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Study on Mechanical and Durability Properties of Ternary Blended Hybrid Fibre Polymer Concrete with M30 Grade

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Abstract: ***Over the past several decades, extensive research work is in progress throughout the globe in concrete technology in finding alternative materials which can partially or fully replace ordinary Portland cement (OPC) and which can also meet the requirements of strength and durability aspects. Among that many alternative materials tried as partial cement replacement materials, the strength, workability and durability performance of industrial by products like flyash, blast furnace slag, silica fume, metakaolin, rice husk ash, etc., now termed as complimentary cementitious materials (CCM) are quite promising. Subsequently, these have led to the development of binary, ternary and tertiary blended concretes depending on the number of CCM and their combinations used as partial cement replacement materials. In this report Slump, water absorption, compressive strength, split tensile strength, flexural strength and durability tests were conducted on concrete to investigate the possible use of ternary blended (cement+ silica fume+ GGBS) and hybrid polymers (polypropylene+ polyester fibre) as partial replacement for cement. Ordinary Portland cement (OPC) was replaced with 5%, 10%, 15%of silica fume and 10%, 20%, 30%, of GGBS and 0.4%, 0.6%, 0.8% of polypropylene and 1%, 1.2%, 1.4% of polyester. The cubes, cylinders and beam samples were water-cured and tested to determine their compressive strength at 7, 28 and 56 days. The results obtained showed that workability increased as percentage replacement of cement with silica fume and GGBS increased and also replacement of hybrid polymer is also increased the strength. The results of the compressive ,split tensile strength and flexural strength revealed that concrete containing 10% silica fume, 20% GGBS and 0.4% polypropylene and 1.2% polyester increases and later on decreases for 7,28 and 56 days. The durability studies can show that how the structure will react for the acid rains. Here the project will be done for two type of acids alkaline acid (H_2SO_4) and nitric acid (HNO_3). The durability studies are done for 30,60 and 90 days. It shows good result for ternary blended hybrid fiber polymer concrete. It can resist the structure form the environmental reactions like acid rains. Regression analysis is also done in this present study.***

Keywords: silica fume, GGBS, polypropylene, polyestre, Compressive Strength, Split tensile Strength, Flexural strength, Durability and regression analysis

1. Introduction

Sustainability was a major issue that being worry in making an advancement. This is on the grounds that practical advancement has turned into a key perspective in the public eye, financial matters and improvement. Sustainable development will address the issues of the present without bargaining capacity of future age to addresses their very own issues. It likewise demonstrates that advancement that going to be made to continue the planetary assets by utilizing them successfully without making pointless wastage. Concrete is a blend of element of bond, fine total, coarse total and water. It very well may be formed into any shape in plastic stage. The overall amount of fixings control the property on cement in wet stage just as in solidified stage. Before a few decades prior, the creation of cement for development of structure with OPC with the instance of accessibility of element of cement independent of value was by and by without thinking about the fate of solid structure. Presently with the progression of time in the advanced time examination since last a few decades made by the specialists and researchers keeping in view the auxiliary solidness of structure which needs quality cement with improved quality, toughness attributes determine the scan for advantageous cementitious materials. In this quick advancement of foundation in the nation utilization of high quality and elite bond (HPC) is presently in like manner practice. In the adventure of research silica fume, fly ash, ggbs and so forth are discovered reasonable and most ordinarily utilized cementations materials in fractional substitution of concrete. Significantly utilization of mechanical results spare the expense and vitality notwithstanding meet out the necessity of ecological mindfulness silica rage pozzolanic materials is observed most appropriate modern as to be utilized in concrete as fractional trade rate for getting greatest 28 days quality of cement ran from 5 to 15%. Bond supplanting up to 12% with silica seethe prompts increment in compressive quality. At the point when pozzolanic materials are consolidated to concrete, the silica present in these materials respond with the calcium hydroxide discharged amid the hydration of bond and structures extra calcium silicate hydrate (C-S-H), which improve sturdiness and the mechanical properties of cement. Ternary solid blends incorporate three diverse cementations materials. This report tends to those blends of portland concrete, slag bond, and a third cementitious material. The third segment is regularly fly fiery debris, however silica rage isn't unprecedented. ASTM C595 mixed bond utilized in mix with a third cementitious material likewise is con-sidered a ternary blend. Different materials in mix with portland and slag bond, for example, metakaolin or rice husk cinder, are not as of now in like manner utilization and won't be examined here.

