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Utilization of Waste Foundry Sand in Concrete Paver Blocks

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ABSTRACT
The current paper presents the effective use of waste foundry sand i.e. industrial by-product as a substitute of regular sand in concrete. The waste foundry sand is replaced as a fine aggregate in concrete with natural sand at six percentage levels i.e. (2.5%, 5%, 7.5%, 10%, 12.5% and 15%). Properties examined in this investigation by performing several tests were compressive strength, split tensile strength and flexural strength. The maximum strength was achieved in compressive strength was 9.3%, split tensile strength was 11.24% and flexural strength was 12.34% for 5% inclusion of WFS in concrete at 28 days of curing age. The test results of these properties indicate that there is an increment in strength with the increase in replacement level of WFS up to certain limit in concrete and after that limit as the replacement levels of WFS goes on increasing there is a systematic decrease in strength. From following investigation, it was concluded that inclusion of 7.5% WFS can be used suitably for making concrete paver blocks and after inclusion of 7.5 % WFS is not profitable in any aspects.

I. INTRODUCTION

Concrete is the backbone of the rising industries of construction in the world. Cement, natural sand, and gravels are the primary constituents of concrete and with increasing human population the demands of constituents are rising for the developments of infrastructure as per their needs. Globally, the production of cement was 2.4 billion tons in China, 86.63 million tons was in USA and 270 million tons was in India at 2017 year. As per composition used in USA for every 1 ton of cement the usage of aggregates are 10 tones for the production of concrete[1]. Globally, construction industries consumes 8 to 12 million tons of fine and coarse aggregates for production of concrete annually after 2010 year[2]–[4].

To satisfy the needs of the population increasing around the world, large amount of material between 47-59 billion tons is extracted from environment every year[5] from which aggregates i.e. sands and gravels accounted for the largest share (68%-85%)[6],[7]. The massive use of concrete in industrialization and urbanizations has resulted in several harmful consequences like increasing riverbed depths, major impact on river deltas, marine ecosystem, coastal erosion, decrease in sediment supply and lowering of water tables. Furthermore, government have restricted the extraction of natural aggregates severely affects the existing construction industries due to rise in the costs of aggregates. Thus, it leads us to use the waste materials and by products of various industries as the alternative source in construction field. Various materials that's are produced from industries like fly ash, slag, palm oil clinker, waste foundry sand, wood ash etc. has the specific properties that are related to construction material and can be helpful to produce concrete. Many literature and research are also available on usage of waste materials to produce concrete and to produce applications of concrete. Foundry sand is a by-product of metal casting industries. Foundries purchase high quality of silica sand for casting and moulding operations. These sands are reused or recycled various times and when it can no longer be reused or recycled is expelled from the casting process in foundries is termed as waste foundry sand.

II. LITERATURE REVIEW

In this paper, insistence is on the use of waste foundry sand in concrete and various application of concrete. There are several investigations related to the use of waste foundry sand as partial and complete replacement with fine aggregate in concrete.

Siddique et al.[8] concluded that with increasing WFS up to 30% content there is an increase in compressive strength, modulus of elasticity, flexural strength and splitting tensile strength and further there is also improve in these properties with age. Siddique et al.[9] have reported that a maximum increment in the strength properties was up to 15% inclusion of WFS for both ages 28 and 91 days and WFS inclusion increases the UPV value but there was a decrease in chloride ion penetration in concrete. Author observed that suitably WFS can be used in production of concrete. Similar results were reported by Siddique et al.[10] for strength properties and observed that 20% of WFS inclusion gives maximum value as well as similar results as compared to control mix for abrasion resistance in concrete. Siddique et al.[11] studied the influence of WFS as a partial replacement with natural sand on two grades (M20 & M30) of concrete mixtures. Author reported that M20 results are better as compared to M30 grade for all strength properties and for UPV as well as chloride ion penetration in concrete. Siddique et al.[12] investigated on the strength, durability and micro-structural properties by partially replacing WFS with fine aggregates in concrete. Author reported that 30% replacement level is optimum to use, and it should not exceed 50% in concrete.

