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Experimental studies on Impact resistance of Ternary concrete and Steel Fiber Reinforced Ternary concrete using MS and GGBS

Vijaya Bhaskar Reddy Suda[1], P.Srinivasa Rao[2]
Professor and Head, Dept of Civil Engineering, CMR Technical Campus, Hyderabad, T.S. India[1]
Professor and Principal, Dept of Civil Engineering, J.N.T.U. College of Engineering.Hyderabad, T.S. India[2]

Abstract: *Concrete is an intrinsically brittle material prone to damage through the impact of heavy objects and loads. There are several situations in which concrete structural elements are subjected to impact loading particularly industrial floors, Runways, exposed edges and rises. In this investigation, an attempt is made to study the impact resistance of Ternary blended concrete (TBC) subjected to drop weight test in accordance with the procedure suggested by ACI committee 544.2R-89. Ternary concretes were obtained by adding MS (5%, 10% and 15%) and GGBS (20% 30% 40% and 50%) to the Ordinary Portland cement. And also the study was extended to assess the impact resistance of Steel Fiber Reinforced Ternary Blended Concrete (SFRTBC).The concrete composites comprises of crimped steel fibers of aspect ratio (l/d) as 60 in various proportions viz., 0%,0.5%,1.0%,1.5%,2.0% by volume of concrete, with water to cement ratio 0.55. Impact strength characteristic of ternary concrete (TC) and fibrous ternary concrete for all the combinations were determined at 7, 28, and 90 day curing. The addition of steel fibers to concrete has improved the impact resistance considerably. The test results showed the variation of impact energy strength with different volume fraction of fibers. Investigation program included the determination of the optimum fiber content which can be provided in the concrete composites for different mix ratios.*

Keywords: *Crimped steel fiber, GGBS, Impact strength, Micro silica, Steel fiber reinforced ternary Concrete, Ternary 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. **[1]** In the recent times, impact resistance of concrete is recognized as an important property in infrastructure construction. Several methods have been suggested by different guidelines that evaluate the impact resistance of FRS (ACI committee 544) such as Charpy test, Projectile test, Explosive test and Drop weight test. Among them drop weight is simplest, popular and attractive method suggested by the ACI committee 544.

Impact resistance is one of the important attributes of FRC. Conventionally, impact resistance has been characterized by measure of the number of blows in a “repeated impact” test to achieve a prescribed level of distress in the test specimen. Steel Fiber Reinforced Concrete [SFRC] promises good ductility and improved mechanical responses. The addition of Steel fibers to concrete improves the impact and fracture that are governed by toughness characteristics of concrete. In fact, Steel fibers bridge these cracks and restrain their widening and thus improve the post peak ductility and energy absorption capacity. Toughness can determine from the experimental and analytical evaluation. A repeated drop weight impact test (equipment and procedures) has been published by ACI committee 544. This reports yields number of blows required to cause a certain level of distress in fiber Reinforced concrete [FRC] specimen **[2].**

The present experimental investigation is to study the influence of mineral admixtures (MS and GGBS) and Crimped steel fiber on impact strength of Ternary concrete as well as on SFRTBC. The results are to be compared to the control specimens that contains without mineral admixtures and without steel fibers. With the appropriate interpretation of the obtained results, it can be possible to determine the optimum percentage levels of Micro silica and ground granulated blast furnace slag in Ternary concrete and steel fiber percentage in SFRTBC.

II. Literature Survey

A.Alavi Nia, M. Hedayatian, M. Nili and V. Afrough Sabet **[3]** conducted experiments on impact resistance on fiber-reinforced concrete, and found that, 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 and different fiber types including cellulose fiber, polypropylene fiber and steel fibers were considered at volume fractions of 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 **[4].** P.S. Song, J.C. Wu, S. Hwang and B.C.Sheu **[5]** investigated and found that the Hybrid fiber-reinforced concrete 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. Mahmoud Nili and V. Afrough sabet**[6]** reported that the 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 and the ductility of the resulting concrete are considerably increased.

3. Research objectives

To determine impact strength of Ordinary concrete.
To determine combined influence of Micro silica and GGBS on impact strength of Ternary concrete.
To determine effect of crimped fiber on impact strength of ordinary concrete as well as Ternary concrete
To assess the optimum percentage levels of MS and GGBS in TBC.
To obtain optimum fiber content in Ordinary concrete as well as in Ternary concrete
To evaluate the post crack resistance for all combinations
To utilize Industrial by products and find out the economical and performance evaluation of concrete mix.
To create healthy environment world-wide by using industrial by products wisely.

