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Experimental Investigation on Impact Resistance of Flyash Concrete and Flyash Fiber Reinforced Concrete

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ABSTRACT

The present Experimental investigation is to study the Impact Resistance of the Fly ash concrete reinforced with steel fibers. The concrete composite comprises of steel fibers in different percentages and partial replacement of cement in different proportions. Steel fibers varied from 0%, 0.5%, 1% and 1.5% by weight of cement and replacement of fly ash varied from 0%, 10%, 20%, 30% and 40% by weight of cement. Specimens were tested for 28 days, 60 days and 90 days and behaviour of the flyash concrete, steel fiber reinforced concrete and flyash concrete reinforced with steel fibers were studied. When the specimens were tested for 28 days strength, reduction in the Impact strength were observed, while the 90 days strength of the specimens were found to increase considerably. Based on the test results on control specimens, it was found that improvement in strength of concrete is achieved with an optimum steel fiber content of 1.5% and replacement of cement upto 30% by fly ash. The investigation included the possibility of using steel fibers and flyash in concrete for enhancement of impact resistance. The specimens for impact studies were tested by drop weight method which was recommended by ACI-544 Committee. Experiments were conducted to study the behaviour of flyash concrete reinforced with steel fiber. The investigation programme included the determination of the optimum fiber content which can be provided in the concrete composites for different mix ratios. Optimum fiber content was determined based on Impact strength of the standard specimen. The test results reveal that the increase in Impact strength was found to vary between 23% and 252% times the conventional concrete. As the steel fiber percentage selected for our investigation is upto 1.5% by weight, it is suggested that this percentage may be increased to explore the possibility of using more steel fibers in flyash concrete.

***Keywords* -** Energy absorption, Flyash concrete, Flyash Fiber reinforced concrete, Impact strength, Steel Fiber reinforced concrete.

I. INTRODUCTION

Today, the structural Engineers are facing the problem of ensuring the safe structures which will withstand for the impact loads in addition to static loads. Many concrete structures are often subjected to short duration dynamic loads. These loads originate from sources such as impact from missiles and projectiles, wind gusts, earthquakes and machine vibrations. The need to accurately predict the structural response and reserve capacity under such loading had led researches to investigate the mechanical properties of the component materials at such high rates of strain. Impact is a complex dynamic phenomenon involving crushing shear failure and tensile fracturing. It is also associated with penetration, Perforation, Fragmentation and scaling of the target being hit. The use of fibers was found to be advantageous in both static and impact conditions. One method to improve the resistance of concrete when subjected to impact or impulsive loading is by the incorporation of randomly distributed short fibers. Concrete so reinforced is called Fiber Reinforced Concrete (FRC). Many investigators have shown that addition of fibers greatly increase the energy absorption and cracking resistance characteristics of concrete.

The greatest advantage of using fiber reinforced concrete is that fiber additions improve the toughness, so that the fiber addition gives the concrete a considerable amount of apparent ductility. Studies have shown that the shape, volume percentage, aspect ratio, nature of deformation and orientation of fibers are influencing the toughness of FRC. The same parameters that influence the maximum load related to the concept of toughness is the impact resistance of FRC. Many studies have shown that the impact resistance of concrete can increase dramatically with the addition of steel fibers. The American Concrete Institute (ACI Committee 544 on fiber reinforced concrete) recommends a drop weight type test for Impact resistance of Concrete. The drop weight impact test is adopted in this investigation.

The increase in the fiber volume fraction will increase the Impact resistance of the concrete specimens and hooked end steel fibers with an aspect ratio of 80 at 0.5% and 1% volume fractions are more effective at increasing impact resistance than polypropylene fibers at 0.2%, 0.3% and 0.5%

