

A Comparison of Compressive Strength of Concrete by Using Different Brands of Portland Composite Cement for Grade M15 and M20

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Abstract

The primary objective of the study is to determine the compressive strength of concrete by using different brands of Portland composite cement. The secondary objective is to compare compressive strength of concrete by using different brands of portland composite cement for two different grade M15 and M20. Concrete construction is becoming increasingly complex and the importance of producing structures that are both cost effective and durable has never been higher. Many experimental works have performed to determine the compressive strength of different brands of portland composite cement. The objectives of the study are to determine the compressive strength of concrete by using different brands of Portland Composite Cement (PCC) for two different grades M15 and M20. The materials used for the experiment are 3 brands. They are PCC cement, Bholagonj stone, Sylhet sand and water. The mass of the specimens was recorded carefully. For 7 days, the values of compressive strength of concrete for Brand 1, Brand 2 and Brand 3 are 6.66 Mpa, 8.20 Mpa and 8.69 Mpa respectively of grade M15. For 28 days, the values are 13.68 Mpa, 13.63 Mpa and 14.18 Mpa respectively for the same brands of cements of grade M15. For 7 days, the highest compressive strength of the concrete found 11.16 Mpa for Brand 3 of grade M20 and the lowest compressive strength is 6.66 Mpa for Brand 1 of grade M15. For 28 days, the highest compressive strength of the concrete found 22.39 Mpa for Brand 3 of grade M20 and the lowest compressive strength is 13.63 Mpa for Brand 2 of grade M15. The compressive strength of Brand 3 was better than the other brands of cement.

Keywords: Compressive strength, Portland composite cement, Concrete, Grade M15, Grade M20

1.0 INTRODUCTION

Concrete has the benefits of strength, availability, durability, flexibility, and economy. The concrete mix productivity is a direct function of the amount and quality of the cementitious material [1]. Concrete is the most widely used human-made material for building infrastructure on Earth due to its versatility [2]. In the design of concrete structures, the compressive strength of concrete is a crucial factor. Testing the compressive strength of a concrete cube provides comprehensive information about its characteristics. The Pozzolana Cement (PPC) is produced by blending fly ash with Ordinary Portland Cement (OPC), up to a maximum of 35% [3]. The process of blending cement involves using a ball mill to mix Ordinary Portland Cement, gypsum, and fly ash until a uniform quality of cement is achieved. The strength of concrete is influenced by several factors such as the ratio of water to cement, the strength of the cement, the quality of the concrete materials, and the level of quality control maintained during the production process. [4]. It is crucial to have a quick and accurate method for predicting the strength of concrete. This test helps determine if the concrete construction has been completed correctly. The compressive strength of concrete used for general construction ranges from 15 MPa to 20 MPa but is higher in commercial and industrial structures. The test to determine compressive strength is typically conducted on either a cube or a cylinder. Various standard codes recommend using a concrete cylinder or cube as the standard specimen for this test.

1.1 Compressive Strength

Concrete mix design is a process that involves using code recommendations and the experience of the engineer. Factors that influence concrete strength include aggregate quality, cement strength, water content, and water-cement ratio [5]. To determine the compressive strength of a material, a formula is used that involves the load applied at the point of failure and the cross-sectional area of the face on which the load was applied. To conduct a test on a specimen, cement paste is placed and smoothed over the entire area. For cylinder tests, a cylinder of either 10.16 cm x 20.32 cm is used, depending on the size of the aggregate. After the cement paste is spread, it is poured into the mold and properly tempered to ensure that there are no voids.