4. Research significance

In the recent and past, investigators attempted to enhance the impact strength of Ordinary concrete and binary concrete using Steel fiber, Polypropylene and hybrid fiber. Though enhancement in the strength properties of binary blended concrete through mineral admixtures like Fly ash, metakaolin, etc., but there exists little understanding of Micro silica and GGBS combinations and the information is still scanty. Therefore, and attempt has been made to study the effect MS, GGBS and crimped steel fiber combination on the impact resistance of ternary mix..

5. Experimental program

The experimental program was planned to produce three (Ordinary concrete, Ternary concrete and Steel Fiber Reinforced Ternary concrete) , with reduced cement content and by adding different percentages of steel fiber. Procedure for blending, mixing, casting and curing of specimens are shown in Fig. 1 to Fig 5.

5.1 Materials

5.1.1 Cement: Ordinary Portland cement (OPC), 53 grade confirming to BIS 12269-1987(specific gravity: 3.16, Blaine fineness: 320 $m^{2.}$ /kg)

5.1.2 Micro Silica: Micro Silica -920D **[7]** as a mineral admixture in dry dandified form was obtained from "ELKEM South Asia (P) Ltd., Navi Mumbai confirming to ATSM-C (1240-2000) having specific gravity 2.2 and fineness 20000 m^2/kg.

5.1.3 GGBS: GGBFS was collected from JSW-HYD **[8].** Confirming to IS: 12089 – 1987. (Specific gravity: 2.87 Fineness: m^2/kg.)

5.1.4 Fine Aggregate: Locally available river sand confirming to zone II of table 4 of BIS: 383-1970 (specific gravity: 2.6 and fineness modulus 3.17 and bulk density 1793 kg/m^3) was used as fine aggregate.

5.1.5 Coarse Aggregate: Locally available quarried and crushed granite stones confirming to graded aggregate of nominal size between 20mm and 4.75mm as per table 2 of BIS:383-1970 (specific gravity: 2.9, fineness Modulus: 6.87, bulk density: 1603kg/m^3)

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5.1.6 Crimped steel fiber: Crimped steel fiber (0.5x30 mm) aspect ratio 60 was obtained from "STEWOLS INDIA (P) LTD." **[9]** Nagpur Industrial Estate INDIA having density 7.8g/cm^{3}and tensile strength 1000 MPa
5.1.6 Water: Clean drinking water available in the college campus was used for mixing and curing of concrete Confirming to IS 456-2000.
5.1.7 Super Plasticizers: Chemical admixture based on Sulphonated Naphthalene Formaldehyde condensate-CONPLAST SP 430 **[10]** confirming to BIS 9103-1999 and ASTM C-494.

5.2 Mix Proportions

5.2.1 Ordinary concrete**:** Mix design was carried out as per guide line given in IS: 10262-2009**[11]**, which yielded mix proportion of 1:2.42:3.37, for water cement ratios of 0.55. Total of 09 specimens were made as reference mix. The composition of ordinary concrete is given in Table 1.

Table 1: Quantity of Material Required per 1m^3 of TBC

Water -Cement Ratio	Cement (kg)	Water (litres)	FA(kg)	CA(kg)	SP (litres)
W/C=0.55	324	178	785	1093	0
	1	0.55	2.4	3.373	0

Table 2: Mix Proportions of the Ternary Blended Concrete Mixtures per 1m^3

Mix Id	Ternary concrete (TC) (C%+MS%+GGBS %)	Cement	MS	GGBS	FA	CA	Water (Liters)	SP (liters)
CC	C100%+MS 0%+GGBS 0%	324	0	0	785	1093	178	3.24
TM1	C75%+MS 5%+GGBS 20%	243	16.2	64.8	785	1093	178	
TM2	C65%+MS 5%+GGBS 30%	210.6	16.2	97.2	785	1093	178	
TM3	C55%+MS 5%+GGBS 40%	178.2	16.2	129.6	785	1093	178	
TM4	C45%+MS 5%+GGBS 50%	145.8	16.2	162	785	1093	178	
TM5	C70%+MS 10%+GGBS 20%	226.8	32.4	64.8	785	1093	178	
TM6	C60%+MS 10%+GGBS 30%	194.4	32.4	97.2	785	1093	178	
TM7	C50%+MS 10%+GGBS 40%	162	32.4	129.6	785	1093	178	
TM8	C40%+MS 10%+GGBS 50%	129.6	32.4	162	785	1093	178	
TM9	C65%+MS 15%+GGBS 20%	210.6	48.6	64.8	785	1093	178	
TM10	C55%+MS 15%+GGBS 30%	178.2	48.6	97.2	785	1093	178	
TM11	C45%+MS 15%+GGBS 40%	145.8	48.6	129.6	785	1093	178	
TM12	C35%+MS15%+GGBS 50%	113.4	48.6	162	785	1093	178	

