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Evaluation of Concrete Compressive Strength by incorporating Used Foundry Sand

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Abstract: - The main objective of this study was to evaluate the compressive strength of concrete by utilizing three types of used foundry sand; with bentonite clay, with sodium silicate & with phenolic resin as partial replacement of fine aggregates. To accomplish the research an experimental program was conducted in which ten concrete mixtures were casted, by keeping all other parameters for concrete proportioning as constant and only change made was in the amount of fine aggregates. Ten, Twenty and Thirty percent replacement level of river sand by used foundry sands was maintained in this study. All fine aggregates were selected after achieving desired physical and chemical tests. Workability, compressive strength and modulus of elasticity were measured and compared with the conventional concrete termed as control mixture. It was observed that workability increased with replacement levels. The cubes were crushed at 7, 28 and 63 days of standard moist curing. The compressive strength of all concrete specimens increased with increase in curing age. With exception to foundry sand with phenolic resin, compressive strength of concrete mixtures was decreased with increase in replacement level at all ages. Similar trends were observed in modulus of elasticity of concrete.

Keywords: - *Fine aggregate, Used Foundry sand, Compressive strength, Modulus of Elasticity*

I. INTRODUCTION

Metal foundries (ferrous & non ferrous) utilize high quality sands in production of metal castings. The sand is mixed with variety of additives and binders according to type of metal casting. It is recycled and reused multiple times in the process until it loses its characteristics and thus discarded. Foundry sand discarded by foundries is called used foundry sand (UFS). According to researcher [1] UFS was a mixture of sand, residues from metal casting process & variety of binders. UFS classified as non-hazardous waste when produced by iron, steel and aluminium foundries. [2-3]

The physical and chemical properties of UFS depend upon: type of metal being poured, casting process, type of binder system, type of furnaces and type of finishing process like grinding, blast cleaning and coating [4]. Depending on type of binder systems used in metal casting process, used foundry sands are classified as; Clay bonded sand (Green sand) and chemically bonded sands. Green sand is black in colour due to high carbon content. Being a combination of sand, clay and water, spent green sands are effective in geotechnical applications like base courses, structural fills, embankments etc. Chemically bonded sand is utilized in mould making as well as in core making where high strengths are essential to bear the high temperature of molten metal. Colour of chemically bonded sand is lighter than clay bonded sands. Their texture is coarser than clay bonded sands. Chemically bonded sands lack the hydraulic characteristics of green sands and are effective in agricultural and construction use [5].

The phenomenon of reusing UFS in applications other than landfills is quite well established in places like Europe, England and North America, where UFS is utilized in manufacturing of cement, concrete, asphalt, bricks & controlled low strength material (CLSM). Some of these reuse options are beginning to be adopted in some developing countries like India [6]. UFS is utilized in Turkey, where it was mostly used as land fill cover only a small amount was reused for engineering applications like in Portland cement, concrete parking/paving, garden seating etc. [7]

In past, limited work has been carried out on the utilization of UFS in mortar and concrete which is being reported here. One researcher investigated the compressive strength of concrete with UFS as a partial replacement accounting to 0%, 25%, 50% and 100% of ordinary sand [8]. It was concluded that, strength of concrete was decreased by increasing the replacement of UFS. Another author assessed the effects of UFS (green sand) as partial replacement of fine aggregates in cement mortars and concrete by replacing regular sand by 10%, 20% and 30% of UFS in mortar mixtures and 7% and 10% in concrete mixtures [9]. Its results revealed that mortar and concrete mixtures with UFS exhibited lower compressive strength by 20%-30% as compared to control mixtures. Modulus of elasticity tested at 28 days, did not show significant variations. One reported the utilization of UFS in high strength concrete by replacing natural sand by 0%, 5%, 10%, and 15% of UFS [10]. They concluded that increase in the replacement level of UFS, decreased the compressive strength, tensile strength and modulus of elasticity of concrete. According to one author reported that UFS could be utilized in the production of good quality Ready Mixed Concrete (RMC), with no major mechanical, micro-structural and environmental impacts [7]. It was reported that fly ash stabilized phenolics better than ordinary cement concrete, Strength analyzed and leachability of stabilized mixes of UFS to assess the feasibility in construction and geotechnical applications as CLSM [11]. In one study, effect of UFS on mechanical properties of concrete analyzed and reported that UFS could be used as partial replacement of fine aggregates for producing good quality concrete [12]. Marginal increase in strength & durability of concrete incorporating UFS investigated and concluded that UFS could be effectively used in producing structural grade concrete [4]. In one case abrasion resistance of concrete was investigated by utilizing UFS and it was found that abrasion resistance of concrete increased due to inclusion of UFS at all ages [13]. Depth of wear decreased with increase in UFS levels. Concrete with utilization of up to 15% UFS can effectively be used in production of structural concrete and in applications where abrasion is of major concern. Industrial by-products like UFS could be utilized to manufacture durable concrete with sufficient strength [6]. The characteristics of concrete assessed by utilization of metallurgical industry by-products as partial replacement of aggregates. Chemically bonded foundry sand (CFS) and green foundry sand (GFS) were utilized as partial replacement of fine aggregates. Higher workability was obtained in case of concrete added with CFS. [14]

