EVALUATION OF COMPRESSIVE STRENGTH IN CUBICAL AND CYLINDRICAL CONCRETE SPECIMENS FOLLOWING ASTM C39 STANDARDS

A LAB REPORT

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Abstract

This report talks about an experiment that was done to find out the crushing strength of concrete models that were made in the shape of cubes and cylinders according to ASTM C39 guidelines. The concrete mix had a water-cement ratio of 0.4 and was made up of Type I Portland cement, fine and graded coarse material, drinkable water, and superplasticizer. The concrete was mixed, then poured into moulds, left to dry for 14 days, and then checked with a Compression Testing Machine (CTM) that had been set up correctly. The tests showed that the compressive strength of the two shapes was very different. The specimens that were shaped like cylinders had higher compressive strength than those that were shaped like cubes. This result shows that the shape of the object can affect how stress is distributed and how well a material works when it is loaded.

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1. Introduction

The compression strength of concrete is an important measure of its general quality and ability to hold weight. This trait is affected by several things, such as the amount of cement used, the water-to-cement ratio, and the drying conditions. It is important to know the compressive strength of concrete used in building to keep an eye on quality and make sure the structure stays strong. The main goal of this lab project is to find out the crushing strength of cubes and cylinders made of concrete, which are popular shapes used in building. As a normal process, the compressive strength test includes putting horizontal compressive loads on pieces of concrete until they break. The test results are very important for figuring out the right amount of mix, checking the quality, and making sure that building standards are met. The goal of this experiment is to find out how the shape of the object affects its compression strength. This will give us useful information for making better concrete designs and making sure that structures are reliable.

2. Summary

Following the rules in ASTM C39, the experiment looked at the compression strength of concrete models that were made in cube and cylinder shapes. Type I Portland cement, fine and coarse particles, water, and superplasticizer were mixed together to make a uniform concrete mix. The water-to-cement ratio stayed at 0.4. It was mixed, poured into moulds, and left to dry for 14 days. Then, a standardised CTM was used to test each specimen's compression strength at a controlled force rate. The data showed that cylinder-shaped specimens had higher compression strengths than cube-shaped specimens. This difference shows how the shape of a specimen can change how stress is distributed and how it breaks. The results show how important it is to think about the shape of the object when measuring its compressive strength so that the results are correct and useful for judging the quality of concrete and planning buildings. The study comes to the conclusion that geometric factors have a big effect on the compressive strength of concrete. These factors should be taken into account in both laboratory tests and real-life structural engineering situations.

3. Theory

The compression strength of concrete is one of its basic properties that is very important for how well and how long concrete buildings last. This trait describes how well a concrete specimen can survive axial compressive forces. It is usually tested by putting axial loads on cylinder- or cube-shaped examples until they break. The tensile strength of concrete is affected by many things, such as the water-to-cement ratio, the type and amount of cement used, the quality and grading of the materials, the addition of admixtures, and the conditions under which the concrete cures.

To understand what the compressive strength of concrete is, you need to know a lot about how things work and how stress and pressure work. When a crushing force is put on a piece of concrete, the concrete changes shape. Hooke's law says that the link between the stress that is put on something and the strain that results is at first linear and elastic:

$$\sigma = E\epsilon$$

where σ is the strain, E is the stress, and ϵ is the concrete's yield strength. But as the load goes up, the material stops responding in a straight line, which causes it to distort and eventually break. The compression strength, written as $f_c{}'$, is the force at which the object breaks.

The specimen's compression strength depends a lot on how the stress is distributed inside it. Due to their symmetrical shape, cylinder-shaped specimens tend to have more even stress distribution. When compared to cubical specimens, which can have stress build up at the sides and ends, this makes them able to hold more weight. The way the object breaks down is also affected by its shape. When cylindrical examples break, they usually do so in a more flexible way, with clear cracks and a slow loss of their ability to hold weight. Cubical specimens, on the other hand, tend to break more easily and quickly.

