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Investigation of Abrasion Test and Mechanical Properties of Concrete Using Fly Ash as A Partial Replacement of Cement

Om Tripathi[1], Vishal Rawat [2], Abhishek Mishra[3], Kumar Vanshaj[4]
[1]*PG Student, (M.Tech. Structural Engg,* [2,3,4]*Assistant Professor, Civil Engineering Department, Institute of Engineering and Technology, Lucknow*

Abstract: ***Concrete is one of the most versatile and widely used material in the construction sector. With the development and advancements of concrete, Civil engineering has reached its technological pinnacle. Despite its global and excessive demands, the consumption of cement is increasing day by day which is to be managed. Also there are many challenges related to its consistent strength performance , Abrasion resistance, Durability etc. so there is a great need to overcome these problems by the application of a pozzolanic admixture known as Fly ash which is responsible for improving various mechanical properties of concrete such as Abrasion Resistance and strength aspects and also reducing the consumption of cement at the same time. In this experimental Work, the Inclusion of Fly Ash and its effect on the various mechanical properties of the concrete i.e. Abrasion resistance, compressive strength, split tensile strength and flexural strength etc is investigated. The present investigation is carried on M35 Grade concrete. Firstly, concrete mixes is prepared by using Ordinary Portland cement(OPC 53) as a reference concrete mix and then blended concrete mixes is prepared by partial replacement of cement using fly ash in range of 10%, 20%, 30%, 40%, 45% by the weight of cement. This experimental study is carried for Determining the differences in the various mechanical properties of blended concrete (Fly ash and cement) and conventional concrete. The optimum percentage of using fly ash with cement in the concrete mixes is determined. The various parameters studies of concrete investigated are Abrasion resistance , workability of freshly prepared concrete mixes, compressive strength at 7 and 28 days, split tensile strength at 28 days. All these tests on concrete mixes is to be performed for both conventional concrete mixes (using only OPC) and also with blended concrete mixes (OPC and its partial replacements with fly ash).***

Keywords: Abrasion, Fly Ash, Compressive strength, Split tensile strength ,flexural strength, Durability, workability, Ordinary Portland cement, Concrete.

I. INTRODUCTION

Concrete is highly versatile composite material having a mixture of cement, fine aggregate ,coarse aggregate and water that hardens with time to a great strength. Due to its wide application in every region of the world, certain admixture ie. Fly Ash are preferred in addition to cement in the preparation of concrete providing improved mechanical properties in the concrete. Also the usage of fly ash makes concrete sustainable and economical by reducing the overall consumption of cement and thereby reducing CO_2 emission in cement industry. cenzig duran atis [1] reported that on replacement of cement by 50-70% of fly ash caused increased abrasion resistance of concrete abrasion resistance increases with compressive strength of concrete. wen liu et al.[2] reported that concrete made with fly ash has improved the abrasion resistance, also encouraging mortar densification and void reduction. Also reported that reduction in the w/cm ratio increases the tested concrete abrasion resistance. Ramesh kumar and sharma [3] reported that the incorporation of aggregates and pozzolanic admixture improves the abrasion resistance properties of resulting concrete. siddiqui et al. [4] reported that Abrasion resistance of concrete is strongly linked by its compressive strength and content of fly ash. Atis and celik [5] has reported that HVFA concrete proved to have better abrasion resistance than conventional mixes,at high tensile strength. V Santa Rao et al. [6] reported that on replacement of cement by 40% using fly ash and GGBFS with equal proportion of (20+20)% increases the compressive ,split tensile and flexural strength by 9.6%,15.7% and 42 % respectively at 28 day strength. Swaroop et al.[7] have reported that the strength of fly ash concrete when replaced with 20% cement is increased and beyond 40% replacement, it had decreased. Kamaldeep and shyam [8] reported that The maximum compressive strength of cubes containing the mixture of Fly ash and cement is obtained for 35% of Fly ash content. Its compressive strength is 31.2 N/mm for 28 days.Gull and wani et al.[9] reported that the optimum percentage of using fly ash replacing the cement is limited upto 15% after which strength decreases considerably.

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Saddam akhtar and hossain [10] reported that 12% cement is replaced by fly ash to achieve the desired strength of M20 grade concrete and also economical as 9.9% cost in preparation of concrete is reduced.

The purpose of this experimental work is to study the effect of including Fly ash in abrasion and other various mechanical properties of concrete which is used as a partial replacement of cement incorporated with OPC to produce blended concrete mixes. The concrete mixes are casted and tested at 7 and 28 days for, Compressive strength, Split tensile strength, flexural strength. Workability of freshly prepared concrete mixes is also carried out in this study.the optimum percentage of using fly ash with cement is determined, then at that particular percentage , Cubes of 70.6 mm size are casted for determining abrasion resistance of concrete mixes.

II. EXPERIMENTAL STUDY

Concrete mixes is prepared by using Ordinary Portland Cement (OPC) of grade 53 as a binding material, coarse aggregate, fine aggregate, water, super plasticizer , Fly Ash is used as a partial replacement of cement in the preparation of blended concrete mixes.

