International Journal of Engineering Applied Sciences and Technology, 2021
Vol. 5, Issue 12, ISSN No. 2455-2143, Pages 1-9
Published Online April 2021 in IJEAST (http://www.ijeast.com)

REVIEW PAPER ON NON-DESTRUCTIVE TESTING AND THEIR ACCURACIES TO MEASURE THE MECHANICAL PROPERTIES OF CONCRETE

Adan Bishar Hussein,
Master student Department of Civil Engineering, Cyprus International University, Nicosia, Northern Cyprus

Mohamed Abdi ,
Master student Department of Civil Engineering, Cyprus International University, Nicosia, Northern Cyprus

Abstract- **This paper aims to respond to these concerns through the identification and explanation of the most popular and effective NDT approaches in concrete structures and also their accuracies. The fundamentals of the non-destructive test methods are discussed in terms of their capacity, limits, inspection techniques and interpretations. Factors that affect the performance of NDT an approach are discussed and means of mediate their influence was suggested. Ultrasonic pulse velocity and SONREB methods of Non-destructive test are showed in this paper as past experiments of NDT. NDT of concrete was found to be increasingly recognized as a way of measuring the strength, integrity, resilience and other properties of existing concrete structures, Perceptions of NDT inadequacy are attributed to lack of knowledge of the building materials and the NDT approaches themselves. The goal of this paper is to resolve these issues reviewing some articles already done and defining and discussing the most common popular NDT methods applied to concrete structures.**

Keywords: **Concrete, Non-destructive test, Mechanical properties, Durability, Compressive strength.**

I. INTRODUCTION

There are various approaches for assessing materials or components, and non-destructive test methods with multiple implementations are important types among them. The non-destructive testing involves the identification and characterization of exterior and internal material injury without cutting or harming a portion of the material [1]. In recent years, the topic has received increasing attention, especially in the characterization of the quality of destroyed concrete structures by NDT testing.[2].The benefits of Non-Destructive testing (Malhotra 1976, reduced work usage of precautions), reduced structural risk to buildings where the heart can be drilled, and the use of inexpensive testing equipment's as composed of core testing) are reduced. The findings are the results of the Non-Destructive experiments. These benefits do not occur until the findings are accurate, reflective, and as similar to the true strength of the section of the system being evaluated. Rebound hammer is helpful for identifying time-long shifts in concrete properties such as cement hydration in order to eliminate shapes or shoring's [2]. The aim is to estimate the structural properties of concrete in non-destructive on-site testing. The compressive strength is most often the desired property. An established link between the results of the in-place test and the strength of the concrete is required for the evaluation of strength. Typically, in the field this interaction is calculated. The specificity of the strength prediction depends on whether the concrete strength is associated to the number of in-situ tests calculated.[3]. That most of these experiments were originally designed for applications of vibrating concrete of normal strength, but in the 1990s others were modified for use in vibrating concrete of high strength. The NDT application procedures are specified by national norms, as well as by minor variations between them, published in many countries. The variety of NDT available can differ from the most cost-efficient, easy to use, to cost-effective. For the exactness of the findings and for minimizing prices, the sparing range of the kinds of experiments that can be combined in each case is fundamental. In this method the factors influencing the test outcomes and associations must be noted, provided that some experiments are more sensitive than others.[4].

II. NON-DESTRUCTIVE TESTING METHODS

Although invasive measures do not change the future usefulness of a part or system, testing techniques are not deemed destructive. Coring, for example, is a typical NDT procedure used to collect and analyze samples of concrete components to determine in situ concrete's properties. Coring modifies the appearance and marginalizes the structural integrity of the part. Coring preserves the operability of the structure part when performed correctly and is thus called non-destructive [5].The non-destructive test, the sample not being damaged and the test being done, is very critical for evaluating or estimating the strengths of current buildings or structures (crack detection, defect detection, imperfection, resilience and concrete absorption characteristic),Such methods have many drawbacks, such as not immediately anticipated performance, specimens concrete can vary from real construction and concrete strength properties depend on size and form. Several NDT methods have therefore been designed to address the limitations. NDT processes are dependent on whether the strength and stability of buildings can be attributed to the physical and chemical properties of a concrete. These techniques are used for over 3 decades to determine a structure's condition; NTDs have now evolved from a hammer to the Echo-and-Impulse response in the present century. (Limand Cao, 2013).[6]

2.1. Surface hardness methods

Non-destructive methods of surface hardness are non-invasive techniques that analyze substrate strength properties. Indication methods and rebound methods are two categories which describe concrete surface hardness techniques. These approaches aim to rely on observational associations between concrete strength characteristics and surface hardness as calculated by indentation and rebound. Originating in the 1930s, indentation techniques in the structural engineering industry are no longer popular although rebound methods are mostly used to analyze the basic strength properties, with reference to standard testing and interpretation guidelines [7].The basic rebound hammer test is the most widely used surface hardness technique. The test was invented by Swiss engineer Ernst Schmidt in 1948 and is generally called the Schmidt Rebound Hammer [8].

