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Enhancement in the Physical Properties of Concrete by Partial Replacement of Cement and Sand by Hypo Sludge and Steel Fiber by adding Superplasticizer

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***Abstract*— In the worldwide reinforced concrete structure, the major construction typology is the major use of concrete and steel. Apart from this, concrete is the most extensively used material. Greenhouse gas (GHG) emissions are produced during the manufacturing processes of these materials. Reduction of its environmental impact and enhancing the sustainability of partial replacement of cement without altering concrete's physical and mechanical properties can lead to a reduction in GHG emissions. The disposal of these materials causes serious environmental pollution. Hypo Sludge (HS) is a waste material from the paper industry and is disposed of in large amounts in the form of slurry. Therefore, usage of HS as a partial replacement of cement in concrete manufacturing can help in minimizing the environmental pollution issue. In the present study, based on past research, usage of HS as partial replacement of cement varying up to 40% for concrete manufacturing in combination with the addition of Steel Fiber (SF) up to 4% with superplasticizer of concrete is done, with the objective of finding an acceptable optimum replacement of HS without significant reduction in physical and mechanical properties compared to normal concrete of the same grade. Results were concluded based on lab tests for identification of mechanical properties like compressive strength, split tensile strength, and flexural strength done after 7 days and 28 days of curing. Concrete mix design and experiments were done using relevant Indian Standards. The result indicates the addition of both HS and SF increases the compressive, tensile, and flexural strength of concrete at all curing ages up to a certain point. The best combination of compressive, tensile, and flexural strength of concrete is 20% of HS, 2% steel fiber, and 800 ml of superplasticizer to give the maximum strength and workability and also give an initial and final setting. Compressive strength is measured at 7 and 28 days and found 24.78 kg/cm2 and 43.72 kg/cm2. Split Tensile Strength is 7.66 kg/cm2 and 5.87 kg/cm2 after 7 days and 28 days and Flexural Strength is at 2.94 kg/cm2 and 3.85 kg/cm2. HS and SF mixed concrete reduces 6.51% of the cost with respect to normal concrete strength and up to 7.5% for split tensile and flexural strength.**

***Keywords*— Hypo Sludge (HS), Steel Fiber (SF), Compressive Strength, Split Tensile Strength, Flexural Strength, Workability.**

I Introduction

Through the integration of industrial waste into concrete, the environment and energy can be saved. The use of these by-products offers environmental advantages like diversion of the material from the waste bodies, reduction of the energy used in processing virgin materials, usage of virgin materials and a decrease in pollution. For the production of ordinary Portland Cement (OPC), we use earth resources like limestone. During the manufacturing of one tonne of OPC, an equal amount of carbon dioxide is released into the atmosphere, which is harmful to the environment. So, there is a need to choose an alternative. In urban cities, solid waste management is a very challenging task, which is a critical pollution problem. The reason is the generation of large quantities of solid waste. Also, at present, the cost of cement is increasing day by day. It is necessary to use industrial waste products in an appropriate manner to reduce environmental problems and costs. Many research organizations are doing massive work on waste materials concerning Paper mill sludge is a major environmental and economic issue for the board and paper industry. The material is a by-product of the de-inking and re-pulping of paper mills. The paper industry is the primary source of hypo sludge, as it generates a large amount of waste hypo sludge. It is estimated that around 18% of waste (sludge) is generated during the production of pulp.

Hypo sludge contributes advantageous properties to the concrete while helping to maintain the economy. Therefore, numerous contemporary research works have focused on the application of hypo sludge in cement and concrete production to attain sustainable development. Many researchers have investigated the possibility of using the paper industry waste in concrete production. Disposal cost of paper industries can be reduced by using hypo sludge in concrete and produced the green concrete for construction.

II Literature Reviews

Manmeet Kaur et al. (2015), this research work is concerned with the experimental investigation of the strength of concrete blended with hypo sludge. The cement has been replaced by hypo sludge in the range of 0%, 5%, 10%, 15% and 20% for M-20 mix. Concrete mixtures were produced, tested and compared with the conventional concrete mix in the terms of workability, compressive strength and splitting tensile strength. The tests were carried out after 7, 14 and 28 days. The workability of concrete decreases with the increase in content of hypo sludge the gradual increase was seen in compressive strength and splitting tensile strength of concrete blended with 0% to 10% of hypo sludge content for all curing ages. Beyond that there is a significant reduction in strength. The maximum compressive strength and splitting tensile strength were 27.62 N/mm2 and 3.79 N/mm2. Also, the cost analysis indicates that with incorporation of hypo sludge decreases the cost of concrete, but at the same time strength also decreases. 20% replacement of cement with hypo sludge leads to 18.35% reduction in cost.