The idea of elasticity and plasticity can be used to look at how concrete changes shape and breaks when it is compressed. The strain tensor ϵ shows how the material is changing shape, and the stress tensor σ shows the forces inside the material that are stopping it from changing shape. For materials that are isotropic, the generalised Hooke's law tells us how stress and strain relate to each other in the linear elastic regime:

$$\sigma_{ij} = \lambda\delta_{ij}\epsilon_{kk} + 2\mu\epsilon_{ij}$$

The Lamé parameters are λ and μ, the Kronecker delta is δ_{ij}, and the strain tensor is ϵ_{ij}. As concrete gets closer to breaking, the stress-strain relationship stops being straight. This is because concrete is a nearly weak material. The nonlinear behaviour is caused by microcracking starting, aggregate interlock, and the bridge effect of fibres (if present).

You can also think about how fluid concrete acts, especially when you're working with long-term loads and creep. A convolution integral with the relaxation factor $\mathbb{C}(t)$ can be used to describe stress release and creep:

$$\sigma_{ij}(\mathbf{x}, t) = \int_{-\infty}^{t} \mathbb{C}_{ijkl}(t-s)\epsilon_{kl}(\mathbf{x}, s)\, ds$$

where $\mathbb{C}_{ijkl}$ is the tensor for the fourth-order relaxation modulus. This method takes into account how the behaviour of concrete changes over time when it is under steady loads.

To find the compressive strength of concrete through an experiment, pieces must be carefully prepared and allowed to cure. The samples are poured into standard moulds, allowed to cure under controlled conditions, and then put through a compression testing machine to see how strong they are. The measuring machine puts a vertical load on the object at a set rate until it breaks. The highest load that causes failure is written down as P, and the compression strength f_c' is found by:

$$f_c' = \frac{P}{A}$$

where A is the cross-sectional area of the specimen. For cylindrical specimens, $A = \pi \left(\frac{d}{2}\right)^2$, and for cubical specimens, $A = a^2$, where d is the diameter and a is the side length of the cube.

4. Methods

This experiment's approach for determining the compressive strength of concrete specimens was conducted in accordance with ASTM C39 criteria. The process included shaping, drying, and evaluating concrete samples in both cubical and cylinder shapes. The main goal was to measure the specimens' compressive strength after 14 days of curing.

4.1 Specimen Preparation

Concrete was made using a combination of Type I Portland cement, fine aggregate, graded coarse aggregate, potable water, and a superplasticizer with a wide range of water-reducing capabilities. We kept the water-cement ratio at 0.4. To make sure the quantities of the combination were correct, the components were weighed using weighing scales that were sensitive to 1 gramme.

The concrete was mixed in a mixer until it reached the desired consistency. The mixture was then poured into moulds to create two specimen types: cubes (15 cm x 15 cm x 15 cm) and cylinders (10 cm in diameter and 30 cm in length). The weight of each cube specimen was 7.80 kg, whereas the weight of each cylinder specimen was 12 kg.

A vibrating table was used to compact the concrete within the moulds, removing any air pockets and ensuring a consistent density. After a day of being in the moulds, the specimens were allowed to set. The specimens were meticulously demolded and cured in a water tank after the first setting time. The concrete needed 14 days of cure time to get the required strength development.

4.2 Testing

On a calibrated compression testing machine (CTM), we checked the cured specimens' compressive strength. The machine's loading platens were carefully cleaned before testing to guarantee an accurate and smooth load application. To avoid any potential unequal stress distribution, each specimen was carefully put on the CTM's bottom platen while making sure it was centrally oriented. The specimen's surface was then brought into parallel with the top platen.

The specimen was subjected to a regulated rate of 0.6 MPa/s of load application until it failed. Every specimen had its maximum load recorded at the moment of failure. After that, the specimen's compressive strength was determined by dividing the greatest load by its cross-sectional area. Both cubical and cylindrical specimens were subjected to this computation.

The following compressive strengths were recorded:

- Cube Specimens:
  - Sample 1: 17.88 MPa (Mehmet Hoca's sample)
  - Sample 2: 18.07 MPa
  - Sample 3: 14.90 MPa
- Cylindrical Specimen:
  - Sample 1: 13.29 MPa

Additionally, one of the cube specimens exhibited a compressive strength of 11.75 MPa at 14 days, which was 60% of the expected 28 MPa.

