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# Effect of the Water Cement Ratio on the Strength of M35 Grade Concrete

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**Abstract**: This study explores the relationship between the water-cement ratio compressive strength, water absorption and flexural strength in M35 grade concrete, a widely utilized high-strength mix in the construction industry. The research investigates how the compressive and flexural strength of M35 grade concrete changes when the water - cement ratio ranges from 0.35 to 0.50 after 7,14 and 28 days curing period. In this experiment, fabricated 150 mm cubes of M35 grade concrete following the guidelines outlined in IS 10262:2009 (Guidance on mix design). The results revealed a decrease in compressive and flexural strength with an increase in the water-cement ratio. The highest compressive strength and flexural strength recorded after 28 days were 39.55 N/mm² and 3.35 N/mm² respectively at a water-cement ratio of 0.40. Water absorption test was also carried on a set of cubes at 28 days. But, the highest water absorption was recorded 0.83% at a water cement ratio of 0.45. This indicates the significant role of water-cement ratio in concrete production. By selecting an appropriate water-cement ratio, one can achieve an effective, cost-efficient, and suitably strong concrete mix. These findings are valuable for engineers in making informed decisions when using M35 concrete in construction projects, contributing to more resilient and environmentally-conscious building practices.

**Keywords:** Water cement ratio, Compressive strength, Flexural strength, Water absorption, M35, Design mix

## I. INTRODUCTION

Concrete, a fundamental building material, owes its strength and durability to a delicate balance of its constituent components. Concrete is like the backbone of buildings composed of a blend of cement, aggregates and water, it undergoes a chemical transformation through a process called hydration, solidifying into a robust and resilient structure [1].

M35 grade concrete is a high-strength mix commonly used in construction projects that require durable and robust structures. The "M" stands for mix, and the number represents the specified compressive strength of the concrete after 28 days of curing. Concrete of the M35 grade has a compressive strength of 35 megapascals (MPa), which denotes that it is a very resilient material. This type of concrete is used for such as in bridges, high-rise structures, and other crucial infrastructure [2].

The use of aggregate gives concrete structural stability and makes it ideal for a variety of construction projects. The qualities of the concrete, such as strength, workability, and durability, can be considerably influenced by the kind, size, and quality of the aggregates used. [3].

In concrete, the term "compressive strength" describes the material's capacity to sustain compression or pressure. The ability of a concrete mix to operate well under load-bearing situations is a key characteristic. Megapascals (MPa) or pounds per square inch (psi) are common units for measuring this strength. This characteristic is crucial in the building industry because it guarantees that concrete structures, such as those used in buildings, bridges, and other infrastructure projects, can withstand the loads they would be subjected to in everyday life. Concrete cubes that are uniformly sized at 150 mm x 150 mm x 150 mm are used for compression tests to measure the compressive strength of the concrete. While the concrete mix proportions do influence its strength, the water-cement ratio stands out as the most pivotal factor in this regard. The findings indicate that as the water-cement ratio rises, there is a noticeable decline in compressive strength [4].

The 150mm cubes after casting were cured in water for 28 days. These specimens were then oven dried for 24 hours at the temperature $110^0$ C until the mass became constant and then weighed again.

  

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Flexural strength was conducted as per recommendation IS:516-1959. The flexural strength test was done in Universal testing machine on Beam specimens of dimensions 150×150×700mm. The flexural strength was calculated according to the type of fracture in the beam.

However, the present work aims at experimentally comparing the compressive strength, water absorption and flexural strength of concrete mix M35 under varied water cement ratio at 7, 14 and 28 days is evaluated.

## II. METHODOLOGY

**A.) Material and Specimen preparation -** In this study, the materials employed consist of cement, gravel, and water. The size distributions of the all-in aggregates, which encompass a combination of sand and gravel, were established through sieve analysis, resulting in the attainment of appropriate grading limits. The confirmed grading limits for these all-in aggregates affirm a well-suited distribution, ultimately contributing to favorable workability and durability [5].

