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EXCOGITATED COMPOSITE MULTIFUNCTIONAL LAYER FOR PAVEMENT SYSTEMS

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EXCOGITATED COMPOSITE MULTIFUNCTIONAL LAYER FOR PAVEMENT SYSTEMS

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EXECUTIVE SUMMARY

The important material parameters for the Excogitated Composite Multifunctional (ECM) layer components were evaluated. Moisture vapor transmission, reinforcement layer strength, and shear properties were evaluated. Through use of a modified CBR test the initial behavior properties of a prototype ECM layer were studied. The test results from this study indicate that an ECM layer which would contribute to major improvement in pavement performance was feasible.

Through additional research and testing, a New Improved ECM layer was developed which provided better multiple function properties than the initial ECM layer as well as a geogrid product. The three-dimensional design of the New Improved ECM layer was found to provide both excellent shear properties to a granular layer in addition to reinforcement properties.

The New Improved ECM layer was evaluated in a large 1.83-m X 1.83-m X 1.02-m deep (6-ft X 6-ft X 3.33-ft) test cell under dynamic loading conditions. A test section consisting of 10.16 cm (4 in.) of open graded CA7 crushed stone base placed on 76.2 cm (30 in.) of AASHTO A-6 subgrade soil compacted at a dry density of 1810.1 kg/m3 (113 pcf) and optimum water content of 15% was used in the study. A water table level was held at the bottom of the clay layer. Permanent deformation in a 30.48-cm (12-in.) diameter plate loaded at a unit pressure of 292.3 kPa (42.4 psi) was measured as a function of dynamic load pulse. Load deformation tests were conducted to evaluate the performance of the New Improved ECM layer placed between the open graded CA7 crushed stone base and the A-6 subgrade soil when compared to other materials.

Load-deformation tests were conducted with base course-subgrade separation layers consisting of a 227 g (8 oz) nonwoven geotextile, a Tensor BX-1200 geogrid, the New Improved ECM layer, and a section with no separation layer (basecourse directly on subgrade). Figure 11 shows the results from the large cell load-deformation tests. As shown in Figure 11, the New Improved ECM layer performed far better than the geotextile and geogrid sections and the section with no separation layer.

In summary it was found that the New Improved ECM layer shows promise to satisfy multiple performance functions in pavement systems to include base course-subgrade separation, base course shear strength, base course tensile strength, and drainage. The New Improved ECM layer performed better than other geosynthetics evaluated. Full scale testing of the ECM layer in the field is proposed.

INTRODUCTION TO IDEA PRODUCT AND RESEARCH OBJECTIVES

The purpose of this study was to develop an innovative excogitated composite multifunctional (ECM) layer that would provide for design and construction of pavements with improved performance and design life. The ECM layer (see Figure 1) was envisioned as a three-dimensional material that would satisfy multiple functions in the pavement system by providing for subbase layer-subgrade separation, subbase shear strength, subbase tensile strength, drainage, and protection of the subgrade from surface infiltration.

The general objective of this study was to develop, fabricate, and evaluate one or more ECM layers for pavement systems. The study tasks to achieve these objectives were as follows:

- ⇒ TASK 1: Develop the concept of the ECM layer.
- ⇒ TASK 2: Select materials for the ECM layer and fabricate a prototype ECM layer.
- ⇒ TASK 3: Complete experimental testing and improvements in the ECM layer at bench scale.
- ⇒ TASK 4: Determine the efficacy of the ECM layer for pavement application.
- ⇒ TASK 5: Complete a Final Report.

CONCEPT AND INNOVATION

The ECM layer is considered to be a bold, innovative concept for pavement design and construction and should provide significant improvement in pavement performance and design life at minimal increase in pavement cost. The ECM layer has the traits of rapid deployment, easy construction, portability, strength, and durability. Because it is flexible, the ECM layer can be taken to the construction site in a roll and placed by methods similar to those for placing geotextiles. Placement costs for the ECM layer are expected to be minimal.

The ECM layer is expected to be highly effective when used with open-graded aggregate subbases since it will act as a separation layer and provide improved shear to the subbase. It will eliminate the need for a geotextile filter layer or granular filter layer between the subgrade and the open-graded subbase. It is also believed that the ECM layer concept could be used to decrease reflective cracking in asphalt concrete overlays.

IDEA PROJECT INVESTIGATION

The main objective of the IDEA project was to develop, fabricate, and evaluate one or more innovative ECM layers for pavement systems. Research was conducted in the design and selection of materials that would satisfy the geometry and multifunctional requirements of the ECM layer in a pavement system. Major emphasis was placed on the development of lightweight and strong materials that can easily be deployed into rapid and economical pavement construction using available construction equipment. Both natural and synthetic materials were investigated for use in the ECM layer.

The major requirement of the ECM layer is to satisfy multiple pavement performance requirements by providing lateral drainage, subgrade protection and separation, tensile strength, and shear resistance in an aggregate subbase. To accomplish these multifunctional requirements, the development and evaluation of a three-dimensional material were emphasized.

This study used finite element procedures to define relationships between the ECM layer geometry, load, and material property requirements. The major finite element program used for this task is ILLI-PAVE (1). The ILLI-PAVE program can model composite designs with different numbers of layers, different ordering of layers, different layer properties, and a variety of other material characterizations. Once material properties were defined using ILLI-PAVE, the ECM layer was fabricated and evaluated in the laboratory to determine if it met the required performance criteria.

On the basis of initial ECM layer evaluations, a New Improved ECM layer was developed to meet the criteria necessary for substantially increased pavement performance.

MATERIALS SELECTION AND INITIAL EVALUATION OF ECM LAYER

Numerous materials, both synthetic and natural, were evaluated for use in the ECM layer for pavement systems. Materials properties were rated with both standard and non-standard index test methods. Index tests were employed to compare material properties rather than evaluating performance behavior. The index tests performed on the prospective materials were utilized to isolate and compare specific material properties that were important to development of the ECM layer.

A broad range of wide strip tensile strength data (ASTM D4595) for this project was available from other studies. Considerable strength data was also available for various geosynthetics in the Geotechnical Fabrics Report Specifiers Guide (2).

A series of water vapor transmission tests were conducted following ASTM E96 procedures to identify a geosynthetic to meet the ECM layer vapor conductivity requirements. A non-woven geotextile, MERGE, and a geomembrane-geotextile composite, PETROPAVE MB, (both manufactured by Phillips Fibers Corporation) were compared in these tests. The PETROPAVE MB was modified by needle punching a specified number of holes in order to enhance the vapor conductivity. Study results indicated that the MERGE geotextile provided greater vapor transmission than the PETROPAVE MB, even with needle holes added. The MERGE geotextile also easily met the requirements of the ECM layer for water vapor transmission. The ECM layer must allow subgrade moisture in the vapor state to pass upward to prevent a high water content layer from occurring immediately under the geocomposite.

The shear strength and tensile strength of various materials were examined for the reinforcement component of the ECM layer. Two prototype ECM layers (designated as ECM layer and New Improved ECM layer) were constructed and tested for comparison with generally used materials. The direct shear strength comparisons were made in the lower 2.54 cm (1 in.) of an open-graded aggregate base course material placed on the subgrade soil, a woven geotextile (SUPAC 6WS), a geogrid (Tensar BX-1200), an ECM layer, and a New Improved ECM layer. Figure 2 shows that both the ECM layer and New Improved ECM layer provided greater shear resistance in the lower portion of the open-graded base course aggregate than the other materials. The improved shear strength is especially evident in the New Improved

ECM layer at the higher normal stresses. This is caused by the higher polymer stiffness and more strain-resistant geotextile used in the New Improved ECM layer.