After 24 hours, the molds are removed and the test specimens are placed in water for curing. These specimens are then tested using a compression testing machine after 7 or 28 days of curing. The load should be applied gradually at a rate of 140 kg/cm² per minute until the specimens fail. The compressive strength of concrete is determined by dividing the load at failure by the area of the specimen. This process is mandatory as it represents the quality control process of concrete mixing, placing, compaction, and curing. In designing a concrete structure, the compressive strength of concrete is an essential element. The 28-day compressive strength of concrete is typically considered as the design strength. Concrete has many benefits, including strength, availability, durability, flexibility, and economy. As an engineering material, concrete exists in three states: plastic (fresh), setting, and hardened. It is technically evaluated based on five determining characteristics: strength, workability, durability, cohesiveness, and stiffness. When designing any proposed concrete structure and making considerations for its quality control, the compressive strength of the concrete is generally the specified property [6]. This is because, compared to other properties of concrete, testing its compressive strength is easier. It is typically determined using a Universal Testing Machine (UTM) and reported by a specified technical standard. Three primary factors affect the compressive strength of concrete: [7] which are:

- The impact of the constituent materials (ingredients) and the mix proportions (water/cement ratio, air entrainment, cement brands, maximum aggregate size, and mixing water) on concrete properties.
- The effects of curing conditions (time/age, temperature, and relative humidity) on concrete properties
- Relevant testing parameters.

The term 'workability of fresh (plastic) concrete' refers to the ease with which a concrete mix can be placed, handled, compacted, and finished. The permeability of concrete affects its durability, with higher permeability leading to lower durability and vice versa. Durability refers to the ability of concrete to withstand weathering, environmental action, abrasion, chemical attack, or other processes that could result in its deterioration [8].

1.2 Cement

Cement is a crucial building material used in construction for binding and solidifying other materials. The most common type of cement is Portland cement, and its basic ingredients include:

1. Limestone: The primary source of calcium, which is a key component in cement. Limestone is usually composed of the mineral calcite and may also contain other materials like clay, shale, or silica.
2. Clay or Shale: These materials provide the necessary silicon, aluminum, and iron oxide required for cement production. They are usually mixed with limestone in a specific ratio.
3. Silica (Silicon Dioxide): This ingredient is often added in the form of sand or quartz. Silica imparts strength to the cement and contributes to its overall durability.
4. Alumina (Aluminum Oxide): Derived from clay, alumina adds strength and durability to the cement. It also helps in regulating the setting time of the cement.
5. Iron Ore: Iron provides the necessary iron oxide, contributing to the color of the cement. It also plays a role in the strength and setting characteristics of the final product.
6. Gypsum: Added during the final grinding process, gypsum regulates the setting time of the cement. It slows down the reaction between the cement and water, preventing the mixture from setting too quickly.

The process of making cement involves crushing, blending, heating, and grinding these raw materials to form a fine powder. This powder is then mixed with gypsum to produce the final cement product, which, when mixed with water, forms a paste that hardens over time, binding together aggregates like sand and gravel to create concrete.

1.2.1 Portland Cement

Portland cement is a commonly used building material and an essential element in producing concrete. It is a fine powder that is typically gray in color and is created by grinding clinker - a combination of limestone, clay, and other materials - with gypsum. Here is a breakdown of the essential components and the manufacturing process involved in creating Portland cement:

1. Raw Materials:

- Limestone: Provides the primary source of calcium, which is essential for the formation of clinker.
- Clay or shale: Contributes silica, alumina, and iron, which are necessary for the formation of clinker.
- Iron ore or other supplementary materials: May be added to provide additional elements.

2. Manufacturing Process:

- Mining: Limestone and clay are extracted from quarries and mines.
- Preparation of Raw Mix: The powdered raw materials are blended in the right proportions to form the raw mix.
- Burning: The raw mix is heated in a rotary kiln at high temperatures (approximately 1450°C or 2642°F). This process transforms the raw mix into clinker, which is composed of nodules or granules.
- Cooling: The clinker is then cooled rapidly to maintain its crystalline structure.

3. Clinker Grinding:

- The cooled clinker is finely ground with gypsum to produce Portland cement.

4. Addition of Gypsum:

- Gypsum (calcium sulfate) is added during the grinding process to control the setting time of the cement and prevent flash setting.

