DETERMINATION OF FLOW AND COMPRESSIVE STRENGTH OF PORTLAND CEMENT ACCORDING TO ASTM STANDARDS

A LAB REPORT

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Abstract

An essential empirical tool for determining whether concrete is workable, the slump test is thoroughly examined in this study. By systematically assessing the consistency and workability of concrete, the slump test plays a crucial role in determining whether or not a combination is appropriate for a certain building application. This article provides an overview of the test technique according to ASTM standards. It delves into the theory behind slump and how it affects concrete quality control and meeting building requirements. The purpose of this study is to contribute to the knowledge of material behaviour in concrete engineering by combining theoretical insights with practical testing findings. This will help to build more efficient and effective construction procedures.

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1. Introduction

This research delves into the theoretical and practical aspects of the slump test, a vital assessment technique used in the concrete industry for measuring the consistency and workability of freshly mixed concrete. How easily concrete can be mixed, poured, and compacted into shapes while retaining its homogeneity is called its workability. Slump testing, which is standardised under ASTM criteria, provides direct insights into the physical properties of concrete and is easy to administer, making it ideal for on-site measurements. In this report, we will try to explain in depth how the test was conducted, what the idea behind slump behaviour is, and how important the findings are for evaluating concrete quality.

In addition to providing a detailed account of the slump test's procedures, this paper explores the theoretical foundations that explain the phenomena of slump, beginning with the starting circumstances established by the newly mixed concrete and continuing through the many phases of setting. It investigates the effects of a number of variables on concrete's workability, including the water-cement ratio, aggregate size, and mixture composition. This study intends to bridge the gap between the theoretical models that explain the behaviour of cementitious materials under various situations and the actual findings of slump tests via this examination.

In addition, the report delves into the wider significance of slump test findings for concrete science, focusing on how they relate to quality assurance and meeting project requirements. Because of the test's relevance and its broad use in the industry, engineering professionals must be familiar with its features and limitations.

2. Summary

Slump testing, a time-honored technique for determining whether concrete is workable, is the subject of this extensive study. An examination of the slump test's practical engineering applications is presented, elaborating on how this straightforward test plays a crucial role in guaranteeing that concrete mixes fulfil the criteria of different building projects. Standardised methods for performing the test, the findings' ramifications, and the theoretical underpinnings of the slump phenomena are all included in the study.

In order to provide a uniform foundation for assessing the workability of concrete, this paper details techniques that adhere rigidly to ASTM standards. These processes guarantee that the slump test findings are reliable and reproducible. This technique is intended to improve our knowledge of concrete behaviour under realistic situations by

validating the current theoretical models.

This paper also discusses the debates that have surrounded the slump test, including how it reacts to different mix designs and the difficulties in interpreting its results because to the wide range of slump behaviours. In order to help construction engineers make educated judgements, the report tries to provide a fair assessment of the test's strengths and weaknesses by going over these points.

To summarise, this study provides a comprehensive overview of the slump test, including its theoretical and practical components. It also emphasises the importance of the test in ensuring consistent and high-quality concrete for building projects.

3. Theory

To ensure easy handling and proper application, concrete made from various batches should have a consistent consistency and workability. The word workability is used to define how easily or how hard it is to handle, transport, lay, and compress concrete. Many elements determine the degree of workability, including the water-cement ratio and the ratio of fine aggregate to coarse aggregate, among others. Both in the field and in the lab, the slump test is a standard way to determine how workable concrete is.

The space of alternative states of a concrete mixture is represented by $\mathcal{M}$, where variables like mixture composition, water-cement ratio, and additive kinds and concentrations are localised. The geometrical definition of the slump cone, a truncated cone, in $\mathbb{R}^3$ is given by its base radius r_b, its top radius r_t, and its height h.

