STUDY ON BSALT FIBER REINFORCED POLYMER BARS

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ABSTRACT,

The deterioration of reinforced concrete structures due to corrosion of steel reinforcements is studied and Several improvements (e.g., galvanizing and coating) and alternate reinforcements (like carbon and glass fiber reinforced polymer bars) and have been tried in the past. The recent introduction of Basalt composite rebars, offers a number of advantages over the conventional steel bars as well as FRP bars. The mechanical and chemical properties of these bars are discussed in this paper along with their advantages and drawback. basalt fiber reinforcement bar is a new imerging material in the construction field. BFRP bars have possible solution to the corrosion problems of steel reinforcement in rcc structures though its mechanical properties have to be studied and less research work has been done. Also BFRP bars have not been incorporated into design standard specification. Thus, properties like durability, tensile strength when exposed to aggressive environments, alkaline environment, exposed period and elevated temperature. As well as the degradation mechanism and mode of failure of BFRP bars is to be studied experimentally.

This article describes a new type of reinforcing bars, developed from basalt rocks, which are stronger than steel rods and at the same time are not prone to corrosion.

Keywords: Basalt fiber reinforced polymer bars, Durability, Tensile strength.

I. INTRODUCTION

Basalt Composite bars are manufactured from continuous Basalt filaments, epoxy and polyester resins using a pultrusion process. It is 80% basalt rock fiber by weight, and balance is epoxy, Dacron winding and sand (www.withconcrete.com). It is a low-cost, high-strength, high-modulus, and corrosion-resistant alternative to steel for concrete reinforcement. BCR is a bar with continuous spiral ribbing, formed by a rolling basalt or kevlar thread, for better adhesion with concrete. The ACI Specification, ACI 440.6-08, does not cover BCR, as BCR has been introduced in the market only recently. However, ASTM testing of BCRs indicates that this material will easily meet the minimum performance requirements of ACI 440.6-08. Note that the specifications of BCR change as the diameter increases, with smallerdiameter rods generally having higher tensile strength and modulus of elasticity.

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The advantages of BCR over steel or even FRP reinforcement are given below:

1. Much higher tensile strength than steel or fiberglass rebar of the same diameter: BCR is well over twice as strong in tension to prevent concrete cracking as grade 60 steel!

2. Strength + Zero rusting allows for thinner, lighter panels and decks: Since BCR does not rust or absorb water, the thickness of concrete cover can be reduced. This allows for thinner concrete sections, resulting in savings of materials and cost. Due to these properties BCR is an ideal choice for applications such as marine structures (see Fig.2), off-shore structures, parking structures, bridge decks, highway under extreme environments, and structures highly susceptible to corrosion (paper and chemical industries) and for pervious concrete pavements, which are used to reduce water retention or run off.

3. BCR is 89% lighter in weight than steel rebar (see Table 1); one tonne of basalt reinforcement rods provides the reinforcement of 9.6 tonnes of steel rebar. One man can easily lift a 150 m (500') coil of 10 mm BCR. Thus, we may not require hoists or forklifts to handle BCR supplies in many projects. Moreover, this results in much less fatigue for installation workers (compared to steel), and a reduction in injuries and medical expenses. Yet BCR is at least 2.2 times stronger than steel in tension.

4. BCR's light weight allows for much faster fabrication, installation, handling, and a better overall job.

5. Very high strength allows for smaller diameter reinforcement rods. In many cases, the diameter of the rebar may be reduced when using BCR. Smaller diameter rods allow more rods to be installed in critical structural designs.

6. BCR has the same thermal coefficient of expansion as concrete. Thus they Expand and contract at a rate very close to that of concrete.

7. BCR is naturally resistant to corrosion, rust, alkali, and acids (see Fig.4). Basalt Rebar is inert to a pH of 13. Since BCR cannot rust, spalling of concrete from moisture penetration is totally eliminated! Unlike FRP bars, BCR does not need a special coating to resist the high pH from exposure to concrete.

8. Basalt fibers do not absorb and transfer moisture like glass fibers. Hence, exposed fibers will not create a path for water to penetrate and destroy concrete.

9. BCR does not conduct electricity. This prevents electrolysis in marine applications.

10.BCR is non-magnetic and does not induce magnetic fields when exposed to electromagnetic or radiofrequency (RF) energy. Hence, it can be used in applications like magnetic resonance imaging (MRI) rooms and around Radio Frequency Identification (RFID) reader.