1.1 Triple Blended Concrete

Triple blended concretes belong to that strata of concretes where the strength and durability characteristics are maximized to the highest extent possible, in comparison to various other types of concrete. In simple words, triple blended concrete is characterized by part replacement of cement with mineral admixtures/additives such as pozzolanic admixtures (fly ash, silica fume, granulated slag etc.) or inert fillers. The corresponding concrete is termed as triple blended concrete.

1.2 Ternary Blended Concrete

Ternary blended concrete is characterized by partial replacement of cement with combination of slag with any pozzolonic material like silica fume, fly ash, metakaolin etc. usually fly ash is used as pozzolonic replacement material in ternaryblended concrete.

1.3 Mono Fibre Reinforced Concrete

The combination of cement, coarse aggregate, fine aggregate, water and admixture is know as concrete. If concrete is reinforced with any one fabric material like poly propylene, steel fibre, polyester etc, then that type of concrete is known as mono fibre concrete.

1.4 Hybrid Fibre Reinforced Concrete

A composite can be stated as a hybrid when two or more type of fibers is used in a combined matrix to produce a composite that will reflect the benefit of each of the individual fiber used. This will finally provide a synergetic response to the whole structure. Such a composite of concrete is termed as the Hybrid Fiber Reinforced Concrete (HFC). In this project the use of the alkaline (H_2SO_4), nitric acid (HNO_3). The acids suggest the weight reduction of the cubes. The weight reduction can be the result of acid reaction on the structure.

2. Literature Review

- **N Venkata Ramana: International Journal of Advanced Engineering Research and Studies (4 April 2016)**The study titiled by Study of performance of polyester and polypropylene fibers in concrete. In this study it was observed that the compressive strength of concrete is increased up to 7.98% when compared with conventional mix and the workability of concrete increase with increase in fibers up to 1.2% further decreased.
- **Revenasiddappa Madihale: International Journal Of Engineering Technology and Sciencies IJETS (volume 8, issue 8 Oct2017)**

Experimental investigation on Study on influence of polyester fibers and slag sand on the performance of concrete. From the experimental investigations it can be conclude that the reinforced concrete and he plain cement concrete containing 1.25% of polyester & 15% of slog sand as replacement of cement gives maximum compressive strength, split strength and flexural strengths.

- **Chalamecharla Venu Gopal**

Make a study on partial replacement of cement with GGBS in concrete. In this study it was observed that as GGBS is replaced with the cement, the consumption of cement is reduced and cost of construction is reduced. The durability and service life are improved JARIAIT, volume 3, issue5 April 2014.

- **Sruthi V(1), Elba Helen George(2) A Review On Silica Fume – An Additive in Concrete**

The study conducted on application of silica fume is as pozzolanic material for high performance concrete. Silica fume can also be used in a variety of products such as grouts, and mortars.

- **Dhanya R**

Make a study on strength properties of concrete using GGBS & fiber as partial replacement of cement Considering all the test results, it can be said that for M30 mix, 30% replacement of cement by GGBS & 1% steel fiber is considered as optimum.

- **Gurdeep Singh**

Investigated the effect of partial replacement of cement by SF & sand by quarry dust strength and durability of concrete. The compressive strength as increased in SF content, is increased due to the pozzolonic action and binder formation of SF with cement IRJET, volume 4, issue 9 Sept 2017.

- **Nayudu Gari MK Rao**

Analysed the performanceof partial replacement of cement with P.P fiber and admixtures individual it is perceived that the concrete slump values are decreasing with the increasing fiber percentage. The flexural strength of concrete increase when it is compare with ordinary reinforced concrete at 28days sorted by Amudhavalli N. K and Jeena Mathew [2].