In order to evaluate the reinforcement properties of the ECM layers, the tensile strength properties were determined using the guidelines of ASTM D4595 for wide strip test sections. Figure 3 shows the wide strip tensile test results for a geogrid, ECM layer, and New Improved ECM layer. The letters M and X in the legend refer to the orientation of the materials during the test, with M being the machine direction and X being the cross machine direction. Although the tensile strength of the geogrid was mobilized before that of the ECM reinforcement layers and had higher peak tensile stress values in both orientations, it is believed that the ECM layer tensile strength is well within acceptable limits. The letter F in the legend indicates that a bonded geotextile was part of the ECM layer. The New Improved ECM layer showed improved tensile strength properties when compared to the original ECM layer at low strain values. These strength properties are believed to be adequate to satisfy the reinforcement needs in granular base courses.

A modified California bearing ratio (CBR) test was used to compare granular base course reinforcement and shear influence of the ECM layer with base courses with no geosynthetic (control) and geogrid (Tensor BX-1200). All materials were tested in a 30.48 X 30.48 X 30.48-cm (12X12X12-in.) steel container using varying thickness of open-graded crushed stone (15.24 cm and 20.32 cm [6 in. and 8 in.]) over stiff crumb rubber pads used to model a very soft subgrade, Figure 4. Loads were applied to an Illinois CA16 aggregate surface through a CBR piston at a rate of 2.54 mm/min (0.1 in./min). Figures 5 and 6 show the results of these tests. The New Improved ECM layer provided substantial strength improvement in the open-graded crushed stone material in all the tests when compared with no geosynthetic. This layer performed much better than the geogrid in all tests as well.

The results of these tests indicated that the New Improved ECM layer demonstrated the material properties important to its performance as a multifunctional layer in pavement systems. The magnitude of the loads in Figures 5 and 6 are dependent on both the shear properties and the tensile strength of the ECM layer. It is the three-dimensional design of the ECM layer that provides excellent shear properties that supplement the reinforcement properties.

LARGE TEST CELL EVALUATION OF NEW IMPROVED ECM LAYER

A 1.83-m X 1.83-m X 1.02-m deep (6-ft X 6-ft X 3.33-ft) test cell was constructed for use in evaluating the New Improved ECM layer under dynamic loading conditions. Figure 7 shows the completed test cell along with a computer assisted programmer - controller for the hydraulic loading ram. A commercial Moscow, Missouri brick clay (AASHTO A-6) was compacted in the test cell to a depth of 76.2 cm (30 in.) at a dry density of 1810.1 kg/m3 (113 pcf), and at optimum water content of 15%. A water table level was held at the bottom of the clay layer by use of an external reservoir, Figure 8. Figure 9 shows a typical profile for the layers in the test cell. After the subgrade soil came to equilibrium with the water table, it displayed a CBR strength of about 1.7% as determined from cone penetration data.

Figure 10 shows the 30.48-cm (12-in.) diameter loading plate and frame used to position the load deflection transducers on the plate. A total load of 21.35 kN (4,800 lbs) or a unit pressure of 292.3 kPa (42.4 psi) was applied to the plate. This unit pressure was determined to be similar to the vertical compressive stress on a granular base course caused by a 40.03 kN (9,000 lb) dual wheel load placed on a 7.62-cm (3-in.) thick asphalt concrete surface over the base course. A steel surcharge plate was placed on top of the granular base course to simulate a 7.62-cm (3-in.) thick asphalt concrete surface in the dynamic loading test. The 30.48-cm (12-in.) diameter loading plate was positioned in a 35.56-cm (14-in.) diameter hole in the center of the surcharge plate. The dynamic load pulse was in the shape of a haversine which was applied to the plate at a rate of 60 cycles/min.

The dynamic loading test was conducted using 10.16 cm (4 in.) of open graded Illinois CA7 crushed stone base course material, Table 1. Tests were conducted using a 227 g (8 oz) nonwoven geotextile as the control separation layer between the A-6 subgrade soil and the open graded CA7 base course material. As shown in Figure 11, comparisons of the permanent deformations measured at the 30.48-cm (12-in.) diameter plate as a function of load applications were conducted for the geotextile control section, a Tensar BX-1200 geogrid section, the New Improved ECM layer section, and a section with the crushed stone base course placed directly on the subgrade (identified in Figure 11 as no layer). Figure 11 shows that there was substantially less permanent deformation measured in the New Improved ECM layer section as compared to the geotextile control section, geogrid section, and section where no layer was used (base course directly on subgrade). In all of the tests conducted, it was found that permanent deformation occurred in both the open graded base course material and the subgrade. However, the amount of permanent deformation in the subgrade was observed to be less under the ECM layer when compared to the geotextile control and geogrid sections at the end of the dynamic loading tests. In the geogrid test section, it was observed that some aggregate base course material became mixed with the subgrade soil which contributed to the permanent deformation. A considerable amount of base course and subgrade mixing was noted in the test where no separation layer was used. From Figure 11 it would appear that the New Improved ECM layer provided reinforcement to the open graded base course material and performed better than the geogrid section and geotextile control section. The ECM layer provided separation between the subgrade and open graded base course material similar to that provided by the nonwoven geotextile. It was also felt that the shear properties of the New Improved ECM layer contributed to the lower permanent deformation observed in the dynamic loading tests.

DISCUSSION OF TESTING RESULTS

In the initial evaluation it was found that the New Improved ECM layer provided for substantially greater shear resistance and CBR piston loads than the other products used for comparisons. In the large test cell studies the New Improved ECM layer performed better than the geogrid and geotextile layers when placed beneath a 10.16-cm (4-in.) open graded base course layer. It is believed that the multiple function properties of the ECM layer that included separation, tensile strength, and shear strength contributed to better performance when compared to other materials used in the dynamic loading test program.

It was obvious from the dynamic loading tests that a satisfactory separation layer is required between the open graded CA7 base course material and the soft A-6 subgrade soil. Intermixing of the base course and subgrade was observed in both the geogrid section and the section in which no separation layer was used. Although both the geotextile and ECM layer satisfy the separation criteria, it is felt that the reinforcement and shear properties of the ECM layer are much better than those for the geotextile tested.

APPLICATION OF ECM LAYER

Based on this study, it is believed that the New Improved ECM layer will provide for improved performance in airport and highway pavement systems. It may also be possible to use it to improve ballast performance in railroad track systems.

In this study the ECM layer was found to satisfy multiple functions by providing subgrade separation, shear strength, and tensile strength in a granular base course material. In cases where an open graded base course is used, the ECM layer will also enhance the drainage properties.

When used in airport and highway pavement systems, the New Improved ECM layer should perform well beneath both open graded and dense graded base courses placed under rigid or flexible pavement surfaces.

During testing, the ECM layer was found to bridge over large voids in the underlying subgrade, Figure 12. This property is a function of both the shear strength and tensile strength of the ECM layer. An example of the ECM layer use in this type of application would be in freeze-thaw environments where pavement shoulder rotation often creates large openings in both the subgrade and pavement surface.

An interesting use of the New Improved ECM layer could be in the construction of a thin pavement surface such as that shown in Figure 13. It is felt that the ECM layer could be used to replace some base course materials in low volume roads. This system could work especially well in cases where the subgrade soil strength has been improved through stabilization procedures. It is felt that other applications of the New Improved ECM layer will be found as engineers become familiar with its performance properties and its uses in pavement and track structural systems.