Figure 1: NDT of concrete by Schmidt Rebound Hammer

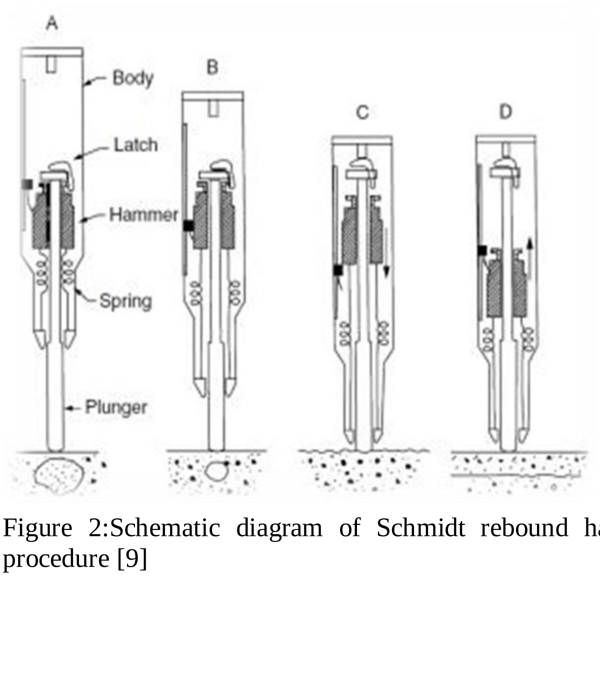

Figure 2:Schematic diagram of Schmidt rebound hammer procedure [9]

2.2. Ultrasonic pulse velocity method

Ultrasonic pulse velocity approaches include the spread of ultrasonic waves in solids as the wave time to travel between transmitting and receiving points is measured. Ultrasonic wave propagation features can be used to describe the composition, shape, elasticity, density and geometry of a substance using the similarities, existing patterns and mathematical relationships formed beforehand This non-invasive technique is often used by studying the diffusion of ultrasonic waves to identify and define material defects and their degree of injury. Additional properties, cement forms, water cement levels, admixtures and age of concrete contribute to the variability of ultrasonic pulses as applied to concrete. [10]In addition, integrated pulse path strengthening may have an important impact on pulse velocity measurements (Concrete Institute of Australia, 2008). Taking these considerations into consideration during research, ultrasonic pulses are excellent ways to conveniently and cost-effectively investigatethe uniformity and resilience of concrete.

Figure 3:Ultrasonic pulse velocity test apparatus

III. LITERATURE REVIEW

Ferhat Aydin and Mehmet Saribiyik have conducted an experimental analysis to establish a correlation and correlate hammer rebound test with a compression test (Destructive Test). Cube samples from numerous reinforced concrete systems were examined and no core samples tested. The cast cubes (15*15*15 m3) were prepared for samples from OPC and from different mixtures of concrete. Hammer rebound and compressive measurements were conducted according to the codal provisions of the specimens. Curves were drawn and data sets were analyzed to obtain the optimal match corrective factors for concrete compressive strengths. The findings indicate that rebound hammer experiments were not suited to estimate the strength of old concrete on existing buildings. The obtained current curves require correction factors of 0.50-0.80 to forecast old-fashioned concrete strength values. Results have shown that rebound hammer testing alone can be used to measure concrete specimen's power.[11].

The results indicate that rebound hammer tests were not suited to estimate the strength of old concrete on existing buildings. The obtained current curves require correction factors of 0.50-0.80 to forecast old-fashioned concrete strength values. Results have shown that rebound hammer testing alone can be used to measure concrete specimen's power. Diagram related to the relationship between the age of Ordinary Portland Cement/Swiss Portland Cement and rebound number was drawn and between the ages of Ordinary Portland Cement/Swiss Portland cement and the speed of ultra-sonic pulse. There was also a link curve between ultra-pulse intensity, rebound number and compressive power. The findings of the tests showed that the measurement readings of ultra-sonic pulses improved with age, but the improvement was very slight. The compressive power could not be found alone the rebound number readings indicated an improvement with age and only rebound numbers could explicitly determine the estimated value. The findings have revealed that the association between rebound number and pulse velocity could forecast and produce more precise results.[12].

A research on concrete estimates of compressive intensity by non-destructive experiments was performed by Yuri Danilo Lopez et al. The key objective was to correlate surface stiffness effects, ultra-sonic pulse velocity and compression power of structural cement in the football stadium bleachers of Paraná, Brazil. The construction of the concrete was 26 years old and had significant flaws including cracking and separation of one sheet. Mapping strengthening was carried out and the IS criteria were adopted for Ultra Sonic Pulse Velocity. Out of all bleacher systems, a total of 26 concrete specimens were collected. For a rebar corrosion fault at the pillar foundation, rebar mapping has been achieved. Simple CTM load tests of 200 tons were conducted on concrete samples. Correlation curves were plotted between outcomes of non-destructive experiments. The findings revealed that its surface index and its velocity for wave propagation became higher when the concrete was heavier. The findings have revealed that both the surface hardness test and the Ultra Sonic Pulse Velocity test are in good harmony. The obtained curves were designed to be used for the measurement of concrete strength for other structural elements as well.[13]

The experimental investigation on contrasting concrete properties by conducting the Ultra Sonic Pulse Velocity test and rebounding hammer was carried out by Sidhart Sankar and Hikmat Raj Joshi as non-destructive experiments and compression tests as destructive tests. Established designs were used for 150 mm, 100 mm, 200 mm, and nondestructive and destructive testing according to IS requirements. The purpose of the test was to create a relationship between non-destructive and destructive testing. Recession research and graphs of rebound and ultra-pulse velocity were performed. The results showed that a relation between compression values of non-destroying target object testing should be used in destructive testing to better assess the intensity of the target.[14].

