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# A Study on bond strength of normal concrete to high volume fly ash concrete

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**Abstract.** Now-a-days the deterioration of concrete is further current due to numerous reasons like improper bonding, corrosion of steel, inferior quality of materials any as improper accomplishment. The deterioration of concrete finishes up in reduction in helpful strength of concrete therefore necessitates the adoption of correct repairing ways in which some repairing / strengthening techniques of concrete structures frequently involve adding new concrete to associate existing concrete 0.5. The bond performance between the existent and repair concretes plays a awfully important role on the powerfulness of this strengthening strategy. Surface treatments like wire - brushing, sandblasting, water spouting, chipping, etc., unit typically adopted. The Bond strength at the interface depends on roughness of the substrate that successively depends on Cohesion and Friction at the interface.at intervals the gift study previous concrete substrates every at 450 angles with vertical and in addition the ash concrete as overlaid material were unreal to live the shear the parameters of the investigation embrace 1) totally utterly completely different grades of concrete substrate (M30 & M60) 2) Roughness condition at the interface (Smooth (as cast) &Rough (chipped indentations)) 3) The overlaid concrete with different percentages of cement replacement with ash (0%, twenty fifth and 50%) 4) Varying percentages of steel reinforcement resisting the shear at the interface (4 No's of 4mm military intelligence (0.502%) and four No's of 6mm military intelligence. The specimen adopted is additionally a customary prism size of 400mm X 100mm X 100mm.The take a look at conducted is 'Slant Shear test' as per SB 6319 zero.5 5.From shear tests it totally was found that the bond strength between the 2 interfaces was accumulated for twenty fifth ash content in overlaid concrete and reduced for five hundredth ash content in overlaid concrete all the same the roughness of the substrate. However, the magnitude of increase in bond strength relied on the roughness of the substrate. further the presence of Steel reinforcement (Substrate with no treatment for the roughness at the interface) accumulated the bond strength at the interface. From the determined Bond strength at the interface it's tried to estimate the planning constant of Cohesion and magnificence constant of Friction at the interface between the normal concrete and the fly ash overlaid concrete

## 1. Introduction



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Concrete is additionally a predominant material utilized in construction and it competes directly with all utterly completely different major construction materials like timber, steel, asphalt, and stone, as a result. However, concrete is additionally a stuff and its properties will vary considerably counting on the selection of materials and proportions for a specific application. However, concrete will have weaknesses that limit its use in bound applications. Now-a-days associate degree outsize vary of existing concrete structures worldwide unit in pressing would adore of effective and sturdy repair. it's been estimable concerning} about zero.5 all concrete repairs fail due to the shortage of reliable and ideal bond. wise bonding between repair materials and existing concrete repair substrate is of significant importance at intervals the concrete repairs. The strength and integrity of the bond depends not alone upon the substrate concrete properties and in addition the interface factors (such as surface roughness and soundness, bond adhesive, standing conditions, ...), however also physical and chemical characteristics of repair materials. In order to form these structures purposeful throughout the remaining years of service life, applicable repairs unit created getable with the assistance of various repair techniques that utilizes the new Commercially out there materials for concrete repair are about to be handily classified as follows • **Resinous materials:** epoxy mortar, polyester mortar, Acrylic mortar mixtures, polymer grouts. • **Polymer-modified whole materials:** SBR (styrene compound rubber) changed, range twelve phosphate changed, alkyl radical vinyl acetate whole materials. • **Cementitious materials:** OPC-Sand mortar, High corundum Cement (HAC) mortar, HAC and OPC mixed mortar, growth manufacturing grout, flowing grouts.

New styles of concrete are developed over the years, such as

- Fiber-reinforced concrete,
- Shrinkage-compensated concrete and
- Latex-modified concrete.

The bond strength at the interface between concrete layers forged at totally utterly completely different ages is very important to form bound the monolithic behavior. The behavior of Concrete composite members is very influenced by the surface conditions of the interface and by the differential shrinkage and stiffness of each concrete components. Repair and maintenance of created facilities is presently a growing balk globally, that involves important expenditure. This could be typically associated with poor proportioning of concrete mixture and lack of management in creating concrete to travel close to the environmental conditions.

### *1.1. Bond Strength*

The bond strength is that the adhesion between overlay and substrate that may be the weakest link of the system. wise bond strength is additionally a key issue to possess a monolithic system. Bond is about to be expressed by shear resistance or tensile resistance. it's important to pick out the one that may higher state the stresses subjected to the structure at intervals the arena. whereas in several cases the strain at intervals the arena is of shear kind it's further informed use the strength for bonding in structural work.

Various factors that may influence the bond strength Bonding agent at the interface between previous and new substrates. Type of the changed to a fault concrete like silicon dioxide fume further, latex epoxy, fiber bolstered concrete

### *1.2. High-volume fly ash*

Currently, alone relating to twenty five to thirty percent of this material is recycled and used as a mineral admixture in concrete and in many applications, like soil stabilization. The rest, regarding seventy to seventy five percent is usually buried in landfills (Coal ash).

### *1.3. Chemical composition and classification of fly ash*

Two categories of ash are outlined by ASTM C618 as 1) category 'F' ash and 2) category 'C' ash. Table 1.1 proportion of assorted parts in several styles of ash.

#### 1.4. Disposal and market sources

In the past, ash made from coal combustion was merely haunted by flue gases and disposed in to the atmosphere. This created environmental and health considerations that prompted laws that have reduced ash emissions to but I Chronicles of ash made. Worldwide, over sixty fifth of ash made from coal power stations is disposed of in landfills. In Asian nation alone, ash lowland covers a locality of forty,000 acres (160 sq.km).

#### 1.5. Fly ash reuse

The recycle of ash as associate degree engineering material primarily stems from its pozzolanic nature, spherical form and relative uniformity. Ash utilization, in falling frequency, includes usage in: Waste stabilization and action, Flow in a position fill, Raw feed for cement clinkers, Mineral filler in mineral concrete and Mine reclamation, alternative applications embrace cellular concrete, roofing tiles, metal castings, and filler in wood and plastic product.

#### 1.6. Environmental problems

Fly ash, like soil, contains trace concentrations of the many significant metals that are better-known to be prejudicial to health in decent quantities. These embrace nickel, vanadium, arsenic, beryllium, cadmium, Barium, Chromium, Copper, Molybdenum, Zinc, Lead, Selenium, Uranium, metallic element and Radium these components are found in very low concentrations in ash, their mere presence has prompted some to sound alarm.

## 2. Objectives and scope of the work

The main objectives of the current experimental investigation is to

- Review the bond strength at the concrete interfaces between traditional concrete and ash concrete.
- What is that the bond strength between the traditional concrete substrate and ash concrete overlay.
- What is that the result of Roughness of the interface on the bond strength
- How the modification in percent of steel (resisting the shear) on bond strength at the interface
- What are the values of style Coefficients for Cohesion and Friction at the interface

#### 2.1. Scope of the present study

In the gift study recent concrete substrates every at 45 degree angle with vertical and also the ash concrete as overlaid material were invented to live the shear bond strength at interface.

The following are the parameters of the experimental investigation

- Different grades of concrete substrate (M30 & M60)
- Roughness condition at the interface (Smooth (as cast) & Rough (chipped indentations))
- The overlaid concrete with totally different percentages of cement replacement with ash (0%, twenty fifth and 50%)
- Different percentages of steel reinforcement resisting the shear at the interface (4 No's of 4mm military intelligence (0.502%) and four No's of 6mm military intelligence (1.13%) bars).