5.2.2 Ternary concrete mixes**:** Twelve Ternary Mixes (OPC + Micro Silica + GGBS) were made with cement replacement. A total of 108 specimens were prepared for all water-cement ratios. All the Ternary mixes were prepared with super plasticizer at a dosage of approximately 1.0 liter/100 kg of cement.
5.2.3 Steel Fiber Reinforced Ternary concrete mixes**:** Twelve Ternary Mixes (OPC + Micro Silica + GGBS) were made by adding steel fiber at volume fraction from 0.5% to 2.0% at an interval of 0.5% . to each mix. A total of 432 specimens were prepared for 7days, 28 days and 90 days curing. All the Ternary mixes were prepared with super plasticizer at a dosage of approximately 1.0 liter/100 kg of cement.

5.3 Mixing and Casting

5.3.1Mixing**:** Mixing was done manually on smooth concrete pavement. Micro silica and GGBS were first blended in the required percentage and subsequently, blended with OPC at the required proportions before mixing with the fine aggregate and coarse aggregate mix in dry condition. Water was then added gradually and the entire heap was mixed thoroughly to ensure homogeneity and to obtain cohesive concrete. Finally, fibers were added in various proportions such as 0.5%, 1.0%, 1.5%, and 2.0%. to the mixture. Each, freshly mixed concrete was then cast into cylindrical discs of standard size (150 mm. dia. x 64 mm thickness) of PVC moulds were used for casting the specimens. The specimens were prepared both by hand compaction as well by imparting vibrating through vibrating table. The specimens were finished smooth and kept under wet gunny bags for 24 hours. The following specimens were prepared for Controlled concrete (CC), Ternary concrete (TC) and SFRTC to perform tests at 7 28 and 90 day of curing

i) For control concrete (3 = 9)
ii) For Ternary blended concrete (12 x 3 x 3 = 108)
iii) For Steel fiber reinforced ternary concrete. (12 x 4 x 3 x 3 = 432)

5.4 Impact Testing Methodology [12]

The impact resistance of the specimen was determined by using drop weight method of Impact test recommended by ACI committee 544 procedures.**[13]** 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 (44.54N) 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 with 63.5 mm diameter was placed on the top of the specimen within the bracket as shown in Fig.9. 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,which is shown in Fig.7. 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.8. The schematic diagram of the impact strength test set up is shown in Fig.10. The number of blows required to cause the first visible crack (N1) and ultimate failure (N2) was recorded as the first crack strength and the ultimate failure strength respectively. The impact energy absorption capacity of the concrete specimen was calculated by the following expression.

$E_{imp} = Nx(mgh)$ (1)

Where

E_{imp} = impact energy (Nm); m=mass of drop hammer in kg; g=9.81m/s^2; h= height of drop hammer in m; N=number of blows.

5.5 Notations and Abbreviations

CC: Control Concrete
TBC: Ternary blended concrete
SFROC: Steel fiber reinforced ordinary concrete
SFRTBC: Steel fiber reinforced ternary
Blended concrete
MP:Mix Proportions

TM: Ternary Mix
N1: No. of blows at first visible crack
N2: No. of blows at ultimate failure crack
E: Impact Energy (Nm)
FVF: Fiber Volume Fraction


Fig.1 Minerl admixtures


Fig.2 aggregates


Fig.3 Crimped fiber


Fig.4 Casting


Fig.5 Curing


Fig.6 Befor Testing


Fig.7 Impact machine base plate


Fig.8 Impact test setup


Fig.9 Impact Testing

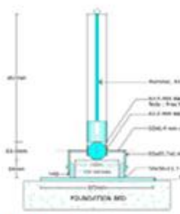
Fig.10 Schematic diagram


Fig.11 Specimens after Failure


Fig.13 over view of specimens


Fig.12 Failure pattern of specimens with different dosage of fiber
(a)Plain concrete, (b) 0.5%, (c) 1.0% (d) 1.5%, (e) 2.0% fiber

