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ANOVA Analysis Of Compressive Strength For Waste Foundry Replaced Concrete

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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%). Tests were performed to examine the mechanical property of compressive strength. The results indicate that the compressive strength was increased from 3.93%–9.3%, for 2.5%-5% replacement levels of waste foundry sand with fine aggregates in concrete and after that there is a systematic decrement in strength as the percentage goes on increasing at curing age of 28 days. From following results, it was concluded that 10% WFS replacement level of WFS with fine aggregate in concrete can be effectively used to make concrete and various application of concrete and beyond 10% WFS replacement level is not beneficial. Analysis using SPSS software was carried out to analyse the correlation between different mechanical properties and replacement levels of WFS. The correlation yielded a negative coefficient of change and R^2 (0.93) of acceptable levels to analyse the reduction of strength parameters under acceptable level. The correlation will help to keep the replaced concrete safe.

Keywords: Anova, Waste Foundry Sand, Compressive Strengths

Introduction

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. Recently, 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. 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. India and China are listed at the top most country as a hotspot for extraction sand from rivers, coastlines and lakes, 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. 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 has been conducted to find an alternative source for a fine aggregate (natural sand).

WFS (Waste Foundry sand) are by-product for metal casting industries and carries almost similar properties as compare to sand. 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.

The major component of foundry sand is silica which is present in high amount in foundry sand and this component is also present in natural sand but in lower amount as compare to foundry sand. The physical properties, chemical properties and mechanical properties of waste foundry sand depends and can vary due to many factors i.e. Different places and industries from which it originates, types of addictive added during casting operations, types of binder and binder's system used, several times sand is recycled for molding and types of addictive used during molding operations.

Literature Review

Siddique et al. evaluated various mechanical, durability and microstructural property by replacing waste foundry sand with fine aggregates at several percentage levels for different curing ages. Author casted cubes and cylinders for checking various compressive strength values. Author found that concrete containing 30% of WFS have more compressive strength i.e. 38.03 MPa as compare to control mix i.e. 36.27 MPa and other percentages at curing age of 28 days. There was a systematic decrease in compressive strength of cylinder for all values as the percentage of WFS goes on increasing of WFS in concrete as compared to control mix i.e. 26.35 MPa but 30% and 50% of WFS in concrete shows almost similar strength i.e. 24.94 MPa and 24.17 MPa as compare to control mix at 28 days of curing age. Author observed that the compressive strength increases with increase in curing age for all concrete specimens and cubes carries more compressive strength as compare to cylinders.

Aggarwal & Siddique evaluated the possibility of inclusion of waste foundry sand and bottom ash i.e. (industrial by-product) with fine aggregates at various percentage levels i.e. (0%-60%) equally by weight in concrete for different curing ages. Author observed that there was a decrement in compressive strength as compare to control mix at 28 days of curing age i.e. 36.27 MPa. There was a drastic decrease in compressive strength at 60% (WFS+BA) replacement levels i.e. 21.08 MPa as compared to other percentage as all other percentages showed similar results at 28 days of curing age. Author observed that the strength of concrete increase with an increase of curing age.

Guney et al. performed various test by replacing waste foundry sand with fine aggregates at different percentage levels at various curing ages. Author reports that 10% of WFS replacements shoes almost similar results as compared to control mix such as 61.3 MPa at 28 days of curing ages. Author observed that 5% and 15% of WFS inclusion in concrete showed decrement in strength as compared to control mix such as 53.2 MPa and 52.3 MPa and the compressive strength increases with the increase in curing age of the concrete.

Prabhu et al. evaluated the effect of utilization of waste foundry sand in concrete at different percentages level with fine aggregates. Author removed several impurities and particles by using washed waste foundry sand. The waste foundry sand is successfully washed for four times and then it was kept for drying under normal environment conditions for two days. Furthermore, several tests were conducted by using it in concrete and author reported that as compare to control mix there was a systematic decrease in compressive strength for all percentage levels. The 20% WFS percentage level showed almost same strength but marginal decrement of 1.6% as compare to control mix at 28 days of curing age such as 33.14 MPa. Author reported that after 30% of WFs inclusion there was drastic decrease in strength such as for 40% WFS inclusion was up to 11.04% and for 50% WFS inclusion was up to 23.95% as compared to control mix at curing age of 28 days. There was increase of degradation in concrete as the percentage goes on increasing and strength reaches almost half in 100% percentage level of WFS in concrete as compared to original strength.