3. Experimental Investigation

In this present investigation Slump, water absorption, compressive strength, split tensile strength, flexural strength and durability tests were conducted on concrete to investigate the possible use of ternary blended(cement+ silica fume+ GGBS) and hybrid polymers (polypropylene+ polyester fibre) as partial replacement for cement. Ordinary Portland cement (OPC) was replaced with 5%, 10%, 15%of silica fume and 10%, 20%, 30%, of GGBS and 0.4%, 0.6%, 0.8% of polypropylene and 1%, 1.2%, 1.4% of polyester. The cubes, cylinders and beam samples were water-cured and tested to determine their compressive strength at 7, 28 and 56 days. The results obtained showed that workability increased as percentage replacement of cement with silica fume and GGBS increased and also replacement of hybrid polymer is also increased the strength. The results of the compressive ,split tensile strength and flexural strength revealed that concrete containing 10% silica fume, 20% GGBS and 0.4% polypropylene and 1.2% polyester increases and later on decreases for 7,28 and 56 days. Cube section dimension is of 15cmx15cmx15cm, cylinder section dimension is 15cmx30cm and prism dimension is 50cmx10cmx10cm. The moulds are applied with a lubricant before placing the concrete. After a day of casting, the moulds are removed. The cubes, cylinders and prisms

are moved to the curing tank carefully.

3.1 Materials

The constituent materials used in these studies are given below:

1) Cement
2) Fine aggregate
3) Normal weight of coarse aggregate
4) Silica fume
5) Ground granulated blast furnace slag
6) Polypropylene fibre
7) Poly ester fibre

a) Cement

The cement used was Ordinary Portland cement (OPC) of 53-grade conforming to IS 12269 is used in experimental work.

Table 1: Cement Test Result

S.No	Property	Value
1	Specific Gravity	2.62
2	Fineness of Cement by sieving	2.4
3	Standard Consistency	32%
4	Setting Time Initial Setting time Final setting time	 60 min 260 min

Aggregate

It should be passed through IS Sieve. As fine aggregate (F.A) natural sand from river is used conforming to IS383-1970.Which comes under zone II. As a course aggregate hard granite chips passing 20mm down where used conforming to IS383-1970. Various tests such as specific gravity water absorption and sieve analysis have been conducted on (F.A) and (C.A) to know the good quality and grading.

Fine Aggregates

The aggregate which are passes by means of 4.75 mm sieve is termed as fine aggregate. Mainly common sand is used as a first-rate aggregate at places the place ordinary sand will not be to be had crushed stone is used as a satisfactory combination. The sand used in this project is of type zone II.

Table 2: Properties of fine aggregate

S.No	Tests Conducted	Value
1	Specific Gravity	2.436
2	Water Absorption	4.16
3	Fineness Modulus	2.69

Natural Coarse Aggregate

The broken stone is generally used as a coarse combination. The character of work decides the maximum size of the coarse aggregate. In the community on hand coarse mixture having the highest dimension of 20 mm was once used within the reward work. The properties of average mixture are provided below.

Table 3: Properties of coarse aggregate

S. No	Tests Conducted	Value
1	Specific Gravity	3.06
2	Water Absorption	0.20%
3	Fineness Modulus	7.30%
4	Maximum size of aggregate	20mm

b) Silica Fume

Silica smolder is likewise knows as smaller scale silica or dense silica rage, is utilized as counterfeit pozzolanic admixtures . It is a material coming about because of decrease of quartz with coal in electric curve heater in the production of silicon or ferrosilicon combination. Expansion of silica rage diminishes the porousness of cement to chloride particles, which shields the strengthening steel of cement from consumption. It diminishes the dying. It hinders the pore spaces present in the crisp cement so water inside the solid isn't permitted to rise to the top. It improves properties like compressive quality, bond quality and scraped spot obstruction.

c) Ground Granulated Blast Furnace Slag

Impact heater slag is a non-metallic material comprising of silicates and alumino silicates of calcium and magnesium together with different mixes of sulfur, iron, manganese, and other follow components. It is delivered from a liquid state at the same time with pig iron in an impact heater. The cemented item is additionally grouped by the procedure by which it was brought from the liquid state. Fineness modulus (FM) of 2.93 was utilized. The particular gravity was observed. Ground Granulated blast furnace Slag, is the side-effect of the production of pig iron in an impact heater it has a concoction creation which is inside a well-characterized structure territory in the SiO2-CaO-Al2O3 stage outline.

