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IMPROVEMENT MECHANICAL PROPERTIES OF CONCRETE USING INDUSTRIAL BY-PRODUCT WASTE FOUNDRY SAND

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ABSTRACT

The need of concrete is increasing every year as the population of humans are increasing as per their demands i.e. infrastructure developments and shifting composition etc. Due to rising demands and fight to produce good quality of concrete, construction industries have overused the natural materials used in concrete, leads us to extinction in natural materials and results in rising prices of materials. Thus, the environmental problems related with excessive extraction and mining from natural sources have been reported in many countries. Due to finite availability of natural materials, and involvement of economy, it has now become very important to look as for the alternative source for natural materials used in concrete i.e. gravels and natural sand. Waste foundry sand (WFS) is a propitious material that can be used as an alternative for the natural sand i.e. (fine aggregates) in concrete. The thesis demonstrates the potential of re-use for waste foundry sand i.e. industrial by-product as a substitute of a fine aggregate in concrete. The fine aggregates i.e. (natural sand) are replaced with WFS in six different substitution rates i.e. (2.5%, 5%, 7.5%, 10%, 12.5% and 15%). Several tests were performed to examine the mechanical properties i.e. (compressive strength, flexural strength and splitting tensile strength) as well as the durability of concrete.
Key woards- compressive strength, flexural strength, splitting, tensile strength,

I. INTRODUCTION

Concrete Concrete is the backbone of construction industries around the world. The need of concrete is increasing day by day as the population of humans is increasing as per their demands i.e. infrastructure developments and shifting composition etc. The primary constituents of concrete like cement, sand and coarse aggregates are depleting as the demand of concrete is rising around the world and leads us to various sustainable issues. Globally, production of cement in China was 2.4 billion tons, in USA was 86.63 million tons and in India was 270 million tons in 2017 year. In the USA, every 1 ton of cement requires 10 tons of aggregates to produce concrete[1].In the production of concrete, aggregates makes its volume of 70% as the principal of component material and industries of concrete globally consumes 8to 12 million tons of aggregates annually after 2010 year[2]–[4].

Increasing population in the world every year, results in the raising the demand for construction materials and this will lead us to shortage in materials, rising prices and negatively affecting the environment in future. As a report published by UNEP February[1], composition of concrete is 25% of fine aggregates, 45% of coarse aggregates, 10% of cement, 18.5% of water and 1.5% of air, and this shows that aggregates are the most essential material for construction industries and 75% of aggregates are used to produce concrete. As per composition of concrete fine aggregates and coarse aggregates are the major ingredients i.e. crushed rocks, natural sand and gravels and reported that 40-50 billion metric ton of these materials are extracted from coastlines, sand near river site and quarry pits the marine environment every year[1]. Globally, an extraction of material from environment is estimated from 47 billion to 59 billion construction tons[5], of which sand and gravels used as a fine aggregates and coarse aggregates in concrete accounted as the largest share in extraction i.e. from 68%-85%[6],[7].

Surprisingly, natural sand as a fine aggregate and gravels as a coarse aggregate in concrete are mined more as compared to other construction material. These raw materials are struggling to cope with increasing demands in many places and areas around the world. Now a days, excess use of concrete give rise to the environmental issues and the sources of great quality of river sand and gravels are rapidly depleting. These materials cannot be extracted from environment in large quantity and used without a negative and serious impact on the environment. Due to rising demands and fight to produce good quality of concrete, construction industries have overused the natural materials used in concrete leads us to extinction in natural materials and results in rising prices of materials[8]. Thus, the environmental problems related with excessive extraction and mining from natural sources have been reported in various locations of Asia, Africa and south America[9]. India and China are listed at the top most country as a hotspot for extraction sand from rivers, coastlines and lakes[10], these countries moreover also lead on the field of infrastructures and infrastructures. Therefore, excessive extraction and mining causes change in PH level, affect the river ecosystem and has led to threaten the number of locations in the world. By seeing these certain fact government of the various countries have banned sand mining and extraction of sand from natural sources which leads now to look for the alternative source of natural sand.

