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ORIGINAL CONTRIBUTION

Use of Fly Ash for Improvement of Bond Strength with Different Development Lengths

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***Abstract*— The goal of this research is to explore the feasibility of using fly ash concrete for structural applications by testing the material's reinforcement bond properties. A pull-out test was performed on specimens with a 0, 20, 25, and 30 percent fly ash replacement of cement and then compared to identical tests performed on control specimens cast from a 100 percent Portland cement mix. The pull-out tests were performed on specimens with 12 mm, 20mm, and 25 mm steel bars used. Also, a compressive test was performed on specimens with 0, 20, 25, and 30 percent fly ash with the replacement of cement. As the fly ash percentage increases the slump value decreases. This creates problems in the workability of the concrete. When the slump decreases, then increase the strength of the concrete. As compared to normal concrete specimens tests performed with 100 percent ordinary Portland cement the use of 20, 25, and 30 percent results in an increase in both compressive and bond strength.**

***Index Terms*— Bond strength, Development length, Fly ash, Concrete**

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I. INTRODUCTION

Numerous scientists around the globe are becoming more involved in the use of fly ash (byproducts of burning coal used in power plants) in the production of fly ash concrete. This is primarily because fly ash represents one of the most affordable aluminum silicate substances, being high in silicon dioxide (SiO_2 40%-70% by weight) along with aluminum (Al_2O_3 15%-30% by weight) [1, 2]. Furthermore, using the residue of fly ash in concrete made from fly ash helps to reduce the negative ecological effects of dumping fly ash in garbage dumps [3]. Nevertheless, fly ashes generated from various power plants exhibit distinct features due to the addition of a variety of types of fuel (bituminous and lignite coal) and various gathering methods, which makes fly ash an unconventional substance [4, 5]. The deterioration of bars made of steel reduces the functional duration of concrete-steel structures, particularly in underwater or near harsh environments [6]. Furthermore, the process of producing cement consumes an enormous quantity of fuel. In reality, the manufacturing of cement accounts for 5-7% of the world's greenhouse gas emissions [7]. As a result, the primary obstacles are structural performance loss of concrete structures and the creation of high-performance concrete components with a small environmental impact. Plenty of scientists and engineers have put forward feasible alternatives to traditional building materials. To address steel-corrosion issues, Fibred Reinforced Polyethylene (FRP) can be utilized as internal reinforcements rather than reinforcement made from steel, improving the long-term reliability of such buildings [8]. Furthermore, by incorporating post-waste content such as fly ash ground, the mineral limestone powder, and crushed blast furnace slag, the resulting Self-Compacting Concrete (SCC) exhibits outstanding properties such as little use of energy, higher flow ability, and ease of constructing [9, 10]. Several investigations have been conducted to investigate the impact of FA on mechanical characteristics, particularly the compressive capacity of concrete [11, 12, 13]. A substantial boost in the strength of combined concrete mixes with 15% FA has been stated [14]. It has been observed that substituting 10% and 17% FA with cement. They tested results in a small rise in compression strength at 28 days and 90 days, respectively [13]. By entirely substituting the cement with FA, they discovered an enormous reduction in the bonding strength and compressive properties of concrete [15]. It was discovered that by supplanting up to 25% of cement with FA, the amount of FA in blends increased. Compressive ability decreases at ages 7 days and 28 days and rises at 90 days [16]. By substituting 15% along with 25% FA in high-strength cement concrete, it can be determined that the substitution of FA in strong concrete reduces the beginning strength while increasing compressive strength in the long term in comparison to plain concrete [17]. It has been discovered that 15 cm3 samples constructed from concrete featuring 50% FA have the identical bonding capacity as the normal untreated controlled specimen [18]. The direct pull-out test has been

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shown to increase the bond's strength by up to 20% [19]. The present research work discusses the effect of fly ash on the behavior of concrete composite. The fly ash has been taken 0 to 30% as a replacement for cement. Concrete specimens were prepared under different percentages of fly ash which was performed for testing after 28 days of age or curing. This research discussed the compressive strength of concrete and also the bond strength between concrete and steel. In there the compressive strength and bond strength of concrete between steels of normal concrete (0% fly ash use) with compare with different percentages of uses of fly ash with the replacement of cement.