Basar & Aksoy partially replaced the waste foundry sand with sand in concrete and studied the effect of waste foundry sand at different percentage levels. Author reported that there was a systematic decrease in strength at all percentage level as compare to control mix without waste foundry sand. The compressive strength was almost similar at 10% inclusion of WFS in concrete such as 44.1 MPa as compared to control mix such as 43.2 MPa and there was a drastic decrease in strength after 20% of inclusion of waste foundry sand in concrete at 28 days of curing age. The compressive strength increased with the increase in curing age for all the sample of concrete.

Singh & Siddique evaluated the strength properties of waste foundry sand containing concrete. The waste foundry sand is partially replaced with fine aggregate at several percentage levels by weight in concrete and various test are performed. Author reported that there was systematic increase in a strength up to 20% inclusion of WFS and maximum strength was found at 15% of WFS inclusion in concrete i.e. 47.36 MPa compared to control mix at 28 days of curing age i.e. 40.03 MPa. Author observed that the main cause of strength decrement after certain level of increment was because of reduction in surface area of matrix in water- cement gel due to witch fine coarse binding process in concrete does not take place properly.

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 reduces the density of concrete which reduces the dead weight of concrete structure.

Materials and Methods

The effect of using waste foundry sand containing concrete was investigated for compressive strength at various percentages as partial replacement with fine aggregates. The material used is described in this section and the mix proportion is also indicated in this section for the experimental studies.

Cement

Portland pozzolana cement (PCC) was used which was conformed as per IS 1489-Part- 1. the various physical properties of cement are initial and final setting time, specific gravity, standard consistency, and fineness which are evaluated by the following procedure given in IS 1489-Part-1.

Natural Sand

The material was locally available with 4.75 mm is the nominal maximum size of the fine aggregates. The fine aggregates were tested as per BIS: 383–1970. Specific gravity, fineness modulus, water absorption and sieve analysis was determined by BIS: 383–1970.

Coarse Aggregate

The material was locally available with 4.75 mm is the nominal maximum size of the fine aggregates. The fine aggregates were tested as per BIS: 383–1970. Specific gravity and water absorption was determined by BIS: 383–1970.

Waste Foundry Sand

The Waste foundry sand was collected in bags from caste iron foundry in MIDC, Nagpur (Maharashtra). Waste foundry sand was tested according to BIS: 383–1970. Specific gravity, fineness modulus, water absorption and sieve analysis was determined by BIS: 383– 1970.

Compressive Strength

Compressive strength is the important mechanical property that used to give characteristic compressive strength of concrete. Compressive strength for all concrete samples are done as per Indian Standard Specifications BIS: 516–1959. Furthermore, the cube sizes in this are kept as 150mm×150mm×150mm and the test was evaluated at the curing age of 7 days, 28 days and 56 days. Concrete samples were kept demolded for 24 hours and after casting, the concrete samples were placed in curing tanks for required curing age. Then after each curing age the samples were taken out and then the testing was done in CTM by applying specified load rate i.e. 140 kg/cm^2/min. Then the load of the machine was increased until the concrete specimens do not break, and the maximum amount of load was taken and noted down of concrete specimens.

Figure 1: Compressive strength testing machine

The formula used to calculate compressive strength is:

$\sigma = P/A$

where,

A = Area of cross section of cube (mm2)

P = Maximum load sustained by the cube (N) σ = Compressive strength (N/mm^2)

The various results of compressive strength testing were done for 3 specimens at 7 days, 28 days and 56 days of curing age for each concrete sample in N/mm^2.

Results

In this section, various results from experiments are reported. The waste foundry sand is partially replaced with fine aggregates at various percentage levels i.e. 2.5%, 5%, 7.5%, 10%, 12% and by replacing waste foundry sand with natural sand various tests were conducted on compressive strength properties of M 30 grade concrete. The results are elaborated in the succeeding sections.

Cement

Properties of the Cement are presented under **table 1** as per the standard tests.

Table 1: Physical properties of the 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 minutes	30 minutes (min)
Final setting time (min)	584 minutes	600 minutes (max)
Specific gravity	2.89	------

Pozzolana Portland cement PPC was used in making for all samples of concrete mix.

Waste Foundry sand

Sieve analysis of waste foundry sand was done as per to BIS: 383–1970. It was categorized under zone 4. The sieve analysis is presented under **Table 2**

Table 2: Sieve analysis of waste foundry sand

Sieve Size	Weight retained (gm)	% retained	Cumulative % retained	% passing
10mm	0	0	0	100
4.75mm	0	0	0	100
2.36mm	0	0	0	100
1.18mm	3.1	.31	.31	99.69
600 microns	2.34	.234	.544	99.45
300 microns	115.6	11.5	12.11	87.89
150 microns	770.5	77.05	89.16	10.84

Mix Proportion

Grade designation: — M40

Type of cement: — OPC 43 grade

Maximum nominal size of aggregate: — 20mm

Minimum cement content: — 320 Kg ………….. (From Table 5 of IS 456:2000)

Maximum water-cement ratio: — 0.45 ……….. (From Table 5 of IS 456:2000)

Degree of Workability: — 100mm slump / 0.92 compacting factor

Exposure condition: — Severe

Type of aggregate: — Crushed angular aggregate

Maximum cement content: — 450 kg/m^3

Compressive strength after Replacement with Waste foundry sand

The fine aggregate i.e., the sand was replaced by WFS and using the compressive testing machine the analysis was done for 56 days and the strength is reported under the table 3 as shown.