Hemraj R. Kuma vat et al approved out an experimental study on collective methods of Non –Destructive Testing in concrete and its evaluation of core A combined non-destructive research methods and its assessment of key examples from existing buildings were researched by Hemraj R. Kuma vat et al. Their analysis was carried out. Core measurements, Ultra Sonic Pulsed Velocity and rebound hammer tests on the specimens were carried out in compliance with IS standards and combined with both techniques. Regression and correlation coefficients have been evaluated and given. Tables have been drawn between bounce numbers, calculation of ultra-sonic pulse velocity in current buildings against core compressive force specimens. Core measurements, Ultra Sonic Pulsed Velocity and rebound hammer tests on the specimens were carried out in compliance with IS standards and combined with both techniques. Regression and correlation coefficients have been evaluated and given. Charts were drawn between bounce numbers, Ultra Sonic Pulse Velocity measure against core compressive strength. The distinction shows that the use of integrated methods allows better precision in measuring the compressive strength of concrete.[15].

The relation between non-destructive and destructive testing of concrete compressive strength was investigated by Duna Samson et al [8]. The concrete cubes of 100 mm*100 mm*100 mm were cast with M20, M30 and M35 between seven, fourteen and two hundred days and were cured. Materials have been checked in advance. Complete 90 cubes of hammer have been developed and rebound experiments have been carried out. On each specimen 10 readings have been taken for rebound hammer compressive power. Recession analysis was done using MINITAB 15 to determine a mathematical linear relationship between compressive force and rebound number. Different tables were drawn and correlations were developed for rebound numbers and compressive power. The results revealed a high number of high compressive strength rebounds. The correlation coefficients were between 92.1 percent and 97.9 percent of the proposed models, which showed that the compressive force and the number of bounces were very high. The total residual error for all projected models is 1.78 percent, 1.29 percent and 1.32 percent for the concrete cube that has been healed for 14 days and 29 days. [16].

Condition measurements can be made using NDT methods to provide details on the structural performance of concrete, such as: Member size; location of splitting, de-lamination and de-bonding; existence of voids and honeycombs; location and size of steel reinforcement; corrosion of reinforcement activity; and degree of freezing and de-icing injury, fire or chemical exposure. [17].

According to S.Gholizadeh[21], the methods of NDT have been studied for the assessment of composites. Composite devices in primary aircraft production are also used in critical-safety applications. Non-destructive research methods are also very important to understand the incipient defects of composite materials. For the determination of composite material defects, Gholizadeh uses a number of non destructive techniques, such as thermography, visual analysis, ultrasonic technology testing and more. During the process, the best NDT system chosen depends on the safety and expense of the service faced. In addition, in order to detect and quantify flaws or destructive errors, non-destructive tests use physical parameters.

Non-destructive processing methods usually use a type of energy monitoring, as described in Sanjay Kumar et al[20], to assess mechanical and physical properties or to demonstrate the existence of material variances (surface, internal or concealed). Most NDT research techniques have also been shown to be used mainly in certain industries, such as the aerospace industry; industrialized sectors are likely to be used for civil service and infrastructure evaluation. It follows from this paper that there is a need for more theoretical studies to be carried out in such a way that these approaches are applicable to the use of civil facilities in the region. In order to reduce the harm, reduce the overall cost of equipment and optimize the protection of equipment, machinery, systems and materials, this article analyzes the various or unlike works in the non destructive test industry, and aims to identify new innovations and patterns feasible in industries and other areas.

The use of several non-destructive approaches is explained by malcolm k. Lim et al[22]. We have not been able to get the necessary outcome from one NDT strategy for some time, so we use the combination of non destructive test strategies to get more accurate details and data. Two non destructive test ultrasonic scanning and impulse response methods were used in this article to assess the state of defects in concrete and concrete structures. We are pursuing more accurate concrete conditions by integrating these methods together.

MR Jolly et al.[23] discusses the extremely reliable and cost-effective NDT method for the thick walled carbon fiber section that can detect delaminating, cracks and other defects and can be implemented in series development at an appropriate cost point. For composite components of thick walled carbon, there are a range of NDT techniques that may be appropriate. It's necessary to detect a delamination size longer than 1 mm. The goal of radiography is penetrated by short wavelength electric radiation. A detector can capture the total volume of radiation passing through the material.

The nonlinear ultrasonic micro-damage testing technique for TATB-based explosive polymer bonded explosives is explained by YanG Zhan-feng et al[24]. We found in the process of this test that the Ultrasonic linear parameter like expand and velocity apparently did not change during the entire loading phase of the fatigue period. Concluding this study, the author proposed that unlike the ultrasonic not linear coefficients, which were very aware to that, the ultrasonic linear parameter is not aware to micro-damage gathering and growth.

M. Rojek et al[25] Description of composite fatigue with epoxy-glass and ultrasonic testing. Composites of epoxy-glass are useful and are increasingly used as engineering components of high efficiency. In areas such as structural engineering, the automobile market, the communications industry, aerospace technology and many others, they also have demanding and difficult applications. Many damaging processes take place during the formation and exploitation of composites. Thermal aging, radioactive and chemical attack, slippage and exhaustion are the major degrading factors. It tells the similarity degree of fatigue-induced power loss and improvements in the characteristics of ultrasonic waves, like wave frequency and damping coefficients. Strong correlations were found between the rate of ultrasonic acoustic waves and the level of fatigue-induced power loss of the epoxy-glass composite. As a realistic method, the fatigue breakdown of polymer composites can be measured by ultrasound. This describes the mechanical properties due to cyclic loadings, such as flexural strength and flexural module reduction. We also consider that there is a strong dependency between the velocity of propagation of ultrasound waves and the number of loading cycles. The sound propagation velocity reduces as the load increases.

