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Study on Bond Strength of Alccofine Based Normal and High Strength Concrete

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Abstract

Plenty of research works in India and abroad focusing on the reuse or recycling of waste materials from many industries. Among that finding out suitable cementitious material for the replacement of cement is significant. Many waste materials such as fly ash, silica fume, GGBS, metakaoline, micro materials, quartz power, etc. are tried out for replacing partially or full of cement in concrete. A new ultrafine material called Alccofine is tried out for replacing partially in this research. M20 and M60 grade of concrete is intended to study the performance of normal and high strength concrete by replacing the cement with alccofine of different dosages. Previous researches showed that the replacement of alccofine increases the strength. Design mix made for M20 and M60 grade and cubes casted with various percentage of alccofine with cement. Hence the study is aimed to assess the bond behavior of M20 and M60 grade of concrete structures as an alternate to the conventional materials. The cubes are prepared initially for the design mix and determined the strength of concrete. Then specimens are prepared for the bond test and tested using pullout test methods. The results are analyzed and observed that the bond strength is increased with increase of alccofine replacement to certain dosage.

Keywords: Alccofine-1203; Conventional Concrete; Conventional Steel Rebar; Bond Behavior.

1. Introduction

Mechanical properties of concrete which includes compressive strength and pull out strength. Compression test is the most common test conducted on hardened concrete partly because it is an easy test to perform and partly because most of the desirable characteristics properties of concrete are qualitatively related to its compressive strength. The compression strength is carried out on the specimen cubical or cylindrical in shape prism is all so used but it is not common in our country. Sometimes the compressive strength of the concrete is determined using parts of a beam tested in flexure. Bond in reinforced concrete refers to the adhesion between the reinforcing steel and the surrounding concrete. It is this bond which is responsible for the transfer of axial force from a reinforcing bar to the surrounding concrete, there by proving strain compatibility and composite action of concrete and steel. If this bond is inadequate, slipping of the reinforcing bar will occur, destroying full composite action. Hence the fundamental assumption of the theory of flexure, viz. plane section plane even after bending, becomes valid in reinforced concrete only if the mechanism of bond is fully effective. It is through the action of bond resistance that the axial stress (tensile or compressive) in a reinforcing bar can undergo variation from point to point along its length.

The Effect of surface texture on bond strength of GRRP bar both sand coated GFRP and plain GFRP in concrete

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with different bar diameters say 9.5, 13, 19, 22 mm. The bond performance of sand coated GFRP rebar's improved by 17-58%, and the bond strength developed mainly due to interlocking friction between sand particles and surrounding concrete [1].The bond deterioration was influenced by the corrosion level, the loading history and amount of confinement reinforcement [2]. The bonded anchor tension resistance limits determined by bond strength provided by the glue. Bond strength is an overall parameter used for description of connection quality between the steel anchor and concrete. The characteristics of glue are the limiting factor for chemical anchoring in high performance concrete [3]. In general the bar diameter is increases the bond stress increases [4]. The bond strength between the ultra-high performance fiber concrete (UHPFC) and normal concrete substrate depends on the surface treatment of the substrate, as the surface treatment increases when the bond strength increases. The highest bond strength was achieved for the sand blasted surface [5]. The polluted and non-polluted steel bars, the small bar sizes have greater bond strength then the large bar sizes if the embedded length was small [6]. The ductility and bond strength of concrete was found to the increased in steel fiber reinforcement concrete [7].

The bottom ash concrete possess bond strength almost same as that of controlled concrete [8]. The bond behavior of the galvanized reinforcing steel was similar to that of the conventional epoxy coated bars [9]. Confinements on the bond strength between concrete and corroded steel bars and the stirrups can limit the longitudinal cracking of concrete cover, and significantly increase the bond strength of corroded steel bars [10]. The ultimate bond strength and the slip at the peak bond stress are greatly influenced by equip-biaxial lateral tension. The slip at the peak bond stress first increases and then decreases [11]. The bond strength between steel bars and high strength concrete increased with the increase of concrete age, the bond strength was 5.89, 14.81, 19.82, 21.95, 22.56, and 25.54 MPa when the concrete age was 1, 3, 5, 7, 14, and 28 days respectively [12].