Table 3: Impact Resistance of Ordinary Concrete with Steel Fiber

MIX ID	MP (C+MS+GGBS) (%)	FVF (%)	7 Days						28 Days							90 Days						
			Avg no of blows at		N2-N1	Impact Energy (E)		% Increase in Post crack resistance	Avg no of blows at		N2-N1	Impact Energy (E)		% Increase in Post crack resistance		Avg no of blows at		N2-N1	Impact Energy (E)		% Increase in Post crack resistance
			N1	N2					N1	N2						N1	N2				
C F0	100+0+0	0	130	132	2	2645.97	2686.67	1.54	225	231	6	4579.56	4701.68	2.67		255	266	11	5190.17	5414.06	4.31
C F0.5	100+0+0	0.5	135	142	7	2747.73	2890.21	5.19	232	267	35	4722.03	5434.41	15.09		260	366	106	5291.93	7449.41	40.77
C F1.0		1	143	155	12	2910.56	3154.81	8.39	250	319	69	5088.40	6492.80	27.60		289	494	205	5882.19	10054.67	70.93
C F1.5		1.5	154	173	19	3134.45	3521.17	12.34	260	384	124	5291.93	7815.78	47.69		320	718	398	6513.15	14613.88	124.38
C F2.0		2	147	162	15	2991.98	3297.28	10.20	252	354	102	5129.11	7205.17	40.48		300	617	317	6106.08	12558.17	105.67

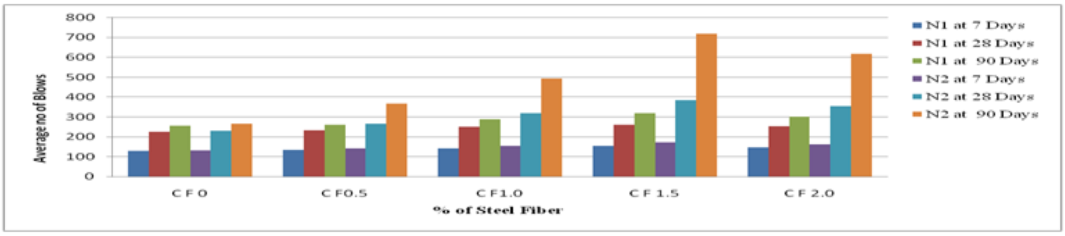

Fig 14: Impact Resistance of Ordinary Concrete with Steel Fiber (0% to 2%)

