PERFORMANCE OF HEMIHYDRATE

PHOSPHOGYPSUM IN ROAD CONSTRUCTION

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ABSTRACT

Occidental Chemical Company constructed a test road with phosphogypsum on Company controlled property at White Springs, Florida. Both dihydrate and hemihydrate phosphogypsum were used to construct the road. The purpose of this test road was to study the performance of phosphogypsum in secondary road construction.

The road was 200 feet long and consisted of four (4) 50' long sections constructed with different materials, as follows:

1) 50' section of road constructed with 12" thick layer of loose hemihydrate gypsum.

2) 50' section of road constructed with 7" of loose hemi-hydrate gypsum, mixed with 5" of sand tailings.

3) 50' section of road constructed with 5" of loose dihydrate gypsum, mixed with 7" of sand tailings.

4) 50' section of road constructed with 12" thick layer of loose dihydrate gypsum. Added 2% by volume emulsified asphalt Fla. D.O.T. AEP-1. A small amount of lime (0.05% by weight) was added in this section to neutralize the acidity.

   All but the first 50 ft. section were mixed in place with the rotomixer before grading and compacting. Finally, the entire road surface was coated with asphalt prime coat.

The durability and performance of the different sections of the road were monitored.

INTRODUCTION

Phosphogypsum is a solid waste chemical by-product of phosphoric acid production. Gypsum consists mainly of calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$) or hemihydrate ($CaSO_4 \cdot \frac{1}{2}H_2O$)

Because of trace impurities and economics, large scale use of phosphogypsum has yet to be found. As a result domestic stockpiles are accumulating at rates which could produce an inventory of over one billion tons of stacked gypsum by the year 2000.

The attention of phosphate research has been focused on finding useful ways to dispose of this otherwise useless waste product. Road construction is one of the most practical and possible uses for phosphogypsum.

<u>TEXT</u>

Occidental Chemical Company constructed the test road on September 17, 1985, with hemihydrate phosphogypsum $CaSO_4 \cdot \frac{1}{2}H_2O$ and dihydrate phosphogypsum $CaSO_4 \cdot 2H_2O$ using conventional road building equipment. The construction, behavior and performance of the gypsum road sections are the subject of this paper.

The site selected is a service road between Suwannee River Chemical Plant and the Mine in White Springs, Florida (See Figure 1). The road is subjected to routine plant traffic and very heavy construction equipment traffic.

The road is 24 feet wide and 200 feet long and consists of four sections constructed as follows: (See Figure 2)

1) 50' section of road constructed with 12" thick layer of loose hemihydrate gypsum, from Swift Creek, compacted to 98% density. (Figure 3)

2) 50' section of road constructed with 7" of loose hemi-hydrate gypsum, from Swift Creek, mixed with 5" of sand tailings compacted to 98% density. (Figure 4)

3) 50' section of road constructed with 5" of loose dihydrate gypsum, from Dorr-Oliver Gypsum Stack, mixed with 7" of sand tailings compacted to 98% density. (Figure 4)

4) 50' section of road constructed with 12" thick layer of loose dihydrate gypsum, from Dorr-Oliver Gypsum Stack. Added 2% by volume emulsified asphalt Fla D.O.T. AEP-1 and compacted to 98% density. (Figure 3) Lime (0.05% by weight) was added in this section to neutralize the acidity.

Water content versus dry density relationships were developed in the lab for each of the four sections of the test road prior to construction (See Figure 5). The curves on Figure 5 show the optimum moisture contents for the different gypsum mixtures used in the construction of the test road. Field tests were made to determine the density of the material in-place after compaction. The water content was measured to determine the degree of compaction by comparing the dry density of the inplace gypsum with the dry density at optimum water content shown on Figure 5.

The water content of gypsum was determined in the field by a method called Speedy. This method gives instant and fairly accurate results for soils but with gypsum it gave biased results. It was discovered that the only accurate tests to determine the water content in gypsum was to oven dry the sample at 40°C. But the speedy method results could be correlated with the oven drying method as shown in Figure 6. This graph enabled us to use the Speedy in the field to determine the field water content and test the compaction by reading the actual water content directly from the graph.

Table 1 shows a comparison in the field test results of the water content using the Speedy, Nuclear and Conventional Methods (40°C oven drying of sample) as recorded from our test road.

The design of each section for the test road was based on tests performed by the University of Miami, Department of Civil Engineering under the direction of Dr. Wen F. Chang.

Unconfined compressive strength, moisture density relationships and load bearing tests were used as the design criteria. Figure 7 shows the unconfined compressive strength versus moisture content for dihydrate gypsum. Figure 8 shows the same relationship for hemihydrate gypsum. As can be seen from Figures 7 and 8 the hemihydrate gypsum maintains good strength even in the soaked condition. Dihydrate gypsum has no strength when soaked indicating very low resistance to water.

Figure 9 shows the unconfined compression strength for hemihydrate gypsum remains unaffected by prolonged soaking after the initial decrease in strength during the first day. Clearly, the hemihydrate phosphogypsum is a superior material for road construction.

In 1985, Florida Department of Transportation (FDOT) tested a sample of Oxy's hemihydrate gypsum in the laboratory at the Bureau of Materials and Research in Gainesville, Florida.

