Strength Studies of Concrete Containing Waste Foundry Sand

A S S Vara Prasad[1], P Srinivas[2], S Ashok Kumar[3]
[1, 2, 3] Department of Civil Engineering
[1, 2, 3] Kakinada Institute of Technology & Science, Divili

Abstract- *Due to ever increasing quantities of waste materials and industrial by-products, solid waste management is the prime concern in the world. Scarcity of land-filling space and because of its ever increasing cost, recycling and utilization of industrial by-products and waste materials has become an attractive proposition to disposal. There are several types of industrial by-products and waste materials. The utilization of such materials in concrete not only makes it economical, but also helps in reducing disposal concerns. One such industrial by-product is Waste Foundry Sand (WFS). WFS is major byproduct of metal casting industry and successfully used as a land filling material for many years. But use of waste foundry sand (WFS) for land filling is becoming a problem due to rapid increase in disposal cost. In an effort to use the WFS in construction materials, research has being carried out for its possible utilization in making concrete as partial replacement of fine aggregate*

This experimental investigation was performed to evaluate the strength properties of M20 (30 MPa) grade of concrete mixes, in which natural sand was partial replaced with waste foundry sand (WFS). Natural sand was replaced with five percentage (0%, 5%, 10%, 15%, 20%) of WFS by weight. A total of five concrete mix proportions M-1, M-2, M-3, M-4 and M-5 for M20 grade of concrete with and without WFS were developed. Compression test, splitting tensile strength test and modulus of elasticity were carried out to evaluate the strength properties of concrete at the age of 7, 28 days. Test results showed that there is increase in compressive strength, splitting tensile strength and modulus of elasticity for M20 grade of concrete mix with inclusion of waste foundry sand (WFS) up to 15% replacement.

Keywords- Cement, Concrete, Waste Foundry Sand, Super plasticizer, Slump Test, Compressive strength

I. INTRODUCTION

1.1 Introduction

Concrete is the most widely used man-made construction materials in the world. Slightly more than a ton of concrete is produced each year for every human being on the planet Fundamentally, concrete is economical, strong, and durable. Although concrete technology across the industry continues to rise to the demands of a changing market place. The construction industry recognizes that considerable improvements are essential in productivity, product performance, energy efficiency and environmental performance. The industry will need to face and overcome a number of institutional competitive and technical challenges. One of the major challenges with the environmental awareness and scarcity of space for land-filling is the wastes/byproducts utilization as an alternative to disposal. Throughout the industrial sector, including the concrete industry, the cost of environmental compliance is high. Use of industrial by-products such as foundry sand, fly ash, bottom ash and slag can result in significant improvements in overall industry energy efficiency and environmental performance.

Foundry industry produces a large amount of by-product material during casting process. The ferrous metal casts in foundry are cast iron and steel, non ferrous metal are aluminum, copper, brass and bronze. Over 70% of the total by-product material consists of sand because moulds usually consist of molding sand, which is easily available, inexpensive, resistance to heat damage, easily bonded with binder, and other organic material in moulds. Foundry industry use high quality specific size silica sand for their molding and casting process. This is high quality sand than the typical bank run or natural sand. Foundries successfully recycle and reuse the sand many times in foundry. When it can no longer be reused in the foundry, it is removed from the industry, and is termed as waste foundry sand (WFS). It is also known as spent foundry sand (SFS) and used-foundry sand (UFS).

1.2 Type of Waste Foundry Sand

Classifications of foundry sand mainly depend primarily upon the type of binder and binder system used in metal casting. There are two types of foundry sand; Green sand (clay bonded) and chemically bonded. Resin coated sand, cold box sand, hot box sand and Co_2 sands are some common type of chemically bonded sand. (Mold and core test handbook, America foundry society).

1.2.1 Green (Clay Bonded) Sand

Green sand (clay bonded) is used for mould making and is mixture of silica sand (80-95%), bentonite clay (4-10%), carbonaceous additive (2-10%) and water (2-5%). Large portion of the aggregate is sand which can be either silica or olivine. There are many recipes for the proportion of clay, but they all strike different balance between mold ability, surface finish and ability of the hot molten metal to design. It still remains very cheapest way to cast metal because of easy availability. Other minor ingredients are flour, cereals, rice hulls and starches. Silica sand is the bulk medium that resist the high temperature, bentonite clay bind the sand grain together, water activate the binding action of clay on sand and add plasticity. Carbonaceous additive prevent the fusing of sand on to the casting surface. Minor ingredients absorb moisture, improve the fluidity of sand. Green sand (clay bonded sand) also contains some chemical like Magnesium oxide (MgO), Potassium dioxide (K_2O), Titanium dioxide (TiO_2).

