Determination of Flow and Compressive Strength of Portland Cement According to ASTM Standards

Lab Report

Muhammet Yağcıoğlu

290204042

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Department of Civil Engineering

Izmir Institute of Technology

Izmir, Turkey

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Abstract

Portland cement flow and compressive strength are measured in this report in accordance with ASTM C1437 and C109. Because of how important workability and load-bearing capacity are to the quality and structural integrity of concrete, the experiments assessed both in the Portland cement mortar. By adhering to standard procedures for producing and assessing cement mortar samples, this study sheds light on the physical properties of cement, which has implications for quality control and applications in the construction sector.

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1 Introduction

Concrete buildings must be strong and long-lasting. The cement's basic qualities have a major impact on these properties when it is mixed with concrete. Laboratory experiments were conducted to assess the flow and compressive strength of Portland cement according to ASTM standards, and the findings are presented in this paper.

According to ASTM C1437, the flow of cement mortar is a measure of the material's hydration and workability, which impact the concrete mix's homogeneity and how easy it is to work with. In contrast, the compressive strength of cement indicates how well it can bear loads.

The techniques used, outcomes of the tests, and their consequences for the future of Portland cement in construction are all laid forth in this paper.

2 Summary

The compressive strength test determines the mortar's ability to endure stresses, an essential quality for structural applications, while the flow test determines how easily the cement can be manipulated and put.

To make sure the findings could be reliably reproduced, the tests were carried out using standard materials under exacting environmental conditions. According to the results of these experiments, the key to getting the best material qualities out of mortar is paying close attention to its exact composition and meticulously controlling its mixing and curing conditions.

Finally, essential data on the performance of Portland cement mortars may be reliably obtained using the testing methodologies specified by the ASTM. To create concrete that can withstand the rigours of today's building projects, these measurements are crucial.

3 Theory

Defined on the manifold $\mathcal{M}$, the flow function $\Phi : \mathcal{M} \to \mathbb{R}$ quantifies the percentage increase in the base diameter of the mortar following standard spreading procedures as stipulated by ASTM C1437. Mathematically, it is expressed as:

$$\Phi(m) = \frac{D_f - D_i}{D_i} \times 100\%,$$

where D_i is the initial base diameter of the mold and D_f is the final spread diameter. This function is central to evaluating the workability and the fluid dynamics of the mortar under varying compositions and mixing techniques.

4 Methods & Procedures

4.1 Experimental Design

To assure the validity and comparability of results for evaluating hydraulic cement mortar qualities, the experimental methodologies used comply with the following standards: ASTM C305, ASTM C1437, and ASTM C109, in that order. Following a methodical procedure meant to resemble conventional laboratory methods for analysing cementitious materials, the procedures include mechanically mixing mortars and then determining their flow and compressive strength.

4.2 Materials

Standard sand that conforms to ASTM C778 and distilled water are among the components used. The recommended amounts of cement and sand for the mixture were 500 g and 1,375 g, respectively, as stated in ASTM C305. For both the flow measurements required by ASTM C1437 and the specimen preparation for compressive strength testing by ASTM C109, the water-to-cement ratio was fine-tuned to get the required plastic consistency.

4.3 Experimental Settings

Room temperature was kept between 20 and 27.5 degrees Celsius, and relative humidity was kept above 50%, in the laboratory. In order to prevent the material qualities from changing as a result of outside weather changes, certain criteria are vital. Observing both the manufacturer's guidelines and the standards set by ASTM, all machinery was regularly calibrated and serviced. In order to achieve uniform and constant mixing, the team used an epicyclic mixer that had variable speeds and a pre-set distance between the paddle and the bowl to avoid material accumulation.

4.4 Mechanical Mixing of Mortars (ASTM C305)

In order to combine the ingredients, an epicyclic mechanical mixer that could rotate and move in a planetary motion was used, which was powered by electricity. In order to achieve regulated and comprehensive component integration, this mixer has two separate speed settings. To begin, prevent clumps by slowly mixing 242 ml of water with 500 g of cement for 30 seconds. Then, while keeping the slow pace to make sure the aggregate was evenly distributed in the mix, 1375 g of sand was added slowly over the following 30 seconds. After that, the mixture was mixed at a medium speed of 285 rpm for one minute, followed by a short resting interval to let the ingredients settle and any particles stuck to the bowl to be manually reincorporated.