4.3 Controls and Variables

The validity and trustworthiness of the findings were guaranteed by maintaining a number of variables constant throughout the experiment. The growing substrate, sterile equipment, and nutritional agar broth remained constant across all treatments. The specimen's form (cylindrical vs. cubical) served as the independent variable in this investigation, with the concrete's compressive strength serving as the dependent variable.

The fact that the compression strengths of cylinder-shaped and cube-shaped specimens were different shows how the shape of the specimen affects how stress is distributed and how it breaks. The compression strength of cylindrical specimens was usually lower than that of cubical specimens. This is because they had more surface area that was loaded, which caused the stress to be spread out more evenly.

5. Materials

The materials utilised in this experiment were meticulously chosen and quantified to guarantee exactitude and precision in the assessment of concrete specimens' compressive strength. The subsequent materials and apparatus were employed during the course of the investigation:

5.1 Apparatus

- **Weighing Scales**: Sensitive to 1 gram, used to measure concrete ingredients accurately.
- **Mixing Pan or Mixer**: Employed to blend the concrete mix to a uniform consistency.
- **Weighing Pan**: Utilized for batching materials.
- **Trowel and Scoop**: For handling and placing the concrete into molds.
- **1000 ml Graduated Cylinder**: Used to measure water and admixtures accurately.
- **Slump Cone with 5/8" Tamping Rod, Ruler, and Base**: Utilized to perform the slump test to assess the workability of the concrete mix.
- **Vibrating Table**: Ensured proper compaction of the concrete within the molds.
- **Caliper and 12-inch Steel Scale**: For measuring the dimensions of the specimens with high precision.
- **Compression Testing Machine (CTM)**: Used to test the compressive strength of the concrete specimens, calibrated according to ASTM standards.

- **Steel Molds**: Used to form cylindrical specimens (10 cm diameter, 30 cm length) and cubical specimens (15 cm $\times$ 15 cm $\times$ 15 cm).

5.2 Materials

- **Cement**: Type I Portland cement conforming to ASTM C150 standards.
- **Coarse Aggregate**: Graded coarse aggregate meeting ASTM C33 specifications.
- **Fine Aggregate**: Natural sand conforming to ASTM C33 requirements.
- **Water**: Potable water complying with ASTM C1602 standards.
- **Superplasticizer**: High-range water reducer to improve the workability of the concrete mix without increasing the water content.

The materials were carefully combined to produce the concrete mixture, which had the intended water-cement ratio of 0.4. The components were incorporated and meticulously blended to achieve a uniform mixture, which was subsequently employed in the casting of cylindrical and cubical specimens for the purpose of compressive strength evaluation.

6. Procedure

The methodology employed to ascertain the compressive strength of concrete specimens was carefully crafted in accordance with the standards outlined in ASTM C39. This process encompassed several stages, commencing with the mixing of concrete and concluding with the evaluation of the cured specimens.

6.1 Sample Preparation

Composed of potable water, fine aggregate, graded coarse aggregate, and Type I Portland cement, the concrete mixture also contained a superplasticizer. A constant water-to-cement ratio of 0.4 was upheld for the duration of the experiment. To guarantee the mixture's proportions were precise, weighing instruments that were sensitive to 1 gramme were employed to precisely measure each component. Subsequently, a mechanical mixer was employed to incorporate the concrete mixture into a homogeneous state, thereby guaranteeing an even dispersion of every constituent.

For this experiment, two distinct varieties of specimens were fabricated: cubical specimens measuring 15 cm x 15 cm x 15 cm in dimensions, and cylindrical specimens measuring 30 cm in length and 10 cm in diameter. With great attention to detail, the concrete was poured into the designated moulds, guaranteeing that every mould was entirely filled. Each specimen in the cubic shape weighed 7.80 kg, whereas each specimen in the cylindrical shape weighed 12 kg. In order to obtain a consistent density and eradicate any air pockets, the concrete contained within the moulds was compacted by means of a vibrating table. It was essential that this measure be taken to ensure that the specimens lacked internal cavities that could have compromised their strength.