d) Polypropylene Fiber

Polypropylene is in numerous angles like polyethylene, particularly in arrangement conduct and electrical properties. The methyl bunch improves mechanical properties and warm obstruction, despite the fact that the substance opposition diminishes. The properties of polypropylene rely upon the sub-atomic weight and sub-atomic weight dissemination, crystalline, type and extent of comonomer (whenever utilized) and the isotacticity. In isotactic polypropylene, for instance, the methyl bunches are situated on one side of the carbon spine. This course of action makes a more noteworthy level of crystallinity and results in a stiffer material that is more impervious to crawl than both atactic polypropylene and polyethylene.

e) Polyester

Polyester is a manufactured fiber gotten from coal, air, water and oil. Polyester filaments can shape long atom that are truly steady and solid. It Diminishes splits amid plastic and solidifying stage. It Decreases water leakages and shields steel from eroding and dividers from hosing. It secures corners in precast chunks and solid deck .Builds scraped spot opposition by more than 40 % there by expanding life of streets, walkways, floors. Additionally diminishes setting of the floor.

f) Water

Water is a significant element of concrete as it effectively takes part in the concoction response with bond. Since it frames the quality giving bond gel, the amount and nature of water is required to be investigated in all respects cautiously. Consumable water is by and large thought to be tasteful. In the present examination, faucet water is utilized for both blending and restoring purposes.

Test Results of M_{30} grade concrete with different replacements

Results for various percentages of mineral admixture

Table 4: Compressive strength results

Mix	Compressive strength(N/mm^2)		
	7 days	28 days	56 days
M_0	18.36	37.56	41.91
M_1	20.28	39.30	43.01
M_2	28.3	53.99	55.38
M_3	24.2	46.33	57.6
M_4	25.66	47.13	58.25
M_5	31.58	52.20	58.96
M_6	30.49	45.97	56.32
M_7	30.45	42.89	52.92
M_8	27.84	40.04	43.23
M_9	27.83	39.68	41.16
M_{10}	22.28	36.68	48.69
M_{11}	**29.8**	**56.12**	**59.90**
M12	25.2	48.32	49.96

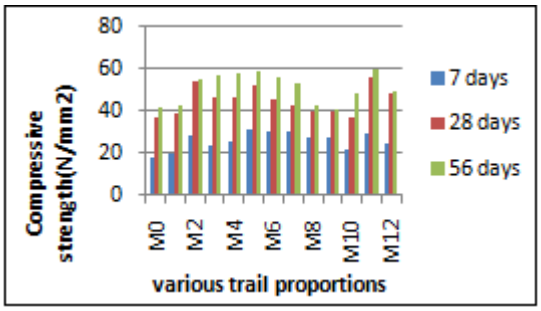

Figure 1: Overall results of compressive strength

Split Tensile Strength

This test was conducted as per IS516-1959. The cylinders of standard size 150mmx300mm were used find the strength of concrete. Specimens are placed on the bearing surface of CTM, of capacity 200T without eccentricity and a uniform rate of loading is applied till the failure of cylinder.

Table 5: Split Tensile Strength

Mix	Split tensile strength (Mpa)	
	7 days	28 days
M0	1.18	2.36
M1	1.26	2.42
M2	2.01	2.75
M3	1.36	2.64
M4	2.12	2.34
M5	2.56	2.89
M6	2.41	2.64
M7	2.71	3.92
M8	2.64	2.83
M9	2.41	2.36
M10	3.51	4.14
M11	3.01	4.49
M12	3.0	3.26

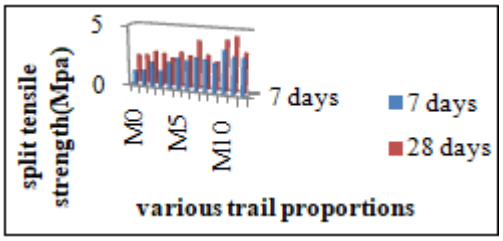

Figure 2: Split tensile testing of cylinder

Flexural Strength:

The steel mould of size 500x100x100 is well tighten and oiled thoroughly. They were allowed for curing in a tank After 28 days curing, prismatic specimens are placed on flexural testing machine having a maximum of 100 KN and a constant rate of loading of 40 kg/m^2 per minute is applied on the test specimen by placing the specimen in such a way that the two point loading should be placed at a distance of 13.3 cm from both the ends. Ultimate load at which the prismatic specimen fails is noted down from dial gauge reading.

Table 6: Flexural strength results

Mix	Flexural strength(Mpa)	
	7 days	28 days
M0	1.31	3.29
M1	1.58	3.41
M2	1.61	3.53
M3	1.24	3.46
M4	1.78	4.57
M5	1.96	5.68
M6	1.87	5.48
M7	2.68	5.93
M8	2.64	5.79
M9	2.65	5.82
M10	2.76	6.51
M11	2.98	6.78
M12	2.91	6.29

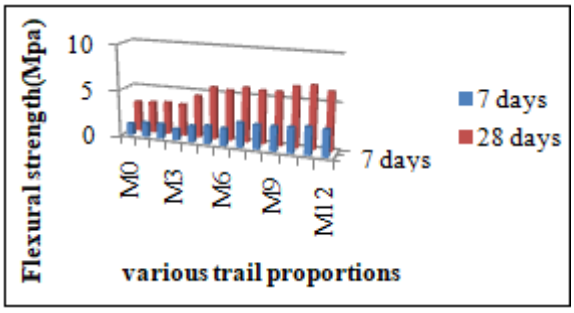

Figure 3: Overall flexural strength of beams

Water Absorption Result

Sillica Fume:-

Table 7: Water absorption of BC (Silica Fume and cement)

S.No	% of Replacement Used	7 Days	28 Days	56 Days
1	5% SF	0.240	0.194	0.170
2	10% SF	0.531	0.434	0.187
3	15% SF	0.411	0.358	0.233

Silica Fume & GGBS

Table 8: Water absorption of TBC (cement, Silica Fume and GGBS)

S.No	% of Replacement Used	7 Days	28 Days	56 Days
1	10% SF + 10% GGBS	0.414	0.357	0.235
2	10% SF + 20% GGBS	0.291	0.286	0.233
3	10% SF + 30% GGBS	0.562	0.531	0.350

Sillica Fume & GGBS & Polypropylene:-

Table 9: Water absorption of ternary blended Mono Fibre (cement, SF, GGBS, Polypropylene)

S.No	% of Replacement Used	7 Days	28 Days	56 Days
1	10% SF + 20% GGBS + 0.4% PP	0.330	0.320	0.291
2	10% SF + 20% GGBS + 0.6% PP	0.371	0.355	0.332
3	10% SF + 20% GGBS + 0.8% PP	0.492	0.481	0.450

Sillica Fume & GGBS & Polypropylene & Polyester:-

Table 10: Water absorption of ternary blended Hbrid Fibre concrete (cement, SF, GGBS, Polypropylene and polyester)

S.No	% of Replacement Used	7 Days	28 Days	56 Days
1	10% SF + 20% GGBS + 0.4% PP + 1% PE	0.735	0.729	0.711
2	10% SF + 20% GGBS + 0.4% PP + 1.2% PE	0.761	0.732	0.708
3	10% SF + 20% GGBS + 0.4% PP + 1.4% PE	0.392	0.369	0.338

Durability Study on Ternary Blended Hibrid Fiber Polymer Concrete:

The concentrations of acids in water are 1% H_2SO_4 and 1% HNO_3. Durability studies of compressive strength of lightweight aggregate concrete is effected with chemicals as follows