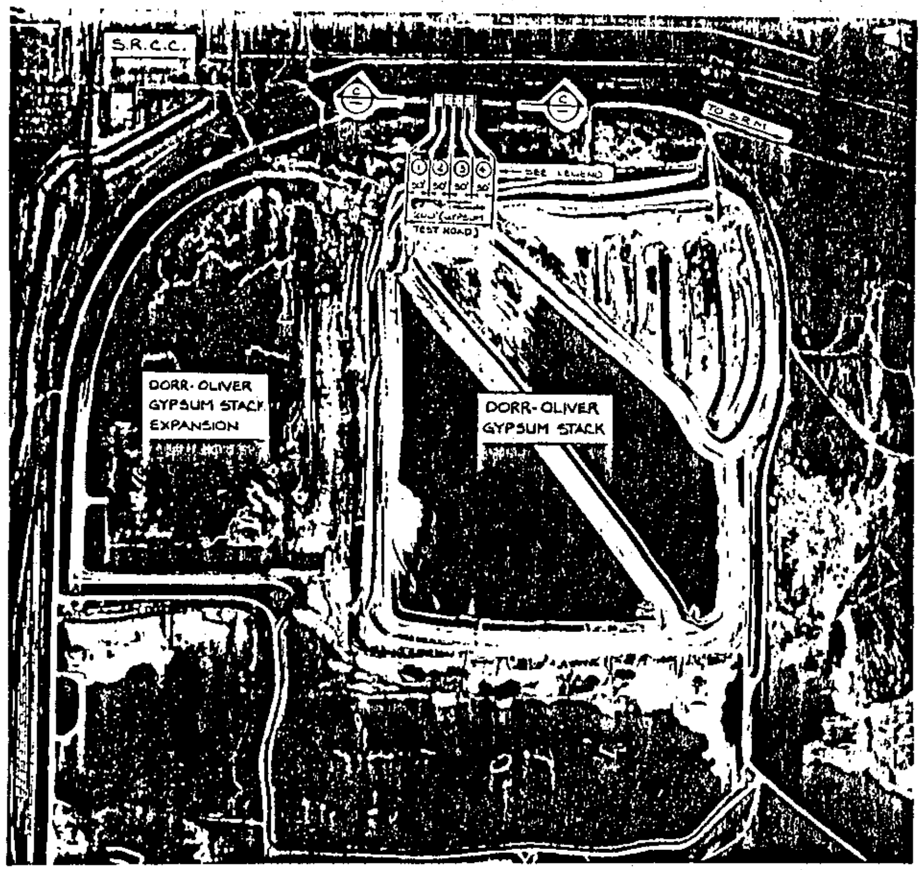
The cumulative total plate deflection versus number of load applications in the soaked moisture conditions are shown in Figure 10. As can be seen the test results show that the hemihydrate gypsum behaved as a good Group 1 base in the FDOT test pit evaluation. Also the hemihydrate gypsum had a Florida lime bearing ratio (LBR) of 241. LBR value of over 100 is considered adequate for road base material. This makes it equal to or better than high grade road base material.

Figure 11 shows the microscopic pictures of the hemihydrate gypsum crystals enlarged one hundred times on the left hand side of the picture and 500 times on the right hand side of the picture. Figure 12 shows the enlarged dihydrate gypsum crystals. When comparing the two crystal structures, the hemihydrate appears as clusters of crystals. The dihydrate crystals have the shape of flat plates. It is belived that the flat plate structure of the dihydrate gypsum may be the reason it is not as strong as the hemihydrate gypsum. Also moisture may work as lubricant between the flat plates which causes the weakness of dihydrate gypsum in the wet condition. On the other hand the raspberry shape of the hemihydrate crystal clusters seems to help bind the crystals together for better cementation. Table 2 shows the chemical composition of the two types of phosphogypsum, for reference.

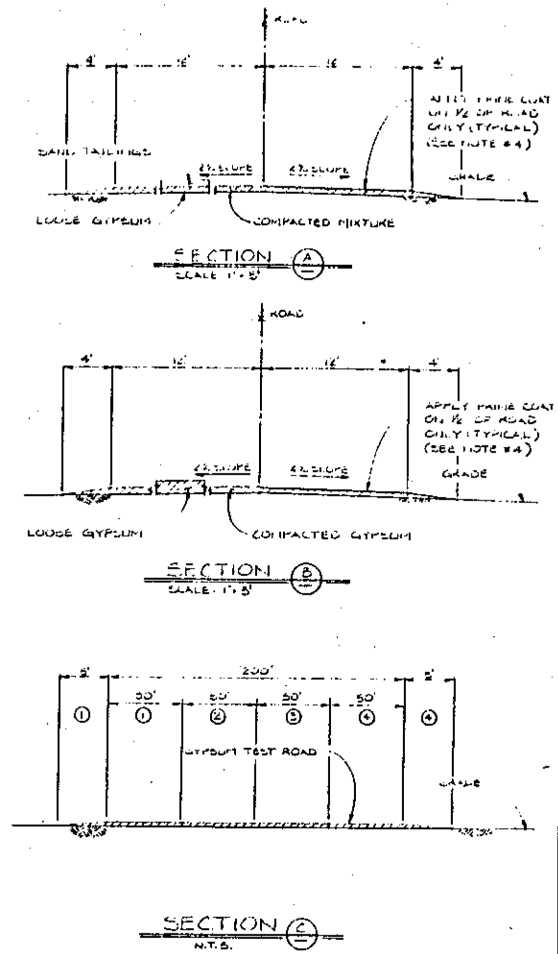
The test road has been monitored since its construction on September 17, 1985. The section of the road built with hemihydrate gypsum is superior to the rest of the road. The dihyrate sections of the road developed some potholes while the hemihydrate section of the road is still intact. We have learned a great deal about the behavior of phosphogypsum in secondary road construction.

CONCLUSION

All laboratory test results show promising future for hemihydrate gypsum use in road construction. The results of the test road performance support the laboratory tests and give us a more practical proof that phosphogypsum is a potential source of flexible pavement base material.



PLAN
SCALE: 1"=250'



LEGEND

1. 50' SECTION OF ROAD CONSTRUCTED WITH 12" THICK LAYER OF LOOSE HEMI-HYDRATE GYPSUM, FROM SWIFT CREEK COMPACTED TO 98% DENSITY. SEE SECTION (B)
2. 50' SECTION OF ROAD CONSTRUCTED WITH 7" OF LOOSE HEMI-HYDRATE GYPSUM, FROM SWIFT CREEK, MIXED WITH 5" OF SAND TAILINGS. MIXTURE SHALL BE COMPACTED TO 98% DENSITY. SEE SECTION (A)
3. 50' SECTION OF ROAD CONSTRUCTED WITH 5" OF LOOSE DIHYDRATE GYPSUM, FROM DORR OLIVER GYPSUM STACK, MIXED WITH 7" OF SAND TAILINGS. ADD 2% BY VOLUME RC-70 CUTBACK ASPHALT. MIXTURE SHALL BE COMPACTED TO 98% DENSITY. SEE SECTION (A)
4. 50' SECTION OF ROAD CONSTRUCTED WITH 12" THICK LAYER OF LOOSE DIHYDRATE GYPSUM, FROM DORR-OLIVER GYPSUM STACK, COMPACTED TO 98% DENSITY. SEE SECTION (B)

NOTES:

1. INPLACE MIXING SHALL BE ACCOMPLISHED BY USING AN INPLACE ROTOMIXER TO MIX THE LAYER OF GYPSUM WITH THE LAYER OF SAND TAILINGS.
2. COMPACT THE ROADWAY MATERIAL BY USING A ROLLER COMPACTOR. COMPACTED THICKNESS IS APPROX. 7" THICK.
3. INPLACE DENSITY TESTS SHALL BE TAKEN DURING CONSTRUCTION TO MONITOR THE COMPACTION.
4. SURFACE TREATMENT PRIME COAT SHALL BE CUTBACK ASPHALT GRADE RC-70. APPLICATION SHALL BE 0.25 GALLONS PER SQUARE YARD. THE TEMPERATURE OF THE PRIME MATERIAL SHALL BE BETWEEN 100° AND 150°(F) TO INSURE UNIFORM DISTRIBUTION.