According to Eiichi Sato et al[26] mentioned his article that the ultrasonic scanning method was identified for the identification of planar defects in graphite material. For graphite ingots, an ultrasonic inspection technique has been used to notice internal planar defects which are directed in a variety of directions. This technique is also meaningful for the quality assurance of solid rocket engine throat inserts. The developed procedure was used in order to produce and inspect a test block along with artificial internal defects. It was cut into some slender disk for analysis. After that the split disk was examined via a normal beam technique using the traditional ultrasonic inspection process. In immersion testing, the intrinsic and natural graphite function of water absorption induced uneven ultrasonic propagation properties, but the issue was overcome by epoxy coating on all surfaces. This provides very well-conformed locations of the existing faults.

Residual stress has a large and significant impact on the mechanical component's performance, particularly on its longevity, tiredness life, decay resistance and dimension stability, as stated by Chunguang Xu et al[27] in his paper. In certain engineered constructions, materials and equipment, residual stresses exist. To ensure reliable estimation, a number of different techniques have been created to determine or test outstanding stress designed for unlike types of materials. The research concept of the ultrasonic wave field is analyses, based on the theory of acoustic elasticity. We learned from this report that the Ultrasonic wave technique has high accuracy, high penetration characteristics, it is the most promising tool in the development of non-destructive and without damage to the human body residual stress monitoring. Using the ultrasonic detector, we performed preliminary checks on the oil pipeline weld joint's residual stress control. The residual stress is tested in the joints of the oil pipeline welds and some other mechanical features. Tests and implementations validate that the ultrasonic LCR wave approach is precise, realistic and widely applicable.

Non-destructive testing using ultrasonic pulse velocity instrumentation of cement-stabilized materials (CSMs) is described by Tirupan Mandal et al[28]. The findings obtained from the ultrasonic pulse velocity experiments revealed that the limited module and P-wave velocity decreased with the decrease in specimen mass, while the limited module and P-wave rate increased among the raise in binder contented and the duration of curing of the specimen. In contrast to invasive approaches, like third point twisting beams experiments, nondestructive analysis is therefore proposed as an effective and expedient tool for evaluating the flexural property of CSM.

Study on ultrasonic inspection of complex parts has been described by Gabriel Dan Tasca et al[29]. To monitor fracture and delaminating that exist under the exterior in titanium element and in exacting in complex molded parts, non-destructive inspection processes have been developed and approved. While an obvious solution could be the X-ray technique, it is not successful in some situations, particularly where the failing has the similar thickness as the substance adjacent it. Ultrasonic waves can sense and recognize differences both in structural softness and in mass. From this paper, we also know that ultrasonic information can be use for to provide a deeper accepting of the mechanism of failure in this substance. Automated ultrasonic scanning was used, where appropriate, to conduct a comprehensive analysis of sensitive equipment or materials, such as nuclear power plants. Moreover, AUT has been extended to other sectors, such as processes and industries.

The concrete core test is widely considered to be the direct representative model for the preservation of concrete strength measurement for calculating the compressive strength of concrete within an in situ structural member. In compliance with the British Standard Institution [30] Requirements, the International Union of Laboratories and Building Materials Experts, Structures and Systems (RILEM)[32] and the Japan Institute of Architecture (AIJ)[31] for NDT, a non-destructive test is proposed for the purpose of measuring the compressive strength of concrete members on the basis of the strength similarity obtained from core strength tests. In the use of a core sample, one of the most critical issues is that the high-speed drill bit during the extraction phase of the cores is quickly damaged [33].

The durability of concrete structures is determined, on the one hand, by the shape and strength of the corrosion mechanisms acting on them and, on the other, by their susceptibility to physical degradation factors (rheological processes, freezing/thawing, degradation, crystallization, leaching, overloading, fatigue, temperature and humidity effects), on the other hand. Chemical processes (carbonization, degradation, aggressive environmental effects, interactions between components of the material) and biological mechanisms induced by the action of living organisms on the concrete structure (microorganisms, plants, animals) [34-37]. The spring proscribed mass reaches the exterior of the experiment target for the rebound hammer test. The accumulation rebound relates on the outside stiffness it reaches and it is possible to equate the rebound values with the concrete's compressive strength [38]. Two transmitters are mounted beside the two surface of the experiment item for ultrasonic pulse velocity measurements. Ultrasonic wave is conveyed starting one transmitter and obtained from the other throughout the procedure. A recognized space between the two outside of the experiment sample can be used to obtain the velocity of the ultrasonic wave. Generally speaking, in terms of density, uniformity, and homogeneity, the speed is greater where the concrete durability is higher. As a consequence, the velocity of the ultrasonic pulse can also be connected to the compressive force of material [39]. While, relative to destructive experiments, NDT method is cheaper and extra duration efficient, one major disadvantage is that while the experiment outcome is use to approximate the compressive force of the concrete. As experiment shown that the compressive strength of concrete estimates has a standard of more than 20 percent indicate fixed proportion error in rebound hammer tests compared to the "real" compressive force obtain by destructive measurements [40] . Researchers propose combined approaches (combined rebound hammer testing and ultrasonic pulse velocity tests, also referred to as SonReb) to optimize concrete measures of compressive strength and achieve strong results [41-46].

Using statistical regression analysis, several of these earlier experiments sought to link the concrete compressive force to rebound hammer values and ultrasonic pulse velocity. As an alternative approach to regression by integrating an artificial intelligence framework, this thesis proposes a novel regression method supporting vector machines. Research has shown that, as opposed to traditional predictive regression analysis, SVMs have increased regression potential [47-49] and, thus, this research aims to integrate SVMs to optimize regression outcomes.

