Experimental Investigation on Bond Strength of Concrete and Steel Bar of Conventional Concrete at Elevated Temperatures

G. Premkumar and Y. Lakshmi Pranathi

Abstract--- *An experimental investigation is done on bond strength of reinforcing bar and surrounding concrete at elevated temperatures. The conventional mix M25 is used and three different types of steel bars of 20 mm diameter are used. A total of 9 pull out specimens are prepared; 3 using plain polished bars, 3 using plain unpolished bars and 3 using deformed bars. Embedment of steel bar inside the concrete specimen is done. The pull out specimens are subjected to room temperature and two different elevated temperatures 100ºC and 300ºC. Comparisons are done between the different steel bars and temperatures. The results indicated that the pull out specimen with deformed bars at room temperature had the highest bond strength compared to the other bars with different temperatures. The plain bars have shown the least bond strength due to the chemical adhesion and friction. When temperature is taken into concern, there was decrease in bond strength for 300ºC compared to room temperature. In the deformed bars, there was a decrease in 14.94 % when subjected to 300ºC. In polished mild steel bars, when subjected to 300ºC decrease in 22.46 % than room temperature. Similarly, in unpolished mild steel bars there was a decrease of 40.86 %.*

Keywords--- *Bond strength, Elevated Temperature, Mild Steel Bars, Deformed Bars, Pull Out Test, Compressive Test, Conventional Concrete, Polished Bars, Unpolished Bars.*

I. INTRODUCTION

The reinforced concrete structures behaviour is completely depends on interaction between the steel and concrete. The definition of bond can be termed as the interaction of the steel bars with the surrounding concrete, which allows the tensile stresses to transfer down to the steel and then into concrete. With the perfect bond between them, the axial forces will transfer from steel bar to the concrete, which will result in the production of tangential stresses along the contact surface. These tangential stresses will act parallel to the bar along the interface can be defined as bond stresses.

The mild steel plain bars do not have ribs on their surface and have plain surface. A few decades back, a large number of reinforced structures were built using plain reinforced bars. Now, due to structural transformations to meet new requirements deformed bars are being used. So the comparison is done for different bars.

There are many studies which are done on bond behaviour but only few studies have been done on bond behaviour at higher temperatures. When the concrete is exposed to high temperatures like fire accidents, the strength loss starts and also the load bearing capacity decreases. This will lead to failure in the structures. Therefore, concrete

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should also have good fire resistance. And it is very important to study the bond behaviour at high temperatures.

II. MATERIALS

2.1 Cement

Ordinary Portland cement with grade 53 was used in this project. Chemical and physical properties of the cement are in the confirmation with IS 12269-2009. Cement was tested in various properties conforming IS standard. The preliminary tests are done on cement. The specific gravity is 3.13, the fineness is 9 mm, and consistency is 35 mm. The result for lump cone test is 75mm.

Figure 1: Cement

2.2 Fine Aggregate

The fine aggregate used in this project was M Sand. M Sand is also called as manufactured sand. This is used as substitute for river sand. This is obtained by crushing hard granite stone. It has having fineness modulus 2.9 m^2 /kg, specific gravity is 2.25 and bulk density is 1620 kg/m^3.

Figure 2: M Sand

2.3. Coarse Aggregate

Coarse aggregate is the major component which adds strength to the concrete. 20 mm szed coarse aggregate was used. Preliminary tests are done. The specific gravity is 2.86 and the fineness is 3.07.

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Figure 3: Coarse Aggregate

2.4 Steel

Steel is the most important building material used in the construction field. Steel is an alloy of iron and carbon. Due to its high tensile strength and low cost, it is majorly used in buildings, infrastructure, machines, ships, automobiles. Three types of steel bars are used in this project. They are polished, unpolished and deformed. 20 mm diameter bars are used.