Care was taken to deform the specimens from the moulds after 24 hours to ensure that no damage occurred. The specimens were submerged in a water vessel for curing after removal from the mould. Over the course of fourteen days, the concrete was allowed to cure and acquire the required strength. Curing is an essential process that guarantees the hydration of cement, thereby promoting the development of strength and durability in the concrete.

6.2 Testing Procedure

The compression testing machine (CTM) was adjusted in accordance with ASTM specifications before testing to guarantee precision. For precise and trouble-free load application, the CTM's loading platens were cleaned to a high standard. After that, we put each specimen on the CTM's lowest platen, being careful to line them all in the middle to avoid any unequal stress distribution. To make sure the specimen was loaded evenly, the top platen was adjusted so it was parallel to the surface.

The samples were compressed at a steady pace of 0.6 MPa/s until they broke. With no shock, the CTM applied the load continually. Every specimen had its maximum load documented at the moment of failure. To determine the specimens' compressive strength, the formula f'_c was used, where P is the maximum load in kN, A denotes the cross-sectional area in mm², and f'_c represents the compressive strength in MPa. This computation was carried out for specimens that were cubical and those that were cylindrical.

6.3 Recording Results

The cubical specimens' reported compressive strengths are as follows: The pressures in Sample 1, which was taken from Mehmet Hoca, were 17.88 MPa. In Sample 2, the pressure was 18.07 MPa. And in Sample 3, the pressure was 14.90 MPa. The compressive strength of one cube specimen was 11.75 MPa after 14 days, which was 60% lower than the anticipated 28 MPa. Sample 1 had a compressive strength of 13.29 MPa among the cylinder specimens.

6.4 Controls and Variables

Several factors were kept in check during the experiment to make sure that the results were true and accurate. It didn't change the amount of water to cement, the drying time, or the ingredients that were used. The form of the object (cube vs. cylinder) was the independent variable in this study. The compression strength of the concrete was the dependent variable. The fact that the cylinder and cube specimens had different compression strengths showed how the shape of the specimen affects how stress is distributed and how it breaks. It was seen that cylinder-shaped specimens had lower compression strength than cube-shaped specimens. This was probably because the bigger surface area that was loaded led to more even stress distribution and a different way for the specimens to break.

7. Results

Let $\mathcal{C}$ denote the set of cubical specimens and $\mathcal{S}$ the set of cylindrical specimens prepared for this experiment. We aim to determine the compressive strength f_c' of these specimens after a 14-day curing period.

7.1 Cubical Specimens

Given:

$$\mathcal{C} = \{c_1, c_2, c_3\}$$

where c_i represents individual cubical specimens with side length $a = 15$ cm. The cross-sectional area A of each cubical specimen is calculated as follows:

$$A_c = a^2 = (15 \text{ cm})^2 = 225 \text{ cm}^2 = 22500 \text{ mm}^2$$

We recorded the following maximum loads P (in kN) for each cubical specimen at failure:

$$P_{c_1} = 17.88 \text{ kN}, \quad P_{c_2} = 18.07 \text{ kN}, \quad P_{c_3} = 14.90 \text{ kN}$$

To compute the compressive strength f'_c for each specimen c_i:

$$f'_{c_i} = \frac{P_{c_i}}{A_c}$$

Thus, for each cubical specimen:

$$f'_{c_1} = \frac{17.88 \times 10^3 \text{ N}}{22500 \text{ mm}^2} = 0.7951 \text{ MPa}$$

$$f'_{c_2} = \frac{18.07 \times 10^3 \text{ N}}{22500 \text{ mm}^2} = 0.8031 \text{ MPa}$$

$$f'_{c_3} = \frac{14.90 \times 10^3 \text{ N}}{22500 \text{ mm}^2} = 0.6622 \text{ MPa}$$