Alkali activated concrete have a better bond with steel in comparison with Portland cement based concrete. The evaluation of bond between steel and concrete, but also for the development of alkali-activated or hybrid cement based steel-fibre concretes [13]. The influence of locally available natural lightweight aggregates for the bond properties of reinforcing steel bars embedded in structural concrete made with, was studied using pull-out tests on cubic specimens of 150 × 150 × 150 mm. The natural lightweight aggregates could be considered as a promising, and cost effective material for designing reinforced concrete members [14]. The pull-out test was conducted and chloride contents were tested at crack area along 40 mm depth. The cracks of width more than 200 microns increased gradually; the chloride content decreased along the depth of concrete, and the chloride content increased as the widths of initial cracks increased or as the bar diameters increased. The ductility of bond specimens decreased as the diameter increased [15]. The chloride penetration of concrete was affected in many ways, including physical, chemical, and mechanical such as permeability, cement binding, and cracking (both internal and external) [16]. On one hand, bond strength was influenced by curing conditions concrete compressive strength, concrete cover, embedded length, preflexural crack length, chemical adhesion and friction [17].

1.1. Alccofine 1203

Alccofine (1203) (AF) is a specially processed product based on slag of high glass content with high reactivity obtained through the process of controlled granulation. Owing to this unique and ultrafine particle size, AF provides requirement of concrete performance. It can also be utilized as high water reducer to improve compressive & flexural strength and also workability to improve the flow. It performs in superior manner than all other mineral admixture used in concrete with in India. Due to its inbuilt CaO content alccofine triggers two way reaction during hydration also consumes by product calcium hydroxide from the hydration of cement to form additional C-S-H gel similar to pozzolans.

AF is a new generation material supplementary cementitious material (SCM) with a built in high tech content. Due to the dense packing of cementitious material, it produces low void content. Strength development increases drastically at early ages and the larger on strength are higher compared to traditional supplementary cementitious material. It has an ability to increase the service life of concrete by its 'packing effect'. Packing effect retards ingression of aggressive agent in concrete even by diffusion and thus enhances durability of concrete. Because of its finer pore structure and chemical stability, AF in concrete is substantially more resistant to chloride diffusion. CaO available in AF contributes to maintain CaO has buffer solution, which helps to maintain pH of pore solution. It can be used in two different ways as a cement replacement. (i) In order to reduce the cement content (ii) An additive to improve concrete properties.

1.2. Properties of Alccofine 1203

It is observed that the major chemical compositions of Alccofine 1203 is 34 percent calcium oxide, 35 percent silicon dioxide and 24 percent aluminum dioxide.

In this research the main objectives are to find the properties of materials, design the mix proportion for normal strength concrete and high strength concrete, the bond strength of steel reinforcement in normal concrete and normal strength concrete using Alccofine and finally to obtain the bond strength of high strength concrete using Alccofine. The main scope are includes casting of cubes and cylinders, experimental study is restricted to assess the bond strength using pull-out test for conventional concrete and concrete with Alccofine 1203.

3. Experimental Investigations

3.1. Preliminary Tests on Materials

Basic tests like specific gravity, sieve analysis, scanning electron microscope (SEM) analysis for OPC and Alccofine were carried out on the materials to be used. Testing was done and the results were tabulated as given below.

3.2. Specific Gravity of Materials

The specific gravity of the materials used for making concrete is determined as per IS 2386 - 1963. The values obtained are given in the Table 1 and the combined specific gravity for cement and alccofine are presented in Table 2.

Table 1. Specific gravity

Sl. No	Name of the Material	Specific Gravity
1	OPC Cement	3.15
2	Alccofine	2.87
3	Fine Aggregate	2.71
4	Coarse Aggregate	2.78

Table 2. Combined Specific Gravity

Sl. No	Name of the material	Combination in %	Specific gravity
1	Cement + Alccofine	C 100% + A 0%	3.15
2	Cement + Alccofine	C 95% + A 5%	3.13
3	Cement + Alccofine	C 90% + A 10%	3.03
4	Cement + Alccofine	C 85% + A 15%	2.97
5	Cement + Alccofine	C 80% + A 20%	2.92

3.3. SEM analysis

The cementitious materials are analysed in SEM analysis to find in the materials shape and size of the samples