1.2.2 Chemically Bonded Sand

Chemically bonded sand is used in both core making and mould making. In core making, high strength is necessary to withstand against high temperature. Chemically bonded sand is mixing of silica sand and chemical binder (1-3%) for mould and core. When binder mixes with the silica sand, then catalyst start the reaction that cures the chemical resin and hardens the sand core or mould. There are various chemical binder system used in foundry industry, some of the binder are furfuryl alcohol, phenolic urethane, phenolic no bake-acid, phenolic resole-ester, sodium silicate, phosphate, alkyd (oil) urethane, shell liquid/powered and flake resins. Some of the most common chemically bonded sands are resins coated sand, hot box, cold box and Co_2sand. Majority of binder used in the foundry are self setting chemical binder.

1.3 Properties of Waste Foundry Sand

1.3.1 Physical Properties

Generally, waste foundry sand (WFS) is sub-angular to round in shape. Green sands are black or grey, whereas chemically bonded sands are of medium tan or off-white color. Grain size Introduction distribution of waste foundry sand is uniform with 85-95% of the material in between 0.6 mm to 0.15 mm and approximately 5 to 20% of foundry sand can be smaller than 0.075 mm. Good gradation and round shape lead to a compact structure and high density. Correlation of absorption with fine content and grain size can be interpreted by the law that a finer particle leads to a higher specific surface area, which favors the absorption of water.

1.3.2 Chemical Properties

Chemical composition of the waste foundry sand depends on the type of metal, type of binder and combustible used. The chemical composition of the foundry sand may influence its performance. Waste foundry sand is rich in silica content. It is coated with a thin film of burnt carbon, residual binder (bentonite, sea coal, resins/chemicals) and dust. Silica sand is hydrophilic and consequently attracts water to its surface.

1.4 Applications of Waste Foundry Sand

Indian foundries produce approximately 1.71 million tons of waste foundry sand each year (Metal World, 2006). In United States of America, metal casting foundries dispose of approximately 9 million metric tons of waste foundry sand (WFS) in landfills in 2000 (Winkler and Bol'shakov, 2000). United States's average land-filling tipping fee of foundry byproducts is US $15-75 per ton inclusive of storage, transportation and labour costs (Winkler et al. 1999). The annual cost of WFS disposal was around US $ 135-675 million. The considerable disposal expense has made the current practice of WFS disposal in landfills less favorable. Besides the financial burden to the foundries, land-filling WFS also makes them liable for future environmental costs, remediation problems and regulation restrict ions. This issue is increasingly addressed by alternate options of reusing WFS beneficially. Waste foundry sand is made up of mostly natural sand material. Its properties are similar to the properties of natural or manufactured sand. Thus it can normally be used as a replacement of sand.

II. LITERATURE REVIEW

2.1 GENERAL

Due to ever increasing quantities of waste materials and industrial by-products, solid waste management is the prime concern in the world. Scarcity of land-filling space, because of its ever increasing cost, recycling and utilization of industrial by-products and waste materials has become an attractive proposition to disposal. There are several types of industrial by-products and waste materials. The utilization of such materials in concrete not only makes it economical but also helps in reducing disposal concerns. Natural sand is getting depleted due to large scale construction. So it is important to find out an alternative of natural sand, which can be used as partial replacement of natural sand (fine aggregate).

There are several types of waste material/byproducts, which have been explored for possible use in concrete as a partial replacement of fine aggregate. Such types of materials are coal bottom ash, recycled fine aggregate, sewage sludge ash, stone dust and glass cullet, and waste foundry sand, etc.