Concrete is a plastic substance composed basically of a binding agent in which fragments or parts of concrete are present. The hydraulic cement concrete binder is made from a combination of hydraulic cement and water [50]. Standard concrete NSC strength is identified by the American Concrete Institute (committee 211.1-02) [51] as 'concrete that has an average compressive strength of 40 MPa or less at 28 days' but should not be less than 17 Mpa (ACI committee 318M-05) [52] and HSC concrete high strength is defined by the American Concrete Institute (ACI committee 363R-97)[53]. The Mix proportions for HSC, including stated performance characteristics, locally available goods, local knowledge, personal preferences and cost, are influenced by several variables with a given average compressive strength of 41MPa or more at 28 days [54]. Proportioning of HSC mixes is a more important method than constructing traditional concrete strength mixtures (ACI Committee 363R-97) [53]. Three fundamental considerations must be taken into account in the production of mixture proportions for HSC[55] in order to produce a mixture design that satisfies the expected property specifications (mechanical properties of the aggregates; mechanical properties of the paste; and bond strength at the interfacial transition zone of the paste-aggregate).

The paper [56] provides a state evaluation of the masonry pillars. Ultrasonic stress waves were used for the inspection and the velocity distribution reconstruction was carried out using computer topographies. The findings revealed the ability of tomography image for characterize the inner pillar component. Special concentration was given to the determination of the bond link between the inside foundations of a steel reinforcement bar and the foundation's surrounding body.
Paper [57] the validation of the following autoclaved aerated concrete approaches is described: semi-non-destructive, non-destructive and ultrasonic techniques. The compressive power of AAC test components with different thickness. Scientific proof, including the form and scale of specimens, is calculated using the general relationship of ordinary concrete from experiments on 494 cylindrical and cuboid specimens and normal cube specimens (Neville curve). In paper [58], non-destructive testing of gantry cranes was carried out using the residual magnetic field (RMF) technique for a period of 7 years. The residual magnetic field tangential distributions and the normal components of their gradients have been established. It has developed a database of magnetograms. The findings suggest that tangential factor gradients can be used in gantry crane beams to classify and localize stress concentration regions. Particular significance was accomplished by the unsymmetrical distribution on the crane beam floor of the tangential component gradient.

International Journal of Engineering Applied Sciences and Technology, 2021
Vol. 5, Issue 11, ISSN No. 2455-2143, Pages 318-324
Published Online March 2021 in IJEAST (http://www.ijeast.com)

Article [59] Submits non-destructive test (NDT) results for beam and slab members applicable to the location and diameter or rebar. The main aim of this article was to show that the NDT methods' precision and deviations could be greater than the acceptable execution or standard deviations. Nine specially prepared tests were tested with lightweight concrete and autoclaved aerated concrete beams. The measuring equipment was used to investigate how the rebar position affected the detection of their diameters and how the amount of rebar detected was determined by their reciprocal spacing. For the use of concrete buildings, predictable concrete compressive strength is important, as shown in [60], which is the primary feature of its protection and durability. Machine learning has gained considerable interest lately and future predictions are becoming more ambitious for this technology. There has been interest in determining vast collections of data as machine learning algorithms have reached a stage where they can recognise patterns that are difficult to recognize using human cognitive skills.

IV. DETERMINATION OF CONCRETE'S MECHANICAL PROPERTIES BY NON-DESTRUCTIVE METHODS

The majority of concrete structural members undergo cumulative stress situations composed of shear, compression, strain, and moment. The fundamental principle of compressive stress resistant concrete and tensile stress resistant steel is the fundamental basis of the structural architecture of reinforced concrete, In specific, in the case of enhanced concrete representatives, For filled compression representatives, the formulation of the scale effect theory based on fracture mechanics was not rigorously studied [18]. Sample sizes and shapes play an important role in the exploration of mechanical properties by non-destructive methods for these purposes.
Experimentally, Gonnerman has found that as the sample size increases, the ratio of compression loss stress to compression strength decreases. This process of specimen-dependent force reduction is called the 'phenomenon of reduction'[19]. Another project for researchers before non-destructive testing is carried out is to reduce the conditions for recovery. The purpose of this study is to use non-destructive research methods to get mechanical property such as tensile strength, modulus of elasticity, and compressive strength of the defined concrete specimens. Concrete compressive strength can be primarily divided into two categories: purely axial compressive strength and compressive strength dependent on SONREB.

4.1 Section and procedures of experimental

4.1.1 Preparation of samples and specimen

Specimen no.	1	2	3	4	5	6	7	8	9
t(μs)	46,60	46,00	47,30	47,20	46,50	48,70	47,00	48,40	49,20
v(km/s)	4,29	4,35	4,23	4,24	4,30	4,11	4,25	4,13	4,07

As shown figure.4 a shear wall with dimensions of 1200 mm x 1000 mm x 200 mm in height is made of C 25 concrete. In the same fresh concrete, at the beginning of the curing process, twelve 100mm x100mm cubic, twelve 150mm x150mm cubic, twelve 100mm/200mm cylindrical and six 150mm/300mm cylindrical samples were obtained and denoted as separate grades.

4.1.2 Experiments

Three specimens of each type and scale were tested using non-destructive methods at the end of the 14th day. The Schmidt hammer rebound test and ultrasonic pulse velocity test are used as ND methods to detect ultrasonic pulse velocity and 14-day-old specimen rebound numbers. At the end of the 28th day, the remaining specimens were checked. Under the same parameters and the same laboratory methods, the same non-destructive experiments were once again applied.

4.2 Results and the modeling of non-destructive approaches

Non-destructive methods classified as ultrasonic pulse velocity test and SONREB methods under two distinct subjects. Every approach applied to all formed and dimensioned specimens. A data composition with ultrasonic pulse velocity and rebound hammer test findings is needed for the SONREB approach. Categories outlined in terms of age and dimension.

