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Damage Detection in Fiber Reinforced Concrete Using Ultrasonic Pulse Velocity

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Abstract: A non-destructive technique called ultrasonic pulse velocity is used to evaluate the characteristics of concrete and spot flaws in both natural and basalt-fiber reinforced concrete, such as fractures. Recovering basalt fiber reinforced concrete is required to address the environmental issue caused by the destruction of ancient concrete structures. The compressive strength of natural concrete should fluctuate, and the concrete cube itself should sustain damage. Cracks in both basalt fiber reinforced concrete and unreinforced concrete were found using the ultrasonic pulse velocity technique. A concrete cube of 150x150x150 mm served as the specimen. Each concrete cube was investigated for sound velocity measurements, elastic technique, and concrete damage caused by applying various loads on NC and BFRC. When the ultrasonic pulse velocity lowers, the damage level rises. According to the data, natural concrete has a greater compressive strength than BFRC, although natural concrete has a velocity that is approximately 15.34% higher. Cracks are also more common in BFRC than in natural concrete. The higher decreased velocity indicates the emergence of cracks. The higher decreased velocity indicates the emergence of cracks. The primary purpose of the research is to compare NC and BFRC, as well as to ascertain the mechanical characteristics of concrete, such as its Young's modulus, and to find concrete damage using an ultrasonic pulse velocity approach.

***Index Terms* – Basalt Fiber (BF), Basalt Fiber Reinforced Concrete (BFRC), Ultrasonic Pulse Velocity (UPV), Non-destructive test (NDT).**

I. INTRODUCTION

Concrete is a composite material comprised of fine and coarse aggregate that is bonded together by a fluid cement that gradually gets firmer. Water is the most useful material, followed by concrete. Over tonnes upon tonnes, concrete is utilized globally. It is most frequently utilized in binding materials. By 2025, the global material concrete business will generate billion in sales from its main sector of concrete. Concrete is necessary to construct structures that can withstand natural disasters and provides a technique to lessen pollution from other industries by absorbing pollutants like coal fly ash or bauxite tailings and residue. A fluid slurry that is easy to pour and shape is produced when aggregate, dry Portland cement, and cement and water are mixed. Most concrete is moulded with reinforcing elements (like rebar) added for tensile strength, resulting in reinforced concrete. The cement and water combine in a process known as concrete hydration to produce a hard material with many uses that mimics stone. The hardening process takes several hours. Because the hydration process is exothermic, the outside temperature greatly impacts how quickly concrete sets.

Concrete that has been reinforced with a fibrous material, often known as fiber-reinforced concrete (FRC), has higher structural integrity. It has uniformly dispersed, short discrete fibers that are randomly orientated. Steel, glass, synthetic, and natural fibres are only a few types of fibers that give concrete different qualities.

Basalt fibre, a material comprised of the minerals plagioclase, pyroxene, and olivine, is produced from very fine basalt fibre. It is far less costly than carbon fibre and has physical and mechanical properties superior than fibreglass. In the aerospace and automotive industries, it is used as a fireproof cloth, and it may be used as a composite to create objects like camera tripods.

The UPV test is a non-destructive in-situ probe used to evaluate the quality of brittle materials like concrete. By measuring the compression pulse velocity passing through the concrete structure, it keeps track of the durability and quality of the concrete. The velocity is then calculated by dividing the distance between the transducers by the arrival time. Lower velocities may signify concrete with fractures or cavities, whilst higher velocities designate concrete consistency and relative quality. Recently, several research have used UPV to examine the characteristics of fiber-reinforced concrete (FRC). For instance, it was evaluated if sonic pulse velocity was reliable for spotting irregularities in the masonry panels that were already in place. They came to the conclusion that sonic testing was quite effective in spotting significant density variations in the materials used for interior walls. Aceves investigated how steel fibres affected the FRC's ultrasonic velocity. When micromechanics and the idea of ultrasonic velocity were combined, taking into consideration the presence of air voids, capillary porosity, and steel, it was discovered that the ultrasonic velocity reduced as the steel volume fraction grew.

II. EXPERIMENTAL WORK

1) Cement

The OPC grade of 53 in this study complies with Indian requirements. The Vicat equipment is utilised to determine the cement's standard consistency and setting time.

2) Fine aggregate

Fine aggregates are those with a particle size of less than 4.75 mm. For making concrete, sand aggregate is crucial. In accordance with IS, tests are performed on the sand and its silt concentration.