3.3.1. OPC- 43 (Figure 1)

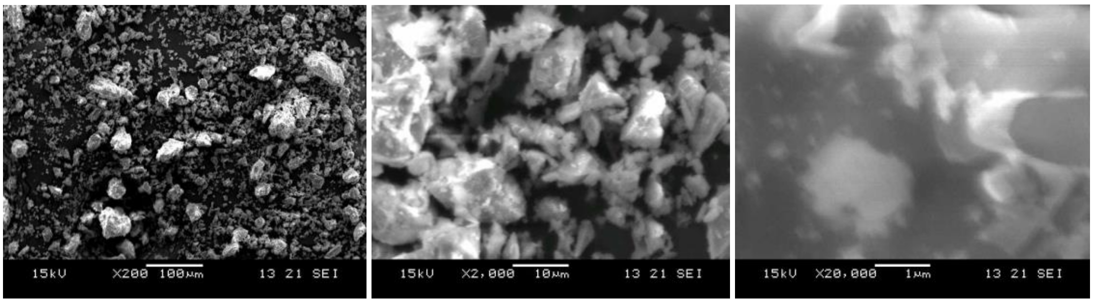

Figure 1. SEM analysis of OPC 100µ, 10µ and 1µ

3.3.2. ALCCOFINE-1203 (Figure 2)

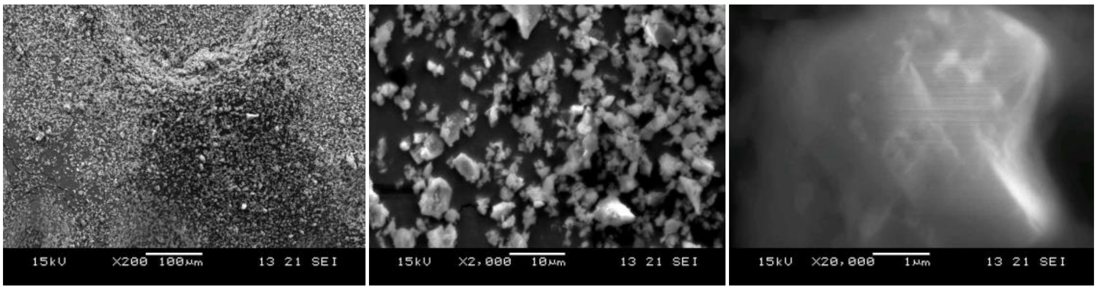

Figure 2. SEM analysis of AF 100µ, 10µ and 1µ

3.3. Mix Ratio for M20 and M60 Grade of Concrete

The design mix for M20 and M60 grade of concrete is carried out as per the standards IS 10262 – 2009. (Table 3 and 4).

Table 3. Mix ratio for M20 grade concrete

Sl. No	Cement	F.A	C.A	W/C
1	1	2.11	3.39	0.55

Table 4. Mix ratio for M60 grade concrete

Sl. No.	Cement	F.A	C.A	W/C	SP
1	1	1	2.05	0.31	0.029

The specimen details for M20 grade concrete with 0, 10, 12, 14 and 16 percent of alccofine and M60 grade concrete with 0, 10, 12, 14 and 16 percent of alccofine are presented in Table 5.

Table 5. Specimen details

Sl. No	Mix	Curing days					Total
		Specimen	3	7	14	28	
1	CA0	Cube M20	3	3	3	3	12
2	CA10		3	3	3	3	12
3	CA12		3	3	3	3	12
4	CA14		3	3	3	3	12
5	CA16		3	3	3	3	12
6	CA0	Cube M60	3	3	3	3	12
7	CA10		3	3	3	3	12
8	CA12		3	3	3	3	12
9	CA14		3	3	3	3	12
10	CA16		3	3	3	3	12

3.4. Confinement of Concrete

The aim of confinement by means of transverse compression or transverse reinforcement is to prevent a failure along a potential splitting crack and to enforce a shear failure, which is associated with the maximum attainable bond strength. The cube shall be reinforced with a helix of 6mm diameter plain mild steel reinforcing bar conforming to grade 1 of IS: 432 (part 1) - 1966 or IS: 226:1962 at 25 mm pitch, such that the outer diameter of the helix is equal to the cube, each end of the helix being welled to the next turn. Figure 3 shows that the typical helical reinforcement for concrete confinement during the casting of specimens. In reinforced concrete, rods are embedded in concrete in such a way that as to function together with the concrete to resist forces. Embedded length can be calculated as per the standards in IS 11309 (Figure 4).