Alternative for Natural Sand (fine aggregates)

As the natural sand supplies from the natural sources are near the point of becoming exhausted, this ultimately leads in increasing the cost of natural sand. The sustainable growth in construction world in modern times for fulfilling the demand of sand is needed as alternative source that should be abundantly available and satisfy all required technical specification for fine aggregated. A lot of research during the past few decades have been conducted to find an alternative source for a fine aggregate (natural sand) [11]–[16].

Now a days, with ongoing various research and development in construction field, researchers found that several waste materials have almost similar properties as compared to fine aggregates. WFS is a by-product for metal casting industries and carries almost similar properties as compare to sand. Waste foundry sand suitably used and recycled various times for casting and moulding operation, and further when recycled sand can no longer be reused in these operations are expelled from the casting industries. The production of waste foundry sand in large amount from industries is also a problem issues for reusing it in a beneficial way. Due to production of WFS in large volume around the world and contains silica content in large amount it attracts interests of lots of government bodies and researchers.

Use of industrial by-product in a serious manner drawn attention of researchers and these by-products has investigated by researchers and industries for several years as a partial and full replacement of waste materials with fine aggregates in concrete. Siddique[17] gave an overview for the utilization of several industrial waste materials as a partial replacement with natural sand in concrete i.e. dust of cement kiln, wood ash, WFS, and coal bottom ash. and furthermore, also discussed chemical, physical and mineralogical properties of these wastes. Dash et al.[4] published an article of review based on utilization of various products and by-

products waste of industries i.e. copper slag, palm oil clinker, coal bottom ash, ferrochrome slag, steel slag, waste foundry sand and imperial smelting furnace slag etc. Each waste product has a different and unique effect on various properties of concrete.

Foundry Sand

The foundries are originated from the region of Mesopotamia and from Iraq and Syria. Fire pits and casting of clay worked to make shapes of silver, copper and gold[18]. The shape of WFS is sub-angular to round suitably, and it has an immense thermal conductivity which is helpful in using it for casting and moulding operations. The foundry sand contains bentonite clay presents in very less amount and it also acts as binder material. Furthermore, foundry sand also contains chemical binders which acts to create sand cores. Foundry sand is used and recycled various times in metal casting industries for mouldings and casting operations to a certain point where it can no longer be reused and when it is no longer be reused is expelled from the operation, and the new sand is introduced and imported to this cycle. Then, the expelled sand from the casting operations and foundries is known as WFS. WFS is a by-product of metal casting industries i.e. (ferrous and non-ferrous) which contain silica in high amount. In metal casting industries, waste foundry sand (WFS) is mainly characterized on the basis of binders and binder's system. Green sand and chemically bonded sand are the sand used in casting process.

Green sand (clay bonded sand) is a mixture of silica sand from (80%-95%), bentonite clay from (4%-10%), carbonaceous addictive from (2%-10%) and water from (2%-5%) and used in various type of mould making processes. Other several ingredients contained by thesetypes of sand is rice hulls, flour, starches and cereals. Presence of silica in high amount in greensand used to resist very immense temperature and presence of bentonite clay combine the clay, whereas presence of water acts to activate the system of bentonite clay. Furthermore, presence of minor ingredients improves the fluidity and these ingredients also absorbs the moisture. Magnesium oxide, titanium dioxide, and potassium dioxide are some of the chemicals which are also presents in green sand. In the iron world of casting, 85% of green sand is used in the operation of moulding. The green sand is called green in colour due to presence of akin to green wood in a wet stage, however it is not green.

Chemically bonded sand is generally use for both the operations like core making and moulding. This sand is a mixture of 1%-3% of chemical binders and also contains very high amount of silica. Silica in very high amount is required to resist temperature that is needed for core making processes. There is various chemical binder that are used in this sand by foundries

industries i.e. urethane (phenolic), phosphate, furfuryl alcohol, sodium silicate, flake resins,

phenolic resole-ester phenolic no bake-acid and alkyd (oil) urethane. The chemical bounded sand that are most commonly used in foundries are cold box, Co2 sand, hot box and resins coated sands. The various binders and binder's system used in foundries are phenolic no- bake, epoxy So2 , alkyd oil- Sodium silicate, phenolic no-bake, phenolic esters, phenolic urethanes, Sulphur dioxide, furan no bake, based on core oil, furan warm box , alkyd oil- Sodium silicate and alkyd urethane use in sand moulding processes. As compare to green sand this sand is lightin colour.