4.5 Determination of Flow (ASTM C1437)

An ASTM-approved flow table and mould were part of the flow test equipment, together with the necessary measurements and operating procedures. The mortar was moved to the flow mould after being mixed according to the steps outlined earlier. Two separate steps of compacting the material using a standardised tamper were used to fill the mould. The surface was levelled with a straightedge after it reached the top of the mould. Flow table activation was triggered to drop 25 times in 15 seconds immediately after preparation, and the mould was removed. Using a calibrated calliper, we measured the mortar's spread at various positions throughout its length, and we reported the flow as a percentage increase over the base diameter.

4.6 Compressive Strength Determination (ASTM C109)

It was immediately after the flow test that the mortar specimens were formed into cubic moulds for the compressive strength testing. To make sure there were no air bubbles or improper packing, the specimens were vibrated before being placed in a controlled atmosphere to cure. Following the specified curing time, the specimens were taken out of their moulds and placed in saturated lime water to provide a normal curing environment, which improved the hydration processes. Every specimen was air-dried and powder-free before testing. Pressure was applied using a calibrated hydraulic press until the specimen broke. The compressive strength was determined by taking the cross-sectional area of the cubes and recording the highest stress that each specimen could survive.

5 Analysis

$$\text{Flow measurements} = \{185, 180, 178, 182\}\ \text{mm},$$

Algorithm 1 Analysis of Hydraulic Cement Mortar Flow

Require: $\mathbf{D} = (d_1, d_2, d_3, d_4)$, a tuple representing the diameters of the mortar spread in millimeters
Require: Base Diameter $\beta = 100$ mm, the initial diameter of the mortar within the mold
Ensure: Accurate computation of the flow percentage as per ASTM C1437

function AverageDiameter($\mathbf{D}$)
    Let n be the cardinality of $\mathbf{D}$, ensuring $n = 4$ for consistent experimental conditions.
    Define $\bar{d} = \frac{1}{n}\sum_{i=1}^{n} d_i$ to compute the mean diameter.
    return $\bar{d}$ ▷ Returns the average of the measured diameters
end function
function CalculateFlow($\bar{d}, \beta$)
    Construct the flow index $F = \left(\frac{\bar{d}-\beta}{\beta}\right) \times 100$, representing the percentage increase in diameter.
    return F ▷ Returns the flow percentage based on the average diameter and base diameter
end function
function FlowAnalysis($\mathbf{D}, \beta$)
    $\bar{d} \leftarrow$ AverageDiameter($\mathbf{D}$)
    $F \leftarrow$ CalculateFlow($\bar{d}, \beta$)
    Print "Flow Percentage: F%"
end function

6 Results

```
Flow Percentage:  81.25%
```

7 Discussion of Results

The data indicate that the cement mortar has great workability, since the computed flow percentage of 81.25% is much higher than the normal objective. This quality may be useful in situations when a fluid combination has to be able to conform to complicated surfaces and moulds. On the other hand, it may mean that there's a lot of water in the mix, which would make the mortar weak and short-lived.

8 Conclusion

Because the final flow percentage of 81.25% is greater than what is normally expected for conventional mixes, this mortar may not be suitable for uses that call for reduced permeability and higher strength. To ensure the mortar satisfies both the practical usability and long-term performance criteria, it is crucial to optimise mix designs to combine workability with mechanical qualities. These findings highlight the significance of this process.

References

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9 Appendix 1

Listing 1: Code 1

```
def average_diameter(diameters):
    n = len(diameters)
    if n == 0:
        raise ValueError("The list of diameters cannot be empty.")
    average_d = sum(diameters) / n
    return average_d


def calculate_flow(average_d, base_diameter):
    flow_index = ((average_d - base_diameter) / base_diameter) * 100
    return flow_index


def flow_analysis(diameters, base_diameter=100):
    try:
        average_d = average_diameter(diameters)
        flow_percentage = calculate_flow(average_d, base_diameter)
        print(f"Flow Percentage: {flow_percentage:.2f}%")
    except Exception as e:
        print(f"Error: {str(e)}")

diameters = [185, 180, 178, 182]
flow_analysis(diameters)
```