Figure 4: Steel

III. METHODOLOGY

16 cube specimens are used. The size is 150 mm and they are cast for both pull out test and compressive strength test. Steel bars of diameter 20 mm are embedded into concrete specimens. The embedded length is 150 mm. The specimens were exposed to 100ºC, 300ºC temperatures. 8 cylindrical specimens are cast with diameter 150 mm and height 300 mm. The pull-out test, compression test and split tensile strength test is done as per IS 2770 (Part I) – 1967 and IS 516:1959 respectively. The concrete mix design is done as per IS 10262:2009.

3.1 Preparation of Specimens

The specimen for pull out test is prepared as per the code IS: 2770 (Part-I). As per the code, the size of the cube selected for 20 mm steel bar is 150 mm. The bar is projected down for a distance of 10 mm from the bottom face of the cube. The embedded length of the bar is taken as 150 mm.

The cube is reinforced with a helix of 6 mm diameter plain mild steel reinforcing bar at 25 mm pitch. The outer diameter of the helix and size of the cube should be equal. The fresh concrete is placed in the moulds. The pull out specimen are cured for 28 days.

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Figure 5: Mould

Figure 6: Pull out specimen

3.2 Specimen Subjected To Heat

The pull out specimen, cubes an cylinders are placed in electrical oven. And they are subjected to temperatures 100ºC and 300ºC for 4 hours. They are left for cooling for 24 hours. Then testing is done.

IV. TESTING OF SPECIMEN

1. Tests On Hardened Concrete

The various tests which are done on hardened concrete cubes are compression test. The test which is done on cylinders are split tensile strength test.

Figure 7: Specimen loaded in Compressive testing machine

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2. Testing Of Specimen

The specimens are taken to test for pull-out test. The physical observations like and crack variation are made. Universal Testing Machine of capacity 1000 kNis used to conduct the pull out test which is used for finding out the bonding strength of concrete. The testing was done as per IS 2770 (Part I) – 1967.

Figure 8: Pull out testing

Figure 9: Specimen undergoing Pull out test

V. RESULTS AND DISCUSSIONS

The cube specimens are tested for compressive strength. The tests are done after 7 days, 14 days and 28 days curing. The analysis of the results are done and also the comparisons are done between the temperatures and the strength. The compressive strength results are given below.