The following are the objectives of the research.

- This research is about finding out the improvement of bond strength in concrete when cement is replaced with fly ash.
- To find out the bond strength with fly ash admixture in concrete.
- To investigate the development length of steel in concrete with different percentages of cement replaced with Fly Ash.
- To evaluate the effect of fly ash on the compressive of concrete.

II. MATERIALS AND METHOD

In this section, the materials and the methodology are discussed. In the materials portion fly ash is used in concrete while the fly ash is used in different percentages i.e. 20%, 25%, and 30% are replaced by cement. However, in methodology, the methods are considered like a collection of material, mixing, testing, curing, etc. so the materials used in the project are given in the following content i.e., cement, sand (fine aggregate), gravel (coarse aggregate), fly ash (FA), tap water and steel are the materials used in the project.

A. Materials

1) Water

The water used in the project was tap water from Sarhad University, Peshawar. Water will be free from sewage, oil acid, strong alkalies or vegetable matter, clay, and loam when used in concrete. The water used is potable and is satisfactory to use in concrete. A water sample was collected from the bore well. Water PH is 6.2 which is under the limit and chloride content is up to 45mg/l.

2) Composition of concrete

The composition of concrete with and without partial replacement is given as follows. Calculation of cement, sand, and coarse aggregate has been done by volume method. Mix designs were prepared by replacing 20%, 25%, and 30% of fly ash with cement. The normal concrete mix design was named NC.

TABLE I
CONCRETE COMPOSITION OF FLY ASH REPLACEMENT WITH CEMENT

Specimen Code	No. of Samples	Mix Design	W/C Ratio	Fly Ash (kg/m^3)	Cement (kg/m^3)	Sand (kg/m^3)	Crush (kg/m^3)
0%	9	1:1.5:3	0.5	0	12.852	21.402	42.804
20%	9	1:1.5:3	0.5	2.5704	10.281	21.402	42.804
25%	9	1:1.5:3	0.5	3.213	9.639	21.402	42.804
30%	9	1:1.5:3	0.5	3.774	9.084	21.402	42.804

B. Methods

The method adopted to carry out the working projects was according to the ASTM (American Society for Testing and Materials). The details of the methodology procedure are given as follows.

1) Mixing

A concrete mixer machine was used to mix the ingredients of concrete. Before pouring the materials like cement, sand, aggregate, fly ash, and water wash the mixing drum so that other waste materials like dust, etc. are already present there should be removed. Now putting the pour materials cement, aggregate, fly ash, and water in the drum according to the standard procedures as per calculation done by the mix design method. Some amount of water was added into the drum before the other materials as it lets not the materials clean the drum. And thus the process was furnished. The concrete materials were mixed for almost about 3 minutes in the mixing machine.

2) Lubrication of the molds

The lubrication was done inner side of the molds so that after 24 hours the specimen should be unmolded. Diesel oil was used for lubrication purposes.

3) The casting of the specimen (Cubes)

Casting is a manufacturing process in which a liquid material is usually poured into a mold. The pour concreted in the cubes is 3 layers and compact each layer 35 strokes with a tamping rod. After the compaction process is complete then finish the top surface with a trowel. The process is followed accordingly.

4) Curing

Curing is the process of keeping the unmolded specimens of concrete in the water for specified days by the ASTM standards. It may be 7, 14, and 28 days normally. In research, the unmolded specimen of the concrete curing process is 28 days. The process is followed accordingly.

5) Testing

The testing on concrete can be done in both fresh and hardened conditions of concrete testing.

6) Fresh concrete testing

In the fresh form of concrete, there were two types of tests which is the one is slump test method and the 2nd was the density of concrete.

7) Hardened concrete testing

The testing done on the hard form of concrete considered its mechanical properties and performed compressive strength of concrete and also perform pull-out test (bond strength) observed by the Universal Testing Machine (UTM).

8) Parameters

The parameters used to determine the effect of fly ash on bond properties of steel and concrete included the amount of fly ash in percentage which is

0%, 20%, 25%, and 30% in the concrete mix and the diameter of the bar is 12mm, 20mm and 25mm throughout the specimen.

III. RESULTS AND DISCUSSION

In this section, the calculation will be discussed as per the procedure and methodology adopted in the previous chapter, and an interpretation of the results will also be presented.