4.2.1 Ultrasonic pulse velocity

For ultrasonic pulse velocity measurement, five different 28-day-old shaped and sized specimens are used. With the exception of three cylindrical specimens measuring 150mm/300mm, nine different specimens are used in all measurements. The test results in Table 1a are summarized. The pulse velocity is measured on the basis of the possible specimen length. In order to achieve amplitude, touching wavelengths of other directions plays an important part in the calculation of ultrasonic pulse velocity. Empirical equations can be expressed as follows:

$\boldsymbol{L} = \mathbf{vt}$........... Equation 1

In which L(mm) is the specimen's length, the ultrasonic pulse frequency is V(km/s) and the wave length is t(μs). Sullivan's ultrasonic pulse velocity-compressive strength relationship was used to determine the compressive strength of the specimens following the results of the pulse velocity test. Table 2 also offers an opinion on the consistency of the concrete without measuring the compressive force of the Whitehurst. The striking ultrasonic wave velocity was associated with the granulometric density of the concrete, according to the Whitehurst plot. The strength of the concrete directly increases as the speed increases.

Table 1a. Core specimen’s 100mm/200mm ultrasonic pulse velocity test results of 28 days old.

International Journal of Engineering Applied Sciences and Technology, 2021
Vol. 5, Issue 11, ISSN No. 2455-2143, Pages 318-324
Published Online March 2021 in IJEAST (http://www.ijeast.com)

Table 1b. Old cylindrical specimen's 100mm/200mm ultrasonic pulse velocity test results of 28 days.

Specimen no.	1	2	3	4	5	6	7	8	9
t(µs)	43,60	45,00	44,40	43,10	44,20	43,60	43,80	45,20	43,90
v(km/s)	4,59	4,44	4,50	4,64	4,52	4,59	4,57	4,42	4,56

Table 1c. Old cube specimens 100mm x 100mm ultrasonic pulse velocity test results of 28 days

Specimen no.	1	2	3	4	5	6	7	8	9
t(µs)	23,90	24,10	24,20	23,20	24,20	23,70	24,10	23,60	23,50
v(km/s)	4,18	4,15	4,13	4,31	4,13	4,22	4,15	4,24	4,26

Table 1d. old cube specimens 150mm x 150mm ultrasonic pulse velocity test results of 28 days.

Specimen no.	1	2	3	4	5	6	7	8	9
t(µs)	35,60	37,00	35,80	35,40	35,30	33,80	34,30	34,10	36,20
v(km/s)	4,21	4,05	4,19	4,24	4,25	4,44	4,37	4,40	4,14

Table 1e. Old cylindrical specimen's 150mm/300mm ultrasonic pulse velocity test results of 28 days.

Specimen no.	1	2	3
t(µs)	65,60	64,20	64,30
v(km/s)	4,57	4,67	6,67

Experimental findings found that cured cylindrical specimens achieved more compressive power at the end of the 28-day span relative to the core specimens.

Table 2. Whitehurst chart (1951)

Ultrasonic pulse velocity(m/s)	Quality of concrete
>4500	Excellent
3500-4500	Good
3000-3500	Suspicious
2500-3000	Weak
<2500	Very weak

Ultrasonic pulse velocity test was accompanied by day impact results. At the end of the 14-day period, the core specimens are worse than the 28-day core specimens.

4.2.2 SONREB combined method

Using both ultrasonic and rebound hammer research approaches, SONREB combined technique used three core cylindrical specimens 100mm/200mm 14 days of age. The experiment's findings are summarized in Table 3.

Table 3. Schmidth hammer recovery, ultrasonic pulse amplitude and combined SONREB examination findings of 14 days old specimens

Parameters		C1	C2	C3
R Rebound Number	Rmax	38	36	38
	Rmin	31	32	30
	RAvrg	34	34	34
V(km/s) Pulse Velocity	Vmax	3,94	3,86	3,98
	Vmin	3,92	3,80	3,98
	Vavrg	3,93	3,83	3,98
Compressive Strength	Fteo (N/mm²)	24,06	23,01	24,60

Conceptual compressive intensity obtained based on the following empiric equation:

$1,15e^{0.038R+0.445V}$ Equation……..2

Although the average rebound sum is R, the ultrasonic pulse velocity is V(km/s). Data found that in disruptive compressive strength test studies, the compressive strength of 14-day-old core specimens had increased strength compared to SONREB's cumulative non-destructive test results.

V. CONCLUSIONS

This paper reviewed non-destructive testing methods and their accuracy to measure mechanical properties of concrete. According to literature review, the following points are concluded;
1) As the size of the specimen increased, the compressive strength of the specimen declined in both the cube and the cylindrical shape, tests also found that the strength of the healing specimens was greater than that of the field specimens.
2) The SONREB approach provides safer performance, beyond the use of the ultrasonic pulse method and the Schmidth hammer rebound test independently.
3) Non-destructive testing methods are the best method used to analysis mechanical properties of concrete without demolishing the structure.

VI. REFERENCE

[1] Lockard, C. D. (2015). Anomaly detection in radiographic images of composite materials via

crosshatch regression (Doctoral dissertation, Mills College).

[2] A. J. A. Kathuriaa, 2013"Combined Use of Non-Destructive Tests for Assessment of Strength of," The 2nd International Conference on Rehabilitation and Maintenance in Civil Engineering ,.

[3] A. E. M. A. E. Ali Abd Elhakam Aliabdo, 27 may 2012"Reliability of using nondestructive tests to estimate compressive strength of building stones and bricks," Alexandria Engineering Journal,.