Guney et al.[13] studied the potential re-use of WFS in production of high-strength concrete by performing several tests by replacing WFS at several percentages (0%, 5%, 10% and 15%) with fine aggregates in concrete. Author reported that the 10% of WFS exhibits almost same value as compared to control mix in strength properties (compressive strength, modulus of elasticity, and splitting tensile). Basar et al.[14] investigated on the effect of WFS as partially replacement of fine aggregates (natural sand) on the microstructural, mechanical and leaching characteristics of RMC (ready mix concrete) by replacing WFS with regular sand at five percentage (0%, 10%, 20%, 30% and 40%) by weight. Author reported that WFS can be used 20% as a replacement with regular sand without affecting the physical and mechanical properties of concrete. Naik et al.[15] investigated on the performance of hardened and fresh concrete containing clean/new foundry sand and waste foundry sand and by replacing it with fine aggregates in concrete at 25% and 35% replacement level by weight. Author observed that waste foundry sand showed 20%-30% lower values as compared to control mix and clean/new foundry sand showed almost similar values as compare to control mix.

Monosi et al.[16] investigated on the production of mortar and concrete for structural application by reusing two types of WFS, collected by the two different stages of processing by the same foundry. These two types of WFS are partially replaced by fine aggregates and author reported that 0% to 30% replacement levels can be used to manufacture the mortar and concrete and is beneficial to use as a disposal in construction. Etxeberria et al.[17] performed several tests by replacing green foundry sand and chemical foundry sand with fine aggregates at several percentages. Author reported that concrete made by 25%, 50% and 100% of chemical foundry sand performed good workability and exhibited more compressive strength after exposure of temperature was high as compare to conventional concrete. Khatib et al.[18] replaced waste foundry sand with fine aggregates by several percentages (0%, 30%, 60% and 100%) in concrete. Author reported that by capillary action in concrete there was a systematic increment in water absorption, decrease in UPV and compressive strength with increasing amount of waste foundry sand in concrete.

Siddique and Singh[19] and Siddique and Noumove[20] have reported the use of WFS in controlled low strength materials (CLSM) and in concrete dominates by size of WFS particles between (150 µm and 600 µm). Similarly, Prabhu et al.[21] have reported that the particle size of WFS varying between (150 µm and 600 µm) can be suitably used for making WFS in production of concrete. Author investigated on the effect on WFS as fine aggregates in production of concrete by partially replacing WFS from 0%-50% with fine aggregates in concrete and suggested that 20% of waste foundry sand inclusion with fine aggregates can be used effectively in the production of good concrete without affecting the standards of concrete.

III. MATERIALS AND METHODS

Several tests were performed to examine the effects of waste foundry sand by replacing it with fine aggregates at several percentage levels in concrete. Also, effect of various properties i.e. (mechanical and durability) for concrete containing waste foundry sand.

3.1. Materials

3.1.1. Cement

PCC i.e. Portland pozzolana cement was used in this investigation that was confirmed according to IS 1489-Part-1[22]. The various tests of physical properties that are given in table 1 of cement was conducted by the procedure given in IS 1489-Part-1[22].

Table 1. Physical properties of cement

Physical test	Results obtained	BIS: 1489(part 1):1991

		Specification
Fineness (retained on 90-µm sieve)	3%	<10%
Standard consistency	33%	------
Initial setting time (min)	92	30 minimum
Final setting time (min)	584	600 maximum
Specific gravity	2.89	------

3.1.2. Aggregates

The fine aggregates were locally available with maximum nominal size of 4.75 mm. The various tests of physical properties that are given in table 3 of fine aggregates was conducted by the procedure given in BIS: 383–1970[23]. The sand was categorized as zone 2 on the basis of sieve analysis test that was conducted as per BIS: 383–1970[23]. The coarse aggregates were locally available with maximum nominal size of 12.5 mm. The various tests of physical properties that are given in table 3 of coarse aggregates was conducted by the procedure given in BIS: 383–1970[23].