Table 3: Compressive strength Analysis

WFS %	7 days (MPa)	28 days (MPa)	56 days (MPa)
0	31.23	42.83	44.37
2.5	32.5	43	45.1
5	33.8	45.8	46.3
7.5	33.1	45.3	47.8
10	32.26	45.25	47.15
12.5	31.19	43.16	44.93
15	29.85	41.26	42.81

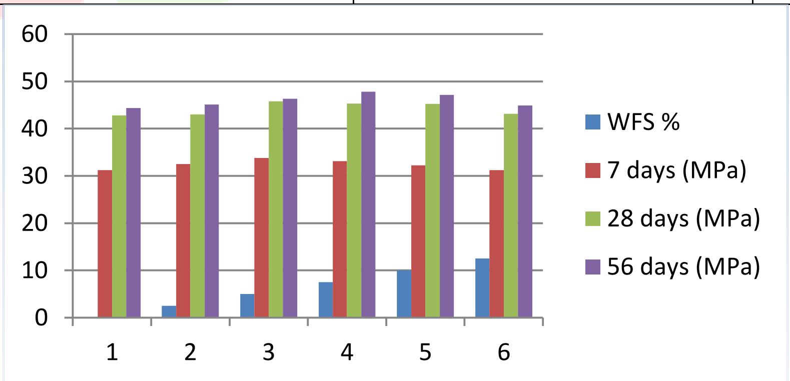
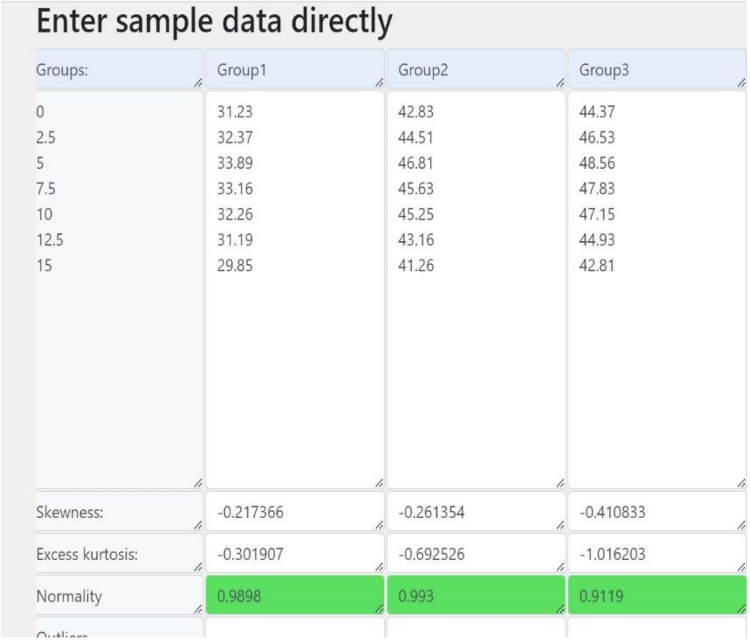


Figure 2: Comparative analysis of WFS replacement

ANOVA analysis of Compressive strength

ANOVA proposes the null hypothesis that all the means of compared groups are equal. The ANOVA is used to determine if there is a difference in population means between three or more groups without using multiple *t*-tests or determining an independent variable's effectsSoftware analysis of the compressive strength reports from tests are carried out. SPSS was used and the Results are presented in the **Figure 3.**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Groups:	Group1	Group2	Group3
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
Skewness:	-0.217366	-0.261354	-0.410833
Excess kurtosis:	-0.301907	-0.692526	-1.016203
Normality	0.9898	0.993	0.9119

Figure 3: Result of the software analysis

The observed effect size f is **large** (3.75). That indicates that the magnitude of the difference between the averages is large. The η^2 equals 0.93. It means that the **group** explains 93.3% of the variance from the average (similar to R^2 in the linear regression).

Conclusions

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. Compressive strength of concrete increased from 3.23%–7.3% and after that there is a systematic decrease in strength. The Anova Analysis of compressive strength determined that the more the levels of WFS the more is the Variance 93% and hence it will not be feasible to use the concrete beyond 10%.

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