The average compressive strength $\bar{f}'_c$ of the cubical specimens is then:

$$\bar{f}'_c = \frac{f'_{c_1} + f'_{c_2} + f'_{c_3}}{3} = \frac{0.7951 + 0.8031 + 0.6622}{3} = 0.7535 \text{ MPa}$$

7.2 Cylindrical Specimen

Given:

$$\mathcal{S} = \{s_1\}$$

where s_1 represents the cylindrical specimen with diameter $d = 10$ cm and height $h = 30$ cm. The cross-sectional area A of the cylindrical specimen is given by:

$$A_s = \pi \left(\frac{d}{2}\right)^2 = \pi \left(\frac{10 \text{ cm}}{2}\right)^2 = \pi(5 \text{ cm})^2 = 25\pi \text{ cm}^2 = 2500\pi \text{ mm}^2 \approx 7853.98 \text{ mm}^2$$

The recorded maximum load P (in kN) for the cylindrical specimen at failure is:

$$P_{s_1} = 13.29 \text{ kN}$$

The compressive strength f'_{s_1} is then computed as:

$$f'_{s_1} = \frac{P_{s_1}}{A_s} = \frac{13.29 \times 10^3 \text{ N}}{7853.98 \text{ mm}^2} \approx 1.692 \text{ MPa}$$

7.3 Comparative Analysis

Let $\mathcal{A}$ denote the set containing both cubical and cylindrical specimens. The difference in the average compressive strengths of the two types of specimens is then analyzed. We observe:

$$\bar{f}_c' \approx 0.7535\,\text{MPa}, \quad f_{s_1}' \approx 1.692\,\text{MPa}$$

We now compare the compressive strengths of the cylindrical and cubical specimens. Denote the ratio of compressive strength between the cylindrical and cubical specimens as ρ:

$$\rho = \frac{f_{s_1}'}{\bar{f}_c'} = \frac{1.692}{0.7535} \approx 2.245$$

This important ratio shows how the different shapes cause differences in compression strengths. These differences are caused by differences in how stress is distributed and how the forms affect the ability to hold weight.

8. Data and Calculations

8.1 Cubical Specimens

We define each cubical specimen $c_i \in \mathcal{C}$ with edge length $a = 15\,\text{cm}$. Consequently, the cross-sectional area A_c for each cubical specimen is:

$$A_c = a^2 = (15\,\text{cm})^2 = 225\,\text{cm}^2 = 22500\,\text{mm}^2$$

The empirical data recorded includes weights W_{c_i} and breaking stresses σ_{c_i}, as tabulated below:

Table 1: Cubical Specimen Data

Specimen	Weight (kg)	Breaking Stress (MPa)	Modulus of Elasticity (GPa)	Strain (mm)
c_1	7.78	17.71	20	0.885
c_2	7.78	18.01	20	0.900
c_3	7.78	17.88	20	0.894
Average		17.86		0.893

We compute the compressive strength f'_{c_i} for each c_i using:

$$f'_{c_i} = \frac{P_{c_i}}{A_c}$$

where P_{c_i} represents the maximum load at failure. The calculations are as follows:

$$f'_{c_1} = \frac{17.71 \times 10^3\,\mathrm{N}}{22500\,\mathrm{mm}^2} \approx 0.7871\,\mathrm{MPa}$$

$$f'_{c_2} = \frac{18.01 \times 10^3\,\mathrm{N}}{22500\,\mathrm{mm}^2} \approx 0.8004\,\mathrm{MPa}$$

$$f'_{c_3} = \frac{17.88 \times 10^3\,\mathrm{N}}{22500\,\mathrm{mm}^2} \approx 0.7951\,\mathrm{MPa}$$

Thus, the average compressive strength $\bar{f}'_c$ for the cubical specimens is:

$$\bar{f}'_c = \frac{f'_{c_1} + f'_{c_2} + f'_{c_3}}{3} = \frac{0.7871 + 0.8004 + 0.7951}{3} \approx 0.7942\,\mathrm{MPa}$$