II. EXPERIMENTAL PROGRAM

The experimental setup was established to assess the influence of UFS as fine aggregate on the fresh and hardened concrete properties. The workability, compressive strength and modulus of elasticity were obtained and compared with those of control mixture.

2.1. Materials

An Ordinary Portland Cement used as binder in proportioning of concrete mixture. Locally available crush was used as coarse aggregate and four types of sands were used as fine aggregate to complete this experimental work. Locally available river sand (NS) was used in proportion of control mixtures while UFS were used in rest of the mixtures. Three types of sands, classified according to the binder used, Foundry sand with Bentonite Clay as binder termed as "FBC", Foundry Sand in which Phenolic Resin used as binder termed as "FPR". Sodium Silicate used as binder in last Foundry sand (FSS) utilized in this study. Three types of foundry sands namely foundry sand with bentonite clay (FBC), Foundry Sand with Phenolic Resin (FPR) and Foundry sand with sodium silicate (FSS) were used.

Figure 1 gives schematic of materials used for preparation of concrete samples in this research work and Table 1 gives properties of materials used in the experimental work. Grain distribution curve of fine aggregates is shown in Figure 2. It is obvious from Figure 2 that NS is coarser than UFSs.

Oxide composition of fine aggregates are shown in table 2, which indicates that silica **(**SiO_2) is the most abundant oxide present in all the sands. Different types of binders present in used foundry sands result in variation in oxide contents present in these sands.

2.2. Concrete Mixture Proportioning

A constant concrete proportion of 1:2:4 was used with a single water cement ratio of 0.6 for all the mixtures. Total ten concrete mixtures were prepared according to standards, one of those was a controlled mixture; CC (without addition of used foundry sand) and in the remaining nine mixtures NS was replaced by 10%, 20% and 30% of three types of UFS. These nine mixtures were named after the binder used in foundry sand (FBC, FSS & FPR) and replacement level, e.g. FBC_{10} denoted 10 % replacement level of NS with FBC.

Total 90 cubes of 100 mm size were casted and cured in curing tank for 7, 28 and 63 days for determination of their compressive strength. Thirty cylindrical moulds (height 300mm and diameter 150mm) were also casted; three for each concrete mixture to get modulus of elasticity at 28 days of age.

III. EXPERIMENTAL RESULTS DISCUSSION

Slump was measured to check the influence of UFS on workability of concrete. The Compressive Strength and Modulus of elasticity were measured at different ages and the obtained results revealed the influence of the UFS on the behavior of hardened concrete. Finally, results were compared with those of control mixture and with data obtained from investigations by various researchers. The discussion is given in following section;

3.1. Workability Test

The slump values of all concrete mixtures used in this research has been shown in Figure 3. Concrete specimen with UFS exhibited higher workability than conventional concrete. The increase in workability may be attributed to the presence of finer UFS. In all cases rapid increase in workability has been observed when replacement level varied from 20% to 30%. The workability results corroborate to the previous research conducted by [14].

3.2. Compressive Strength

Compressive strength results of all concrete mixtures; determined at 7, 28 and 63 days of curing are listed in Table 3 along with standard deviation values given in circular parenthesis ( ). In all cases, Compressive strength increased with the age of concrete and compressive strength of UFS concrete decreased as compared with the control mixture. Figure 4 shows the comparison of UFS with control mixture at all ages and replacement level of 10, 20 and 30%. At age of 7 days, about 15 to 20 % reduction in strength was noticed when NS replaced by 10% UFS and further decrease in strength occurred when replacement level was increased. Similar results have been observed at 28 days but reduction in strength reduced to 8% when NS was replaced by 10% FBC and 25 to 33 % reduction in strength were observed at 30% replacement level. FPR showed better strength at age of 63 days, the compressive strength of control mixture and FBC up to 20% replacement level were almost same.

