# Damage Detection in Fiber Reinforced Concrete by Using Ultrasonic Pulse Velocity

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**ABSTRACT**

Ultrasonic pulse velocity method is used in concrete to self-sense the cracks in the concrete. In the present study a review on the natural coarse aggregate replaced by a percentage of chopped basalt fiber to develop ecofriendly and economical concrete is conducted. A method using ultrasonic pulse velocity can be used to detect the internal damage of BFRC, such as crack. The main contribution of this work lies in determining compressive study of NC and BFRC and detection damage on BFRC using ultrasonic pulse velocity. The fundamental concept, manufacturing process, Ultrasonic pulse velocity, basalt fiber reinforced concrete and damage detection base on ultrasonic test are discussed in this paper. Further, the differences in the current state of knowledge between BFRC, NC and Ultrasonic pulse velocity and offer several future research suggestions are highlighted. This review study will be providing more information about damage detection on BFRC and Ultrasonic pulse velocity for the researcher.

## INTRODUCTION

The development of techniques has made it possible to monitor the evolution and progressions of flaws and defects without causing permanent damage. NDT has provided a lot of techniques to provide scopes to be implemented on metals, alloys, and composite materials. NDT methods have non-destructive nature and convenience.

Basalt fiber-reinforced concrete reduces the width of the cracks. It reduces the total cost of the construction work. It can be easily mixed. Due to its long lifetime, it reduces the cost of repair and maintenance. Concrete's thickness can be reduced.

Basalt fiber is a natural existing compound made of basalt rock. We obtain Basalt fiber by melting the Basalt rock at a temperature we can also obtain chopped, rock on fabrics of basalt it has originated from volcanic magma and volcanoes. It is a type of volcanic rock found in the earth's crust, which solidifies in the open air. It shows good tensile strength and strong chemical properties of alkalis.

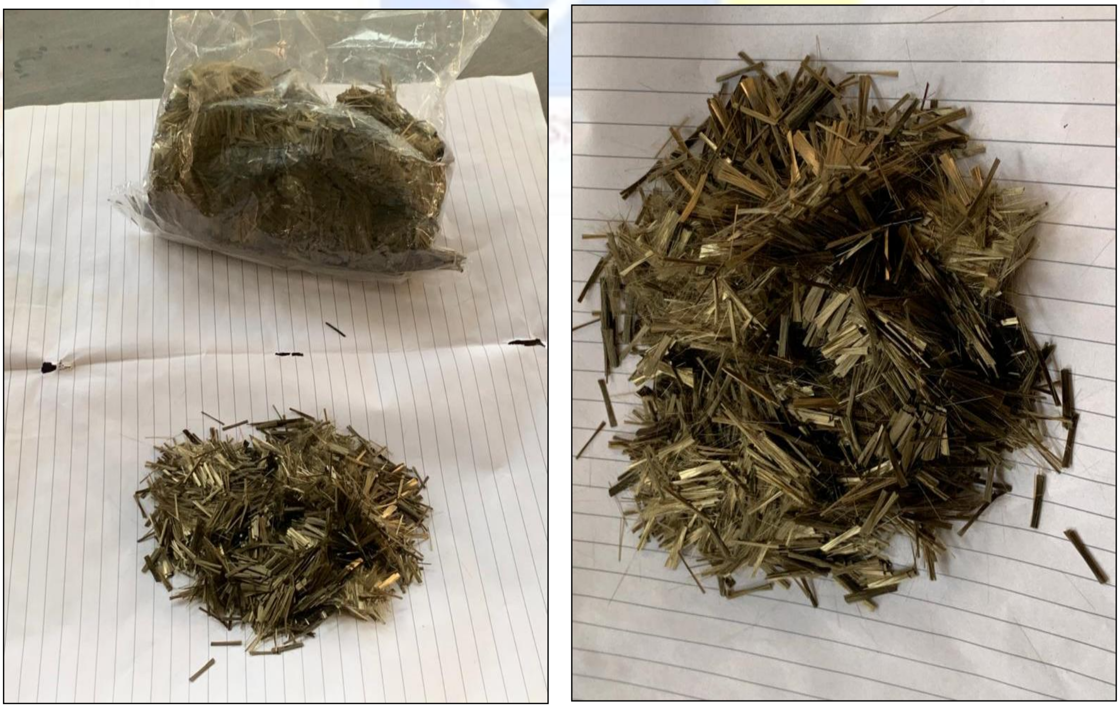

Figure 1. Basalt Fiber

## ULTRASONIC PULSE VELOCITY

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 researchers 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 homogeneities in existing brickwork panels. They came to the conclusion that sonic testing was quite effective in spotting significant density variations in the materials used for interior walls. Accedes investigated how steel fibers 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.