The Global Scenario From 3000 foundries, United States utilizes annually about sand for 100 million tons are used in foundries and per year about (6 to 10) million metric tons is discarded as WFS, which is used in landfills [40],[39]. As per 53rd world casting census production[41], the total global casting production in the world increased up to 112.7 million metric tons as compared to 2018 year there is an increase of 2.6% in 2019 year. China, India and USA holds the top three positions in world casting census production and in India there is an increase of 11% of casting production in 2019 year as compared to previous year[41].

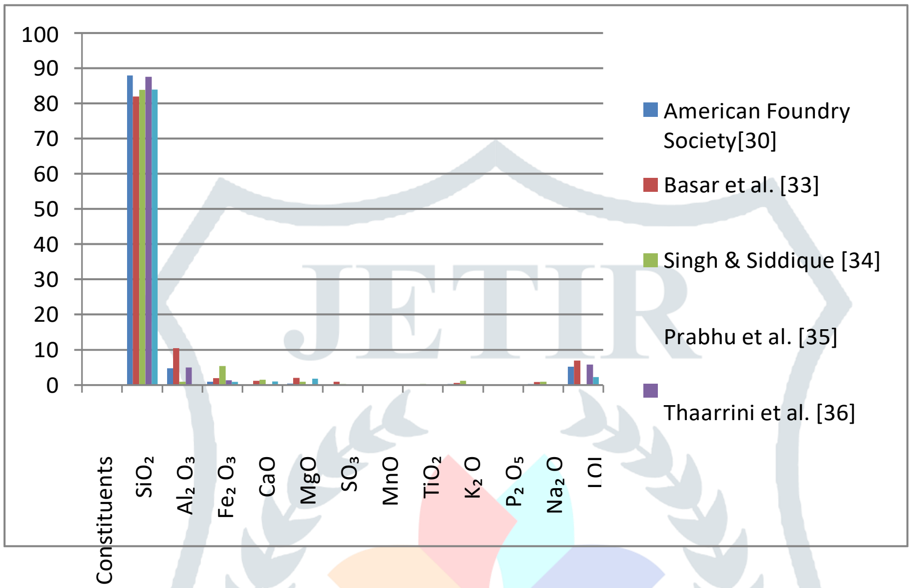

Fig 1.1 Production of casting in the world in million M.T. [42]–[45]

strength and durability, higher recyclability, and resistance to freezing and chemical reactions, better finishing and pumping, as well as a low-cost material, and so forth. This study will introduce a number of agricultural commodities that have been discarded but are pozzolanic by-products that can be employed as greening construction materials and environmentally friendly materials. The framework for utilising industrial waste material for construction purposes, which comprises fly ash, slag, and silica fume, has produced a successful report. As a result, land filled waste materials are disposed of, and land filled is now seen as a significant asset in improving concrete's desirable attributes.

II. LITERATURE REVIEW

Shalokhe & Desai[67] evaluated the properties of concrete by replacing both ferrous and non- ferrous waste foundry sand with fine aggregates in concrete. Author reported that the 30% ferrous foundry sand show maximum increment in the strength i.e. 30.96 MPa and almost have similar result as compared to control mix i.e. 31.7 MPa at 28 days of curing age. Whereas 10% nonferrous foundry sand show maximum increment in the strength i.e.

30.96 MPa and almost have similar result as compared to control mix i.e. 31.7 MPa at 28 days of curing age.

Vardhan et al.[68] performed several test by replacing waste foundry sand with fine aggregates in different grades of concrete (M20, M40, M60). Author reported that 40% of inclusion shows maximum strength in concrete. Author reported that there was a systematic increment in strength up to 40% inclusion of WFS and after that there was a drastic decrease in compressive strength for all grade in concrete. Furthermore, 40% inclusion of waste foundry sand carries a maximum strength for all grades i.e. 34.34 MPa for M20, 54.21 MPa for M30 and 73.21 MPa for M60 at 28 days of curing age.

