# DEVELOPMENT AND CALIBRATION OF A LAB SIZE SLUMP CONE

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**ABSTRACT:** The use of the standard slump cone for the design and quality control of slurry-wall backfill construction is widely employed. This technique, directly from concrete specifications, is suited to a rapid field test during construction, but not so rapid in the lab during design. Laboratory samples of backfill are typically of less volume than one slump cone. A smaller version of the standard, concrete slump cone test is shown to correlate favorably with actual standard slump cone data, and a correlation curve is derived empirically over a range of slump from four to nine inches. The standard slump (in inches) has been found to be two times the lab slump, plus two inches.

## INTRODUCTION

Soil-bentonite backfill is often tested in both the field and the laboratory to ensure the soil-slurry mix will meet the specifications for hydraulic conductivity as well as compatibility. Field conditions typically require a random sampling of the prepared backfill be tested to ensure specifications are met within a desired level of confidence. Because actual projects demand large quantities of backfill, there is plenty of material to test. But the situation is opposite in the laboratory, as a small amount is needed to fulfill the volumetric requirements of any given procedure. Comparatively, a typical CIU test sample, 2½ inches in diameter and 5 inches long has a volume of 24.5 $cm^3$, whereas a slump cone test requires over 1400 $cm^3$ of material.

Previous studies have examined the feasibility of various designs of smaller, lab-sized slump cones[1], and it is the intent of this paper to definitively answer the question: Does a lab size slump cone produce consistent results that can be correlated with an acceptable degree of accuracy? If so, then laboratory study may employ the slump cone test without the burden of producing mass quantities of otherwise unneeded material. Another possible benefit is the added efficiency for field-testing, which could result in better construction.

## APPARATUS

The apparatus are listed below and shown in Figure 1. The lab size slump cone was manufactured in the Project Development Laboratory at Bucknell University. The standard slump cone is available through any supplier of civil engineering equipment.

*Standard Slump Cone* – The standard slump cone used in this experiment meets the specifications listed in section 5, part 1 of the Standard Test Method for Slump of Hydraulic Cement Concrete.

*Tamping Rod* – The tamping rod used in this experiment meets the specifications listed in section 5, part 2 of the Standard Test Method for Slump of Hydraulic Cement Concrete.

*Lab-Size Slump Cone* – This mold is made of #18 gage galvanized steel. Dimensions: 3 inch top diameter; 4 inch bottom diameter; 6 inch vertical height. The steel is shaped and welded together, and the seam meets the specification listed for Standard Slump Cones in section 5, part 1 of the Standard Test Method for Slump of Hydraulic Cement Concrete.

*Lab-Size Tamping Rod* – The tamping rod used in this experiment for the lab-size slump cone is a Pilot V-Ball ballpoint pen. Its overall length is 5.3 inches, with average diameter of 0.35 inches.

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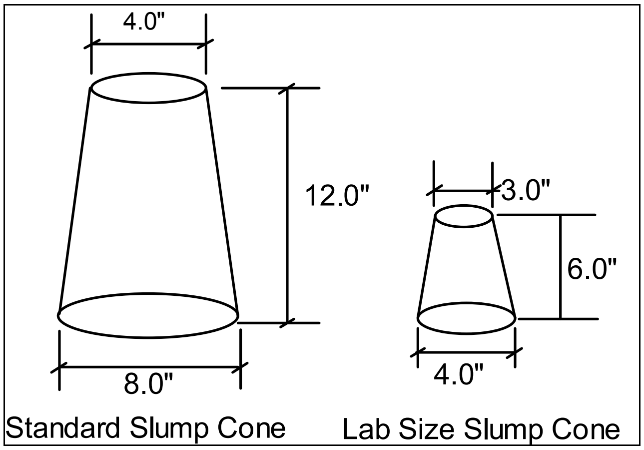


*Figure 1: Dimensions of the Slump Cones*

## PROCEDURE BY ASTM

The procedure as listed in section 7 of Standard Test Method for Slump of Hydraulic Cement Concrete (ASTM C143 – 90a)[2] was generally followed for the data generated by both the standard and the lab-size slump cone. The cones, or molds, were dampened and placed on a flat, moist, nonabsorbent surface, and held firmly during filling. The molds were filled in layers and tamped with 25 strokes of their respective tamping rods. The top-most layer was heaped above the mold, and the excess was stricken off with a spatula. The slump was immediately measured as the vertical difference between the height of the mold and the displaced original center of the top surface of the specimen.

