Comparative Study of Destructive Method and Non-destructive with Ultra-Sonic Pulse Velocity Method

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Abstract-: The appropriate percentages of cement, fine aggregates, coarse aggregates, and water are utilized to make concrete. Due to its relatively low price and widespread availability, it is a ubiquitous building material. Concrete in its fresh state can also be molded into any desired shape and size. Strength and durability are two of concrete's most important characteristics (particularly when used for structural purposes). Verify the concrete's compressive strength before placing it under the expected loads. NDT methods, both destructive and non-destructive, can be used to assess the compressive strength of hardened concrete. A non- destructive test does not harm the concrete specimen, whereas a destructive test (DT) crushes the cast specimen until it breaks. In non-destructive testing, materials, components or assemblies are inspected, tested or evaluated without destroying their serviceability. This study compares the compressive strength of concrete utilising an ultrasonic pulse velocity approach, which is both destructive and non-destructive. Concrete cubes measuring 150 mm by 150 mm by 150 mm were created using the concrete mix grades 25N/mm^2 and 30N/mm^2, and they were allowed to cure for 28 days. There were 12 cubes produced and used for the study. The determine compressive strength between destructive and non -destructive (ultra-sonic pulse velocity) test method.

Keyword-: Durability, compressive strength, non-destructive testing (NDT), destructive testing (DT) ultrasonic pulse velocity, concrete cubes, and mix grades.

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1 Introduction

The construction industry uses concrete more than any other material in today's world. A large number of public structures and buildings are continuously constructed using it. A high-rise building, an earthquake-proof bridge, a dam, and deep foundations are among these structures. Throughout history, humans have used concrete for pioneering architectural feats [1-2]. Concrete-based structures were first constructed around 6500 BC by Nabataea traders in Jordan and Syria. Lime mortars and gypsum were used by ancient Egyptians to build the Pyramids around 3000 BC. A non-reinforced concrete structure that is more than 2000 years old, the Pantheon stands 46 meters tall [3-5]. Concrete contains three main ingredients: water, Portland cement, and stone and sand aggregates. However, there were exceptions when it came to the use of concrete during the 19th century. To control the setting properties of concrete, mixtures are added as chemicals [6-7]. High or low temperatures, windy conditions, or extreme temperatures are the most common conditions they are used for. Large amounts of natural cement, which were made by burning natural lime and clay combinations, were utilised in the era before Portland cement was found [8]. Its properties vary widely due to the fact that natural cement is made from ingredients that are mixed by nature. The Portland cement that is manufactured today is manufactured in accordance with detailed standards [9-13]. A number of compounds found in cement play an important role in hydration and chemical properties. It is made by heating limestone and clay to temperatures between 1,300°F and 1,500°F in a kiln [14-17]. It is possible for up to 30% of the mixture to become molten while the rest remains solid, undergoing a slow series of chemical reactions [18]. When the mix is finally ground into powder, it forms a clinker. Concrete is kept workable longer with the addition of gypsum to slow down the rate of hydration. In order to evaluate a building's serviceability and safety, it must be periodically evaluated 1[9]. A concrete's strength is its most important characteristic, and it can be tested destructively as well as non-destructively. To ensure that concrete structures operate safely and efficiently, they must be tested regularly [20]. It is possible for this schedule to change depending on the structure's use. This method determines a specimen's failure through DT. Performing destructive tests aims to determine the service life of a specimen and identify design weaknesses that would not be apparent under normal conditions [21-25]. A concrete specimen or structure is subjected to NDT in order to investigate its material integrity, keeping in mind that no damage or destruction can be caused to the specimens or structures [26]. The NDT test is used throughout the world to detect variations in structures, changes in surface finish, and cracks, as well as other physical discontinuities in the structure [27-28]. The concrete can be subjected to various destructive and non-destructive tests [29]. Compression tests will be conducted using a CTM, ultrasonic pulse velocity tests, and rebound hammer tests. There are a number of concrete specimens that are suitable and economically optimal for destructive testing that are manufactured in large quantities [30]. The design may not show any defects under typical operating settings; therefore, the major goal of this experiment is to ascertain the system's service life [31]. It includes methods of determining mechanical properties, such as hardness and strength, of concrete specimens. These tests are easy to conduct, easy to interpret, and provide more information than others [32]. Tensile testing, bending testing, and compressive testing are a few of the widely used destructive techniques for evaluating the mechanical characteristics of concrete utilising the universal testing equipment. NDT is one of the most widely used techniques for assessing the quality of concrete and figuring out how strong existing concrete buildings. Ultrasonic scanning is included in NDT tests [33]. To evaluate the homogeneity and integrity of concrete, ultrasonic scanning is a recognized non-destructive evaluation method. Through the use of a liquid coupling material, such as grease or cellulose paste, the pulse generated by the transducer is transmitted into the concrete, where it undergoes several reflections at the boundary between the phases. A complex system of stress waves is created in this case due to the development of longitudinal and shear waves within concrete [34]. A second transducer converts longitudinal waves into electrical signals once they reach the receiving transducer. By using electronic timing circuits, it is possible to measure the pulse's transit time T. In IS 13311 Part-1, the test procedure and the interpretation of the results are explained. In non-destructive testing, materials, components or assemblies are inspected, tested or evaluated without destroying their serviceability [35]. Materials, components, and assemblies are evaluated for quality and integrity using NDT without affecting their function. The destructive testing approach is appropriate and economical for producing concrete specimens on a substantial scale. In this paper, two methods—a destructive method and a non-destructive method (ultrasonic pulse rate)—are used to compare the compressive strengths of concrete. Concrete cubes measuring 150 mm by 150 mm x 150 mm were created using concrete mix grades 25 N/mm^2 and 30 N/mm^2, which were then allowed to cure for 28 days. There were twelve of these study cubes made [36].

