**DEPARTMENT OF TRANSPORTATION**
**ENGINEERING SERVICE CENTER**
**Transportation Laboratory**
**5900 Folsom Boulevard**
**Sacramento, California 95819-4612**

# METHOD OF TEST FOR EVALUATING THE EXPANSIVE POTENTIAL OF SOILS UNDERLYING PORTLAND CEMENT CONCRETE PAVEMENTS (THIRD CYCLE EXPANSION PRESSURE TEST)

**CAUTION:** Prior to handling test materials, performing equipment setups, and/or conducting this method, testers are required to read "**SAFETY AND HEALTH**" in Part 3, Section B of this method. It is the responsibility of whoever uses this method to consult and use appropriate safety and health practices and determine the applicability of regulatory limitations before any testing is performed. Users of this method do so at their own risk.

## A. SCOPE

This method covers the procedure for performing the third cycle expansion pressure test upon soils which are intended to be incorporated in portland cement concrete (PCC) pavement structural sections. The method also includes the calculation of cover requirements along with the application of construction controls to safeguard PCC pavements against slab distortion (curling) caused by expansive subsoil. This test method is divided into the following parts:

I. Modifications to Standard R-Value Test as a Preliminary to Third Cycle Expansion Pressure Test

II. Method of Test for Determining Third Cycle Expansion Pressures

III. Method of Analysis for Design and Application to Construction Control

## PART 1. MODIFICATIONS TO STANDARD R-VALUE TEST AS A PRELIMINARY TO THIRD CYCLE EXPANSION PRESSURE TEST

The first test, which must be undertaken on soil samples submitted for expansive potential analysis, is the standard R-value test, California Test 301.

The R-value test is performed in the normal manner, except that additional specimens are prepared at moisture contents which will span the R-value range of 10 to 30 and will also show where the mechanical compactor foot pressure has to be reduced below 140 kPa. Some experience on the part of the operator is required to determine the range of moisture at the time of fabricating specimens. The following guides will assist the operator:

1. Fabricate at least two specimens at moisture contents low enough to provide firm specimens which will permit the use of full mechanical compactor foot pressure (2410 kPa) during the application of the 100 tamps as described in Part 2, Section B-3, A-N of California Test 301. The moisture contents at compaction, of these specimens, should be arranged to span over a range of at least 3% moisture.

   It is also desirable that the moisture content of the wettest specimen in this group should be as near as possible to the point where the compactor foot pressure must be reduced because of excessive penetration of the foot (see Part 2, Section B-3, K, I of California Test 301). Since the compactor air pressure, used to control the California type mechanical compactor, is directly proportional to the applied foot pressure, it is convenient to use air pressure values as expressions of foot pressure. Normally, the compactor is calibrated on a load cell to provide the full 2410 kPa foot pressure at about 140 kPa air pressure. Therefore, record 140 kPa air pressure on the work card, Form TL-361, where the full 2410 kPa foot pressure is used. Record necessary reductions in air pressure as proportionally decreased foot pressures are used.

2. Fabricate additional test specimens at moisture contents high enough to reduce expansion pressures to a negligible amount and also cover the range of moistures suitable for determining an R-value at equilibrium for the soil sample. Among this group of specimens, there must be at least three specimens which, due to softness at the elevated moistures, require the reduction of foot pressure (recorded as compactor air pressure) to prevent the penetration of the compactor foot in excess of 6 mm in accordance with Part 2, Section B-3, K, I of California Test 301.

3. Exudation pressures are determined in the normal manner when specimens range between 700 (or less) and 5500 kPa exudation pressure. However, the specimens drier than the 5500 kPa exudation pressure level should be given only an 5500 kPa static load for leveling purposes. After compaction, subject all of the specimens to the normal expansion pressure and stabilometer phases of the R-value test (California Test 301).

   The standard R-value test series serves two purposes. First, it provides the equilibrium R-value of the material for stability determinations of the soil for the primary structural section design. Secondly, the individual R-value test specimens and the compactor air pressures are needed in the third cycle expansion pressure analysis for PCC curl potential (see Part 3). The requirements stipulated in items 1 and 2 above, regarding the compactor air pressures, are also essential for establishing the proper moisture range for fabricating both R-value and subsequent third cycle expansion pressure test specimens.

   Record the R-value test data on the work card Form TL-361, as shown in the example, Figure 1.

## PART 2. METHOD OF TEST FOR DETERMINING THIRD CYCLE EXPANSION PRESSURES

### A. APPARATUS

The equipment and tools required for this procedure are the same as those described in Parts B and C, inclusive, of California Test 301.

### B. TEST RECORD FORM

Keep all pertinent data regarding the test specimens on individual test tickets (Form T-328W). Assign a ticket at the time of preparation of the material for the specimen, and keep it with the specimen until the third cycle expansion pressure test is completed. At the start of the third cycle expansion pressure test, copy all data onto the work card, Form TL-361, as shown in the example illustrated in Figure 2.