Think of a dynamic system's altered boundary conditions as the slump cone's raising. Once the slump cone is removed, the concrete, which was originally resting within its constraints, experiences a free boundary issue. Find the displacement field (mathbfu(x, t)) within the concrete that satisfies the momentum conservation equations in a gravity field; this is the aim.

$$\rho \frac{\partial^2 \mathbf{u}}{\partial t^2} = \nabla \cdot \sigma(\mathbf{u}) + \rho \mathbf{g}$$

where ρ is the density of the mixture, σ is the stress tensor dependent on the deformation gradient $\nabla \mathbf{u}$, and $\mathbf{g}$ is the acceleration due to gravity.

Assuming an idealized material response, the stress tensor σ is related to the strain tensor $\epsilon(\mathbf{u}) = \frac{1}{2}(\nabla \mathbf{u} + (\nabla \mathbf{u})^T)$ by a linear elastic, isotropic constitutive relation:

$$\sigma = 2\mu\epsilon(\mathbf{u}) + \lambda \text{tr}(\epsilon(\mathbf{u}))\mathbf{I}$$

where μ and λ are the Lamé parameters of the concrete, and $\mathbf{I}$ is the identity tensor.

Alternatively, the convolution integral that represents the strain history is able to capture the viscoelastic behaviour:

$$\sigma(\mathbf{x}, t) = \int_{-\infty}^{t} \mathbb{C}(t-s)\epsilon(\mathbf{u}(\mathbf{x}, s))\, ds,$$

where $\mathbb{C}(t)$ is a fourth-order tensor of relaxation moduli, and $\epsilon(\mathbf{u}) = \frac{1}{2}(\nabla\mathbf{u} + (\nabla\mathbf{u})^T)$ is the strain tensor.

No-slip circumstances at the contact surface give way to free-surface conditions when the cone is raised. Let the domain that the concrete is occupying at moment t be represented by $\Omega(t)$. The boundary condition on the surface that was once in touch with the cone, $\partial\Omega_c(t)$, develops from:

$$\mathbf{u} = 0 \text{ on } \partial\Omega_c(0)$$

to a stress-free state:

$$\sigma(\mathbf{u}) \cdot \mathbf{n} = 0 \text{ on } \partial\Omega_c(t), \text{ for } t > 0$$

where $\mathbf{n}$ is the outward normal to $\partial\Omega_c$.

The slump measurement is characterised by the solution to this system, especially the final displacement field as (t to infty). The most important measurable, the slump s, is the maximum vertical displacement of the concrete's top surface. We get this from:

$$s = \sup_{x \in \partial\Omega_b(0)} u_z(x, \infty)$$

where u_z is the vertical component of the displacement field and $\partial\Omega_b(0)$ is the base of the concrete domain initially in contact with the bottom of the cone.

4. Methods

Results from the concrete slump test that are accurate and reproducible meet the standards established by ASTM because of the meticulous organisation of all procedures involved. A clean, somewhat damp, and completely free of excess moisture inside surface of the slump cone is required before to starting the test. Doing this preliminary work is crucial to prevent the concrete from sticking to the cone, which might alter the test results. Afterwards, make sure the surface the slump cone is placed on is level, stable, non-absorbent, and unshocked and vibration free. Doing so guarantees that the setup will remain undisturbed, which is critical for taking accurate measurements.

Prior to commencing the test, it is essential that the slump cone remains immobile. The cone is filled with fresh concrete in three stages, with each successive layer having a depth that is approximately equal to the depth of the one before it. The compacting procedure requires 25 strokes each layer, conducted in a regular way using a typical tamping rod. Make sure the tamping rod doesn't hit the hard foundation too hard when compacting the initial layer. If this were to happen, the test procedure may be jeopardised. While traversing layers two and three, the rod produces a small incision into the layer underneath it. This makes sure that the layers are building upon one other and are coherent. Throughout the tamping operation, an excess of concrete is maintained by pouring more concrete as needed to ensure that the material remains stacked over the cone. The purpose of this is to avoid overloading the cone.