Table 11: % Weight loss due to curing in H_2SO_4

S. No	Mix	% of weight loss(H_2SO_4)		
		30days	60 Days	90 Days
1	M0	0.35	0.37	0.39
2	M1	0.34	0.35	0.36
3	M2	0.27	0.29	0.31
4	M3	0.35	0.37	0.39
5	M4	0.47	0.49	0.57
6	M5	0.45	0.48	0.54
7	M6	0.58	0.64	0.71
8	M7	0.77	0.82	0.91
9	M8	1.7	1.8	1.9
10	M9	1.9	1.9	2.0
11	M10	2.2	2.5	2.8
12	M11	1.7	1.8	1.9
13	M12	2.4	2.7	2.9

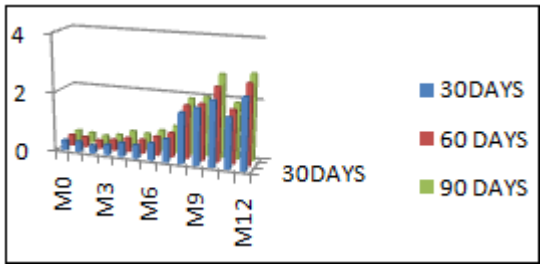

Figure 4: % Weight loss due to curing in H_2SO_4

Table 12: Regression equation of H_2SO_4

S. No	Mineral admixture	Regression equation	Coefficient of determination (R^2)
1	M0	$Y=0.0166X^2+0.128X$	0.9768
2	M1	$Y=0.0119X^2+0.1308X$	0.9766
3	M2	$Y=0.0123X^2+0.1359X$	1
4	M3	$Y=0.0145X^2+0.1451X$	0.9712
5	M4	$Y=0.0828X^2+0.8776X$	0.9868
6	M5	$Y=0.0919X^2+0.9184X$	0.9933
7	M6	$Y=0.01X^2+X$	1
8	M7	$Y=0.0502X^2+0.0342X$	0.9397
9	M8	$Y=0.0421X^2+0.086X$	0.9793
10	M9	$Y=0.0391X^2+0.1208X$	0.9654
11	M10	$Y=0.0563X^2+0.7077X$	0.92
12	M11	$Y=0.0629X^2+0.7878X$	0.9266
13	M12	$Y=0.079X^2+0.9102X$	0.98

Table 13: Compressive strength test results of H_2SO_4

S.No	Mix	Compressive strength(N/mm^2) (H_2SO_4)		
		30days	60 Days	90 Days
1	M0	50.16	45.91	40.97
2	M1	51.30	43.01	40.25
3	M2	53.99	42.38	40.01
4	M3	46.33	41.6	39.28
5	M4	47.13	39.70	39.87
6	M5	52.20	37.96	38.49
7	M6	45.97	37.32	38.28
8	M7	42.89	34.92	36.28
9	M8	37.04	34.23	34.09
10	M9	39.68	32.16	31.23
11	M10	43.68	31.69	31.18
12	M11	56.12	27.90	30.09
13	M12	48.32	25.96	30.01

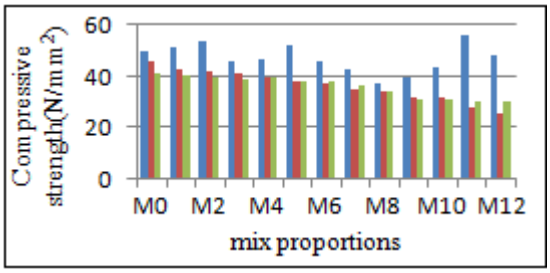

Figure 5: Compressive strength test results of H_2SO_4

Table 15: % Weight loss due to curing in HNO_3

Mix	% of Weight Loss(HNO_3)		
	30 Days	60 Days	90 Days
M0	0.35	0.37	0.39
M1	0.30	0.31	0.32
M2	0.21	0.24	0.30
M3	0.31	0.33	0.34
M4	0.44	0.46	0.50
M5	0.42	0.43	0.48
M6	0.51	0.59	0.61
M7	0.70	0.75	0.78
M8	1.1	1.3	1.5
M9	1.5	1.7	1.9
M10	1.9	2.2	2.5
M11	1.3	1.6	1.8
M12	2.1	2.3	2.6