5. Final Product:

- The resulting fine powder is Portland cement, which is the key binding ingredient in concrete.

6. Properties of Portland Cement:

- Strength: It provides strength to the concrete when mixed with aggregates and water.
- Setting Time: The addition of gypsum controls the setting time, allowing for workability.
- Durability: Properly cured concrete made with Portland cement is durable and resistant to environmental conditions.

Portland cement is extensively used in the construction industry owing to its versatility and its ability to form a robust bond with aggregates. It is an essential component in the production of concrete, which is a fundamental material for constructing structures like buildings, highways, bridges, and other important infrastructure.

1.2.2 Water Cement Ratio

The water-cement ratio is the weight of water used in a concrete mix compared to the weight of cement. A lower ratio can result in a stronger and more durable mix, but it can also make it more challenging to form and work with. However, this can be addressed by using plasticizers or superplasticizers. With conventional mixing technologies, the water-cement ratio usually ranges from 0.50 for grade M15 to 0.50 for grade M20, and the 28-day compressive strength is about 60 to 10 MPa when normal-density aggregate is used. The water quality requirements for concrete are more stringent than those for conventional water. Generally, water used in concrete should be of portable quality.

1.2.3 Aggregates

Aggregates are a commonly used material across multiple industries for various purposes. These aggregates are classified based on their particle size and consistency. There are two main categories of aggregates: natural stone aggregates (such as sand and gravel) and crushed aggregates (including stone chippings and crushed stones). Aggregates are usually available as a standardized homogeneous bulk product, ensuring the necessary levels of reliability and processability. They are essential for the production of concrete and asphalt, and can also be used as filter and fill material or as a basic material for road building and railway construction. However, the product portfolio may vary from country to country.

1.2.4 Coarse Aggregate

Coarse aggregates are irregular and granular materials like sand, gravel, or crushed stone. They are commonly used for making concrete. Coarse aggregates are usually naturally occurring and can be obtained by blasting quarries or crushing them by hand or with crushers. Before using them for producing concrete, it is essential to wash them. The angularity and strength of coarse aggregates affect the concrete in numerous ways. Therefore, selecting these aggregates is a vital process. The size of coarse aggregates impacts several aspects of the concrete, including its strength, workability, and the amount of water required for the mix. It also determines the amount of fine aggregate needed to produce a concrete batch. The larger the size of coarse aggregates, the smaller the bondable surface area for cement, sand, and water. And, with concrete mixes, less water and fine aggregate are required. The size of the coarse aggregate plays a vital role in determining the cement-to-water ratio for grade M15, which is 0.50, while for grade M20, it is 0.50 less. Using less water can strengthen the mix, but it also makes it less workable. One crucial aspect to consider is the space between TMT bars. The aggregate should be smaller than the distance between internal reinforcements [9]. This will enable the aggregate to pass between the rebar and settle uniformly throughout the structure.

The ideal coarse aggregate should be clean, cubical, angular, 100% crushed aggregate with a minimum of flat and elongated particles [10]. Among the different crushed aggregates that have been studied, trap rock, quartzite, limestone, greywacke, granite, and crushed gravel, trap rock tends to produce the highest concrete strength. However, limestone produces concrete strength nearly as high as those achieved using trap rock. Studied trap rock, quartzite, limestone, greywacke, granite and crushed gravel trap rock tends to produce highest concrete strength. Limestone, however, produces concrete strength nearly as high as those achieved using trap rock.

1.1.5 Fine Aggregate

Aggregate is a type of granular material that is used in the construction industry to make concrete or mortar. When the particles of the granular material are small enough to pass through a 4.75 mm sieve, it is referred to as fine aggregate. Fine aggregate plays an essential role in increasing the volume of concrete, making it a cost-effective material. To ensure the best quality of fine aggregate, it is crucial to consider factors such as size, density, and grading zone. Fine aggregate is commonly made of natural sand or crushed stone and is a critical ingredient in concrete. The quality and density of fine aggregate have a significant impact on the properties of hardened concrete.