Figure 2. UPV Machine

## LITERATURE REVIEW

**Liyun Yang**, Huanzhen Xie, Shizheng Fang, Chen Huang, Aiyun Yang, Yuh J. Chao (2021). ), this study demonstrates how basalt fiber composition impacts concrete damage and uniaxial compressive mechanical properties. Acoustic emission (AE) technology was utilized to capture the AE characteristic data (ringing count and energy) during the whole loading process during the uniaxial compression test of basalt fiber-reinforced concrete. Then, it was evaluated how the distinctive parameters changed over time, from the beginning compression to the eventual full failure (BFRC).The surface strain field was captured and the surface fracture growth was followed in real-time using 3D-digital image correlation. According to research, adding basalt fiber in the right amount—6 kg/m3—can increase concrete's compressive strength while lowering the density and intensity of its AE characteristic characteristics. The three stages of initial compaction, stable crack propagation, and unstable crack propagation are included in the change in AE characteristic parameters and are strongly related to the BFRC stress-strain curve. By dispersing AE occurrences in concrete due to an increase in basalt fiber content, the local damage is essentially mitigated. According to the strain contours, adding the right quantity of basalt fiber to concrete can prevent early cracking and lessen transverse strain. When the concentration of basalt fiber ries, the lengthy fissures surface of the BFRC also slowly spilled into numerous microcracks.

**Mahzabin Afoz**, Indubhushan Patnaikuni, Srikanth Venkatesan (2017), this study demonstrates about, basalt fiber has gained interest in the use of infrastructure and civil engineering because mechanical quality, heat resistance, environmental friendliness, and chemical resistance are concerns. The chemical resistance of modified and unmodified basalt fibers is investigated in the current work. Given the concrete media, the fibers were submerged in twelve solutions for 62 days. Using a scanning electron microscope (SEM), the fibers' failure pattern and damage features were categorized, and energy dispersive X-ray spectroscopy was used to determine their compositions (EDX). Furthermore described as the ability for long-term bulk retention. Moreover, work was done to determine the strength maintenance rate of modified fibers in high-performance concrete made with regular Portland cement and high-volume fly ash (HVFA) (OPC). The results indicated that the modified fiber had superior attributes to the non-modified fibers based on morphological and chemical examination. Mechanical test results show that even after 56 days, the modified basalt fiber may significantly improve the indirect tensile and flexural capabilities of HVFA concrete.

**Zhuang Liu**, Robert Worley II, Fen Du, Courtney D. Giles, Mandar Dewoolkar, Dryver Huston, Ting Tan (2021), in this work it states us about, high-resolution temporal measurements used to examine the stress fluctuations during flexure of young basalt fiber reinforced concrete beams. To thoroughly investigate the temporal patterns of the stress fluctuations, an experimental setup was developed to gather stress-time curves at a sampling rate of 100 kHz. Avalanches caused by interactions between cementitious matrices and basalt fibers were represented as stress drops. Avalanches during the flexure of beams with various fiber volume fractions were investigated using four-point bending tests at various loading rates. Measured avalanche statistics or dynamics and mean-field model predictions showed good agreement. A variety of avalanches, including those with restricted size and duration that collapsed onto the scaling regime in the logarithmic scale, those with an incubation period before stress drops beyond the scaling regime, and enormous avalanches that occurred at the fracture of bottom concrete were detected during the flexure of basal fiber reinforced concrete beams. The development of long-lasting, environmentally friendly fiber-reinforced concrete buildings may be facilitated by observations of several avalanche kinds that revealed the essential failure progression during flexure of basalt fiber-reinforced beams.

Haiying Yu, Tao Meng, Yuxi Zhao, Jianping Liao, and Kanjun Ying (2022) In this study, they conducted, the mechanical properties and microstructure of concrete containing powdered basalt fibre are shown (BF). Five volumetric doses of 0, 0.05%, 0.1%, 0.15%, and 0.2% of BF powder were tested for compressive strength and splitting tensile strength. In order to assess the concrete's durability at the suggested dosage, tests for erosion resistance, shrinkage deformation, and steel corrosion rate were also carried out. The evolution of the microstructure was investigated using scanning electron microscopy (SEM) and X-ray diffraction methods. According to the findings of the experiments, the BF powder reinforced the concrete in a dosage-dependent manner. When compared to late strength, it had a stronger reinforcing impact on the early strength of the concrete. Also, the addition of 0.20 vol% BF powder significantly improved the concrete's resistance to abrasion. The SEM shows that the calcium silicate hydrate (C-S-H) produced as a result of the BF powder integration enhanced the porosity and promoted densification. So, this research on the use of BF powder to improve the properties of concrete is crucial for both future study and practical engineering applications.