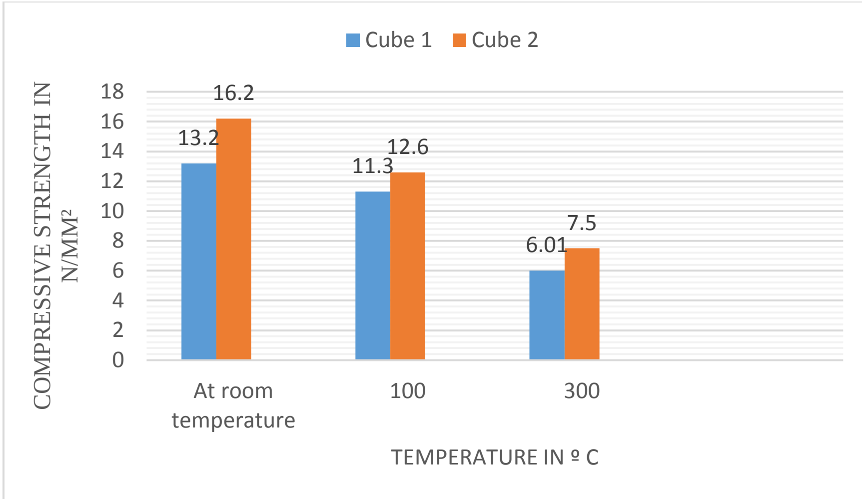

Chart 1: Variation of compressive strength for 7 days

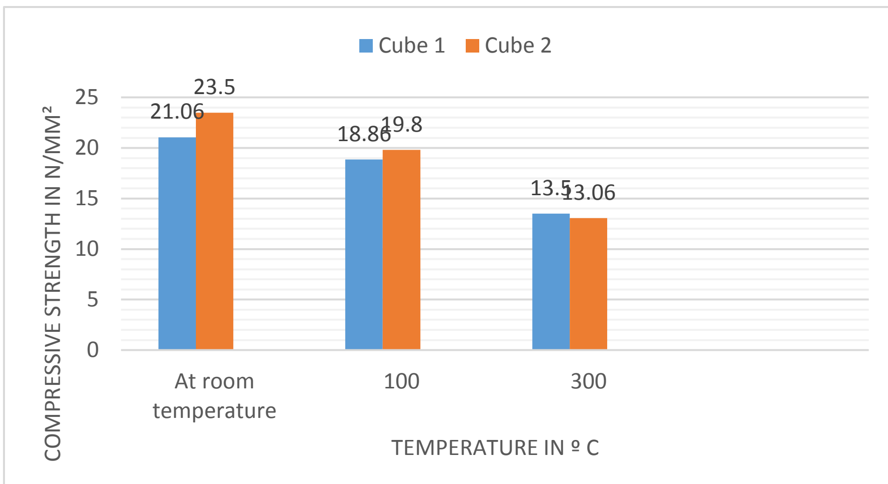

Chart 2: Variation of compressive strength for 14 days

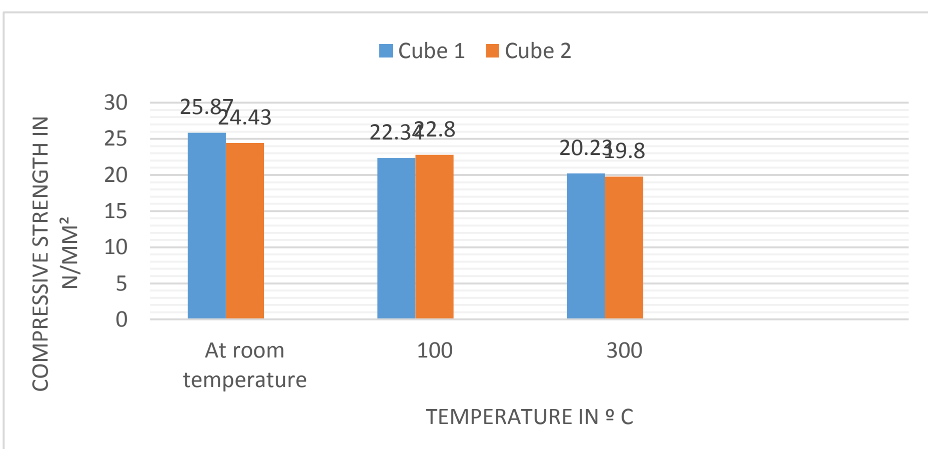

Chart 3: Variation of compressive strength for 28 days

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From the above charts, it is clear that the compressive strength of concrete decreases with the increase in temperature. From chart 1, for 7 days compressive strength test, when the cube was exposed to 100 C, there was a decrease of 22.2% in strength. And when the cube was exposed to 300 C, there was a decrease of 44.7% in strength. From chart 2, for 14 days compressive strength test, when the cube was exposed to 100 C for 4 hours, there was a decrease of 10 % strength. Similarly there was decrease of 40% strength when exposed to 300 C. From chart 3, when the concrete cube was exposed to 100 C and 300 C for 4 hours, there was decrease in 13% and 35% strength respectively.