A. A sieve analysis (Fine aggregates)

TABLE II
OBSERVATIONS AND CALCULATIONS GRADATION OF FINE AGGREGATE

Sieve (mm)	Weight Retained (kg)	Percent Retained (%)	Cumulative Percentage Retained (%)	Cumulative Percentage Passing(%)
4.75	0.0265	2.65	2.65	97.35
2.36	0.0305	3.05	5.70	94.30
1.18	0.121	12.1	17.80	82.20
0.60	0.238	23.8	41.60	58.40
0.30	0.367	36.7	78.35	21.65
0.150	0.153	15.3	93.6	6.35
Pan	0.0165	1.65		

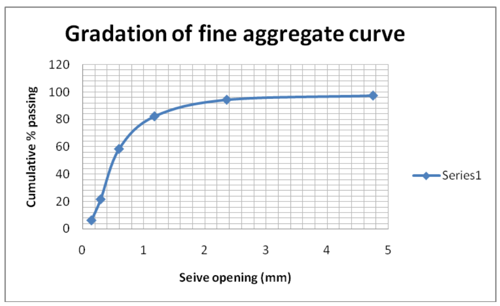

Fig. 1. Gradation of Fine Aggregates

Sum of Cumulative % retained is = 239 and = 239/100 = 2.39

Finally, calculate fines modulus by using the formula = Σ Cumulative % retained /100

B. A sieve analysis (Coarse aggregates)

TABLE III
OBSERVATIONS AND CALCULATIONS OF GRADATION OF COARSE AGGREGATE

Sieve (mm)	Weight Retained (kg)	Percent Retained (%)	Cumulative Percentage Retained (%)	Cumulative Percentage Passing (%)
19	119.78	11.98	88.02	11.98
12.5	384.15	38.42	49.6	50.4
9.5	324.38	32.44	12.16	82.84
4.75	163	16.3	0.86	99.14
				244.36

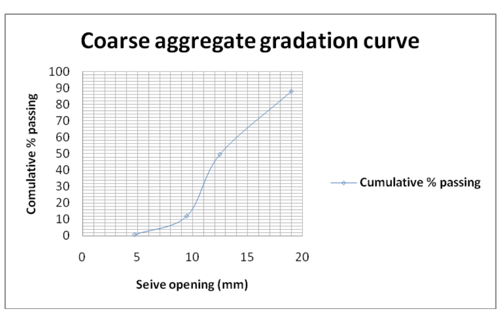

Fig. 2. Gradation of Coarse Aggregate

Finally calculate fines modulus by using formula = Σ Cumulative % retained /100 F.M = 244.36/100 = 2.44

C. Slump test

NC has represented the normal concrete in which 0% fly ash is used and C20, C25, and C30 are represented in which different percentages of fly ash are used e.g., 20%, 25%, and 30% with replacement with cement.

TABLE IV
SLUMP TEST RESULT

S. NO.	Sample Types	Specimen		Slump Value (inch)	Slump Value (mm)
		Fly ash (%)	Cement (%)		
1	CN	0	100	3.5	88.90
2	C20	20	80	1.5	38.10
3	C25	25	75	1	25.40
4	C30	30	70	0.5	12.70

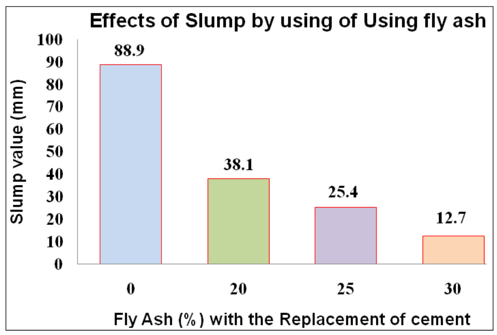

Fig. 3. Slump Test Results

As from Table IV, the introduction of fly ash to concrete significantly reduced the slump and workability. All concrete mixes were designed to have a slump of 88.9 mm; however, all of the mixes had a slump of much less. It was noted that the slump was reduced as the percentage of fly ash was increased. The mix consisting of 20% fly ash had a slump of 38.1mm followed by the 25% fly ash mix having a 25.4mm slump while the mix with 30% replacement of cement by Fly Ash (FA) had a slump of just less than 12.7mm regardless of the rubber having modified surface or not. In general, as the percentage amount of fly ash increased the amount of energy required for casting specimens increased substantially.