NOT FOR CONSTRUCTION

OCCIDENTAL CHEMICAL
AGRICULTURAL PRODUCTS, INC.
FLORIDA OPERATIONS
WHITE SPRINGS, FLORIDA

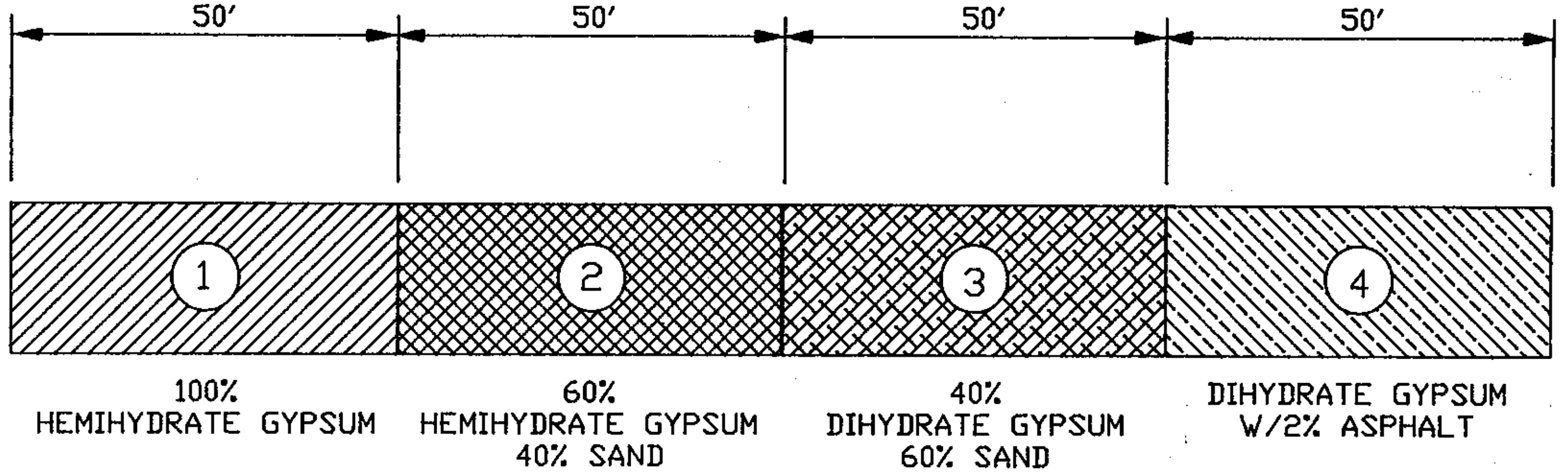
SUWANNEE RIVER CHEMICAL
GYPSUM TEST ROAD

PLANT S.R.C.C.