volume fractions [1] and different fiber types including cellulose fiber, polypropylene fiber and steel fibers were considered at volume fractions of 0.15%, 0.15%, and 0.5% and in addition of cellulose fiber and steel fibers, it significantly improves the first crack strength whereas in the case of increase in the number of post-first crack blows, polypropylene and steel fibers had a remarkable effect in drop weight test [2]. Hybrid fiber-reinforced concrete [3] showed smaller variation in the first-crack strength and failure strength, although larger scatter in the percentage increase were observed in the number of post-first-crack blows, and strength reliability of steel–polypropylene hybrid fiber-reinforced concrete when compared to steel fiber reinforced concrete in drop weight test. By addition of steel fibers [4] at different volume by a ratio of 0%, 0.7%, 1.0% and 1.5% have a little reduction in compression strength but increase in the split tensile strength and also greatly influence the flexural strength. In comparison with three percentage of steel fiber, 1% was recognized as the best fiber volume for both economical and strength aspects and steel fibers in Normal Compacted Concrete and Self Compacted Concrete can effectively restrain the initiation [5] and propagation of cracks under stress, and enhance the impact strength, toughness and ductility of concrete and when steel fiber is introduced into the specimens including silica fume, the impact resistance [6] and the ductility of the resulting concrete are considerably increased. Engineered Cementitious Composites [7] and Self compacting Engineered Cementitious Composites exhibited the good strength under impact loading when the volume fraction of the fiber is kept as 1%. The addition of steel fiber with l% to 1.5% volume fraction [8] to high strength light weight concrete is extremely effective in improving the Impact strength and fracture toughness.

The present experimental investigation is to study the impact strength of fiber reinforced concrete with partial replacement of cement with Fly ash with addition of steel fibers in different percentages. The fly ash fiber reinforced concrete composites specimens are tested for Impact strength in ACI drop weight test method. The results are to be compared to the control specimens that contains without fly ash and without steel fibers. With the appropriate interpretation of the obtained results, it can be possible to determine the optimum steel fiber percentage in fly ash concrete.

II. Material and experimental methods

2.1 Material used

The cement used for the concrete mixtures was 53 grade Ordinary Portland cement conforming to IS: 12269. The specify gravity of the above cement was found to be 3.14. Vaigai River sand passed through 4.75 mm IS sieve was used as the fine aggregate with specific gravity of 2.65 and fineness modulus of 2.64. The hard broken granite stone passing through 12.5 mm IS sieve and retain on 4.75 mm IS sieve was used as the coarse aggregate with the specify gravity of the 2.70. Fly ash procured from the Thermal Power Station at Tuticorin was used and it was tested in the Regional Testing Laboratory, Madurai. The Chemical properties of fly ash were listed in Table No 1. The hooked end steel fibers of length 35mm and Diameter 0.5mm with Aspect ratio of 70 were used in this study.

Table No.1 CHEMICAL PROPERTIES OF FLYASH

Sl. No.	Characteristics	Results
1	Silicon-di-Oxide (as SiO_2) + Aluminium Oxide (as Al_2O_3) + Iron Oxide (as Fe_2O_3), % by mass	85.94
2	Silica (as SiO_2), % by mass	60.21
3	Magnesium Oxide (as MgO), % by mass	1.99
4	Total Sulphur as Sulphur tri Oxide (SO_3), % by mass	2.19
5	Available Alkali as Sodium Oxide (Na_2O), % by mass	0.39
6	Loss on Ignition, % by mass	2.05
7	Moisture content, % by mass	0.28

2.2 Test Program

In this experimental work, concrete specimens were casted with and without fibers. Steel fibers are varied from 0%, 0.5%, 1% and 1.5% by weight of cement and replacement of fly ash varied from 0%, 10%, 20%, 30% and 40% by weight of cement is considered in this investigation. The control concrete contains without steel fibers and without fly ash. For each mix, nine numbers of specimens were used to determine the Impact resistance of concrete for 28 days, 60 days and 90 days. The impact resistance of the specimen was determined by using drop weight method of Impact test recommended by ACI committee 544 procedure. The size of the specimen recommended by ACI committee is 152 mm diameter and 63.5 mm thickness and the weight of hammer is 4.54 Kg with a drop of 457mm. The specimens placed on the base plate with the finished face up and positioned within four lugs of the impact testing equipment. The bracket with the cylindrical sleeve is fixed in place and the hardened steel ball is placed on the top of the specimen within the bracket. The drop hammer is then placed with its base upon the steel ball and held vertically. The hammer is dropped repeatedly. The number of blows required for the first visible crack to form at the top surface of the specimen is to be recorded and also for ultimate failure to be recorded.