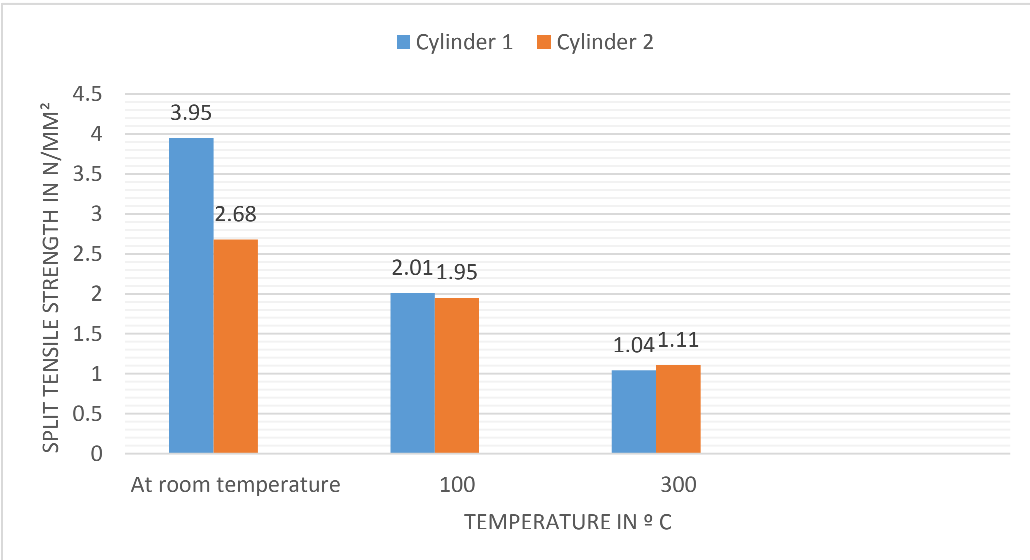

Chart 4: Variation of split tensile strength for 7 days

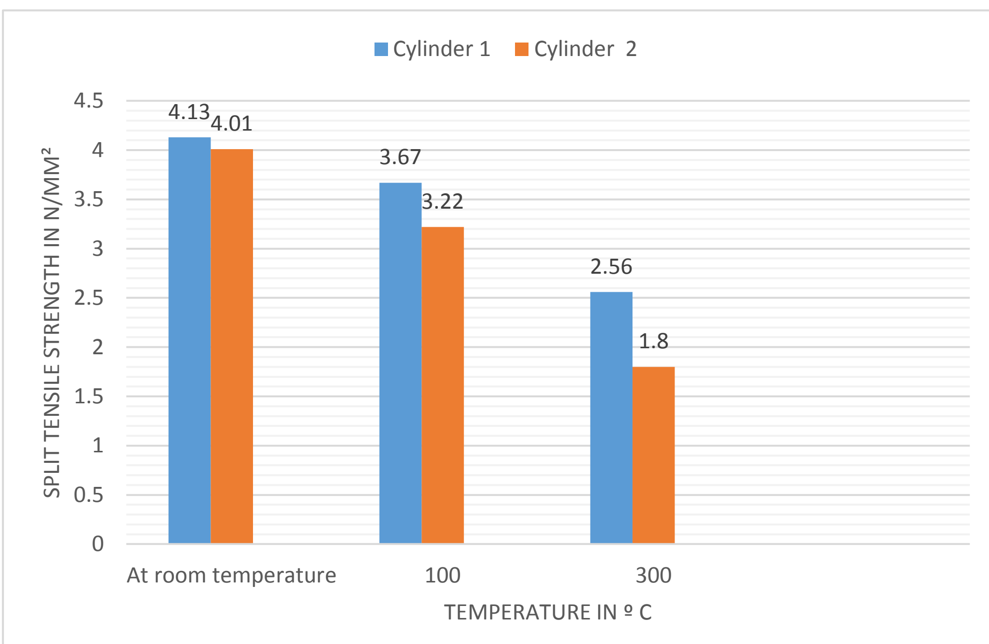

Chart 5: Variation of split tensile strength for 14 days

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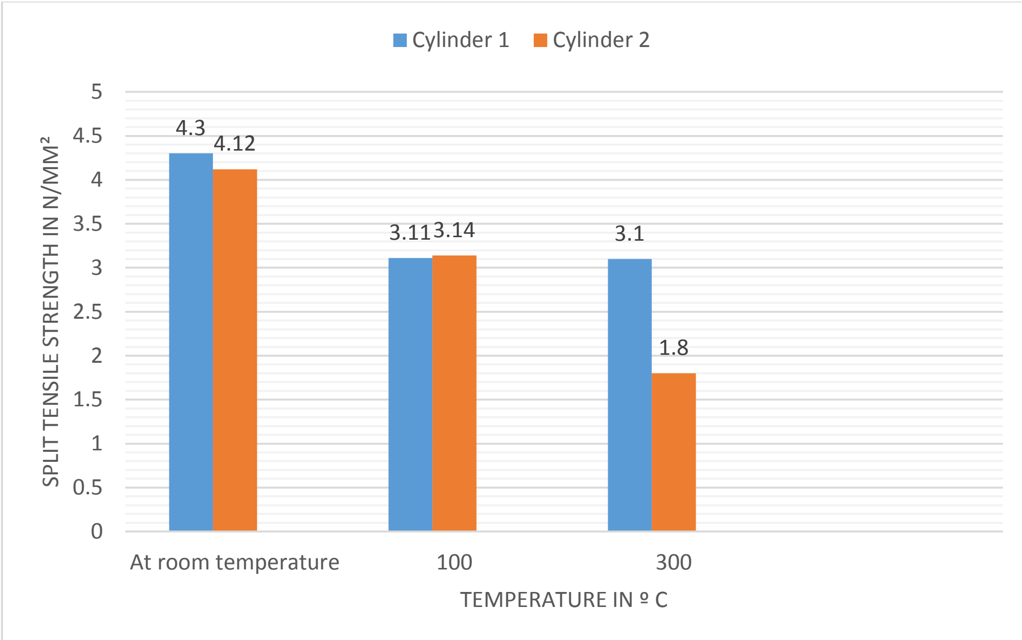

Chart 6: Variation of split tensile strength for 28 days

From the above data, it is clear that the split tensile strength of cylinders decreases with the increase in temperature. From chart 4, for 7 days the split tensile strength decreased by 49% when the concrete cylinder is exposed to 100 C for 4 hours. Similarly when exposed to 300 C there was a decrease of 73%. From chart 5, for 14 days the split tensile strength decreased about 25% and 55% when exposed to 100 C and 300 C respectively. From chart 6, for 28 days the split tensile strength decreased by 27% and 53% for 100 C and 300 C respectively.