However, the following exceptions or clarifications should be made. First, both the standard and lab cones were dampened with PAM®, a common cooking lubricant typically available in a grocery store. The lab-size slump cone was filled in two lifts, as opposed to three for the standard slump cone, and a smaller tamping rod was employed. It is felt the use of common materials improved the efficiency and availability of the test.

## SAMPLE

The sample tested is a soil-bentonite backfill composed of mortar sand and 2% (by dry weight) bentonite mixed with slurry, which was 5% bentonite (by dry weight) and 95% water. The slurry tested has an average API Filter Press[3] volume of 16.0 ml after 30 minutes at 100 psi, an average API Mud Balance[4] density of 1.03 g/cc, and an average Marsh Viscosity[4] of 48.0 seconds.

## RESULTS AND ANALYSIS

Results are presented below in both tabular and graphical format. The analysis follows the results. The tabular data shows as the slump in the standard mold increases, an increase in the lab size slumps was evident. But it is difficult to determine just how precise the relationship is, if one exists, between the two molds. However, that relationship is evident in Figure 2.

**Table 1 – Summary of Test Data**

| *Slump (inches)* | *Lab Size* Cone | *Standard Cone* |
|---|---|---|
| Trial 1 | 1.1 | 4.2 |
| | 1.4 | 4.4 |
| | 1.5 | 4.4 |
| | 1.6 | 5.0 |
| | 1.6 | 5.2 |
| Average | 1.4 | 4.6 |
| Trial 2 | 1.8 | 5.6 |
| | 1.9 | 5.8 |
| | 2.0 | 5.4 |
| | 2.0 | 6.2 |
| | 2.1 | 6.0 |
| Average | 2.0 | 5.8 |
| Trial 3 | 2.3 | 6.8 |
| | 2.4 | 6.8 |
| | 2.5 | 7.6 |
| | 2.6 | 7.4 |
| | 2.7 | 7.0 |
| Average | 2.5 | 7.1 |
| Trial 4 | 2.9 | 8.1 |
| | 3.2 | 8.0 |
| | 3.4 | 7.8 |
| | 3.5 | 8.3 |
| Average | 3.3 | 8.1 |

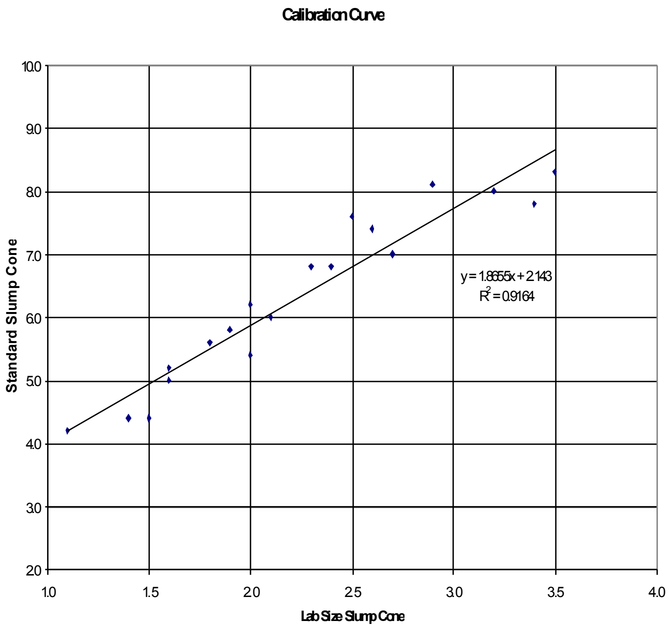


*Figure 2: Calibration Curve for Standard and Lab Size Slump Cones*

The calibration curve derived from a linear fit of the data results in an $R^2$ value of 0.92 – a good fit, statistically. If more data were to be acquired a better fit could be determined, but because the range is typically limited from 4 to 9 inches of standard slump (by convention), this fit should be accurate for laboratory and field studies within that range.