[4] M. C. S. Nepomuceno, 2017 "Analysis of Within-Test Variability of NonDestructive Test Methods to Evaluate Compressive Strength of Normal Vibrated and Self-Compacting Concretes," Materials Science and Engineering,.

[5] M. S. P. M. J. Helal, 2015 "Non-Destructive Testing of Concrete: A Review of Methods," Electronic Journal of Structural Engineering,.

[6] M. K. Lim and H. Cao, 2013. "Combining multiple NDT methods to improve testing effectiveness," Construction and Building and materials , vol. 38, pp. 1310–1315,,

[7] R. Jones, 1996." A review of the non-destructive testing of concrete," London: Institution of Civil Engineering,

[8] J. Kolek, 1969" Non-destructive testing concrete by hardness methods," London: Institute of civil engineering,.

[9] &. N. C. V. Malhotra, 2004 "Surface Hardness Methods.," in Nondestructive Testing of Concrete, New York: CRC Press., Malhotra, V., , pp. 1-9.

[10] T. M. V. &. P. J. Naik, 2004,"The Ultrasonic Pulse Velocity Method. In V," in Handbook on Nondestructive Testing of Concrete, New York, Malhotra, & N. Carino, pp. 87-94.

[11] a. M. S. F. Aydin, 2010. "Correlation between Schmidt Hammer and destructive Compressive testing for Concretes in existing buildings," Scientific Research and Essay, vol. 05, no. 01, pp. 1644-1648,

[12] A. K. ,. K. Y. V. a. M. K. A. Jain, 2013 "Combined use of Non-destructive Tests for Assessments of strength of Concrete in structure," Journal of Procedia Engineering, vol. 54, no. 01, pp. 241-251,.

[13] L. V. a. V. J. Y. Lopez, 2016"Concrete Compressive Strength Estimation by Means of Non-destructive Testing: A Case Study," Open Journal of Civil Engineering, vol. 06, no. 04, pp. 503-515,.

[14] H. H. S. Shankar, 2010 "Comparison of Concrete Properties determined by Destructive and Non-destructive Tests," Journal of The Institute of Engineering, vol. 10, no. 01, pp. 130-134,.

[15] V. P. G. T. a. R. P. R. R. Kumavat, 2017"Utilization of Combined NDT in the Concrete Strength Evaluation of Concrete Specimen from existing building," International Journal of Innovative Research In Science, Engineering and Technology, vol. 06, no. 01, pp. 556-562,.

[16] O. T. M. D. Samson, 2014"Correlation between Non-destructive Testing and Destructive Testing of Concrete," International Journal of Engineering Science Invention, vol. 03, no. 09, pp. 12-17,.

[17] Wankhade, R. L., & Landage, A. B. (2013). Non-destructive testing of concrete structures in Karad region. Procedia Engineering, 51, 8-18.

[18] Kim, J. K., & Yi, S. T. (2002). Application of size effect to compressive strength of concrete members. Sadhana, 27(4), 467.

[19] Gonnerman, H. F. (1925). Effect of size and shape of test specimen on compressive strength of concrete. In Proceedings of ASTM (Vol. 25, pp. 237-250).

[20] Kumar, S., & Mahto, D. G. (2013). Recent trends in industrial and other engineering applications of non destructive testing: a review. International Journal of Scientific & Engineering Research, 4(9).

[21] Gholizadeh, S. (2016). A review of non-destructive testing methods of composite materials. Procedia Structural Integrity, 1, 50-57.

[22] Lim, M. K., & Cao, H. (2013). Combining multiple NDT methods to improve testing effectiveness. Construction and building materials, 38, 1310-1315.

[23] Jolly, M. R., Prabhakar, A., Sturzu, B., Hollstein, K., Singh, R., Thomas, S., ... & Shaw, A. (2015). Review of non-destructive testing (NDT) techniques and their applicability to thick walled composites. Procedia CIRP, 38, 129-136.

[24] Dwivedi, S. K., Vishwakarma, M., & Soni, A. (2018). Advances and researches on non destructive testing: A review. Materials Today: Proceedings, 5(2), 3690-3698.

[25] Rojek, M., Stabik, J., & Sokół, S. (2007). Fatigue and ultrasonic testing of epoxy-glass composites. Journal of Achievements in Materials and Manufacturing Engineering, 20(1-2), 183-186.

[26] Sato, E., Shiwa, M., Shinagawa, Y., Ida, T., Yamazoe, S., & Sato, A. (2007). Ultrasonic testing method for detection of planar flaws in graphite material. Materials transactions, 48(6), 1227-1235.

[27] Xu, C., Song, W., Pan, Q., Li, H., & Liu, S. (2015). Nondestructive testing residual stress using ultrasonic critical refracted longitudinal wave. Physics Procedia, 70, 594-598.

[28] Mandal, T., Tinjum, J. M., & Edil, T. B. (2016). Non-destructive testing of cementitiously stabilized materials using ultrasonic pulse velocity test. Transportation Geotechnics, 6, 97-107.

[29] Taşcă, G. D., & Amza, G. (2012). Research regarding ultrasonic examination of complex parts. UPB Sci. Bull., Series D, 74, 164-172.

[30] Halliday, A. R. (1998). Use of non-destructive testing for the assessment of newly-constructed concrete pavements. Transport Research Laboratory.

[31] Raman, S. N., SAFI, A. M., & ZAIN, F. (2007). Non-destructive evaluation of flowing concretes incorporating quarry waste.