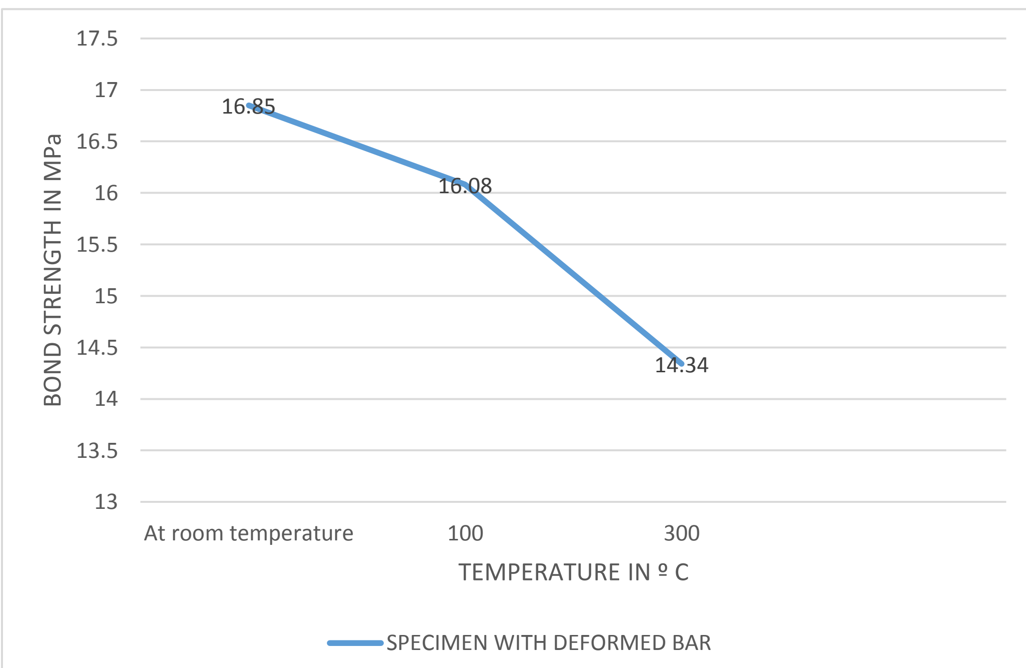

Chart 7: Variation of bond strength in deformed bars

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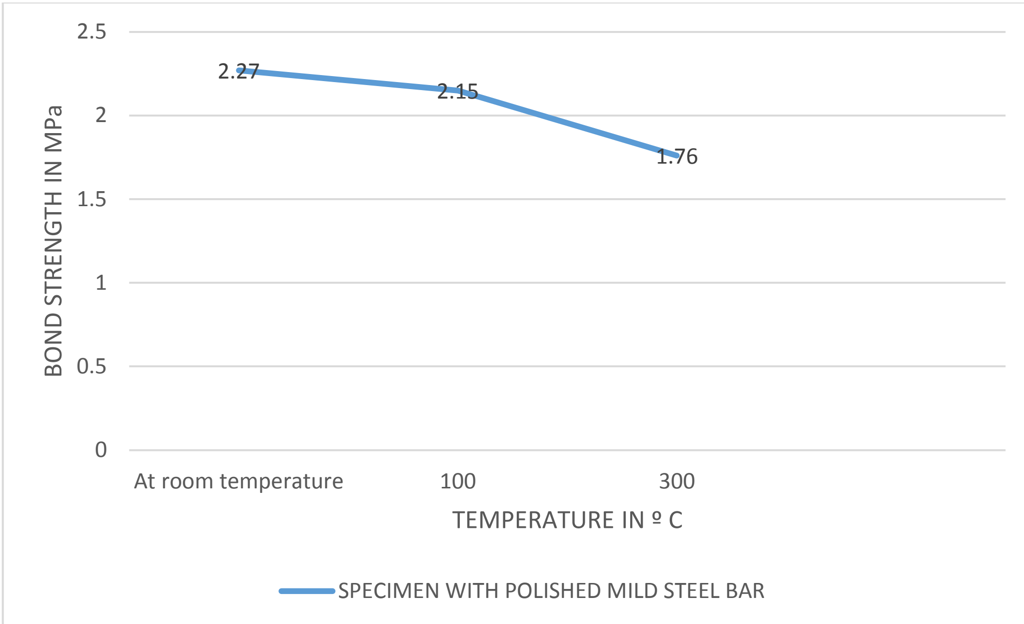