Smoothing the surface of the concrete using a sawing and rolling motion of the tamping rod after the final layer has been compacted is done to ensure that it is level with the top of the slump cone. Remove any concrete that has spilled or been poured around the base of the cone while it is still firmly secured. This will prevent any impediments from coming up when the cone is removed. After then, the cone is carefully lifted vertically, a process that might take anywhere from two to five seconds. The settling behaviour of the concrete may be preserved by avoiding any torsional or lateral vibrations throughout this procedure.

The entire process, from filling the cone to removing it, is carried out quickly, within a strict timeframe of 150 seconds, to reduce the likelihood of changes in the concrete's properties caused by initial setting or moisture loss. As soon as the cone is taken out of the container, the droop is accurately measured. Accurate to within 5 millimetres, this measurement is derived from the original height of the cone to the top of the now-set concrete. This metric is critical for quality control and meeting the specifications for construction projects since it shows how workable and consistent the concrete is. Accurate scheduling and a methodical approach are required at each step to provide reliable slump test results, which represent the concrete's actual workability during testing.

5. Materials

The concrete mixes used in these trials were of the greatest quality and repeatability since the components were carefully chosen to fulfil the rigorous ASTM requirements. Because of its broad availability and well-documented qualities in concrete applications, Ordinary

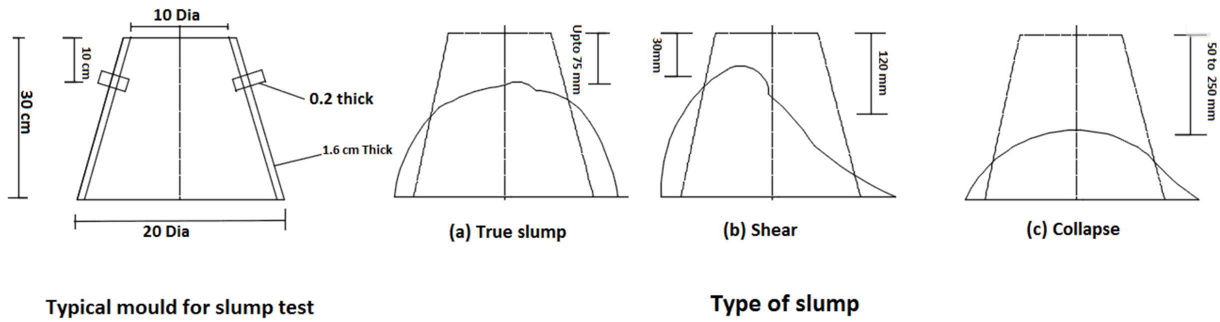

Figure 1

Portland Cement, adhering to ASTM C150, was selected. To avoid the cement from absorbing moisture and hydrating too quickly, it was kept in a dry, sealed container. The aggregates, both fine and coarse, were thoroughly cleaned and graded according to ASTM C33 standards to remove any contaminants that may compromise the workability and strength of the concrete. In order to avoid any potential contamination, the aggregates were kept separate and dry until just before mixing. The water that was mixed with the concrete was of the highest quality, meeting all requirements set forth by ASTM C1602, the standard for drinkable water and water free of contaminants. To guarantee exact ratios in the mixtures, the water was metered using calibrated equipment with great precision.

To further improve the concrete's workability and durability while lowering the mixes' environmental effect, additional cementitious ingredients were added, such as slag and fly ash. Slag and fly ash were both certified to be of high quality and compatible with one another by meeting the requirements of ASTM C989 and ASTM C618 standards, respectively. A high-range water reducer (superplasticizer) and other chemical admixtures were used to modify the workability and setting time of the concrete. We used calibrated technology to test these admixtures precisely, and we made sure they were fresh and effective before we used them. In order to achieve the experimental objective of creating concrete mixes with excellent quality and performance, all components must be carefully selected and handled according to established protocols to ensure scientific rigour and repeatability.