REVISION: A — ISSUED FOR APPROVAL

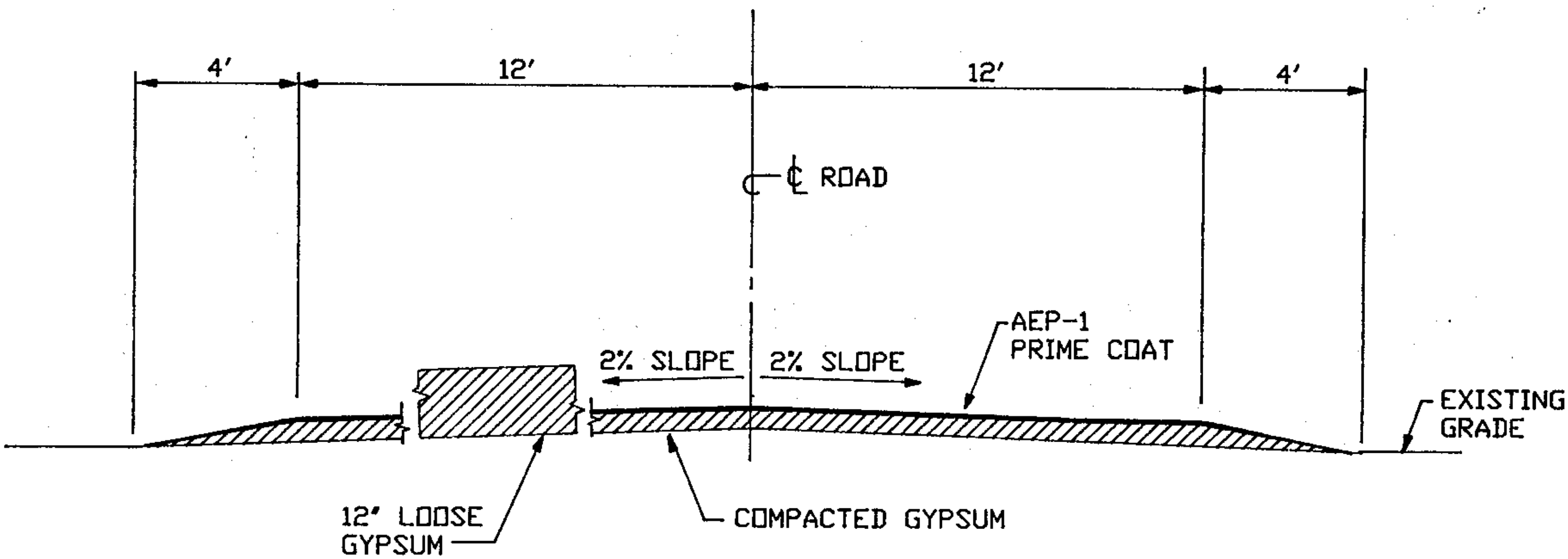
SCALE: AS NOTED

FIGURE 1



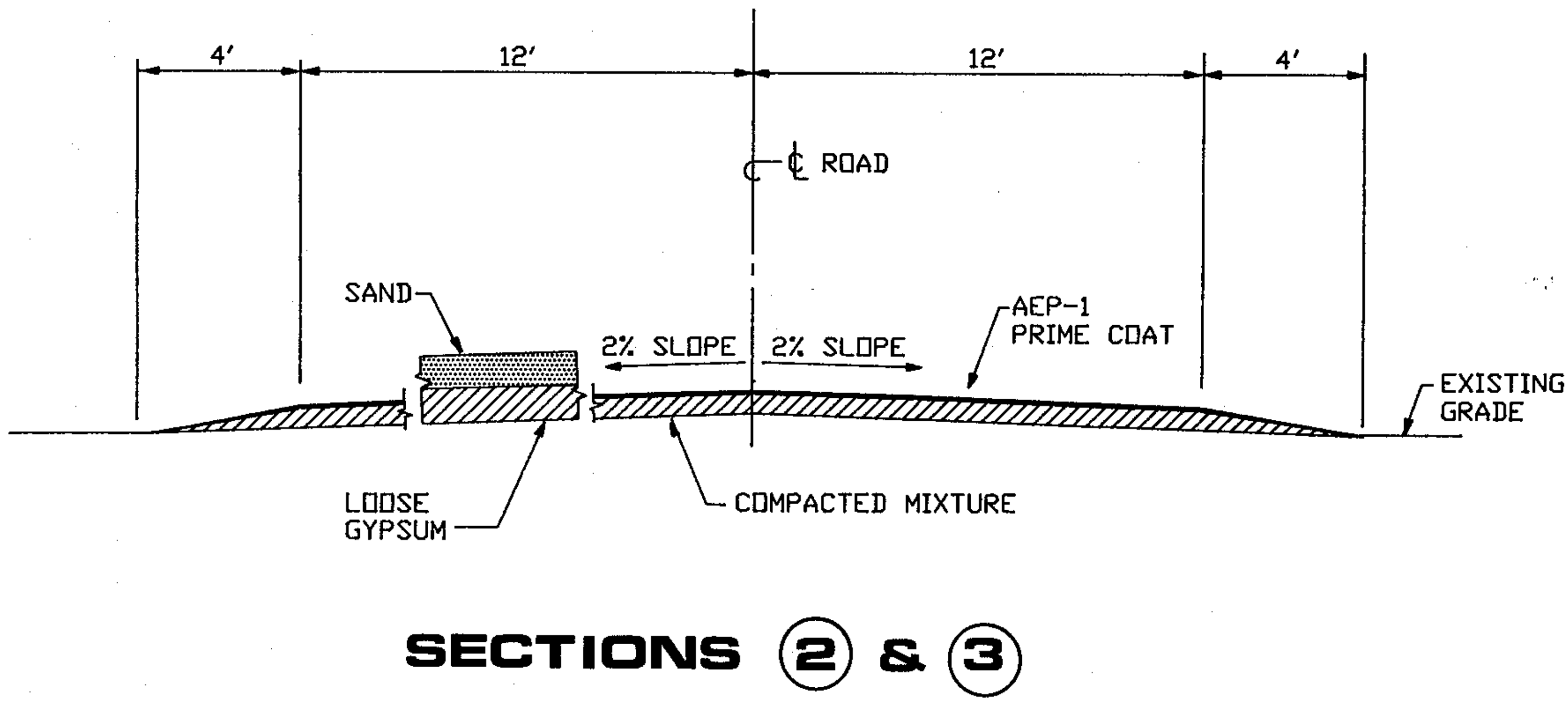
DESIGN SECTIONS
GYPSUM TEST ROAD

FIGURE 2



SECTIONS ① & ④

FIGURE 3



4'
12'
12'
4'
℄ ROAD
SAND
2% SLOPE
2% SLOPE
AEP-1
PRIME COAT
EXISTING
GRADE
LOOSE
GYPSUM
COMPACTED MIXTURE
SECTIONS ② & ③