3.1.3 Waste foundry sand

The waste foundry sand was collected from caste iron foundry in Batala, Jalandhar (Punjab). The various tests of physical properties that are given in table 3 of waste foundry sand was conducted by the procedure given in BIS: 383–1970[23]. The waste foundry sand was categorized as zone 4 on the basis of sieve analysis test that was conducted as per BIS: 383–1970[23].

Table 2. Particle size distribution of aggregates

Sieve (mm)	Cumulative passing (%)	
	Waste foundry sand (WFS)	Natural sand
12.5	100	100
10	100	100
4.75	100	98.8
2.36	100	98.6
1.18	99.69	60.3
0.6	99.45	43.2
0.3	87.89	16.1
0.15	10.84	4.5

3.1.4 Magnesium sulphate

The magnesium sulphate powder was available in nearby chemist shop. It is the admixture which is based on polycarboxylic ether.

Table 3. Properties of aggregates

Property	Fine aggregate	Coarse aggregate	Waste Foundry sand
Maximum size (mm)	4.75	12.5	4.75
Specific gravity	2.63	2.67	2.66
Total water absorption (%)	1.92	2.16	1.26
Fineness modulus	2.78	6.27	1.03

3.2 Mixture proportion

Seven specimens of concrete i.e. (M-1, M-2, M-3, M-4, M-5, M-6 and M-7) were prepared by replacing waste foundry sand at various percentage levels i.e. (0%, 2.5%, 5%, 7.5%, 10%, 12.5% and 15%) with natural sand as a fine aggregate. The control mix of concrete (without waste foundry sand) was proportion according to BIS: 10262–1982[24] to have 40 MPa compressive strength for 28 days of curing ages. The water-to-cement ratio was kept constant i.e. 0.35 for all the mixtures of concrete. Detail of mixture are presented in table 4.

Table 4. Mix proportion of concrete mix containing waste foundry sand

Mix no.	M-1	M-2	M-3	M-4	M-5	M-6	M-7

Cement (kg/m^3)	398.57	398.57	398.57	398.57	398.57	398.57	398.57
Waste foundry sand (%)	0	2.5	5	7.5	10	12.5	15
Waste foundry sand (kg/m^3)	0	21.16	42.34	63.51	84.68	105.85	127.02
Sand (kg/m^3)	850	828.75	807.5	786.25	765	743.75	722.5
W/C ratio	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Water (kg/m^3)	139.5	139.5	139.5	139.5	139.5	139.5	139.5
Coarse aggregates (kg/m^3)	1081.9	1081.9	1081.9	1081.9	1081.9	1081.9	1081.9

3.3 *Specimens preparation and casting*

The casting operation, mixing and batching should be done in a proper manner to achieve the required strength in concrete. Firstly, the materials should be weighed and then should be separately dry mixed unless it achieves the required uniform colour. Then as per requirement the super plasticizer is added separately in different container in water with requited quantity. The sample then is mixed in machine on watertight platform mixed unless it achieves the required uniform colour. All the specimens of concrete were prepared as per procedure given in BIS: 516–1959[25]. The specimens were kept for 24 hours in steel mould under ambient condition of temperature and after that these sample were demoulded in a good manner. Then specimens for curing was put in the curing tank under ambient temperature condition i.e. 27± 2 °C and the specimens are cured as per the test's requirement. All specimens details are given in table 5.

Table 5. Detail of specimens

Tests	Specimen	All testing ages
Compressive strength	150 mm cubes	7, 28 and 56 days
Splitting tensile strength	150 mm x 300 mm	7, 28 and 56 days
Flexural strength	100 mm x 100 mm x 500 mm	7, 28 and 56 days

3.4 *Testing procedure*

Test procedure for compressive strength and flexural strength were conducted as per BIS: 516 – 1959[25]. The test procedure for splitting tensile strength were conducted as per BIS: 5816 – 1999[26]. Specimens for these tests were tested at the ages of 7, 28 and 56 days.

