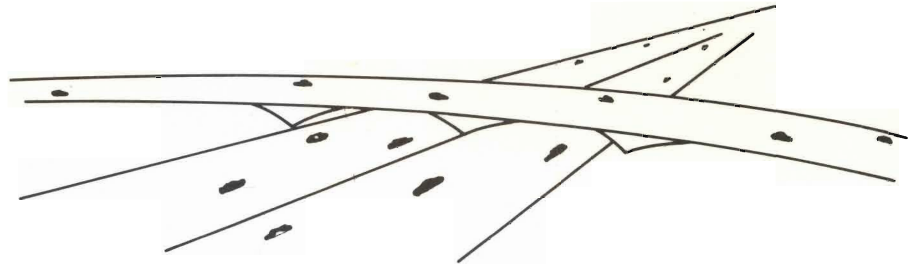

DEPARTMENTAL RESEARCH

Report Number : SS 10.3

ENERGY SAVINGS IN CONSTRUCTION AND THE CONTROL OF SWELLING SOILS

STATE DEPARTMENT OF HIGHWAYS
AND PUBLIC TRANSPORTATION

ENERGY SAVINGS IN CONSTRUCTION AND THE CONTROL OF SWELLING SOILS

Special Study Report 10.3

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District 15

September, 1978

Table of Contents

List of Figures

ABSTRACT

Energy savings are a national goal. They are attainable in many construction areas.

Swelling soils are a 4 billion dollar a year problem in America. Over half the estimated structural damage they cause affects our highways and streets. Another half billion dollars of damages are inflicted on walls, drives, parking lots, airports, railroads and canals. Proper construction techniques can result in significant energy saving.

Restoring these soil movement damages consumes considerable energy. A typical solution to swelling clay displacements is the asphsltic concrete level-up course. It consumes significant energy. There's asphalt to be heated and mixed with aggregates, hauled to the job site in energy consuming trucks spread with burning maintainers and compacted by energy consuming rollers.The whole operation is usually repeated within a matter of years because the movements seldom cease with one effort.

Other corrective measures are similarly energy intensive. They include removing and replacing the affected sections; Another is the "heater planer" ; both are high energy consumers.

Construction techniques offer energy-saving capabilities. The identification and protection of the zone of activity is necessary. The prescription could include one of a variety of possibilities such as ponding, replacement to sufficient depth with lime-treated material, or membrane protection by fabrics and asphalt. Vertical fabric moisture seals are currently being tested and evaluated. Energy savings through construction awareness promises considerable benefits.

INTRODUCTION

Our country is faced with a problem of national importance. As engineers, we must address ourselves to helping find its solution. As Americans, we must help our fellow citizens understand the facts - even if we don't possess the total solution.

Energy is critical to our society. Avoiding bankruptcy is too. Last year our country had a $25 billion balance of payments deficit! In international trade we spent $25 billion more than we took in. We will go bankrupt that way - or have a runaway inflation that will destroy the value of the dollar, wipe out lifetime savings - and in examining world history, face what other countries have faced: the loss of their political freedoms. We cannot let that happen here!

Energy is important. However, according to recent figures, we Americans should be aware of another problem. A year ago petroleum imports amounted to $42 billion a year, our largest single item purchased abroad. Machinery and transportation equipment imports were $33 billion, and other imported manufactured goods, $36 billion. This year it appears that there's been a 10% drop in petroleum imports - estimated to be $38 billion a year; but there'll be $43 billion of imports in machinery and transportation equipment and $51 billion in other manufactured goods![1] This would put petroleum in third place for imported products. The situation is critical. We need to know the facts. We need to conserve and we can.

Before we all have a coronary, let's remember we do export. Agricultural and aerospace manufactured goods are the top two.

Petroleum is a significant problem! We do have a $25 billion a year deficit.

Swelling clays in 1973 were estimated to cause $2 billion dollars in damages in the United States. (2) Today, $4 billion seems to be a realistic estimate. Correcting this $4 billion a year challenge will help with that $25 billion problem in our balance of trade.