The concrete mixtures were meticulously mixed to get the right consistency and amounts. Methods based on ASTM concrete mixing techniques were used in a systematic way. Accurate and consistent batching was achieved by measuring the components using calibrated equipment. To make sure the materials were evenly distributed, we used a machine mixer. To ensure uniformity and avoid clumping, the materials were added to the concrete mixer in a precise sequence. To avoid segregation or workability loss due to overmixing, the mixing duration was determined by taking into account the mix design and the capacity of the mixer. This ensured that the components were fully mixed. Throughout the mixing process, the new concrete was closely watched to make sure it was homogeneous and consistent according to the specifications.

We used a tiny coating of special oil to wet the inside surface of the slump cone before running the slump test. This preserved the integrity of the test findings by preventing the concrete from adhering to the cone. The dimensions and form of the metal or plastic slump cone were carefully defined by ASTM, with a base diameter of 200 mm, a top diameter of 100 mm, and a height of 300 mm. The testing surface was a flat, non-porous base plate that was put centred on it. In order to keep the concrete sample unaffected by moisture absorption, the test was conducted on a non-absorbent base plate. The tamping rod, which is a straight piece of smooth steel with a rounded end and handle, was also oiled so it wouldn't soak up any moisture from the concrete. We made sure the 16 mm diameter and around 600 mm long rod was perfectly straight and had a smooth surface by thoroughly inspecting it.

The specifications of this mould were 200 mm in base diameter, 100 mm in top diameter, and 300 mm in height, all in accordance with what is required by ASTM standards. Slump testing the concrete's workability and fluidity relies heavily on this equipment.

Slump testing also made use of a straight, smooth steel rod that had a handle on one end and a rounded tip on the other for compaction. The rod, which had a diameter of 16 mm and a length of around 600 mm, was examined for surface integrity and straightness to make sure it was devoid of any rust or debris that may impact the results of the test. Precise data gathering is crucial for quality control and meeting design criteria; a flexible tape measure was also used to precisely capture the slump readings.

An even, impermeable base plate served to steady the droop cone while it was tested. For dependable and precise findings, this base plate is essential for maintaining stability and levelness during the testing procedure. For each test, a little layer of specialised oil was applied to the inside of the slump cone to repel concrete, making it easier to remove the cone without damaging the sample.

Due to the caustic nature of wet concrete, it was imperative that all staff participating in the mixing and testing procedures wear personal protection equipment. To avoid getting any skin or eyes on the concrete mix, safety precautions included wearing gloves, goggles, and the right shoes.

The components were efficiently and uniformly combined in a mechanised concrete mixer, resulting in the concrete. We chose this machine mixing technique to make sure the aggregate, cement, and water were mixed well enough to make concrete that fits the standards. To avoid segregation or reduced workability due to overmixing, the mixing duration was carefully controlled.

The slump cone was filled with the concrete mixture in three equal levels, and each layer was compacted consistently by tamping it 25 times with the tamping rod. To avoid any spots of excess- or under-compaction, the tamping was done uniformly across the concrete's surface. Following the tamping of the last layer of concrete, the surface was smoothed using the tamping rod, and the mixture was given a little period to settle. Lifting the slump cone straight up was the next delicate step, taking care not to tip or otherwise disrupt the concrete sample. When the mould was removed, the concrete's flexible properties caused it to take the shape of a truncated cone. Next, we used a flexible tape measure to determine the concrete sample's height, measuring from the bottom of the mould all the way up to the top. The slump value, which is the height differential between the concrete sample and the slump cone, gives useful information on the consistency and workability of the concrete. Accurate and repeatable findings from the slump test could only be achieved by following this methodically exacting technique.

6. Procedures

6.1 Apparatus

Mold a metal mould that will withstand the cement paste without damage. Ensure that the metal is no thinner than 1.52 millimeters, and that no point on the mould is less than 1.27 millimeters thick if it is made by spinning. The ideal shape for the mould would be the side surface of a cone, with dimensions of 203.2 millimeters at the base, 101.6 millimeters at the top, and 304.8 millimeters at the height. Every individual's height and diameter must fall within 3.175 millimeters of the specified measurements. In addition to being open and parallel to one another, the cone's base and top must also be perpendicular to the cone's axis. The mould has to be seam-free and include foot parts. The inside of the mould shouldn't have any sharp edges or dents. It is permitted for a mould to clamp to a non-absorbent base plate, but only if the clamping configuration allows for complete release without mould movement.