**Flow diagram of working procedure**

| Designing of M35 grade concrete mixture |
|---|
| Preparing material and mixing process |
| Slump Test |
| Curing |
| Check the Strength |
| Results |

**B.) Experimental Work -** The mix proportions for M35 grade (1:1.74:3.39) concrete three cubes were determined using cement, fine aggregates, and coarse aggregates, in weights of 3.39 kg of cement, 6.84 kg of fine aggregates, and 13.32 kg of coarse aggregates, respectively. Water was then added to the cement in varying weights to achieve water-cement ratios of 0.35, 0.40, 0.45, and 0.50. This entire mixture was transformed into paste. Simultaneously, cubic moulds for the concrete were lubricated to facilitate the demoulding process later on. Subsequently, the concrete was poured into cubes according to their respective water-cement ratios and subjected to 2 minutes of vibration to eliminate trapped air. The cubes were then shielded with polythene to prevent evaporation. After a 24-hour setting period, the cubes were demoulded and immersed in a curing water tank for 7, 14 and 28 days. Following this curing period, the cubes underwent crushing using a compression testing machine to determine their compressive strength [6].

**Table - 1 Material Mixing Proportions**

The actual quantities (Kg/m$^3$) of different constituents required for the mix are:

| Description | Quantity |
|---|---|
| Water | 139.5 |
| Cement | 387.5 |
| Sand | 666.07 |
| 20 mm Coarse aggregate | 786.44 |
| 10 mm Coarse aggregate | 524.3 |
| Superplasticizer | 3.87 |
| Free water cementitios materials | 0.35 |
| Total | 2508.03 |

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**Fig. - 1 Mixing Process** **Fig. - 2 Slump Test**


**Fig. - 3 Water Absorption Test** **Fig. - 4 Flexural Test**

**C) Results and Discussion:** Table 2 and table 4 illustrates the association between the strength of the concrete mix and different water-cement ratios. Notably, a lower water-cement ratio corresponds to higher compressive strength and flexural strength in the concrete. Additionally, it was observed that the compressive strength and flexural strength increased with the duration of curing. Consequently, the results for concrete consistency and water absorption of water-cement ratio and the weight of the concrete showed in table 3 [7].

The graphical representation of compressive strength and flexural strength for the concrete mixes at 7, 14, and 28 days, in Fig. (5), Fig. (6), Fig. (7) and Fig. (8), Fig. (9), Fig. (10) respectively, affirms that the optimal compressive strength and flexural strength is attained after 7, 14 and 28 days from the time of casting.

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### 3.1 Compressive Strength Test

To get the compressive strength of each specimen, divide the highest load (in N) by the plan area (in $mm^2$).

**Table - 2 Results for Compressive Strength at 7,14 and 28 days**

| Water Cement Ratio | No. of Days | Crushing Load in KN | Compressive Strength in N/MM$^2$ |
|---|---|---|---|
| 0.35 | 7 | 570 | 25.33 |
| 0.40 | 7 | 610 | 27.11 |
| 0.45 | 7 | 520 | 23.11 |
| 0.50 | 7 | 490 | 21.77 |
| 0.35 | 14 | 720 | 32 |
| 0.40 | 14 | 760 | 33.77 |
| 0.45 | 14 | 690 | 30.66 |
| 0.50 | 14 | 650 | 28.88 |
| 0.35 | 28 | 820 | 36.44 |
| 0.40 | 28 | 890 | 39.55 |
| 0.45 | 28 | 790 | 35.11 |
| 0.50 | 28 | 740 | 32.88 |