3) Coarse Aggregate

Coarse aggregates are defined as those with a size higher than 4.75 mm. The aggregate sizes employed in this study are 20 mm and 10 mm, respectively, at a weighted percentage of 60% and 40%.

4) Water

During combining and curing, water is utilised. Potable water is generally considered for mixing concrete. Water used for mixing should be pure and devoid of any harmful substances such as salt, sugar, oils, acids, or other organic materials.

5) Properties Of Basalt Fiber

A) Physical Properties

table 1. physical properties of basalt fiber

Colour	Golden brown
Diameter	13 – 20 microns
Length (mm)	6, 8, 12
Density	2.75 g/cm^3
Friction coefficient	0.42 - 0.50
Elastic Modulus	93 GPa
Tensile Strength	3200 - 3850 MPa

B) Chemical Properties

Basalt's stability is improved by strong alkalis. Furthermore, significantly decreased is weight loss while using hot water, alkali, and acid.

exhibit resistance to microbial, bacterial, and UV radiation contamination.

It is compatible with resins made of phenol.

The amount of humidity absorbed decreases.

C) Thermal Properties

The basalt fibres have a temperature range of -260 °C to 982 °C, a melting point of 1450 °C, and a low thermal conductivity of 0.031 – 0.038 w/mk, making them ideal for fire prevention and insulation applications. Basalt fibres are the least expensive alternative for increasing brake life and reducing quick overheating when compared to other high-temperament materials including E-glass, silica, ceramics, stainless steel, and carboby. offer heat and mental safety while sacrificing three times the thermal efficiency of asbestos. The greatest substitute for asbestos is basalt fibre. Basalt fibre is both explosion-proof and non-combustible. The basalt fibres lose some of their initial strength after exposure to temperatures below 400 °C, whereas E-glass loses more than 50%.

D) Mechanical Properties

The particular tenacity of basalt fibres is often greater than the rupture stress to density ratio of steel

Basalt fibres have a strong resistance to moisture since they are neither capillary nor hygroscopic.

Basalt typically has less than 3% shot content.

figure 1. basalt fiber

table 2. mechanical properties of basalt fiber

Material type	Elastic modulus	Yield stress	Tensile strength
	E (GPa)	fy (MPa)	fu (MPa)
13-mm-diameter steel bars	200	375	560
10-mm-diameter steel bars	200	360	550
6-mm-diameter steel bars	200	400	625
10-mm-diameter BFRP bars	48.1	-	1113
6-mm-diameter BFRP bars	47.5	-	1345
BFRP sheet	91	-	2100

1) Concrete Mix Design

The test cube was prepared for compressive and ultrasonic pulse velocity testing by mixing concrete using a mixing machine. The parameters of NC and Basalt Fiber Concrete, including its elastic modulus and poison ratio, as well as any damage, such as fractures in the concrete, were evaluated using a concrete cube after mixing. This project uses a cube with the dimensions 150x150x150 mm. The cube was placed in water after casting the concrete to cure it. After the cube test in 7, 14, and 28 days, the concrete is tested on days where it is kept outside the tank for 24 hours to cure.

table 3. for 1 meter cube

MATERIAL	QUANTITY
Cement	448.053 kg
Fine Aggregate	581.28 kg
Coarse Aggregate (20mm)	1086.080 kg
Water	201.62 Lit
W/C Ratio	0.45

table 4. for 1 meter cube, we have replaced coarse aggregate with basalt fiber in 0.20%

MATERIAL	QUANTITY
Cement	448.053 kg
Fine Aggregate	581.28 kg
Coarse Aggregate (20mm)	1086.080 kg
Water	201.62 Lit
W/C Ratio	0.45
Basalt Fibre	2.172kg

figure 2. ultrasonic pulse velocity

figure 3. transducer

figure 4. compressive strength test

figure 5. UPV test

III. RESULTS AND DISCUSSION

The basalt fibre reinforced concrete and natural concrete are both checked for deterioration, such as cracks, using the ultrasonic pulse velocity. Concrete's characteristics and the velocity value obtained from ultrasonic pulse velocity are also relevant. The ultrasonic equipment recorded the concrete's compressive strength after 7, 14, and 28 days.

1) Compressive Test for NC and BFRC concrete

table 5. compressive strength test for nc and bfrc.

