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Evaluation of mechanical properties of basalt fibre reinforced concrete

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Abstract— **Concrete is the most widely used building material in the construction industry. It consists of a rationally chosen mixture of binding material such as cement, well graded fine and coarse aggregates, water and admixtures. Conventional concrete is modified by random dispersion of short discrete fine fibres to improve its mechanical properties. The improvement in structural performance depends on the strength characteristics, volume, spacing, dispersion and orientation, shape and the aspect ratio of the fibres. For fibres to be more effective, each fibre needs to be fully embedded in the matrix, thus cement paste requirement is more. It is relatively strong in compression but weak in tension and tends to be brittle. These two weaknesses have limited its use. Another fundamental weakness of concrete is that cracks start to form as soon as concrete is placed and before it has properly hardened. Glass, fibre, carbon fibres are commonly used in manufacturing of reinforcing bars for concrete applications. This study present the art of knowledge of basalt fibre, it is relatively new material. Basalt is an igneous rock, It is a single material fibre manufactured by melting of basalt and extruding the molten basalt through small nozzles to produce continuous filaments of basalt fibre. It is a high performance non-metallic fibre made from basalt rock melted at high temperature. In the last decade, basalt has emerged as a contender in the fibre reinforcement of composites. In this report Evaluation of mechanical properties in basalt fibre reinforced concrete were investigated. The volume fractions of basalt fibre of (0.1, 0.2, 0.3, and 0.5% by total mix volume) were used. Properties such as compressive and splitting tensile strengths were examined. Results indicated that the strength increases with increase the fibre content till 0.3% then there is a slight reduction when 0.5% fibre used. The modulus of elasticity shows the trend of the strengths results. Many applications of basalt fibre are residential, industrial, highway and bridges etc.**

Keywords: Chopped Basalt Fibre, Compressive Strength of BFRC, Tensile Strength of BFRC, Fibre reinforcement of composites.

I. INTRODUCTION

CONCRETE is known as the construction material most used around the world. It is strong in compression as the aggregates can effectively carry the compression load. However, concrete is weak in tension, as the cement holding the aggregate can crack, causing concrete to break. An effective way to improve the tensile strength of concrete and reduce the number of defects is by adding different fractions of fibres, Youjiang Wang [36]. Fibres can enhance the concrete strength, which enables the construction to withstand external forces. However, fibres are manufactured specially to prevent the effect of shattering forces by tightly holding concrete together, NRMCA [19].

The rapid increase in the use of fibres in concrete is attributed to its positive effect on the mechanical properties of the cementations composites. It is proven that the addition of fibres to concrete has a significant impact on improving the mechanical properties of fresh and hardened concrete, such as compressive strength, tensile strength, flexural strength, and workability. The use of fibres has undergone major development in the last 30 years, and this composite material has been used successfully in various applications of civil engineering. The current new generation of fibre applications in concrete include Slurry Infiltrated Fibrous Reinforced Concrete (SIFCON), Engineered Cementations Composite (ECC), and Reactive Powder Concrete (RPC), P.K. Mehta [24].

One of the promising new materials used in the construction industry is basalt fibre. It is only in the last few years that extensive research and tests have been conducted on this product, with a view to its application in the building sector. Basalt fibre has a similar chemical composition to glass fibre, but has better strength characteristics and, unlike most glass fibres, is highly resistance to alkaline, acidic and salt attack, making it an excellent product to reinforce concrete. Compared with other types of fibre, its use in the civil engineering market is very low, Richard E.Prince [26].

Basalt is a type of igneous rock formed by the rapid cooling of lava. It is found at a depth of hundreds of kilometres beneath the earth, and it reaches the surface as molten magma. When magma reaches the surface, it cools down and can be mined as a raw material, R.Karthigeyan [27]. Basalt fibre is a material made from extremely fine fibres of basalt, which is composed of several minerals extracted from the basalt volcanic rock. High quality fibres are made from basalt deposits with uniform chemical makeup.

Basalt fibres have excellent characteristics: for instance, they can bond chemically with cement. When water is added to cement, hydration starts, resulting in the production of two main components, which are:

1. CSH Calcium Silicate Hydrate
2. Ca(OH)2 Calcium hydroxide

Cement Hydration Equation:

Cement (C3S, C2S) + H2O → CSH-gel + Ca(OH)2

Basalt Fibre Reaction:

Ca(OH)2 + SiO2 → CSH-gel

Basalt fibre has a high content of SiO2, which reacts with the Ca(OH)2 produced by the hydration of Portland cement.

Table 1: The chemical composition of basalt fibres

Compound	*w% in Basalt fibres*
SiO2	*51.6 -57.5*
Al2O3	*16.9 -18.2*
CaO	*5.2 - 7.8*
MgO	*1.3-3.7*
B2O3	*--*
Na2O	*2.5-6.4*
K2O	*0.8-4.5*
Fe2O3	*4.0-9.5*

II CURRENT AVILABLE BASALT FIBRES ON THE MARKET

Basalt Fibre can be used for the reducing of susceptibility to concrete cracking. Testing results of mortars with basalt fibres show a change of failure type from brittle to ductile and strain softening.