Celik et al. (1996), Sahu et al. (2003), Tripathy and Barai (2006) and Shi -cong et al (2009) have reported the use of stone dust (SD) as partial replacement of fine aggregate. Celik et al. (1996) reported that increasing the dust content up to 10% improve the compressive strength and flexure strength of concrete. Sahu et al. (2003) concluded that there is significant increase in compressive strength, modulus of rupture and split tensile strength of concrete when sand was partially replaced by stone dust up to 40 percent. Tripathy and Barai (2006) investigated the compressive strength of mortar made with crusher stone dust (CSD) under normal, hot water curing and autoclaving curing. They concluded that up to 40% cement replacement by crusher stone dust and autoclave curing of mortar mix, gave same or better compressive strength than the control mortar mix (without CSD and normal curing). Shi-cong et al (2009) investigated the properties of concrete with crushed fine stone (CFS), furnace bottom ash (FBA) and fine recycled aggregate (FRA) as a fine aggregate.
Cyr et al. (2007) used sewage sludge ash (SSA) in cement based materials. They observed that compressive strength of mortars containing 25% and 50% of SSA was always lower than those of reference mortars but it shown that SSA has a long term positive effect which might be related to a slight pozzolanic activity.

2.2 Literature Related to Waste Foundry Sand (WFS)

There is another industrial waste, which is called waste foundry sand (WFS). It is also known as spent foundry sand (SFS) and used-foundry sand (UFS). Use of waste foundry sand in concrete and concrete related products like bricks, blocks and paving stones has been reported by Khatib and Ellis (2001), Naik et al. (2003), Naik et al. (2004), Fiore and Zanetti (2007), Siddique et al. (2009; 2011), Etxeberria et al. (2010) and Guney et al. (2010).Bakis et al. (2006) reported the use of waste foundry sand (WFS) in asphalt concrete. In this section literature related to the, effect of waste foundry sand in concrete, is reported properties wise.
Mishra et al. (1994) investigate the effect of blast furnace slag, fly ash and silica fume on permeability of concrete. They concluded that use of these waste in concrete decreased the permeability of concrete and increases the quality of concrete.

2.2.1 Workability (Slump)

Guney et al. (2010) studied the effect of waste foundry sand (WFS) on the slump of concrete. Fine aggregates were partially replaced with 0, 5, 10 and 15% WFS It was observed that waste foundry sand decreased the fluidity and the slump value of the fresh concrete.

2.2.2 Water Absorption and Void Ratio

Guney et al. (2010)determined the water absorption and void ratio of concrete containing WFS as partial replacement of fine aggregates. Water absorption test for each mixture was conducted at the age of 28 and 56 days. It was observed that (i) water absorption of the concrete with 5% waste foundry sand are higher than that of the concrete without waste foundry sand at the age of 56 days; (ii) water absorption ratio decreased for the specimens having waste foundry sand of 10, and 15%. This may be explained as the usage of waste foundry sand decreases the voids in the concrete. Therefore water absorption values have tendency to decrease in the specimens with greater waste foundry sand than 5%; (iii) void ratio of the samples with and without waste foundry sand are similar to the water absorption test results. Greater than 5% replacement of waste foundry sand with fine sand, void ratio decreases for all ages.

2.2.3 Compressive Strength and Modulus of Elasticity

Khatib and Ellis (2001) studied the influence of three types of foundry sand as a partial replacement of fine aggregate on the compressive strength of concrete, up to the age of 90 days.

(i) with the increase in the replacement level of standard sand with foundry sand, the strength of concrete decreased; (ii) the concrete containing white sand showed somewhat similar strength to those containing waste sand at all replacementlevels; (iii) presence of high percentage of blended sand in the concrete mixture caused a reduction in strength as compared with concrete incorporating white sand or waste sand; (iv) increase in strength was not observed at low replacement levels (less than 50%).

Guney et al. (2010) examined the influence of inclusion of WFS as partial replacement of fine aggregates on the compressive strength and modulus of elasticity of concrete up to the age of 28 days. Fine aggregates were partially replaced with 0, 5, 10 and 15% WFS. It was observed that the concrete with 10% waste foundry sand replacement exhibited highest compressive strength at the age of 28 days. Compressive strength decreased with an increasing amount of foundry sand.

2.2.4 Splitting Tensile Strength

Bakis et al. (2006) explored the possible use of waste foundry sand (WFS) in asphalt concrete. In asphalt Concrete mixtures, fine aggregates were replaced with 0, 4, 7, 10, 14, 17 and 20% WFS. Indirect tensile strength tests were conducted as per AASTHO (1989). As the percentage of WFS was increased, the strength of the asphalt concrete mixtures linearly decreased, yielding values from 1.39 MPa with 0% WFS to 0.94 MPa with 20% WFS.