Raw Materials and their Properties

OPC of brand BIRLA UTTAM of Grade 53 is used for this study. The cement test results were: normal consistency = 28 %; initial setting time = 115 minutes; final setting time = 235 minutes; specific gravity = 3.10; CS = 45.25 MPa (28 days). These test values satisfied the provisions of IS: 12269-1987 [11]. Natural FA of rounded shape was used (conforms to zone II, IS: 383-1970 [12]). It's bulk density and specific gravity is found to be 1680 kg/m^3 and 2.65 respectively. The CA of size 10 mm and 20 mm having: Specific gravities = 2.67 and 2.75 respectively; water absorptions= 0.21% and 0.30% respectively were used and satisfied IS 383-1970 [12]. The bulk density of 10 mm and 20 mm size aggregate were 1600 kg/m^3 and 1650 kg/m^3, individually. The FM i.e. Fineness Modulus of FA was 2.45, & its value for the CA of size 10 mm and 20 mm was 6.25 and 7.07 individually. Fly ash, a pozzolanic admixture (procured from Tanda NTPC thermal power plant, Uttar Pradesh.) of dark greyish color having specific gravity 2.4. A Superplasticizer, Sika-ViscoCrete having density approximately 1.08kg/l. was used. The chemical compositions of OPC is shown in Table 1 as provided by suppliers.

III. METHODOLOGY

In this study, M35 grade concrete mixes are prepared using OPC 53 Grade using IS 10262-2019 [13] with required proportions: Total cement binder content = 362 Kg/m^3, FA = 696 Kg/m^3, CA=1261 Kg/m^3, super plasticizer = 1.16 litre/m^3 and w/c = 0.42. The experimental work was carried on referral concrete of M35 grade mix concrete. Initially Concrete mixes of grade M35 were made using OPC 53 alone as Control cube and then replacing cement by weight 10%, 20%, 30%,35% 40% with fly ash using each additive one at a time. The mechanical parameters of concrete mixes examined are Workability of freshly prepared concrete, CS at 7 and 28 days, STS at 28 days, FS at 28 days and Abrasion Resistance at 28 days .Cubes of 150 mm were casted to determine CS at the age of 7 and 28 days. In the same manner cylinders of diameter 100 mm and height 200 mm. is casted to determine the STS Beams of 700mm×150mm×150mm are casted to determine FS. The specimen was tested after curing them in-tap water for 7 and 28 days. The CS of concrete cubes was determined using compression testing machine (capacity 2000 KN) as per the provisions contained in IS: 516-1959 [14]. To determine the FS, Three point load method of testing was done after 28 days curing as per the provisions contained in IS: 516-1959 [14]. STS was determined as per the provisions of IS: 5816-1999 [15] Final mix proportions for M35 grade concrete are shown in Table 2. The optimum percentage of using Fly ash (optimization) used as a partial replacement of cement is to be determined. After the optimization of Fly ash with Cement, the Abrasion resistance of blended Concrete mixes at that optimum percentage is determined using tile abrasion machine as per the provision of IS 1706-1972.[16]

Table 1. Chemical Properties of OPC & Fly ash

Chemical Composition	OPC (%)	FLY ASH (%)
Silicon Dioxide	20.1	64.6
Calcium Oxide	62.0	1.9
Aluminum Oxide	5.3	24.7
Iron Oxide	4.3	2.8
Magnesium Oxide	2.7	0.4
Potassium Oxide	0.9	0.3
Sodium Oxide	0.2	0.6
Loss of ignition	3.12	2.6

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Table 2. Mix Proportion of M35 Concrete

Design mix	Quantity per M^3
W/C ratio	0.42
OPC	362 kg/m^3
Workability	100 mm
Coarse Aggregate	1261 kg/m^3
Fine Aggregate	696 kg/m^3
Water	152 Litres
Superplasticizer	1.16 $Litre/m^3$

IV. RESULT AND DISCUSSION

A. Fresh Properties of Concrete

Workability of Fly Ash blended Concrete

The effect of including Fly ash on workability of concrete is given in Fig 4.1 in which slump height was measured as fly ash content is varied from 0 to 40%. It is evident from this figure that workability of freshly prepared concrete mixes increases with increase in %age of fly ash. This is because of the spherical and glassy surface of fly ash particles which is adsorbed on the surface of cement particles responsible for preparing the concrete mixes cohesive, reduced bleeding tendency and improving workability.