11. Basalt can be used in a wider temperature range, 260/-200 oC to about 650/800 oC, as the melting point is 1450 oC. Though, the resins in the BCR, limit the working temperature range as -70 °C to +100 °C, BCR is useful in applications that demand fire resistance. BCR also has low heat conductivity (Thermal conductivity is the quantity of heat transmitted through a unit thickness in a direction normal to a surface of unit area, due to a unit temperature gradient under steady state conditions), inflammable and does not emit any harmful substances on fire.

12.BCR can be cut easily to length in the field with common tools.

13.Use of BCRs, increases the life of reinforced concrete structures, resulting in sustainable structures. With these bars as reinforcements, we can now design RCC for a life span of 100 years or more.

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Drawbacks and Field Handling Consideration:

1. BCRs are brittle in nature (they do not stretch as far as steel bars before breaking); hence not suitable for use in earthquake prone areas.

2. Field bends are not allowed in BCR, and it is not-weldable.n

3. BCRs are designed to be used in tension only, as their compressive and shear strengths are low.

4. As compared to steel, BCR has a lower Modulus of Elasticity. Panel deflection will be the limit to application. When pushed to its bending limit, it will just snap off cleanly. From a practical stand point, when installed in a properly engineered pour, the bending limit will be much higher than the crushinglimit of the concrete, so in a properly engineered pour BCR's lower modulus is NOT an issue.

5. Unrolling BCR coils: Substantial kinetic energy is stored during the coiling process. Care must be exercised when uncoiling to prevent tangling and uncontrolled movement of ends. Coils are shipped with U clamps to allow uncoiling from the inside of the coil for safety reasons.

6. Cutting in the field: Bolt cutters are not recommended as they dull quickly and break themselves resulting in shattered steel. Cable cutters do work well on sizes 12mm and smaller, however frequent sharpening is required. Hacksaws or abrasive wheels will work. The best choice is an inexpensive, 4" battery circular saw with common inexpensive diamond tile blade. They last a long time for the money. Bulk cuts may be done with chop saw, or gas saw with a masonry blade, but wet saw is preferred.

7. Unlike steel, BCR are not ductile, and failure will be brittle, once the ultimate tensile strength is reached. It is therefore important to keep the (sustained) loads below the ultimate strength by an adequate margin of safety.

8. The cost of these bars may be higher than steel bars. The sales price of BCR is slightly more than that of FRP bars and less than that of epoxy coated steel.

Availability of BCR bars:

Basalt/epoxy rebar is currently being pultruded in the Ukraine, and is in the process of being certified for U.S. construction. A few manufacturers have already started manufacturing Basalt rebars in USA. One of the products, with the name Rock RebarTM is marketed by Southwestern Composite Structures Inc. Another company, Sudaglass Fiber Technology (Houston, Texas), a basalt fiber producer with facilities in Russia and the Ukraine, has broken ground on a U.S. production facility in northern Texas.

Specifications :

Sr. No	Characteristics	SR	BCR	Comments
1	Density , g/cm^3	7.8	1.95	-
2	Weight of 1 linear meter, kg 10mm diameter 12mm diameter	0.617 0.888	0.15 0.221	BCR in 4 times lighter than SR
3	Ultimate strength, N/mm Tensile compressive	485 485	1200 420	BCR is more than 2 times stronger than SR
4	Young's Modulus, GPa	200	52-57	BCR has 66-111 times less heat conductivity than SR
5	Thermal conductivity ocoef ficient, kcal/(hr m C)	38	0.35-0.59	Expansion of BCR is 12 times less than SR
6	Coefficient of linear thermal -6expansion, 10 m/m K	12	1	-
7	Amount of 1 metric ton of rebars, linear meter 10mm diameter 12mm diameter	1621 1126	5848 4330	With BCR we can transport 4 times more rebars at a time
8	Percentage elongation	14.5	2.2	BCR not suitable for EQ zones

Table 1 Comparison of Steel Rebar (SR) with Basalt Composite Rebar (BCR)

II. LITERATURE REVIEW

1. **David Pawlowski, Maciej Szumigala (June 2015)**tried to explain flexural behaviour of BFRP RC beams by carrying out tensile test on simply supported BFRP RC beams. The different reinforcement ratio were used. From the results it was concluded that the reinforcement ratio has a significant effect on the flexural behaviour of BFRP RC beams. The increase in the reinforcement ratio results in an increase in the ultimate loads in the stiffness of the beams. When the reinforcementratio is greater than the balanced reinforcement ratio the beams fail by concrete crushing. Behavior of beam exhibits some ductility. However when the reinforcement ratio is less than balanced reinforcement ratio(according to ACI 440.IR-06), the beams fail suddenly due to reinforcement rupture.
2. **Enrico Quagliarini, Franesco Monni, Federica Bondioli, Stefano Lenci (December 2015)** studied the tensile characters comparatively between the other fiber reinforced polymer bar and basalt fiber bars. The other fiber reinforeced polymer bar consisted of steel fiber, glass fiber, carbon fiber and apoxy resin fibers. the tested BFRP bars seems to be not so rigid (less than FBR bars) but rather deformable and with good tensile strength The comparision between experimental results and the ones of other similar fiber bars shows that BFRP bars could be a good alternative to other FRP bars.