Bilal et al.[58] evaluated the behavior of waste foundry sand partially replaced with natural sand in concrete at different percentage level and performed several test for compressive strength and (RCS) residue of compressive strength. Author reported that the maximum strength was achieved at 30% inclusion of WFS in concrete. There was an incrementup to 7.82% at 28 day of curing age. In RCS, the samples of concrete are check after and before the exposure of required temperature and in RCS author observed that with the rise in the temperature of specimens there was a loss in the compressive strength and 30% yielded inclusion of WFS showed excellent outcomes. It have been observed from following studies that some of the studies shows 20% inclusion of WFS gives better results as compare to other percentage and some literatures shows 30% inclusion of the WFS in concrete is optimum percentage to use without any negative affect. The fungal treated WFS shows maximum increment in strength as it improves the C-H-S gel formation in concrete as compared to untreated WFS. WFS inclusion with fine aggregates in concrete reduce the density of concrete which reduces the dead weight of concrete structure.

III. PROPOSED METHODOLOGY

Objectives

The main objective of the investigation is to study the effective use of waste foundry sand in concrete by partially replacing with natural sand in concrete without any negatively affecting the properties of concrete. In this study the waste foundry sand is partially replaced with natural sand at several percentage levels. The different of this investigation are given below:

a) To examine the effect of waste foundry sand in M40 i.e. (high grade of concrete).
b) To attain the required specific strength in control mix.
c) To compare the mechanical properties i.e. (compressive strength, splitting tensile strength and flexural strength) of concrete containing waste foundry sand by partially replacing regular sand with conventional mix.
d) To compare the durability properties i.e. (sulphate resistance) of concrete containing wastefoundry sand by partially replacing regular sand with conventional mix.
e) To find the optimum percentage of waste foundry sand, so it can be used without any negatively affecting the properties of concrete and can be used suitably for making concrete paver blocks.

various results are discussed that are reported in experimental programs. In first section, the physical testing results are given i.e. cement, natural sand, waste foundry sand and coarse aggregates. For cement, the following physical test that are done is initial and final setting time, specific gravity, normal consistency and fineness. For natural sand, the following physical test that are done is specific gravity, sieve analysis, water absorption. For waste foundry sand, the following physical test that are done is specific gravity, sieve analysis, water absorption. For coarse aggregates following physical test are done i.e. water absorption and specific gravity. In next section, the waste foundry sand is partially replaced with fine aggregates at various percentage levels i.e. 2.5%, 5%, 7.5%, 10%, 12% and 15% and by replacing waste foundry sand with natural sand various tests were conducted on mechanical and durability properties of M 40 grade concrete. Mechanical property includes compressive strength, splitting tensile strength and flexural strength, and durability property include sulphate resistance. The mechanical and durability properties are also discussed with other studies as well as their change in strength by inclusion of waste foundry sand in concrete.

Natural Sand

The material was locally available with 4.75 mm, that is the maximum nominal size of the fine aggregates. The all test of natural sand was done according to the Indian Standard Specifications which is given in BIS 383:1970[83] and by doing these test this sand categorized under zone 2. The physical properties of natural sand are given in table no. 4.2.

Table 1.1 Physical properties of natural sand

Property	**Fine aggregate**
Maximum size (mm)	4.75 mm
Specific gravity	2.63
Total water absorption (%)	1.92%
Fineness modulus	2.78

Waste Foundry Sand

The Waste foundry sand was collected in bags from caste iron foundry in Batala, Jalandhar (Punjab). The waste foundry sand was tested according to BIS: 383–1970[83] and physical properties of waste foundry sand is given in table no. 4.3.