FIGURE 4

MOISTURE — DENSITY RELATIONSHIP
FOR GYPSUM

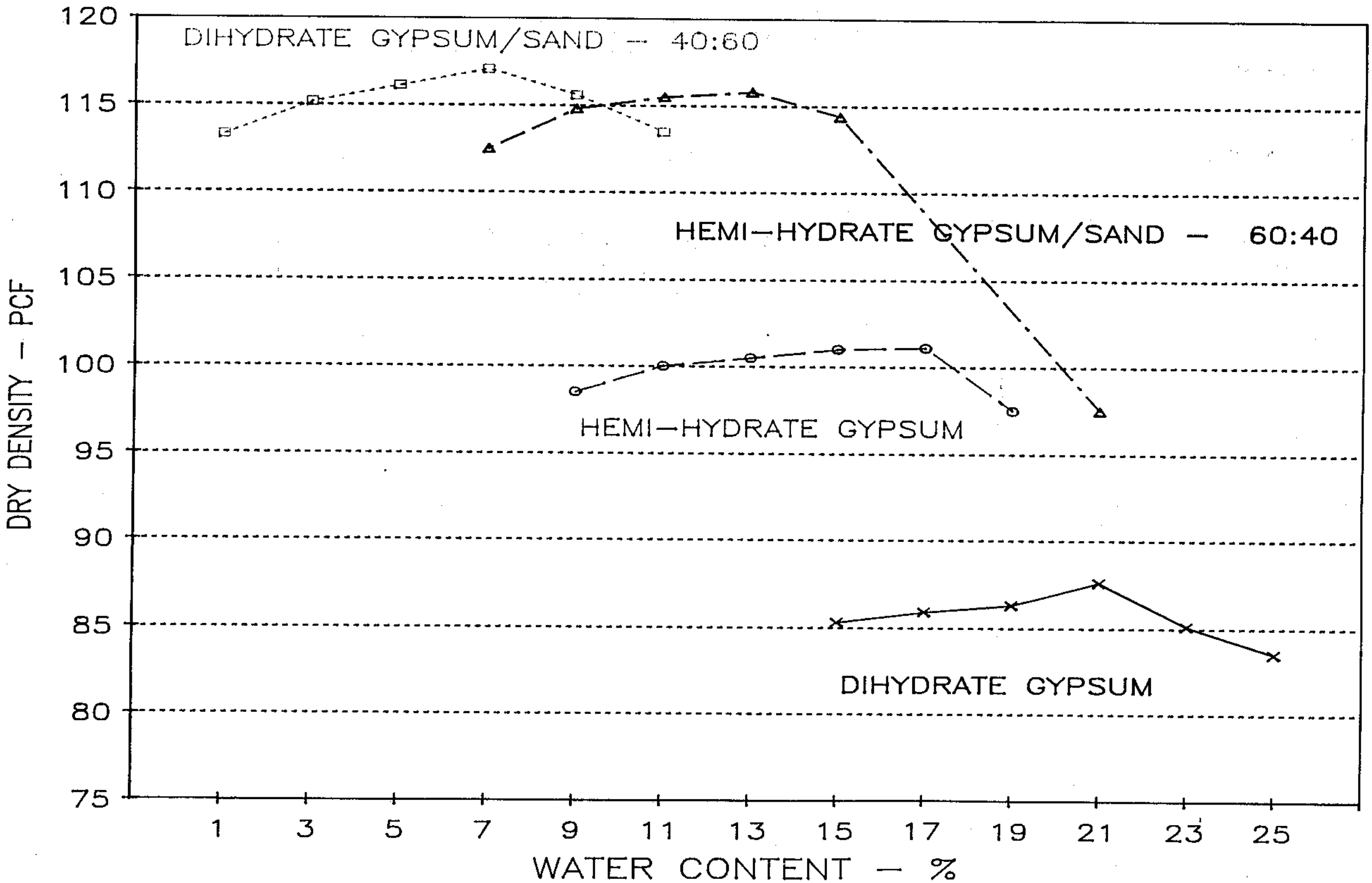
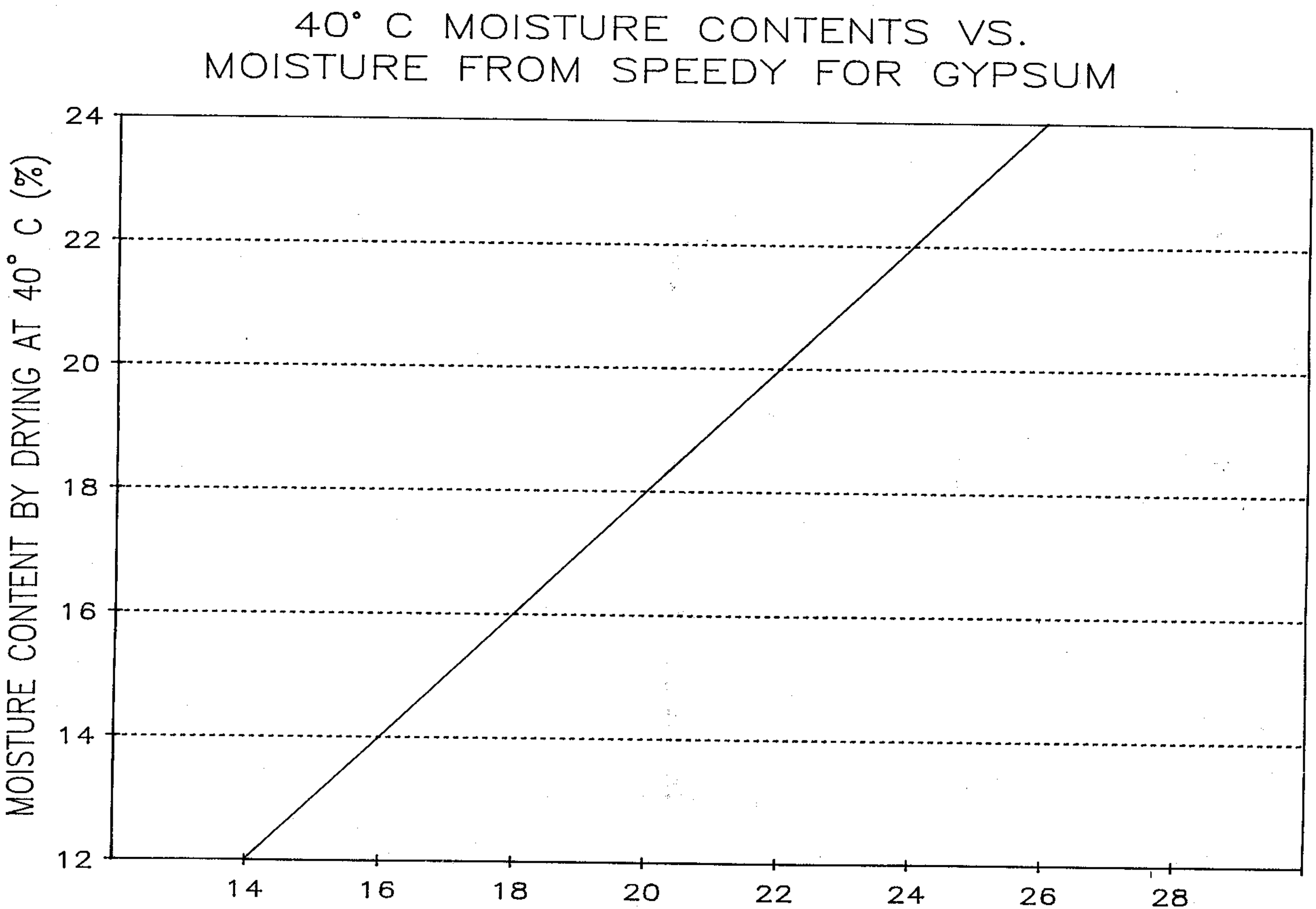


FIGURE 5


40° C MOISTURE CONTENTS VS.
MOISTURE FROM SPEEDY FOR GYPSUM
MOISTURE CONTENT BY DRYING AT 40° C (%)
24
22
20
18
16
14
12
14
16
18
20
22
24
26
28
MOISTURE CONTENT WITH SPEEDY (%)
FIGURE 6

Dehydrated Phosphogypsum

(Modified Proctor Method)