The specimen adopted could be a customary prism size of 400mm X 100mm X 100mm. The check conducted is 'Slant Shear test' as per BS 6319 part five.

## 3. Experimental study

The experimental program was designed to review the bond strength between recent concrete and new concrete interface the following interfaces are created. They are:

- M30-M40: The recent substrate of M30 grade concrete with smooth surface and rough surface and also the over laid substrate of M40 grade concrete with HVFA with 0%, 25%, 50%.

- M30-M60, The recent substrate of M30 grade concrete with swish surface and rough surface and also the over ordered substrate of M60 grade concrete with HVFA with 0%, 25%, 50%.
- M30-M40, The recent substrate of M30 grade concrete with 4mm and 6mm military intelligence bars and also the over ordered substrate with M40 grade of concrete.
- M30-M60, The recent substrate of M30 grade concrete with 4mm and 6mm diameter bars and also the over ordered substrate with M60 grade of concrete.

### 3.1. Materials used

Cement utilized in the investigation was fifty three Grade OPC confirming to IS: 12269. The fine aggregate conforming to Zone-2 in keeping with IS: 383 were used, the fine aggregate used was obtained from a close-by stream supply. relative density of the sand is 2.58. The coarse aggregate was obtained from an area crushing unit having 20mm traditional size and well stratified mixture in keeping with IS: 383 was utilized in this investigation with relative density of the coarse aggregate is 2.65. Water is a vital ingredient of concrete because it truly participates within the chemical action with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is needed to be looked into fastidiously. Mineral admixtures are included in the overall cementitious material system. The optimum quantity to be used should be established by testing in laboratory.

In this specific study, entirely the fly ash is employed as a result of the mineral admixture .in this context, tolerably information is gathered in regard of ash that's helpful in experimental work. Class 'F' ash, obtained from Vijayawada Thermal station, was used and its properties are given in (IS: 3812-2003). Chemical admixtures-water reducers, retarders, high vary super plasticizers and consistence modifying agents. Super plasticizers-Conplast SP 430 is required to spice up the workability. Reinforcements-4mm and 6mm bars are utilized in sleek surface substrate to crate roughness at intervals the place of break the previous substrate.

### 3.2. Tests on bond strength

#### 3.2.1. Slant shear test

One in each of the foremost common forms of bonding tests is “Slant Shear Test” at intervals that the interface is to a lower place combined state of compression In compressive take a glance at, concrete failure happens as a results of the shear cracks at intervals the incline plane. The angle of failure plane with horizontal direction is in theory between  $50^\circ$  and  $70^\circ$ , thus thus could be associate correct assumption. Therefore, throughout this take a glance at technique the interface is placed inclined with constant angle and a compressive force is applied to the system.



**Figure 1.** Slant shear test



**Figure 2.** Split tensile test

It need to be noted that the ASTM C882-99 focuses on bond strength of epoxy-resin system. So, in ASTM the take a glance at procedure is to position two match cylinder halves and bond them with epoxy. aside from testing the bond strength of two absolutely all wholly totally different materials the second need to be compelled to be cast once substrate having been cured and prepared.

### 3.2.2. Rebound hammer test

All members to be marked with well-defined grid points - spacing of 2 hundred - 300 metric amount most well liked. Each grid purpose to be clean and surface swish. A minimum of half-dozen readings to be obtained at each purpose and average thought of omitting too low and too high values.

### 3.2.3. Ultrasonic pulse velocity test

This technique accustomed certify the Homogeneity of concrete - Presence of voids, cracks or general loss of integrity - Qualitative and relative condition of concrete - a combination of rebound numbers and UPV values helps to identify corrosion prone locations.

### 3.2.4. Moulds

standard prism size of 400mm X 100mm X 100mm mould is employed for casting the prisms. A standard mixer of rotating drum quite half bag capacity was used for mixing the concrete. A plate vibrator was used for compacting the prisms. For old substrate a plate was arranged in between the two fresh concrete surfaces to create required angles of 45 degree angle as in below figure



**Figure 3.** Process of casting prism making regular 45<sup>0</sup> angle by keeping a steel plate



**Figure 4.** Specimen that had chipped at intervals after 28 days of curing at 45<sup>0</sup>

For new substrate, the previous substrate was unbroken at intervals the mould and remaining portion need to be compelled to be packed with up thus far concrete.



**Figure 5.** Casting of new substrates over the old substrate

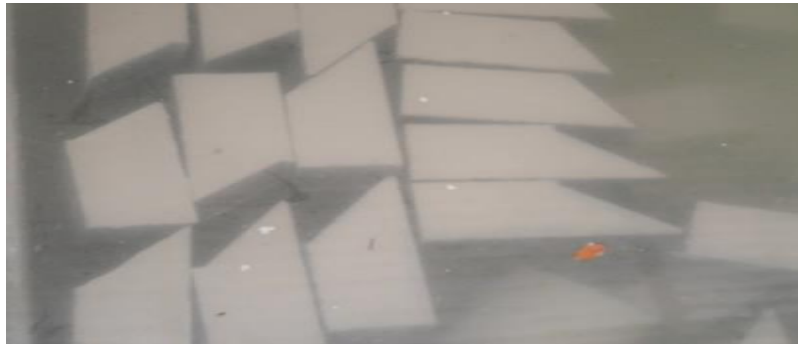


**Figure 6.** Specimen that had casted with 6mm diameter bars at 45<sup>0</sup>



**Figure 7.** Casting of new substrate with steel plate creating an angle 45<sup>0</sup>

The specimens left in mould that possessing the shut conditions viz. temperature of a try of 7 two C and ninetieth quantitative relation for 24 hours.



**Figure 8.** Old substrates kept for curing



**Figure 9.** Specimen after adding new substrate to the old substrate kept for curing

This take a glance at is performed on cube specimens to determine compressive strength at varied ages.



**Figure 10.** CTM prisms are tested under compressive strength

**4. Results and discussion**

*4.1. Bond strength Vs you're taking care of ash content comparisons for various proportions.*

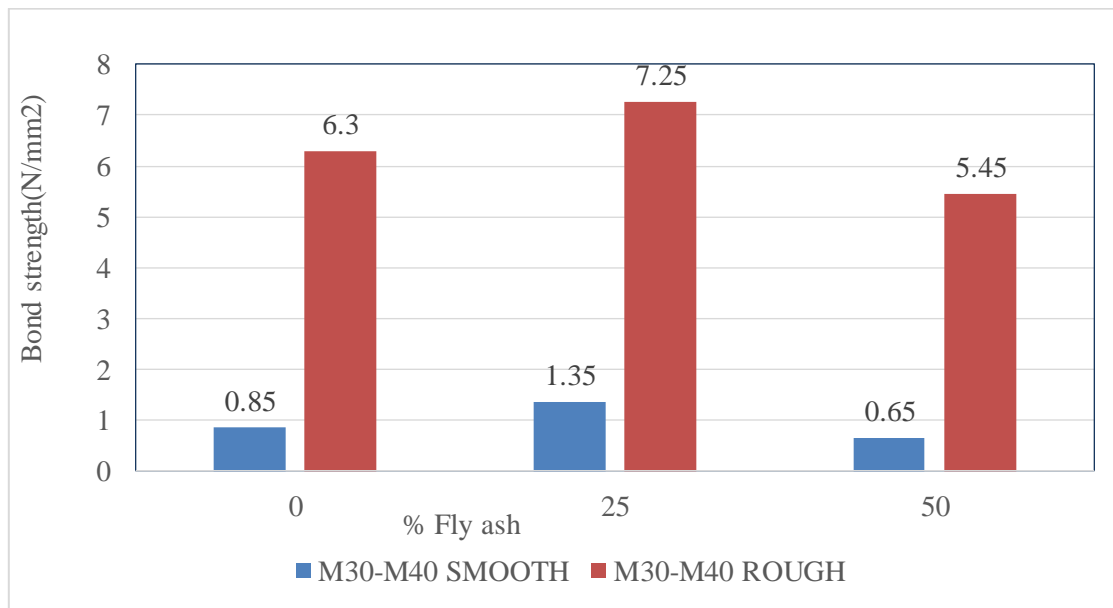
**Table 1.** Bond strength in smooth and rough surfaces with % of fly ash in M30-M40 for concrete