M_{30} grade of Concrete	Compressive strength (in N/mm^2) after 7 days	Compressive Strength (in N/mm^2) after 14 Days	Compressive Strength (in N/mm^2) after 28 Days
Natural Concrete (NC)	20.77	25.26	35.67
Basalt Fiber reinforced concrete (BFRC)	19.42	23.43	33.18

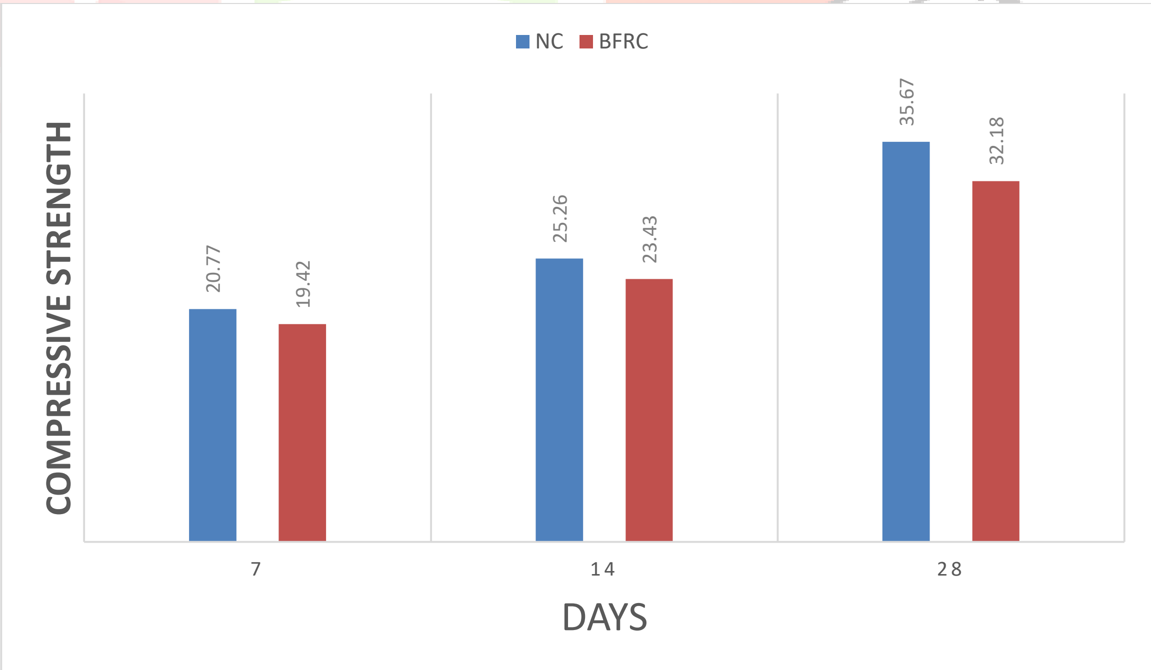

figure 6. graph comparing the result of compressive strength for NC and BFRC

2) Properties of BFRC and NC concrete using Ultrasonic Pulse velocity

The ultrasonic technique is used to determine the characteristics of BFRC and NC. According to IS code 13311 (Part 1) 1992, the pulse velocity measured on the cube size is 150x150x150mm, and the Poisson's ratio is 0.32. To calculate the velocity and gauge time passage through the concrete, the direct technique was used. The equation is used to calculate the concrete's modulus of elasticity. The values of the concrete's elastic modulus and pulse rate are listed in the table.

Table 6. Properties of NC and BFRC concrete by using Ultrasonic pulse velocity

MATERIAL	LOAD	TIME	UPV
NORMAL CONCRETE	0 KN	30.29	4952.13
	100 KN	33.5	4477.62
	200 KN	36	4166.68
	300 KN	40	3750.00
	400 KN	42	3571.43
	500 KN	65	2307.69
BFRC	0 KN	36.3	4132.24
	100 KN	38.5	3896.10
	200 KN	39	3846.15
	300 KN	41.2	36407.8
	400 KN	44.5	33707.8
	500 KN	52.3	28680.6

IV. Acknowledgment

- The compressive strength in normal concrete seems to be higher than in basalt fibre reinforced concrete. For M30 grade for 28 days is 6.98%
- After anal the compressive strength of NA is higher the BFRC and the velocity of NC is around 15.34% higher than BFRC and cracks occur more in BFRC as compared to natural concrete.