[32] RILEM CNDT-Committee. (1980). RILEM Tentative Recommendations for In-Situ Concrete Strength Determination by Non-Destructive Combined Methods. RILEM CND TC, 43.

[33] Bartlett, F. M., & MacGregor, J. G. (1995). Cores from high-performance concrete beams. Materials Journal, 91(6), 567-576.
[34] Hoła, J., Bień, J., & Schabowicz, K. (2015). Non-destructive and semi-destructive diagnostics of concrete structures in assessment of their durability. Bulletin of the Polish Academy of Sciences. Technical Sciences, 63(1), 87-96.
[35] Czarnecki, L., & Woyciechowski, P. (2013). Prediction of the reinforced concrete structure durability under the risk of carbonation and chloride aggression. Bulletin of the Polish Academy of Sciences: Technical Sciences, 173-181.
[36] Hoła, J., Bień, J., & Schabowicz, K. (2015). Non-destructive and semi-destructive diagnostics of concrete structures in assessment of their durability. Bulletin of the Polish Academy of Sciences. Technical Sciences, 63(1), 87-96.
[37] Bień, J. (2010). Defects and diagnostics of bridge structures. Wydawnictwa Komunikacji i Łączności, Warszawa.
[38] Malhotra, V. M., & Carino, N. J. (2003). Handbook on nondestructive testing of concrete. CRC press.
[39] Komlos, K., Popovics, S., Nürnbergerová, T., Babal, B., & Popovics, J. S. (1996). Ultrasonic pulse velocity test of concrete properties as specified in various standards. Cement and Concrete Composites, 18(5), 357-364.
[40] Wang, Y. R., Kuo, W. T., Lu, S. S., Shih, Y. F., & Wei, S. S. (2014). Applying support vector machines in rebound hammer test. In Advanced Materials Research (Vol. 853, pp. 600-604). Trans Tech Publications Ltd.
[41] Mohammed, B. S., Azmi, N. J., & Abdullahi, M. (2011). Evaluation of rubbercrete based on ultrasonic pulse velocity and rebound hammer tests. Construction and Building Materials, 25(3), 1388-1397.
[42] Shariati, M., Ramli-Sulong, N. H., Arabnejad, M. M., Shafigh, P., & Sinaei, H. (2011). Assessing the strength of reinforced concrete structures through Ultrasonic Pulse Velocity and Schmidt Rebound Hammer tests. Scientific Research and Essays, 6(1), 213-220.
[43] Breysse, D. (2012). Nondestructive evaluation of concrete strength: An historical review and a new perspective by combining NDT methods. Construction and Building Materials, 33, 139-163.
[44] Samia, H., & Mohamed Nacer, G. (2012). Application of the combined method for evaluating the compressive strength of concrete on site. Open Journal of Civil Engineering, 2012.
[45] Nobile, L. (2015). Prediction of concrete compressive strength by combined non-destructive methods. Meccanica, 50(2), 411-417.
[46] Pucinotti, R. (2015). Reinforced concrete structure: Non destructive in situ strength assessment of concrete. Construction and Building Materials, 75, 331-341.
[47] Gunn, S. R. (1998). Support vector machines for classification and regression. ISIS technical report, 14(1), 5-16.
[48] Smola, A. J., & Schölkopf, B. (2004). A tutorial on support vector regression. Statistics and computing, 14(3), 199-222.
[49] Trafalis, T. B., & Ince, H. (2000, July). Support vector machine for regression and applications to financial forecasting. In Proceedings of the IEEE-INNS-ENNS International Joint Conference on Neural Networks. IJCNN 2000. Neural Computing: New Challenges and Perspectives for the New Millennium (Vol. 6, pp. 348-353). IEEE.
[50] Al-Ameeri, A. S., Hussain, K. A., & Essa, M. (2013). Predicting a Mathematical Models of Some Mechanical Properties of Concrete from Non-Destructive Testing. Civil and Environmental Research, 3, 78-97.
[51] Dixon, D. E., Prestrera, J. R., Burg, G. R., Chairman, S. A., Abdun-Nur, E. A., Barton, S. G., ... & Carter, A. C. (1991). Standard Practice for Selecting Proportions for Normal, Heavyweight, and Mass Concrete (ACI 211.1-91).
[52] Code, A. (2005). Building Code Requirement for Structural Concrete and Commentary (ACI 318M-05). American Concrete Institute, Farmington Hill, Michigan.
[53] Samman, T. A., Wafa, F. F., & Radain, T. A. (1999). Mechanical properties of normal and high-strength concrete with steel fibers. J. King AbdulAziz Univ.: Eng. Sci, 12(1), 87-104.
[54] Russell, H. G. (2000). High-performance concrete mix proportions. Concrete Products, 103(6), 74-75.
[55] Price, B. (2003). High strength concrete. Advanced concrete technology (processes). Elsevier Ltd.
[56] Zielińska, M., & Rucka, M. (2018). Non-destructive assessment of masonry pillars using ultrasonic tomography. Materials, 11(12), 2543.
[57] Jasiński, R., Drobiec, Ł., & Mazur, W. (2019). Validation of selected non-destructive methods for determining the compressive strength of masonry units made of autoclaved aerated concrete. Materials, 12(3), 389.
[58] Juraszek, J. (2019). Residual magnetic field non-destructive testing of gantry cranes. Materials, 12(4), 564.
[59] Drobiec, Ł., Jasiński, R., & Mazur, W. (2019). Accuracy of eddy-current and radar methods used in reinforcement detection. Materials, 12(7), 1168.
[60] Ziolkowski, P., & Niedostatkiewicz, M. (2019). Machine learning techniques in concrete mix design. Materials, 12(8), 1256.