The first crack was based on visual observation (N1). White washing the surface of the test specimen facilitated the identification of this crack. Ultimate failure is defined in terms of the number of blows required to open the cracks in the specimens (N2) sufficiently to enable fractured pieces to touch three of the four positioning lugs on the base plate. The stages of ultimate failure are clearly recognized by the fractured specimen butting against the lugs on the base plate. Impact test apparatus setup is shown in Fig No.1.

Fig No.1 Impact test apparatus

2.3 Mixing and casting details

Concrete was mixed using a tilting type mixer and specimens were casted using steel moulds, compacted by table vibrator. Specimens were demoulded 24 hours after casting and cured at $27^{o} \pm 2^{o}$C in water until the testing age of 28 days, 60 days and 90 days. The specimens were numbered as per the nomenclature using Indian ink before being placed under water for curing. The details of the Impact test specimens used for this investigation are shown in the Table No. 2.

Table No.2 DETAILS OF THE IMPACT SPECIMENS.

Mix No.	Steel fiber %	Fly ash %
C	0 %	0 %
S0F10	0%	10%
S0F20	0%	20%
S0F30	0%	30%
S0F40	0%	40%
S0.5	0 .5%	0 %
S1	1 %	0 %
S1.5	1.5 %	0 %
S0.5F10	0.5 %	10 %
S0.5F20	0.5 %	20 %
S0.5F30	0.5 %	30%
S0.5F40	0.5 %	40%
S1F10	1%	10%
S1F20	1%	20%
S1F30	1%	30%
S1F40	1%	40%
S1.5F10	1.5%	10%
S1.5F20	1.5%	20%
S1.5F30	1.5%	30%
S1.5F40	1.5%	40%

III. Test results and Discussion

3.1 Impact Resistance

The impact resistance of the specimen was determined at 28 days, 60 days and 90 days. The failure patterns of the Impact specimens after ultimate failure are shown in Fig No.2. The first visible crack (N1) and then cause ultimate failure (N2) were noted for all the specimens. The results of the Impact strength in number of blows are shown in Table No.3. The impact energy delivered to the specimen are calculated by each impact is calculated [8] as follows:

$$E_I = Nmgh$$

where E_I is impact energy (N m), N is the number of blows, m is mass of the drop hammer (kg), g is gravity acceleration (N/kg), and h is height of drop hammer (m). The energy absorption of Impact specimens are shown in Table No.4. The comparisons of Percentage improvement of flyash fiber reinforced concrete with control concrete at first crack are shown in Table No.5. Impact resistance of flyash concrete reinforced with 0%, 0.5%, 1% and 1.5% steel fibers with varying percentage of 0%, 10%, 20%, 30% and 40% flyash are shown in Fig No. 3 to Fig No. 7.

Fig No.2 Part of the specimens after ultimate failure

3.1.1 Effect of steel fibers in concrete (0% Fly ash)

The impact resistance of fiber reinforced concrete with 1% steel fiber content was found to be more when compared with impact resistance of plain concrete and SFRC (Steel Fiber Reinforced Concrete) with 0.5% and 1.5% fiber content. The impact resistance of fiber reinforced concrete with 1% steel fiber content was found to be vary between 69% and 75% more when compared with plain concrete. The impact resistance of SFRC with 0.5% steel fiber content was found to be varying between 45% and 50% more when compared with plain concrete. The impact resistance of SFRC with 1.5% steel fiber content was found to be varying between 57% and 63% more when compared with plain concrete.

3.1.2 Effect of Fly ash content (0% Steel Fiber)

The impact resistance of fly ash concrete with 30% fly ash content was found to be more when compared with impact resistance of plain concrete and 40%, 20% and 10% fly ash content. The impact resistance of fly ash concrete at 90 days with 30% fly ash content was found to be 98% more when compared with plain concrete. The impact resistance of fly ash concrete at 60 days with 30% fly ash content was found to be 10% more when compared with plain concrete. The impact resistance of fly ash concrete at 28 days with 30% fly ash content was found to be 38% less when compared with plain concrete.