IV. RESULT AND DISCUSSION

4.1. *Compressive strength*

Compressive strength is measured by the compression test of the hardened concrete. It is the measure of concrete which have the ability to resist the loads which tends to compress it. The results of compressive strength are used to determine the requirements of the specific strength of concrete mixtures that has been delivered on the sites, in the job specification. The compressive strength of concrete mixtures containing WFS increases up to certain percentage level and after that there was a systematic decrease in strength. At the 7 days of curing age, the maximum increment in strength was 8.6% for concrete mixture (M-3) and after that there was a systematic decrease in strength i.e. 6.17% and 3.3% for concrete mixtures (M-4 and M-5), whereas the strength of concrete mixture (M-6 and M-7) was found lower i.e. 0.13% and 4.5% as compare to control mixture (M-1) i.e. 31.23 MPa.

At the 28 days of curing age, the maximum increment in strength was 9.3% for concrete mixture (M-3) and after that there was a systematic decrease in strength i.e. 6.54%, 5.7% and 0.71% for concrete mixtures (M-4, M-5 and M-6), whereas the strength of concrete mixture (M-7) was found lower i.e. 3.67% as compare to control mixture (M-1) i.e. 42.83 MPa. At the 56 days of curing age, the maximum increment in strength was 9.45% for concrete mixture (M-3) and after that there was a systematic decrease in strength i.e. 7.8%, 6.27% and 1.27% for concrete mixtures (M-4, M-5 and M-6), whereas the strength of concrete mixture (M-7) was found lower i.e. 3.52% as compare to control mixture (M-1) i.e. 44.37 MPa. It was observed that there was an increment in compressive strength up to certain limit in concrete containing WFS and after that there was a systematic decrease in strength as the WFS percentage level goes on increasing in concrete. The strength also increased with the increase in curing age of concrete mixtures. The maximum strength was found at M-3 (5%) for all the curing ages of concrete mixtures. The variation in compressive strength values for all ages can be easily observed by fig 1. Similar observation and results were reported by Siddique et al.[11], Guney et al.[13], Prabhu et al.[21], Singh & Siddique[10], Basar & Aksoy[14], Siddique et al.[8].

Siddique et al.[11] reported that the strength increases up to 34.4 MPa and 43.3 MPa for both types of grades and observed that M 20 grade gives better results as compared to M 30 grade of concrete. Guney et al.[13] reported that 10% inclusion of WFS in concrete gives almost similar results as compared to control mix i.e. 60.3 MPa at 28 days of curing age. Author also observed that the strength increases with the increase in curing age of concrete. Prabhu et al.[21] reported that 10% of inclusion of WFS in concrete carries almost similar results as compared to control mix i.e. 33.14 MPa at 28 days of curing age. After 10% WFS there was a systematic decrement in strength as the percentage level goes on increasing.

Singh & Siddique[10] reported that there was a increment in strength up to certain level of inclusion of WFS and after that there was a systematic decrement in strength. The strength increased up to 8.3 % at 10 % of inclusion of WFS in concrete at 28 days of curing age. The maximum strength at 28 days of curing was reached up to 13.5% and after that there was a systematic decrease in compressive strength. Basar & Aksoy[14] reported that 10% of inclusion of WFS in concrete give almost similar results as compared to control mix i.e. 43.2 MPa at 28 days of curing age. After 10% of inclusion of WFS there was a systematic decrease in compressive strength. Siddique et al.[8] reported that the increment in strength was from 4.2% to 9.2% for 10 % to 30% of inclusion of WFS in concrete as compared to control mix at 28 days of curing age.

