulse and compared all the recorded values in accordance with Indian Standard 13311 (part1): 1992 and predicted the test values in terms of rate of the pulse generated for various mixes. It was noted that the higher rate of hardening was 4.405 km/sec at 56-days and proved the microstructures that are the excellent quality of concrete having fewer pores/voids occurred during the hardening process of hydration.

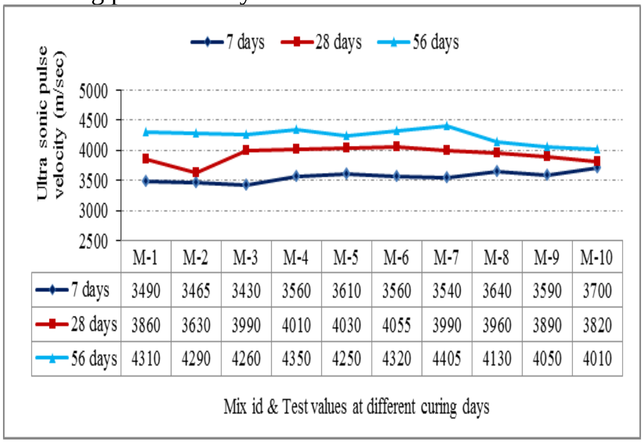


**Fig. 12. Ultrasonic pulse velocity of concrete at different curing days**

### F. Rapid chloride penetration resistance

The permeation of chloride ions in concrete test values is graphically plotted for different percentages of waste foundry sand for 28-days and 90-days of curing as shown in Figure 13. It experimented that the test values showing fewer coulombs were increases the curing age (90-days) thus resulting to improve the microstructures in concrete during the hydration process. The RCPT values for 20% waste foundry sand with 1.5% steel fibres the values are 710 and 400 coulombs at 28 and 90 days, when compared to controlled concrete was found to be 310 coulombs for 28-days and 90-days respectively. From this studies, the important parameters were identified that's for fine aggregate to coarse aggregate materials ratio, curing/testing methods and usage of waste by-products in the combination of 10% of marble waste with 20% WFS in concrete having less ingress of chloride ion penetrates into the concrete and extend their lifespan.

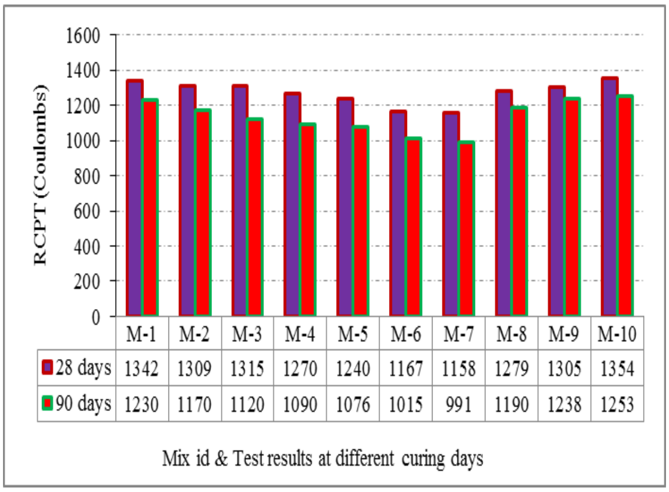


**Fig. 13. Various rapid chloride permeability of concrete at different curing days**

## V. CONCLUSION

The influence of high range water reducer type of Polycarboxylic either based superplasticizer was used to avoid the shortage of water content for various mixes as a result of good quality of workability. The packing density of material ability in mix constituents in F/c-ratio 0.6 with w/b ratio 0.3 along with 20% of waste foundry sand produced the excellent strength gain and introduced the superior quality of concrete properties. The maximum addition of steel fibres up to 1.5% with 10% of WMP and 20% WFS produced the compressive, flexural strength and modulus of elasticity of concrete increased up to 26.38%, 11.46% and 14.01% at 28 days respectively than plain cement concrete. Further, It was also noted that the lower strength reached while the addition WFS up to 30%. The best combination mix in concrete has 20% of WFC with 10% of WMP showed a good range of UPV values and also RCPT results shows the low permeability of concrete for various mixes. The mass production of steel fibres reinforced concrete suitable in construction industries and more economic for alternative building materials. Also, it holds a big promise for the restoration of damaged pavement on airport runways.

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