The impact resistance of fly ash concrete at 28 days with 10%, 20% and 40% fly ash content was found to be less from 13% to 50% when compared with impact resistance of plain concrete. The impact resistance of fly ash concrete at 60 days with 10% and 20% fly ash content was found to be 0% and 5% more when compared with plain concrete. The impact resistance of fly ash concrete at 60 days with 40% fly ash content was found to be 2% less when compared with plain concrete. The impact resistance of fly ash concrete at 90 days with 10%, 20% and 40% fly ash content was found to be 33%, 43% and 26% more when compared with plain concrete.

3.1.3 Effect of fly ash concrete reinforced with steel fibers

The impact resistance of fly ash concrete reinforced with steel fibers with 30% fly ash and 1.5 % fiber content was more than in 90 days when compared with impact resistance of plain concrete and all other combinations of fly ash content and fiber content in concrete. The impact resistance of fly ash concrete reinforced with steel fibers with 30% fly ash and 1.5 % fiber content was found to be varying between 23% and 252% more when compared with plain concrete. The impact resistance of fly ash concrete reinforced with steel fibers with 30% fly ash and 1% fiber content was found to be varying between 25% and 212% more when compared with plain concrete. The impact resistance of fly ash concrete reinforced with steel fibers with 30% fly ash and 0.5% fiber content was found to be vary between 5% and 162% more when compared with plain concrete.

The impact resistance of fly ash concrete reinforced with steel fibers with 10% fly ash and 1.5 % fiber content was found to be vary between 35% and 162% more and 10% flyash with 1% fiber content was found to be vary between 53% and 121% more and also 10% flyash with 0.5% fiber content was found to be vary between 30% and 93% more when compared with plain concrete. The impact resistance of fly ash concrete reinforced with steel fibers with 20% fly ash and 1.5 % fiber content was found to be vary between 20% and 202% more and 20% flyash with 1% fiber content was found to be vary between 38% and 140% more and also 20% flyash with 0.5% fiber content was found to be vary between 20% and 114% more when compared with plain concrete.

The impact resistance of fly ash concrete reinforced with steel fibers with 40% fly ash and 1.5 % fiber content was found to be vary between 10% less and 174% more and 40% flyash with 1% fiber content was found to be vary between 13% and 131% more and also 40% flyash with 0.5% fiber content was found to be vary between 5% less and 90% more when compared with plain concrete.

Table No.3 ACI Drop Weight Impact Test Results

% of Fly ash	0%			10%			20%			30%			40%		
Curing Period in days	28	60	90	28	60	90	28	60	90	28	60	90	28	60	90
0% of Fiber Average No. of drops at first crack (N1)	40	41	42	35	41	56	30	43	60	25	45	83	20	40	53
Average No. of drops at failure (N2)	46	46	47	39	50	62	35	47	68	30	50	88	25	44	59
N2-N1	6	5	5	4	9	6	5	4	8	5	5	5	5	4	6
0.5% of Fiber Average No. of drops at first crack (N1)	60	61	61	52	60	81	48	56	90	42	61	110	38	50	80
Average No. of drops at failure (N2)	80	81	81	64	78	110	60	75	121	53	82	141	44	67	101
N2-N1	20	20	20	12	18	29	12	19	31	11	21	31	6	17	21
1% of Fiber Average No. of drops at first crack (N1)	70	71	71	61	72	93	55	67	101	50	72	131	45	57	97
Average No. of drops at failure (N2)	104	105	104	90	107	127	83	98	145	75	105	162	60	83	131
N2-N1	34	34	33	29	35	34	28	31	44	25	33	31	15	26	34
1.5% of Fiber Average No. of drops at first crack (N1)	65	65	66	54	68	110	48	61	127	49	68	148	36	51	115
Average No. of drops at failure (N2)	90	90	90	71	95	141	66	85	162	54	94	172	44	71	140
N2-N1	25	25	24	17	27	31	18	24	35	5	26	24	8	20	25