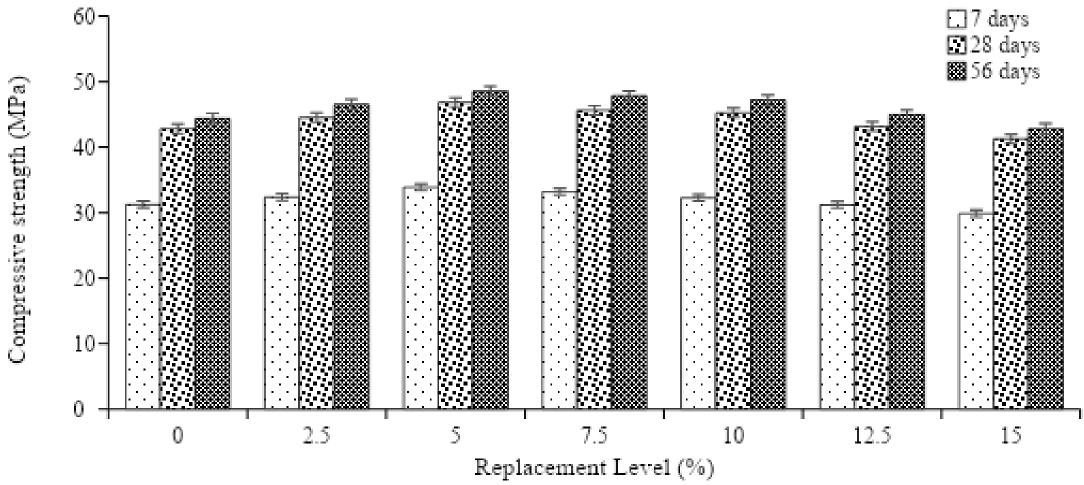

Fig 1. Compressive strength versus age

4.2. Splitting tensile strength

Concrete is weak in tension and strong in compression, so this test is necessary to prevent concrete from cracking it in tension zone. The concrete cannot resist direct tension because concrete is very weak in tension. Furthermore, the indirect method is used for determining the tensile strength of concrete. The splitting tensile strength of concrete mixtures containing WFS increases up to certain percentage level and after that there was a systematic decrease in strength. At the 7 days of curing age, the maximum increment in strength was 10.8% for concrete mixture (M-3) and after that there was a systematic decrease in strength i.e. 7.97%, 3.51% and 1.6% for concrete mixtures (M-4, M-5 and M-6), whereas the strength of concrete mixture (M-7) was found lower i.e. 4.78% as compare to control mixture (M-1) i.e. 3.14 MPa.

At the 28 days of curing age, the maximum increment in strength was 11.37% for concrete mixture (M-3) and after that there was a systematic decrease in strength i.e. 8.34%, 4.05% and 2.53% for concrete mixtures (M-4, M-5 and M-6), whereas the strength of concrete mixture (M-7) was found lower i.e. 3.79% as compare to control mixture (M-1) i.e. 3.96 MPa. At the 56 days of curing age, the maximum increment in strength was 12.84% for concrete mixture (M-3) and after that there was a systematic decrease in strength i.e. 8.63%, 4.21% and 3.32% for concrete mixtures (M-4, M-5 and M-6), whereas the strength of concrete mixture (M-7) was found lower i.e. 3.54% as compare to control mixture (M-1) i.e. 4.52 MPa. It was observed that there was an increment in splitting tensile strength up to certain limit in concrete containing WFS and after that there was a systematic decrease in strength

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as the WFS percentage level goes on increasing in concrete. The strength also increased with the increase in curing age of concrete mixtures. The maximum strength was found at M-3 (5%) for all the curing ages of concrete mixtures. The variation in splitting tensile strength values for all ages can be easily observed by fig no 2. Similar observation and results were reported by Siddique et al.[11], Guney at el.[13], Prabhu et al.[21], Siddique et al.[10], Siddique et al.[8].