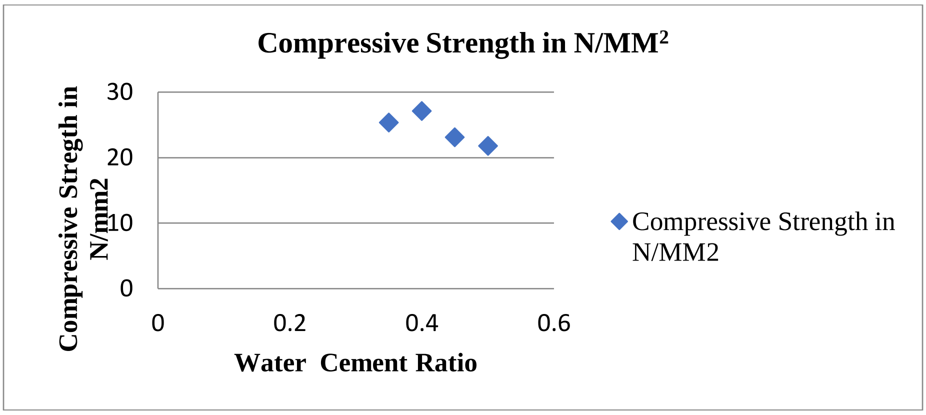


**Fig. - 5 Water - cement ratio vs. compressive strength at 7 days**

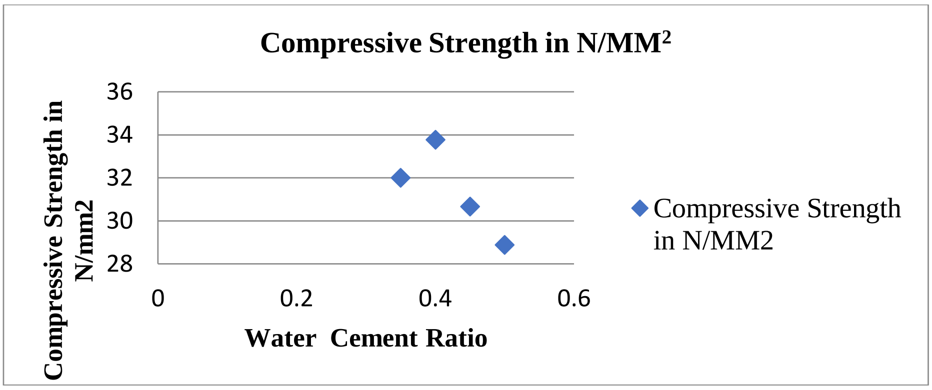


**Fig. - 6 Water - cement ratio vs. compressive strength at 14 days**

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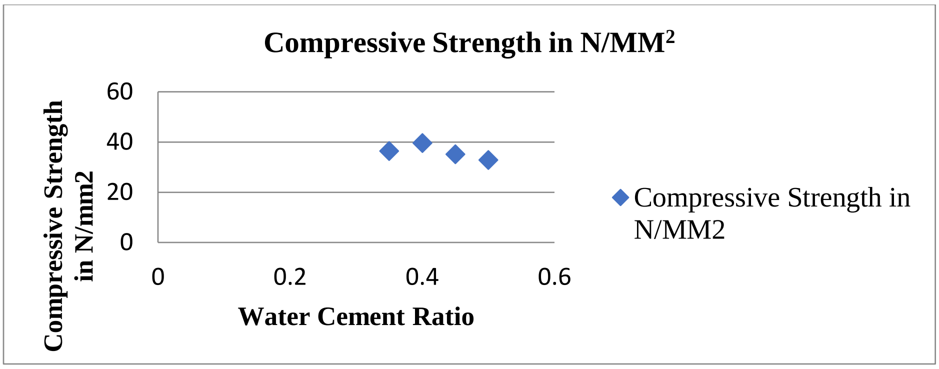


**Fig.- 7 Water - cement ratio vs. compressive strength at 28 days**

### 3.2 Water Absorption Test

Results for water absorption of concrete for water - cement ratio ranges from 0.35 to 0.50 after 7, 14 and 28 days curing period are shown in table 3.