S.No.	Properties	Basalt Fibre
1.	Breaking Strength (MPa)	3000-4840
2.	Modulus of Elasticity (GPa)	79.3-93.1
3.	Breaking Extension (%)	3.1
4.	Fibre Diameter (micrometer)	6-21
5.	Linear Density	60-4200
6.	Temperature withstand	-260to +700

III COMPOSITE STRENGTH OF A MATERIAL CONTAINING FIBRES AND AGGREGATES

In each material, stress is determined by its modulus of elasticity. Materials with high modulus of elasticity can resist higher stress than materials with low modulus of elasticity. In practice, composites that contain low modulus of elasticity are reinforced by fibres with different proportions to enhance strength and stress resistance. Therefore, the addition of fibres to composite materials is essential to enhance their modulus of elasticity. For example, from Figure 1 it is clear that the content of fibres in the composite material is relatively high. As a result, the composite material will be capable of resisting higher stress, and the failure of the matrix will be hardly noticed. Therefore, the total load will be carried by fibres before it reaches a failure point. Now consider Figure 2: fibre content is very low, and up to a certain level, the addition of fibres reduces the strength of the composite. Fibres will fail first: the major portion of the load will be transferred to the composite, which is incapable of carrying this load, and an immediate failure will occur. Therefore, the addition of fibres with different proportions to the composite will have a significant effect on the modulus elasticity of the material.

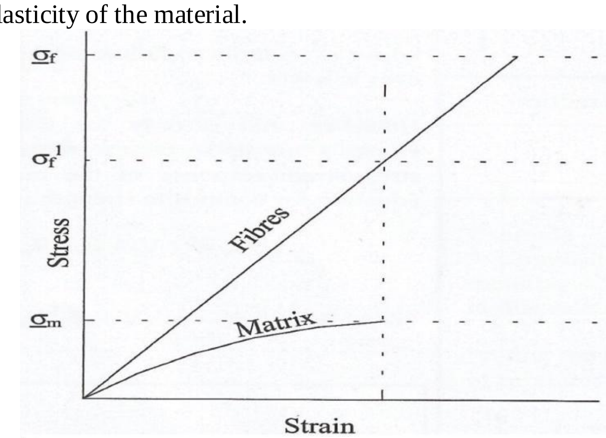


Fig. 1: High fibre content in a composite material

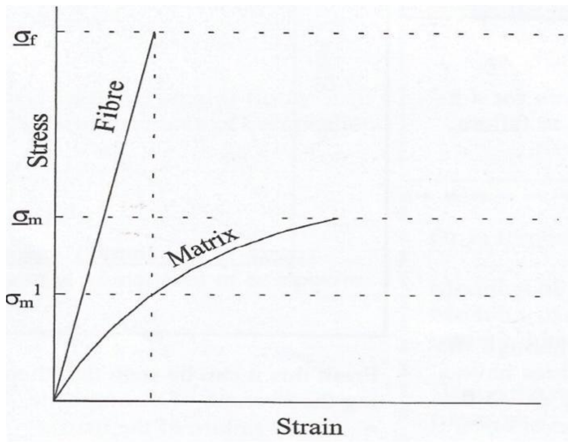


Fig. 2: Low fibre content in a composite material

On the other hand, aggregates play an essential role in absorbing and reducing stress on a matrix. When load is applied, failure occurs in aggregates not only through aggregate-mortar interface, but also through the aggregates themselves. In particular, aggregates tend to fail and break when high load is applied. Therefore, it is essential to test the ability of aggregates to withstand load, and determine the effect of aggregates on the stress-strain relationship of concrete.

IV. MECHANICAL PROPERTIES OF CONCRETE

A. Workability

Workability is the ease with which a fresh mix of concrete or mortar can be handled and placed. It is also defined as the ability of the concrete mix to fill in the shape of a form/mould with the desired work, and without reducing the concrete quality. Several factors affect the workability of fresh concrete: water content, aggregate shape, mix proportions, grading of aggregates, and the use of fibres. Workability of concrete is measured using a slump test; the addition of fibres can change the water cement ratio and, as a result, reduce its slump. Different basalt fibre lengths of 10mm, 20mm and 30mm were used with different dosages of 3, 5 and 7kg/m3. The decrease in slump occurred for two main reasons: the increase of the coefficient of friction between fibres and cement during mixing; and the absorption of certain moisture by the basalt fibre, causing the slump to reduce. Tumadhir and Borhan [33] observed the influence for workability of reinforcing concrete with different basalt fibre contents (0%, 0.1%, 0.2%, 0.3%,0.4%, 0.5%). The results showed that increasing the percentage volume of fibres leads to a decrease in slump. This is because basalt fibres affect the flow ability of fresh concrete, which results in a decrease in workability. Experimental results obtained by R.Singaravadivelan [28] showed that, as the fibre content increases in concrete, the slump of fresh mixed concrete of different basalt fibre content decreases, as well as the workability.