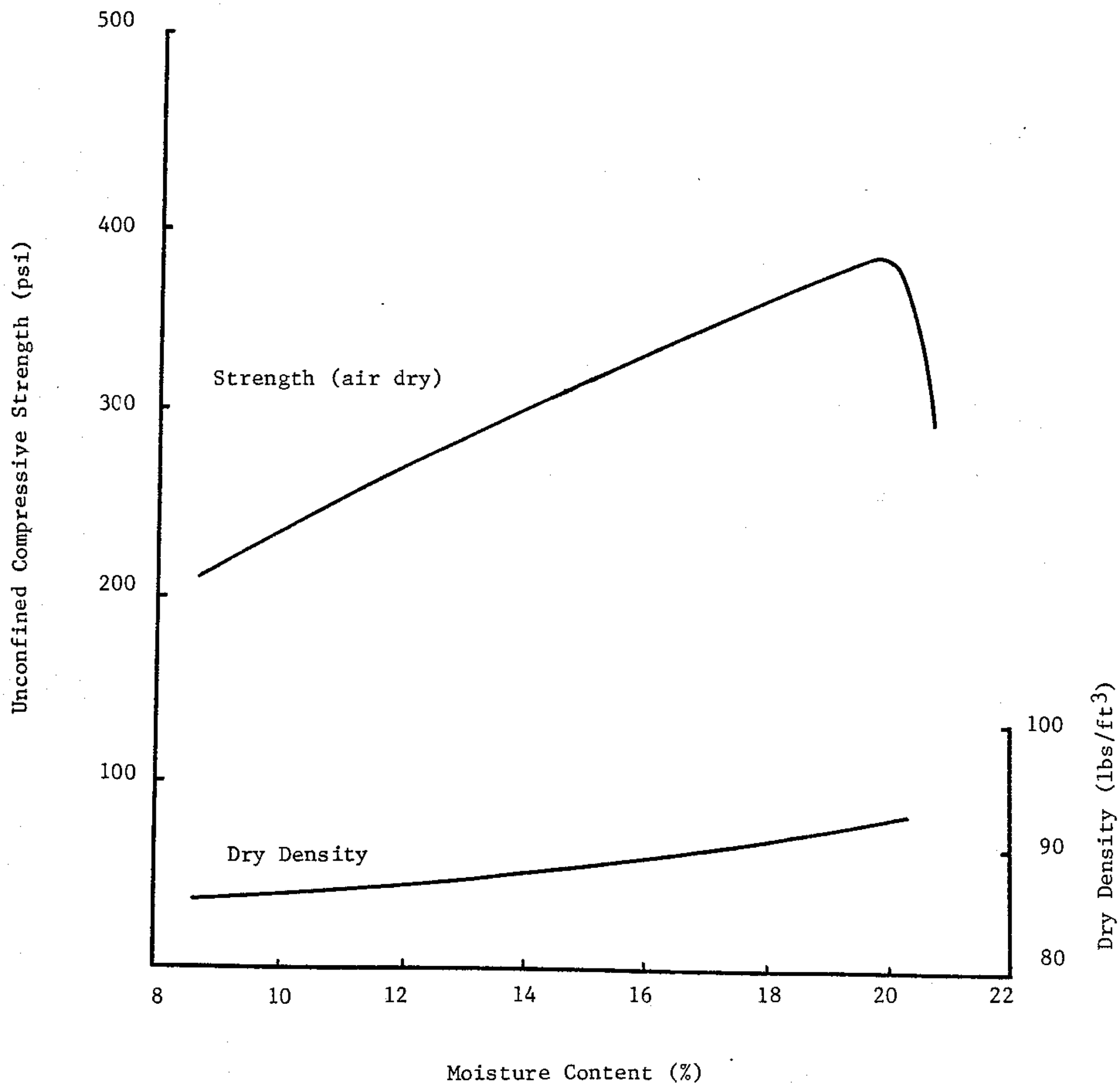
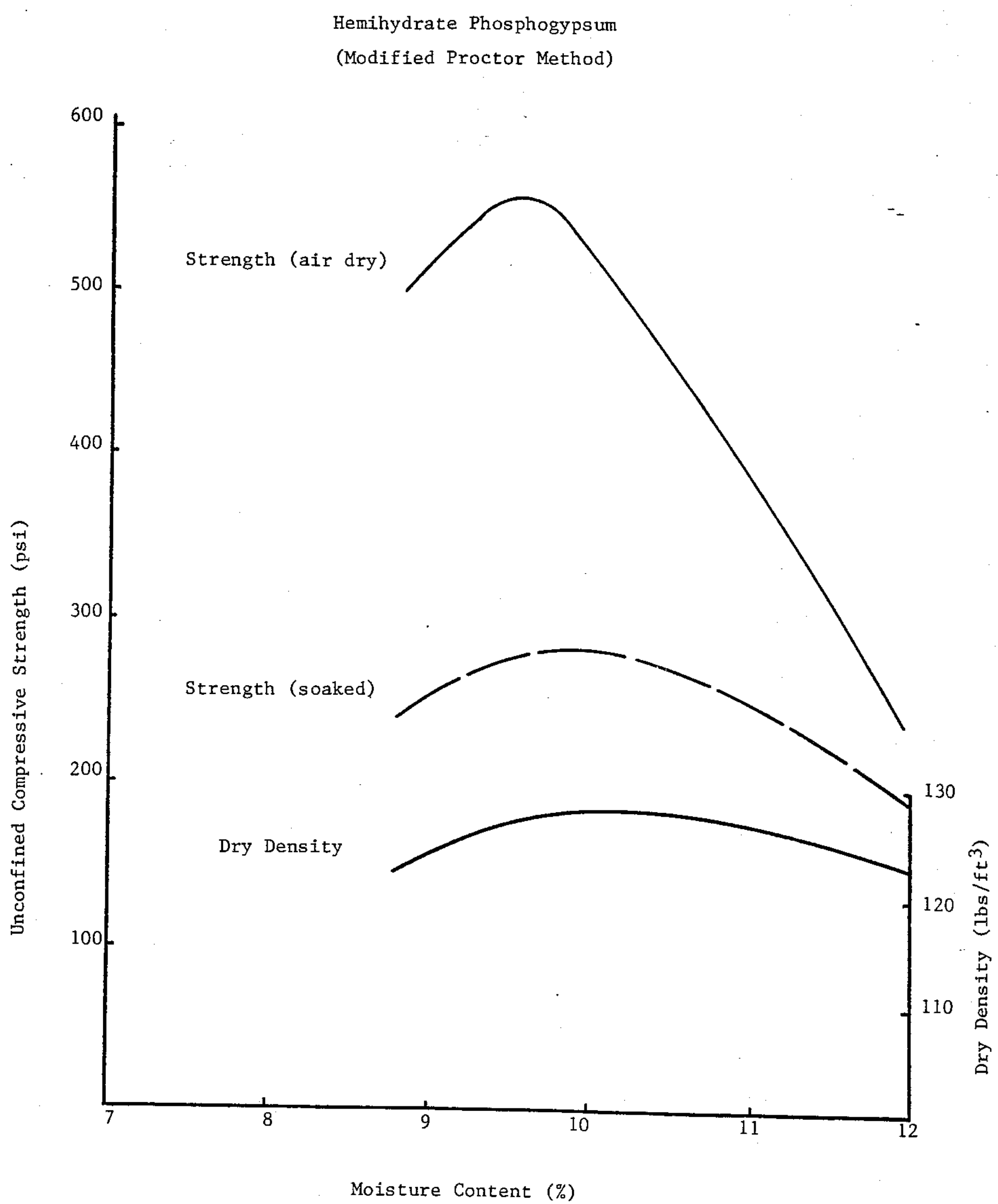