Figure 3. Helical spring

Figure 4. Embedded bar

3.5. Casting and Curing of Specimens

In reinforcing steel loose scale and rust shall be removed by wire brushing and bars inspected to ensure that they are free from grease, paint, or other coating which would affect their bond. The conventional concrete samples mixing were done with pan mix. During the compaction process on the table it was necessary to hold the reinforcement bars in place by hand. Once taken of the table both the concrete were stiffs enough to hold the reinforcement bars firmly in place on their own are shown in Figures 5 and 6.

Figure 5. Helical reinforcement kept in position while casting

Figure 6. Specimens under curing

3.6. Pull out Test

The pull out test was conducted in universal testing machine (UTM). The specimens were placed in inverted position as shown in Figure 7. Concrete cube specimen fixed with upper jaws and another edge of the reinforcement rod was fixed with lower jaw as shown in figure. When the machine started the lower jaw will be coming down by that way the rod is pulled. The load applied gradually through UTM by the incremental value of 0.2. Slip occurs at the time of testing were noted with the help of vernier scale, when the specimens attain the maximum bond stress leads to failure. Maximum slip value and load value was observed.

Figure 7. Specimen kept in position for pull out test

3.7. Bond Strength

In this test the bond strength is expressed in terms of the average bond stress obtained from pullout test. The force around the embedded length is calculated through UTM and the average bond stress is calculated and the test results are tabulated. Table 6 shows the bond stress and slip values obtained during the experiment for the normal strength concrete i.e. M20 grade of concrete. Table 7 shows the bond stress and slip values obtained during the experiment for the high strength concrete i.e. M60 grade of concrete.

Table 6. Maximum load and slip values of specimens for M20

Grade of concrete	No. of days of curing	Percentage of alccofine	Maximum load in N	Maximum slip in mm	Bond stress in N/mm^2
M 20	7	0	15000	6.25	3.97
		10	16000	5.22	4.24
		12	17000	4.22	4.50
		14	17000	4.10	4.50
		16	22000	3.80	5.80
M20	14	0	17000	5.22	4.50
		10	18000	5.20	4.77
		12	18000	4.20	4.77
		14	19000	4.23	5.03
		16	23000	3.75	6.10
M20	28	0	19000	4.50	5.03
		10	21000	4.85	5.57
		12	23000	3.90	6.10
		14	21000	3.22	5.57
		16	23000	3.21	6.10

Table 7. Maximum load and slip values of specimens for M60

Grade of concrete	No. of days of curing	Percentage of alccofine	Maximum load in N	Maximum slip in mm	Bond stress in N/mm^2
M60	7	0	23000	4.50	6.10
		10	25000	4.20	6.63
		12	26000	3.80	6.89
		14	27000	3.50	7.16
		16	30000	3.50	8.48
M60	14	0	25000	4.20	6.63
		10	27000	4.00	7.16
		12	27000	3.50	7.16
		14	28000	3.25	7.42
		16	31000	3.20	8.22
M60	28	0	26000	3.90	6.80
		10	30000	4.00	7.95
		12	31000	3.40	8.22
		14	33000	3.05	8.75
		16	32000	3.10	8.40

4. Results and Discussion

The Pull out is used for determining the bond strength for both normal and high strength concrete. From the bond test bond stress and slip is calculated and the results are tabulated and shows in the Table 4.7 and 4.8. The graphical representation is as follows for all the specimens and mixes.

4.1. Normal Strength Concrete (M20)

The load vs. slip curve for normal concrete with alccofine 0,10,12,14 and 16 percent are shown in Figures 8 to 12.