The compressive strength decreases by increase of UFS in concrete mixture,. All three UFS utilized in this research were finer than the ordinary sand. Thus, higher surface area of fine particles led to decrease in volume of cement paste with the aggregates in concrete mixture and caused decreases in strength. The results for compressive strength of the present work have been compared with previous investigations by evaluating the relative strength at different replacement ratios of UFS. It can be depicted from Figure 5 that the results of this study are consistent with the previous investigations. However, the relative strength varied in different patterns for different researchers. The increase or decrease in compressive strength of concrete with UFS might be due to different kinds of UFS used by different researchers. Properties and quality of UFS vary from foundry to foundry and it depends on type of casting process and binders used. Almost all the researchers have concluded that percentage replacement of fine aggregates by UFS should be in the range of 10% to 20%. At higher levels of UFS, strength decreased drastically due to higher proportion of fine particles in UFS.

5.3. Modulus of Elasticity

The modulus of elasticity of ordinary concrete mixture (CC) was 22.9 GPa. Consistent with the values of compressive strength, the Modulus of Elasticity (E) of UFS-concrete mixtures was smaller than that of control mixture. However, the variation among E values of the concrete specimen was very small. The decline of E showed in Figure 6, was similar in nature to previous investigations.

IV. CONCLUSIONS

Following conclusions are deduced from the experimental results:

1. Compressive strength increases with increase in curing age in all cases and at 28 days of curing, 80% of compressive strength was reached in all concrete specimens.
2. Strength decreased with increase in percentage replacement of UFS; compressive strength of control mixture (CC) was more than concrete mixtures with UFS at all curing ages

3. After 28 days the difference of strength between concrete mixtures with 10% UFS and control mixture was least distinct.
4. Strength loss in UFS concrete mixtures was due to presence of anti-binder in the form of very fine powder of carbon and clay in the UFS, which resulted in lack of contacts between the aggregates and cement paste**.**
5. FPR concrete mixtures showed somewhat favorable strength results as compared to FBC and FSS concrete mixtures. It achieved almost same strength as CC mixture at 63 days of curing. FSS concrete mixture showed lower strength values than FPR and FBC concrete mixture.
6. No significant variation was observed in modulus of elasticity values of different concrete specimen. Average value of modulus of elasticity of UFS-concrete mixtures was 20.5 Gpa, as compared to 22.9 GPa of control mixture.

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Table 1: Physical Properties of Materials

Cement Characteristics		**Values Obtained**			
1	Type	ASTM 1			
2	Specific gravity	3.15			
3	Blaine Fineness	3656 cm^2/g			
Coarse aggregates Characteristics					
1	Maximum size	20 mm			
2	Density	1550 kg/m^3			
3	Fineness modulus	7.8			
Fine aggregates Characteristics		**Type of Fine Sand**			
		NS	**FBC**	**FSS**	**FPR**
1	Specific gravity	2.76	2.48	2.65	2.60
2	Bulk relative density, kg/m^3	1590	1440	1325	1500
3	Moisture content, %	1.84	3.11	1.44	0.1
4	Fineness modulus	3.8	3.1	2.7	2.3

Table 2: Oxide Composition of Fine Aggregates

Constituents	Description	Oxide Content			
		NS	FBC	FSS	FPR
SiO_2	Silica	16.4	12.3	18	9.8
Al_2O_3	Aluminium oxide	4.03	4.38	3.82	5.27
Fe_2O_3	Ferrous oxide	2.32	3.79	4.17	2.11
SO_3	Sulphur trioxide	0.27	1.41	2.35	1.2
CaO	Calcium oxide	7.42	1.23	0.45	1.09
MgO	Magnesium oxide	6.01	0.23	0.52	0.3
L.O.I	Loss on ignition	6.51	7.25	5.45	6.23

Table 3: Compressive Strength with different replacement levels of UFS at all ages.