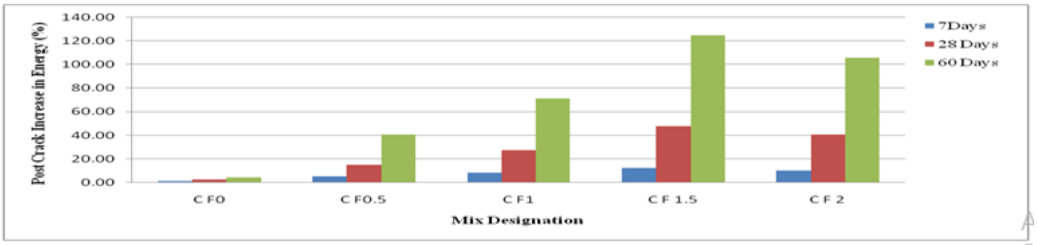

Fig 15: % Increase in Post Crack Energy of Ordinary Concrete with Steel Fiber

Table 4: Impact Resistance of Ternary Blended Concrete over Control Concrete

MIX ID	MP (C+MS+GGBS) (%)	7 Days						28 Days							90 Days					
		Avg no of blows at		N2-N1	Impact Energy (E)		% Increase in Post crack resistance	Avg no of blows at		N2-N1	Impact Energy (E)		% Increase in Post crack resistanc	Avg no of blows at		N2-N1	Impact Energy (E)		% Increase in Post crack resistance
		N1	N2					N1	N2					N1	N2				
CC	100+0+0	130	132	2	2645.97	2686.67	1.54	225	231	6	4579.56	4701.68	2.67	255	266	11	5190.17	5414.06	4.31
TM1	75+5+20	129	130	1	2625.61	2645.97	0.78	230	240	10	4681.33	4884.86	4.35	264	280	16	5373.35	5699.01	6.06
TM2	65+5+30	128	129	1	2605.26	2625.61	0.78	222	229	7	4518.50	4660.97	3.15	270	288	18	5495.47	5861.83	6.67
TM3	55+5+40	127	127.00	0	2584.91	2584.91	0.00	193	198	5	3928.24	4030.01	2.59	255	266	11	5190.17	5414.06	4.31
TM4	45+5+50	126	126	0	2564.55	2564.55	0.00	187	190	3	3806.12	3867.18	1.60	234	239	5	4762.74	4864.51	2.14
TM5	70+10+20	124	125	1	2523.85	2544.20	0.81	237	250	13	4823.80	5088.40	5.49	279	299	20	5678.65	6085.72	7.17
TM6	60+10+30	124	125	1	2523.85	2544.20	0.81	231	242	11	4701.68	4925.57	4.76	284	307	23	5780.42	6248.55	8.10
TM7	50+10+40	123	124	1	2503.49	2523.85	0.81	172	177	5	3500.82	3602.59	2.91	243	255	12	4945.92	5190.17	4.94
TM8	40+10+50	122	122	0	2483.14	2483.14	0.00	154	157	3	3134.45	3195.51	1.95	199	205	6	4050.36	4172.49	3.02
TM9	65+15+20	119	119	0	2422.08	2422.08	0.00	156	160	4	3175.16	3256.57	2.56	174	181	7	3541.52	3684.00	4.02
TM10	55+15+30	118	118	0	2401.72	2401.72	0.00	150	153	3	3053.04	3114.10	2.00	160	166	6	3256.57	3378.70	3.75
TM11	45+15+40	115	115	0	2340.66	2340.66	0.00	149	151	2	3032.69	3073.39	1.34	154	159	5	3134.45	3236.22	3.25
TM12	35+15+50	112	112	0	2279.60	2279.60	0.00	146	147	1	2971.62	2991.98	0.68	149	153	4	3032.69	3114.10	2.68

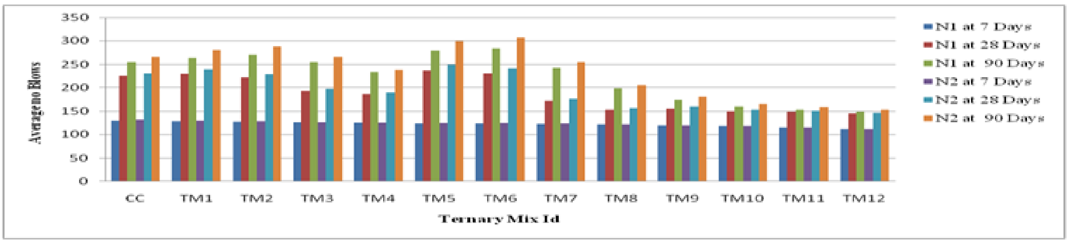

Fig 16: Impact Resistance of Ternary Blended Concrete over Ordinary Concrete with (MS 5%, 10%, 15% and GGBS 20%-50%)

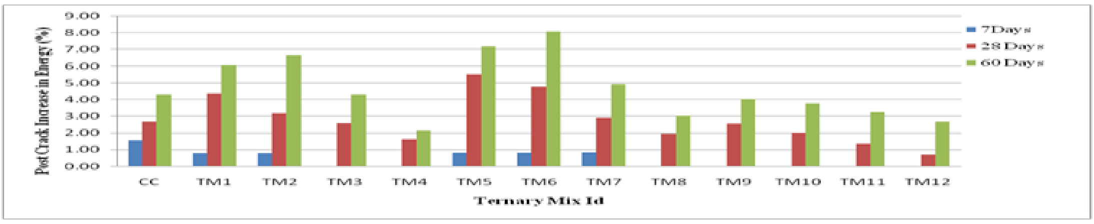

Fig 17: % Increase in Post Crack Energy of TBC (MS 5%,10%,15% and GGBS 20%-50%)

Table 5: Maximum Impact Resistance of Steel Fiber Reinforced Ternary Blended Concrete with Steel Fiber Reinforced Ordinary Concrete and Ordinary Concrete