Table No.4 Energy Absorption of Impact Specimens

% of Fly ash	0%			10%			20%			30%			40%		
Curing Period in days	28	60	90	28	60	90	28	60	90	28	60	90	28	60	90
0% of Fiber Impact Energy (Nm) at First Crack	814	834	854	712	734	1139	610	875	1221	508	915	1689	407	814	1078
Impact Energy (Nm) at Failure	936	936	956	793	1017	1261	712	956	1384	610	1017	1791	508	895	1200
0.5% of Fiber Impact Energy (Nm) at First Crack	1221	1241	1241	1058	1221	1648	976	1139	1831	854	1241	2238	773	1017	1628
Impact Energy (Nm) at Failure	1628	1648	1648	1302	1587	2238	1221	1526	2462	1078	1668	2869	895	1363	2055
1% of Fiber Impact Energy (Nm) at First Crack	1424	1445	1445	1241	1465	1892	1119	1363	2055	1017	1465	2666	915	1160	1974
Impact Energy (Nm) at Failure	2116	2137	2116	1831	2177	2584	1689	1994	2951	1526	2137	3297	1221	1689	2666
1.5% of Fiber Impact Energy (Nm) at First Crack	1322	1322	1343	1099	1384	2238	976	1241	2584	997	1384	3012	732	1038	2340
Impact Energy (Nm) at Failure	1831	1831	1831	1445	1933	2869	1343	1730	3297	1099	1913	3500	895	1445	2849

Table No.5 Effect of flyash and steel fiber content on ACI Impact Resistance (No of Drops) at first Crack for flyash concrete reinforced with steel fiber with respect to plain concrete in Percentage.

% of Fly ash	0%			10%			20%			30%			40%		
No. of Days	28	60	90	28	60	90	28	60	90	28	60	90	28	60	90
0% of Fiber	-	-	-	-13	0	33	-25	5	43	-38	10	98	-50	-2	26
0.5% of Fiber	50	49	45	30	46	93	20	37	114	5	49	162	-5	22	90
1% of Fiber	75	73	69	53	76	121	38	63	140	25	76	212	13	39	131
1.5% of Fiber	63	59	57	35	66	162	20	49	202	23	66	252	-10	24	174

$$\text{Percentage Comparison} = \frac{[\text{Strength of flyash fiber reinforced concrete - Strength of control concrete}]}{\text{Strength of control concrete}]} \text{ X 100}$$

Fig No.3 Impact Resistance of Flyash Concrete Reinforced with Steel Fiber for 0% Flyash