Abdul Ghaffar et al. (2022), main purpose of this research is based on the investigation of the use of steel fibres in structural concrete to enhance the mechanical properties of concrete. The objective of the study was to determine and compare the differences in properties of concrete containing without fibres and concrete with fibres. This investigation was carried out using several tests, compressive test and flexural test. A total of eleven mix batches of concrete containing 0% to 5% with an interval of 0.5% by wt. of cement. 'Hooked' steel fibres were tested to determine the enhancement of mechanical properties of concrete. The workability of concrete significantly reduced as the fibre dosage rate increases

Rajib Kumar Biswas et al. (2021), steel fibers and their aspect ratios are important parameters that have significant influence on the mechanical properties of ultrahigh-performance fiber-reinforced concrete (UHPFRC). Steel fiber dosage also significantly contributes to the initial manufacturing cost of UHPFRC. This study presents a comprehensive literature review of the effects of steel fiber percentages and aspect ratios on the setting time, workability, and mechanical properties of UHPFRC. It was evident that an increase in steel fiber dosage and aspect ratio negatively impacted workability, owing to the interlocking between fibers; compressive strength was positively influenced by the steel fiber dosage and aspect ratio; and a faster loading rate significantly improved the mechanical properties. There were also some shortcomings in the measurement method for setting time. Lastly, this research highlights current issues for future research.

Amit Gupta et al. (2020), he use of Steel Fibre Reinforced composites in infrastructure applications is becoming more popular with the introduction of new high-performance materials. Steel Fibre Reinforced composites are introduced to enhance the overall performance of structures, such as composite bridge decks, beams, bearing walls, etc. This review from the past experiences presents the results of experimental and analytical studies done on composite material made of Fibre reinforced concrete overlaid on Conventional Reinforcement with Concrete. Results show that the composite structures possess good compressive strength, tensile strength, flexural strength, cracking strength and ultimate capacity.

Amol Naitam and Dr. Arif Khan (2019), The innovative use of hypo sludge in concrete formulations as a supplementary cementation's material was tested as an alternative to traditional concrete. These tests were carried out to evaluate the mechanical properties like compressive strength up to 28 days. This research work is concerned with experimental investigation on strength of mortar and optimum percentage of the partial replacement by replacing cement via 4% to 16% of Hypo Sludge. Keeping all this view, the aim of investigation is the behavior of mortar while adding of waste with different proportions of Hypo sludge in mortar by using tests like compression strength.

III Methodology

3.1 Properties of OPC

In all my work, 43 grade OPC cement is used and purchased in local market. It was the current packing, a sealed pack, fresh and free from moisture. For best results, cement should be stored in moisture-less storage. To find out the physical properties of cement, the following test is performed, which is shown in Table 3.1, and the corresponding standard for that parameter as per BIS: 8112-2013 is also listed in Table 1.

Table 1: Properties of OPC 43 grade cement

S. No.	Particulars	Result Values After Test	Requirements of IS:8112-2013 [24]	
1.	Normal Consistency (%)	32%	---	---
2.	Setting Time (Minutes)			
	I. Initial Setting Time	150-170 Minutes	30 Minutes	Minimum
	II. Final Setting Time	210-300 Minutes	600 Minutes	Maximum

3.2 Hypo Sludge: -

Hypo sludge was dried in the sun light till the moisture exhaust and after that it was grinded. The hypo sludge used in concrete contains 90% particles passing 45-micron sieve. The chemical and physical properties of hypo sludge and its comparison with cement

Table 2: Comparison of the Properties of Hypo Sludge with Cement

S No	Constituents	Properties of Cement (%)	Properties of Hypo Sludge (%)
1	Lime (CaO)	60-67	37-48
2	Silica (SiO_2)	17-25	3-12
3	Magnesium (MgO)	0.1-4	0.1-4
4	Aluminum (Al_2O_3)	3-8	2-7
5	Calcium Sulphate (Ca_2SO_4)	1.5-4	0.5-4.5

3.3 Steel Fiber: -

Steel fiber was free from moisture as well as corrosion. The steel fiber used in concrete contains 95% particles passing 4.75-microns sieve and its shape and size also same as fine aggregate.