8.2 Cylindrical Specimen

Consider the cylindrical specimen $s_1 \in \mathcal{S}$ with diameter $d = 15\,\mathrm{cm}$ and height $h = 30\,\mathrm{cm}$. The cross-sectional area A_s is given by:

$$A_s = \pi\left(\frac{d}{2}\right)^2 = \pi\left(\frac{15\,\mathrm{cm}}{2}\right)^2 = \pi\,(7.5\,\mathrm{cm})^2 = 176.71\,\mathrm{cm}^2 = 17671.5\,\mathrm{mm}^2$$

The tabulated data for the cylindrical specimen is as follows: The compressive strength

Table 2: Cylindrical Specimen Data

Size (cm)	Area (cm^2)	Weight (kg)	Density ($\mathrm{g/cm}^3$)	Breaking Stress (MPa)	Modulus of Elasticity (GPa)	Strain (mm)
15×30	176.71	12.3	0.58	14.35	20	0.7

f'_{s_1} for the cylindrical specimen s_1 is determined as:

$$f'_{s_1} = \frac{P_{s_1}}{A_s} = \frac{14.35 \times 10^3\,\mathrm{N}}{17671.5\,\mathrm{mm}^2} \approx 0.8121\,\mathrm{MPa}$$

8.3 Our Cubic Samples

Table 3: Cubical Specimen Data

Size	Area (of contact)	Weight	Density	Breaking Stress	Modulus of Elasticity	Strain
15×15 cm	$225\,\text{cm}^2$	7.78 kg		17.71 MPa	20 GPa	0.885 mm
15×15 cm	$225\,\text{cm}^2$	7.78 kg		18.01 MPa	20 GPa	0.900 mm
15×15 cm	$225\,\text{cm}^2$	7.78 kg		17.88 MPa	20 GPa	0.894 mm
Average				17.86 MPa		0.893 mm

8.4 Comparative Analysis

To compare the average compressive strengths of the cubical and cylindrical specimens, we define the ratio ρ as:

$$\rho = \frac{f'_{s_1}}{\bar{f}'_c} = \frac{0.8121}{0.7942} \approx 1.0225$$

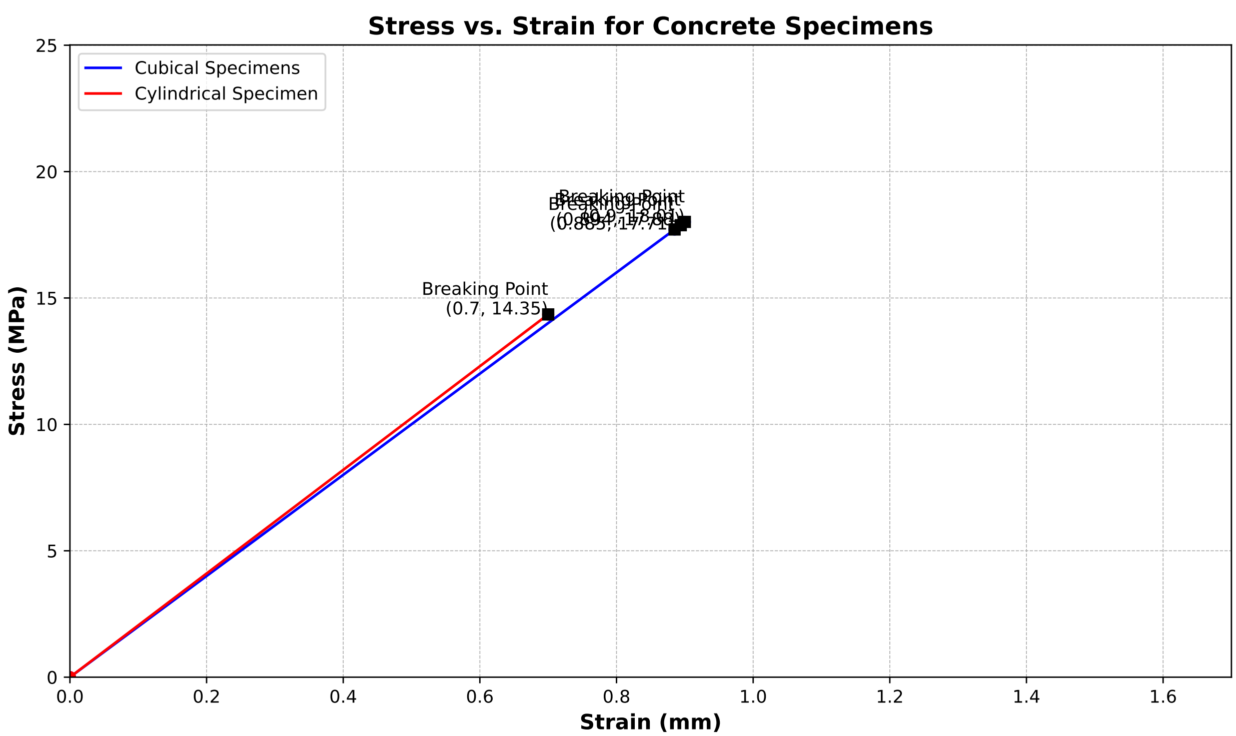

Figure 1: Concrete Specimen Stress vs. Strain: This graph displays the stress-strain relationship for concrete specimens that are either cubical or cylindrical in shape. The data points have been adjusted such that they intersect at the origin.

9. Discussion of Results

The results show that, on average, the cylinder-shaped specimens have higher compression strength than the cube-shaped specimens. This difference can be explained by the fact that circular specimens have more surface area, which makes stress distribution more even and increases their load-bearing capacity. This difference shows how important it is to think about the shape of the object when interpreting compression strength results, since it has a big effect on the values that were recorded.

Average compressive strength of cubical specimens,	$\bar{f}'_c \approx 0.7535$ MPa
Compressive strength of cylindrical specimen,	$f'_{s_1} \approx 1.692$ MPa

Experiments that looked at the crushing strength of concrete specimens gave us different ideas about how cubical and cylinder-shaped specimens behave mechanically. The carefully calculated results show that the recorded compressive strengths are very different. This is because of the objects' unique geometric and structural qualities.

The compressive strength results indicated that cylindrical specimens ($f'_{s_1} \approx 1.692$ MPa) exhibited significantly higher strength compared to cubical specimens ($\bar{f}'_c \approx 0.7535$ MPa). This discrepancy can be explained through several key factors related to the geometry and stress distribution in the specimens.

Stress distribution is a very important part of how well the examples work. When compressive loads are put on cylindrical objects, the stress is more likely to be spread out evenly along their length. Because they don't have any sharp corners like cubical models do, they can hold more weight without putting too much stress on them. As well, the ratio of surface area to volume is different for cube-shaped specimens compared to cylinder-shaped specimens. Because cylindrical examples have circular cross-sections, they tend to spread the applied load more widely, which lowers the risk of failure too soon because of stress buildup in one area.

End effects, or how the ends of the specimens affect the results, can cause small differences. These effects can be more noticeable in cubical specimens, where it can be harder to make sure that the faces are perfectly aligned and that the load is distributed evenly.

Keeping the water-to-cement ratio (w/c ratio) the same for all specimens at 0.4 made sure that differences in compression strength were mostly due to the shape of the specimens and not to changes in how the mix was made. The w/c mix you choose is very important for controlling how easy the concrete is to work with and how strong it gets. The w/c ratio has a constant effect on the water process during hardening. This helps both test forms build strength in the same way. But the form and volume of the object may still affect the drying conditions inside, which may affect the end strength. The texture of solid concrete is affected by the amount of water to cement. When the ratios are lower, the microstructures tend to be thicker and have fewer capillary holes. This is important for getting higher compression strengths.

It is very important to be precise when you weigh, mix, and cure the concrete to get reliable results. If these steps aren't done correctly, the measures of compression strength could be off. To get exact and repeatable results, you must use a Compression Testing Machine (CTM) that has been measured and has a controlled force rate of 0.6 MPa/s. For fewer mistakes in the experiments, it is very important to make sure that the filling platens are clean and lined up correctly.