D. Compressive strength

Partial replacement of cement with 0% of fly ash.

TABLE V
PARTIAL REPLACEMENT OF FLY ASH 0% WITH CEMENT

S.NO	Sample Name	Specimen		Compression Strength (psi)	Average Compression Strength (psi)
		Fly Ash (%)	Cement (%)		
1	CN 1	0	100	1799	2309
2	CN 2	0	100	2728	
3	CN 3	0	100	2400	

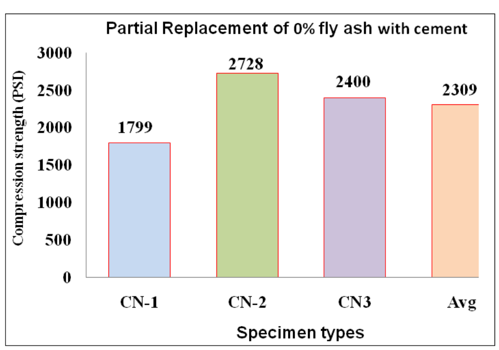

Fig. 4. Partial Replacement of 0% Fly Ash with Cement

IV. DISCUSSION

From Table V, NC1, NC2, and NC3 are the different samples with replacement 0% of fly ash in the concrete cube. It shows the compressive strength of each cube as shown in the above graph. The average values of these three samples are above 2200 psi which is recommendable for the compressive strength ranges from 2200 psi to 4400 psi for residential concrete. From Figure 4, NC2 is the maximum compressive strength while NC1 and NC3 are the minimum compressive strength. To this NC2 samples, the compressive strength of other % replacement of samples will be compared.

A. Partial Replacement of Cement with 20% of Fly Ash (FA)

TABLE VI
PARTIAL REPLACEMENT OF 20% OF FLY ASH WITH CEMENT

S.NO.	Sample Name	Specimen		Compression Strength (psi)	Average Compression Strength (psi)	Control Average NC
		Fly Ash (%)	Cement (%)			
1	CN 1-20	20	80	991.9	1408.86	2309
2	CN 2-20	20	80	1756.4		
3	CN 3-20	20	80	1478.3		

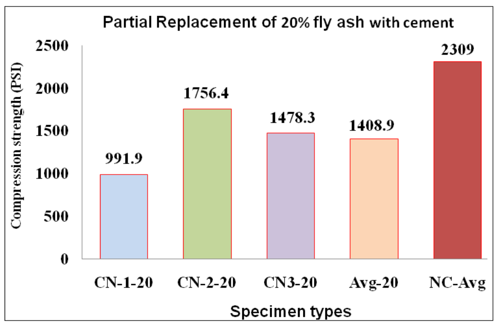

Fig. 5. Partial Replacement of 20% Fly Ash with Cement

Table VI and Figure 5, show the comparison of each cube with 20% of fly ash (FA) to the concrete. NC -1-20, NC-2-20, and NC-3-20 are the samples replaced by fly ash, showing the compressive strength of each cube. The compressive strength is reduced as introduced the 20% of fly ash is to the concrete as compared with the control sample. The graph shows the NC-2-20 sample's maximum value and the other minimum value. The average values come from these three samples are equal to 1408.9.

B. Partial Replacement of Cement with 25% of FA

TABLE VII
PARTIAL REPLACEMENT OF 25% WITH CEMENT

S.NO	Sample Name	Specimen		Compression Strength (psi)	Average Compression Strength (psi)	Control Average NC
		Fly Ash (%)	Cement (%)			
1	CN-1-25	25	75	2345.9	2554. 56	2309
2	CN-2-25	25	75	2723		
3	CN-3-25	25	75	2594.8		

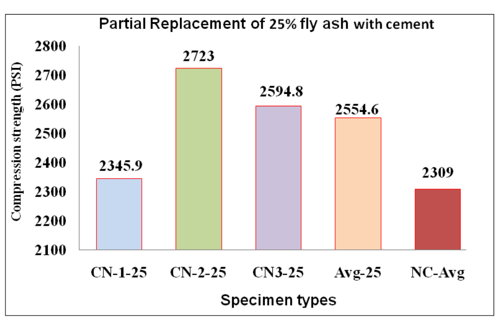

Fig. 6. Partial Replacement with 25%

Table VII to an increase in the amount of fly ash from 20% to 25%, then the strength of fly ash replacement with 25% increasing more than to compare with 20% of replacement. Average compression is increased up to 2554.6 psi. From Figure 6, the CN-2-25 is maximum compressive strength and the other specimen is minimum compressive strength. The average control using 25% is increased here but the Control specimen (0% fly ash used) average compressive strength is decreased.