RESEARCH SUMMARY

A research study was conducted to develop an Excogitated Composite Multifunctional (ECM) layer for pavement systems. Based on research findings, a New Improved ECM layer geosynthetic was developed that shows promise for satisfying the multiple performance functions in pavement systems to include base course-subgrade separation, base course shear strength, base course tensile strength, and drainage. The New Improved ECM layer performance in laboratory tests was considerably better than that of other geosynthetics evaluated.

The ECM layer has the important traits of rapid deployment, easy construction, portability, strength, and durability. The ECM layer can be shipped to the construction site in rolls and can be easily placed by roll-out procedures similar to geotextiles.

IMPLEMENTATION OF ECM IDEA RESULTS AND PRODUCT

The New Improved ECM layer is ready for full scale testing in a field setting. It is proposed that a field test site be developed for further ECM layer performance evaluation. Possible construction projects include but are not limited to major highway or airport systems, low volume roads, thin pavement overlays, and railroad track systems.

After construction in the field, the ECM layer system performance should be evaluated against control sections. Cost/benefit evaluation of the ECM layer should also be conducted at this time.

Based on the laboratory research results, it is believed that the ECM layer concept will be highly beneficial to improved long term pavement performance.

GLOSSARY

- ⇒ *ECM*: Excogitated Composite Multifunctional
- ⇒ *Excogitate:* To consider or think something out carefully and thoroughly.
- ⇒ *Geosynthetic:* A planar product manufactured from polymeric material used with soil, rock, earth, or other geotechnical engineering related material as an integral part of a man-made project, structure, or system.

REFERENCES

1. M.R. Thompson, ILL-PAVE Users Manual, Department of Civil Engineering, University of Illinois, Urbana-Champaign, IL, 1992.
2. Geotechnical Fabrics Report, 1993 Specifiers Guide, St. Paul, MN, 1993.

Table 1. Illinois CA7 Course Aggregate Gradation

Sieve Size
Percent Passing

GRADE	38.1 mm	25.0 mm	19.0 mm	12.5 mm	9.5 mm	4.75 mm	1.18 mm	300 um	75 um
GRADE	(1 ½")	(1")	(3/4")	(½")	(3/8")	(No. 4)	(No. 16)	(No. 50)	(No. 200)
CA7	100	95+5	-	45+15	-	5+5	-	-	-

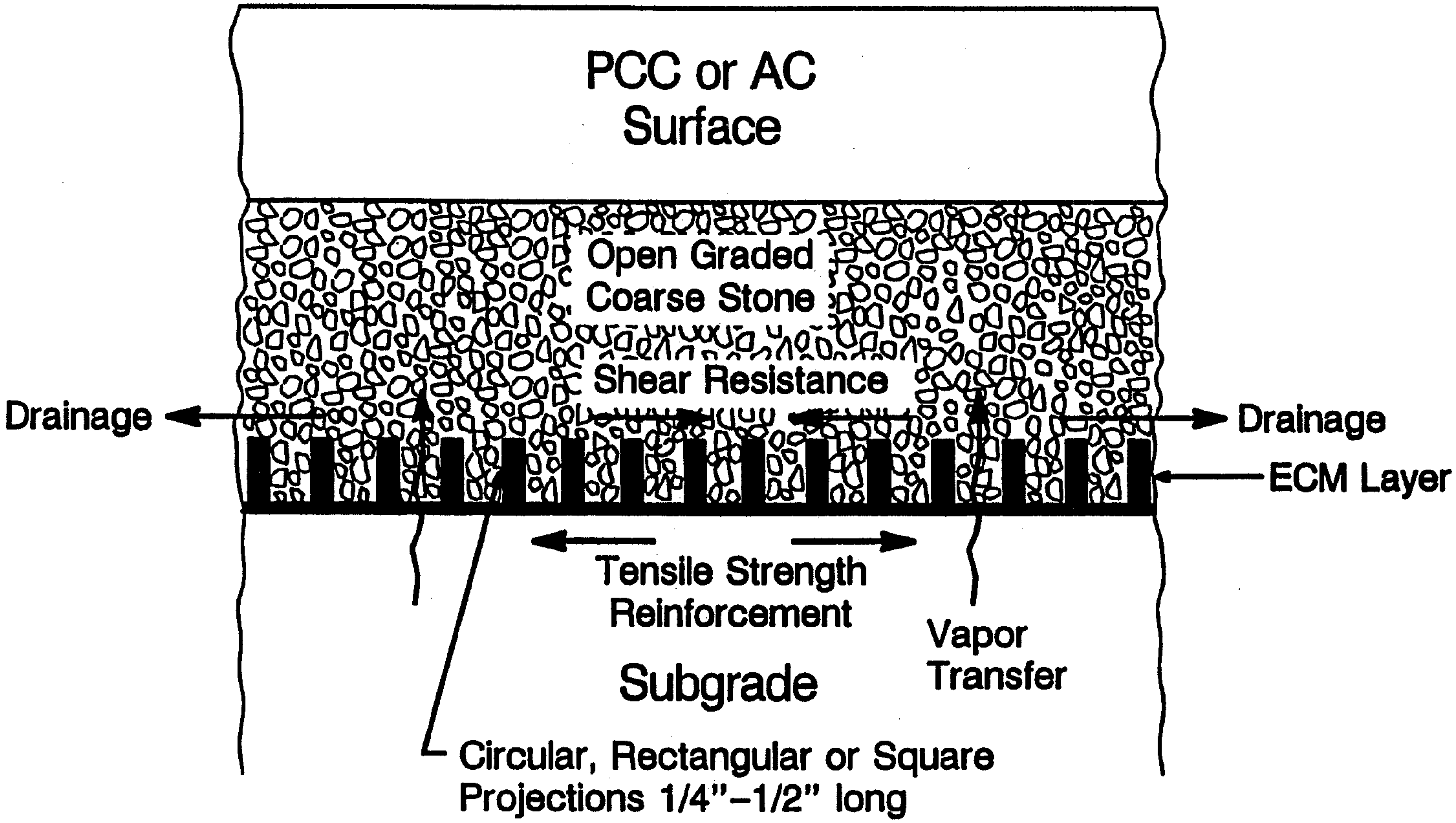

Figure 1. ECM Layer Concept and Functions.