Table 3: Properties of Steel Fiber

S No	Constituents	Properties of Steel Fiber	Remarks
1	Tensile Strength	1600 MPa	More than Sufficient for Concrete
2	Compressive Strength	6000 MPa	More than Sufficient for Concrete
3	Split Tensile Strength	1000-1300 MPa	More than Sufficient for Concrete
4	Flexural Strength	8.81 MPa	More than Sufficient for Concrete
5	Melting Point	1000-1300^{0}C	More than Sufficient for Concrete

3.4 Workability of concrete as per IS: 1199-1959

Workability is the property of fresh cement concrete mix which shows the ability of ease in working like mixing, handling, placing, compacting and final finishing. The appropriate workability and strength reduced labour cost. Workability test methods have been classified in terms of the type of flow produced during the test.

Table 4: Workability of all mixes of Hypo Sludge (HS) and Steel Fiber (SF) with Superplasticizer mix Concrete

S. No.	Hypo Sludge in %	Steel Fiber in %	SP in ml/100 kg of cement	Slump Value in mm
1	0%	0%	0 ml/100 kg	123.33
2	10%	1%	400 ml/100 kg	141.66
3	20%	2%	600 ml/100 kg	158.33
4	30%	3%	800 ml/100 kg	173.33
5	40%	4%	1000 ml/100 kg	185.00

3.5 BIS Mix Design Method: -

The following steps used to design mixed of concrete summarized below: -

i) In first step we have to find out target mean strength from the specified characteristics strength on the level of quality controlled.

ii) In second step select W/C ratio (Water Cement Ratio) for target strength.

iii) In third step with the help of slump cone test determine water content.

iv)The cement content can be determined from the water/cement ratio determined by slump cone test and water content obtained in step (ii) and (iii) respectively and is checked for the water requirements.

v) With the help of characteristics of course and fine aggregate find out proportion of fine and coarse aggregate.

vi) The trial mix proportions are determined.

vii) After verifying compressive strength with the trial mixes tested are made to get there the final mix composition.

Table 5: Prepared Mixes for Tests of all Strengths performed on concrete

Mix No.	W/C Ratio	Slump (mm)	Hypo Sludge in % of Cement Wt	Steel Fiber in % of Sand Wt	SP in ml/100 kg of cement	Water (l/m3)	Cement Kg/m3	Sand Kg/m3	Coarse Aggregate Kg/m3
Mix 1	0.45	100	0	0	0	197	438	686.31	1082.71
Mix 2	0.45	100	10	1	400	197	438	686.31	1082.71
Mix 3	0.45	100	20	2	600	197	438	686.31	1082.71
Mix 4	0.45	100	30	3	800	197	438	686.31	1082.71
Mix 5	0.45	100	40	4	1000	197	438	686.31	1082.71

Table 6: Mix proportions of different concrete mixes for Hypo Sludge (HS)

Mix	W/C Ratio	HS %	HS kg/m³	Cement kg/m³	Fine aggregates kg/m³	Coarse Aggregate kg/m³	Water l/m³
Mix 1	0.45	0	0	438.00	686.31	1082.71	197
Mix 2	0.45	10	43.80	394.20	686.31	1082.71	197
Mix 3	0.45	20	87.60	350.40	686.31	1082.71	197
Mix 4	0.45	30	131.40	306.60	686.31	1082.71	197
Mix 5	0.45	40	175.20	262.80	686.31	1082.71	197

Table 7: Mix proportions of different concrete mixes for Steel Fiber (SF)

Mix	W/C Ratio	SF %	SF kg/m³	Cement kg/m³	Fine aggregates kg/m³	Coarse Aggregate kg/m³	Water l/m³
Mix 1	0.45	0	0	438	686.31	1082.71	197
Mix 2	0.45	1	6.86	438	679.45	1082.71	197
Mix 3	0.45	2	13.73	438	672.58	1082.71	197
Mix 4	0.45	3	20.59	438	665.72	1082.71	197
Mix 5	0.45	4	27.45	438	658.86	1082.71	197

Table 8: Mix proportions of different concrete mixes for Superplasticizer (SP)

Mix	W/C Ratio	SP in ml/100 kg of cement	Cement kg/m3	Fine aggregates kg/m3	Coarse Aggregate kg/m3	Water l/m3
Mix 1	0.45	0 ml/100 kg	438	686.31	1082.71	197
Mix 2	0.45	400 ml/100 kg	438	686.31	1082.71	197
Mix 3	0.45	600 ml/100 kg	438	686.31	1082.71	197
Mix 4	0.45	800 ml/100 kg	438	686.31	1082.71	197
Mix 5	0.45	1000 ml/ 100 kg	438	686.31	1082.71	197

3.5 Compressive Strength of HS and SF mixed Concrete:

The compressive strength of all the prepared mixes was determined at the ages of 7 and 28 days for the various addition levels of HS and SF with cement concrete. The values of average compressive strength for different mixes prepared by addition of HS (0%, 10%, 20%, 30% and 40%) and SF (0%, 1%, 2%, 3% and 4%) at the completion of different curing periods (7 days and 28 days) are given in the various Tables below.