Mix #	Designation	UFS content	Compressive strength f_c, Mpa		
			7 days	28 days	63 days
M1	**CC**	0 %	**26** (0.97)	**31**(0.83)	**33**(0.49)
M2	**FBC-10**	10 %	**22**(1.92)	**28**(1.88)	**30**(0.67)
M3	**FBC-20**	20 %	**20**(1.17)	**24**(1.55)	**28**(1.50)
M4	**FBC-30**	30 %	**19**(0.97)	**23**(0.71)	**27**(0.85)
M5	**FPR-10**	10 %	**21**(0.82)	**27**(0.88)	**33**(1.31)
M6	**FPR-20**	20 %	**25**(1.68)	**29**(1.38)	**32**(1.33)
M7	**FPR-30**	30 %	**19**(0.81)	**23**(1.67)	**27**(0.96)
M8	**FSS-10**	10 %	**21**(0.07)	**25**(0.41)	**25**(0.97)
M9	**FSS-20**	20 %	**19**(1.23)	**25**(0.26)	**26**(0.78)
M10	**FSS-30**	30 %	**18**(0.21)	**21**(0.89)	**23**(1.03)

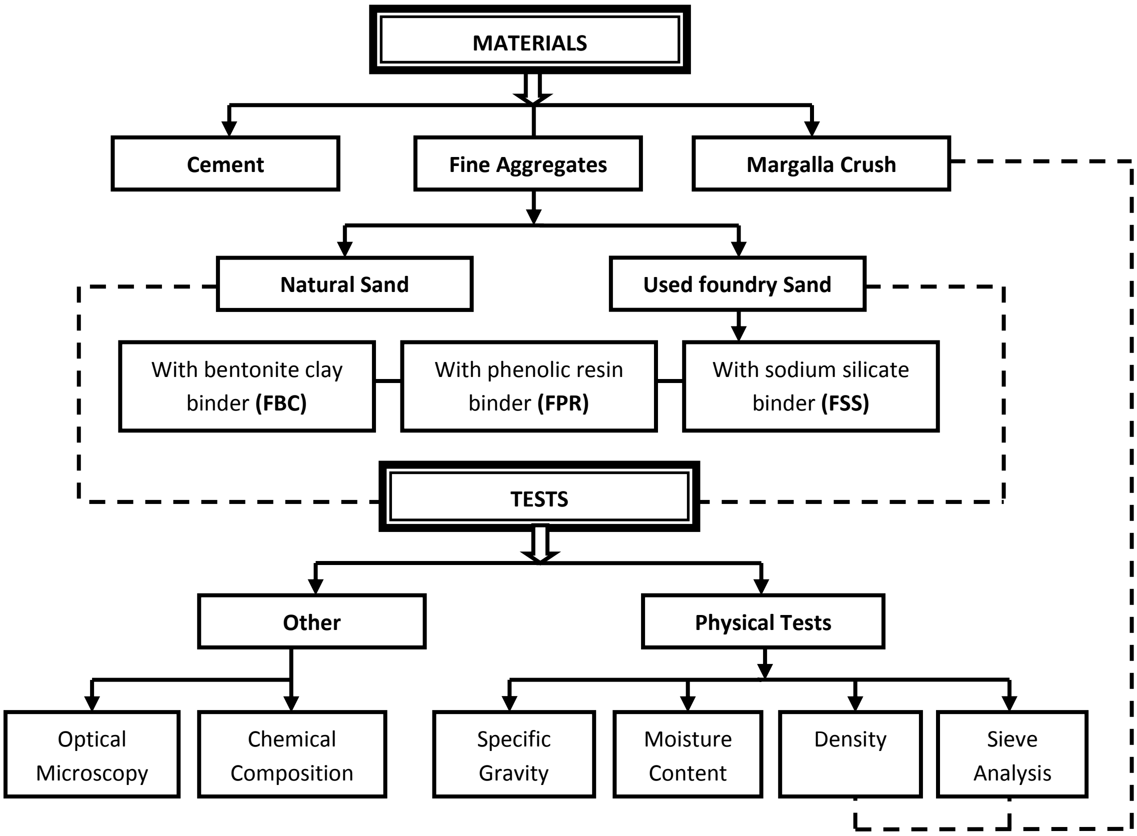


Figure 1 Schematic of Materials used in Concrete Proportioning