C. Partial Replacement of Cement with 30% of Fly Ash

TABLE VIII
PARTIAL REPLACEMENT OF 30% WITH CEMENT

S.NO.	Sample Name	Specimen		Compression Strength (psi)	Average Compression Strength (psi)	Control Average NC
		Fly ash (%)	Cement (%)			
1	CN-2-30	30	70	2169.7	2463.69	2309
2	CN-2-30	30	70	2745		
3	CN-3-30	30	70	2476.36		

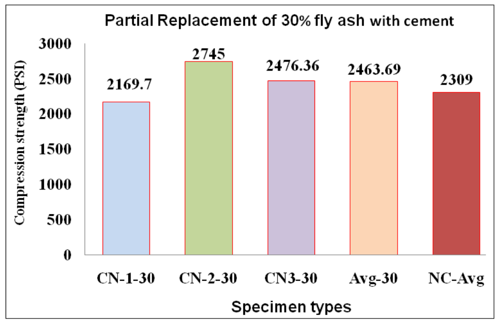

Fig. 7. Partial Replacements of 30% Fly Ash with Cement

From Table VIII, NC-1-30, NC-2-30, and NC-3-30 show the replacement of 30% of fly ash with cement. The strength is decreased by fewer amounts as increase the fly ash from 25%. From Figure 7, sample NC-2-30 is the maximum compressive strength value, and sample NC-1-30 and NC-3-30 is the minimum compressive strength value. The average control reduces by using 30% of fly ash.

D. Results of All the Percentages of Compressive Strength

TABLE IX
COMPRESSIVE STRENGTH RESULT

S.NO.	Sample Name	Percent Replacement (%)	Control Sample (psi)	No. of Samples	Compression Strength (psi)	Average Compression (psi)
1	NC-1	0	2309	3	1799	2309
	NC-2				2728	
	NC-3				2400	
2	NC-1-20	20	2309	3	991.9	1408.86
	NC-2-20				1756.4	
	NC-3-30				1478.3	
3	NC-1-25	25	2309	3	2345.9	2554.56
	NC-2-25				2723	
	NC-3-25				2594.8	
4	NC-1-30	30	2309	3	2169.7	2463.69
	NC-2-30				2745	
	NC-3-30				2476.36	

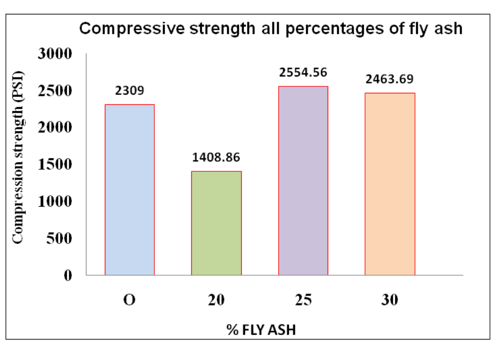

Fig. 8. Compressive Strength Results

Table IX results from the test program show a significant only 20% fly ash specimen sample compressive strength decreased to compare the control samples. Other 25% and 30% samples of fly ash content specimens are increased by comparing the control specimen with 0% fly ash. This table shows the percentage changes in compressive strength for each mix.

E. The Bond Strength between Steel and Concrete

1) Using 0% fly ash (FA)

The concrete specimen dimension of (150mm X 150mm X 150mm) was used and the results demonstrate that using the same proportion of fly ash with different diameter of bars give different values and the projected length of bars is according to the formula 5db are used. For example for 12mm diameter of steel bars is 5 X 12 = 60mm say 2 inches. The highest value of stress load (KN) is shown in Table IX.