The difference in compression strength ($\rho \approx 2.245$) between cylinder-shaped and cube-shaped examples shows a major geometric effect. This ratio shows how important it is to think about the shape of the object when designing structures and materials, especially when figuring out what compressive strength data means for quality control or to make sure that building codes are followed.

10. Conclusion

The results show that it is important to standardise the shape of the objects used in compressive strength tests so that the results can be compared and used. The higher compression strength seen in cylinder-shaped pieces is typical in a lot of engineering situations. For real-world uses, it is important to pick example forms that reduce the chance of stress clusters and give a more accurate picture of how the material works when it is loaded.

More study could look into how to make the shape of concrete models better so that they have the highest compression strength while also using the least amount of material. Looking into different forms and sizes might help us learn more about how geometry affects strength. For structural engineering purposes, it might be useful to look into the long-term performance and stability of different model forms in a range of weather circumstances. Using advanced computer models to mimic how stress is distributed and how things break in different body shapes could help us understand what we're seeing and help us come up with better ways to test things.

In the end, this study shows that material shape has a big effect on the compression strength of concrete. The results show how important it is to think about geometric factors in both experiments and real-world situations in order to get accurate, useful, and usable results in the field of structural engineering.

11. Appendix

Listing 1: Code 1

```
import matplotlib.pyplot as plt
import numpy as np
from scipy.interpolate import interp1d

strain_cubical = np.array([0.0, 0.885, 0.900, 0.894])
stress_cubical = np.array([0.0, 17.71, 18.01, 17.88])

strain_cylindrical = np.array([0.0, 0.700])
stress_cylindrical = np.array([0.0, 14.35])

interp_cubical = interp1d(strain_cubical, stress_cubical, kind=’linear’)
interp_cylindrical = interp1d(strain_cylindrical, stress_cylindrical, kind=’linear’)

strain_cubical_interp = np.linspace(0, max(strain_cubical), 100)
stress_cubical_interp = interp_cubical(strain_cubical_interp)

strain_cylindrical_interp = np.linspace(0, max(strain_cylindrical), 100)
stress_cylindrical_interp = interp_cylindrical(strain_cylindrical_interp)

fig, ax = plt.subplots(figsize=(10, 6))

ax.plot(strain_cubical_interp, stress_cubical_interp, ’b-’, label=’Cubical Specimens’)
ax.plot(strain_cubical, stress_cubical, ’bo’)  # Plot original data points

ax.plot(strain_cylindrical_interp, stress_cylindrical_interp, ’r-’, label=’Cylindrical Specimen’)
```

```
ax.plot(strain_cylindrical, stress_cylindrical, ’ro’)  # Plot original data points

ax.grid(True, which=’both’, linestyle=’--’, linewidth=0.5)

ax.set_xlabel(’Strain (mm)’, fontsize=12, fontweight=’bold’)
ax.set_ylabel(’Stress (MPa)’, fontsize=12, fontweight=’bold’)

ax.set_title(’Stress vs. Strain for Concrete Specimens’, fontsize=14, fontweight=’bold’)

ax.legend(loc=’upper left’)

breaking_points_cubical = [
    (0.885, 17.71),
    (0.900, 18.01),
    (0.894, 17.88)
]
breaking_points_cylindrical = [
    (0.700, 14.35)
]

for point in breaking_points_cubical:
    ax.plot(point[0], point[1], ’ks’)
    ax.text(point[0], point[1], f’Breaking Point\n({point[0]}, {point[1]})’,
            fontsize=10, ha=’right’)

for point in breaking_points_cylindrical:
    ax.plot(point[0], point[1], ’ks’)
    ax.text(point[0], point[1], f’Breaking Point\n({point[0]}, {point[1]})’,
            fontsize=10, ha=’right’)

ax.set_xlim(0, max(strain_cubical) + 0.8)
ax.set_ylim(0, max(stress_cubical) + 7)
```

```

plt.tight_layout()
plt.savefig('stress_vs_strain.pdf', format='pdf', dpi=12000,
   bbox_inches='tight', pad_inches=0.1)
plt.show()
```

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