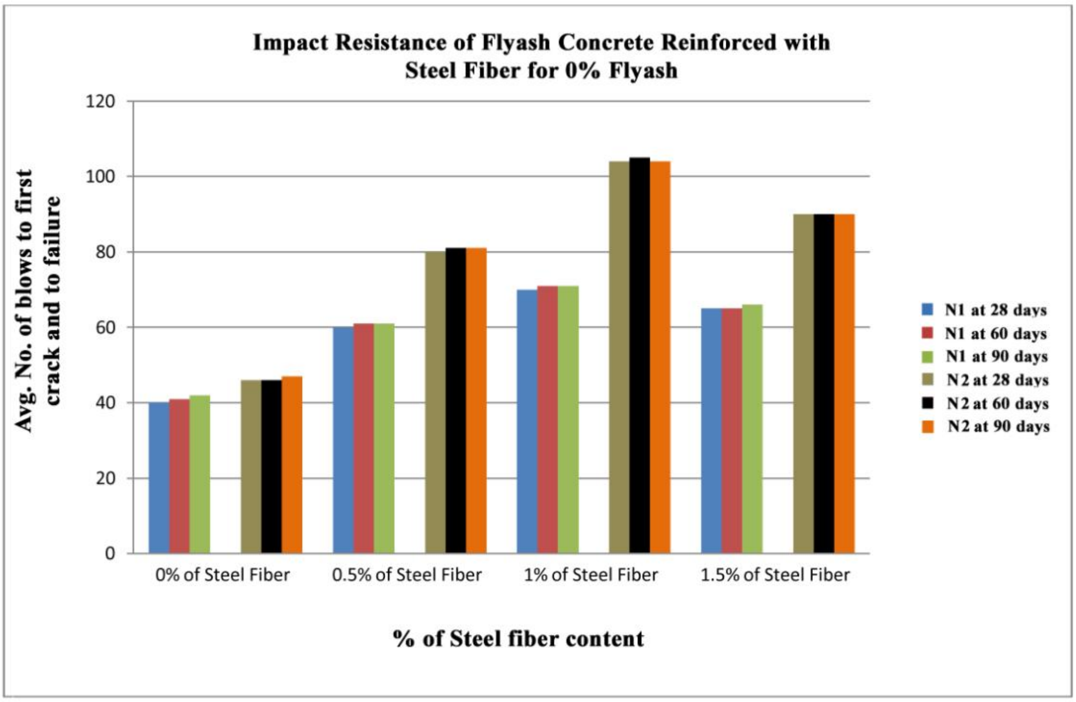


Fig No.4 Impact Resistance of Flyash Concrete Reinforced with Steel Fiber for 10% Flyash

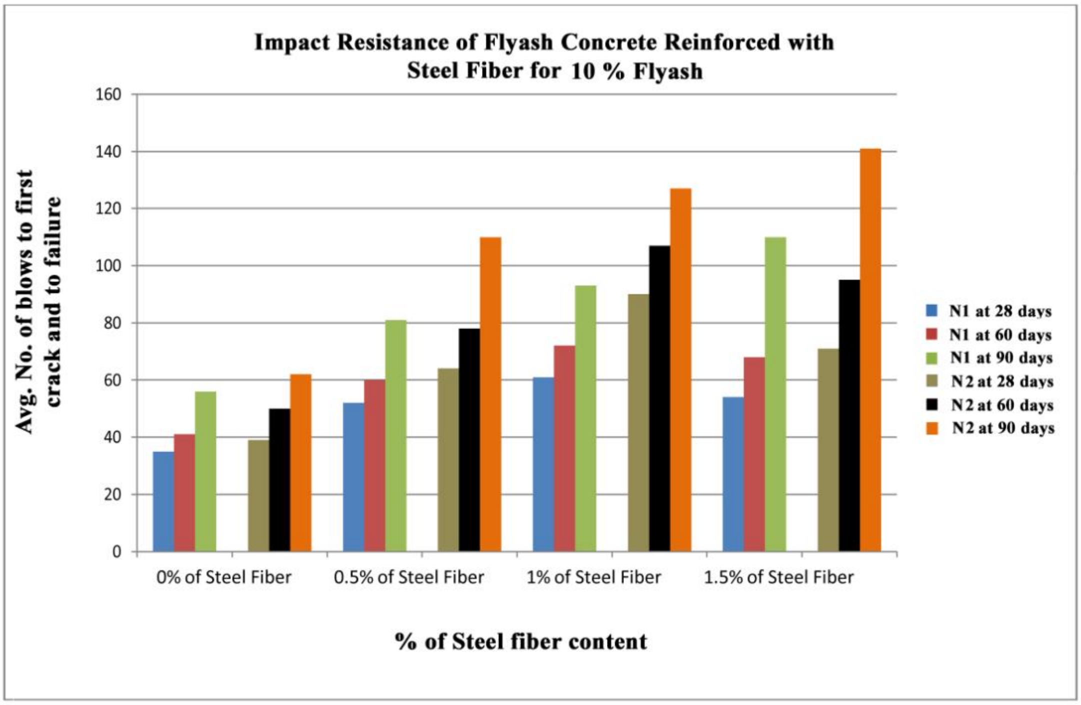


Fig No.5 Impact Resistance of Flyash Concrete Reinforced with Steel Fiber for 20% Flyash