TABLE X
EFFECT OF BOND STRENGTH WITH 0% FLY ASH

S.NO.	Sample Name	Steel's Bar Diameter (mm)	No's of Sample	Bars Projected Length (Inch)	Specimen		Max Load (KN)
					Fly Ash (%)	Cement (%)	
1	NC-1	12	2	2	0	100	48.468
	NC-2						62.839
2	NC-1	20	2	3	0	100	66.812
	NC-2						78.394
3	NC-1	25	2	4	0	100	77.778
	NC-2						86.893

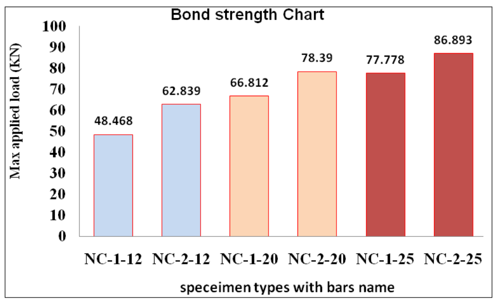

Fig. 9. Using 0% of Fly Ash (Bond Strength)

F. Using 20% Fly Ash (FA) with the Replacement of Cement

The concrete specimen dimension of (150mm X 150mm X 150mm) was used and the results demonstrate that using the same proportion of fly ash with different diameter of bars give different values and the projected length of bars is according to the formula 5db are used. For example for 12mm diameter of steel bars is 5 X 12 = 60mm say 2 inches. The highest value of stress load (KN) is shown in Table X.

TABLE XI
EFFECT OF BOND STRENGTH WITH 20% FLY ASH

S.NO.	Sample Name	Steel Bar Diameter (mm)	No. of Samples	Bars Project Length (Inch)	Specimen		Max Load (KN)
					Fly Ash (%)	Cement (%)	
1	NC-1-20-12	12	2	2	20	80	35.658
	NC-2-20-12						44.784
2	NC-1-20-20	20	2	3	20	80	55.546
	NC-2-20-20						68.947
3	NC-2-20-25	25	2	4	20	80	70.132
	NC-3-20-25						89.934

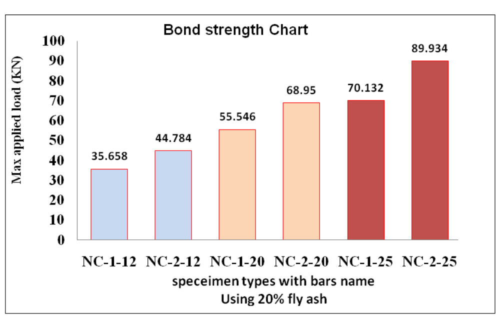

Fig. 10. Using 20 % Fly Ash

G. Using 25% Fly Ash (FA) with the Replacement of Cement

The results demonstrate that using the same proportion of fly ash with different diameter of bars give different values and the projected length of bars is according to the formula 5db is used. The highest value of stress load (KN) is shown in Table XII.

TABLE XII
EFFECT OF BOND STRENGTH WITH 25% FLY ASH

S.NO.	Sample Name	Steel Bar Diameter (mm)	No. of Samples	Bars Project Length (Inch)	Specimen		Max Load (KN)
					Fly ash (%)	Cement (%)	
1	NC-1-25-12	12	2	2	25	75	34.728
	NC-2-25-12						47.829
2	NC-1-25-20	20	2	3	25	75	59.712
	NC-2-25-20						64.26
3	NC-1-25-25	25	2	4	25	75	80.462
	NC-2-25-25						98.678

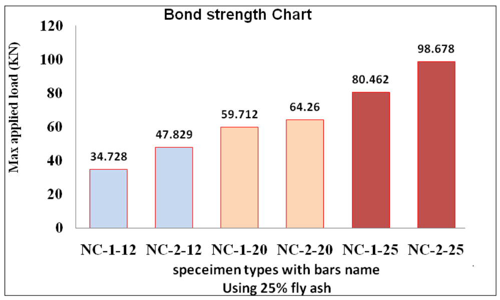

Fig. 11. Using 25% Fly Ash

H. Using 30% Fly Ash (FA) with the Replacement of Cement

The results demonstrate that using 30% of fly ash with different diameter of bars give different values and the projected length of bars is according to the formula 5db is used. The highest value of stress load (KN) is shown in Table XII.