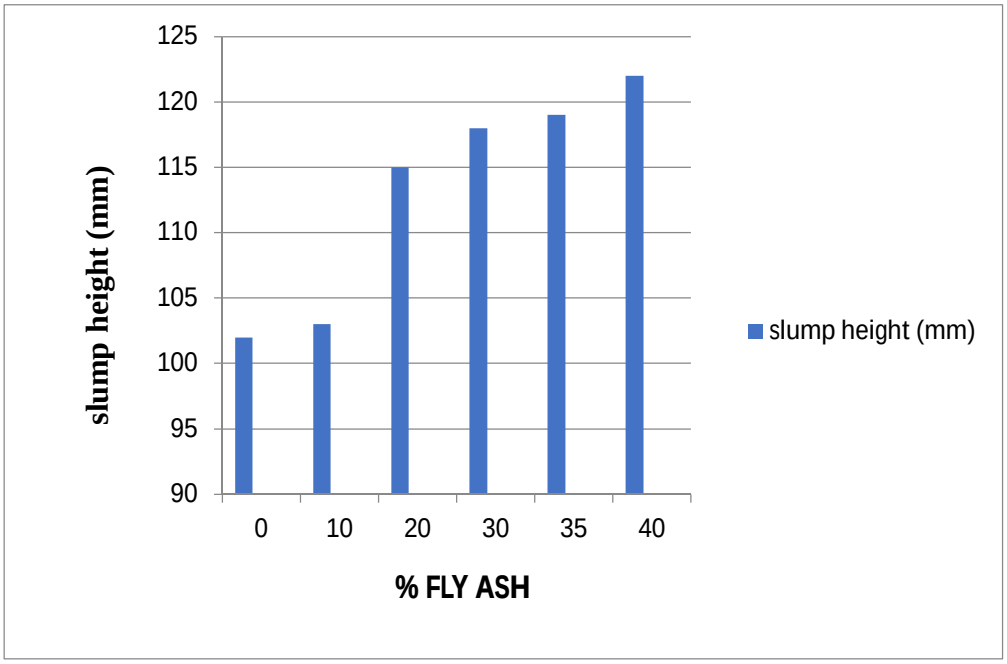


Fig. 4.1 Slump Vs % of Fly Ash in concrete

B. Hardened Mechanical Properties of Fly ash blended Concrete

Optimization of Fly Ash in Concrete

CS of concrete at 7 and 28 days is listed in table 3, CS , STS and FS at 28 days are given in Table-4 .The substitution of OPC with Fly ash is done at 0%, 10%, 20%, 30%, 35% and 40%. It is clear from the Table that the CS increases with the addition of fly ash till 35% and later decreases considerably at 40% replacement of OPC with fly ash. It is also observed from this Table that increment in CS is 5.80% and 13.48% at 7 and 28 days respectively with respect to the referral concrete. STS and FS of concrete at the age of 28 days are also given in Table-4. It is evident from this Table that STS and FS increases upto35% replacement of OPC with Fly ash in concrete and after further addition of Fly ash at 40% replacement of cement, the respective strength decreases However, strength is higher at all replacement levels as compared to that of referral concrete. Percentage increase in STS and FS is found to be 11.39% and 19.90% respectively more with respect to referral concrete mix at 28 days.

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Table 3 CS at 7 and 28 days at various % of Fly Ash

% FLY ASH	CS at 7 days (MPa)	CS at 28 days (MPa)
0	30.31	45.25
10	29.50	44.80
20	30.14	48
30	30.56	48.10
35	32.07	51.35
40	27.85	45.60

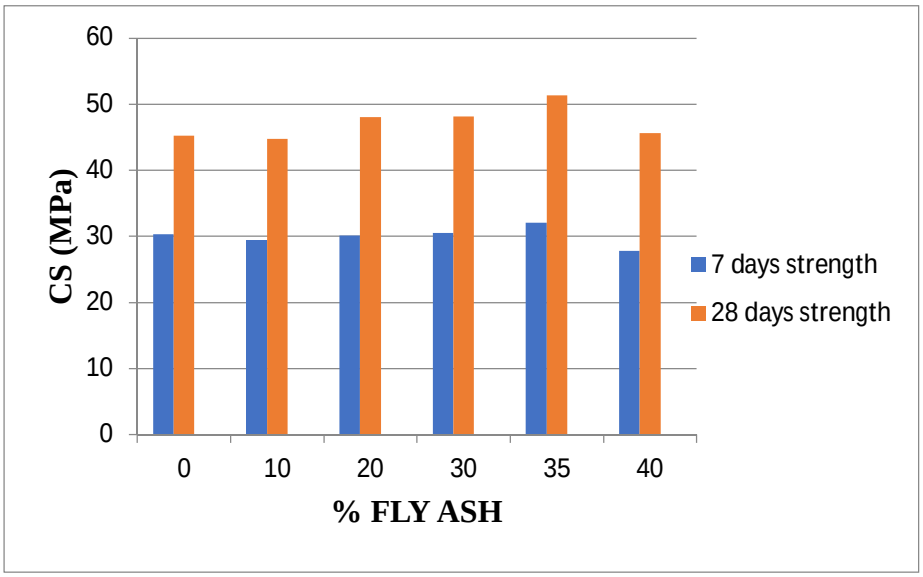


FIG 4.2 Relation between % fly ash and Compressive Strength of concrete at 7 and 28 days.

Table 4 CS, STS & FS of 28 Days at various % of Fly Ash

% FLY ASH	CS at 28 days (MPa)	STS at 28 days (MPa)	FS at 28 days (MPa)
0	45.25	3.25	6.31
10	44.80	3.33	6.69
20	48	3.42	6.77
30	48.10	3.46	6.79
35	51.35	3.62	7.57
40	45.60	3.34	6.48