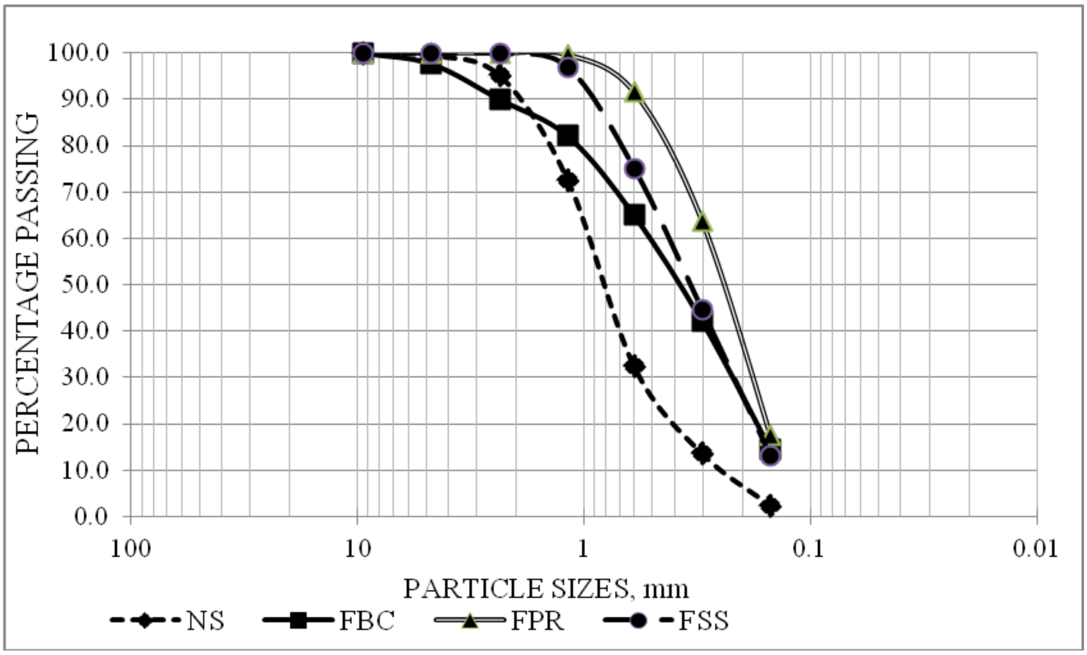


Figure 2 Grain size distribution curve of the fine aggregates

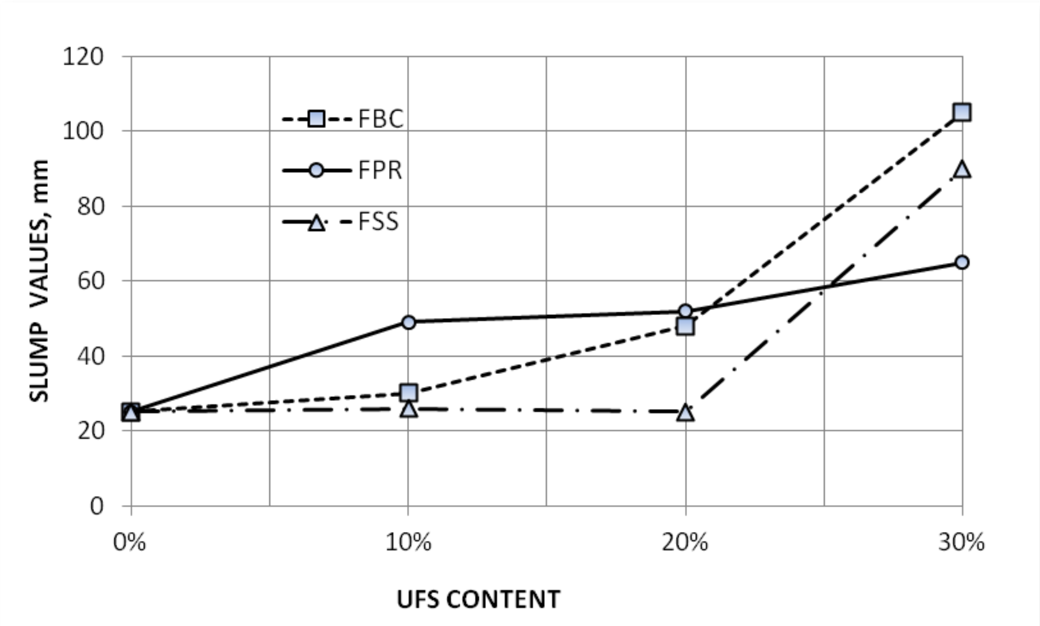


Figure 3 workability of all Concrete Mixtures in term of Slump

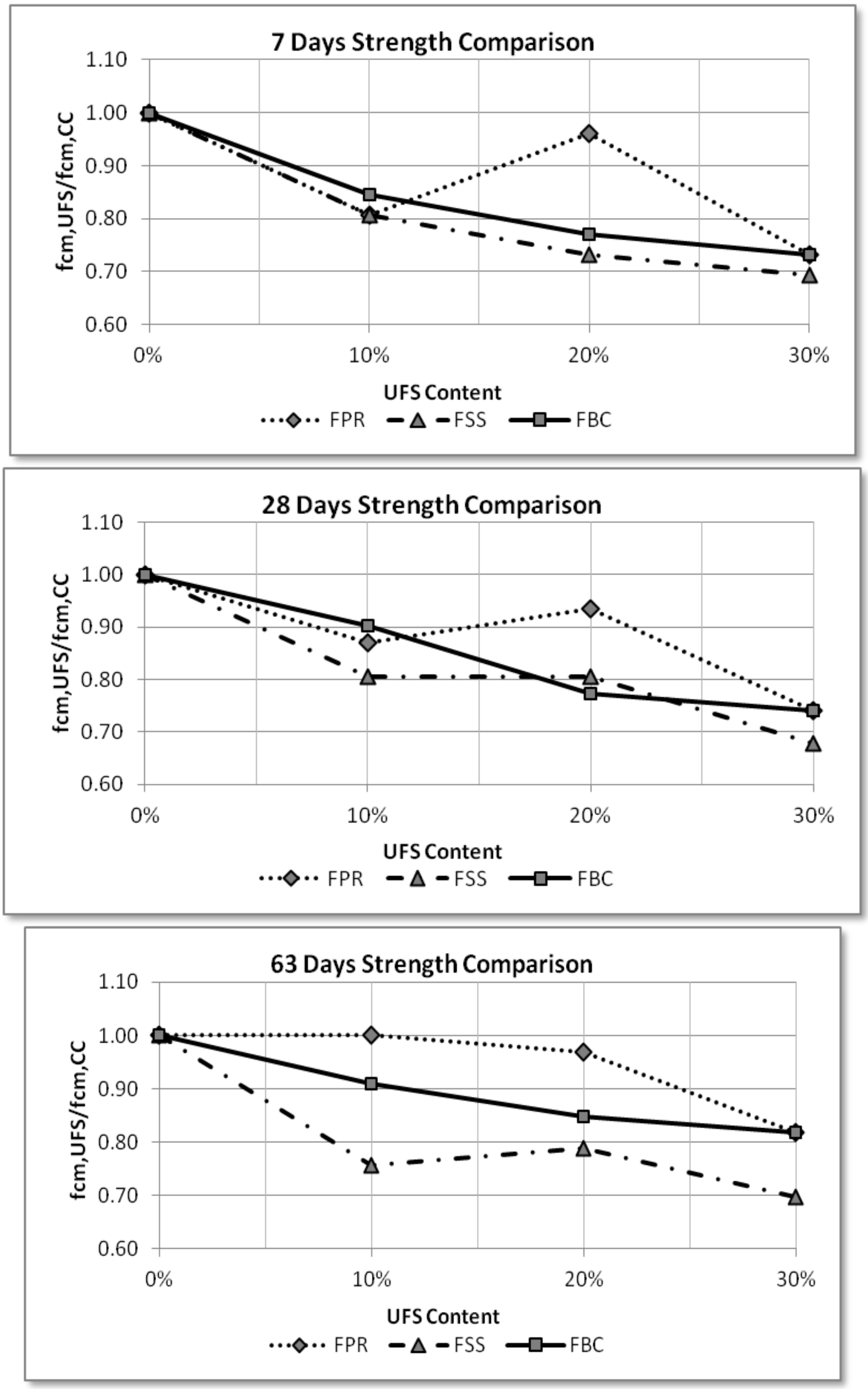


Figure 4 : Compressive strength of all concrete mixtures at different ages of curing