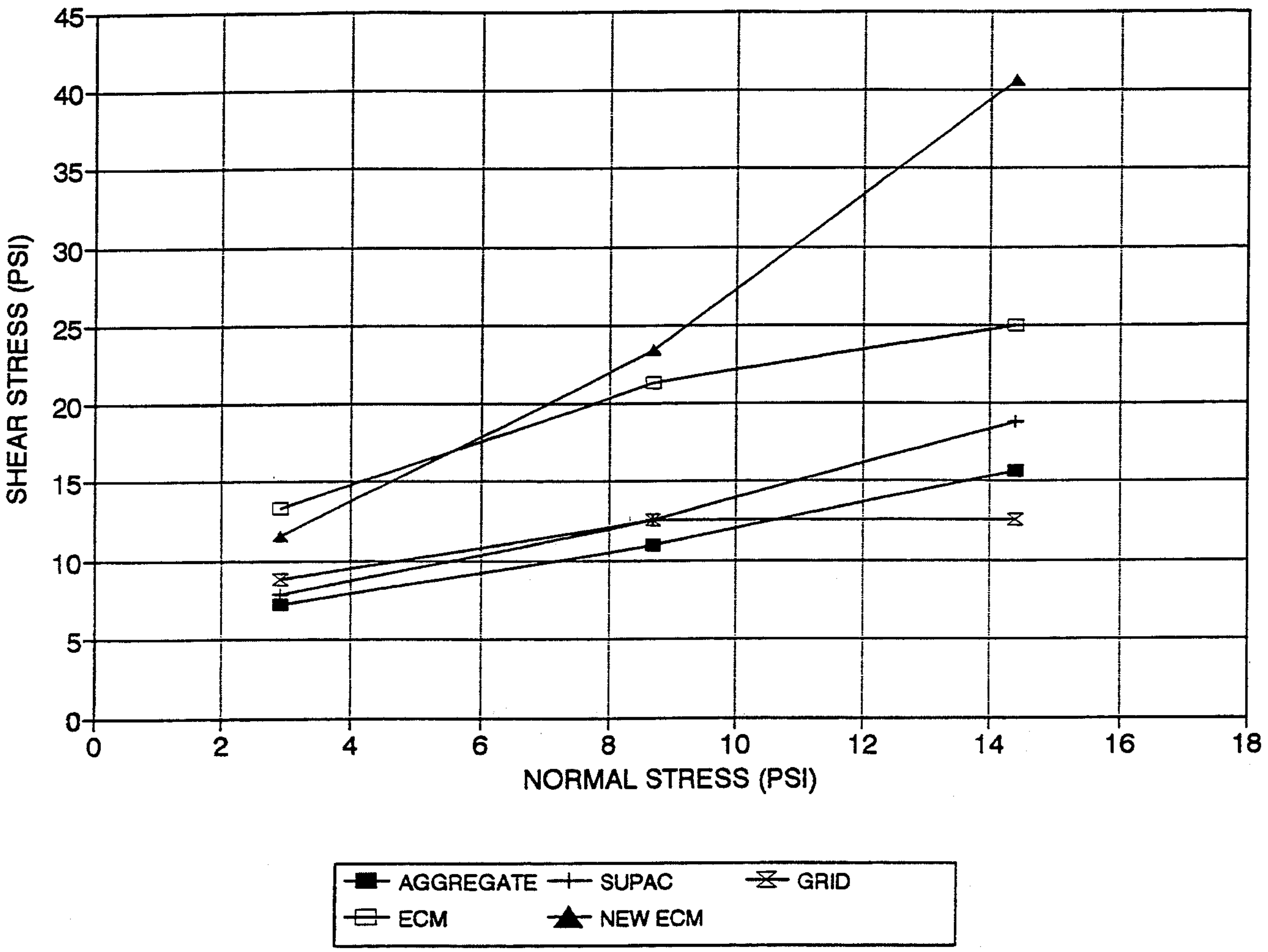

Figure 2. Direct Shear Stress Results Between Aggregate Base and Test Materials.

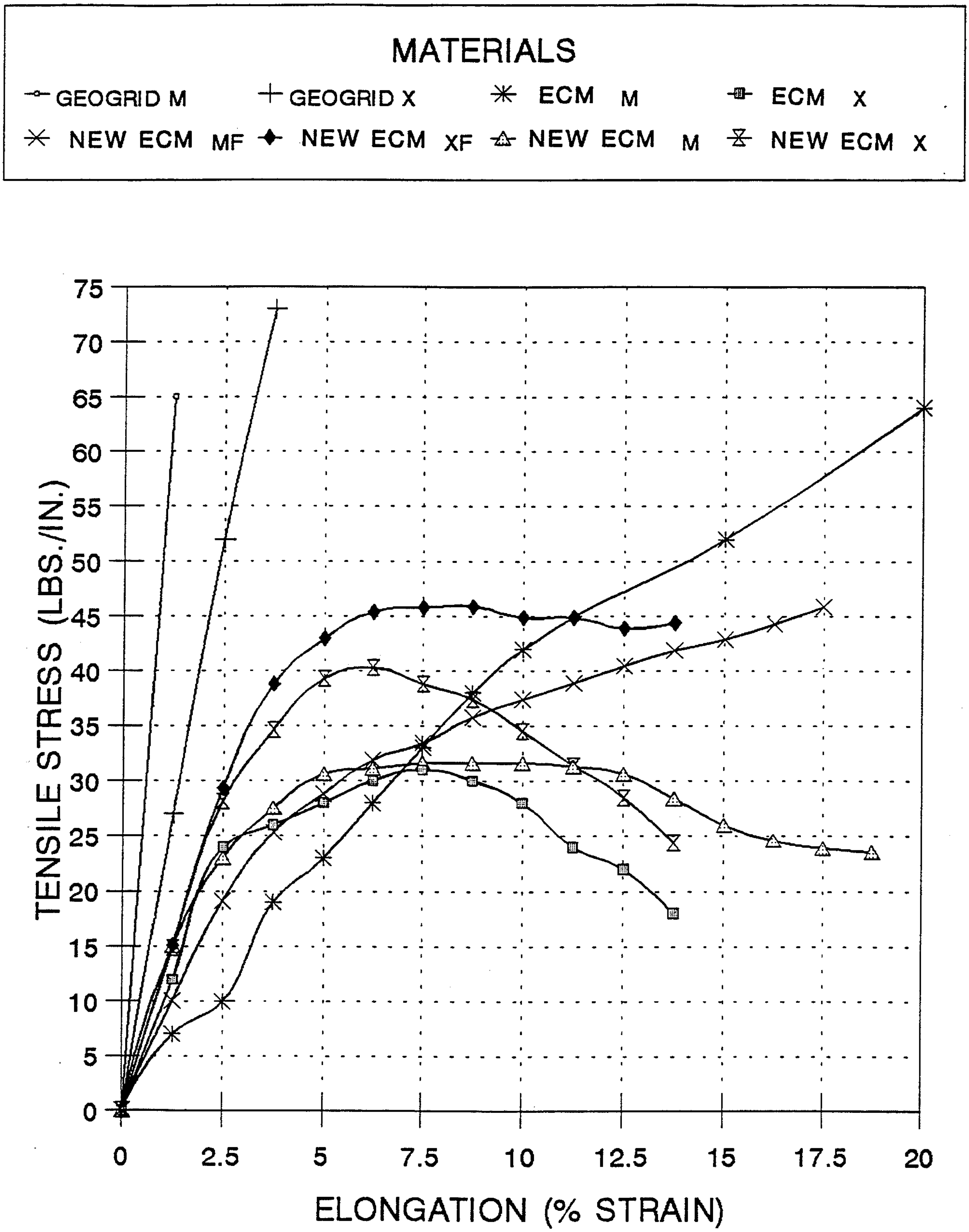

Figure 3. Wide Strip Tensile Strength Results
(Loading Rate 0.5 in./min.).