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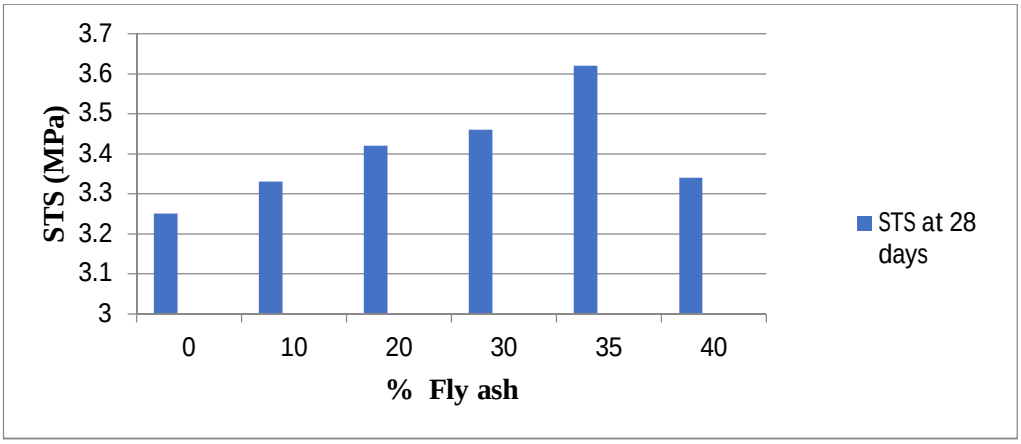


FIG 4.3 Relation between % Fly ash and Split tensile strength at 28 days.

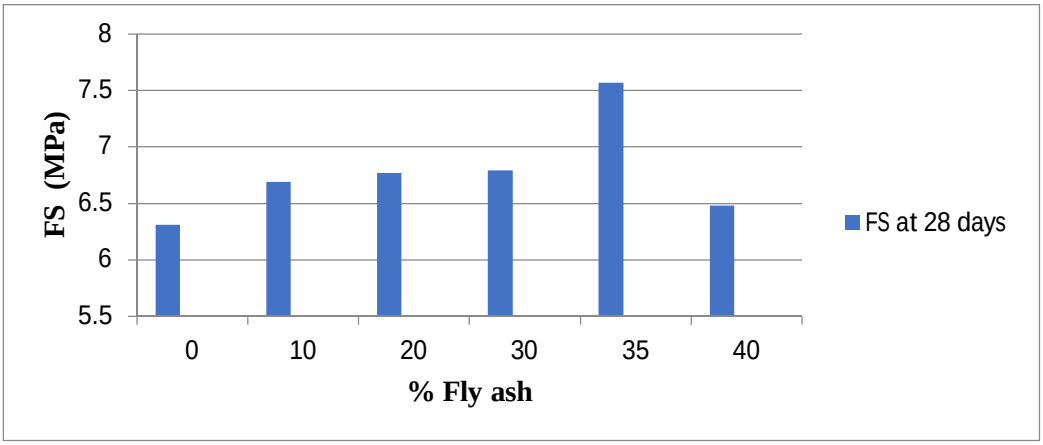


FIG 4.4 Relation between % Fly ash and Flexural strength at 28 days.

C. Relation among CS, FS & STS of Fly ash blended Concrete

Relation between FS & CS , STS & FS , CS& STS of fly ash blended concrete mixes developed & plotted and are given in Figs 4.5 - 4.7. Regression coefficient , R^2 values among the different parameter is found 0.953, 0.932 and 0.938 respectively. The high values of correlation coefficient indicates that there is a strong relationship with each of the strength properties (compressive, flexural and split tensile).