Table 1.2 Physical properties of waste foundry sand

Property	**Waste foundry sand**
Maximum size (mm)	4.75
Specific gravity	2.66
Total water absorption (%)	1.26%
Fineness modulus	1.03

Coarse Aggregates

The material was locally available with 12.5 mm, that is the maximum nominal size of the coarse aggregates. The coarse aggregates were tested according to BIS: 383–1970[83]. The physical properties of coarse aggregates

Table 1.3 Physical properties of coarse aggregates

Property	Coarse aggregates
Maximum size (mm)	12.5 mm
Specific gravity	2.67
Total water absorption (%)	2.16%
Moisture content	Nil

Table 1.4 Compressive strength versus age

WFS %	7 days (MPa)	28 days (MPa)	56 days (MPa)
0	31.23	42.83	44.37
2.5	32.37	44.51	46.53
5	33.89	46.81	48.56
7.5	33.16	45.63	47.83
10	32.26	45.25	47.15
12.5	31.19	43.16	44.93
15	29.85	41.26	42.81

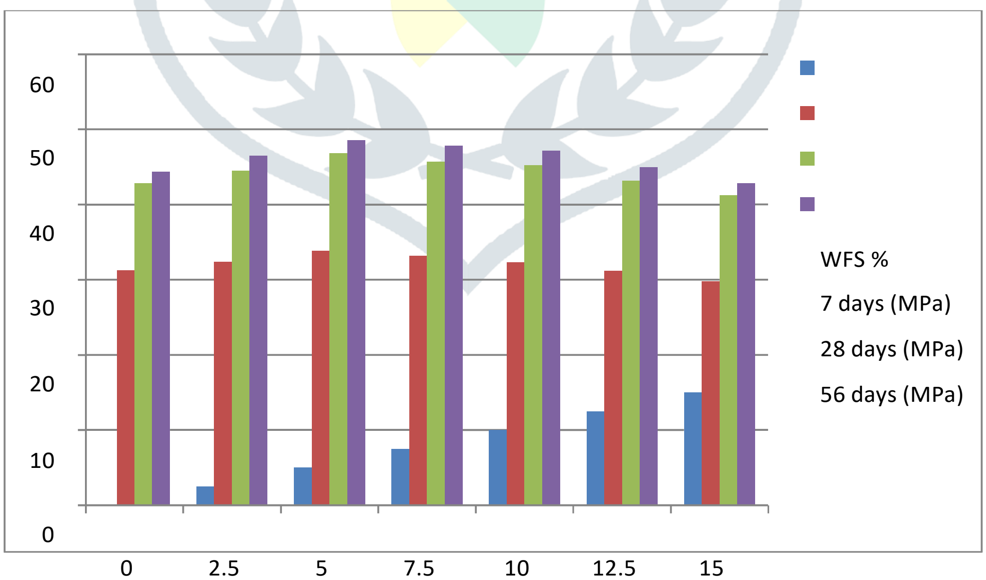

Fig .1.2 Compressive strength versus age

5.1 Conclusion

1. The present investigation is on the study of effective use of waste foundry sand as a partial replacement by regular sand as a fine aggregate in concrete. Mechanical i.e. (compressive strength, splitting tensile strength and flexural strength) and durability properties

2. i.e. sulphate resistance) of concrete were checked by replacing waste foundry sand at several percentages i.e. (0%, 2.5%, 5%, 7.5%, 10%, 12.5% and 15%) with natural sand in concrete. Test results in this investigation indicates that industrial by-product i.e. waste foundry sand is suitable and can be used in concrete as a substitute for regular sand in concrete

3. The inclusion of waste foundry sand with fine aggregates in concrete enhance the strength properties with increasing content of WFS up to certain replacement level and further the strength properties also improved with the increase in curing age.
4. Compressive strength of concrete increased from 3.93%–9.3% and after that there is a systematic decrease in strength, splitting tensile strength of concrete increased from 4.8% - 11.37% and after that there is systematic decrease in strength, flexural strength of concrete increased from 3.81%-12.27% and after that there is systematic decrease in strength at 28 day of curing age.

5. The maximum strength was observed at 5% WFS of inclusion with fine aggregates in concrete at all curing ages in mechanical properties i.e. (compressive strength, splitting tensile strength and flexural strength).The increment in strength can be observed because WFS contains silica content in high amount which helps in the formation of C-S-H gel and this is due to the packing behavior of matrix particles.

6. The sulphate resistance test was done on concrete mixture containing waste foundry sand and observed that 10% of WFS replacement level gives the maximum compressive strength value i.e. 51.73 MPa for 28 days of curing age. The increment in strength is because of the waste foundry sand that increases the strength of magnesium sulphate due to presence of traces of Sulphur (SO_3) in it which causes deterioration in concrete

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