GRADE	% OF FLY ASH	LOAD VALUES(KN)	LOAD VALUES(KN )	AVERAGE BOND STRENGTH(N/mm <sup>2</sup> )	AVERAGE BOND STRENGTH(N/mm <sup>2</sup> )
M30-	0	30	195	0.85	6.3
M40		25	215		

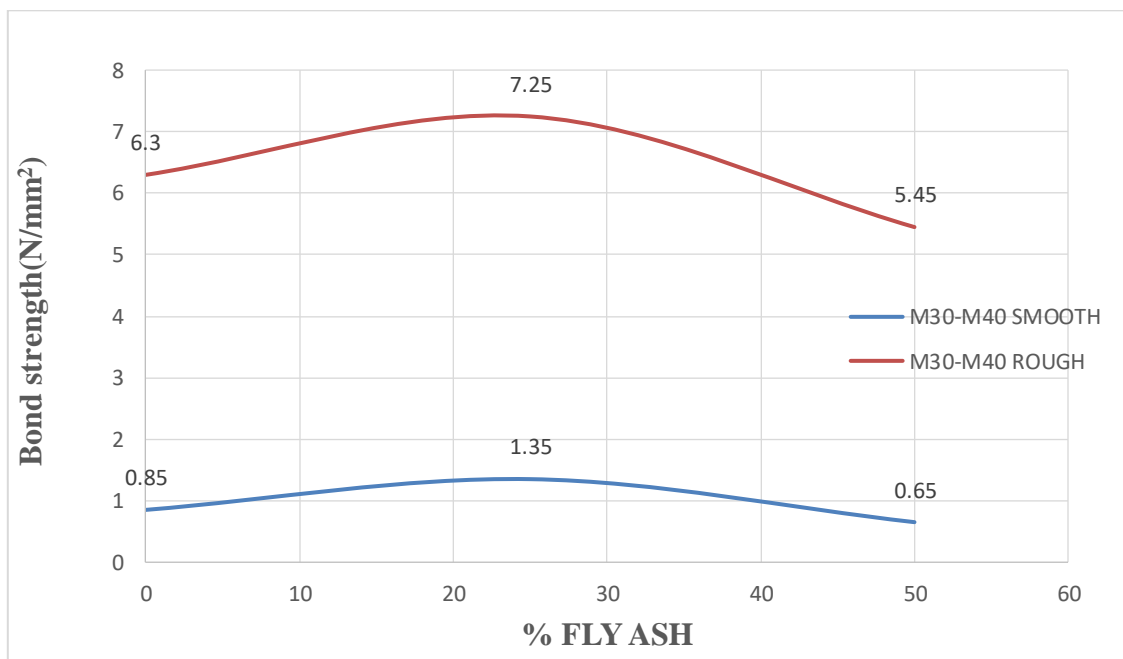


	30	220		
	45	240	1.35	7.25
25	50	230		
	40	255		
	25	190	0.65	5.45
50	20	170		
	20	185		

- a) In M30-M40 smooth interface the value of the bond strength can increase by 50 % once ash replaced 25%. And for 50% replacement of fly ash the bond strength value decreases by 20%.
- b) In M30-M40 smooth interface the value of the bond strength can increase by 50 % once ash replaced 12.9%. And for 50% replacement of fly ash the bond strength value decreases by 14.7%.



**Figure 11.** Bar chart for bond strength for M30-M40 with smooth and rough interfaces



**Figure 12.** Bond strength Vs % of fly ash content curve for M30-M40 with smooth and rough substrates at 45°

4.2. Bond strength Vs you're taking care of ash content comparisons for various proportions.

Table 2. Bond strength in smooth and rough surfaces with % fly ash in M30-M60 grade of concrete

GRADE	TYPE OF INTERF ACE	% OF FLY ASH	SMOOTH	ROUGH	SMOOTH	ROUGH
			LOAD VALUES(KN)	LOAD VALUES(KN)	AVERAGE BOND STRENGTH(N/mm <sup>2</sup> )	AVERAGE BOND STRENGTH(N/mm <sup>2</sup> )
M30-M60	SMOOTH	0	50	270	1.45	7.85
			40	255		
			55	260		
		25	70	280	2.35	8.65
			85	275		
			80	310		
	ROUGH	0	30	205	0.9	5.45
			25	240		
		50	35	220		

a) In M30-M40 smooth interface the value of the bond strength can increase by 26 % once ash replaced 25%. And for 50% replacement of fly ash the bond strength value decreases by 35%.

b) In M30-M40 smooth interface the value of the bond strength can increase by 10.16 % once ash replaced 25%. And for 50% replacement of fly ash the bond strength value decreases by 27.18%.

4.3. Bond strength Vs diameter of the bar

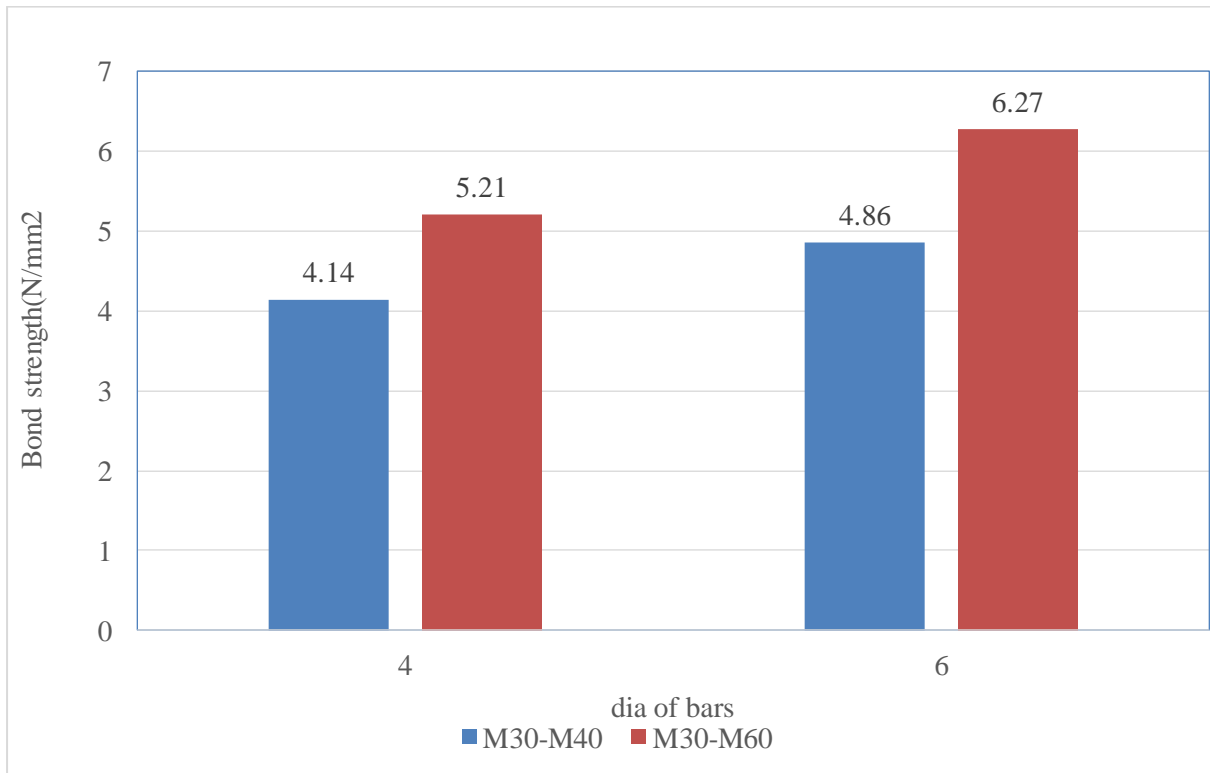
4.3.1. For M30-40 grade concrete and M30-M60 interfaces

