LIQUID LIMIT: CONE PENETROMETER METHOD

1 SCOPE
This method describes the procedures for the determination of the Cone Liquid Limit of soils and granular materials.

2 SAFETY
This method does not attempt to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this method to establish appropriate occupational health and safety practices that meet statutory regulations.

3 REFERENCED METHODS
Main Roads Western Australia
WA 105.1 Preparation of Disturbed Soil and Granular Pavement Material Samples for Testing
WA 110.1 Soil and Granular Pavement Material Moisture Content: Convection Oven Method

4 DEFINITIONS
The Liquid Limit is the moisture content at which the soil passes from the plastic to the liquid state as determined by the Cone Liquid Limit test.

5 APPARATUS
(a) Penetrometer, any suitable penetrometer which permits the cone assembly to move vertically in its guide without appreciable friction and which is capable of indicating the depth of penetration to the nearest 0.1 mm. The sides of the guide shall be vertical.

(b) Penetration Cone Assembly, a stainless steel cone with a cone angle 30 ± 1°. The conical surfaces shall be a smooth, unblemished polished surface and shall be replaced when the point can no longer be felt when brushed lightly with a finger tip when the tip of the cone is pushed through a hole, 1.5 ± 0.1 mm diameter bored through a metal plate 1.75 ± 0.05 mm thick. The total moving mass (of the cone assembly) shall be 80.00 ± 0.1 g. Suitable designs are shown in Figures 1 and 2.

(c) A rigid cup of near constant internal diameter of approximately 53mm and internal height of approximately 40mm with a smooth rim parallel to a flat base.

(d) Timing device capable of measuring 5 ± 1 second.

(e) Mixing bowl of convenient size or a thick, flat, rigid mixing plate of suitable size made of non absorbent material.

(f) Wash bottle or beaker containing distilled or de-ionised water.

(g) Humidifier, air tight and containing free water or suitable air tight container with close fitting lid.

(h) Spatula.

6 PROCEDURE
(a) Obtain a test portion that has been prepared in accordance with Test Method WA 105.1 (Consistency Limits).

(b) Place the sample in the mixing bowl or on the mixing plate and add distilled or de-ionised water in increments, mixing thoroughly with the spatula for not less than 5 minutes after each increment of water

NOTE: Soils of medium to high plasticity will require mixing times of more than 5 minutes to obtain uniform distribution of moisture throughout the test portion.

(c) Continue adding distilled or de-ionised water and mixing until the soil becomes a thick homogeneous paste. Cure for at least 12hr, at room temperature in a humidifier or suitable air tight container with close fitting lid.

NOTE: Soils of medium to high plasticity will require mixing times of more than 5 minutes to obtain uniform distribution of moisture throughout the test portion.

(i) Certain clayey soils may be required to stand for twenty-four hours or longer to allow thorough permeation of the water through the soil. If tested without appropriate curing, inconclusive results may occur, particularly with certain types of clayey soils.

(ii) The consistency of the test portion should be such that when tested, a penetration of approximately 15 mm is obtained.

(d) Raise the cone assembly to the highest position possible and level the penetrometer. Raise the penetration head as required.
(e) Remove the test portion from the humidifier or air tight container and thoroughly mix for at least 1 minute.

(f) Fill the penetration container by placing a quantity of the cured test portion in the bottom of the container and exert adequate pressure on the spatula to displace the cured soil in an outward direction so as to remove air bubbles from the cured soil. Completely fill the container in this manner and then level off the surface of the cured soil with the spatula with the blade held almost flat. No more than 3 strokes of the spatula shall be used when levelling the surface.

NOTE: This procedure is best facilitated by placing the penetration container at a slight angle on the workbench and then drawing the spatula blade in a downward and outward movement against the inside lip of the container.

(g) Position the penetration container filled with the cured soil, centrally under the point of the penetration cone.

(h) Lower the penetrometer head until the point of the cone just makes contact with the surface of the cured soil.