### C. FABRICATION OF TEST SPECIMENS FOR THE THIRD CYCLE EXPANSION PRESSURE TEST

1. Batch and compact from four to eight test specimens in accordance with California Test 301.

   a. Arrange the moisture contents[1] of the individual test specimens to cover the range from about 4140 kPa exudation pressure and spanning the driest specimen as described for the R-value test under Part 1 of this test method.

   b. Apply a 2410 kPa-leveling load to all specimens.

### D. TEST PROCEDURE

1. Allow specimens to set for at least one-half hour after completion of the exudation test or application of the 2410 kPa leveling load before proceeding with the following steps.

2. Clean off all dust and foreign material from the spring steel bar and gauge surfaces of the expansion pressure device.

3. Place deflection gauge in position on top bar of expansion pressure device. The single bearing end must rest on the adjustment plug.

4. Use an Allen wrench to raise or lower the adjustment plug until the deflection gauge is on minus 0.025 mm.

[1] It is neither necessary nor desirable, in fabricating the third cycle expansion pressure test specimens, to duplicate the moisture contents used in the R-value series. Selection of somewhat different moisture contents will provide additional points for interpreting compactor air pressure data in Part III of this test method.

5. Place perforated brass plate with rod on top of test specimen.

6. Place a filter paper on turntable then place mold on turntable.

7. Seat perforated brass plate firmly on specimen with pressure applied from fingers.

8. Turn table up until the dial indicator reads zero.

9. Pour approximately 200 mL of water on specimen in mold and allow standing undisturbed for 16 to 24 hours.

10. At the end of the standing period, relieve any expansion pressure that has been developed[2] (first cycle) by turning the turntable down until the rod on the perforated plate just barely breaks contact with the spring steel bar.

    a. If, as a result of this relieving of pressure, the deflection gauge returned to the initial starting reading of minus 0.025 mm, then *immediately* raise the turntable until the deflection gauge reads zero. Allow standing for 16 to 24 hours.

    b. If the deflection gauge does not return completely to the starting value of minus 0.025 mm (indicating that a set has been taken by the spring steel bar), then *immediately* use the Allen wrench to turn the adjustment plug and reset the deflection gauge to minus 0.025 mm. Then turn the turntable up to zero on the gauge as before. Allow standing for 16 to 24 hours.

11. At the end of the second standing period (second cycle), relieve the expansion pressure which has developed and reset in accordance with paragraph 10.a or 10.b, whichever applies. Allow standing for another 16 to 24 hours.

12. Read and record deflection gauge reading at the end of the *third standing period (3rd cycle)*. No correction should be made at this point for any set in the spring steel bar, which may be noted when the pressure is relieved by completely backing off the turntable.

13. Convert the dial reading into expansion pressure (kPa) by using the following formula.

    Expansion Pressure (kPa) =
    81.4 x Dial Reading, mm

14. This is the third cycle expansion pressure value which is used in the analysis covered in Part 3 of this test method.

[2] The expansion pressure readings at the end of the first and second cycle are of no consequence to the purposes of this test method. However, they should be recorded for check purposes.