MIX ID	MP	FVF (%)	7 Days						28 Days						90 Days					
			Avg no of blows at		N2-N1	Impact Energy (E)		% Increase in Post crack resistance	Avg no of blows at		N2-N1	Impact Energy (E)		% Increase in Post crack resistance	Avg no of blows at		N2-N1	Impact Energy (E)		% Increase in Post crack resistance
			N1	N2					N1	N2					N1	N2				
CC	100+0+0	0	130	132	2	2645.97	2686.67	1.54	225	231	6	4579.56	4701.68	2.67	255	266	11	5190.17	5414.06	4.31
C F1.5	100+0+1	1.5	154	173	19	3134.45	3521.17	12.34	260	384	124	5291.93	7815.78	47.69	320	718	398	6513.15	14613.88	124.38
TM1 F 1.5	75+5+20	1.5	378	429	51	7693.66	8731.69	13.49	696	963	267	14166.10	19600.51	38.36	759	1532	773	15448.38	31181.70	101.84
TM2 F 1.5	65+5+30	1.5	354	393	39	7205.17	7998.96	11.02	724	1019	295	14736.00	20740.31	40.75	846	1771	925	17219.14	36046.21	109.34
TM3 F 1.5	55+5+40	1.5	342	366	24	6960.93	7449.41	7.02	548	680	132	11153.77	13840.44	24.09	785	1228	443	15977.57	24994.21	56.43
TM4 F 1.5	45+5+50	1.5	326	348	22	6635.27	7083.05	6.75	531	645	114	10807.76	13128.07	21.47	800	1230	430	16282.87	25034.92	53.75
TM5 F 1.5	70+10+20	1.5	385	439	54	7836.13	8935.23	14.03	715	1015	300	14552.82	20658.90	41.96	825	1728	903	16791.71	35171.01	109.45
TM6 F 1.5	60+10+30	1.5	365	414	49	7429.06	8426.39	13.42	748	1087	339	15224.49	22124.35	45.32	956	2134	1178	19458.03	43434.56	123.22
TM7 F 1.5	50+10+40	1.5	354	385	31	7205.17	7836.13	8.76	624	796	172	12700.64	16201.46	27.56	954	1527	573	19417.33	31079.93	60.06
TM8 F 1.5	40+10+50	1.5	341	370	29	6940.57	7530.83	8.50	599	748	149	12191.80	15224.49	24.87	1000	1532	532	20353.59	31181.70	53.20
TM9 F 1.5	65+15+20	1.5	326	337	11	6635.27	6859.16	3.37	495	558	63	10075.03	11357.30	12.73	759	1014	255	15448.38	20638.54	33.60
TM10 F 1.5	55+15+30	1.5	285	293	8	5800.77	5963.60	2.81	475	521	46	9667.96	10604.22	9.68	724	915	191	14736.00	18623.54	26.38
TM11 F 1.5	45+15+40	1.5	276	283	7	5617.59	5760.07	2.54	486	522	36	9891.85	10624.57	7.41	557	660	103	11336.95	13433.37	18.49
TM12 F 1.5	35+15+50	1.5	267	273	6	5434.41	5556.53	2.25	456	478	22	9281.24	9729.02	4.82	541	606	65	11011.29	12334.28	12.01

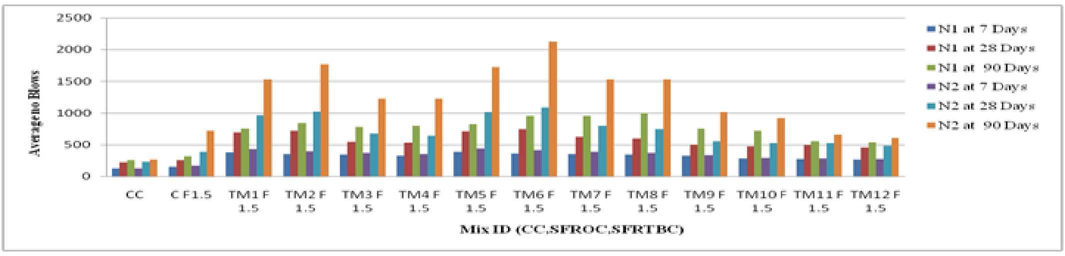

Fig 18: Maximum Impact Resistance of Steel Fiber Reinforced Ternary Blended Concrete with Steel Fiber Reinforced Ordinary Concrete and Ordinary Concrete