III. METHODOLOGY

General

The present method deals with evolution of Mechanical Properties of Concrete Compressive Strength and Split-Tensile Strength. The program involves Casting and Testing of specimens where the standard size of the cube (150mm x 150mm x150mm) and standard size of cylinder (150mm x 300mm).Fine Aggregate is partially replaced with Waste Foundry Sand of dosages (5%,10%,15% and 2%) in Standard Grade of M20 according to IS: 10262-2009.

Procurement of Materials

The Materials used for the study are:

Cement

Cement is a material that has cohesive and adhesive properties in the presence of water. such cements are called hydraulic cements. these consist primarily of silicates and aluminates of lime obtained from lime stone and clay.

Foundry Sand

Foundry sand obtained from Insaf foundry, Model Town, MandiGobindgarh, Punjab was used.

Concrete

Mixing concrete is simply defined as the "complete blending of the materials which are required for the production of a homogeneous concrete". Batching is the "process of weighing or volumetrically measuring and introducing into the mixer the ingredients for a batch of concrete".

IV. RESULTS AND DISCUSSION

4.1 GENERAL

In this chapter, the findings of experimental investigations are presented. In which, various tests were conducted to evaluate the effect of waste foundry sand on compressive strength, splitting tensile strength, modulus of elasticity. Waste foundry sand was used as a partial replacement of fine aggregate at the percentage of 0, 5, 10, 15 and 20%.

4.2 COMPRESSIVE STRENGTH

4.2.1 Compressive Strength of M20 Grade (30 MPa) Concrete

Effect of WFS on compressive strength of M20 Grade concrete mixes M-1(0% WFS), M-2 (5% WFS), M-3(10% WFS), M-4 (15% WFS) and M-5(20% WFS) at the age of 7, 28 days are shown in Fig. 4.1.

Mix proportion of control concrete mix M-1 (0% WFS) was 390 kg cement, 569kg fine aggregate and 1165 kg coarse aggregate per cubic meter of concrete with water-cement ratio 0.5.

Compressive strength of control concrete mix was 30 MPa at the age of 28 days. It was found that, at the age of 7 days, compressive strength of mix M1 (0% WFS) was 19.7 MPa and mixes M-2 (5% WFS), M-3 (10%WFS), M-4 (15% WFS) and M-5 (20% WFS) were 22.4, 23.3, 25.3 and 24.8 MPa, respectively. Maximum compressive strength (25.3 MPa) was observed for M-4 (15% WFS) concrete mix; it was 28.42 % more than the control mix M-1(0% WFS). At the age of 28 days, percentage increase in compressive strength was 14.6, 22.6, 26 and 23.3% for mixesM-2, M-3, M-4 and M-5 than control mix M-1(30MPa). At 91 days, concrete mixes M-2, M-3, M-4 and M-5 exhibited increase in compressive strength 11.69, 18.8, 20.8 and 18.2% respectively than M-1 (34.5 MPa). Similarly, at the age of 365 days, there was 9.45, 17.82, 21.6 and 18.9 % increase in compressive strength for concrete mixes M-2, M-3, M-4 and M-5 in comparison to control M-1 (37 MPa). In investigation, it was observed that compressive strength of concrete increased with the increase in WFS content up to 15% as partial replacement of sand.