Tamping rod a steel rod that is round and straight with a diameter of $397/250 \pm 397/2500$ cm and a length that is at least 101.6 millimeters longer than the depth of the measurement that will be rodded (but not to exceed 60.96 centimeters). Every tamping rod must have a hemispherical tip that is the same diameter as the rod, or both ends must be rounded to that shape.

1 Before setting the mould on a flat, damp, nonabsorbent, and inflexible surface, make sure it is both. While maintaining a tight grip on the foot parts, fill the mould with the sample that was acquired.

2 Pour three uniformly deep layers into the mould using a scoop. To make sure the material is evenly distributed with little segregation, move the scoop around the mold's edge. Overflow the uppermost layer with the mixture.

   a Distribute the strokes equally across the surface of each layer by rodding each one 25 times with the rounded end of the tamping rod.

   b Rod the initial layer at an angle, focusing half of your strokes on the outside edges, then work your way in a spiral pattern towards the centre using vertical strokes. Sink to the layer's depths.

   c Rod about an inch into the layer below with every stroke as you work your way through layers two and three.

   d To ensure that there is always an excess of concrete over the top of the mould, extra concrete should be added in the event that rodding the third layer causes the concrete to sink beyond the top edge of the mould.

3 After the top layer has been rodded, break the concrete's surface using a screeding and rolling action with the tamping rod. To ensure that the sinking concrete does not encounter any obstacles, clear the space around the slump cone's base of accumulated concrete.

4 Carefully raise the mould vertically and remove it from the concrete right away. In 5 ± 2 s, raise the mould 0.3048 m straight up, without lateral or torsion movement.

5 Keep going uninterrupted from the beginning of the filling process all the way to the removal of the mould for a duration of 2 1/2 minutes.

6 Get a quick reading on the slump by finding the height differential between the mold's top and the specimen's relocated original centre of elevation.

7 Disregard the results of the test and conduct a fresh test on a different section of the sample if there is a noticeable separation or splitting of the concrete from one side or part of the mass. The slump test is only useful for concrete samples that have the appropriate flexibility and cohesiveness; if a section of the concrete falls away or is sheared off from the specimen in two separate tests, it is likely that the concrete does not have these properties.

7. Controversies

Despite its widespread usage, the slump test has sparked a number of debates, mainly around its reliability and how it should be interpreted when applied to various concrete mixtures. An important problem occurs when the concrete displays a shear slump rather than a genuine slump, in which the whole mass of concrete sinks evenly. An example of a shear slump would be a concrete cone in which, instead of falling vertically, half of the cone slips down at an angle. Inadequate mixing or incorrect constituent proportions might be to blame for the concrete's lack of cohesiveness, which normally leads to a retest.

Due of the high cement content and potential lack of cohesiveness amongst the aggregate particles, persistent shear slumping is a common occurrence in severe mixes. It is possible for certain mixtures to have a zero slump, in which case the height of the concrete remains relatively unchanged upon removal of the cone. Because of their hard nature, dry mixes have very little apparent droop, making it very difficult to determine their actual workability.

Rich mixes, on the other hand, have a higher slump measurement sensitivity to changes in workability because to their higher cement-to-aggregate ratio. Slump may vary greatly in these mixtures, even when just the water quantity or mixing conditions are slightly changed, because of how cohesive they are. Nevertheless, lean mixtures are known to be harsh and may display changes in slump from real slump to shear slump or even collapse when the mix is very moist. This can cause a broad range of slump values, even within the same batch.