**Table - 3 Results for concrete consistency and water absorption**

| Water Cement Ratio | No. of Days | Slump in mm | Initial weight of cube in kg | Final weight of cube after curing | Water absorption in % |
|---|---|---|---|---|---|
| 0.35 | 7 | 0 | 8.38 | 8.40 | 0.23 |
| 0.40 | 7 | 10 | 8.40 | 8.44 | 0.47 |
| 0.45 | 7 | 20 | 8.44 | 8.48 | 0.47 |
| 0.50 | 7 | 25 | 8.45 | 8.48 | 0.35 |
| 0.35 | 14 | 0 | 8.36 | 8.40 | 0.47 |
| 0.40 | 14 | 10 | 8.38 | 8.40 | 0.23 |
| 0.45 | 14 | 20 | 8.40 | 8.44 | 0.47 |
| 0.50 | 14 | 25 | 8.42 | 8.48 | 0.71 |
| 0.35 | 28 | 0 | 8.35 | 8.38 | 0.35 |
| 0.40 | 28 | 10 | 8.37 | 8.40 | 0.35 |
| 0.45 | 28 | 20 | 8.40 | 8.47 | 0.83 |
| 0.50 | 28 | 25 | 8.41 | 8.48 | 0.83 |

### 3.3 Flexural Strength Test

Beam specimens with dimensions of 150x150x700mm were created. During testing three point loading was adopted on an effective span of 450mm as per IS 516-1959.

Flexural strength is calculated using the equation: $F = PL/bd^2$
Where, F = Flexural strength of concrete (in MPa), P = Failure load (in N),

L = Effective span of the beam (450mm), b= Breadth of the beam (150mm),
D = Depth of the beam (150mm).

Results for flexural strength of concrete for water-cement ratio ranges from 0.35 to 0.50 after 7,14 and 28 days curing period are shown in table 4 and fig. 8 to fig. 10.

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**Table - 4 Results for flexural strength at 7,14 and 28 days**

| Water Cement Ratio | No. of Days | Flexural Strength in $N/MM^2$ |
|---|---|---|
| 0.35 | 7 | 1.73 |
| 0.40 | 7 | 2 |
| 0.45 | 7 | 1.86 |
| 0.50 | 7 | 1.6 |
| 0.35 | 14 | 2.4 |
| 0.40 | 14 | 2.66 |
| 0.45 | 14 | 2.26 |
| 0.50 | 14 | 2 |
| 0.35 | 28 | 2.93 |
| 0.40 | 28 | 3.35 |
| 0.45 | 28 | 2.66 |
| 0.50 | 28 | 2.8 |