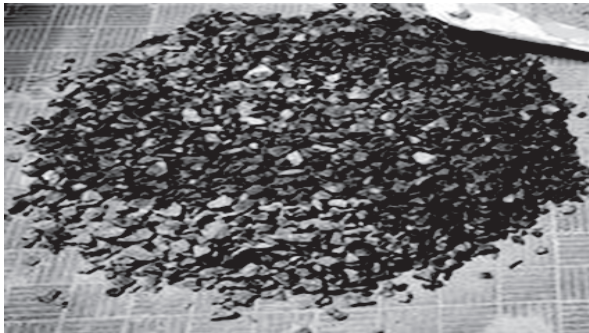


Fig. 1: Coarse Aggregates



Fig. 2: Fine Aggregates (Sylhet sand)

2. Methodology

2.1 Preparation of Cylinders

To produce cylindrical specimens, non-absorbent materials such as steel or cast iron are utilized. For the experiment, a total of 24 standard cube-sized specimens measuring 4 x 8 inches or 100 x 200 mm are tested. The molds are designed to securely hold the concrete mix without any leaks. Before filling the mold with concrete, the interior is appropriately greased to ensure easy removal of the hardened cylinder. The mixed concrete is then added in layers no less than 5 cm deep, each compacted with at least 30 strokes to allow air voids to escape and reach underlying layers. For 24 hours, the specimens must remain untouched in a location with a relative humidity of no less than 90% and at room temperature. After this period, the samples should be soaked in clean and fresh water until they reach the age necessary for testing.

2.2 Concrete Mixing

The process of creating concrete involves combining cement, sand, aggregate, water, and admixture to achieve the desired grade. Properly mixing the concrete materials according to the mix design is crucial to achieving the desired strength. For example, a mixture of 1-part cement, 1.5 parts sand, and 3 parts aggregate will result in a concrete mix with a strength of around 3000 psi. Once water is added, a paste is formed that binds the materials together until they harden. Although mixing concrete can be difficult, following standard procedures can ensure high-quality results. It's important to note that the same materials can result in both good and poor-quality concrete depending on the proportions and mixing methods used. Therefore, creating high-quality concrete requires knowledge and proper care.



Fig. 3: Mixing of Sand, Cement & Stone



Fig. 4: Mold Ready for Casting.

2.3 Casting of Cylinder

When designing a cylinder head, it's crucial to select the casting method early on in the process. Expertise in casting and pattern-making should be taken into account when creating the initial design. Keep in mind that not all casting methods can achieve the desired geometries. The shape and position of the intake and exhaust ducts, as well as the shape of the combustion chamber, primarily determine the overall geometry of the cylinder head. Moreover, proper cooling is vital since fuel combustion produces high temperatures in the cylinder head, given the large cylinder bore and distance between cylinders.



Fig. 5: Casting of Cylinder

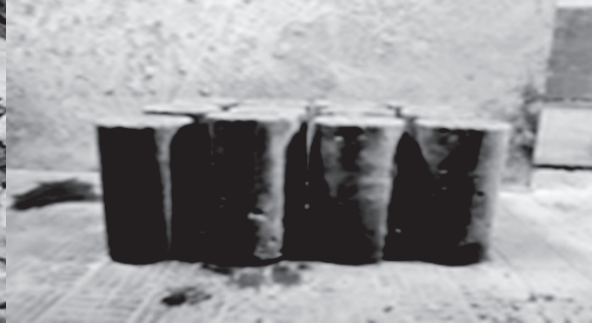


Fig. 6: Preparation of Cylinder

2.4 Curing

During the first 24 to 48 hours following molding, it is essential to ensure that all test specimens are stored under conditions that accurately reflect the concrete in the structure or pavement. After this initial curing period, the specimens may be transported to the laboratory for additional curing and testing. Curing is a critical process that leads to a more durable, resilient, and stable substance, such as concrete. Depending on the curing method, it may be necessary to maintain specific temperature, humidity, or pressure levels to achieve optimal results.