Table 9 Compressive Strength of Hypo Sludge (HS) and Steel Fiber (SF) with Superplasticizer mix Concrete for all Mixes

S. No.	Hypo Sludge in %	Steel Fiber in %	Compressive Strength After 7 Days (kg/cm²)	Compressive Strength After 28 Days (kg/cm²)
1	0%	0%	20.60	38.24
2	10%	1%	23.30	40.16
3	20%	2%	24.78	43.72
4	30%	3%	23.73	39.36
5	40%	4%	21.68	36.34

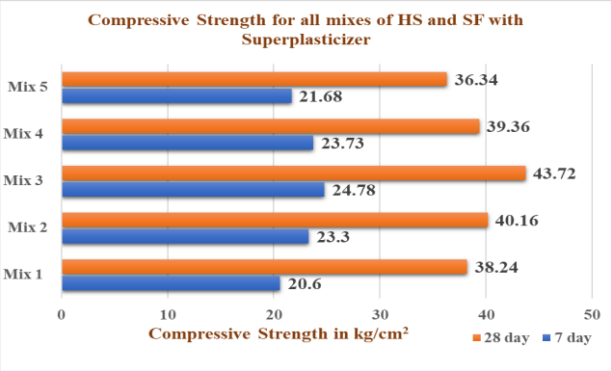

Figure 1: Combine Compressive strength in kg/cm2 for all % of HS and SF with Superplasticizer at 7 days and 28 days

By these test results we can say that compressive strength of Hypo Sludge and Steel Fiber with Superplasticizer concrete can be increased 43.72 kg/cm2 by adding Hypo Sludge 20% of the weight of the cement content and Steel Fiber 2% of the weight of the sand. It is also clear by these results that more than 20% Hypo Sludge and 2% Steel Fiber start reducing the compressive strength of concrete therefore we can also say that the Mix 3 is the best suitable mix for compressive strength.

Figure-2 Cube Casting

Table-10 Split Tensile Strength of Hypo Sludge (HS) and Steel Fiber (SF) with Superplasticizer mix Concrete for all Mixes

S. No.	Hypo Sludge in %	Steel Fiber in %	Split Tensile Strength After 7 Days (kg/cm²)	Split Tensile Strength After 28 Days (kg/cm²)
1	0%	0%	2.44	4.36
2	10%	1%	2.76	4.54
3	20%	2%	3.66	5.87
4	30%	3%	2.37	4.46
5	40%	4%	2.14	3.91

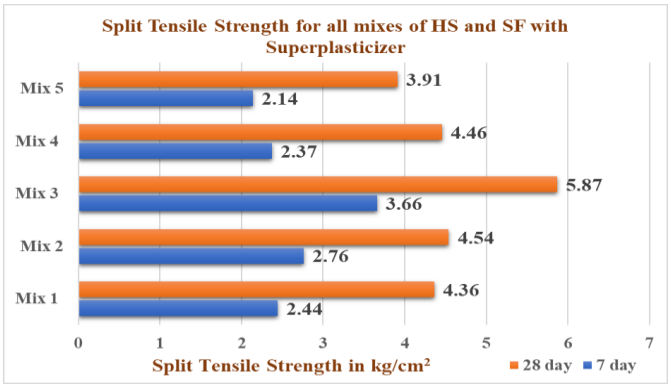

Figure 3: Combine split tensile strength in kg/cm2 for all % of HD and SF with Superplasticizer at 7 days and 28 days

By these test results we can say that split tensile strength of Hypo Sludge and Steel Fiber with Superplasticizer concrete can be increased 5.87 kg/cm2 by adding Hypo Sludge 20% of the weight of the cement content and Steel Fiber 2% of the weight of the sand. It is also clear by these results that more than 20% Hypo Sludge and 2% Steel Fiber start reducing the split tensile strength of concrete therefore we can also say that the Mix 3 is the best suitable mix for split tensile strength.