Table 3. Bond strength with respect to reinforcement content in M30-M40 and M30-M60 grade of concrete

GRADE	DIAMETER OF BARS (mm)	LOAD VALUES(KN)		AVERAGE BOND STRENGTH(N/mm <sup>2</sup> )
		WITH CONSIDERING REINFORCEMENT EFFECT(p)	WITH OUT CONSIDERING REINFORCEMENT EFFECT (p <sub>c</sub> = p <sub>ps</sub> )	
M30-M40	4	140	136.45	4.14
		150	146.20	
		135	131.58	
	6	170	160.62	4.86
		180	170.06	
		165	155.89	
M30-M60	4	170	165.69	5.21
		195	190.06	
		225	212.58	
	6	210	198.41	6.27

230

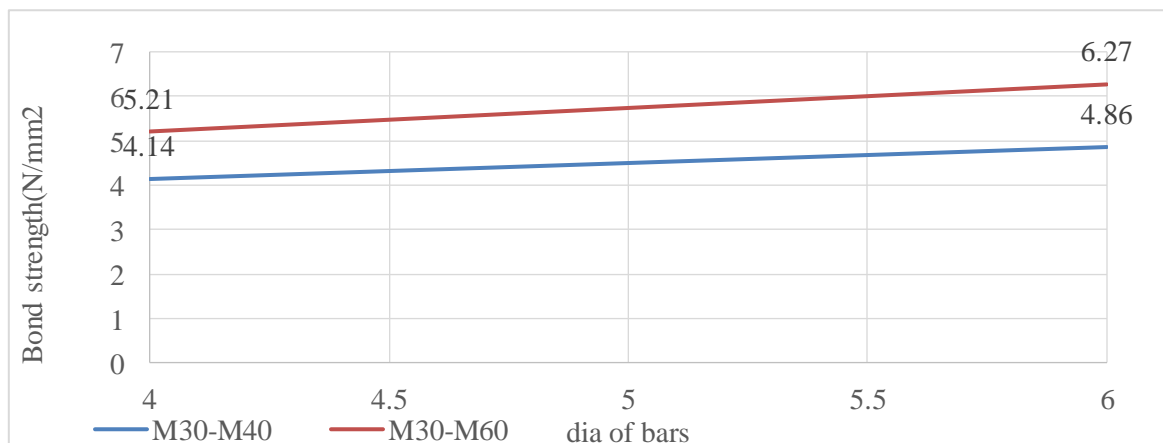
217.31



**Figure 13.** Bar chart for bond strength Vs diameter of reinforcement content for M30-M40 and M30-M60 interface

- a) For the M30-M40 interface when the diameter of bars increased from 4 mm to 6 mm the bond strength value 21.18% increases.
- b) For M30-M60 interface interface when the diameter of bars increased from 4mm to 6 mm the bond strength value 25.25% increases.
- c) For M30-M40 and M30-M60 interfaces when the dia. of bars is 4 mm the bond strength value increases by 25.84%.
- d) For M30-M40 and M30-M60 interfaces when the dia. of bars is 6 mm the bond strength value increases by 30.6%.

When the diameter of bars and grade of concrete of new substrate is increases the bond strength value increases.



**Figure 14.** Bond strength Vs diameter of bars content curve for M30-M40 and M30-M60 interface with smooth and rough substrates at 45°

#### 4.4. Rebound hammer test results

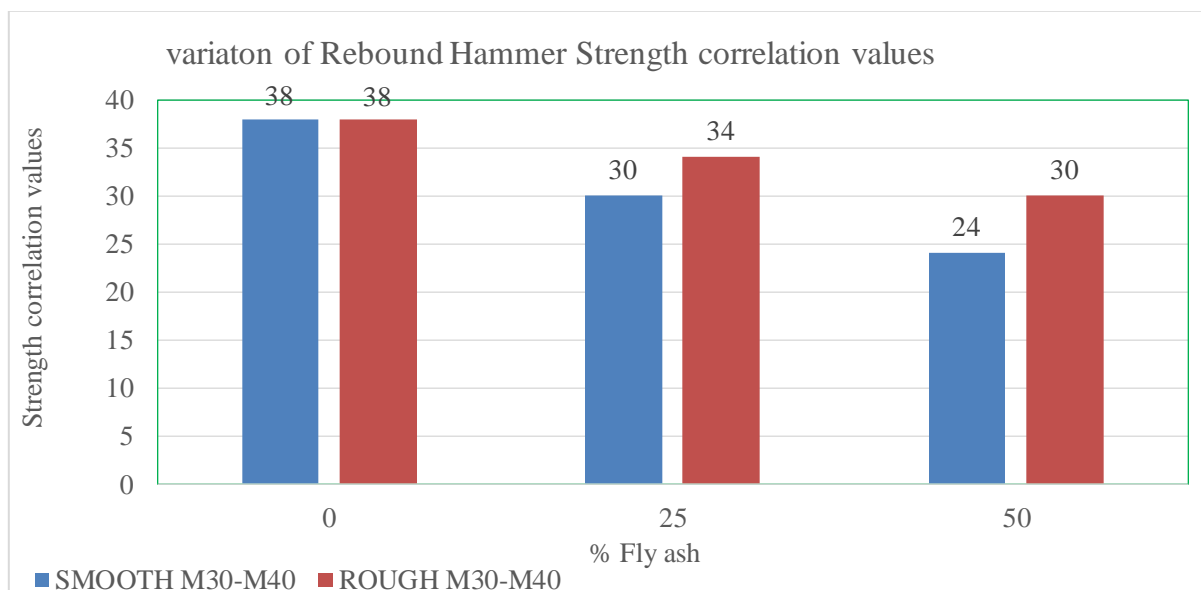
##### 4.4.1. For M30-M40 and M30-M60 grades of concrete interface

**Table 4.** Variation of Rebound Hammer Strength correlation values with respect to M30-M40 grade of concrete with smooth and rough substrate.