Fig. 7: Curing of Cylinder

3. Experiment part

3.1 UTM Machine

The Universal Testing Machine, also known as a UTM tester, materials testing machine, or material testing frame, is a critical tool for assessing the compressive strength of materials. With varying capabilities designed for specific industries and sectors, UTMs play a vital role in the development of infrastructure, roads, and highways. They are widely utilized in R&D labs and Quality Control departments, making them one of the most versatile pieces of equipment available.

3.2 Compressive Strength Test

The compressive strength test is a mechanical evaluation that determines the maximum amount of compression that a material can withstand before breaking. The test typically involves a cylindrical sample, which is gradually compressed between two plates using a compression testing machine. While brittle substances like rock, brick, cast iron, and concrete may demonstrate high compressive strengths, they will ultimately fracture. In the case of concrete, its crushing strength is determined by breaking a cylinder, also known as the cylinder strength. Meanwhile, ductile metals like mild steel may have considerable compressive strengths, but accurately measuring these values can be challenging. When a ductile metal is subjected to a load, it will initially deform elastically before experiencing plastic deformation. In some cases, increasing loads can flatten a sample without causing it to fracture, which enables the calculation of compressive strength for grades M15 and M20.

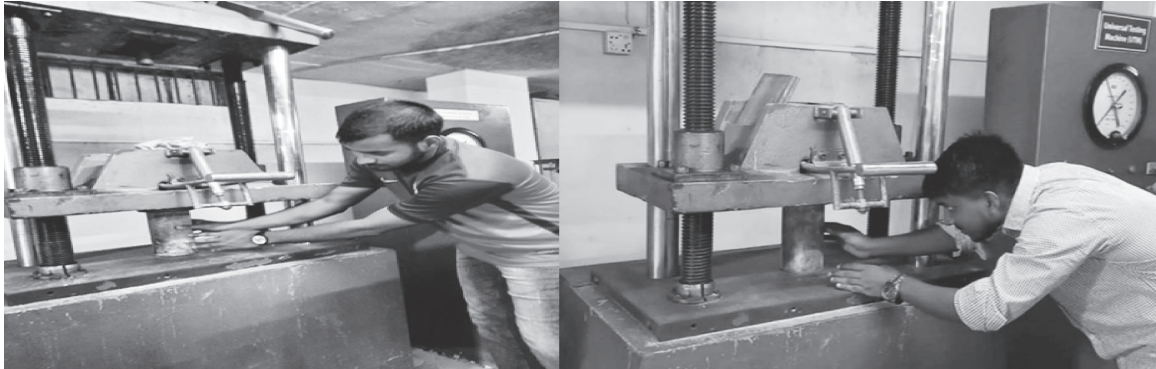


Fig. 8: Place the cylinder in UTM machine.

3.3 Compressive Fracture of Cylinder

During the testing process, the specimens were placed at the center of the UTM machine and crushed one by one, with their values being noted at 7 and 28 days respectively. A total of 24 specimens were crushed in the Sonargaon University lab using the UTM machine.

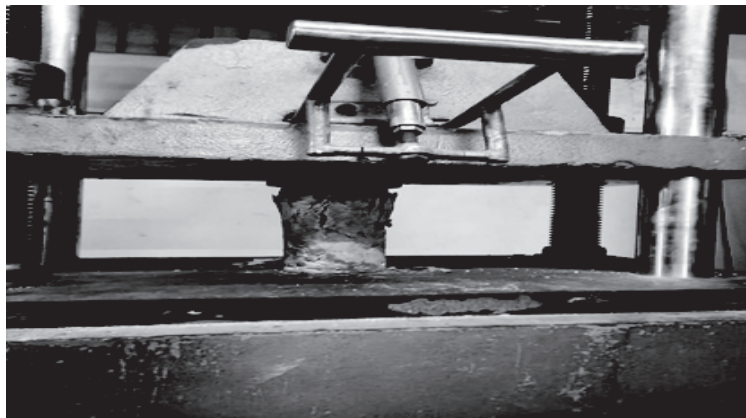


Fig. 9: Compressive fracture of Cylinder.