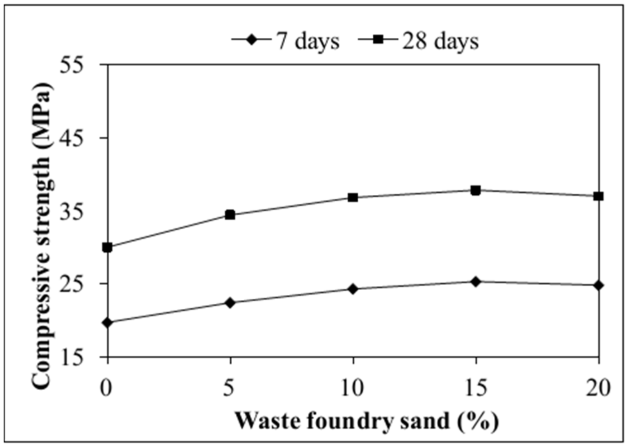

Fig 4.1: Compressive Strength verses Waste Foundry sand

Effect of age on compressive strength

Effect of age on compressive strength of M20 Grade (30 MPa) concrete mixes are shown in Fig. 4.2. Compressive strength of all concrete mixes increased with age. Concrete mix M-1 (0% WFS) achieved an increase of 52.3, 75.48 and 88.23 % at the age of 28 days respectively, when compared with 7 days compressive strength (19.7 MPa). For mix M -2 (22.4 MPa), compressive strength was increased by 54, 71.1 and 81.45% at the age of 28 days respectively, whereas an increase of 51.4% was observed at 28 for M-3 (10% WFS). When M-4 (15% WFS) was compared with 7 days compressive strength (25.3 MPa), it was found that it increased by 50, 65.6 and 78.8%. Similarly, increase in compressive strength for mix M-5(20% WFS) was 50, 65.4 and 78.7% at the age of 28, 91 and 365 days, respectively than 7 days compressive strength (24.8 MPa).

Comparative study of compressive strength between 7 to 28 days indicate that % increase in compressive strength was observed as 52.3, 54, 51.4, 50.1 and 50% for mix M-1, M-2, M-3, M-4 and M-5 respectively.

Concrete mix M-1, M-2, M-3, M-4 and M-5 exhibited increase in compressive strength by 15, 11.1, 11.4, 10.3 and 10.2% when comparative study was done between 28 and 91 days, whereas % increased was 7.3% for M-1, 6.1% for M-2, 6.3% for M-3, 7.9 % for M-4 and 7.8% for concrete mix M-5.

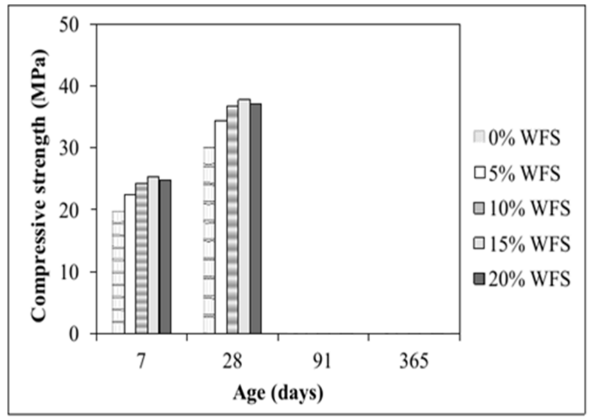

Fig 4.2: Compressive Strength verses Age

Comparative study of compressive strength between all ages indicated that % increase in compressive strength decreased with the increase in WFS content for all mixes. It decreased by 54% to 50% in 7 to 28 days, decrease was observed when comparative study was done between 7 to 28 days.

4.3 SPLITTING TENSILE STRENGTH

4.3.1 Splitting Tensile Strength for M20 Grade (30MPa) Concrete

Effect of WFS on splitting tensile strength of concrete mixes is shown in Fig. 4.6.

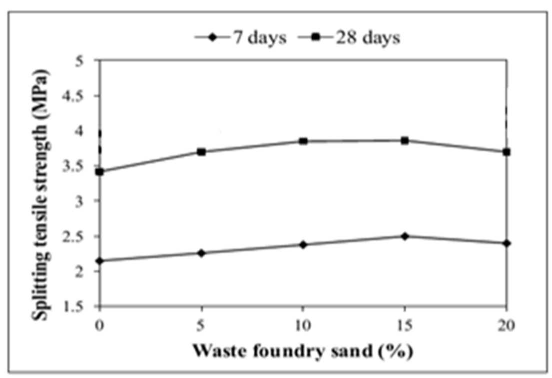

Fig. 4.3: Splitting Tensile Strength verses Waste Foundry Sand

The variations in splitting tensile strength with waste foundry sand content were similar to that observed in case of compressive strength. Splitting tensile strength of concrete mixes increased with the increase in WFS content. Splitting tensile strength of control mix M-1(0% WFS) was 2.15 MPa at 7 days. It increased by 5.1%, 10.7%, 16.3% and 11.6% for M-2 (5% WFS), M-3 (10% WFS), M-4 (15% WFS) and M-5 (20% WFS) respectively. Higher value of splitting tensile strength was observed at 15% WFS. At the age o f 28 days, increase was 8.2%, 12.5%, 12.8% and 8.2% for M-2, M-3, M-

4 and M-5 concrete mixes respectively than mix M-1 (4.23MPa).