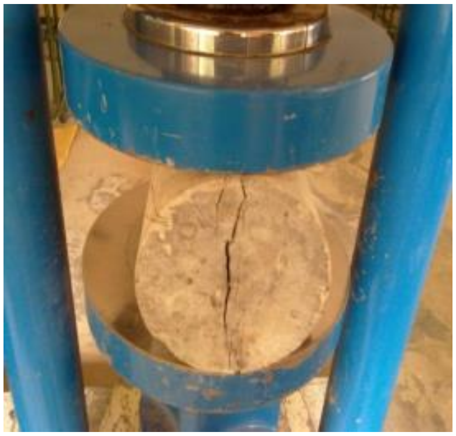
B. Compressive Strength

The compressive strength of concrete is the most common performance measure used by civil engineers in designing buildings. Compressive strength is defined as the capacity of materials to withstand load that reduces its size.

In general, concrete is strong in compression and can exhibit high strength. However adding different basalt fibre lengths and content has an effect on the compressive strength of concrete. as the basalt fibre content increases in the concrete mixture, the compressive strength of the concrete decreases, when testing concrete strength after 7 days. However, when testing concrete strength after 28 days, the compressive strength of the concrete increases with an increase in basalt fibre content to reach its maximum value at fibre content of 1%.

C. Tensile Strength

Although concrete is weak in tension, the knowledge of concrete tensile strength is essential to determine the load under which cracks will develop. This load has an influence on the formation of cracks and their propagation to the tension side of the concrete and other concrete members. Reinforcing concrete with basalt fibres reduces the crack width, thus improving concrete strength and durability. The specimens were kept in water for curing for 7 days, 14 days and 28 days, and on removal were tested by spraying water on the concrete. The results showed the tensile strength of concrete gradually increases with curing age. adding 1% content of basalt fibre to the mixture reduces the tensile strength of the concrete. Determined the tensile strength of basalt fibre reinforced concrete after 28 days, and the results showed that the tensile strength of the concrete improved significantly by 19% of its ordinary concrete.



D. Flexural Strength

In the construction and engineering field, knowing some terms such as the flexural strength of the material is essential in order to make sure that the material is strong enough to be used in structures. the flexural strength of concrete after 7 days, with and without the addition of basalt fibres.

The results show that as 1% of basalt fibre is added to concrete, the flexural strength decreases. The basalt fibre content increases, the flexural strength of the concrete increases.

The different basalt fibre content (Volume fraction of 1%), tested in a laboratory using different concrete prisms.

The results were compared with a normal concrete mixture, and it is clear that adding basalt fibres to the concrete mixture increases the mechanical properties in general, including the flexural strength.

Basalt fibres were mixed with concrete and the results were compared with ordinary Portland cement. The author carried out flexural concrete strength tests using prisms for different samples.

The results showed that the flexural strength of concrete increases for all concrete mix proportions with age.

V. SIGNIFICANCE OF THE STUDY

The use of basalt fibres in a range of industrial applications has increased significantly over the last decade. The possibilities of utilising basalt fibres with materials are now being realized, as a result there are now numerous examples where basalt fibres have found application in a number of diverse sectors. For example chopped fibres are used mainly in the building of foundations, wall panels, slab floors, and for reinforcing of asphalt concrete road. For volumetric formed reinforcement needs about 2 – 5 kg of basalt chopped fibre for 1 metric cubic concrete (one cubic includes about 100 filament fibres with length of 12mm). Results of the volumetric formed reinforcement in the hardened concrete include: (Basalt fibre & composite materials)

- Compressive strength to be increased by 8%,
- Tensile load increase by 19%,
- Gain of crack growth resistance under load

VI. CONCLUSION

Based on this literature, the effect of basalt fibre length and content on workability showed that the slump decreases as the content of basalt fibres increases. Most authors agreed that the maximum compressive strength is reached when the basalt fibre content is 0.25%; this drops as the fibre content increases. The maximum compressive strength using different basalt fibre lengths was achieved when using basalt fibre lengths between 10 and 20 mm. The literature also confirmed that adding different basalt fibre content to improve the tensile strength of concrete has a significant effect. The longer the basalt fibres used in the mixture, the higher the tensile strength achieved. Moreover, the literature agreed that increasing both content and length of basalt fibres in reinforced concrete increases the flexural strength, elastic modulus, and crack resistance of concrete. The literature showed that concrete reinforced with basalt fibres of different lengths and content achieves a higher level of permeability and less porosity. This is because basalt fibres can bond chemically with the cement, which decreases the number of pores in concrete, and consequently enhances its permeability.

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