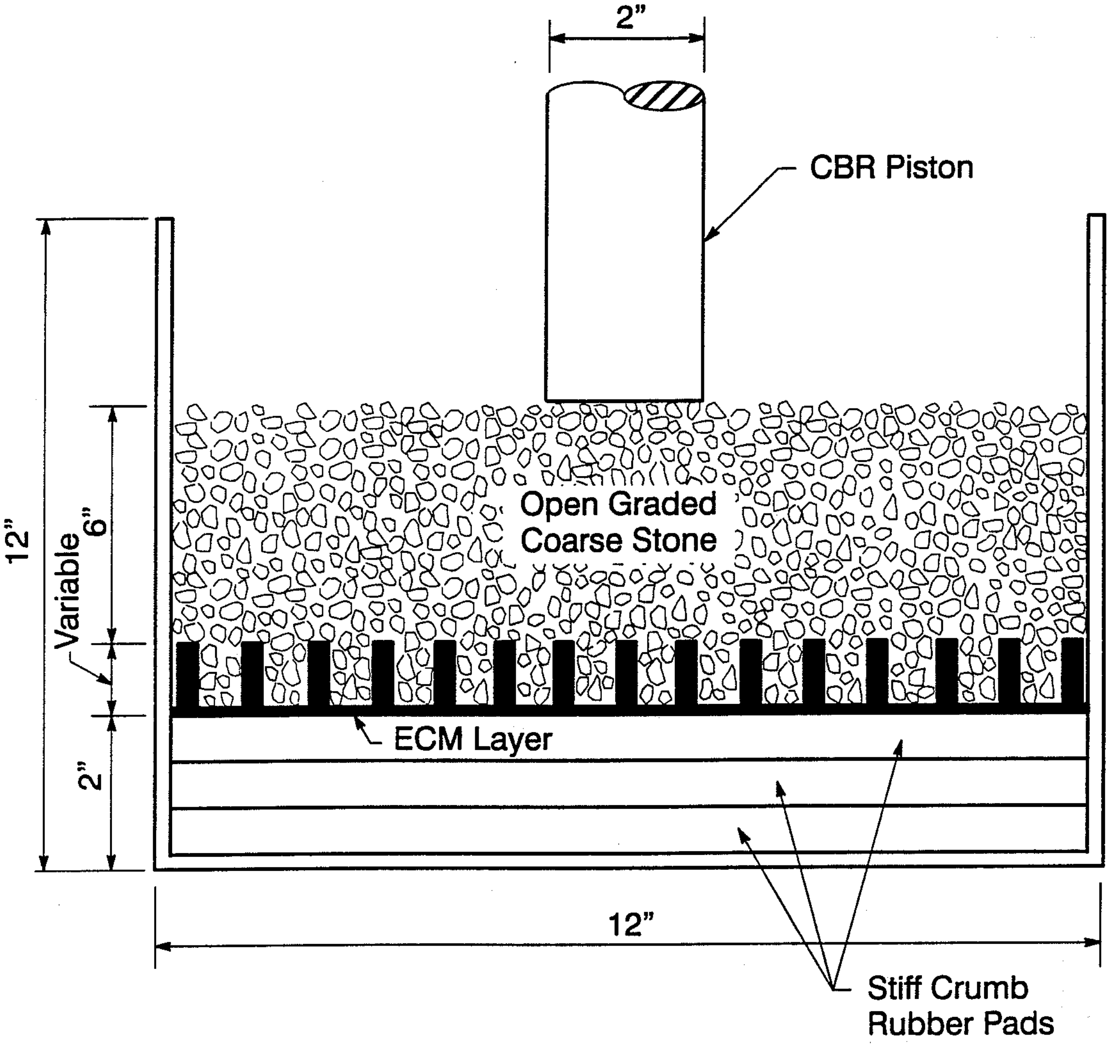

Figure 4. Test Chamber for CBR Piston Loadings.

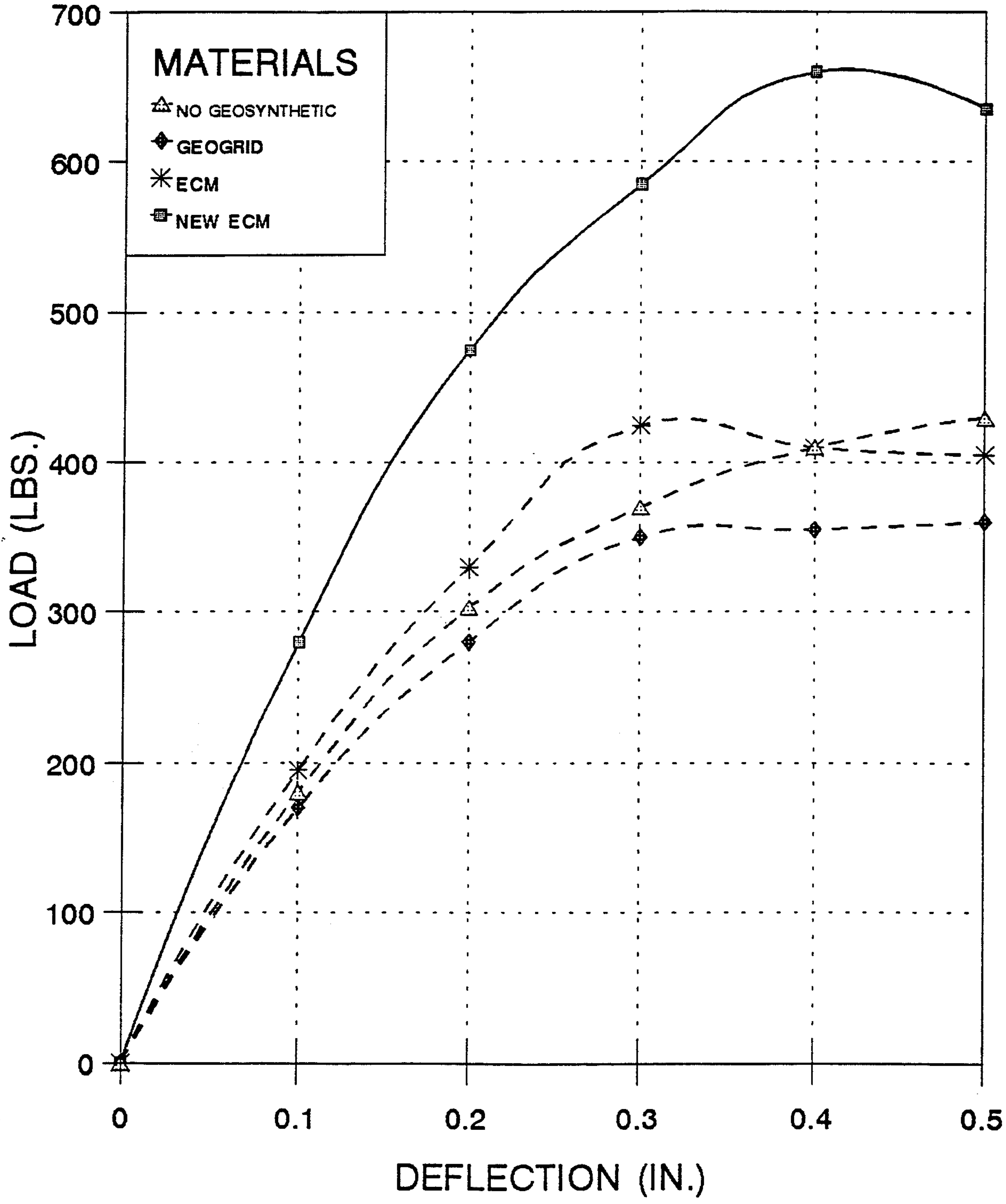

Figure 5. Load-Deflection Relationships for 6 in. of CA-16 Aggregate.