3.4 Compressive Strength Formula

Compressive strength is a crucial measure of a solid material's ability to withstand gradually applied loads without fracturing. It is determined by dividing the maximum load by the original cross-sectional area of a specimen in a compressive test. Concrete's compressive strength is particularly significant and useful, with design strength typically evaluated on the 28th day. Essentially, compressive strength can be described as concrete's capacity to bear loads without breaking. calculation of compressive strength involved the utilization of an equation.:

$$\text{Compressive strength (F)} = \frac{\text{Failure load (P)}}{\text{Loaded Area (A)}}$$

Here,

F is the compressive strength of specimen in Pound per square inch (Psi).

P is the maximum applied load by Pound.

A is the cross-sectional area (inch square).

4.0 RESULTS

To find out the compressive of concrete for Grade M15, a total of 12 tests have been conducted for 7 days and 28 days. Similarly, for Grade M20, a total of 12 tests have been conducted for 7 days and 28 days in the laboratory. Total 24 specimens were used for the experiments. The water cement ratio remains same for all conditions to compare the results with each other. The details of the experiments given below for Grade M15 and M20 for the different brands of cement.

4.1 Results of Compressive Strength Test of Grade M15 Ratio

Table 3: Compressive Strength test for 7 days

No	Name of Cement	Mix Properties	Water Cement (Ratio)	Compressive Strength (PSI)	Average Strength (PSI)	Average Strength (Mpa)
1	Brand 1	1:2:4	0.50	948	966	6.66
				984		
2	Brand 2	1:2:4	0.50	1163	1189.5	8.20
				1216		
3	Brand 3	1:2:4	0.50	1288	1269.5	8.75
				1251		

Table 4: Compressive Strength test for 28 days

No	Name of Cement	Mix Properties	Water Cement (Ratio)	Compressive Strength (PSI)	Average Strength (PSI)	Average Strength (Mpa)
1	Brand 1	1:2:4	0.50	2021	1994	13.75
				1967		
2	Brand 2	1:2:4	0.50	1896	1976.5	13.63
				2057		
3	Brand 3	1:2:4	0.50	2092	2056.5	14.18
				2021		

4.2 Results of Compressive Strength Test of Grade M20 Ratio

Table 5: Compressive Strength test for 7 days

No	Name of Cement	Mix Properties	Water Cement (Ratio)	Compressive Strength (PSI)	Average Strength (PSI)	Average Strength (Mpa)
1	Brand 1	1:1.5:3	0.50	1467	1484.5	10.23
				1502		
2	Brand 2	1:1.5:3	0.50	1395	1368	9.43
				1341		
3	Brand 3	1:1.5:3	0.50	1610	1619	11.16
				1628		

Table 6: Compressive Strength test for 28 days

No	Name of Cement	Mix Properties	Water Cement (Ratio)	Compressive Strength (PSI)	Average Strength (PSI)	Average Strength (Mpa)
1	Brand 1	1:1.5:3	0.50	2325	2441.5	16.84
				2558		
2	Brand 2	1:1.5:3	0.50	2539	2503.5	17.26
				2468		
3	Brand 3	1:1.5:3	0.50	3363	3246.5	22.39
				3130		

4.3 Comparison Chart between Grade M15 and M20

The Comparison between different brands of cement brands for grades M15 and M20 is given below:

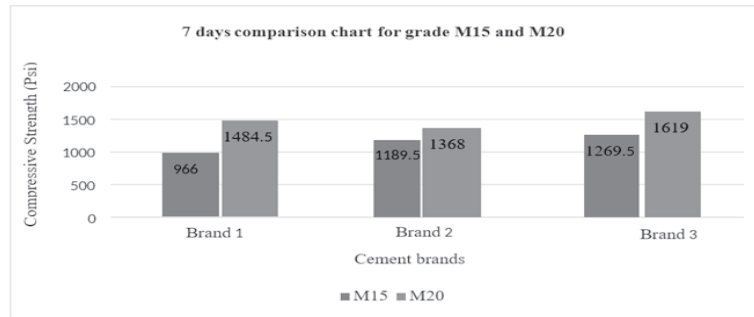


Fig. 10: Seven days comparison chart of Grade M15 and M20 for different brands Cement

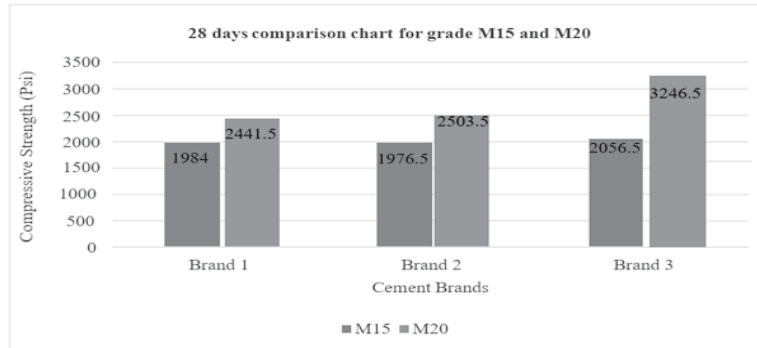


Fig. 11: Twenty-eight days comparison chart of Grade M15 and M20 for different brands Cement

Following the completion of compressive strength tests, it was determined that the outcomes for brands 1, 2, and 3 did not comply with the M15 grade criteria within 7 days. Nevertheless, after 28 days, the results were almost satisfactory. Conversely, the results for brands 1, 2, and 3 did not satisfy the M20 grade requirements within 7 days. After 28 days, brands 1 and 2 still fell short of the requirements, but Brand 3 did meet the conditions for the M20 grade.

5. CONCLUSIONS

After the experiment shows below the result-

- a) For Grade M15 Compressive strength of the concrete is to reach 8.75 Mpa in 7 days & and 14.18 Mpa in 28days of Brand 3.
- b) For Grade M15 Compressive strength of the concrete is to reach 6.66 Mpa in 7 days & and 13.68 Mpa in 28 days of Brand 1.
- c) For Grade M15 Compressive strength of the concrete is to reach 8.20 Mpa in 7 days & and 13.63 Mpa in 28 days of Brand 2.
- d) For Grade M20 Compressive strength of the concrete is to reach 11.16 Mpa in 7 days & and 22.39 Mpa in 28 days of Brand 3.
- e) For Grade M20 Compressive strength of the concrete is to reach 10 Mpa in 7 days & and 16.84 Mpa in 28 days of Brand 1.
- f) For Grade M20 Compressive strength of the concrete is to reach 9.43 Mpa in 7 days & and 17.26 Mpa in 28 days of Brand 2.

The compressive strength of the concrete was measured to be 18.71 Mpa after 28 days, with utmost cylinders meeting the standard strength in under seven days. On average, the concrete's compressive strength was 22.39 Mpa. Brand 3 of grade M20 showed the loftiest compressive strength at 11.16 MPa after 7 days, while Brand 1 of grade M15 had the smallest at 6.66 MPa. At the 28-day mark, Brand 3 of grade M20 showcased the loftiest compressive strength at 22.39 Mpa, while Brand 2 of grade M15 showed the smallest at 13.63 Mpa. Eventually, Brand 3 offered the most emotional compressive strength compared to other cement brands, with the loftiest strength attributed to this brand and the smallest attributed to Brand 1. In conclusion, Brand 3 proved to have a constantly advanced compressive strength overall compared to other cement brands.

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