2 Methodology

Building and other structures are designed using the compressive strength of concrete as a performance measure. Compressive stresses are the most efficient way to resist concrete, which has always been used as a construction material. Cement type and quality, water-cement ratio during curing, time of hardening, and temperature at which concrete hardened influence compressive strength. When concrete is tested using DT, its compressive strength is measured using a compression testing machine (CTM). In addition to measuring porosity, voids, fracture widths, depths, and inclinations, ultrasonic pulse velocity is one of the most accurate methods of evaluating hardened concrete. In this test, the smoothness of the contact surface impacts the measurement of ultrasonic pulse velocity. Several types of tests are being conducted in the experimental program, including two types of nondestructive tests and one type of destructive test. Tests that do not cause damage are ultrasonic pulse velocity tests. A destructive test is the compressive strength test, which is a type of destructive test. In total, the program consists of 12 specimens of concrete with M25 and M30 grades, with a total of 12 specimens per grade. Total 12nos. of specimens consist 6 no's of cubes of each concrete grade for 28days.
Concrete Testing Techniques-

- Ultrasonic pulse velocity tests: this technique uses high-frequency based sound waves to check concrete quality and integrity without damaging the samples.
- Compressive strength tests: this type of strength testing is categorized as destructive tests, require concrete specimens monitored for failure or cracking.
- Such type of tests provide information about the material's ability to bear the applied loads, crucial in construction projects.
- Testing namely, DT and NDT ensures concrete able to meet the strength and safety requirements.

A total of 24 specimens are used for this testing program, divided evenly between M25 and M30 concrete grades. In order to evaluate maximum strength, half of the specimens are tested after 28 days for each grade, following standard curing timeframes. This type of structured approach allows for a comprehensive assessment of each grade's performance characteristics, ensuring that both grades are tested under consistent conditions to generate results that are reliable and comparable. Concrete grades must be rigorously tested for suitability to specific construction needs, so that empirical strength data and longevity predictions can be incorporated into material selection.