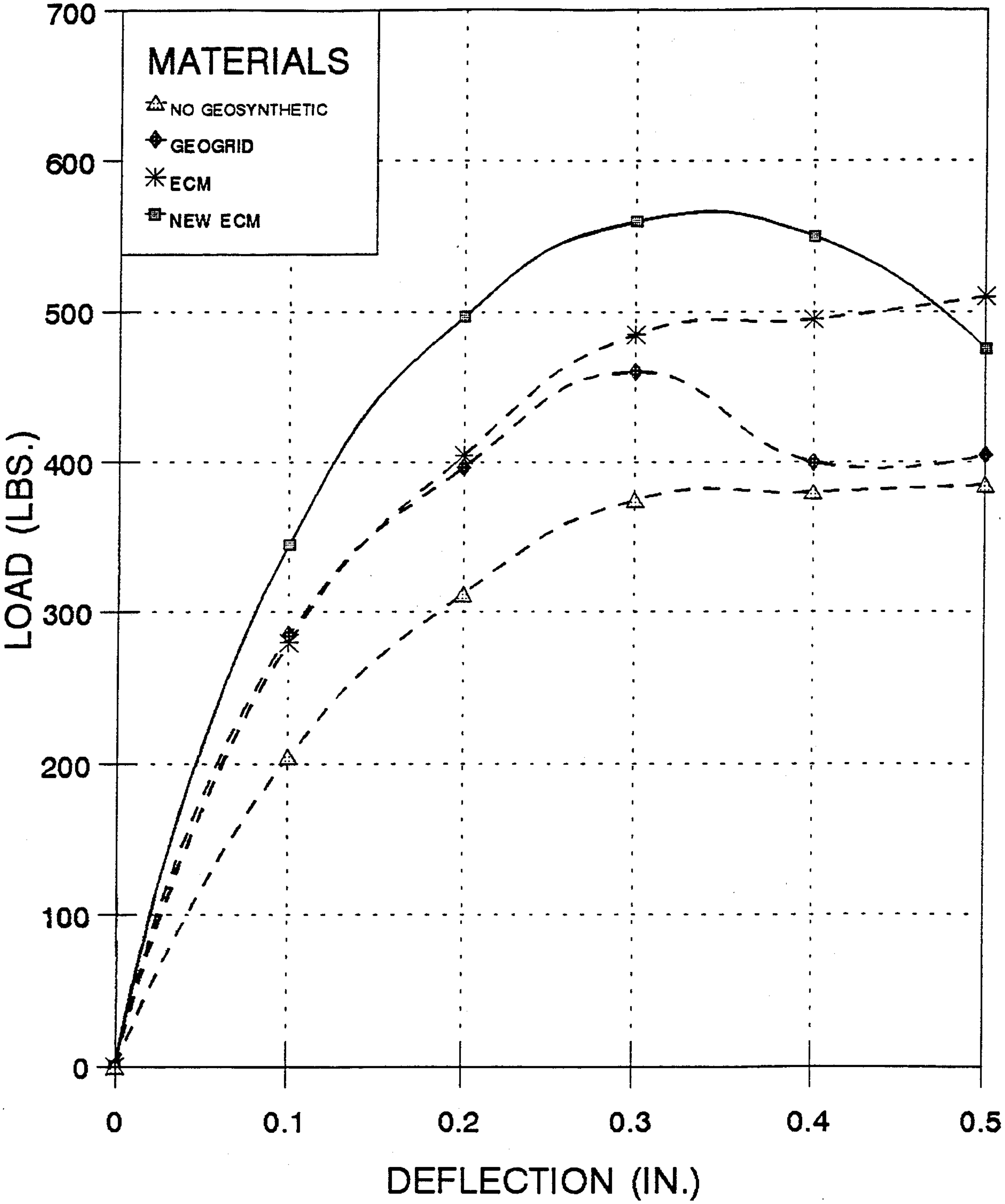

Figure 6. Load-Deflection Relationships for 8 in. of CA-16 Aggregate.

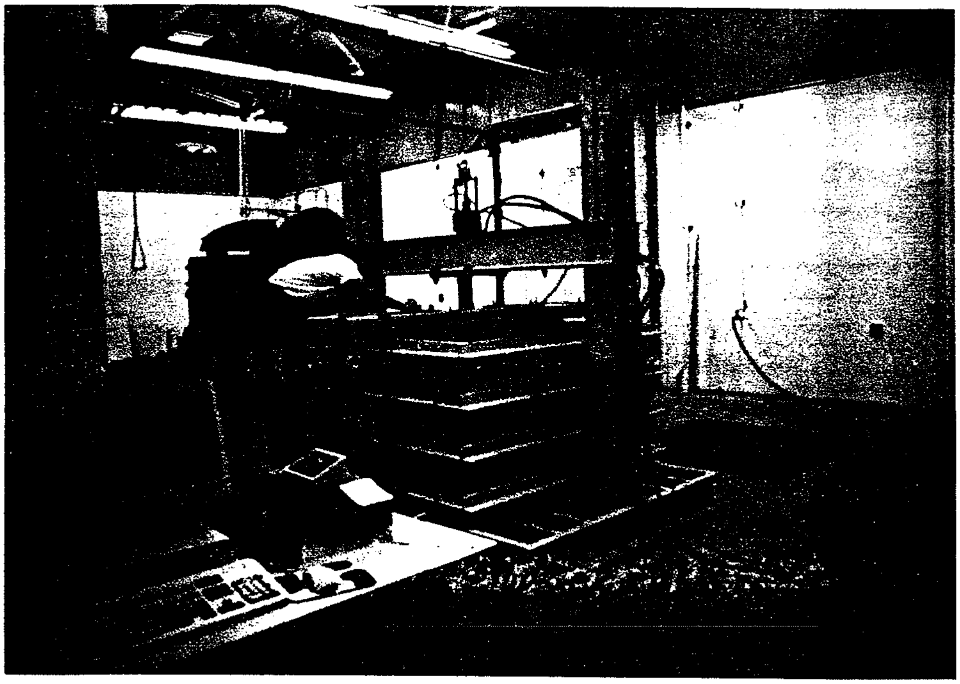

Figure 7. Large Laboratory Test Cell

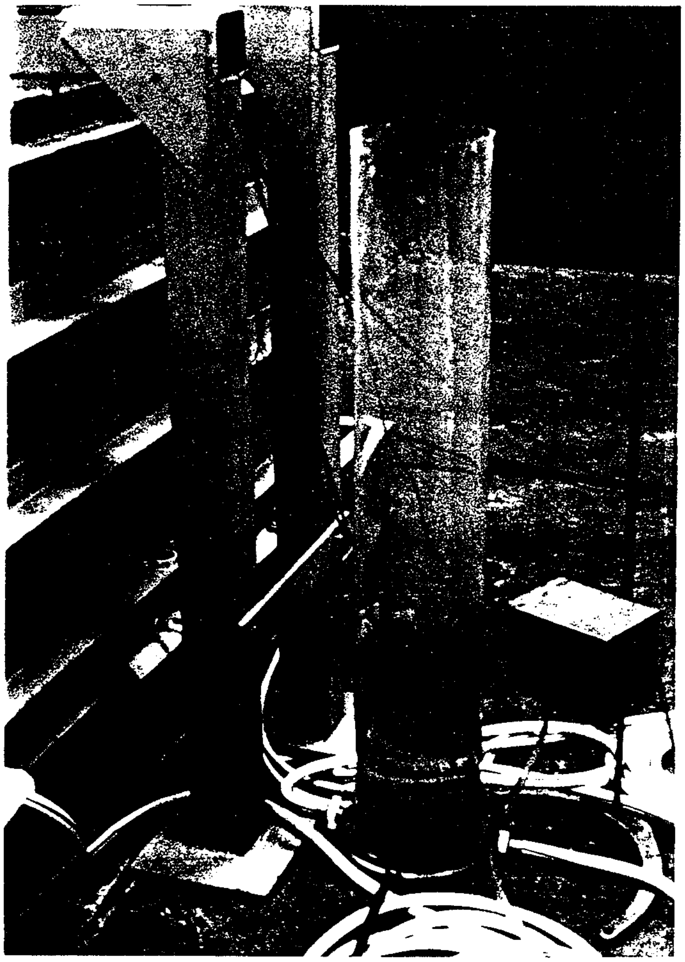

Figure 8. External Reservoir for Water Table Control in Test Cell.

