A Review Paper on Basalt Fiber Reinforced Polymer (BFRP) Rebar as a Corrosion Resisting Reinforcement in Concrete

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Abstract— In today's era, Reinforced Concrete is the widest building material which is used in the world. Hence, it comes as no surprise that an enormous amount of research has been undertaken to enhance its performance, making it possible to build bigger, safer, and more economic structures that are durable in environments. But with change in environmental condition, reinforced steel is susceptible to degradation. Corrosion is the most common and important factor which affect the durability of concrete, which greatly reduces the service life of concrete structures. To overcome from such effects the fiber reinforced polymer (FRP) rebar is the best alternative for steel in concrete. The Basalt Fiber Reinforced Polymer (BFRP) rebar has much more potential to replace the conventional steel bar. But the temperature, alkali and alkaline concentration affect more on the degradation and such various properties of BFRP bars. The Basalt Fiber Reinforced Polymer rebar is in a phase of research, the properties such as strength, durability, alkaline resistance, propagation of crack, and its behaviour is researched by various authors but the long-term properties of bars such as corrosion creep are still not studied completely. Also, the available few studies of corrosion are not compared to conventional steel rebar.

Keywords: BFRP Rebar, Basalt Fiber, Corrosion Resisting Material, New Reinforcement Material, RC Concrete

I. INTRODUCTION

Concrete is the universally accepted construction material. Hence, it comes as no surprise that research has been undertaken to enhance its performance, making it possible to build safer, bigger, and more economic structures that are durable in environments. The various materials are used with concrete such as aluminum, steel, timber, etc. One of them to make it more sustainable is steel. It is used with concrete due to its strength, stability, durability, ductility, etc. properties (also known as reinforced cement concrete). But with change in environmental condition, it is susceptible to degradation. Corrosion is the most common and important factor which affect the durability of concrete, which greatly reduces the service life of concrete structures. Therefore, the research of steel corrosion in concrete is important for the sustainability of the concrete structure.

To overcome from such effects, the fiber reinforced polymer (FRP) rebar is the best alternative for steel in concrete. There are various types of FRP rebars such as Glass reinforced polymer (GFRP), Carbon reinforced polymer (CFRP), Aramid reinforced polymer (AFRP), And Basalt reinforced polymer (BFRP). Besides from that, the basalt fiber reinforced polymer rebar, produced from basalt stone, is a kind of high-tech fiber not harmful to human beings. The application temperature range of basalt fibers is –300 to +700 C. In addition, basalt fibers have better mechanical property to improve a thermal and chemical stability of concrete than steel and also than other FRP rebars. Due to such properties of higher application of temperature in manufacturing, harmlessness to human beings and excellent resistance to alkaline and acid attack on basalt rock, basalt fibers are increasingly being used as a replacement of steel as a reinforcement material in polymer concrete and metallic matrices.

II. LITERATURE REVIEW

1) Miaomiao Zhu[1] (2017), he reviews the uses of the basalt fiber Reinforced Polymer (BFRP) in concrete. From that he seen and commented the BFRP is one such material of interest currently being extensively used, which is cost-effective and offers exceptional properties over glass fibers and less inexpensive than carbon fiber. The important advantages of these composites include high specific mechanical, physical, and chemical properties. The BFRP used as a reinforcement material for concrete, and discusses the enhancement in mechanical, thermal and chemical resistant properties achieved for the use of BFRP for applications in specific industries in recent 5 years.
2) Fareed Elgabbas[2] (2015), studied the experimental investigation of the physical, mechanical, and durability characteristics of basalt fiber-reinforced polymer (BFRP) bars. The BFRP bars are conditioned in an alkaline solution simulating the concrete environment (up to 3000 h at 60^0 C) for assessing the durability and long-term performance as internal reinforcement for concrete elements. After that the properties are evaluated and compared with the unconditioned (reference) values. Also the three types of BFRP bars were investigated. The test results showed that the BFRP bars had better mechanical behaviour than GFRP and could be placed in the same category as grade II and grade III GFRP bars (according to tensile modulus of elasticity). Their tensile strength was higher than that provided by CAN/CSA S807-10 for CFRP bars. But the result shows that the BFRP bars showed poor alkali resistance and exhibited a remarkable reduction in mechanical properties due to the resin fiber interface issues, which needs to be prohibited to achieve the required durability characteristics.
3) Suraksha Sharma[3] (2020), studied on the degradation of the basalt fiber reinforced polymer bar in a seawater and sea sand concrete environment with two different approaches a) Degradation rate based approach b) Diffusion based approach to investigate of basalt fiber reinforced polymer bar in sea water and sea sand concrete solution under various temperature (32^0, 40^0, 48^0, 55^0 C). The degradation of material was quantified in a COMSOL Multi-physics Software using simple 2-

Diamentional model of basalt fiber reinforced polymer bar. The finding from both the approaches they suggested the BFRP bars become more susceptible to degradation as the exposure temperature increases and in greater geometrical deformities.