3 Destructive Test Methods

In a destructive test, concrete specimens (cubes) are loaded until they collapse in the laboratory and the strength properties of the concrete are determined. Using the test result, it is possible to make a rough interpretation of the durability, impermeability, and other characteristics of the product. For the concrete specimens that are produced on a large scale and that are used in the destructive testing method, the method is suitable and economically beneficial for testing concrete specimens. Under normal working conditions, it might not be possible to detect the weaknesses of the design, which may not appear during the testing. As part of the testing method, concrete specimens are broken so that the mechanical properties, such as hardness and strength, can be assessed. In addition to being very easy to perform, this type of testing also yields a lot of information that is easy to interpret. In order to determine mechanical properties of concrete using the universal testing machine, some destructive methods have been popularly used, such as the tensile test, bending test, and compressive test. There are a number of destructive tests that can be performed, including mechanical tests (bending, impact tests, and tensile tests), macro- and micro-hardness tests, as well as metallographic examinations. It is well known that when engineers are designing buildings and other concrete structures, they usually use the concrete's compressive strength as a performance metric. As a building material, concrete has always been intended to endure compressive loads as well as feasible. For determining concrete's compressive strength, it is necessary to consider multiple factors, including the cement grade and type, the cement-to-water ratio during curing, and the hardening temperature. Concrete's compressive strength is measured by CTMs (compression testing machines).

4 Non-Destructive Test Methods

The engineering community is rapidly recognizing the benefits that NDT can offer in terms of practical applications and engineering applications. Using NDT to determine the quality of damaged concrete structures has become increasingly popular in recent years. A "non-destructive test" is a test that is performed without destroying the structure or mechanical integrity of a material, component, or assembly. Materials, components, and assemblies can be tested using non-destructive testing (NDT) without being affected by how well they perform. An NDT test can be performed to determine concrete strength and quality. With the ultrasound pulse velocity of concrete, you can measure the strength, porosity, voids, crack depths and widths, inclination, and crack widths of hardened concrete. Considering smoothness of the test surface is crucial to measuring ultrasonic pulse velocity accurately. Providing the coupling medium is applied smoothly and the transducers are pressed on the concrete surface, most concrete surfaces should provide good acoustical contact. It is necessary to smooth the concrete surface when there is roughness and irregularity in the concrete surface to enable the pulse velocity measurement to be performed, or the measurement will give incorrect values if the surface is rough. The main variables influencing ultrasonic pulse velocity concrete are its identity and modulus of elasticity, which are influenced by the components and ratios of the mixture as well as the techniques employed for putting, compacting, and curing the concrete.

Table 1 depicts the results of a sieve analysis conducted on fine aggregate, showcasing the percentage of material passing through various sieve sizes alongside the limitations of the Effective Specific Surface (ESS) percentage. The sieve sizes range from 10 mm to 0.16 mm, with corresponding cumulative percentages indicating the distribution of particle sizes within the aggregate. A sieves size decreases as smaller particles pass through, indicating that finer particles are passed through less. As shown by this table data, the "limitation of ESS" column provides permissible ESS percent ranges for each sieve size, which is important for determining whether or not aggregates can be used to make concrete. It is important to establish the fine aggregates' properties in addition to the particle length distribution. Such is done so that concrete for a given application can be considered based on the ESS characteristics.

Table 1: Fine aggregate of Sieve Analysis

Sieve size (mm)	Cumulative % pass	Limitation of ESS* %
10	100	100
5	97.5	90-100
2.5	93.55	59-100
1.25	87.25	30-100
.63	67	20-100
.31	11.6	5-70
.16	2.2	0-15

Table 2: Course aggregate of sieve analysis

Sieve size (mm)	Cumulative % pass	Limitation of ESS* %
10	100	100
5	91.975	90-100
2.5	30.5	59-100
1.25	7.67	30-100
.63	1.23	20-100
.31	.625	5-70
.16	.625	0-15

Detailed information about coarse mixture sieves can be found in Table 2. From 10 mm to 0.16. mm, this table shows the percentage of particles that pass through extraordinary sieve sizes. The finer debris bypasses the sieve more easily as the sieve size decreases, indicating that fewer finer particles are contained in the coarse combination. ESS chances are given in this column, which is crucial to determining whether a mixture is suitable for concrete application. In order to achieve favored homes and performance standards for concrete mixes, this information provides valuable perception about particle length distribution and ESS characteristics of coarse aggregates.