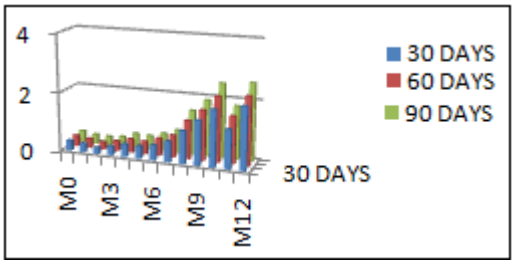

Figure 6: % Weight loss due to curing in HNO_3

Table 14: Regression equation of HNO_3

S.no	Mineral admixture	Regression equation	Coefficient of determination (R^2)
1	M0	$Y=0.0166X^2+0.128X$	0.9768
2	M1	$Y=0.012X^2+0.132X$	0.9821
3	M2	$Y=0.0129X^2+0.130X$	1
4	M3	$Y=0.0136X^2+0.139X$	0.9658
5	M4	$Y=0.0106X^2+0.1458X$	0.9365
6	M5	$Y=0.0055X^2+0.1265X$	1
7	M6	$Y=0.0093X^2+0.1534X$	0.9369
8	M7	$Y=0.0365X^2+0.0329X$	0.9913
9	M8	$Y=0.0445X^2+0.0218X$	0.9736
10	M9	$Y=0.0547X^2+0.0018X$	0.9658
11	M10	$Y=0.0413X^2+0.5642X$	0.9239
12	M11	$Y=0.063X^2+0.728X$	1
13	M12	$Y=0.0724X^2+0.83X$	0.9768

Table 16: Compressive Strength Test Results of HNO_3

S.No	Mix	Compressive strength(N/mm^2) (HNO_3)		
		30days	60 Days	90 Days
1	M0	50.16	49.91	47.97
2	M1	51.50	49.01	47.25
3	M2	53.99	48.38	46.01
4	M3	46.33	46.67	44.28
5	M4	47.13	44.70	42.87
6	M5	52.20	43.96	40.49
7	M6	45.97	43.32	39.08
8	M7	42.89	41.92	36.91
9	M8	37.04	41.23	34.09
10	M9	39.68	40.16	32.08
11	M10	43.68	38.69	30.76
12	M11	56.12	34.90	28.23
13	M12	48.32	25.96	30.01

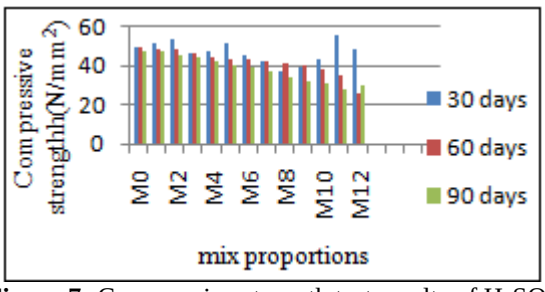

Figure 7: Compressive strength test results of H_2SO_4

4. Conclusions

- Experimental results show that with replacement of cement with silica fume compressive strength, flexural and split tensile strength increases up to 10% of silica fume replacement and later on decreases.
- Experimental results shows that with replacement of cement with 10% silica fume and 20% GGBS the compressive strength, flexural and split tensile strength increases and later on decreases.
- Experimental results show that with replacement of cement with 10% silica fume, 20% GGBS and 0.4% polypropylene the compressive strength, flexural and split tensile strength increases and later on decreases.
- Experimental results show that with replacement of cement with 10% silica fume, 20% GGBS and 0.4% polypropylene and 1.2% polyester the compressive strength, flexural and split tensile strength increases and later on decreases.
- By cost analysis it is found that the triple blended high strength hibrid fiber reinforced concrete showed a decrease in cost by 16.52% with out compramising the strength compared to normal mix and addition of fiber.
- From the strength test results it can be concluded that the use of silica fume, GGBS, polypropylene and polyester is suitable in construction and also it is environmental friendly.
- Sulphuric acid solution was found to be more weight loss when compared to nitric acid solution. Perfect regression for M11.
- The combination of 10% silica fume,20%GGBS,0.4% polypropylene and 1.2% polyester shows more weight loss with compared to other mixes of concrete.

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