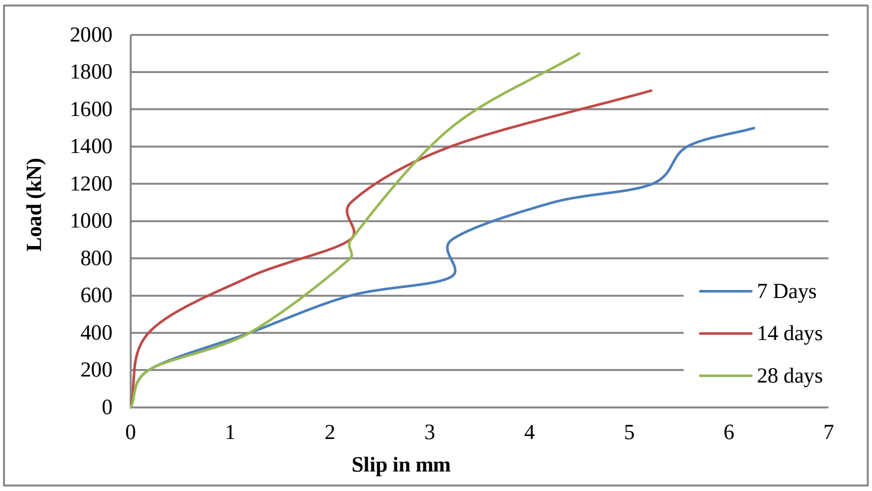

Figure 8. Load vs. slip curve (A0%)

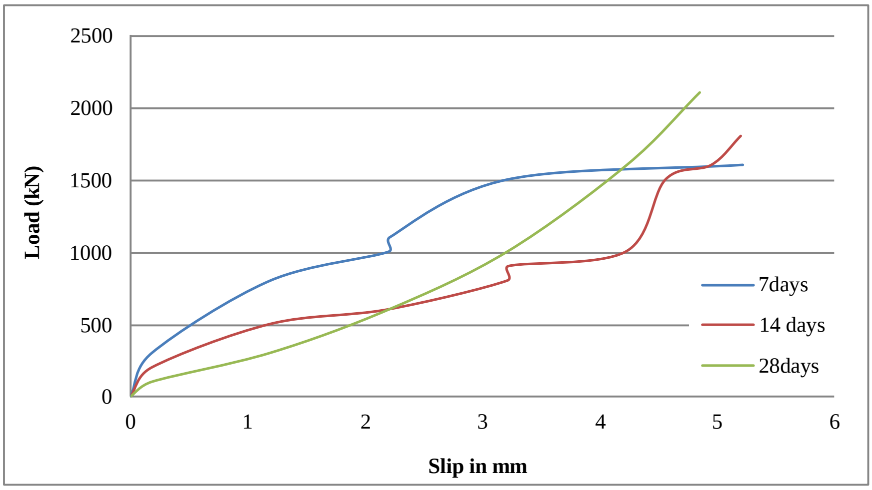

Figure 9. Load vs. slip curve (A10%)

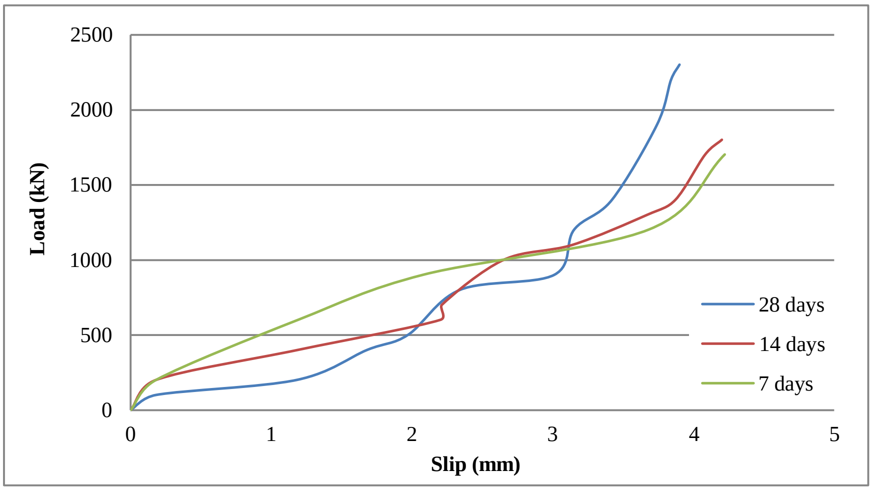

Figure 10. Load vs. slip curve (A12%)