An empirical equation is calculated and reported to be y = 1.8655x + 2.143. Without significantly compromising the accuracy, yet drastically enhancing the usefulness and expediency of the linear correlation, that equation can be rounded to:

$$y = 2x + 2$$

Where ***y*** is the standard slump, in inches, and ***x*** is the lab size slump, also in inches. Furthermore, an analysis of the average values in Figure 2 below produces an equation of y = 1.9082x + 2.0374. These values are even closer to y = 2x + 2, and the $R^2$ value is higher at 0.98, indicating a greater degree of accuracy, as shown in Figure 3.

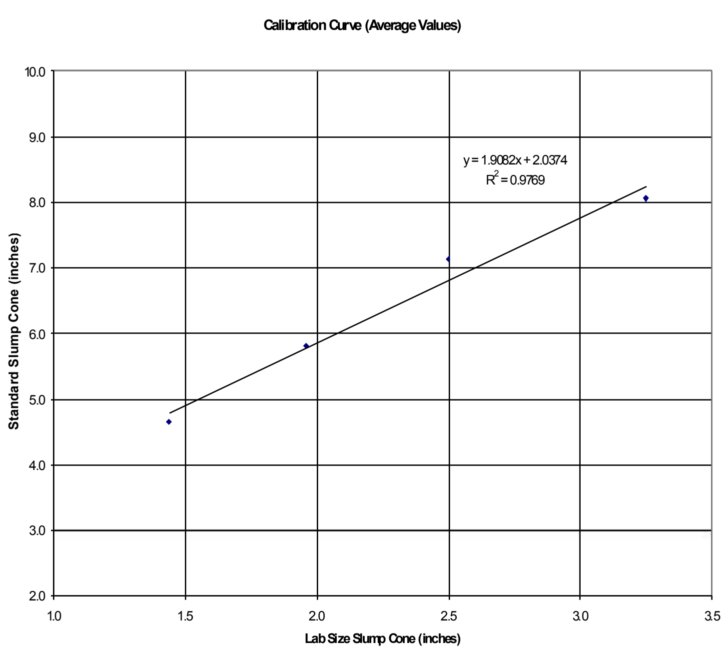


*Figure 3: Average Values Calibration Curve for Standard and Lab Size Slump Cones*

The variability of the data within each trial resulted from any slight variance in technique, such as pulling the molds away at an imperceptible angle, or less effective tamping between lifts. It should be noted that the data was generated continuously, that is the subsequent trials were conducted after the first, and each subsequent trial included more slurry than the previous trial. A general trend toward a larger slump in the later data points of each trial was observed; however the reasons for this could be random or a gradual mixing of the backfill to a more homogenous medium. Yet despite these variances the data still correlates favorably with a linear trend line over the given range.

## CONCLUSIONS & RECOMMENDATIONS

The lab size slump cone produces values of slump that can be accurately correlated to those found with a standard slump cone. An empirical equation, rounded to whole-number coefficients, will prove to be useful and expedient. Variables that can adversely affect the outcome are the type of backfill and the constituents of the backfill. Identification and isolation of each of these variables should be conducted for each laboratory experimenter and field engineer, as well as for each backfill to be studied.

It is recommended that more data, of similar and dissimilar materials, perhaps even concrete with rather fine aggregate, be gathered and compared against the empirical relationship. It would be useful to have a calibration curve and equation for any given backfill in a chart format so one could reference it when conducting slump cone tests.

[1] Connors, Scott R. "Relationship Between A Standard Slump Cone And A Lab Size Slump Cone," Bucknell University, no publication date given.

[2] *Annual Book of ASTM Standards,* Volume 4.02. "Standard Test for Slump of Hydraulic Cement Concrete," Designation C143 – 90a. Approved July 9, 1990.

[3] American Petroleum Institute. *Standard Procedure for Field Testing Drilling Fluids, API Recommended Practice,"* API RP 138, 10th ed., Dallas, Texas, June 1, 1984.