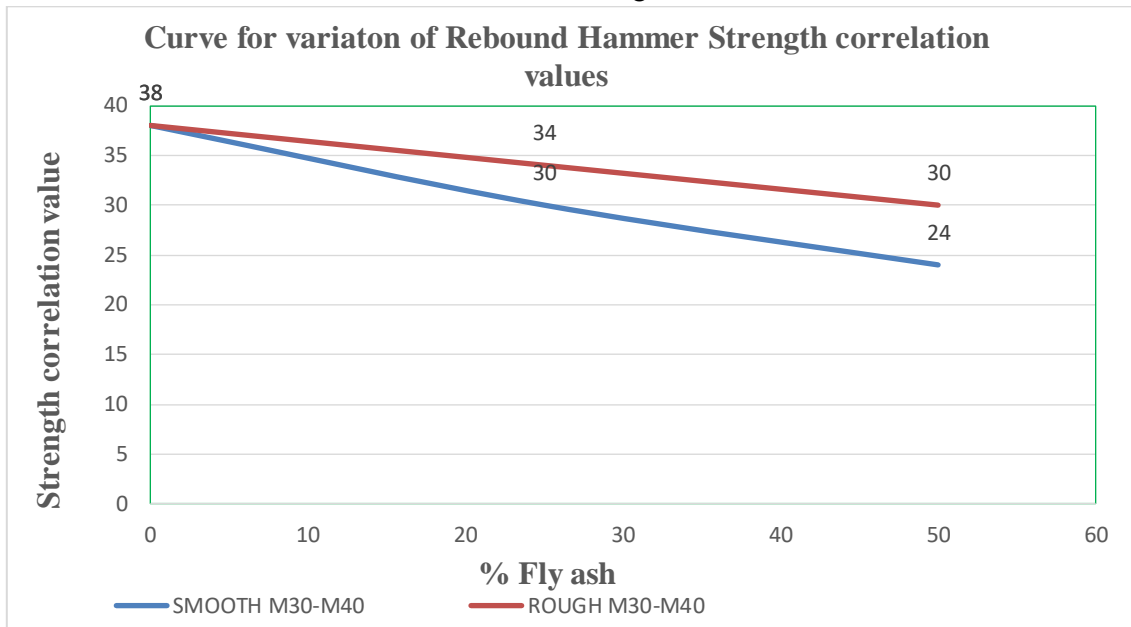
MIX	% of FLY ASH	Value 1	Value 2	value3	Average	Strength correlation values in N/mm <sup>2</sup>
<b>M30-40 smooth</b>	0	32	32	38	34	38
	25	30	28	32	30	30
	50	23	30	-	27	24
<b>M30-40 rough</b>	0	32	35	36	34	38
	25	30	33	-	32	34
	50	28	33	30	30	30

- In M30-M40 grade of concrete interface with smooth interface when Fly ash content replaced to 25% the rebound hammer Strength correlation value decreases by 26.66% similarly when Fly ash content replaced to 50% the rebound hammer Strength correlation value decreases by 58.33%.
- In M30-M40 grade of concrete interface with rough interface when Fly ash content replaced 25% the rebound hammer Strength correlation value decreases by 11.7% similarly when Fly ash content replaced to 50% the rebound hammer Strength correlation value decreases by 26.66%.

As the fly ash % increases 0, 25, 50 percentages in both M30-M40 smooth and M30-M40 rough interfaces the rebound hammer Strength correlation value decreases.



**Figure 15.** Bar chart for Rebound Hammer Strength correlation values for M30-M40 with smooth and rough interfaces.



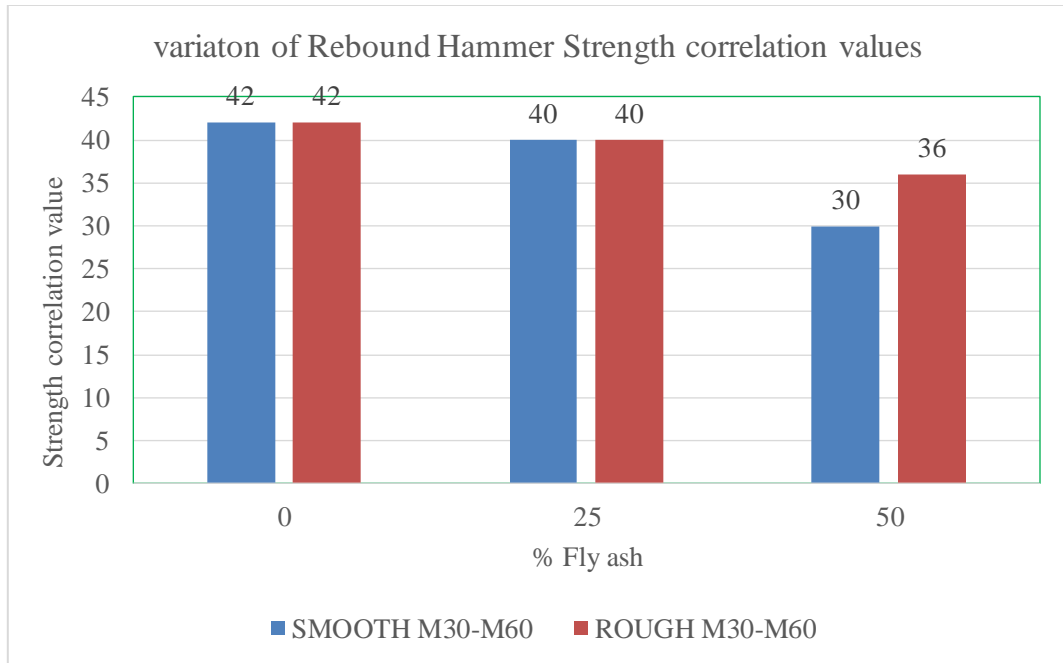
**Figure 16.** Curve for variation of Rebound Hammer Strength correlation values Vs % fly ash content curve for M30-M40 Interface with smooth and rough substrates 45<sup>0</sup>

**Table 5.** Variation of Rebound Hammer Strength correlation values with respect to M30-M60 grade of concrete having smooth and rough substrate