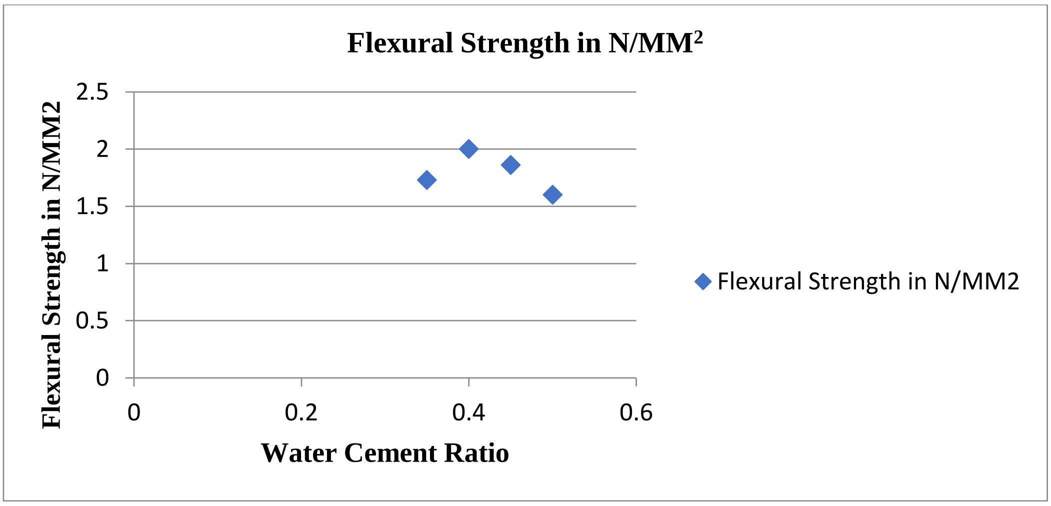


**Fig. - 8 Water - cement ratio vs. flexural strength at 7 days**

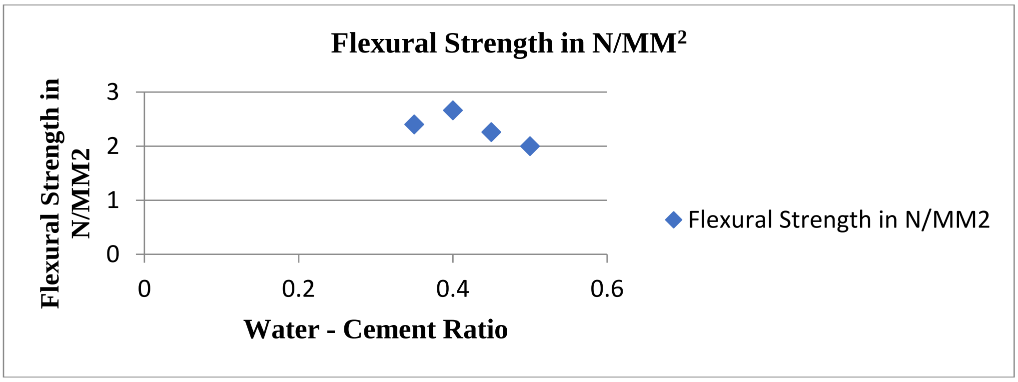


**Fig. - 9 Water cement ratio vs. flexural strength at 14 days**

 

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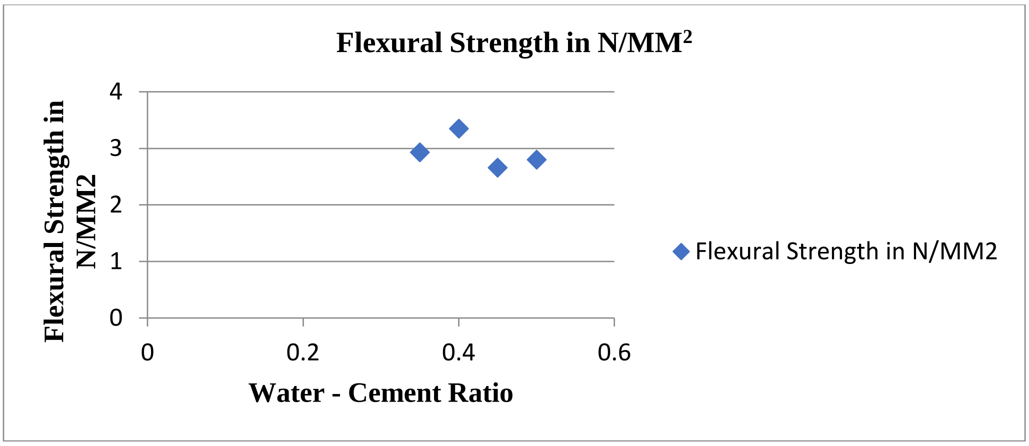


**Fig. - 10 Water cement ratio vs. flexural strength at 28 days**

## III. CONCLUSION

**The study's findings led to the following conclusions:**

- When the water cement had a 0.40 content after 7, 14, and 28 days of curing, greater compressive and flexural strengths were attained.
- Water absorption is far less than the permitted limit, with an observed maximum at a water-to-cement ratio of 0.45.
- With the increase of the water - cement ratio in concrete increasing its workability and reduces strength.

## IV. RECOMMENDATION

Utilizing an appropriate cement-to-water ratio in a concrete mix plays a crucial role in determining both the anticipated weight and strength of the resulting mixture. This principle establishes a direct connection between the cost-effectiveness of a concrete mix and its cement-to-water ratio. It's really important to find the right balance between how much water the concrete soaks up and how easy it is to work with (known as slump). This balance ensures that the concrete stays strong and easy to handle while being used in construction. These observations are crucial for making smart choices about using M35 grade concrete in lots of different kinds of building projects.

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