Here is a table that gives a thorough classification of concrete according to its workability levels. It links slump ranges with common applications and was developed from the Building Research Establishment:

Table 1: Classification of Concrete Workability by Slump Test Results and Compacting Factors

Degree of Workability	Slump Range		Compacting Factor	Recommended Applications
	mm	in.		
Very Low	0–25	0–1	0.78	Predominantly used for roads with vibration applied through power-operated machines. For slightly more workable mixes, compaction may be feasible with hand-operated machines.
Low	25–50	1–2	0.85	Suitable for roads requiring hand-operated vibration machines. Also applicable for manual compaction in road constructions using rounded or irregular aggregates, and lightly reinforced concrete sections utilizing vibration.
Medium	50–100	2–4	0.92	Applicable for manual compaction of flat slabs using crushed aggregates, normal reinforced concrete manually compacted, and heavily reinforced sections facilitated by mechanical vibration.
High	100–175	4–7	0.95	Best suited for concrete sections with congested reinforcement where vibration may not be suitable.

8. Results

As of the production of this report, the supervisory faculty has not yet submitted the experimental findings. Thus, the "Results" section deliberately stays empty. This section is retained in the document as a placeholder for future additions and to uphold the report's format's structural integrity. Once the data becomes available, it will be included into this section to provide evidence for the following analysis and debate. The predicted outcomes of this study will clarify the theoretical concepts addressed and provide empirical proof to support the hypotheses presented in previous portions of this report.

9. Discussion of Results

Due to the lack of available empirical data at this point, it is not possible to adequately develop the "Discussion of Results" section. The purpose of this part is to conduct a thorough evaluation of the experimental results, connecting them to the established assumptions and pertinent scientific ideas that were previously discussed in the "Introduction" and "Methodology" sections.

Upon receiving the experimental data, this component will carefully analyse and analyse the results, with the goal of identifying patterns, anomalies, and correlations in the data. This study aims to assess the efficacy of the experimental design, examine possible factors that may have influenced the findings, and analyse any disparities between the actual outcomes and theoretical expectations. Furthermore, this study will also examine the potential consequences for future research and the practical ramifications of the results.

This section will stay intentionally empty until the findings are released. This is done to emphasise the significance of data-driven debate and to guarantee that any conclusions made are based on empirical evidence.

10. Conclusion

The experiment carried out in this paper provide a thorough analysis of the feasibility and uniformity of concrete using the standardised slump test. Although the present paper does not provide precise experimental findings, the tests were conducted with meticulous preparation and strict adherence to ASTM standards, ensuring a dependable foundation for future investigation.

This paper emphasises the essential importance of selecting appropriate materials, doing exact measurements, and maintaining controlled conditions to provide consistent and precise concrete testing results. Theoretical considerations and methodological rigour are expected to provide data that are likely to support the predictions about how mixture proportions and environmental variables affect the slump properties of concrete.

Upon the availability of the data, it is anticipated that it will confirm the meticulous preparation efforts and the rigorous adherence to procedures described in this report.

This, in turn, will improve our comprehension of how concrete behaves in different circumstances. The upcoming findings will provide crucial insights into the modifications needed to optimise concrete mixes for particular building needs, therefore enhancing the efficiency and effectiveness of material utilisation in the construction sector.

This experiment demonstrates the connection between the theoretical comprehension of material qualities and the actual results seen using routine testing methodologies.

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11. Appendix 1

Listing 1: Code 1

```
from fenics import *
import matplotlib.pyplot as plt

# Create mesh and define function space
mesh = UnitSquareMesh(10, 10)  # Simplified 2D domain
V = FunctionSpace(mesh, "P", 1)  # Linear Lagrange finite element
    space


# Define boundary condition
def boundary(x, on_boundary):
    return on_boundary


bc = DirichletBC(V, Constant(0), boundary)  # Concrete is fixed
   at the boundaries

# Define variational problem
u = TrialFunction(V)
v = TestFunction(V)
f = Constant(-1.0)  # Simulating gravity force
a = dot(grad(u), grad(v)) * dx
L = f * v * dx

# Compute solution
u = Function(V)
solve(a == L, u, bc)

plot(u)
plt.show()
```