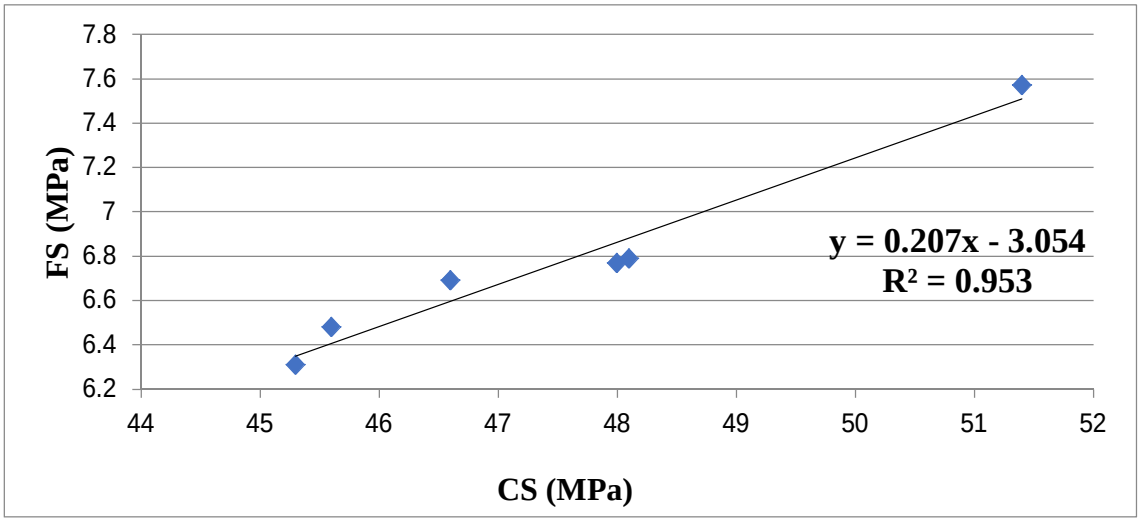


Fig. 4.5 Relation between FS & CS of fly ash blended concrete mix

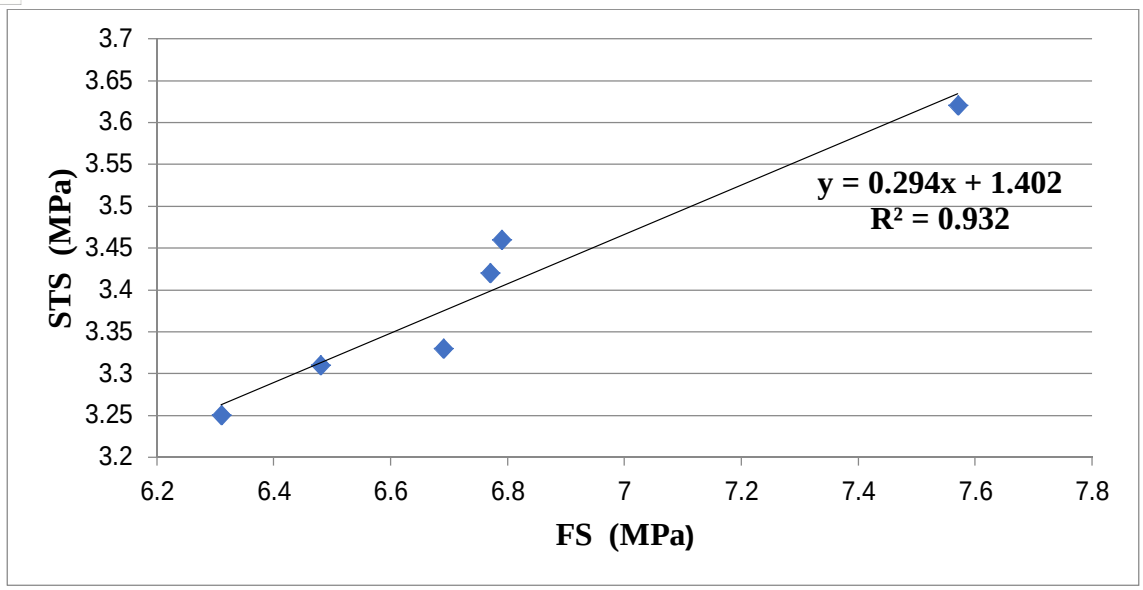


Fig. 4.6 relation between STS & FS of fly ash blended concrete mix

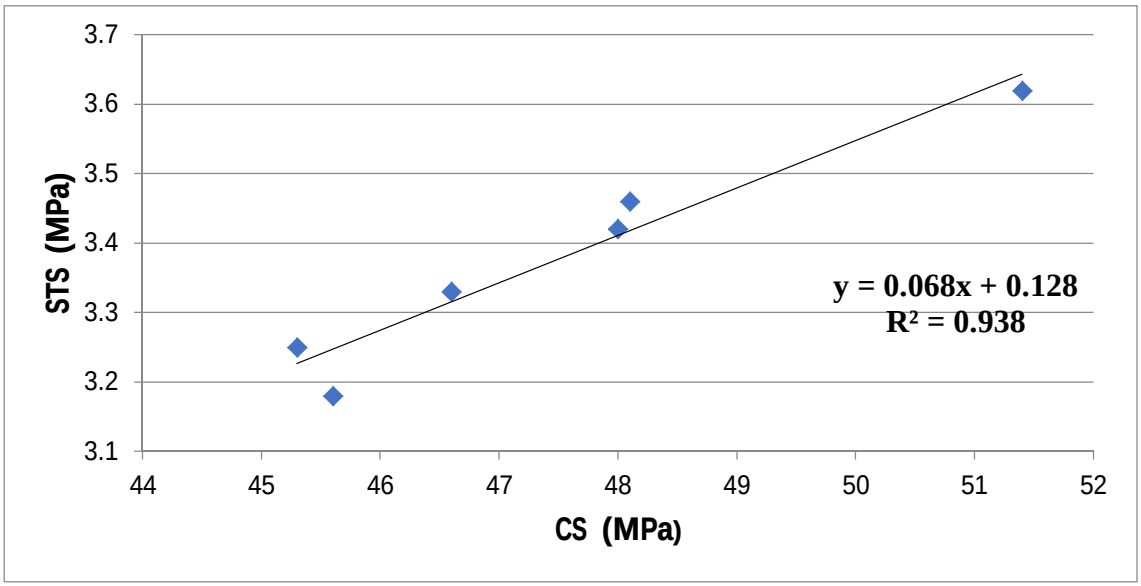


Fig. 4.7 Relation between STS & CS of fly ash blended concrete mix

D. Abrasion Resistance of Concrete

Abrasion resistance test is determined using tile abrasion machine as per IS code :1706-1972.for each samples of concrete mixes(referral and fly ash blended concrete mixes), cubes of 70.6mm were casted and subjected to grinding path of abrasion machine after 28 days curing. Depth of cubes is measured at 5 points(four at corners and one at the center).weight of cubes and loss in depth of cubes(depth of wear) is measured before abrasion test and recorded after every 22 sets of revolutions. this process is repeated till 220 revolutions. this is shown in table 5. The extent of abrasion was determined from the difference in values of thickness measured before and after the abrasion test.

The variation of depth of wear (mm) increases with the no.of revolutions and decreases with age of curing. The depth of wear in referral concrete is 2.48mm and loss in weight is 32.24 gms .On the replacement of OPC with 35% fly ash ,the depth of wear is found to be 1.93mm and loss in weight is 24.98 gms. thus there is improvement in abrasion resistance in fly ash blended mixes as the depth of wear and loss in weight is decreased in fly ash blended concrete mixes as shown in fig 4.8.