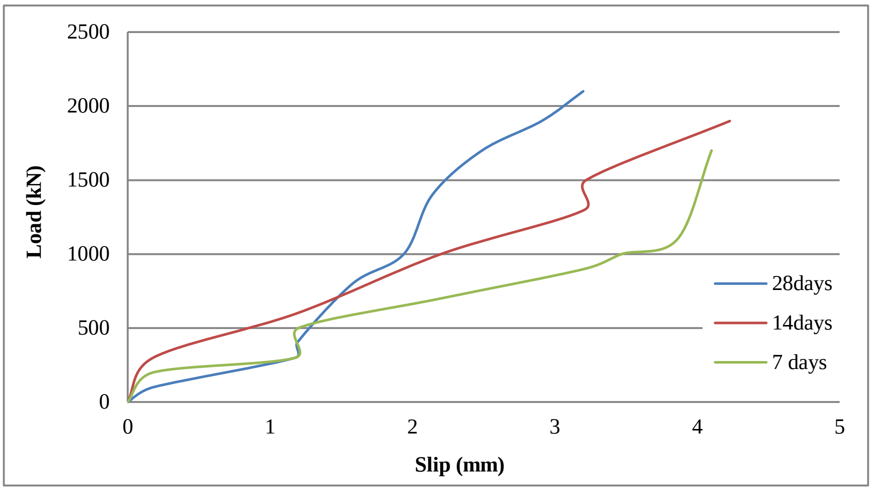

Figure 11. Load vs. slip curve (A14%)

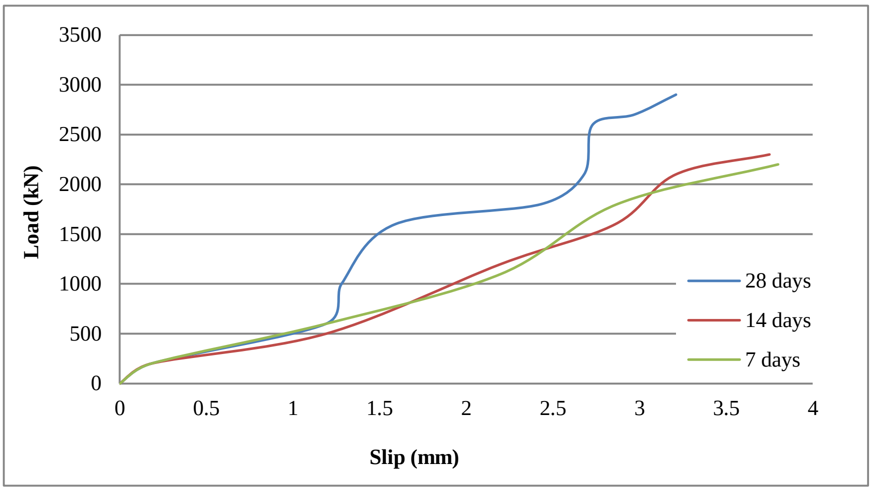

Figure 12. Load vs. slip curve (A16%)

From the above graphs (Figures 8 to 12) the following results were obtained:

- Bond stresses increased with the increase of percentage replacement of alccofine except 16% replacement.
- Slip value decreased with the increase of percentage replacement of alccofine in all the replacements.
- The maximum load is 23000 N/mm^2 and the corresponding slip is 3.21mm.
- All the curves obtained through the experiment are not smooth because of some slippage error occurred during the experiment.

4.2. High Strength Concrete (M60)

The load vs. slip curve for high strength concrete with alccofine 0, 10, 12, 14 and 16% are shown in Figures 13 to 17.