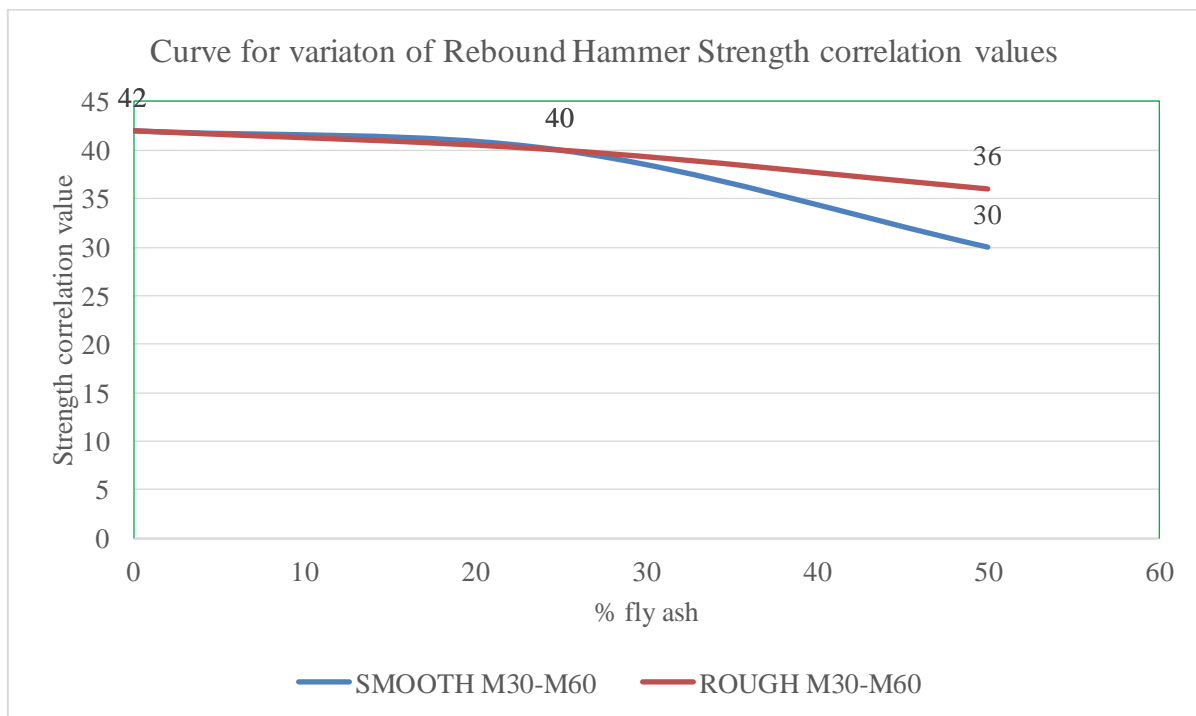
MIX	% of FLY ASH	Value 1	Value 2	value3	Average	Strength correlation values in N/mm2
M30-60 smooth	0	39	36	-	37	42
	25	38	36	32	36	40
	50	30	-	-	30	30
M30-60 rough	0	39	38	36	37	42
	25	35	35	37	36	40
	50	32	32	34	33	36

- a) In M30-M60 grade of concrete interface with smooth interface when Fly ash content replaced 25% the rebound hammer Strength correlation value decreases by 5% similarly when Fly ash content replaced to 50% the rebound hammer Strength correlation value decreases by 40%.
- b) In M30-M60 grade of concrete interface with rough interface when Fly ash content replaced 25% the rebound hammer Strength correlation value decreases by 5 similarly when Fly ash content replaced to 50% the rebound hammer Strength correlation value decreases by 16.66%.
- c) As the fly ash % increases 0, 25, 50 percentages in both M30-M60 smooth and rough interfaces the rebound hammer Strength correlation value decreases.

When fly ash content increases in both M30-M40 and M30-M60 smooth interfaces the rebound hammer strength correlation value of M30-M60 decreases less when compare with M30-M40 interface.



**Figure 17.** Bar chart for Rebound Hammer Strength correlation values for M30-M60 with smooth and rough interfaces.

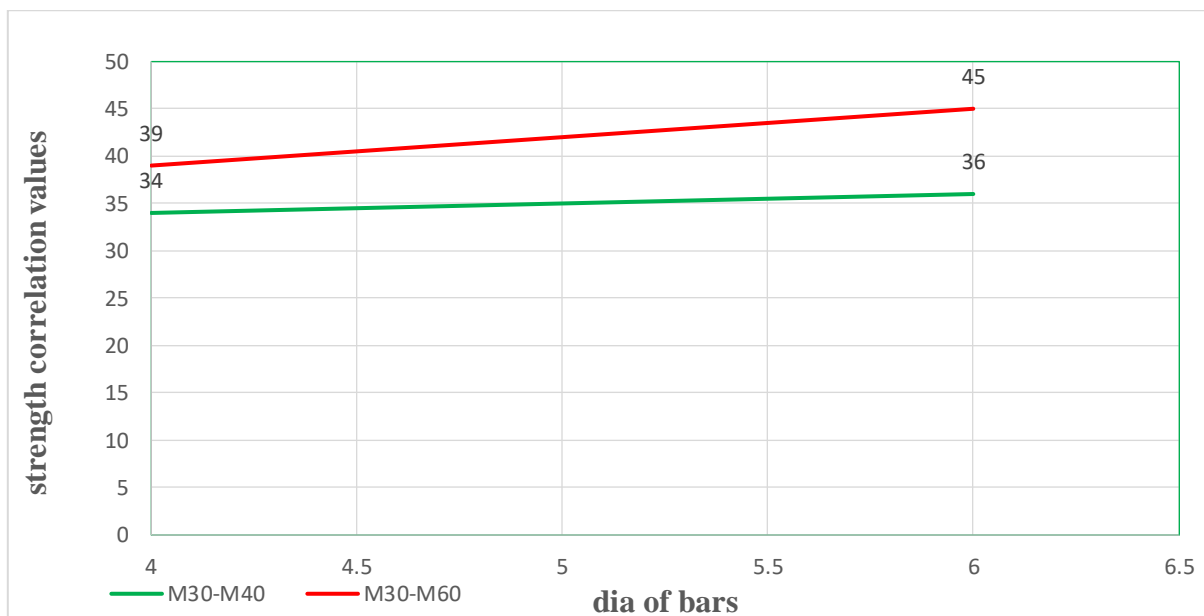


**Figure 18.** Curve for variation of Rebound Hammer Strength correlation values Vs % fly ash content curve for M30-M60 Interface with smooth and rough substrates at 45°

#### 4.4.2. Rebound hammer test results for reinforcement

**Table 6.** Variation of Rebound Hammer Strength correlation values with respect to M30-M40 and M30-M60 grade of concrete having 4mm and 6mm dia. bars.

MIX	DIA OF BARS	Value 1	Value 2	value3	Average	Strength correlation values in N/mm <sup>2</sup>
M30-	4	32	32	32	32	34
M40	6	32	34	32	33	36
M30-	4	36	34	36	35	39
M60	6	40	39	36	39	45



**Figure 19.** Curve for variation of Rebound Hammer Strength Correlation values Vs dia. of bars content curve for M30-M40 and M30-M60 Interface with substrates at 45°

- In M30-M40 substrate when diameter of bars increases from 4mm to 6mm the rebound hammer Strength correlation value increases by 5.8%.
- In M30-M60 substrate when diameter of bars increases from 4mm to 6mm the rebound hammer Strength correlation value increases by 15.38%.
- In M30-M40 and M30-M60 interfaces with 4mm dia. of bars the rebound hammer Strength correlation value increases by 14.7%.
- In M30-M40 and M30-M60 interfaces with 6mm dia. of bars the rebound hammer Strength correlation value increases by 25%

This shows when the concrete grade of the new substrate and dia. Of the bars increases the rebound hammer strength correlation value increases.