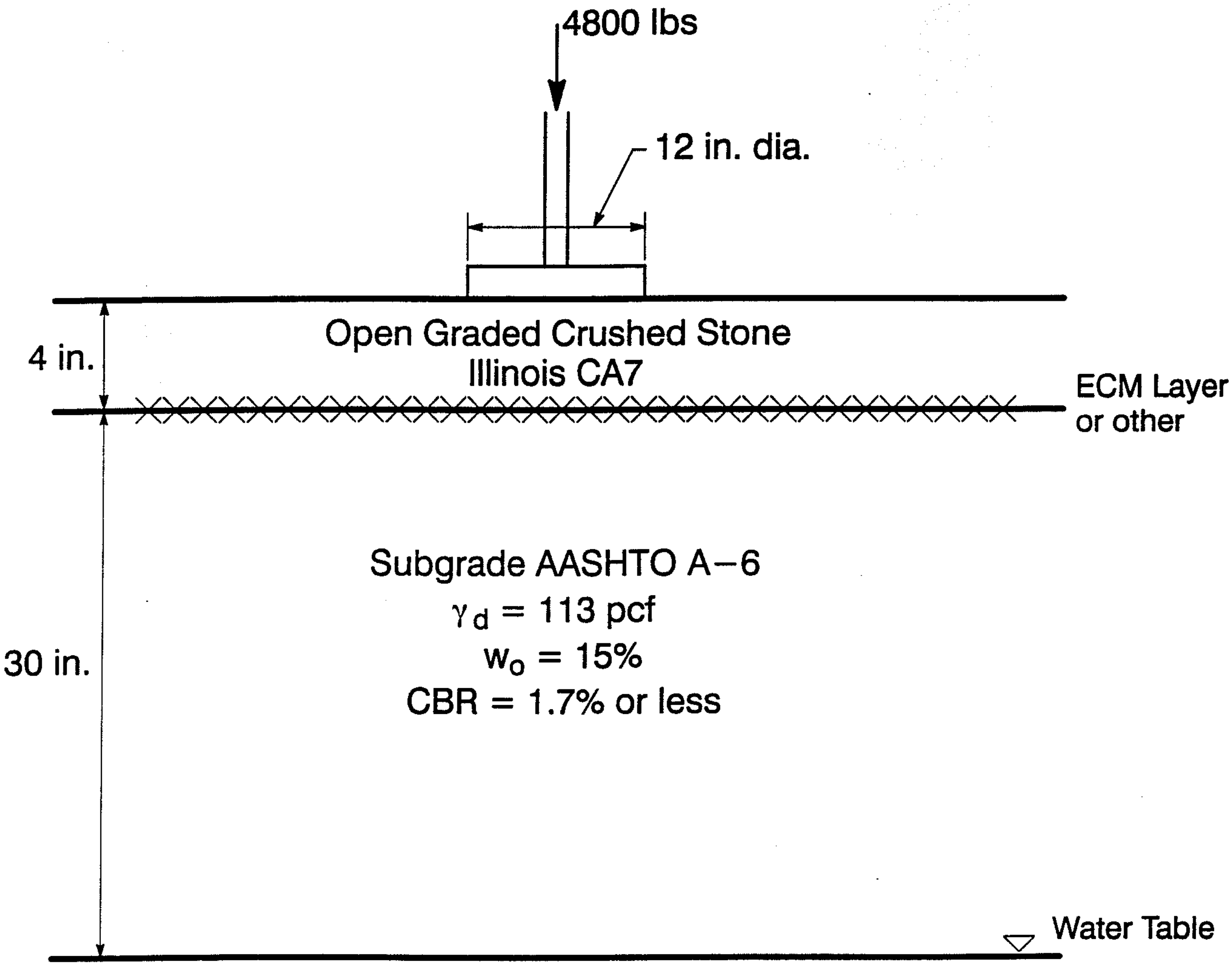

Figure 9. Layer Profile in Large Test Cell

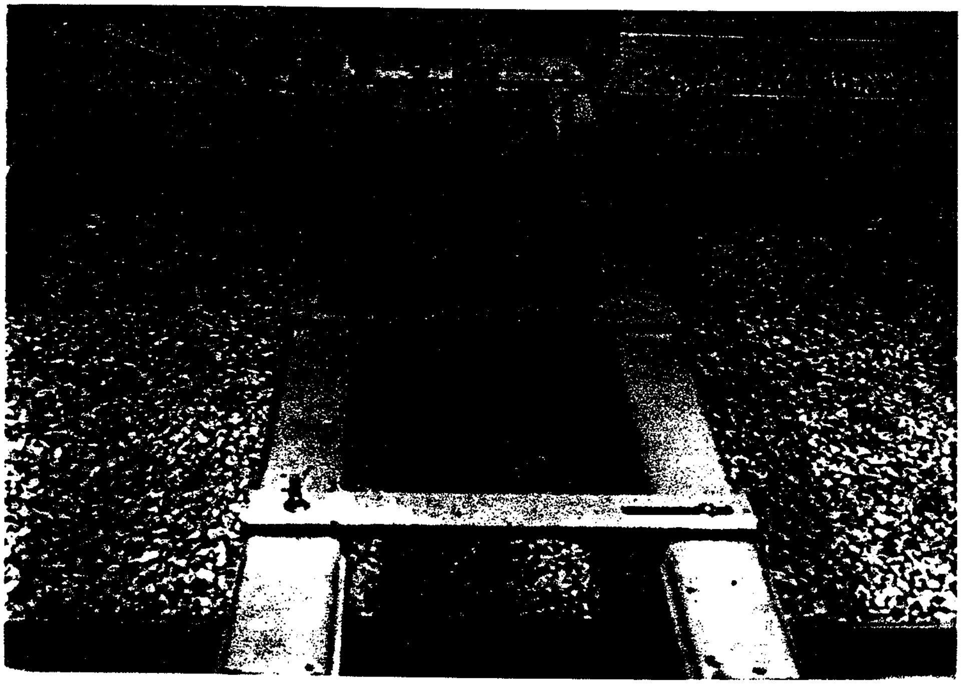

Figure 10. Loading Plate and Transducer Frame for Large Test Cell.