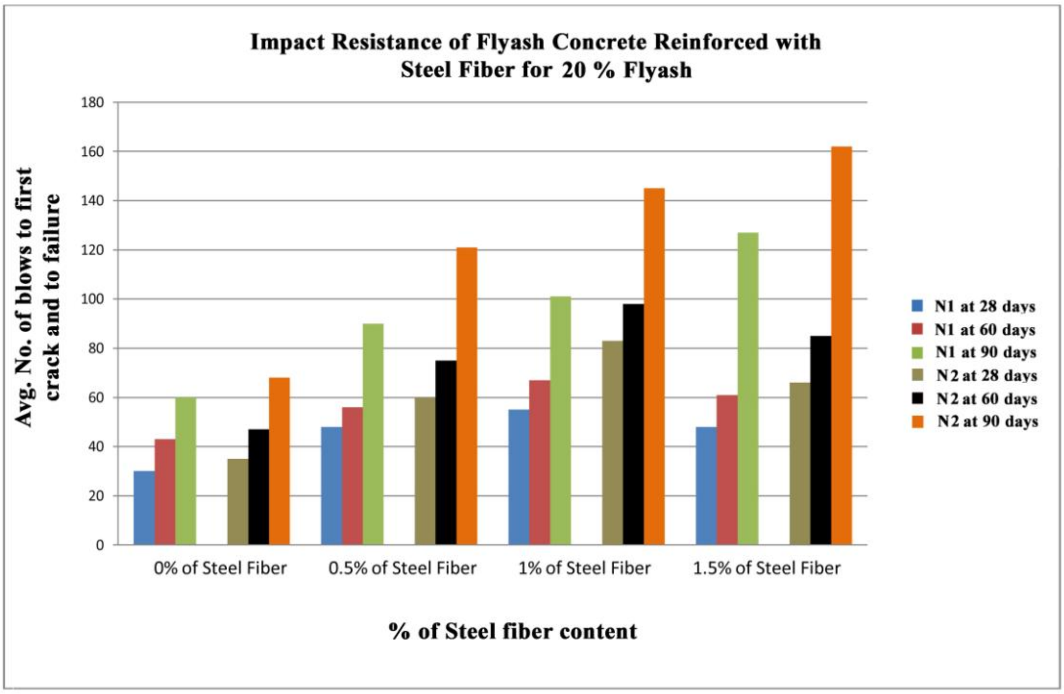


Fig No.6 Impact Resistance of Flyash Concrete Reinforced with Steel Fiber for 30% Flyash