Relation between No. Of revolution and depth of wear at 0% and 35% replacement of fly ash is shown in fig.4.9. Relation between No. Of revolution and loss in weight at 0% and 35% replacement of fly ash is shown in fig.4.10.

Table 5 : Relation between No. Of revolutions, loss in weight and Depth of wear(mm) in concrete mixes

No. Of Revolutions	Referral concrete		Fly ash blended concrete (35% replacement of fly ash)	
	Depth of wear (mm)	Loss in weight (gms)	depth of wear (mm)	Loss in weight (gms)
0	0.00	0.00	0.00	0.00
22	0.27	3.61	0.17	2.22
44	0.52	6.80	0.38	5.11
66	0.73	9.57	0.57	7.45
88	1.02	13.34	0.74	9.61
110	1.27	16.46	0.93	12.40
132	1.36	17.88	1.13	13.90
154	1.55	20.53	1.31	16.89
176	1.89	24.68	1.51	19.53
198	2.23	28.96	1.71	22.16
220	2.48	32.24	1.93	24.98

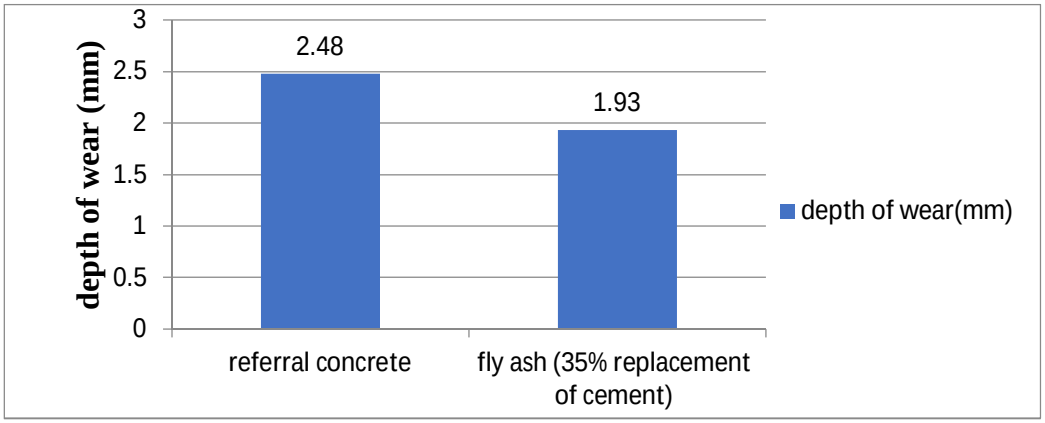


Fig. 4.8 Relation between depth of wear (mm) at 28 days with its corresponding concrete mixes

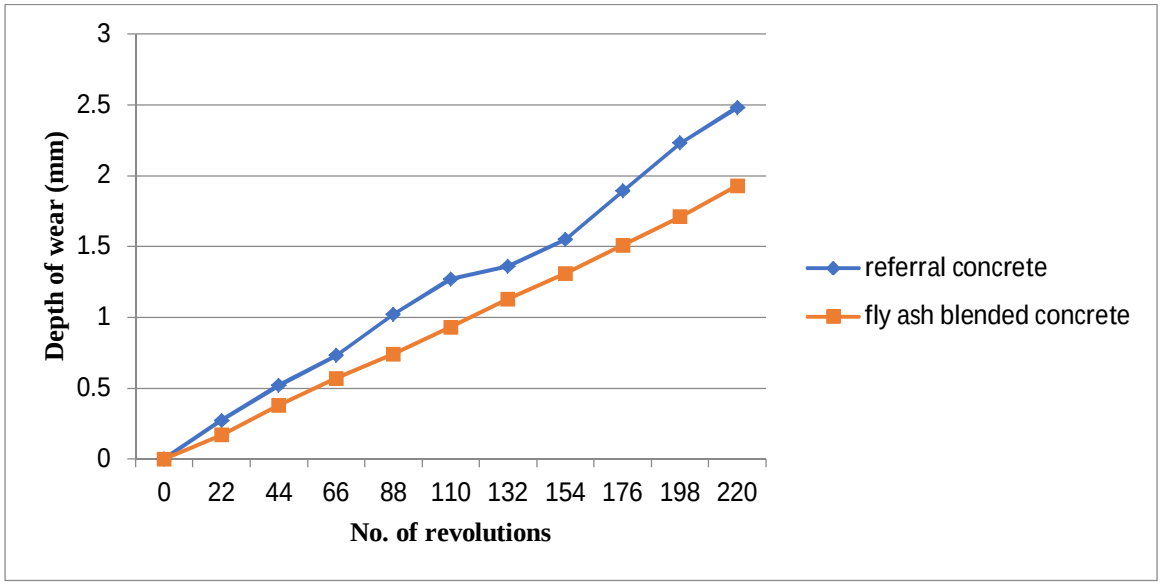


Fig. 4.9 Relation between No. Of revolution and depth of wear in referral concrete and fly ash blended concrete mix.