(i) Depress the indicator rod of the dial gauge until it lightly touches the top of the shaft. Record the dial gauge reading to the nearest 0.1 mm.

(j) Release the penetrometer shaft and allow the cone to penetrate the cured soil for a period of 5 ± 1 seconds and then restrain the penetrometer shaft.

(k) Depress the indicator rod of the dial gauge as in Procedure 6(i). Record the dial gauge reading to the nearest 0.1 mm.

(l) Calculate the difference between the two dial gauge readings and record as the penetration value.

(m) Raise the penetrometer head to remove the cone from the cured soil.

(n) Clean the cone thoroughly.

(o) Return the soil in the penetration container to the mixing bowl and remix for about 30 seconds. Repeat procedures 6(f) to 6(n) and determine a second penetration value.

(p) Determination of average penetration values.

(q) If the difference between the first and second penetration values is not greater than 1.0 mm, determine the average of the two values and record. Remove a test increment of not less than 10 g, with a spatula, from near the area penetrated by the cone and determine the moisture content in accordance with Test Method WA 110.1

(r) If the range of the two penetration values exceeds 1.0 mm the cured soil in the penetration container shall be returned to the mixing bowl and thoroughly remixed with the test portion. Repeat Procedures 6(f) to 6(r). If a valid penetration still cannot be obtained the test portion shall be returned to the humidifier or air tight container for further curing and Procedures 6(f) to 6(r) repeated. If on repetition of Procedures 6(f) to 6(r) a valid penetration is still not obtained the test shall be abandoned and reported as not obtainable.

NOTES:

i. The quantity of 10 g which is taken as the moisture content test increment is less than that recommended in Test Method WA 110.1. However, because of the uniformity of the soil which constitutes the test increment, it is considered to be a satisfactory quantity.

ii. In soils of low plasticity, it is possible that moisture movements in the vicinity of the cone during penetration by the cone will mean the moisture content of the material around the penetration hole is not representative. For these soils, sampling the moisture content determination has to be from the mixing bowl. For soils of medium to high plasticity, the sample for moisture content determination may be taken from the soil around the penetration hole in the cup.

(s) Return the remaining cured soil in the penetration container to the test portion and thoroughly remix. Clean and dry the penetration container thoroughly.

(t) Repeat Procedures 6(f) to 6(r) at least three times using the same test portion to which further increments of water have been added followed by thorough mixing for about 3 minutes after each addition of water. Control the addition of water to achieve at least four penetration values evenly distributed between about 15 mm and 25 mm.

NOTE: Always proceed from the drier to the wetter condition. If at any time during the course of the test procedure the depth of penetration decreases with the addition of water, all previous moisture content test increments should be rejected and fresh attempts made to stabilise the penetration versus moisture content relationship commencing with Procedure 6(f).

7 CALCULATIONS

(a) Plot the moisture contents against their corresponding penetration values on a linear graph with the percent moisture content on the horizontal axis and the penetration value on the vertical axis. Draw a straight line of best fit through the plotted points.

(b) Determine the moisture content corresponding to the intersection of the line of best fit and the 20 mm penetration ordinate. This moisture content is then Cone Liquid Limit of the soil.
NOTE: Alternatively, the equation to the line of best fit for the cone penetration versus moisture content may be calculated and thus the moisture content corresponding to 20 mm can be determined.

8 REPORTING

(a) Report the percentage Cone Liquid Limit to the nearest 0.1%. If a result could not be obtained, report the result as “not obtainable”.

(b) Reference to this Test Method

9 FIGURES AND DRAWINGS

![Figure 1](image_url)
FIGURE 2
10 ISSUING AUTHORITY

Document Owner
Pavements Manager

11 REVISION STATUS RECORD

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<td>Procedure 6 (t)</td>
<td>Amended to clarify the requirement to achieve at least 4 uniformly distributed points between 15 mm and 25mm</td>
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