**Yeou-Fong Li** , Jia-Yin Hung , Jin-Yuan Syu , Shu-Mei Chang , Wen-Shyong Kuo (2022), in this research paper we looked into how we use an air compressor. In this study, the basalt fiber (BF) was pneumatically dispersed before being inserted, both the original BF and the BF that had the sizing removed following the heat treatment. normal strength concrete becomes BF-reinforced concrete (BFRC). Compressive, splitting tensile, and flexural tests were performed on the BFRC specimens with two different BF kinds, three different BF weight ratios, and three different BF lengths. The test results show that the specimens with size removed and a weight ratio of 10 had the greatest strength when compared to the other BFRC specimens. The original basalt fiber (BF) and the BF with the sizing removed after the heat treatment were pneumatically distributed and put into the experiment using an air compressor. normal strength concrete becomes BF-reinforced concrete (BFRC). Compressive, splitting tensile, and flexural tests were performed on the BFRC specimens with two different BF kinds, three different BF weight ratios, and three different BF lengths. The test results show that the specimens with size removed and a weight ratio of 10 had the greatest strength when compared to the other BFRC specimens.

**Chaohua Jiang**, Ke Fan, Fei Wu, Da Chen (2014), in this research we studied about the Fiber reinforced concrete (FRC) is utilized frequently because, it has a high degree of elasticity and enough durability. It also examines how the volume proportion and length of basalt fiber (BF) affects the mechanical characteristics of FRC. The microstructure of BF concrete was also investigated in conjunction with the scanning electron microscope (SEM) and mercury intrusion porosimeter (MIP). The findings demonstrate that, while the compressive strength does not increase, the addition of BF greatly increases the tensile strength, flexural strength, and toughness index. Additionally, the mechanical qualities are impacted by the length of BF.

Comparing reinforced concrete with 12 mm BF to ordinary concrete results in increases in the compressive, splitting tensile, and flexural strengths of 0.18–4.68%, 14.08–24.34%, and 6.30–9.58%, respectively. Strengths rise by 0.55–5.72%, 14.96–25.51%, and 7.35–10.37%, respectively, as BF length grows to 22 mm. Early on, a strong connection between the BF and the matrix interface is seen. Yet, around 28 days, this relationship begins to degrade somewhat. Moreover, the MIP findings show that the concrete containing BF has greater porosity.

**A. Villarreal** , M. Cosmes-Lopez , F.M. Leon-Martinez , F. Castellanos , S.E. Solis-Najera , L. Medina (2019), According to this study, the carbonation process in concrete, which is caused by the interaction of the cement paste with atmospheric carbon dioxide, alters the elastic properties and microstructure of the cementitious matrix and decreases the durability of the concrete structure by causing the development of microcracks and chips. what happens as a result Chemical reactions can be seen using an ultrasonic non-destructive method based on the incident pulse's scattering. Acoustic phase velocity analysis was performed on signals acquired from specimens of cement paste with various water-to-cement ratios during a controlled carbonation technique. The results show that the acoustic dispersion increases with CO2 exposure duration and that 0.6 water-to-cement ratio probes respond to carbonation more quickly due to their microstructure. These results are supported by the experimental carbonation index, which was calculated using the well-known Fourier Transform Infrared Spectroscopy technique.

**Michal Janku** , Petr Cikrle , Jiri Grosek , Ondrej Anton , Josef Stryk (2019), According to this study, infrastructure pieces including buildings, bridges, roads, and others need to be constantly inspected and maintained in order to ensure their long-term viability. Early problem detection frequently results in significantly reduced repair costs than waiting for the structure to degrade for months or years. Non-destructive testing techniques are an essential tool for finding concealed flaws. In this investigation, measurements were made on a concrete bridge and a lab specimen with created faults that resembled cavities to compare three non-destructive procedures. Three methods—ground-penetrating radar, ultrasonic pulse-echo, and infrared thermography—were used to gauge the size and depth of holes in the concrete panel. The tests were performed using two separate thermal imaging cameras from the same brand as well as two different types of radar. Last but not least, the general performance metrics were used to compare the NDT techniques' accuracy, testability, and cost.