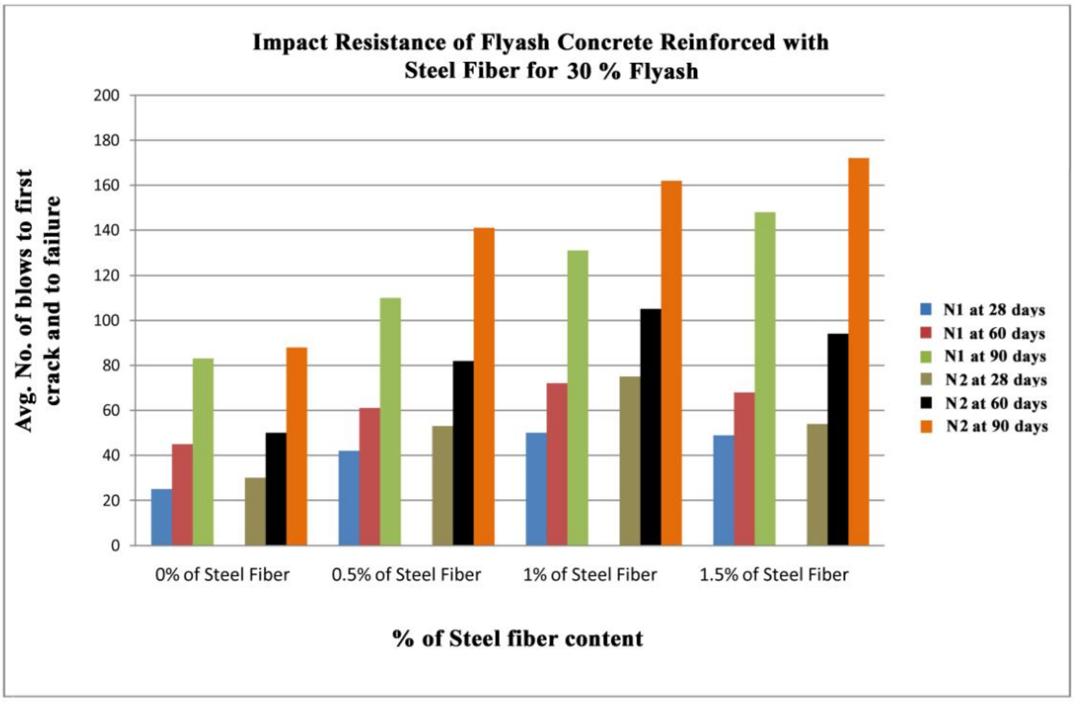
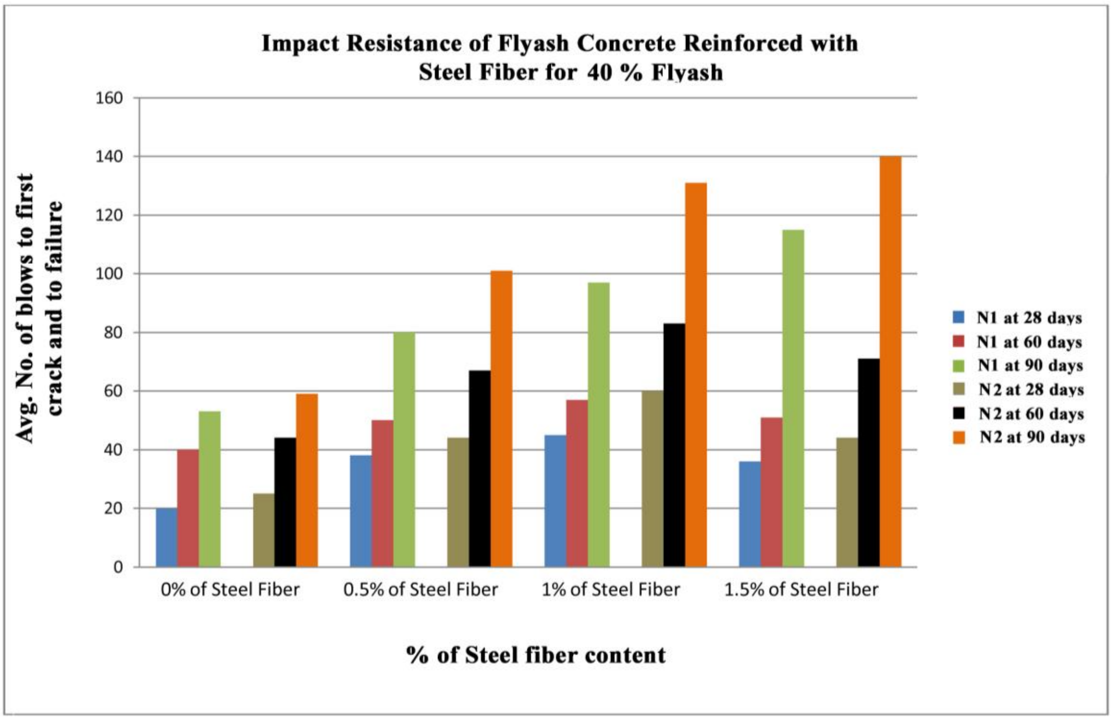


Fig No.7 Impact Resistance of Flyash Concrete Reinforced with Steel Fiber for 40% Flyash



IV. CONCLUSIONS

Based on experimental results, following conclusion are drawn.It was found that the amount of steel fibers which can be added to the concrete for improving its strength characteristics may be 1% by weight. Addition of steel fibers more than 1% generally affects the Impact strength of the concrete. The optimum steel fiber may be added to the concrete without flyash may be taken as 1%. The optimum steel fiber may be added to the concrete with flyash may be taken as 1.5%. It was found that the amount of flyash which can replace cement in concrete for improving its strength characteristics at 90 days was 30% by weight. Based on the analysis of test results, it is concluded that cement in concrete can be replaced upto 30% by flyash with incorporation of steel fibers upto 1.5% to improve its strength characteristics.

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