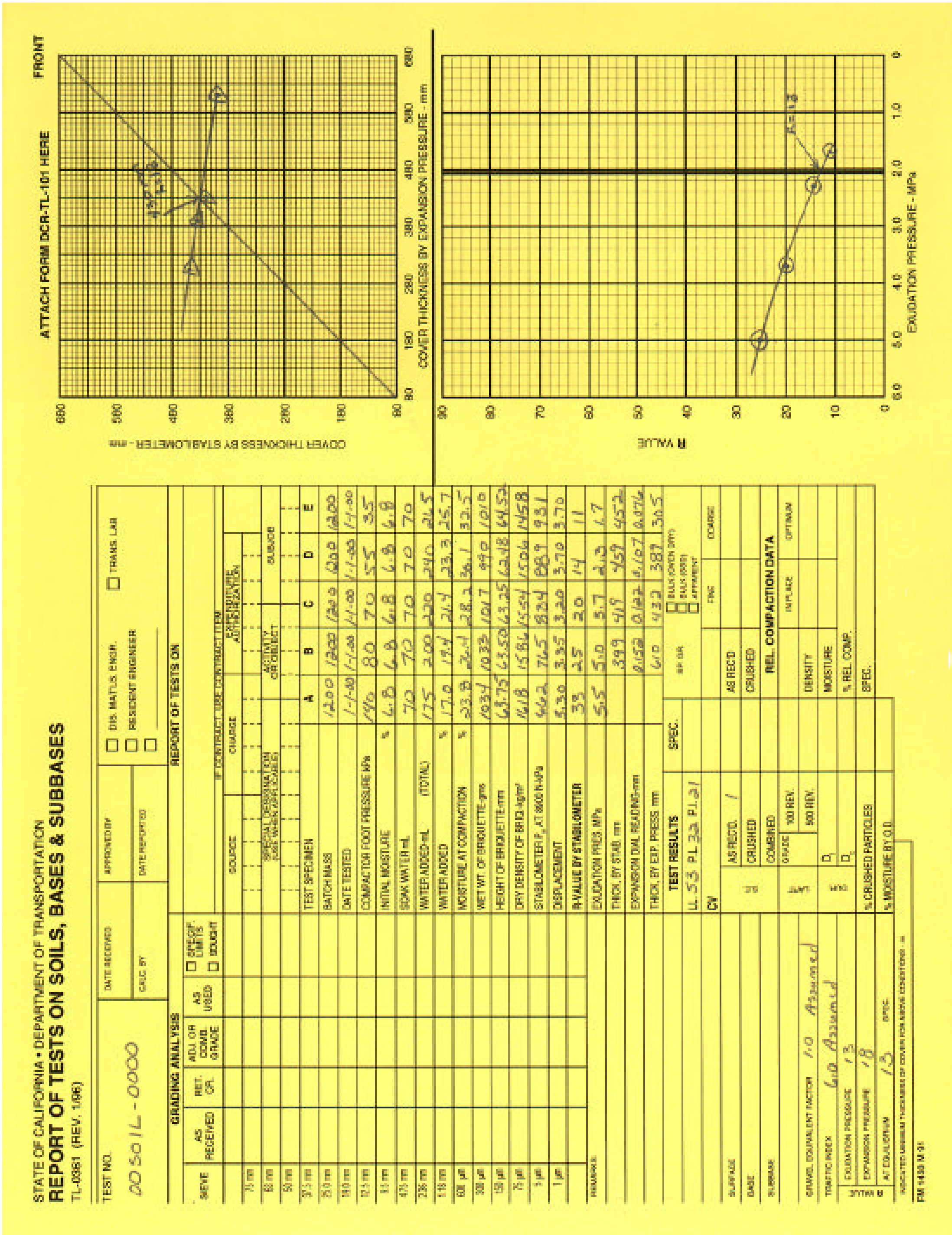
STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION
REPORT OF TESTS ON SOILS, BASES & SUBBASES
TL-0361 (REV. 1/96)
ATTACH FORM DCR-TL-101 HERE
FRONT
GRADING ANALYSIS
REPORT OF TESTS ON
COVER THICKNESS BY EXPANSION PRESSURE - mm
COVER THICKNESS BY STABILOMETER - mm
R VALUE
EXUDATION PRESSURE - MPa
TEST RESULTS
REL. COMPACTION DATA

FIGURE 1

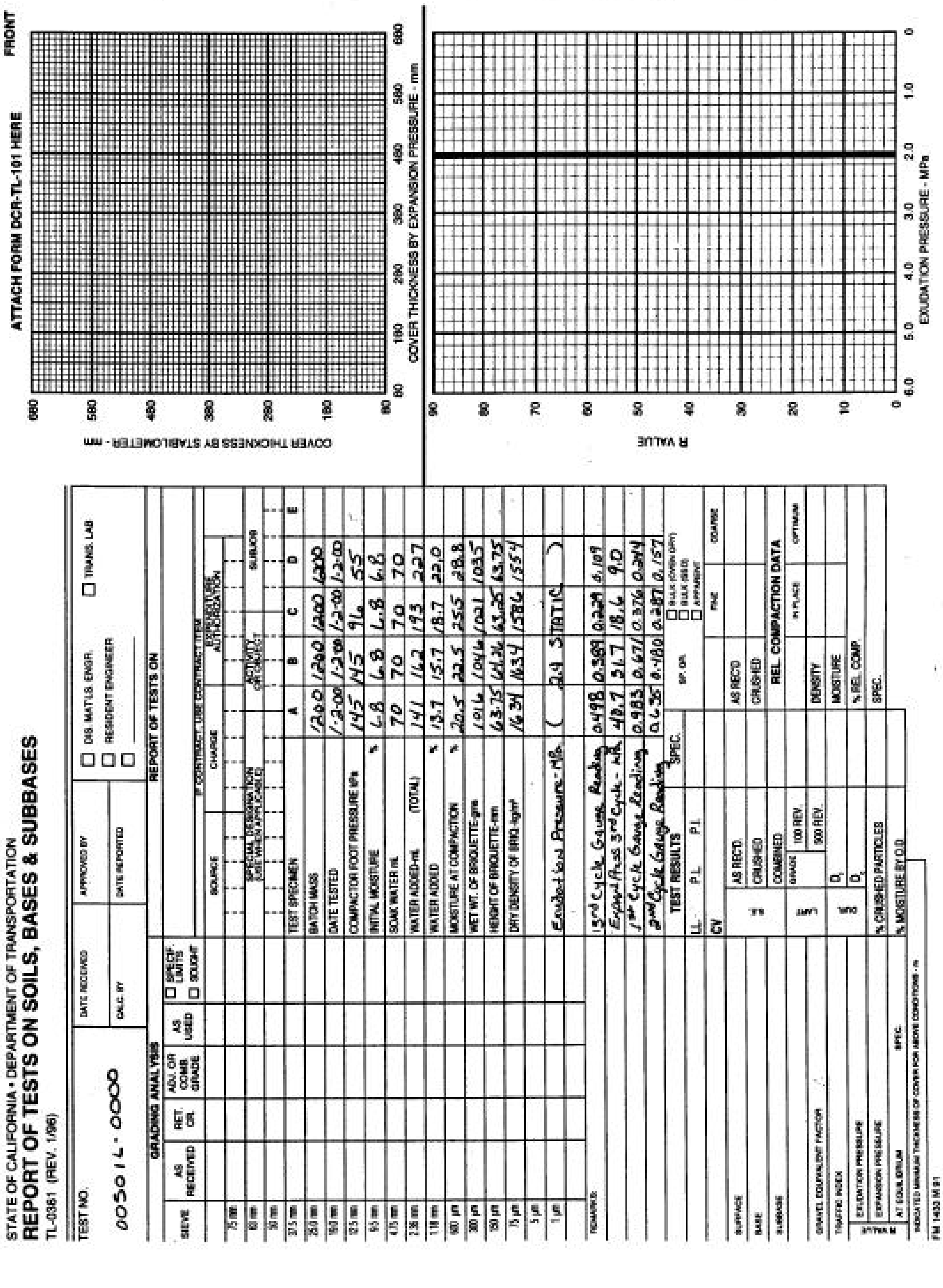
STATE OF CALIFORNIA • DEPARTMENT OF TRANSPORTATION
REPORT OF TESTS ON SOILS, BASES & SUBBASES
TL-0361 (REV. 1/96)
TEST NO.
00501L-0000
DATE RECEIVED
APPROVED BY
DATE REPORTED
DIS. MAT'LS. ENGR.
RESIDENT ENGINEER
TRANS. LAB
GRADING ANALYSIS
REPORT OF TESTS ON
TEST SPECIMEN
BATCH MASS
DATE TESTED
COMPACTOR FOOT PRESSURE kPa
INITIAL MOISTURE
SOAK WATER mL
WATER ADDED-mL (TOTAL)
WATER ADDED
MOISTURE AT COMPACTION
WET WT. OF BRIQUETTE-gm
HEIGHT OF BRIQUETTE-mm
DRY DENSITY OF BRIQ-kg/m³
Exudation Pressure - MPa
STATIC
TEST RESULTS
REL. COMPACTION DATA
% CRUSHED PARTICLES
% MOISTURE BY O.D.
ATTACH FORM DCR-TL-101 HERE
FRONT
COVER THICKNESS BY STABILOMETER - mm
COVER THICKNESS BY EXPANSION PRESSURE - mm
R VALUE
EXUDATION PRESSURE - MPa