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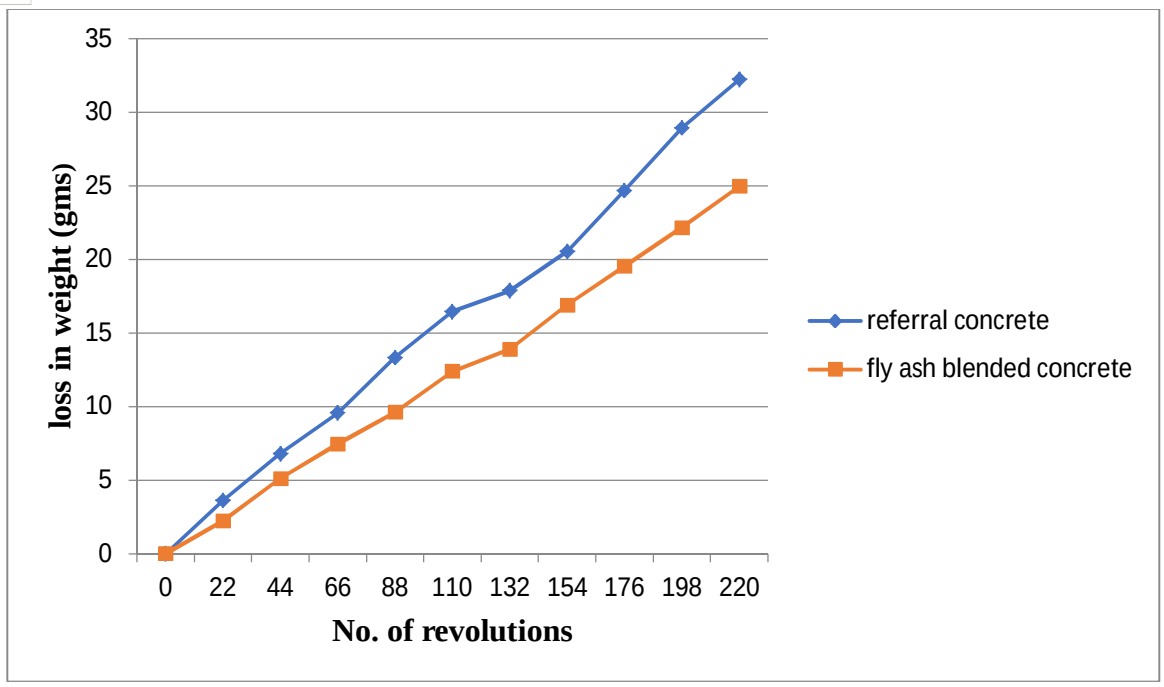


Fig. 4.10 Relation between No. Of revolution and loss in weight in referral concrete and fly ash blended concrete mix.

E. Relation between Compressive strength and Abrasion resistance

There is a relation between the compressive strength and abrasion resistance (depth of wear)as shown in fig.4.11. it is evident from the fig.4.11 that abrasion resistance is closely related with its compressive strength as the The depth of wear decreases with increment in compressive strength of concrete mixes. The depth of wear has decreased from 2.48mm (Referral concrete, CS = 45.25 MPa) to 1.93mm (Fly ash blended concrete mix, CS = 51.35 MPa).also the depth of wear is inversely related to its corresponding abrasion resistance, as the depth of wear decreases so the abrasion resistance increases. Thus the abrasion resistance in fly ash blended concrete mix (35% replacement of OPC with fly ash) is higher as compared to referral concrete mixes.