5 Results and Discussion

Modern construction uses a large amount of concrete as the main material of construction. Today, this type of technology continues to be used in the design and construction of large public buildings. These constructions involve amongst other things, deep foundations, towering structures, earthquake-resistant bridges, and dams. This study compares the compressive strength of concrete utilizing an ultrasonic pulse velocity approach, which is both destructive and non-destructive. Concrete cubes measuring 150 mm by 150 mm by 150 mm were created using the concrete mix grades 25N/mm^2 and 30N/mm^2, and they were allowed to cure for 28 days. There were 12 cubes produced and used for the study. Compressive strength is calculated by testing cube specimen on CTM to failure for 28 days. Results obtained from the compressive strength test on cube. One reading of ultra-sonic pulse velocity at each face of cube is considered. The average of those six readings for each cube specimen for 28 days are noted. At the end average reading for each day is calculated below. Two readings of velocity are taken for each cube with direct transmission. Average of two readings are taken for each cube for 28 days. At the end average reading for each day is calculated below. Ultrasonic pulse velocity test results obtained from the compression test and ultrasonic pulse velocity test of the cube.

Table 3: Compressive strength of M 25 grade of concrete at 28 days

Cube No.	**Compressive Strength (N/mm^2)**	**Strength from UPV (N/mm^2)**
1	24	28.3
2	24.2	28.1
3	26.2	26.6
4	26.3	26.9
5	26.9	28
6	30	30
Average Strength	26.2	27.9

According to the Table 3, six distinct concrete cubes have been assessed through traditional compression tests and ultrasonic pulse velocity (UPV) tests for concrete grade M25. A unique number is assigned to each cube for identification. In the "Compressive Strength (N/mm^2)" column, strength values were calculated by standard compression tests, whereas in the "Strength from UPV (N/mm^2)" column, strength estimates were obtained by ultrasonic wave propagation through a material as a non-destructive method. Calculated separately for each test method, the average compression strength across all cubes emphasizes the variance in results. To comprehensively evaluate concrete quality, it is important to employ multiple testing techniques, since differing methods may result in divergent strength assessments.

Table 4: Compressive strength of M 30 grade of concrete at 28 days

Cube No.	**Compressive Strength (N/mm^2)**	**Strength from UPV (N/mm^2)**
1	28	34.3
2	29.9	33
3	32.2	32.5
4	32.3	32.9
5	32.4	34.3
6	35	35
Average Strength	31.6	34.1

Table 4 summarizes the compressive strength characteristics of six concrete cubes, determined by traditional compression tests as well as ultrasonic pulse velocity (UPV) tests. There is a unique number assigned to each cube for reference. In the "Compressive Strength (N/mm^2)" column, the direct strength values are shown, while in the "Strength from UPV (N/mm^2)" column, the non-destructive UPV test provides strength estimates derived from ultrasonic waves. The average compressive strength for all six cubes is calculated separately for each test method, revealing an average of 31.6 N/mm^2 from compression tests and 34.1 N/mm^2 from UPV tests. The results of UPV testing tend to be slightly higher than those of traditional compression testing.

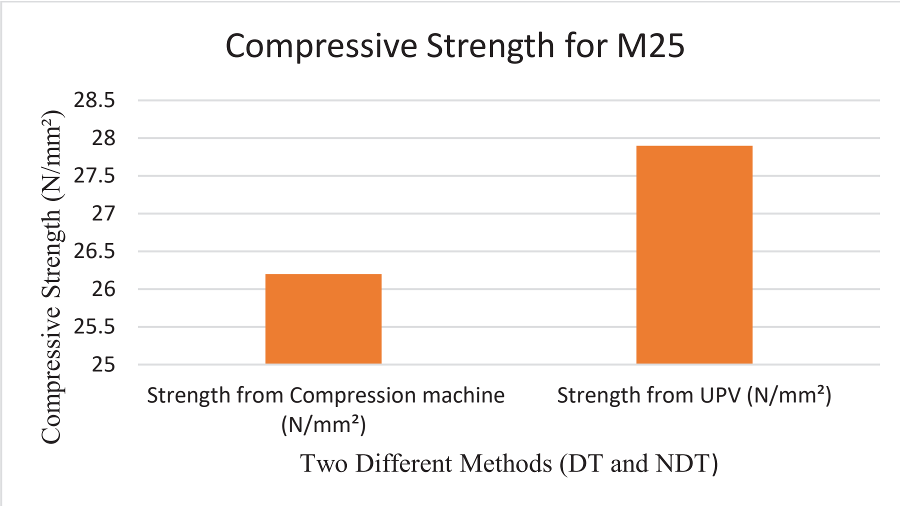

Fig. 1: Compressive strength from Destructive and Non -Destructive methods for M25 concrete grade