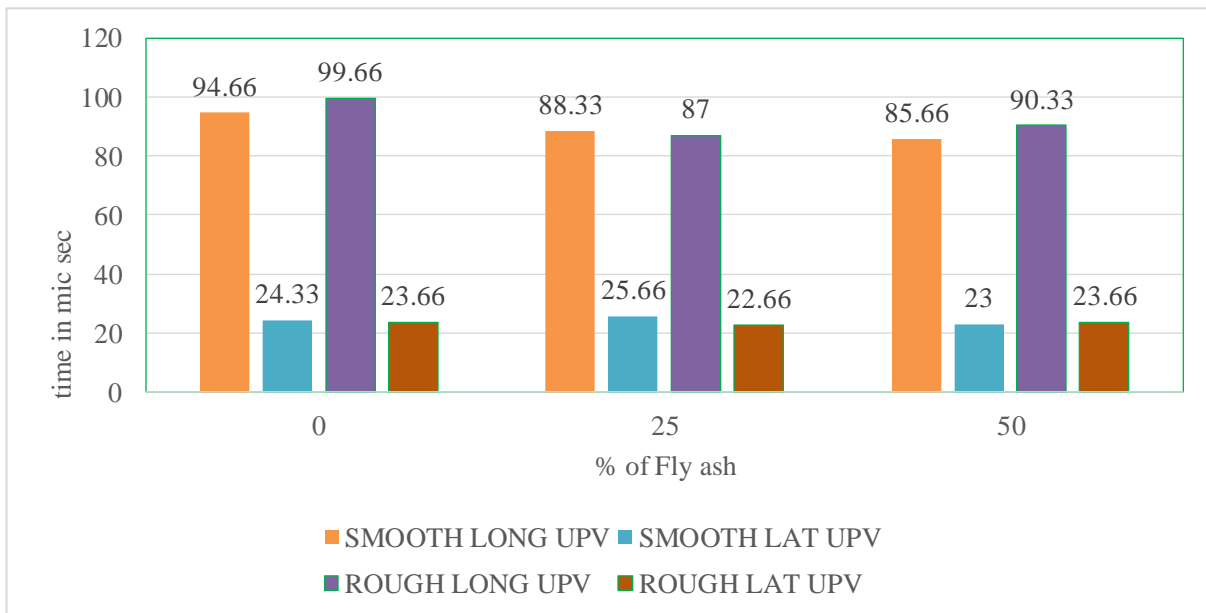
4.5. Ultrasonic pulse velocity test results

4.5.1. For M30-M40 and M30-M60 grades of concrete interfaces

**Table 7.** Time taken for UPV longitudinal (mic-sec) and UPV lateral (mic-sec) directions with respect to variation in fly ash percentage and M30-M40 grade of concrete having smooth and rough substrates

MIX	% of Fly ash	UPV LONG (micsec)		Long Velocity(km/sec)	LAT Velocity()	Uniformity
M30-40 smooth	0	108.66	26.33	3.68	3.79	GOOD BUT POROUS
	25	83.33	23	4.8	4.34	GOOD
	50	85.33	23	4.68	4.34	GOOD
M30-40 rough	0	95.66	24	4.18	4.16	GOOD
	25	81.66	23.33	4.89	4.28	GOOD
	50	90.66	24.66	4.41	4.05	GOOD

In M30-M40 grade of concrete interface with smooth interface when Fly ash content replaced 25% the time taken for UPV in longitudinal direction is decreases by 30.3% and the UPV value increases from 3.68 to 4. Fly ash content from 0 to 50% the time taken for UPV in longitudinal direction is decreased by 27.3%. And the UPV value increases from 3.68 to 4.68. In M30-M40 grade of concrete interface with smooth interface when Fly ash content replaced 25% the time taken for UPV in lateral direction

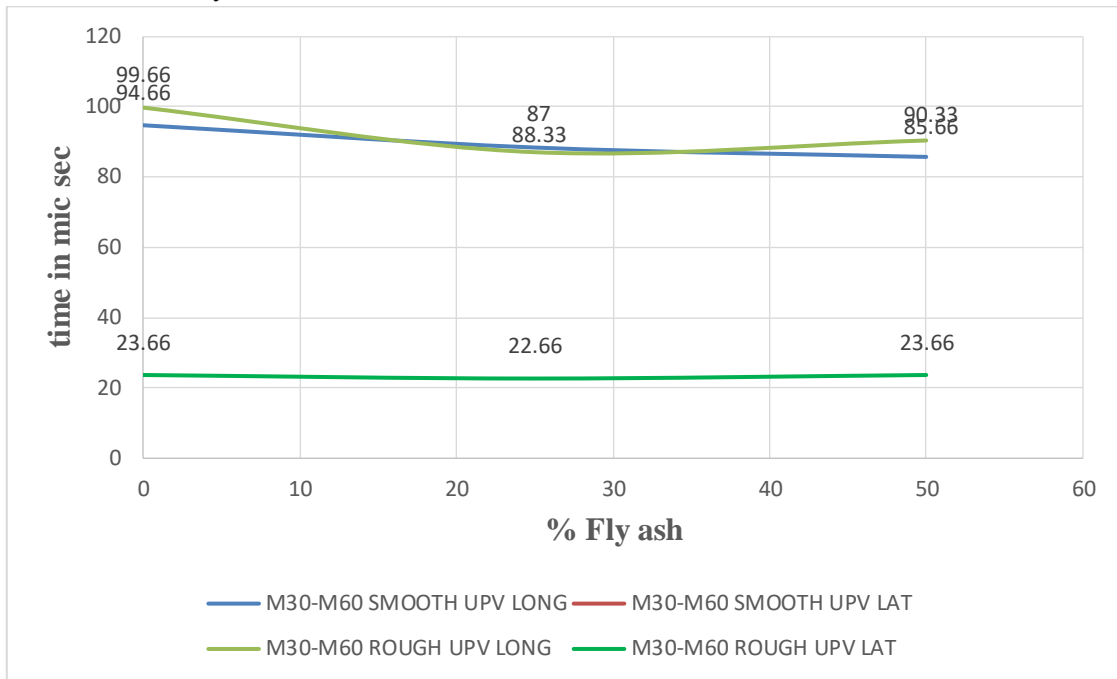


is decreases by 14.4% and the UPV value increases from 3.79 to 4.34 similarly Fly ash content from 0 to 50% it is decreased by 14.4%. And the UPV value increases from 3.79 to 4.34

**Figure 20.** Bar chart for time taken in UPV longitudinal and lateral directions for M30-M60 smooth and rough substrates when fly ash content increases



Curve for time taken in UPV longitudinal and lateral directions for M30-M60 smooth and rough substrates Vs when fly ash content increases at 45°



**Figure 21.** Curve for time taken in UPV longitudinal and lateral directions for M30-M60 smooth and rough substrates Vs when fly ash content increases at 45°

- In M30-M60 grade of concrete interface with rough interface when Fly ash content increases 25% the time taken for UPV in longitudinal direction is decreases by 17.7% and the UPV value increases from 4.18 to 4.89 similarly when Fly ash content increases to 50% the time taken for UPV in longitudinal direction is increased by 11.2% and the UPV value is decreased from 4.8 to 4.68 but Fly ash content from 0 to 50% the time taken for UPV in longitudinal direction is decreased by 27.3%. And the UPV value increases from 4.18 to 4.41.
- In M30-M60 grade of concrete interface with rough interface when Fly ash content increases 25% the time taken for UPV in lateral direction is decreases by 2.8% and the UPV value increases from 4.16 to 4.28 similarly when Fly ash content increases to 50% the time taken for UPV in longitudinal direction is increased by 2.7% but Fly ash content from 0 to 50% it is decreased by 2.71%. And the UPV value increases from 4.16 to 4.05.