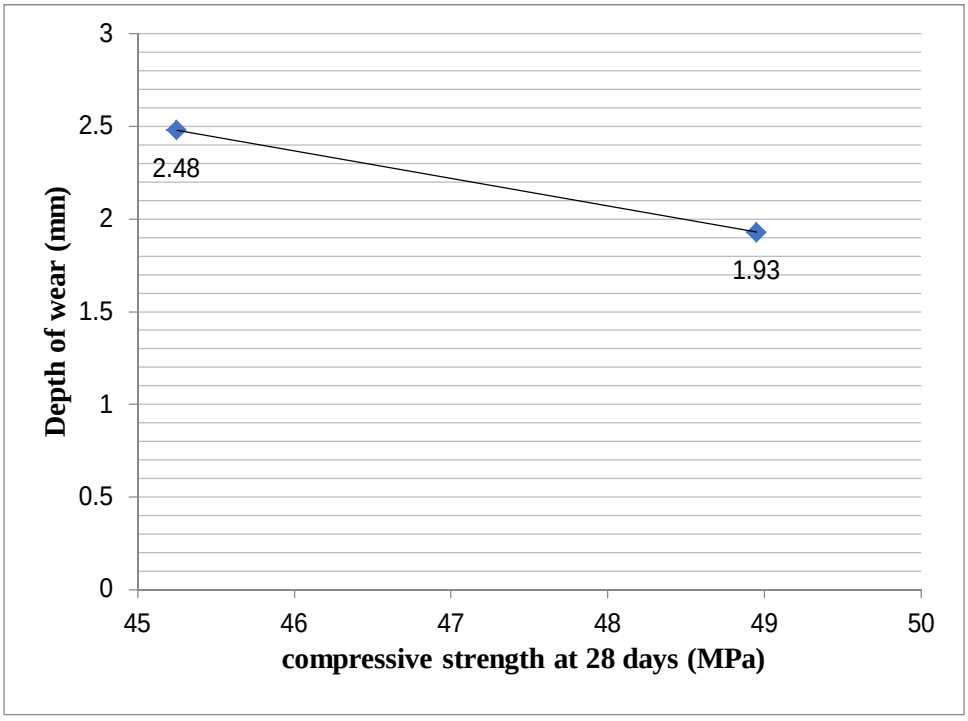


Fig.4.11 Relationship between compressive strength and depth of wear

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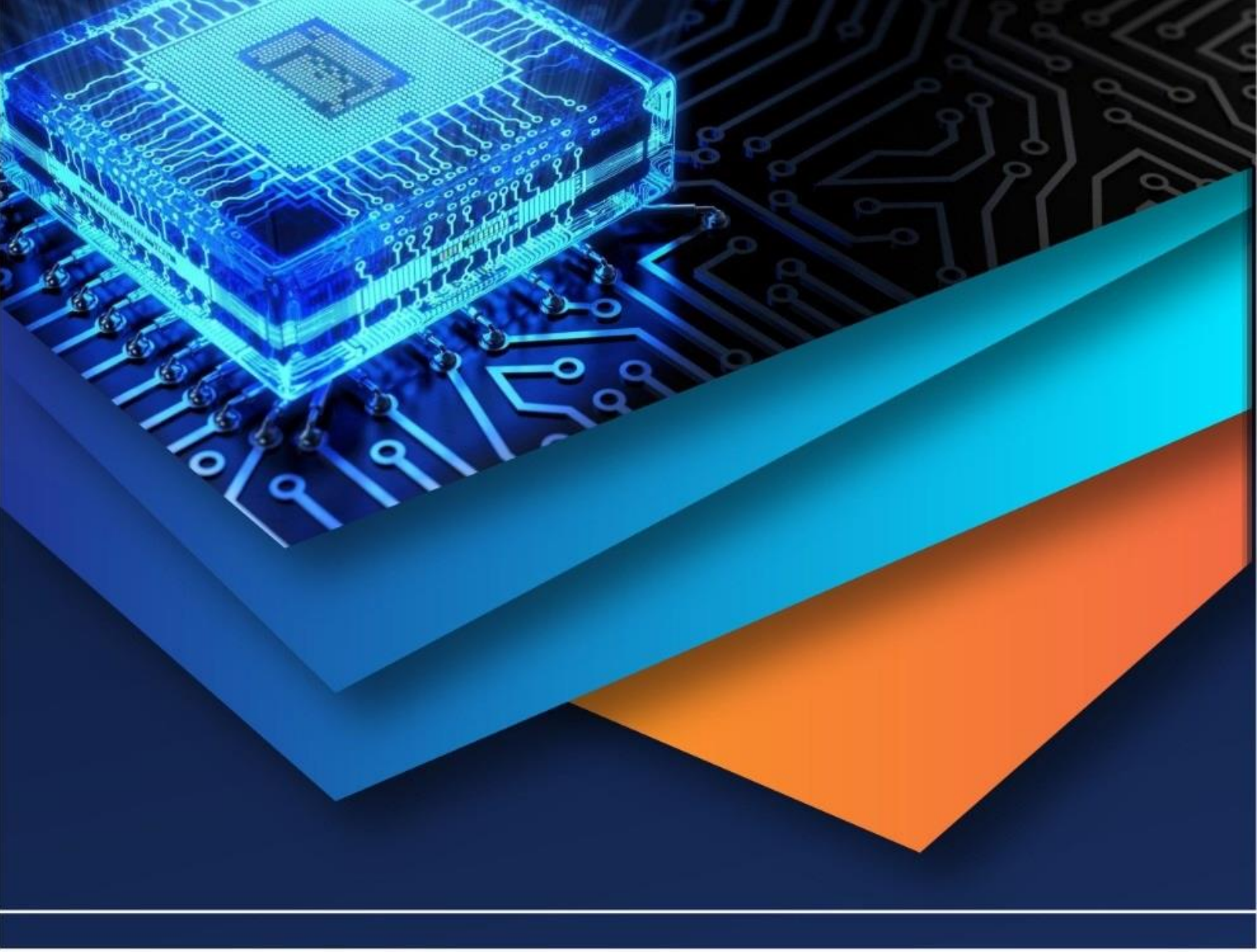
V. CONCLUSION

Workability (slump height) of concrete mixes after the replacement of cement with fly ash is increased considerably at all replacement levels. The optimum percentage level of replacing cement with fly ash is found to be at 35%.CS of fly ash blended concrete mixes at 35% replacement of cement is increased by 5.80% and 13.48% as compared to referral concrete at 7 and 28 days respectively.STS and FS of fly ash blended concrete mix is increased by 11.39% and 19.96% at 28 days with respect to referral concrete mix. Regression coefficient (value of R^2) is determined among strength properties ie. FS & CS, FS & STS and CS & STS and is 0.953, 0.932 and 0.938 respectively. Increment in regression coefficient, R^2 values of blended concrete mixes is increased by the addition of fly ash. Abrasion resistance of concrete mix at 35% replacement of cement with fly ash is increased as depth of wear has decreased considerably from 2.48mm (in referral concrete) to 1.93mm (in fly ash blended concrete mix).On the optimization of fly ash (at 35%) in concrete mixes, the depth of wear is reduced upto 22.17%.Thus Abrasion resistance is higher in fly ash blended concrete mixes with respect to referral concrete. Abrasion resistance of concrete is strongly correlated with % of fly ash content used and its compressive strength.

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