References

[1] Yang, L., Xie, H., Fang, S., Huang, C., Yang, A., & Chao, Y. J. (2021, June). Experimental study on mechanical properties and damage mechanism of basalt fiber reinforced concrete under uniaxial compression. In *Structures* (Vol. 31, pp. 330-340). Elsevier.
[2] Afroz, M., Patnaikuni, I., & Venkatesan, S. (2017). Chemical durability and performance of modified basalt fiber in concrete medium. *Construction and building materials*, *154*, 191-203.
[3] Liu, Z., Worley II, R., Du, F., Giles, C. D., Dewoolkar, M., Huston, D., & Tan, T. (2021). A study on avalanches of early age basalt fiber reinforced concrete beams during flexure. *Journal of Cleaner Production*, *279*, 123695.
[4] Yu, H., Meng, T., Zhao, Y., Liao, J., & Ying, K. (2022). Effects of basalt fiber powder on mechanical properties and microstructure of concrete. *Case Studies in Construction Materials*, *17*, e01286.
[5] Li, Y. F., Hung, J. Y., Syu, J. Y., Chang, S. M., & Kuo, W. S. (2022). Influence of sizing of basalt fiber on the mechanical behavior of basalt fiber reinforced concrete. *Journal of Materials Research and Technology*, *21*, 295-307.
[6] Jiang, C., Fan, K., Wu, F., & Chen, D. (2014). Experimental study on the mechanical properties and microstructure of chopped basalt fibre reinforced concrete. *Materials & Design*, *58*, 187-193.
[7] Villarreal, A., Cosmes-López, M., León-Martínez, F. M., Castellanos, F., Solis-Najera, S. E., & Medina, L. (2019). Ultrasonic phase velocity of carbonated cement paste probes. *Applied Acoustics*, *154*, 129-134.
[8] Janků, M., Cikrle, P., Grošek, J., Anton, O., & Stryk, J. (2019). Comparison of infrared thermography, ground-penetrating radar and ultrasonic pulse echo for detecting delaminations in concrete bridges. *Construction and Building Materials*, *225*, 1098-1111.
[9] Carrillo, J., Ramirez, J., & Lizarazo-Marriaga, J. (2019). Modulus of elasticity and Poisson's ratio of fiber-reinforced concrete in Colombia from ultrasonic pulse velocities. *Journal of Building Engineering*, *23*, 18-26.
[10] Majdi, H. S., Shubbar, A. A., Nasr, M. S., Al-Khafaji, Z. S., Jafer, H., Abdulredha, M., ... & Hashim, K. (2020). Experimental data on compressive strength and ultrasonic pulse velocity properties of sustainable mortar made with high content of GGBFS and CKD combinations. *Data in Brief*, *31*.
[11] Güçlüer, K. (2020). Investigation of the effects of aggregate textural properties on compressive strength (CS) and ultrasonic pulse velocity (UPV) of concrete. *Journal of Building Engineering*, *27*, 100949.
[12] Fitzka, M., Karr, U., Granzner, M., Melichar, T., Rödhammer, M., Strauss, A., & Mayer, H. (2021). Ultrasonic fatigue testing of concrete. *Ultrasonics*, *116*, 106521.
[13] Paktiawal, A., & Alam, M. (2021). A study of age effect through NDT and crushing strength of concrete with different industrial wastes under loading and unloading conditions. *Materials Today: Proceedings*, *46*, 8686-8693.
[14] Chen, H., Nie, X., Gan, S., Zhao, Y., & Qiu, H. (2021). Interfacial imperfection detection for steel-concrete composite structures using NDT techniques: A state-of-the-art review. *Engineering Structures*, *245*, 112778.
[15] Abdallah, W., Sbartaï, Z. M., Saliba, J., Elachachi, S. M., Chehade, F. H., & Sadek, M. (2021). Assessment of the reliability of concrete evaluation by multi-physical inversion of NDT measurements–A probabilistic approach. *Construction and Building Materials*, *300*, 124371.
[16] Wang, D., Han, L., Kang, M., Wan, M., & Ju, Y. (2022). Influence of corrosion on the bond performance of reinforcements and basalt fibre high strength concrete. *Case Studies in Construction Materials*, *17*, e01394.
[17] Lencis, U., Udris, A., & Korjakins, A. (2021). Frost influence on the ultrasonic pulse velocity in concrete at early phases of hydration process. *Case Studies in Construction Materials*, *15*, e00614.
[18] Zhang, Y., & Aslani, F. (2021). Compressive strength prediction models of lightweight aggregate concretes using ultrasonic pulse velocity. *Construction and Building Materials*, *292*, 123419.