**Julian Carrillo**, Julieth Ramirez, Juan Lizarazo-Marriaga (2019), This study indicates that the Poisson's ratio and the modulus of elasticity are the two crucial mechanical properties of concrete for figuring out the flexural and shear stiffness of concrete components. Modern construction laws are beginning to permit the use of steel fibers, however, they do not offer formulas for calculating the elasticity modulus and Poisson's ratio of fiber-reinforced concrete (FRC). Although if the direct measurement of the modulus of elasticity and Poisson's ratio is correctly established, the application of non-destructive technologies, such as the Ultrasonic Pulse Velocity (UPV) test, offers an economical and straightforward alternative that must be examined. In order to calculate the dynamic modulus of elasticity and Poisson's ratio of concrete reinforced with steel, synthetic, and hybrid fibers, this study proposes empirical connections using data from UPV testing. The study also aims to evaluate the effects of test setup (direct, semi-direct, and direct), assess the results of models reported in a literature review, and establish a relationship between the dynamic modulus of elasticity of FRC and the properties of steel, polypropylene/polyethylene, and hybrid fibers. As part of the experimental program, 29 actual specimens were put through both static destructive tests and dynamic non-destructive tests. The fiber type (steel, synthetic, and hybrid), fiber content, and ultrasonic pulse velocity configuration were the experimental program's variables (direct and semi-direct). Their dimensions were 50 mm, 1.05 mm, and 48 for steel fibers whereas they were 50 mm, 0.68 mm, and 74 for synthetic polypropylene/polyethylene fibers. The fiber volume percentages in the concrete ranged from 0.17% to 0.93%. The study also contrasted the outcomes of the static tests with the outcomes of the dynamic tests to distinguish between static and dynamic behavior.

**Hasan Sh Majdi** , Ali Abdulhussein Shubbar , Mohammad Salah Nasr , Zainab S. Al-Khafaji , Hassnen Jafer , Muhammad Abdulreddha , Zainab Al Masoodi , Monower Sadique , Khalid Hashim (2020), This study paper suggests that the rise of the construction industry and population growth need an increase in the usage of building materials, particularly concrete. As cement is used as the binding substance in concrete, higher cement production will increase energy use and carbon dioxide emissions. The need for alternate cement ingredients was sparked by this negative impact on the environment, and it turns out that using waste or byproducts from other industries can be a viable option in this situation. Cement kiln dust and ground granulated blast furnace slag (GGBS) are frequent ingredients (CKD). This dataset covers the compressive strength and ultrasonic pulse velocity of mortar that contains a significant quantity of GGBS and CKD combinations as a partial substitute for cement (up to 80%) at the ages of 1, 2, 3, 7, 14, 21, 28, 56, 90, and 550 days. This dataset may be used by the researchers to learn more about the behavior of GGBS and CKD at high cement replacement levels in both young (1 day) and old

(550 days) individuals. The authors suggest that by using trash or products from other industries in place of the cement that would otherwise be used, the knowledge offered here may be utilised to create mortar or concrete combinations that are substantially less detrimental to the environment.

**Kadir Gucluer** (2020), this study demonstrates that, the qualities of both freshly-poured concrete and cured concrete can be impacted by the aggregate's strength and durability. The texture of the aggregate can affect the characteristics of hardened concrete in addition to strength and durability. This study looked at how aggregate textural attributes affected the properties of hardened concrete. Concrete samples were made using two unique types of aggregates made from crushers with varied technical quality and river aggregates. The investigation of cut, hardened concrete samples using an image analysis technique helped to detect the aggregates' textural characteristics. After evaluating the aggregates' textural attributes, such as their aspect ratio, roundness, width, and length, the total aggregate area inside the cross-sectional area was determined using an image analysis method. It has been shown that aggregate aspect ratio and aggregate roundness both increase the compressive strength of concrete. Both the concrete's compressive strength and the ultrasonic pulse velocity were found to be improved by the increased aggregate surface roughness.

**Michael Fitzka** , Ulrike Karr , Maximilian Granzner , Tomas Melichar , Martin Rodhammer , Alfred Strauss , Herwig Mayer (2021) Using an ultrasonic fatigue testing method with a 19 kHz cycle frequency and contrasting it with servo-hydraulic tests carried out at 60 Hz, the cyclic compression fatigue characteristics of concrete are examined in this work. Ultrasonic testing has been proven to be helpful for the speedy development of very high cycle fatigue (VHCF) data for concrete. Since cyclic stresses in displacement-controlled ultrasonic testing decrease with increased compliance, fatigue cracks can form but specimens do not rupture. Successful techniques for analyzing fatigue damage include resonance frequency observation, higher-order harmonic vibration analysis, and computed tomography of specimens. Calorimetric evaluations may be used to determine the cyclic irreversible strain, which accounts for around 1% of the elastic strain in the ultrasonic VHCF test.

## CONCLUSION

The natural aggregate in certain percentage of replacement by basalt fiber can be used in construction site. Based on research we can compare the compressive strength of natural aggregate of concrete and basalt fiber and natural aggregate replacement 0.1%,0.2%,0.3%,0.4% and 0.5% with basalt fiber. During hydration process and temperature variation, cracks occur inside the concrete. With the use of the ultrasonic pulse velocity method, the fracture is measured using three different techniques: direct, indirect, and semi-direct. Young modulus elasticity and concrete crack depth are two of the two approaches that are most frequently used to determine the characteristics of concrete.

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