Chart 8: Variation of bond strength in mild steel polished bars

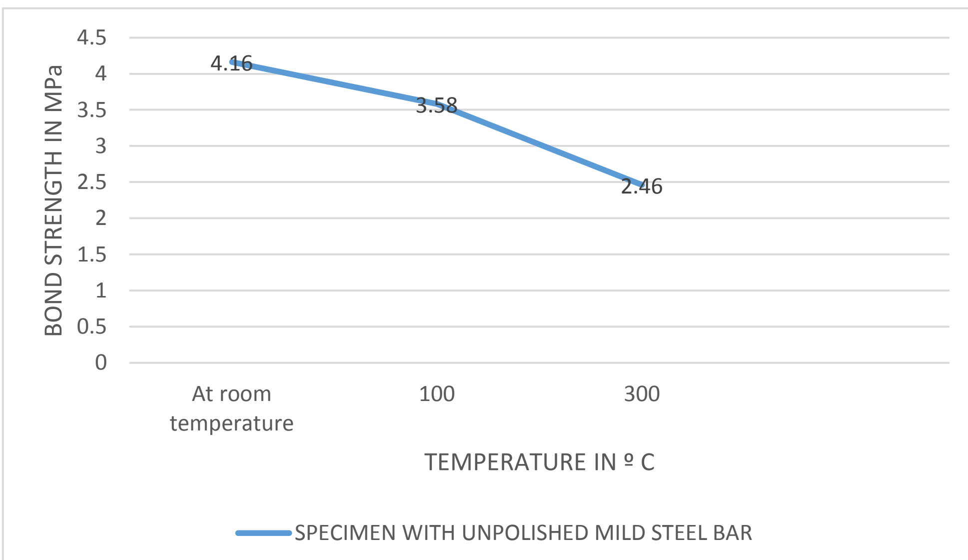

Chart 9: Variation of bond strength in mild steel unpolished bars

From the above charts, it is found that the pull out specimen with deformed bar has more strength than the pull out specimens with polished and unpolished bars. And it is also clear that the bond strength decreases with the increase in temperature. From chart 7, the pull out specimens with deformed bars, there was a decrease in 4.56% and 14.89% when the specimens are subjected to 100 C and 300 C for 4 hours. From chart 8, the pull out specimens with polished bars, there was a decrease of 5.28% and 22.46 % when subjected to 100 C and 300 C respectively. From chart 9, the pull out specimens with unpolished bars have decreased in 13.94% and 40.86% when subjected to 100 C and 300 C respectively.

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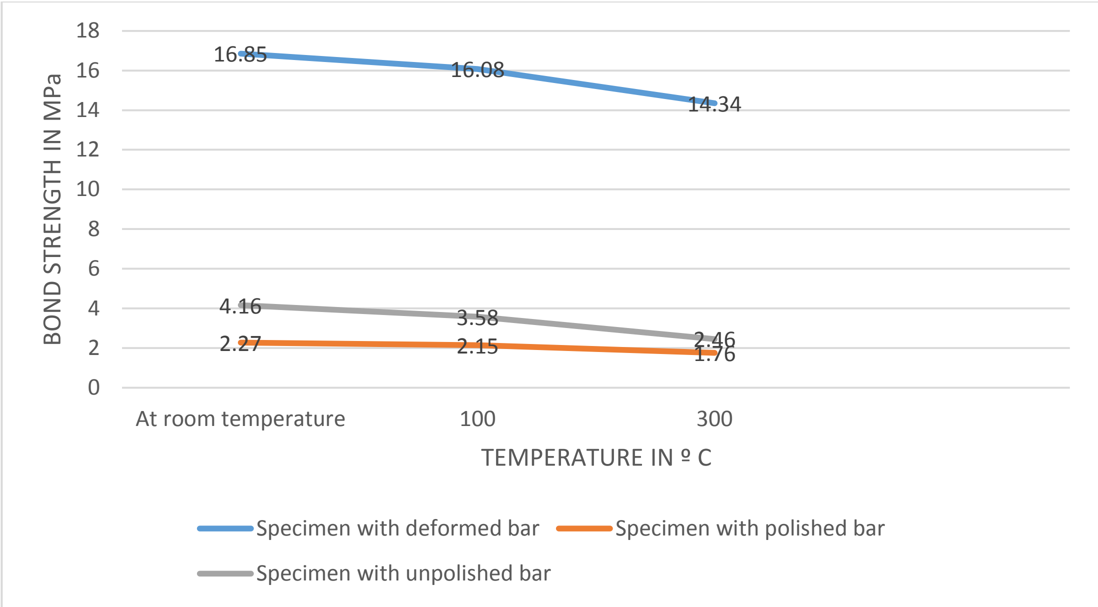

Chart 10: Variation of bond strength in all bars

The above chart shows the comparisons of three different bars and their bond strengths at different temperatures. It is observed that all three bars decrease in bond strength with decrease in temperature. The deformed bar has more bond strength even at high temperatures compared to the other bars. The polished bar has low bond strength even at low temperature. Due to chemical adhesion and friction.

VI. Conclusions

- The bond strength of the steel bar and surrounding concrete decreases with increase in temperature.
- The deformed bar has more bond strength even at the elevated temperatures.
- The polished bar has low bond strength even at the room temperature.
- The compressive strength and split tensile strength also decreases with the increase in temperature.

Figure 10: Failed specimen

- The failure which is observed when the pull out test is done is splitting failure.

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