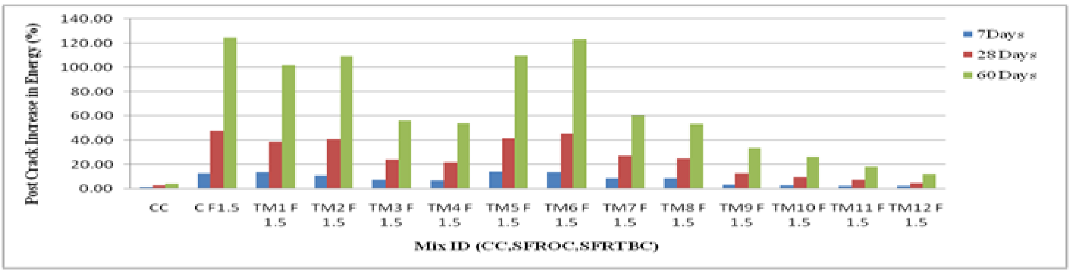

Fig 19: % Increase in Post Crack Energy (Maximum) of Steel Fiber Reinforced Ternary Blended Concrete With Steel Fiber Reinforced Ordinary Concrete and Ordinary Concrete

III. Results And Discussions

Workability

The workability of fresh concrete was measured by the slump cone test, and it was observed that, the workability increases with addition of GGBS up to 30% at MS 10% as constant and there after it decreases even with increase of GGBS content in Ternary mixes.And also noticed that, the workability decreases with the addition of steel fiber. Hence in the Ternary Blended Concrete mixes with steel fiber, somewhat high dosage of super plasticizer is necessary to maintain medium workability.

Impact Test Results and Discussion

Impact resistance was determined by drop weight test method recommended by ACI committee 544.2R-89. at 7 day, 28 day and 90 day curing. The number of blows resulting in the initiation of the first crack (N1)and the number of blows required for final fracture (N2) of Plain concrete, Steel fiber reinforced concrete, Ternary blended concrete, and Steel fiber reinforced ternary blended concrete with different volume fraction of fiber content and the impact Energy performance are indexed in (Table 3 to 5) . The number of blows (N1 and N2) given in the table are the average values of three discs specimens. Fig.6 shows the specimens before failure, and the ultimate failure pattern of specimens are shown in Fig.11 to Fig 13.The test results are presented in terms of number of blows and impact energy as shown in Table:3 to Table:5. Percentage increase in post crack energy illustrated in Fig.14 to Fig, 19.

Performance of Ordinary concrete with Crimped steel ordinary fiber (CSOF)

From the Table-3, it was observed that, the Number of blows required causing the visible of the first crack (N1) and failure crack (N2) of the Plain concrete specimen was not differentiated considerably at 7 day curing, but a considerable defiance was observed with increase in curing days.

The Number of blows (N1 and N2) increased by the addition of Crimped Steel Fiber (CSF) up to 1.5% by volume of concrete, and there after the number, decreases as shown in Table-3

The number of blows required for ultimate fracture (N2) of Crimped steel fiber plain concrete (CSFPC) had 7.57%, 17.42%, 31.06% and 22.72% higher than the Plain concrete at 0.5%, 1.0%, 1.5%, and 2.0% respectively for 7 day curing. At 28 day curing it had 15.58%, 38.10%, 66.23%, and 53.25% and at 90 days curing the number of blows enhanced by 37.59%, 85.71%, 169.92%, and 131.95% over Plain concrete

The percentage increase in post crack energy also increased by the addition of steel fiber up to 1.5% and there after it deceases gradually.The post crack energy (%) of crimped steel fiber concrete (CSFC) had 5.19%, 8.39%, 12.34% and 10.20% higher than the Plain concrete at 0.5%, 1.0%, 1.5%, and 2.0% respectively for 7 day curing, and at 28 day and 90 day curing it had 15.09%, 27.60%, 47.69% and 40.48% and 40.77%, 70.93%, 124.38% and 105.67% respectively.

Influence of Micro silica and GGBS on Impact resistance of Ternary blended concrete (TBC)

From the Table-4, It was observed that, the performance of Micro silica and GGBS is almost negligible in resisting impact loads at 7 day curingBut it was noticed that the impact strength of Ternary concrete attains max at 20% replacement of GGBS with MS (5%,10% and 15%), and there after it decreases even increase in GGBS content. And also observed that the impact strength increases with increase in percentage replacement of Micro silica up to 10% and there after the strength decreases even increase of MS content, irrespective of GGBS percentage at 28 day and 90 day curing.From the Table 4. It was observed, the number of blows required for failure crack of Ternary mix TM1 and TM5 shows higher, and conversely TM9 shows lower over Plain concrete for 28 day curing, but it was noticed that the Ternary mix TM2 and TM6 attained max number of blows among all ternary combination including plain concrete at r 90 days curing. Similarly percentage increase in post crack energy of ternary concrete followed the same trend.