4) Chunhong Tang[4] (2018), he studied the tensile strength and corrosion properties of basalt fibers using the Sodium Hydroxide (NaOH) solution with various concentration and temperature. And from this they found that from quantitative X-Ray Fluorescence (XRF) showed that the mass loss of Basalt Fibers was mainly due to the leaching of silicon aluminium and potassium ions. And the corrosion shell enabled an increase in strength and elongation at break of basalt fibers considerably. Results showed that the tensile strength of fibers was greatly dependent on temperature and concentration. After the basalt fiber immersed in 1 mol/L NaOH solution at 50 ◦C for 1 h, 3 h, 6 h, 1 day and 3 days, their retention ratios of strength were 67.6%, 57.8%, 52.5%, 49.0%, 58.2%, correspondingly. The result shows that as the temperature increases corrosion rate of basalt fibers also increases, from 25 to 70 ◦C, the mass loss of fibers increased from 2.4% to 33.8% for fibers immersed in 1 mol/L of NaOH for 3 days.
5) Hao Meng[5] (2019), they studied the durability of basalt fibre reinforced concrete (BFRC) under the alkaline environment and analyse its corrosion mechanism in his research the 20% sodium hydroxide (NaOH) solution was used to simulate the alkaline environment, and the control group of clear water was also set by immersing and corroding the test blocks for 90 days, 180 days and 270 days respectively. Afterwards, the crack propagation, Na+ migration, water absorption, and compressive bearing capacity of the test blocks are analysed under different corrosion time and the failure system was discussed. The results show that the addition of BF can efficiently reduces the generation and propagation of concrete cracks. As compared with ordinary concrete, in an alkaline environment, the BF can efficiently prevent the migration of Na+, but its effect decreases with the increase of corrosion time. He also concluded that the bearing capacity of concrete can be increased by addition of BF in alkaline environment up to a certain degree, but inadequate or unnecessary addition will negatively affect the durability of concrete.
6) Jianxun Liu[6] (2018), he studied the alkali salt resistance of two different resin matrix a) vinyl resin matrix and b) epoxy resin matrix of BFRP bars under wet and dry cycles, experiments of BFRP bars under continuous immersion were also conducted. The tensile and shear strength of BFRP bars are tested. Also the mechanisms of the two different conditions were analyzed by scanning electron microscopy (SEM). A relationship between the degradations under continuous immersion and wet and dry cycling was established. The results showed the vinyl resin matrix in a BFRP bars was better alkali salt resistance than that of epoxy resin matrix BFRP bars under wet and dry cycles.
7) Preyash Bhatt[7](2017), in his study he took a review on a Basalt Reinforcement with Conventional reinforcement and they concluded that the basalt rebars are 89% light in weight than steel and also non corrosive in nature with high tensile strength. The mechanical properties like tensile strength and modulus of elasticity are tested compared with the steel. The physical properties like strength and durability will also be tested compared to steel. The beam and slab will be casted by using basalt rebars and the load carrying capacity will be checked.
8) Paul Archbold[8] (2018), studied the corrosion resistance of precast concrete in underground utility vaults using basalt fiber reinforced polymer BFRP bars and carbon fiber reinforced polymer CFRP grid reinforcement by replacing steel reinforcement. In his research he tested the panels reinforced with basalt fiber reinforced polymer and carbon fiber reinforced polymer grid panels and the result are compared with panels that are steel reinforced and unreinforced. And from this he concluded that the BFRP-reinforced panels showed a better failure mode than the CFRP-grid-reinforced panels. The failure of the CFRP-grid-reinforced panel was influenced by using a less-thanbalanced amount of reinforcement. The comparison between the BFRPreinforced and CFRP-grid-reinforced panels shows the significance of reinforcing FRP-reinforced panels with more than the balanced amount of reinforcement. The test results show that replacing steel with an equal volume of BFRP satisfies both service load and ultimate load–level recommendations, while CFRP-grid-reinforced panels show unacceptable serviceability criteria at service load level. Therefore, it is possible to replace steel with corrosion resistant BFRP bars.
9) Hanbing Liu[9] (2020), he studied the evaluation of the corrosion of steel bars embedded in basalt fiber modified reactive powder concrete (BFRPC) using an electrochemical technique. It is a NDT testing and real-time monitoring technique used to exemplify the corrosion behaviour of steel bars entrenched in concrete structures. The main cause of corrosion of steel in concrete is Crack and steel concrete interface damage (SCID). Hence, for evaluating the steel corrosion behaviour the specimens with crack and SCID were prepared using both the reinforced fiber free RPC and BFRPC are prepared and tested using electrochemical methods. The results show that the both crack and SCID would aggravate the steel corrosion, and the crack was the major factor that affects the corrosion process. Also the use of BF in a BFRPC specimen shows that bridging action of BF reduces the concrete cracking and steel corrosion process of concrete.
10) S. K. Kirthika[10] (2018), studied by carried out the experiment on the basalt fibre-reinforced concrete by adding the percentage volume fraction of fibre 0.50 (13.0 kg/m3), 0.75 (19.5 kg/m3) and 1.00 (26.0 kg/m3) in concrete. And he found that the increase in compressive, splitting tensile and flexural strength is in the order of 26.79, 42.71 and 44.06%, respectively, for 0.50% amount of basalt fibres as compared to control concrete. Also he commented that the basalt fibre is amorphous and hydrophilic in nature.
11) Zhensheng Guo[11] (2018), studied and reviews the alkali resistance of Basalt Fiber Reinforced Concrete and Static