FIGURE 2

## E. PRECAUTIONS

1. The precautions concerning equipment cleanliness and vibration, as given in Part 1, Section D of California Test 301, must be followed.

2. Since only highly expansive soils are normally subjected to this test, there is often a permanent set imparted to the spring steel bar as a result of the high expansion pressures developed. As a consequence, it is frequently necessary after the third cycle test to remove the bar, replace it in an inverted manner, and recalibrate the device before using again.

3. The operation involved in making the "initial" gauge setting, as described in Section D.10.a or D.10.b of this test method, *must* be accomplished as *rapidly* as possible in order to minimize the detrimental effect of permitting the specimen to expand freely in an unconfined condition in the presence of free water. The time during which the specimen is unconfined at the end of the first and second periods *must not* be more than five seconds.

## PART 3. METHOD OF ANALYSIS FOR DESIGN AND APPLICATION TO CONSTRUCTION CONTROL

## A. SCOPE

In order to adequately safeguard a PCCP against curling, as a consequence of expanding underlying soils, it is necessary to employ both mass of cover to restrain expansion and the introduction of sufficient moisture into the soil to minimize its expansive potential. The use of the restraining mass of cover alone, without moisture control, is uneconomical and, in many cases, impossible where soils of high expansive potential are encountered. It is, therefore, the purpose of this design analysis to determine the thinnest structural section possible using moisture control within the limitations set by practical construction operations.

## B. DESIGN ANALYSIS

1. Plot R-value, compactor air pressure, and third cycle expansion pressure test data, as determined in Part 1 and Part 2, against moisture content at compaction on Form TL-3051, as illustrated in Figure 4.

2. Connect the plotted points with respective smooth curves. In the case of the compactor air pressures, interpret a smooth curve (normally concave upward) from the "reduced" air pressure points (less than 140 kPa) and extrapolate to intersect the 140 kPa line. This intersection will not necessarily coincide with the "wettest" 140 kPa point, but will, more often than not, intersect somewhat to the right of this point (see example in Figure 4).

3. Since it is desired to obtain the most economical structural section that will safeguard against PCC curl, the final thickness of cover, over the expansive soil, will be primarily dependent upon the highest moisture level which can be attained in construction and still maintain workability or firmness of the working table to permit construction operations. Therefore, the next step, in this analysis, is to establish a minimum control moisture (MCM) content that will allow a reasonable range of workability up to a limiting moisture level. This is accomplished by determining from the previously plotted curves (on Form TL-3051) which of the following three criteria provide the lowest moisture content:

    a. Moisture content at the intersection of the reduced compactor air pressure curve with 140 kPa air pressure (commonly referred to as "compactor pressure break-off point").

    b. Moisture content at 30 R-value (as interpreted from the R-value curve).

    c. Moisture content at 10 R-value minus 4% moisture.