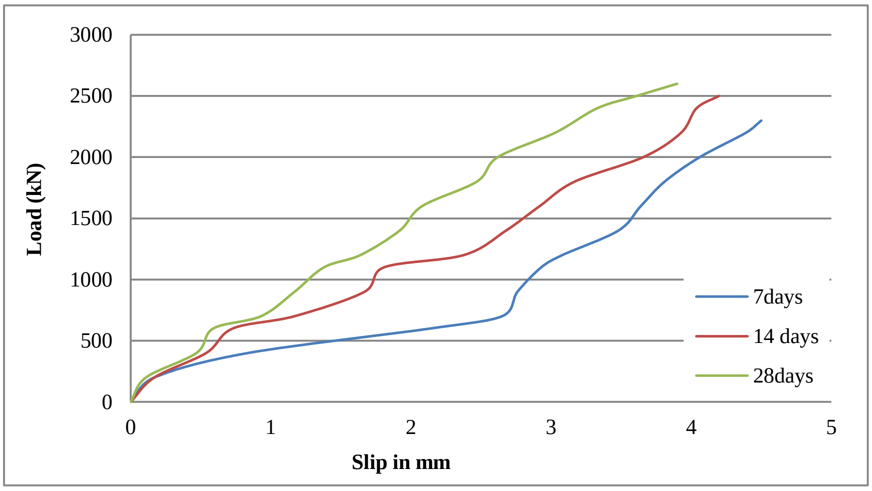

Figure 13. Load vs. slip curve (A0%)

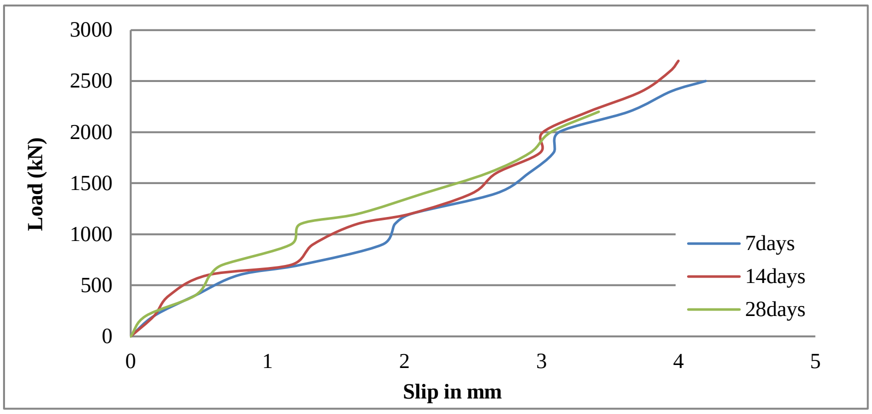

Figure 14. Load vs. slip curve (A10%)

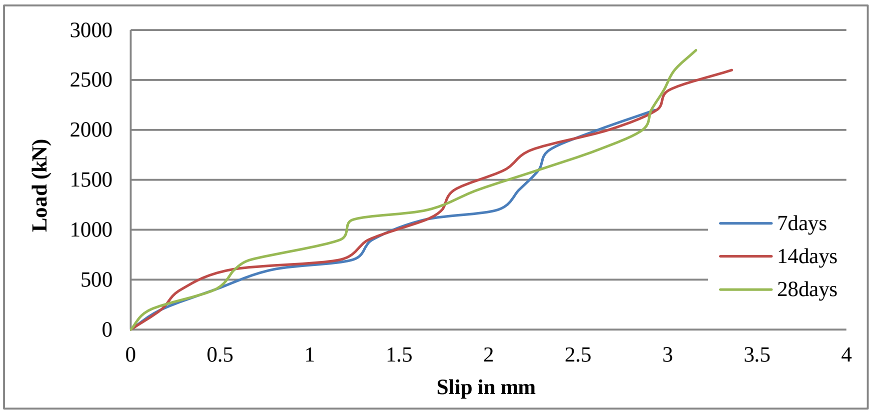

Figure 15. Load vs. slip curve (A12%)

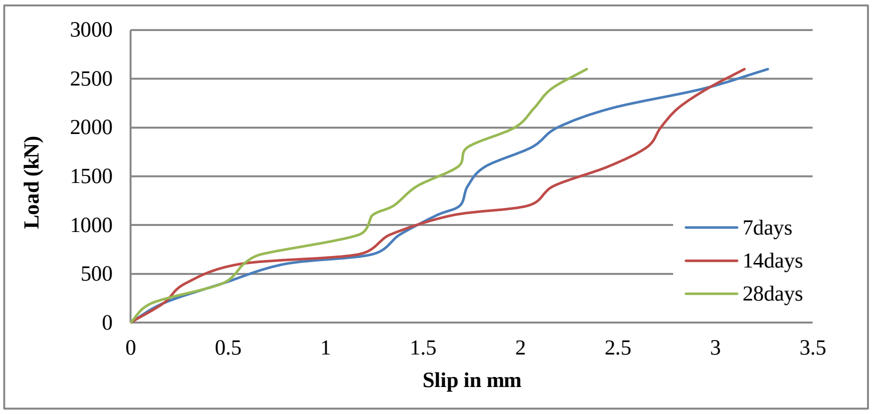

Figure 16. Load vs. slip curve (A14%)