Table-10 Flexural Strength of Hypo Sludge (HS) and Steel Fiber (SF) with Superplasticizer mix Concrete for all Mixes

S. No.	Hypo Sludge in %	Steel Fiber in %	Flexural Strength After 7 Days (kg/cm²)	Flexural Strength After 28 Days (kg/cm²)
1	0%	0%	1.34	2.27
2	10%	1%	1.67	2.72
3	20%	2%	2.94	3.85
4	30%	3%	1.84	3.04
5	40%	4%	1.30	2.56

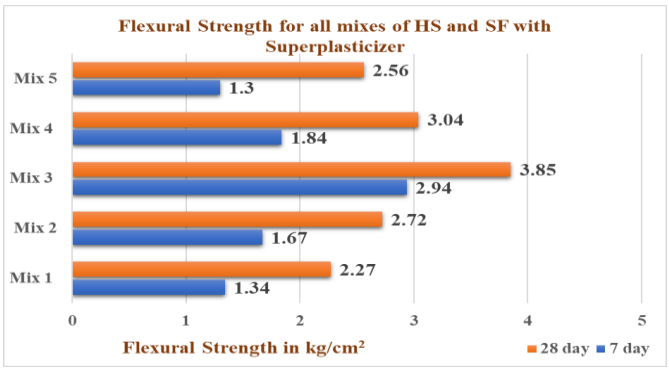

Figure 4: Combine flexural strength in kg/cm2 for all % of HD and SF with Superplasticizer at 7 days and 28 days

By these test results we can say that flexural strength of Hypo Sludge and Steel Fiber with Superplasticizer concrete can be increased 3.85 kg/cm2 by adding Hypo Sludge 20% of the weight of the cement content and Steel Fiber 2% of the weight of the sand. It is also clear by these results that more than 20% Hypo Sludge and 2% Steel Fiber start reducing the flexural strength of concrete therefore we can also say that the Mix 3 is the best suitable mix for flexural strength.

Table-11 Initial and Final Setting for all Mixes of Hypo Sludge (HS) and Steel Fiber (SF) with Different Quantities of Superplasticizer (SP) in Concrete

S. No.	HS in %	SF in %	SP in ml/100 kg of cement	Initial Setting Time in Minutes	Final Setting Time in Minutes
1	0%	0%	0 ml/100 kg	244	383
2	10%	1%	400 ml/100 kg	317	403
3	20%	2%	600 ml/100 kg	374	471
4	30%	3%	800 ml/100 kg	433	517
5	40%	4%	1000 ml/100 kg	485	596

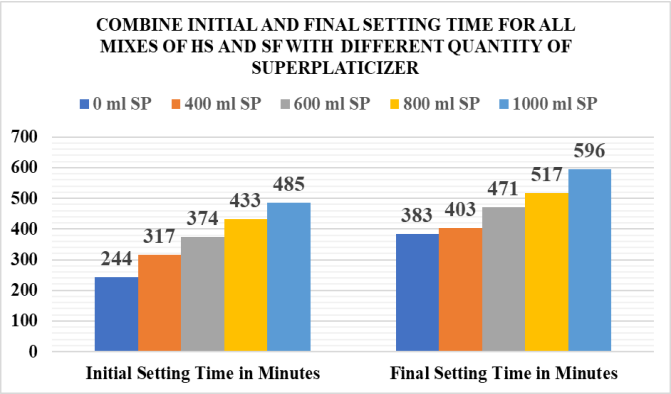

Figure 5: Combine Initial and final setting time in minutes at all % of HS and SF with different quantities of superplasticizer in ml

3.4 Cost Estimation

The cost estimation has been done separately for every mix proportion that being used in this work. The rate applied to the all the used materials to estimate cost is from current 2022 market price. Quantity estimation of all materials which are batched is done as per 1 cubic meter such that total quantity of each material can be calculated separately, and so on rates of each material as per market price are applied as per kilogram. Rate analysis shows that as the percentage of HS and SF material increases, the cost goes on decreases. Reduction in cost can be achieved easily without affecting strength of concrete

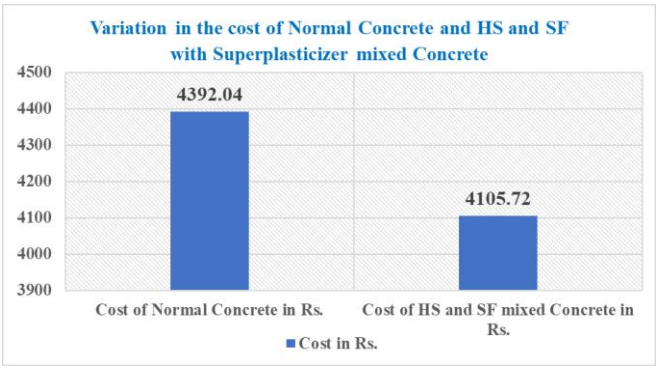

Figure 6: Variation in the cost of normal and HS and SF with superplasticizer mixed concrete in Rs