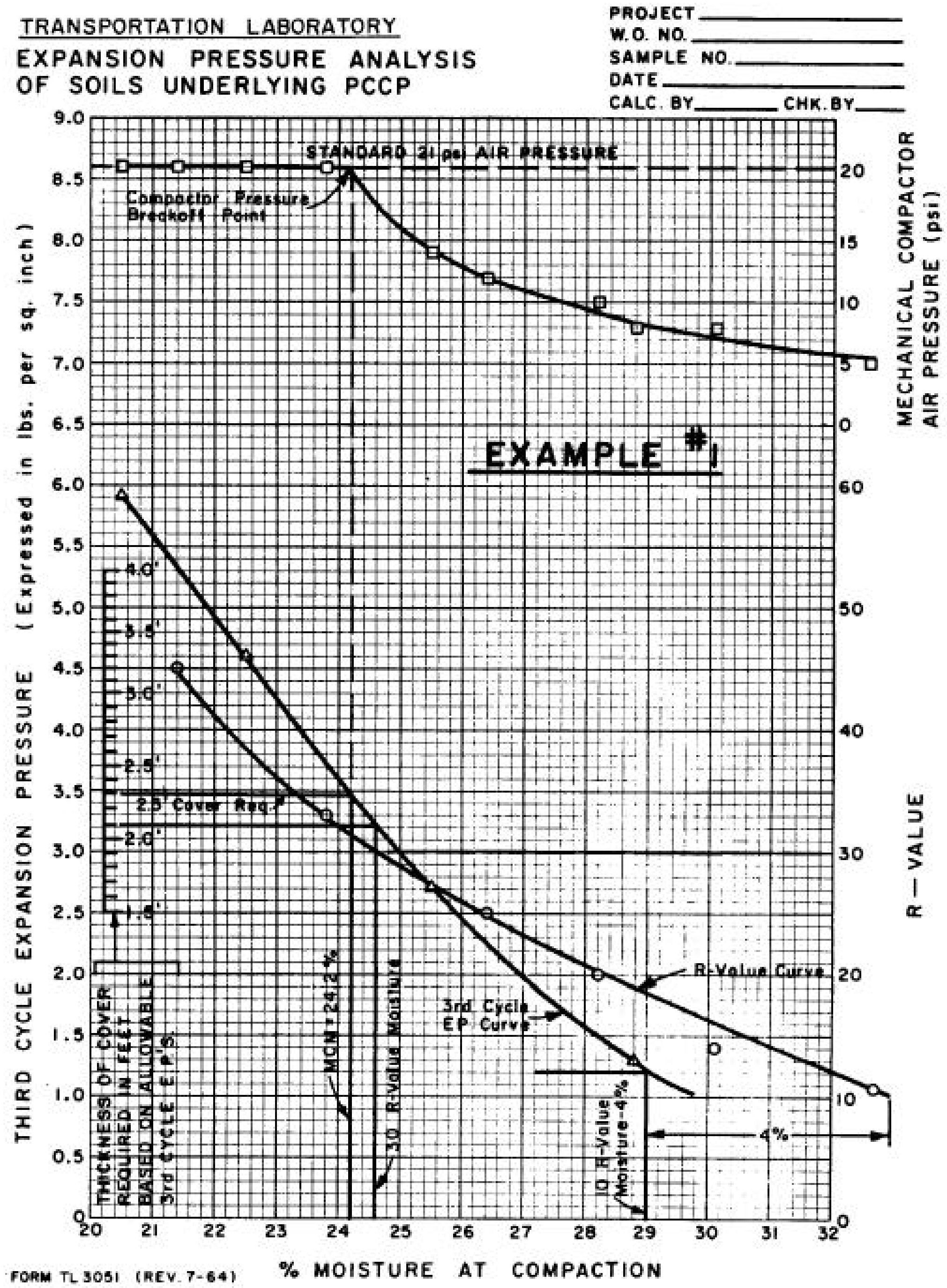
TRANSPORTATION LABORATORY
EXPANSION PRESSURE ANALYSIS
OF SOILS UNDERLYING PCCP
PROJECT
W.O. NO.
SAMPLE NO.
DATE
CALC. BY
CHK. BY
STANDARD 21 psi AIR PRESSURE
Compactor Pressure
Breakoff Point
EXAMPLE #1
THIRD CYCLE EXPANSION PRESSURE (Expressed in lbs. per sq. inch)
MECHANICAL COMPACTOR
AIR PRESSURE (psi)
R — VALUE
2.5' Cover Req.
THICKNESS OF COVER
REQUIRED IN FEET
BASED ON ALLOWABLE
3rd CYCLE E.P.'S.
MCM = 24.2%
30 R-Value Moisture
3rd Cycle
EP Curve
R-Value Curve
10 R-Value
Moisture-4%
4%
% MOISTURE AT COMPACTION
FORM TL 3051 (REV. 7-64)