Effect of age on splitting tensile strength

Effect of age on splitting tensile strength of M20 Grade concrete mixes are shown in Fig. 4.7. Splitting tensile strength of all concrete mixes increased with age

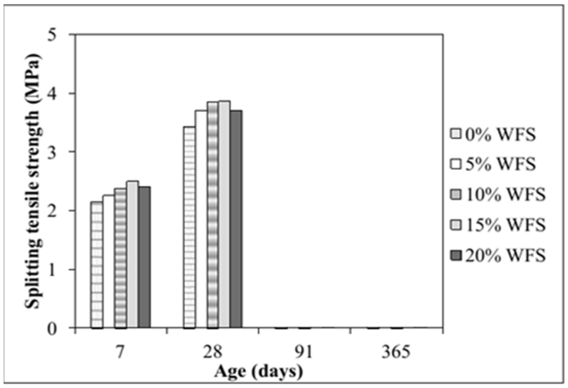

Fig. 4.4: Splitting Tensile Strength versus Age

Concrete mix M-1 (0% WFS) achieved an increase of 59.1, 73.9 % at the age of 28 days respectively, when compared with 7 days splitting tensile strength (2.15 MPa). For mix M-2 (2.26 MPa), splitting tensile strength was increased by 63.6% at 28 days, respectively, whereas an increase of 61.7% was observed at 28 days. For M-3 (10% WFS). When M-4 (15% WFS) was compared with 7 days splitting tensile strength (2.5MPa), it was found that it increased by 54.4 %.

Similarly, increase in splitting tensile strength for mix M-5(20% WFS) was 54.2% at the age of 28 than 7 days splitting tensile strength (2.4 MPa).

4.4 MODULUS OF ELASTICITY

4.4.1 Modulus of Elasticity of M20 Grade (30MPa) Concrete

Effect of WFS on modulus of elasticity of concrete at the age of 7, 28 days are shown in Fig. 3.11. At 7 days, modulus of elasticity of mix M-1(0%WFS) was 20.5GPa; with increase in WFS content in concrete, modulus of elasticity of mixes M-2 (5% WFS), M-3 (10% WFS), M-4 (15% WFS) and M-5 (20% WFS) were 21.1, 21.3, 21.9 and 21.5 GPa respectively.

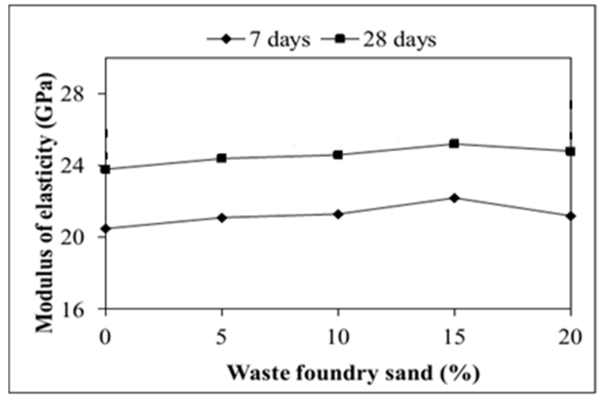

Fig. 4.5: Modulus of Elasticity verses Waste Foundry sand

At 28 days, modulus of elasticity of mix M-1(0%WFS) was 23.8GPa. It increased to 25.2 GPa with 15% WFS; 5.9% increase was observed for mix M-4(15%WFS) when compared with M-1(0%WFS). Similar gain in modulus of elasticity was observed at the age of 28 days.

Effect of age on modulus of elasticity

Effect of age on modulus of elasticity is shown in Fig. 3.12. It is evident that, inclusion of WFS in concrete mixtures led to increase in modulus of elasticity at all ages.