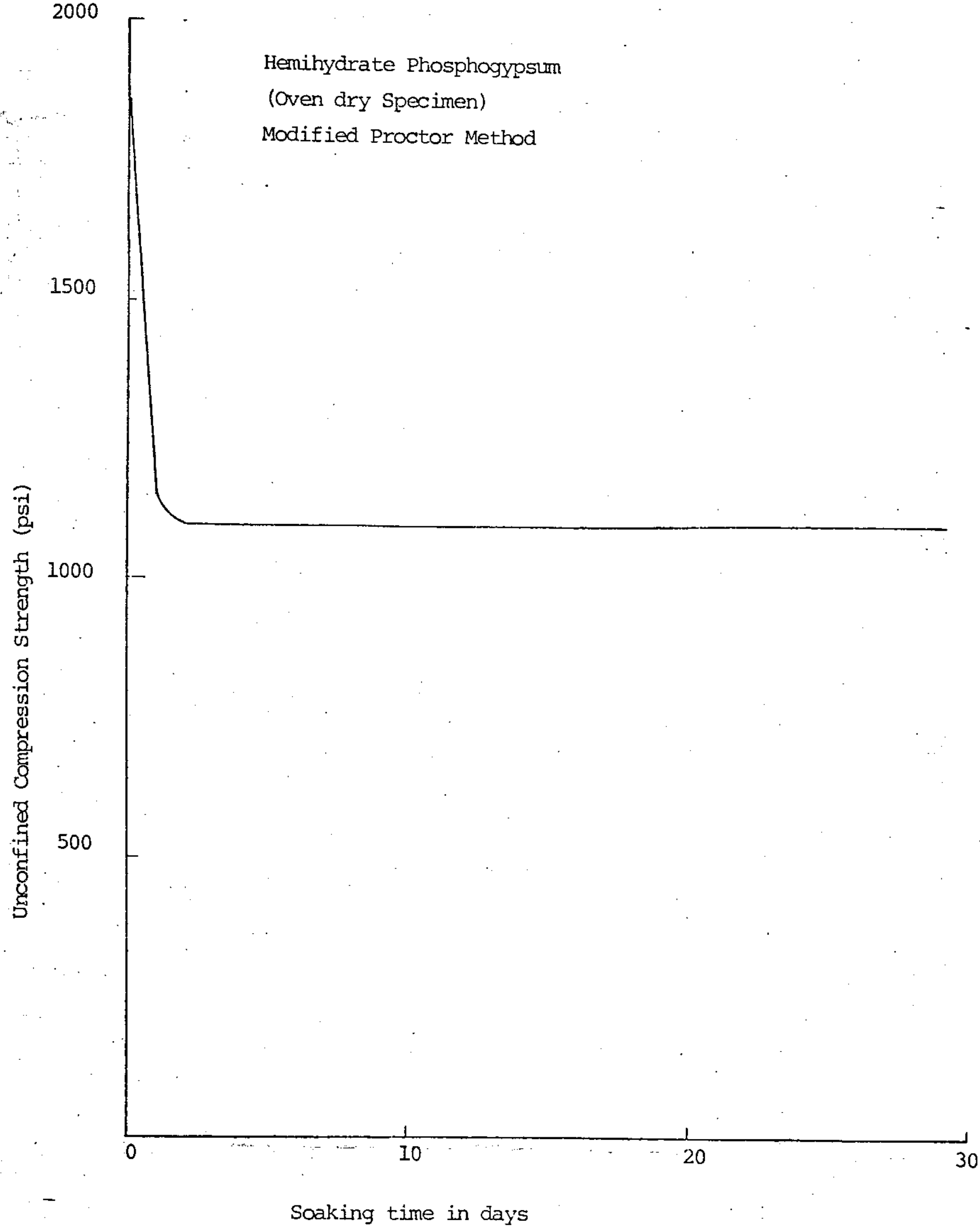