FIGURE 3

4. After determining the MCM as the least of the above three moisture contents, refer to the inside scale on the left ordinate of Form TL-3051 or the following Table 1 for allowable third cycle expansion pressure values corresponding to various depths below profile grade:

TABLE 1

MAXIMUM ALLOWABLE THIRD CYCLE EXPANSION PRESSURES

| Depth Below Profile Grade (M) | Third Cycle E.P. (kPa) |
|---|---|
| 0.5 | 17 |
| 0.6 | 21 |
| 0.75 | 25.5 |
| 0.9 | 29.5 |
| 1.05 | 33 |
| 1.2 | 36.5 |

5. Enter the abscissa of the chart at the MCM and note the intersection with the third cycle EP curve. Read the thickness of cover required at this intersection from the ordinate scale (to the nearest 0.03 m). This is the design thickness of the structural section over the soil represented by the sample while the MCM represents the *minimum* moisture content which must be attained in the top one foot of the basement soil, during construction, for the particular thickness of structural section determined. In addition, the MCM must be maintained during construction until upper layers are placed to prevent the escape of moisture from the basement soil.

## C. NOTES

The above analysis processes are probably most effectively demonstrated by the use of examples. Therefore, the following three examples are given in order to cover analysis situations that are most frequently encountered in practice. The first example is quite straightforward and demonstrates the basic principles of analysis. Examples 2 and 3 concern special situations when soils of low expansive potential are involved.

Example No. 1 (Figure 3):

The test data for the samples illustrated in this example are shown on the work cards in Figures 1 and 2. Referring to Figure 3, this data is plotted on Form TL-3051, and appropriate smooth curves are drawn through the respective points. The moisture contents related to the three criteria (see Section B.3, Items a, b, and c of this Part 3) are then interpolated from the curves, as shown. These moisture contents are listed for this example as follows:

| | | |
|---|---|---|
| Moisture at compactor air pressure break-off point . . . . . . . . . | = | 24.2% |
| Moisture at 30 R-value . . . . . . . . . . . | = | 24.6% |
| Moisture at 10 R-value — 4% . . . . . . | = | 29.0% |

Since the compactor air pressure break-off point gives the lowest moisture value, 24.2%, this becomes the “minimum control moisture” (MCM). Intersection of the MCM with the third cycle EP curve indicates that 0.70 m of cover will be required over soil represented by this sample.

Example No. 2 (Figure 4):

This example illustrates a method for determining whether the expansive potential of a soil is sufficient to warrant any consideration from design and moisture control standpoints. It is noted that, in this case, the 10 R-value moisture minus 4% is the governing criteria and would be the MCM. However, it is also noted that the third cycle EP at this point is only 2 kPa, and at more than $2^1/_2$% moisture below the MCM, the pressure only rises to 6 kPa. As a rule, when third cycle EP specimens, fabricated at least 2% moisture below the MCM, do not indicate third cycle EPs in excess of 7 kPa, then the soil sample is considered *non-expansive* for the purpose of this test method.

Example No. 3 (Figure 5):

The soil represented by this sample is also relatively low in expansive potential. It is noted that at the controlling compactor pressure break-off point, the third cycle EP is 5 kPa. However, unlike the previous example, the third cycle EPs increase markedly as the moisture content is reduced and will approach a cover requirement of 0.8 m with a moisture reduction of about 3%. In this case, the design thickness should be established at 0.5 m of cover and the MCM adjusted downward to coincide with the 0.5 m cover requirement. The “adjusted” MCM is 20% moisture in this example.

A situation similar to that demonstrated in Example No. 3, involving a sharply rising expansion curve, may occur where the driest specimen does not attain the level of third cycle EP represented by 0.5 m of cover (but greater than 7 kPa third cycle EP). In this instance, the design thickness would also be established at 0.5 m of cover, but the MCM would only be adjusted to the moisture content of the driest specimen.

Occasionally, a soil will be encountered which possesses such an extremely high expansive potential that the MCM intersection with the third cycle EP curve will be considerably above the level of the allowable pressure at the 1 m cover requirement. Since the mechanisms which result in the PCC curl phenomenon are not considered to be effective beyond depths of 1 m, structural design is not carried to greater thickness than 1 m. However, some moisture control must still be maintained since excessively large volume changes may be expected from these materials if allowed to dry out. Therefore, the MCM should still be the ruling minimum moisture to be attained during construction.

## D. SAFETY AND HEALTH

Prior to handling, testing or disposing of any waste materials, Caltrans testers are required to read: Part A (Section 5.0), Part B (Sections: 5.0, 6.0 and 10.0) and Part C (Section 1.0) of Caltrans Laboratory Safety Manual. Users of this method do so at their own risk.