mechanical properties of Composites in China. In his study he took a deep Research on three-dimensional randomly distributed BFRC and it was analyzed and summarized. Also the result showed the BF are considerably affected by the fiber component and alkali corrosion temperature; the BF has little effect on the compressive strength of the concrete; the tensile and flexural strengths of the composites considerably increase compared with plain concrete, and the fiber content has a considerable effect on the strength.

III. Conclusion

The research of the above literature shows that the Basalt Fiber Reinforced Polymer BFRP rebar has much more potential to replace the conventional steel bar. As it has high strength to weight ratio, durable, non-corrosive in nature. But the temperature, alkali and alkaline concentration affect more on the degradation and such various properties of BFRP bars. The Basalt Fiber Reinforced Polymer rebar is in a phase of research the properties such as strength, durability, alkaline resistance, propagation of crack and its behavior is researched by above authors but the long term properties of bars such as corrosion, creep are still not studied completely. Also, the available few studies of corrosion are not compared with the conventional steel rebar property, which has a great significance for study.

Reference

[1] Miaomiao zhu, jianxun ma '*a review on the usage of basalt fiber reinforced polymer (BFRP) in concrete*' apfis2017 - 6 th asia-pacific conference on frp in structures singapore, 19-21st july 2017

[2] Fareed elgabbas, ehab a. Ahmed, brahim benmokrane *'Physical and mechanical characteristics of new basalt-FRP bars for reinforcing concrete structures'* Construction and Building Materials vol. 95 (2015) 623–635 http://dx.doi.org/10.1016/j.conbuildmat.2015.07.036 accepted 12 July 2015

[3] Suraksha sharma, daxu zhang, and qi zhao '*degradation of basalt fiber– reinforced polymer bars in seawater and sea sand concrete environment*' advances in mechanical engineering 2020, vol. 12(3) 1–11 the author(s) accepted: 11 february 2020

[4] Chunhong tang, hao jiang, xu zhang guangyao li, and junjia cui '*corrosion behavior and mechanism of basalt fibers in sodium hydroxide solution*' materials 2018, 11, 1381; doi: 10.3390/ma11081381 www.mdpi.com/journal/materials published: 8 august 2018

[5] Hao meng, jun wei and haowei li '*study on corrosion behaviour of basalt fibre reinforced concrete under NaOH environment*' 4th international conference on energy equipment science and engineering iop conf. Series: earth and environmental science 242 (2019) 052051

[6] Jianxun liu, ning li, meirong chen, jianping yang, biao long and zhishen wu *'durability of basalt fiber-reinforced polymer bars in wet-dry cycles alkali-salt corrosion'* sci eng compos mater 2019; 43–52 https://doi.org/10.1515/secm-2018-0030 accepted august 3, 2018

[7] Preyash bhatt, yash chokshi, kushal shah, juned bhojawala *'a review paper on comparative study on basalt reinforcement with conventional reinforcement'* international journal of advance engineering and research development volume 4, issue 8, august -2017

[8] Paul archbold and gobithas tharmarajah *'evaluation of corrosion-resistant basalt-fiber-reinforced polymer bars and carbon-fiber-reinforced polymer grid reinforcement to replace steel in precast concrete underground utility vaults'* precast/prestressed concrete institute, c/o pci journal, 200 w. Adams st., suite 2100, chicago, il 60606.

[9] Hanbing liu, xiang lyu , yuwei zhang, guobao luo, and wenjun li *'steel corrosion evaluation of basalt fiber rpc affected by crack and steel-concrete interface damage using electrochemical methods'* sensors 2020, 20, 5027; doi:10.3390/s20185027 www.mdpi.com/journal/sensors

[10] S. K. Kirthika, s. K. Singh *'experimental investigations on basalt fibre-reinforced concrete'* article in journal of the institution of engineers (india) series a a (december 2018) 99(4):661–670 https://doi.org/10.1007/s40030-018-0325-4

[11] Zhensheng guo, chunfeng wan, mengye xu, and jinxiang chen *'review of basalt fiber-reinforced concrete in china: alkali resistance of fibers and static mechanical properties of composites'* hindawi advances in materials science and engineering volume 2018, article id 9198656, 11 pages https://doi.org/10.1155/2018/9198656