According to the Fig. 1 the concrete sample's characteristics under two distinct evaluation methods for M 25 concrete grade are 26.2 N/mm^{2}for compressive strength and 27.9 N/mm^2 for strength. Compressive strength is determined by a traditional compression test, in which increasing loads are applied until failure occurs, indicating the material's ability to withstand compression. A non-destructive way of estimating strength is through ultrasonic waves, which measure sound propagation speed through concrete. While both methods provide valuable information about concrete quality, UPV testing may give a slightly higher indication of strength potential

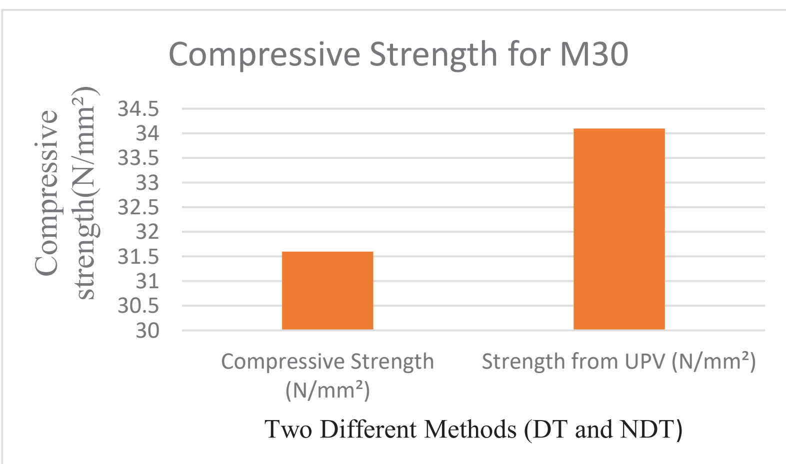

Fig. 2: Compressive strength from Destructive and Non -Destructive methods for M30 concrete grade

According to the Fig. 2 for M30 concrete grade, the compressive strength and strength values provided by ultrasonic pulse velocity testing (UPV) offer insight into the concrete sample's properties under two different assessment methods. The compressive strength of materials is determined through traditional compression tests, which provides a direct indication of their structural durability. UPV testing yields slightly greater strength estimates than traditional testing, revealing that UPV testing is a more accurate method of estimating strength. In the presence of this disparity, it seems possible that the concrete sample exhibits marginally greater strength potential when it is tested using UPV.

5 Conclusion

The construction industry uses concrete more than any other material in today's world. A large number of public structures and buildings are continuously constructed using it. A high-rise building, an earthquake-proof bridge, a dam, and deep foundations are among these structures. In this paper, the ultrasonic pulse velocity technique is analyzed in terms of destructive and non-destructive testing methods. Tests were conducted to evaluate the accuracy of calculating concrete strength using the DT and NDT (ultrasonic pulse velocity) methods. Employing a combination of the designs as M25 and M30, twelve samples (cubes measuring 150 × 150 × 150 mm) were created at 28 days with a uniform w/c ratio of 0.45. Test results for hardened concrete show a reasonable of compressive strength with the Ultrasonic Pulse Velocity.

- Concrete sample evaluation methods destructive and non-destructive test methods for M 25 and M30 grades at 28 days.
- M 25 concrete grade has compressive strength of 26.2 N/mm^2 and 27.9 N/mm^2 under two evaluation destructive and non-destructive (ultrasonic pulse velocity) methods.
- M 30 concrete grade has compressive strength of 31.6 N/mm^2 and 34.1 N/mm^2 under two evaluation methods.
- Traditional compression test determines compressive strength, while ultrasonic waves measure sound propagation speed.
- UPV testing provides a slightly higher indication of strength potential.
- UPV testing yields slightly greater strength estimates than traditional testing, suggesting a marginally greater strength potential

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