TABLE XIII
EFFECT OF BOND STRENGTH WITH 30% FLY ASH

S.NO.	Sample Name	Steel Bar Diameter (mm)	No's of Samples	Bars Project Length (Inch)	Specimen		Max Load(KN)
					Fly Ash (%)	Cement (%)	
1	NC-1-30-12	12	2	2	30	70	55.282
	NC-2-30-12						64.678
2	NC-1-30-20	20	2	3	30	70	57.312
	NC-2-30-20						73.669
3	NC-1-30-25	25	2	4	30	70	63.552
	NC-2-30-25						84.987

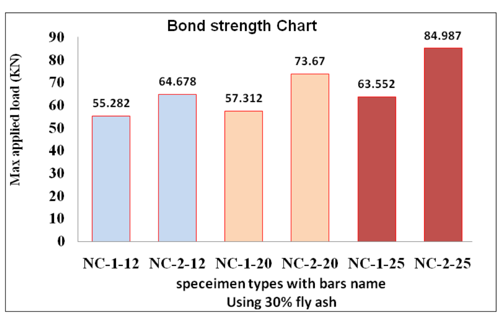

Fig. 12. Using 30% Fly Ash with the Replacement of Cement

I. Comparing Different Bar No with Different Percentages of Fly Ash

The combined results of 12mm bar with 0%, 20%, 25%, and 30% fly ash in which used. The results of 12mm steel bars are stress maximum in 30% fly ash as compared to 0%, 20%, and 25% in concrete cube specimens. The control specimen is high stress other than 20%, 25%, and less than 30% of using fly ash. Also discussed was the result of 20mm diameter of the bar used in the concrete cube specimen with using 0%, 20%, 25% and 30% of fly ash. As the result are the control specimen is high in which 0% fly ash used. The using of fly ash with 25% stress is more than 20%, 25%, and less than the control specimen with 0%. In a 25mm diameter of the bar, the stress is high in using 25% fly ash. And the control specimen stress is more than 20%, 30%, and less than 25% using fly ash with replacement of cement. As shown in given Table XIV.

TABLE XIV
COMPARED BOND STRENGTH WITH A DIFFERENT BAR OF DIAMETER WITH DIFFERENT % OF FLY ASH

S.NO.	Steel Bar Diameter (mm)	Bars Project Length (Inch)	Specimen		Average Max Load (KN)
			Fly Ash (%)	Cement(%)	
1	12	2	0	100	55.653
			20	80	40.22
			25	75	41.278
			30	70	59.98
2	20	3	0	100	72.603
			20	80	62.246
			25	75	61.986
			30	70	65.9
3	25	4	0	100	82.34
			20	80	80.03
			25	75	89.7
			30	70	74.26

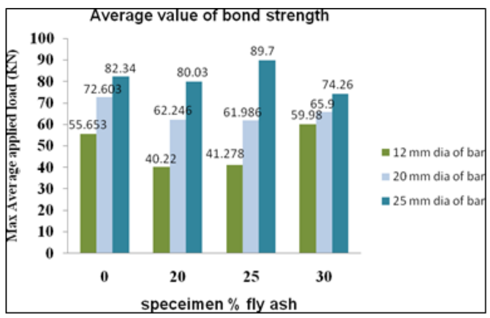

Fig. 13. Comparing Different Diameter of Bars and Different % Ages of Fly Ash

V. CONCLUSION

From the experimental studies, the following conclusions are drawn.

- From the above study, it concluded that bond strength is high when adding 25% of fly ash with a diameter of bar 25mm (24% increases).
- The pull-out specimen with a large diameter of bar size has greater bond strength as compared to the specimen with a small diameter of bar.
- With the addition of 25% fly ash, average compression is increased up to 2554.6 psi as compared to the average of the control specimen, 20%, and 30% by using fly ash.
- By adding fly ash the compressive strength is increased in the percentage of 25% and 30% as compared to the sample of the control specimen but by using 20% fly ash the compressive strength decreased over the control specimen.
- With the increase in fly ash percentage, the slump value decreases.
- In the control specimen the slump value is 88.90mm by using 30% fly ash slump value is 12.70.
- The difference in slump value is 76.2% between the control specimen concrete and using 30% fly ash.

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