Siddique et al.[11] reported that M 30 grade almost similar results i.e.4.38 MPa as compared to control mix 4.32, whereas there was a increment in results for M 20 grade i.e. 3.7 MPa as compared to control mix i.e. 3.42MPa for 10% of inclusion of WFS in concrete at 28 days of curing age. Guney at el.[13] reported that there was a increment in strength up to 3.91 MPa as compared to control mix i.e.3.57 at curing age of 28 days. Author also observed that strength in all mixtures increases with the increase in curing ages. Prabhu et al.[21] reported that 10% of inclusion of WFS in concrete carries almost similar results as compared to control mix i.e. 2.765 MPa at 28 days of curing age. After 10% WFS there was a systematic decrement in strength as the percentage level goes on increasing. Siddique et al.[10] reported that with the increase in percentage level of WFS the strength also increases in concrete. The strength increases from 3.55% to 10.40% for 10% to 30% percentage level in concrete as compare to control mix i.e. 4.21 at 28 days of curing ages. Siddique et al.[8] reported that the increment in strength was up to 9% for 10 % to 30% of inclusion of WFS in concrete as compared to control mix i.e.2.75 MPa at 28 days of curing age.

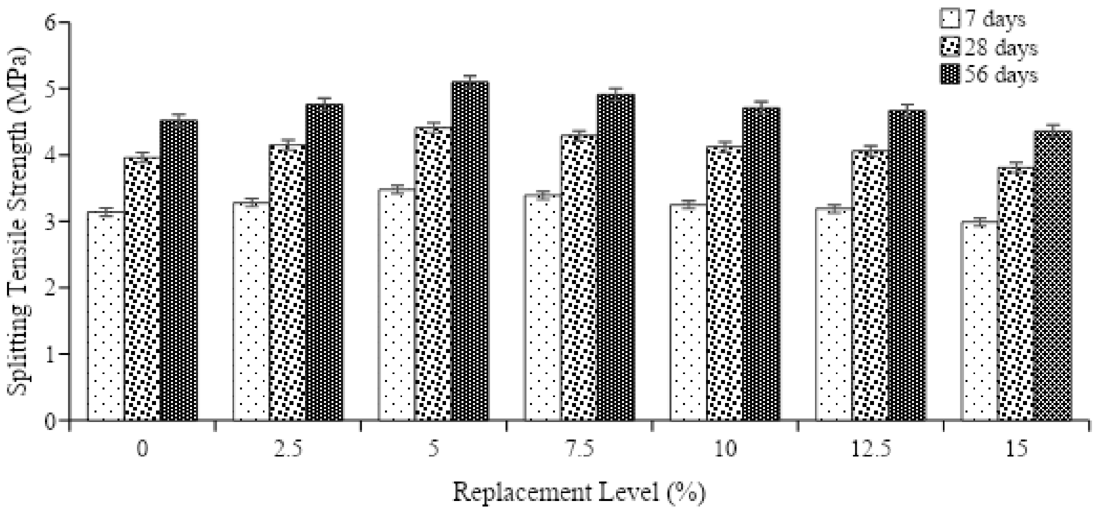

Fig 2. Splitting tensile strength versus age

4.3. Flexural strength

Flexural strength is very important mechanical perimeter that is known for bend strength so this test is necessary as it tells about the ability of material that can resist deformation under load. The flexural strength of concrete mixtures containing WFS increases up to certain percentage level and after that there was a systematic decrease in strength. At the 7 days of curing age, the maximum increment in strength was 10.09% for concrete mixture (M-3) and after that there was a systematic decrease in strength i.e. 7.21%, 4.33% and 3.18% for concrete mixtures (M-4, M-5 and M-6), whereas the strength of concrete mixture (M-7) was found lower i.e. 4.61% as compare to control mixture (M-1) i.e. 3.47 MPa.

At the 28 days of curing age, the maximum increment in strength was 2.27% for concrete mixture (M-3) and after that there was a systematic decrease in strength i.e. 8.66%, 5.29% and 3.39% for concrete mixtures (M-4, M-5 and M-6), whereas the strength of concrete mixture (M-7) was found lower i.e. 5.08% as compare to control mixture (M-1) i.e. 4.73 MPa. At the 56 days of curing age, the maximum increment in strength was 13.26% for concrete mixture (M-3) and after that there was a systematic decrease in strength i.e. 10.6%, 7.58 and 4.93% for concrete mixtures (M-4, M-5 and M-6), whereas the strength of concrete mixture (M-7) was found lower i.e. 5.69% as compare to control mixture (M-1) i.e. 5.28 MPa. It was observed that there was an increment in flexural strength up to certain limit in concrete containing WFS and after that there was a systematic decrease in strength as the WFS percentage level goes on increasing in concrete. The strength also increased with the increase in curing age of concrete mixtures. The maximum strength was found at M-3 (5%) for all