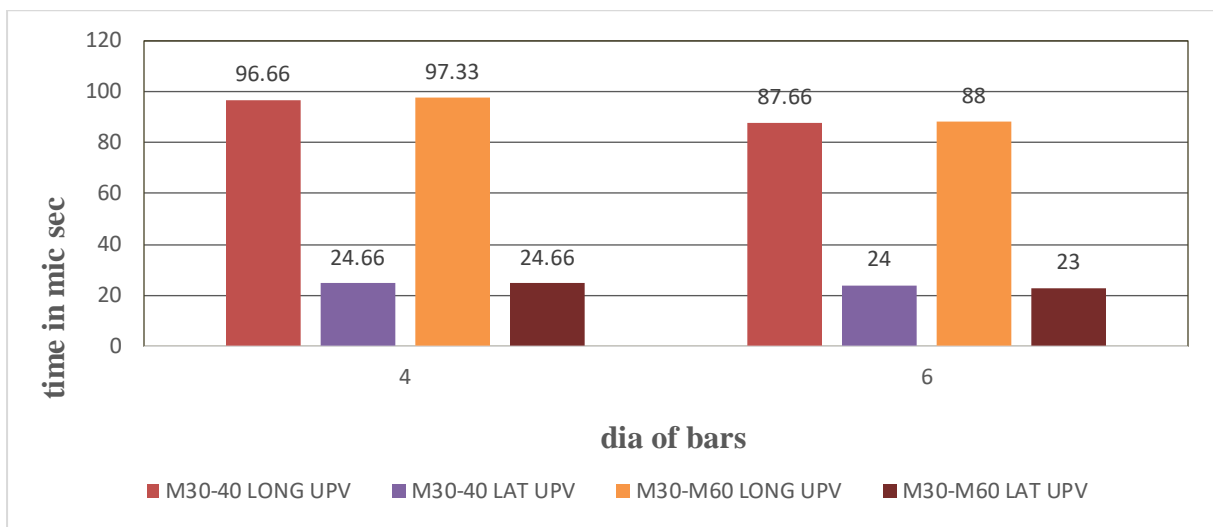
4.5.2. Ultrasonic pulse velocity test results for reinforcement

**Table 8.** Time taken for UPV longitudinal (mic-sec) and UPV lateral (mic-sec) directions with respect to dia. of bars and M30-M60 grade of concrete having smooth and rough substrates

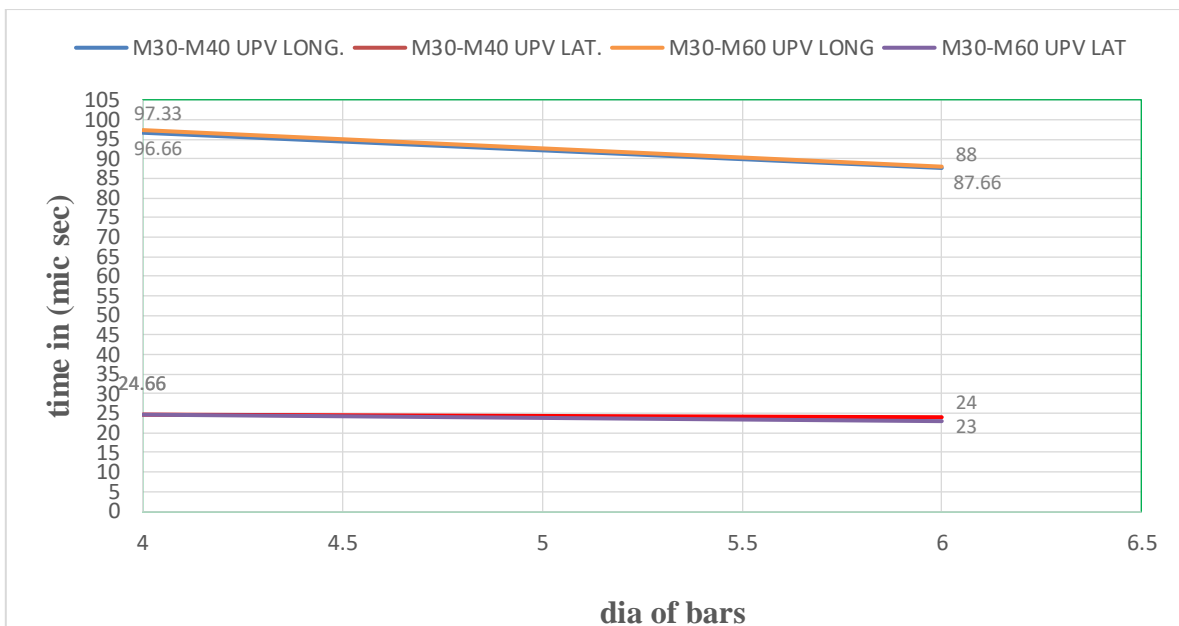
MIX	DIA OF BARS	UPV LONG(mic sec)	UPV LAT(mic sec)	Long Velocity(km/ sec)	LAT	Uniformity
					Velocity()	
M30-M40	4	96.66	24.66	4.137	4.109	GOOD
	6	87.66	24	4.56	4.16	GOOD

M30-M60	4	97.33	24.66	4.10	4.055	GOOD
	6	88	23	4.54	4.34	GOOD

- a) In M30-M40 substrate with 4mm and 6mm dia. Bars the time taken for UPV in longitudinal direction is decreased by 10.2% whereas the velocity is increased from 4.137 to 4.56.
- b) In M30-M40 substrate with 4mm and 6mm dia. Bars the time taken for UPV in lateral direction is decreased by 2.7% whereas the velocity is increased from 4.109 to 4.16.
- c) In M30-M60 substrate with 4mm and 6mm dia. Bars the time taken for UPV in longitudinal direction is decreased by 10.6% whereas the velocity is increased from 4.10 to 4.54.
- d) In M30-M60 substrate with 4mm and 6mm dia. Bars the time taken for UPV in lateral direction is decreased by 7.2 % whereas the velocity is increased from 4.055 to 4.34.



**Figure 22.** Bar chart for time taken UPV longitudinal and lateral directions for M30-M40 and M30-M60 interfaces with 4mm and 6mm diameter Bars



**Figure 23.** Curve for time taken n UPV longitudinal and lateral directions for M30-M60 and M30-M40 substrates having dia. of 4mm and 6mm at 45°



**Figure 24.** Failure of the specimen under slant shear test



**Figure 25.** Failure of the specimen having smooth interface under slant shear test



**Figure 26.** Failure of the specimen with rough interface reinforcement under slant shear test



**Figure 27.** Failure of the specimen with under slant shear test

## 5. Conclusions

Results obtained from experimental investigation; they are:

- i. The bond strength value between the normal concrete to high volume fly ash concrete in both M30-M40 and M30-M60 for smooth and rough increases up to 25 percentage fly ash for 50 percentage fly ash decreases.
- ii. As the roughness of the substrate increases the bond strength value increases in both interfaces
- iii. As the percentage of the steel increases the bond strength value increases and the grade of the concrete increases then also the bond strength value increases.
- iv. The cohesion and the friction values are same the both grades of concrete irrespective of the type of interface and grade of concrete.
- v. As we are using 4mm and 6mm dia. Bars the bond strength values are increasing when we compare with concrete –concrete smooth interfaces. And the bond strength values are less than the rough interface.
- vi. Rebound Hammer strength correlation values are decreasing as the fly ash content is increasing.
- vii. Ultra-sonic pulse velocity shows that the concrete is uniform, no voids, cracks etc.

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