The cost is low to the normal mix for M-30 grade of concrete and it is increase when increases of proportion of Hypo Sludge and Steel Fiber material in the design mix. The difference between normal mix and design mix is **286.32** Rs. It is saved in per meter cubic of concrete.

IV Conclusion

[1] After the detail analysis of the test results, we can say that the addition of waste hypo sludge and steel fiber with Superplasticizer significantly affect the 7 day and 28 days compressive strength, split tensile strength and flexural strength of the concrete. From the critical difference, it can be clearly seen that the addition of waste hypo sludge and steel fiber with superplasticizer in certain amount of the weight of cement and sand increases the compressive strength as well as split tensile strength and flexural strength. Experimental results also show similar trend. Hence, the results of statistical analysis are equivalent to the experimental results. From the experimental investigation this research work can be concluded as follows: -

[1] HS and SF waste material improves the compressive strength, split tensile strength and flexural strength of concrete.

[2] The addition of waste HS and SF increases the strength of concrete for all curing ages up to a certain point. After that there is an abrupt reduction in the strength of the HS and SF mixed concrete. Because at higher dosage, concrete loses its ability to make a proper bond.

[3] The gradual increase is seen in the compressive strength of Hypo Sludge and Steel Fiber mixed concrete at 7 days and 28 days of curing with 20%

addition of HS and 1% addition of SF in the amount of 43.72 kg/cm2, but after that it starts reducing the compressive strength with an increase of HS and SF addition and the mix which gives the maximum compressive strength is Mix 3.

[4] The split tensile strength of Hypo Sludge and Steel Fiber mixed concrete is 5.87 kg/cm2 after 7 days and 28 days of curing with 20% HS and 1% SF addition, but it begins to decrease with an increase in HS and SF addition, and the mix with the highest compressive strength is Mix 3.

[5] The Flexural strength of Hypo Sludge and Steel Fiber mixed concrete is 3.85 kg/cm2 after 7 days and 28 days of curing with 20% HS and 1% SF addition, but it begins to decrease with an increase in HS and SF addition, and the mix with the highest flexural strength is Mix 3.

[6] The workability of Hypo Sludge and Steel Fiber with superplasticizer mixed concrete is 185 cm for fresh concrete with 40% HS and 4% SF addition and the mix with the highest workability is Mix 5.

[7] The initial and final setting time of Hypo Sludge and Steel Fiber with superplasticizer mixed concrete is 485 minutes and 596 minutes for fresh concrete with 40% HS and 4% SF addition and the mix with the highest initial and final setting time is Mix 5.

[8] The mix which was prepared with the addition of 20% HS and 2% SF with superplasticizer possess the maximum compressive strength, split tensile strength and flexural strength and final mix is Mix 3. Therefore, this mix is recommended for maximum strength.

[9] After estimation of normal concrete (M-30) and the HS and SF with superplasticizer mixed concrete is found that per m3 concrete save 286.32 Rs.

V Recommendations

In the construction industries that is purely managed work has good communication and clear guideline on the scope of the work are essential in the construction to avoid undesirable and confusion for the right and the accurate result, we have to prepare assessment report for every activity and every step of work to ensure the proper degree of control.

[1] For the right and the accurate result, we have to prepare assessment report for every activity and every step of work to ensure the proper degree of control.

[2] We prepare for result new and accurate machine and updated IS codes for formulation.

[3] Allocation of financial and skilled human resources for the purpose of effective and efficient quality management should be provided.

[4] There should be training program and quality guidelines to assure desired quality.

VI Scope for the future

[1] Further studies need to be conducted for the test of durability, soundness, thermal insulation, crack pattern and water absorption of the concrete.

[2] Further studies need to be conducted by using other waste materials (combination of artificial and natural material) with cement could increases strength of concrete.

[3] If we increase the Ca in the HS in concrete then we increase huge the strength in compressive strength.

[4] Experiments can be performed to study the behavior of soil reinforced with HS and SF.

[5] Experiments can be performed to study the behavior of higher mix of concrete like M-40, M-50 and many more.

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