**REFERENCES:**
**California Tests 201 and 301**

**End of Text (California Test 354 contains 11 pages)**

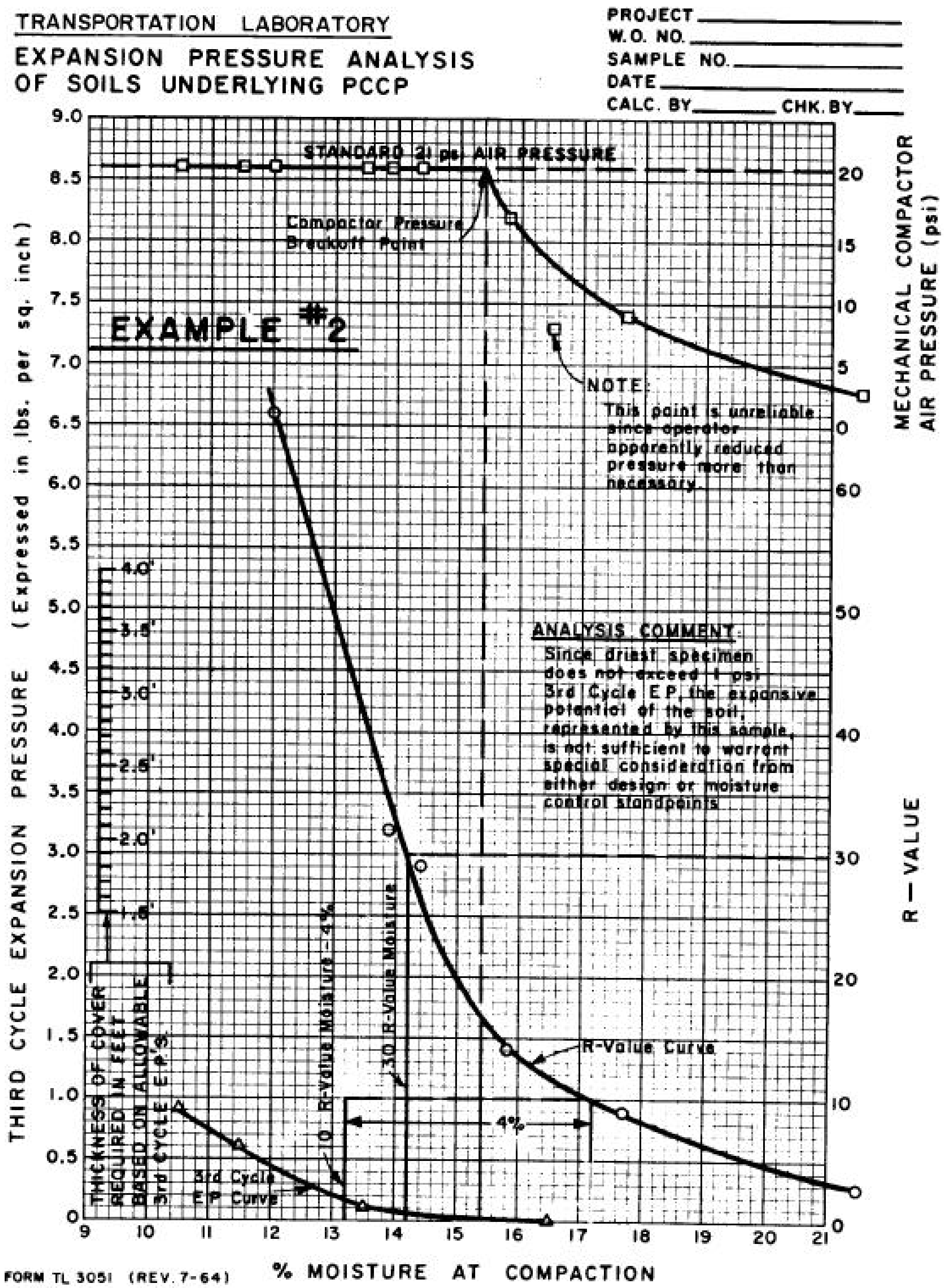
TRANSPORTATION LABORATORY
EXPANSION PRESSURE ANALYSIS
OF SOILS UNDERLYING PCCP
PROJECT
W.O. NO.
SAMPLE NO.
DATE
CALC. BY
CHK. BY
STANDARD 21 psi AIR PRESSURE
Compactor Pressure Breakoff Point
EXAMPLE #2
NOTE:
This point is unreliable since operator apparently reduced pressure more than necessary.
ANALYSIS COMMENT:
Since driest specimen does not exceed 1 psi 3rd Cycle E P, the expansive potential of the soil, represented by this sample, is not sufficient to warrant special consideration from either design or moisture control standpoints
THIRD CYCLE EXPANSION PRESSURE (Expressed in lbs. per sq. inch)
MECHANICAL COMPACTOR AIR PRESSURE (psi)
R — VALUE
THICKNESS OF COVER REQUIRED IN FEET BASED ON ALLOWABLE 3rd CYCLE E.P.'S
R-Value Moisture - 4%
3.0 R-Value Moisture
4%
R-Value Curve
3rd Cycle E P Curve
% MOISTURE AT COMPACTION
FORM TL 3051 (REV. 7-64)