FIGURE 7



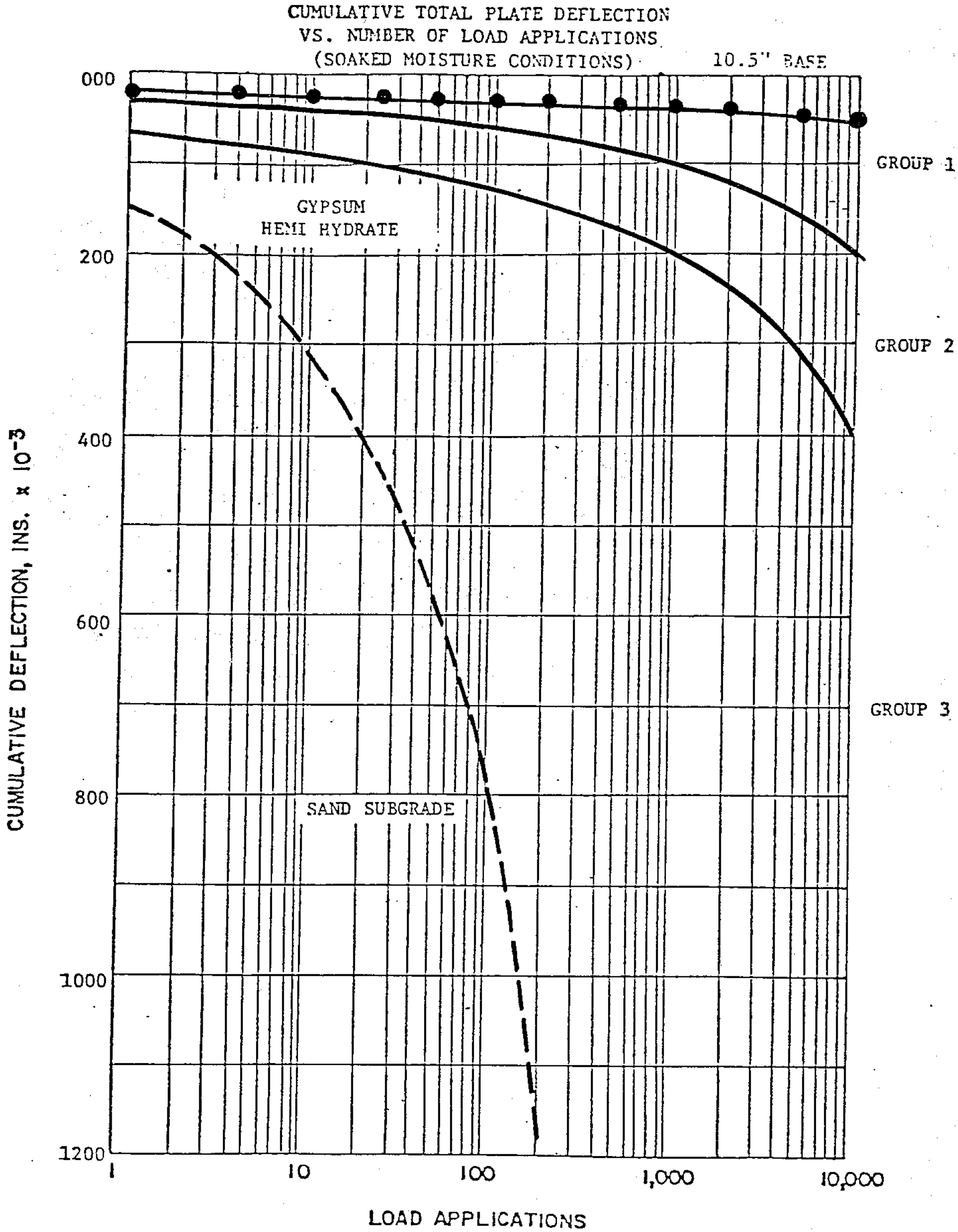
Hemihydrate Phosphogypsum
(Modified Proctor Method)
Unconfined Compressive Strength (psi)
600
500
400
300
200
100
Strength (air dry)
Strength (soaked)
Dry Density
130
120
110
Dry Density (lbs/ft3)
7
8
9
10
11
12
Moisture Content (%)

FIGURE 8



Hemihydrate Phosphogypsum
(Oven dry Specimen)
Modified Proctor Method
2000
1500
1000
500
Unconfined Compression Strength (psi)
0
10
20
30
Soaking time in days

FIGURE 9

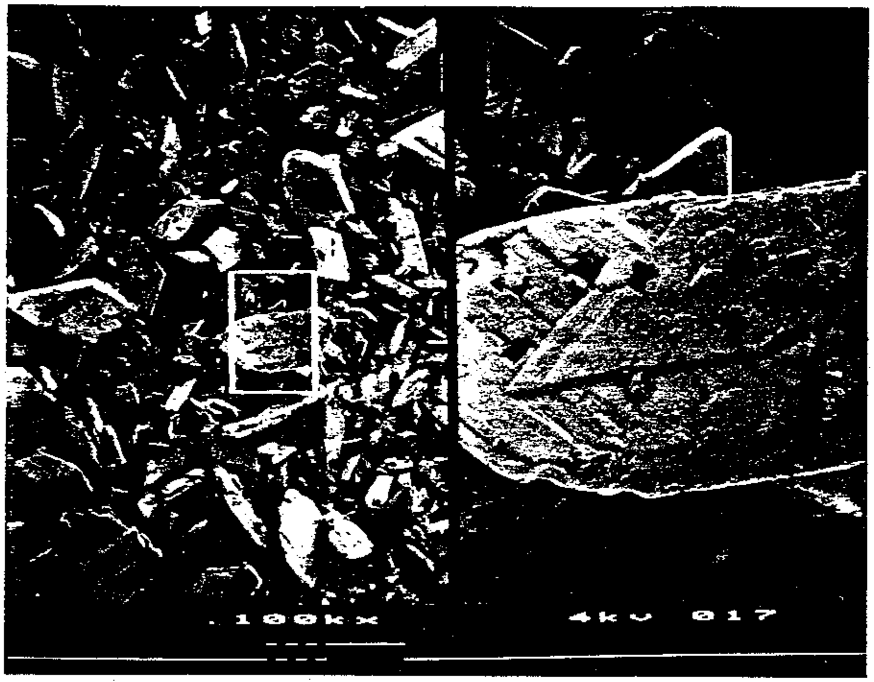


BASE MATERIAL TESTED USING STANDARD
FDOT TEST PIT METHODS

FIGURE 10

CRYSTALS OF HEMIHYDRATE PHOSPHOGYPSUM

FIGURE 11



CRYSTALS OF DIHYDRATE PHOSPHOGYPSUM

FIGURE 12

MOISTURE CONTENT TESTS FOR GYPSUM TEST ROAD

% OPTIMUM H20 CONTENT %	SECTION NUMBER	SPEEDY METHOD	NUCLEAR METHOD	CONVENTIONAL METHOD
14.5	1	12.4	19.6	16.3
14.5	1	17.6	21.5	21.7
10.7	2	9.9	17.8	12.5
10.7	2	7.5	17.1	13.5
7.0	3	17.0	20.9	11.4
7.0	3	9.9	18.2	9.0
20.5	4	13.9	24.0	15.3
20.5	4	15.9	28.2	16.8

TABLE 1

ANALYSIS OF PHOSPHOGYPSUM USED IN THE TEST ROAD (WT %, ON DRY BASIS)

COMPONENT	HEMIHYDRATE STACK SAMPLE	DIHYDRATE STACK SAMPLE
CaO	35	34
SO_4	60	61
SiO_2	1.5	1.8
FREE MOISTURE	19	16
pH	3.8	2.4
% HEMIHYDRATE	3	0

TABLE 2