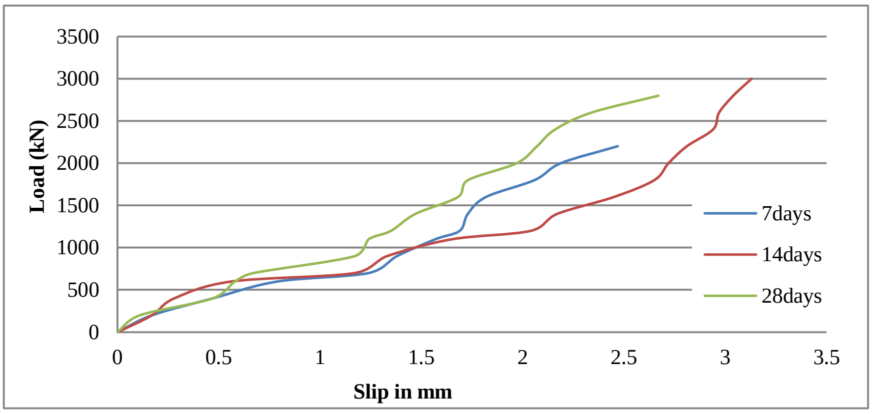

Figure 17. Load vs. slip curve (A16%)

From the above graphs (Figures 13 to 17) the following results were obtained

- Bond stresses increased with the increase of percentage replacement of alccofine except 16% replacement.

- Slip value decreased with the increase of percentage replacement of alccofine in all the replacements.
- The maximum load is 33000 N/mm2 and the corresponding slip is 3.05 mm.
- All the curves obtained through the experiment are not smooth because of some slippage error occurred during the experiment.

5. Conclusions

Based on the experimental investigation the following conclusions are drawn.

- The bond stress are determined through pull out test only for all the specimens, it is observed that the bond strength increases for increase in percentage of Alccofine replacement.
- The embedded bar is pulled out through UTM, the rod slips are measured, the slip is decreasing with the increase in load as well as in increasing the percentage replacement of Alccofine.
- For M20 grade concrete, it is observed that the strength of the concrete increases rapidly in early ages that is 7 days and after that it gradually increases. The maximum bond stress obtained at the age of 7 days is 22000 N/mm2 for 16% replacement of Alccofine.
- For M20 grade concrete, at 7 days the bond stress for 16% replacement of alccofine increases by 45% whereas when compared at 28 days the bond strength 12% replacement shows higher strength than conventional concrete by 20%.
- For M20 grade concrete, the maximum bond stress achieved at 28 days for 12% replacement of alccofine with cement is 23000 N/mm2.
- Hence it is understood that the replacement of alccofine with cement yields increase in bond strength and also decrease in slip for all the specimens.
- For M60 grade concrete, it is observed that the strength of the concrete increases rapidly in early ages that is 7 days and after that it gradually increases. The maximum bond stress obtained at the age of 7 days is 32000 N/mm2 for 16% replacement of Alccofine.
- For M20 grade concrete, at 7 days the bond stress for 16% replacement of alccofine increases by 20% whereas when compared at 28 days the bond strength 12% replacement shows higher strength than conventional concrete by 10%
- For M20 grade concrete, the maximum bond stress achieved at 28 days for 14% replacement of alccofine with cement is 33000 N/mm2.
- The bond stress increased with the increase of concrete strength as well as the slip is reduced.
- The maximum slip for normal strength concrete obtained is 6.25 mm for the conventional concrete at the age of 7 days where as for high strength concrete 4.5 mm. At the age of 28 days the percentage of slip reduced by 10 to 20% invariably.
- The lesser amount of slip is calculated for 28 days, 3.21 at 16% replacement of alccofine and 3.05 at 14% replacement of alccofine respectively for normal and high strength concrete.

6. Conflict of Interest

The authors declare no conflict of interest.

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