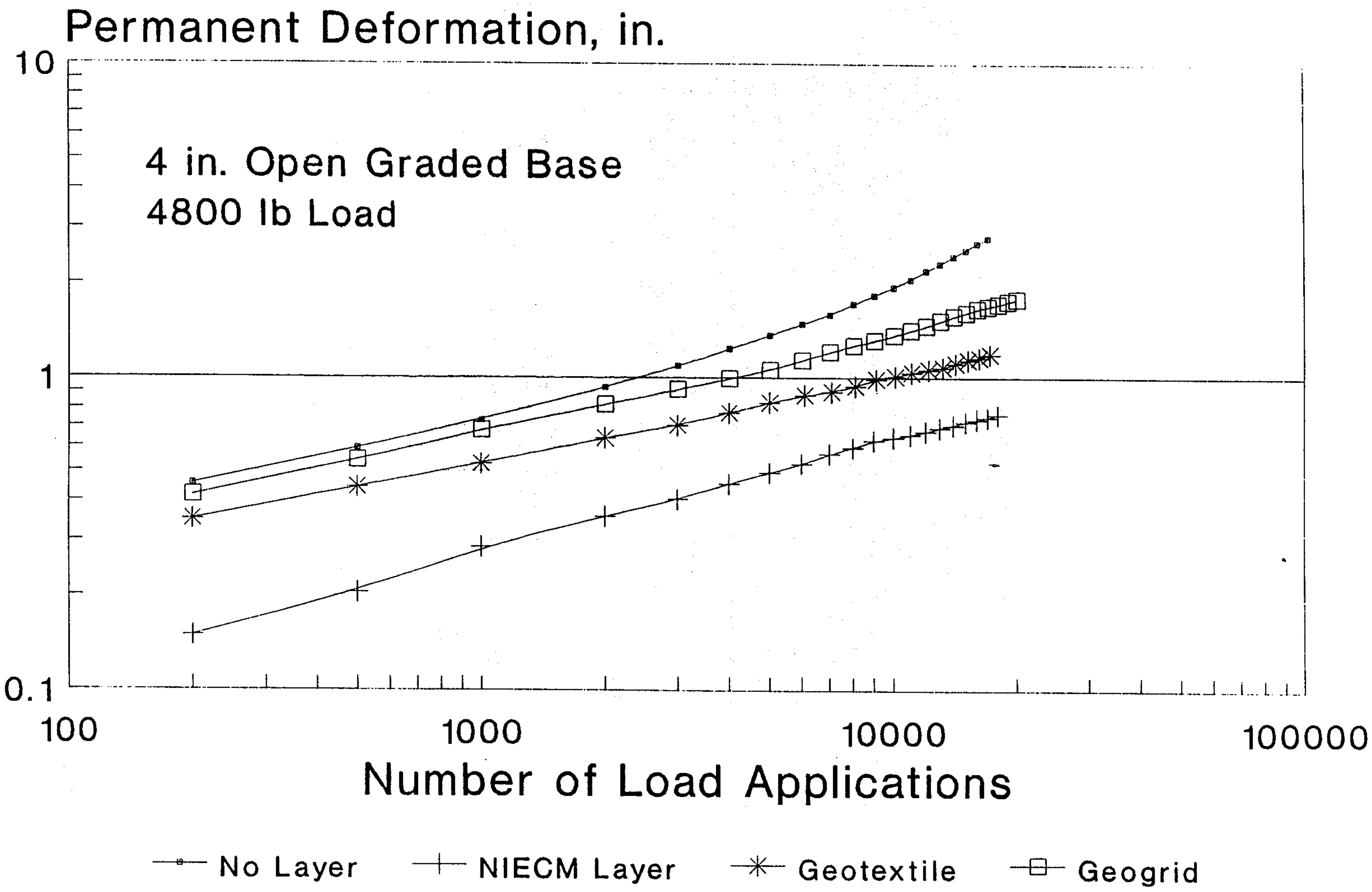

Figure 11. Permanent Deformation vs Load Applications for Large Test Cell Study.

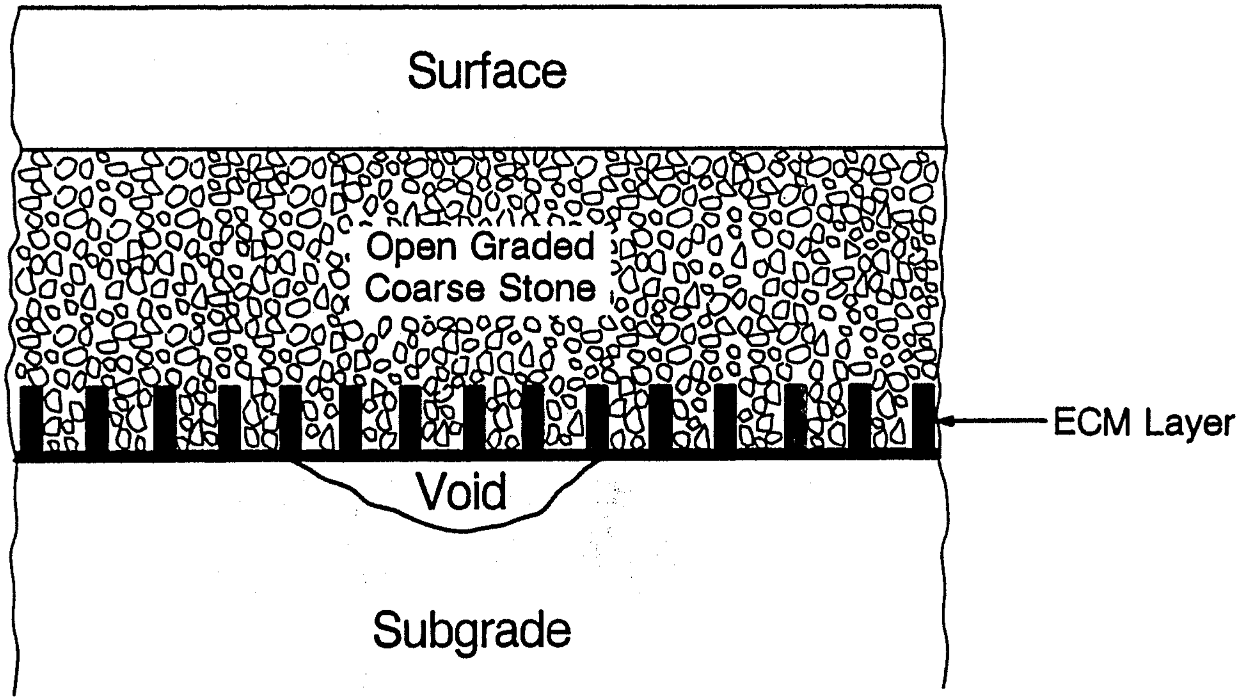

Figure 12. ECM Layer Bridging Subgrade Void.

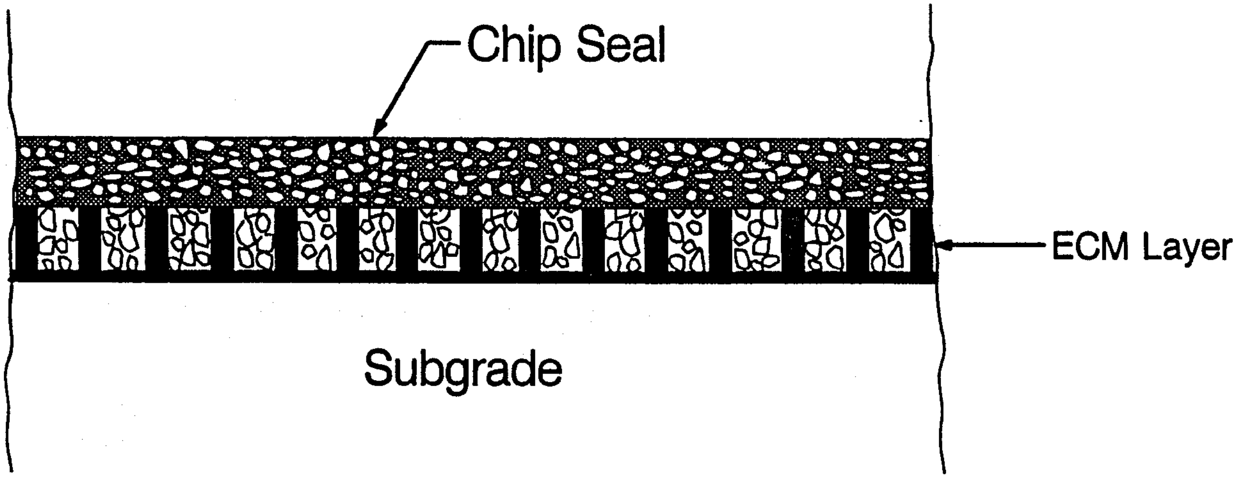

Figure 13. ECM Layer in Thin Surface Course Applications.