3. **Andreea Serbescu, Maurizio Guadagnini, Kypros Pilakoutas (June-2014)** carried out tensile tests on BFRP bars and strength retention in conditioned enviornmants by varying the temperature and pH value. It shows that when the pH value is increased to that of concrete the bars loose slightly more strength. When the temperature is increase to 60^{o} C , significant drop in strength is observed. In this test the tensile strength of BFRP bars obtained was in the range 972 Mpa to 1481 Mpa while the elastic modulas varied from 34 to 47 Gpa.
4. **Marek Urbanski , Andrzej Lapko ,Andrzej Garbacz (April 2013)** Determined the tensile strength of BFRP Bars of 8mm dia. & compared the styrength with steel bars. Due to the anisotropic nature of the BFRP bars , basalt fibre strength in the transverse direction is very small compared to the very high strength in longitudinal direction. The important aspect of BFRP bars is thst the stress-strain relationship is always linear, until destruction , this linearity means that there is no redistribution of stress & consequently the bars cannot be used in construction of structures requiring large plastic deformation. In the steel reinforcement bars case, the cause of destruction was the concrete crash in the compression zone. There was no rupture of basalt bars in the flexure reinforcement. The destruction of the was due to shera force in the support zones and it had a brittle nature. It was noted that critical load for tested beams reinforced with BFRP bars was much greater then carrying capacity of beams with steel reinforcement .
5. **Mohamed Hassan, Brahim Benmokrane, Adel Elsafty, Amir Fam**(**September 2016)**presented some results of an entensive program investigating the bond durability behaviour of BERP bars in concrete structures and the long term bond strength retention predications of the BFRP bars on the basis of short term result. The physical and mechanical properties of the BFRP bars were determined in accordance with ACI 440.6M(20). These properties were compared to the minimum requirement for the FRP bars as mention in ACI440.6M(20). The main objective of this study was to investigate the band durability of BFRP bars to embedded in concrete when exposed to harsh environment. Bond strength increased as did the temperature when the specimen were exposed to accelerate conditioning environment as a result of an increase in concrete strength during immersion.
6. **Zhiqiang Dong, Gang wu , Bo Xu, Xin Wang, Luc Taerwe(December 2015)** this paper present a bond durabilitry test for the BFRP bars to concrete immersed in sea water compared with GFRP bars, CFRP bars and steel bar. Test results show that the maximum bond strength of the BFRP bars coated with vinyl ester and GFRP bars coated with vinyl ester experiences degradation, while the value of basalt epoxy bar to concrete remains essentially unchanged. For ribbed BFRP bars, surface sand coating lowered the short term bond strength but significantly improved the bond durability. The short term bond strength of the ribbed FRP bars were higher than the bond strength of steel bars.

III. RESULTS AND DISCUSSIONS

Above literature studied about the mechanical properties of the BFRP bars in comparision with steel and other reinforced bars. Due to the much large width of crack in beams reinforced with basalt bars compared to reinforced concrete beams, it is necessary to determine the appropriate minimum amount of reinforcement, which will reduce the width of crack in bending. The bond strength retention prediction after 50 years of service life in dry, moist and moisture saturated environments with mean annual temperature between 5^{o}C and 35^{o}C ranged from 71% to 91%.

IV. CONCLUSION

From the study of above literature, it can be concluded that the performance of BFRP bars in aggressive environment and sea water is better than the steel reinforcement and other fiber reinforced polymer bars. Basalt composite rebars (BCR) have been introduced recently into the market as an alternative to steel bars. They offer a number of advantages over the conventional steel bars as well as FRP bars. Their light weight combined with non-corrosive nature will result in economic and sustainable reinforced concrete structures. BCR is an ideal choice for applications such as marine structures, off-shore structures, parking structures, bridge decks, highway under extreme environments, and structures highly susceptible to corrosion (paper and chemical industries) and for pervious concrete pavements.

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