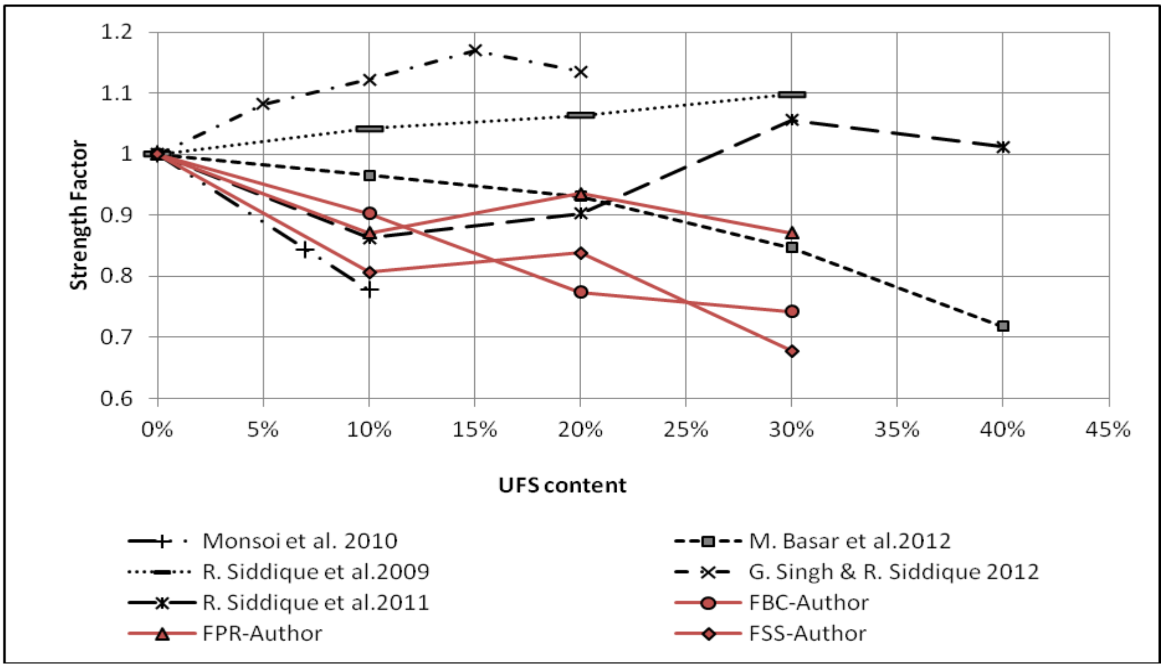
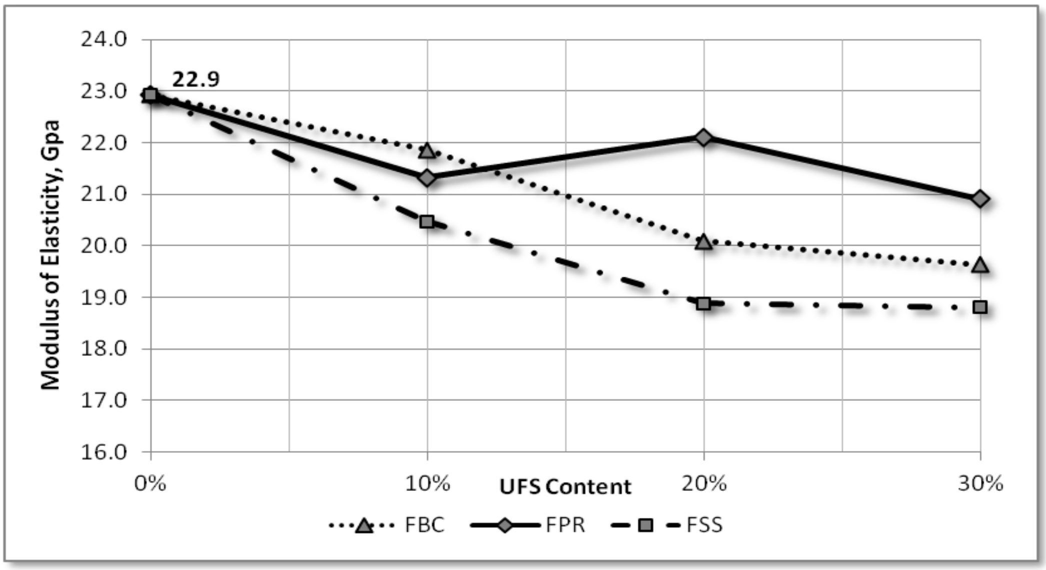


Figure 5: Compressive Strength variation at 28 days



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