Performance of Steel fiber reinforced Ternary blended concrete (SFRTBC)

Performance of Plain concrete, Steel fiber reinforced ordinary concrete (SFROC) and (SFRTBC) in terms Number of blows (N1 and N2) and percentage increase in post crack energy by considering mineral admixtures (MS and GGBS) and Crimped steel fiber (CSF) of 1.5%, (optimum) were presented in the Table 5

From the Table 5, It was observed that the (SFRTBC) mixes i.e. TM1, TM5, TM9 required higher number of blows for ultimate failure crack (N2) over plain concrete and (SFROC) for 7 day curing, but at 28 and 90 day curing the (SFRTBC) mixes i.e. TM2,TM6 and TM 9 attained higher number (N2) respectively.

At 7 day curing The (SFRTBC) Mix TM5 had 232.5% and 153.75 % over Plain concrete (CC) and (SFROC) respectively and it had 370.56% and 183.07 % for 28 day curing and for 90 day curing the SFRTBC shows 702.25% and 197.2% higher than CC and SFROC respectively.From the Fig.19, it seems that the percentage increase in post crack energy of (SFRTBC) mix i.e. TM5 had 814% and14.08% higher than plain concrete (CC) and (SFROC) respectively for 7 day curing. But at 28 day curing the Mix (SFRTBC) TM6 had 1600% higher than Plain concrete and 4.82% lower than (SFROC). Similarly the percentage increase in post crack energy of TM6 had 2758.9% higher than plain concrete (CC) and is almost equal to (SFROC)

IV. Conclusions

From the above results and discussions the following conclusions can be drawn

- The plain concrete showed poor performance in resisting the impact loads at early age, but later on it increases at 28 and 90 day curing, therefore plain concrete should not allow for impact loads.
- Percentage increase in post crack Energy is almost negligible at 7 day curing, it represents the energy absorption capacity of plain concrete is very poor and energy absorption capacity increases gradually with the age of concrete

- The increase in volume crimped steel fiber leads to increase in impact resistance
- The difference between first failure crack and ultimate fracture crack increases with increase in percentage of steel fiber, and also increases with age of concrete, with this it can be concluded that the plain concrete attains considerable energy absorption capacity at 28 day and attains maximum at 90 day curing relatively.
- By incorporation of steel fiber to the plain concrete, the failure mode was changed from brittle to ductile behavior which shows the beneficial effects of FRC used in structural engineering applications
- The Ternary concrete showed considerable performance in resisting impact loads at 90 day curing with the mix combination (MS5%+GGBS30%) over plain concrete and at 28 day and 7 day curing the mix does not show much performance comparatively. From this it can be concluded that the MS and GGBS replacement levels could be recommended up to 10 % and 30% respectively, after certain limit, the GGBS could not enter into reaction , but behaves like fine aggregate.
- The impact resistance of SFRTBC over plain concrete increases enormously with increase in steel fiber volume for all curing days.
- Percentage increase in post crack energy increase with increase in fiber content and also absorption capacity increase predominantly with age of concrete.

V. Recommendations

From the above test results, the authors recommending the use of crimped steel fiber 1.5% by volume of plain concrete, and replacement of cement by MS 10%,+GGBS20% in Ternary blended concrete and the combined of both for (SFRTBC) to get economical and impact resistant concrete at 28 day curing.

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About The Authors

Mr. S.Vijaya Bhaskar Reddy, Professor and Head of Civil Engineering Department in CMR Technical Campus, Hyderabad. Specialized in Structural Engineering having 12 years of academic experience and published 6 research papers. Research interests are Concrete Technology, Blended Concretes, Earth Quake Resistance Design of Structures, and Life Member of ISTE, Fellow Member of Institution of Engineering, Member Indian Society of Earth Quake Technology, Member Indian Concrete Institute.

Dr.P.Srinivasa Rao, Professor and Vice principal of Dept of Civil Engineering, J.N.T.U. College of Engineering. Hyderabad, T.S. India.Specialized in structuralengineering. Research interests are Concrete Technology, Structural Design, High Performance Concrete Prefabricating Structures, Special Concretes and use of Micro Silica, Fly ash in Building Materials. He has been associated with a number of Design projects, for member of organizations and involved as a key person in Quality control and Mix Designs.Has 24 years of academic, research and industrial experience published over 100 research papers. He guided four Ph.Ds and 100 M.Tech projects. Guiding 15 Ph.Ds students delivered invited lectures in other organizations and institutions.Member of ISTE, Member of ICI and Member of Institute of Engineers.