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the curing ages of concrete mixtures. The variation in splitting tensile strength values for all ages can be easily observed by fig 3. Similar results and observations were reported by Prabhu et al.[21]. Prabhu et al.[21] reported that the 10% and 20% of WFS inclusion in concrete shown almost similar results i.e. i.e. 3.986 MPa and 3.988 MPa as compared to control mix i.e. 4.089 MPa at 28 days of curing ages.

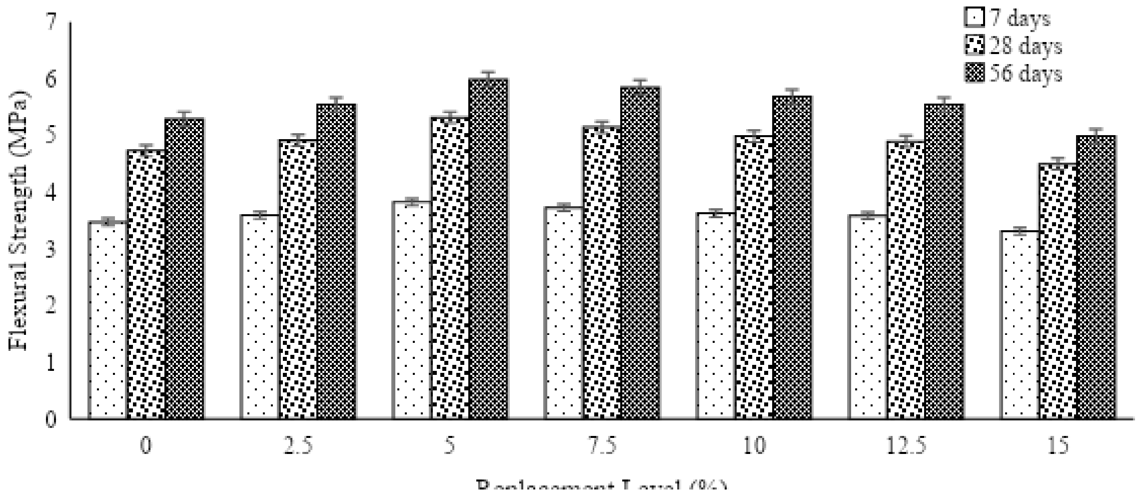

Fig 3. Flexural strength versus age

V. CONCLUSION

The reuse of waste foundry sand as a substitute of natural sand as fine aggregates for production of concrete up to certain replacement level in this research is based on to evaluate the mechanical and durability properties of concrete. The several extensive tests are carried out on seven mix and following conclusion based on these tests have been made.

a) The inclusion of WFS with natural sand as fine aggregates in concrete enhance the strength properties with increasing percentage level of WFS up to certain limit and further the strength properties of concrete also improved with the increase in curing age.

b) Compressive strength of concrete containing WFS increased from 3.93%–9.3% and after that there is a systematic decrease in strength, splitting tensile strength of concrete containing WFS increased from 4.8% - 11.37% and after that there is systematic decrease in strength, flexural strength concrete containing WFS increased from 3.81%-12.27% and after that there is systematic decrease in strength at 28 day of curing age.

c) The maximum strength was observed at 5% waste foundry sand of inclusion with fine aggregates in concrete at all curing ages in mechanical properties i.e. (compressive strength, splitting tensile strength and flexural strength).

d) From following observation, it was observed that 7.5% of waste foundry sand replacement level can be successfully used to make concrete and in various applications of concrete like concrete paver blocks, whereas beyond this replacement level is not beneficial.

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