FIGURE 4

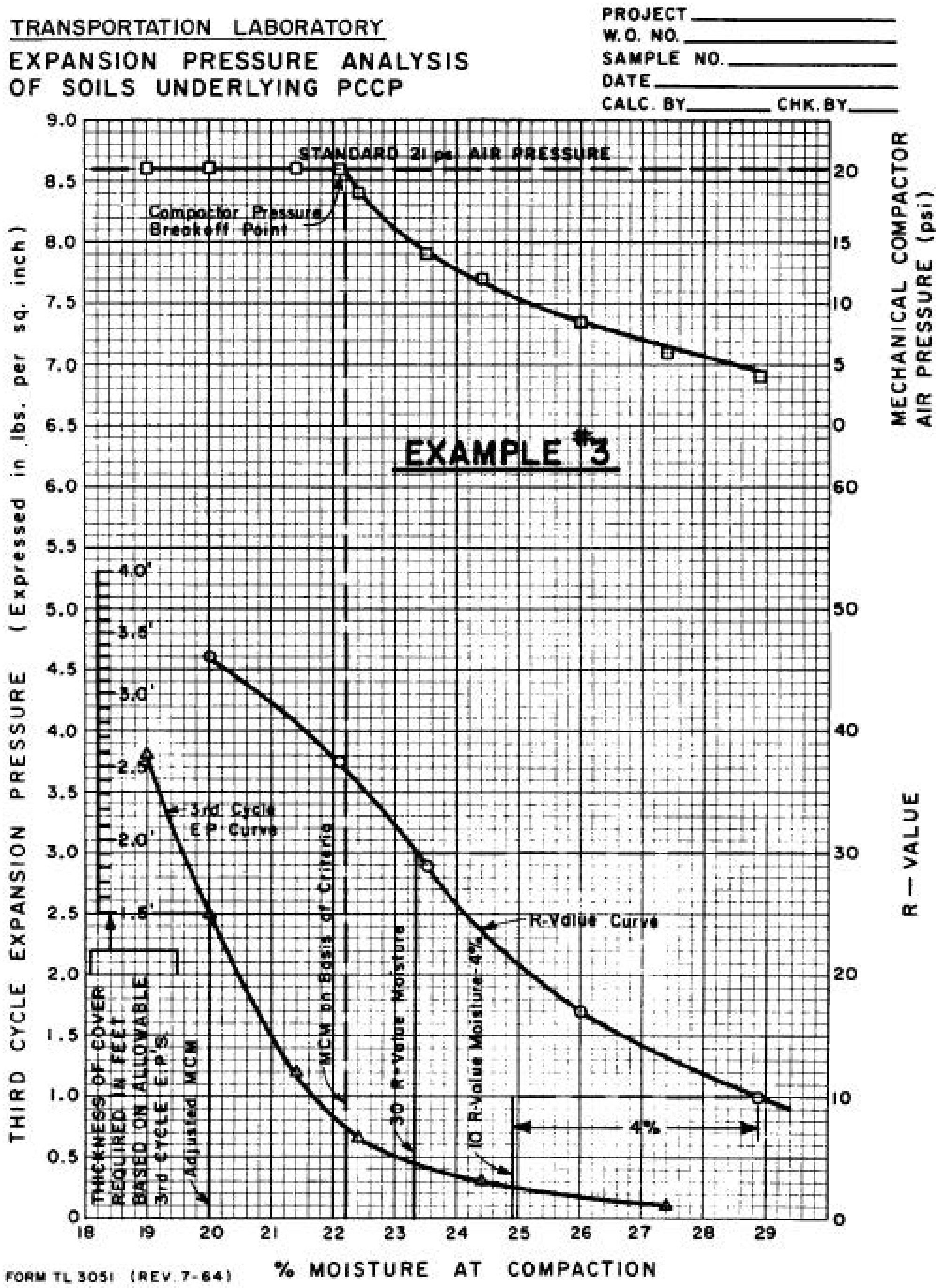
TRANSPORTATION LABORATORY
EXPANSION PRESSURE ANALYSIS OF SOILS UNDERLYING PCCP
PROJECT
W. O. NO.
SAMPLE NO.
DATE
CALC. BY
CHK. BY
STANDARD 21 psi AIR PRESSURE
Compactor Pressure Breakoff Point
EXAMPLE #3
3rd Cycle E.P. Curve
R-Value Curve
MCM on Basis of Criteria
30 R-Value Moisture
10 R-Value Moisture-4%
4%
THICKNESS OF COVER REQUIRED IN FEET BASED ON ALLOWABLE 3rd CYCLE E.P.'S
Adjusted MCM
THIRD CYCLE EXPANSION PRESSURE (Expressed in lbs. per sq. inch)
MECHANICAL COMPACTOR AIR PRESSURE (psi)
R — VALUE
% MOISTURE AT COMPACTION
FORM TL 3051 (REV. 7-64)

FIGURE 5