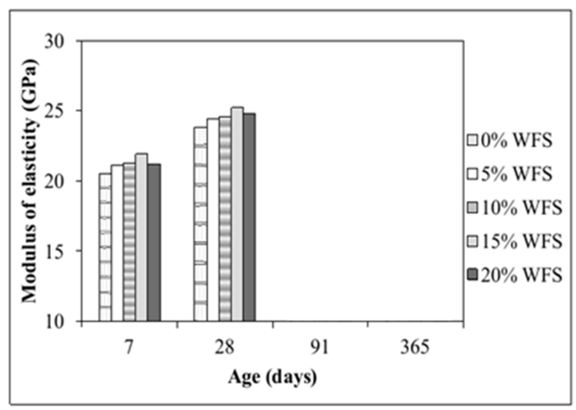

Fig. 4.6: Modulus of Elasticity verses Age

Modulus of elasticity of mix M-1(0%WFS) increased by 16.2.% at the age of 28, .days,. when compared with 7-day modulus of elasticity (20.5GPa). Whereas an increase of 15.5% was observed at 28 days. for M-3(10%WFS). Concrete mix M-3(10% WFS) achieved an increase of 15.5.% at the age of 28 days.when compared with 7-day result (21.3GPa).When mix M-4 (15% WFS) was compared with 7 days modulus of elasticity (21.9GPa), it was observed that it increased by 15.2%. Similarly, percentage increase found for mix M-5(20% WFS) was 15.3% at 28 days than 7 days modulus of elasticity (21.5GPa).

V. CONCLUSION

5.1 GENERAL

The present work investigated the influence of waste foundry sand as partial replacement of fine aggregate (sand) on the properties of two grades (M20 & M30) of concrete. On the basis of the results from the present study, following conclusions are drawn.

5.2 STRENGTH PROPERTIES

5.2.1 Compressive Strength

i. Compressive strength of both grades of concrete mixes (M20 and M30) increased due to replacement of fine aggregate with waste foundry sand. However, compressive strength observed for both grades of concrete mixes were appropriate for structural uses.

ii. M20 (30 MPa) grade concrete mix obtained increase in 28-day compressive strength from 30MPa to 37.8MPa on 15% replacement of fine aggregate with WFS, whereas it increase was from 40MPa to 46.8MPa for M30 grade of concrete mix. Maximum strength was achieved with 15% replacement of fine aggregate with WFS. Beyond 15% replacement it goes to decrease for both grades of concrete, but was still higher than control concretes

5.2.2 Splitting Tensile Strength

i. Concrete mixes obtained linear increase in 28-day splitting tensile strength from 3.42MPa to 3.86MPa for M20 grade of concrete mix (M-1) on replacement of fine aggregate with waste foundry sand at various percentages of 5% to 20%.

ii. Splitting tensile strength of all concrete mixes for both grades of concrete was found to increase with increase in with varying percentage of waste foundry sand.

iii. At the age of 28 days, splitting tensile strength of M20 grade of concrete mix (M-1) increased by 12.8% whereas increase was 10.4%. Development of splitting tensile strength was more in M20

iv. Maximum increase in splitting tensile strength was observed at 15% replacement of fine aggregate with waste foundry sand at all age for both grades of concrete mixes.

5.2.3 Modulus of Elasticity

i. At 28 days, modulus of elasticity increased from 23.8GPa to 25.2GPa for M20 grade of concrete mix(M-1) and 29GPa to 31.3GPa for M30 grade of concrete mix (M-6) on replacement of fine aggregate with waste foundry sand with various percentage from 0% to 20%

ii. Modulus of elasticity for M20 grade of concrete mixes was observed to increase with increase in age. Mix M-4 (15%WFS) exhibited better modulus of elasticity compared to control mix M-1 (0%WFS) for M20 grade concrete.

In above conclusions, it was found that inclusion of waste foundry sand as a partial replacement of fine aggregate in concrete mixes gives better effect on strength properties of concrete. Enhancement in strength properties was observed due to addition of waste foundry sand. Strength properties results indicate that waste foundry sand could be very conveniently used in making good quality concrete and construction materials.

5.3 SUMMARY

This chapter deals with the conclusions based of the findings of strength and durability properties of both grades of concretes. Inclusion of waste foundry sand as a partial replacement of fine aggregate in concrete improved the strength and durability properties of both the grades of Concrete. Further, concrete made with 15% replacement of natural sand with WFS could suitable

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