How did we get into this petroleum energy situation? It was easy! Imported oil cost the United States an average of $2.30 a barrel in 1970 - $14.10 in 1977! In 1974 we imported less that 20% of our oil. We are now importing half our oil and its price is being set by a cartel. We are using over 20 million barrels of petroleum a day.

Let's look at national energy sources and where it goes! In 1975 44% came from petroleum products; 56% from other sources. It was expended by industry (32%); by electric generation losses (18%); by the automobile (14%); in commercial establishments (13%); in residences (13%); and by farm, freight and public transportation (11%). (3)

Transportation is a significant consumer of our energy (25%). Over 90% of this transportation energy comes from oil. Motor vehicles consume 72%. (4)

How do we use the motor vehicles? The automobile uses more than half the energy consumed by the transportation sector. Over 40% of these miles were driven to earn a living. Social and recreational uses claimed 33% of the mileage, family business including shopping - 20%, educational, civic, religious and others were 6%. (5)

Again, before we get to despairing, if we carpooled on our work trips and increased auto ridership from 1.2 passengers to 2.0, we would save over 40% of the work trip energy. If we did this in a small car, the savings would be a whopping 70%!

Another approach was taken in California. Energy expenditures were compared between the Bay Area heavy rail system and putting these travelers in automobiles with increased highway lanes. It was estimated that if average miles per gallon remained as it is today, it'd be 168 years before BART became more energy efficient than the motor vehicle solution. If the federal regulation continues and the automobile meets the 28 mpg standard, the rail system energy saving will never become the most efficient.

However, with automobile, truck or buses, highways are important, and they take energy.

CONSTRUCTION

How can we reduce energy consumption through construction? Annually, construction consumes billions of tons of aggregates, millions of tons of asphalt, lime, and portland cement. Billions of tons of earth are excavated, hauled, dumped, shaped and compacted.(6) All very intensely energy consuming.

Let's look at some of these energy expenditures. It takes 11,000 BTU to generate 1 KWH of electricity (a BTU-British thermal unit is a usual way to measure energy - an MBTU is one million BTU's). Burning of fuel to generate electricity is 31% efficient, to obtain power in engines - 34% efficient; with 46% efficiency for gasoline and diesel engines.

It takes 356,000 BTU to produce a 94 lb. sack of portland cement. Lime requires 6 million BTU/ton or 282,000 BTU's if stuffed in that 94 lb. sack. Crushed stone will use 70,000 BTU/ton. It requires from 10,000 to 75,000 BTU to produce a barrel of asphalt plus from 36,000 to 60,000 BTU to further process and handle it.

Energy expenditures for a ton of asphaltic concrete are estimated at 512,000 BTU. This includes manufacturing with a 50 mile haul for the asphalt, stone, sand and filler, plant operations, hauling and placing.

Similarly a cubic yard of portland cement concrete pavement will use 2,436,000 BTU - 8" of portland cement concrete pavement will require 541,000 BTU's per square yard - an 8" base course and 4" surface will use 236,000 BTU. (7)

Frequently using energy to construct a facility can reduce energy consumption by the autos, buses and trucks that use it several times over. Motor vehicles get twice as many miles per gallon on a freeway as they do in a city street. Congested traffic burns more energy, emits more pollutants and doesn't move well. Energy losses on streets and highways needing repair are also considerable.

Beyond construction costs are the expenses involved in maintaining a structure, a highway, a railway or runway. What about that $4 billion a year problem of the damages caused by swelling soils or expansive clays? Probably $2 billion are damages to transportation facilities. Their repair takes tons of asphalt, aggregates and gallons of fuel. It's got to be produced, refined, heated, hauled in energy consuming trucks, spread with energy consuming maintainers and compacted with energy consuming rollers. Failure to maintain the roadway can double motor vehicle energy consumption. The cost in dollars and energy is significant.

The problem of swelling clays and expansive soils is international. It has been studied on a worldwide basis for decades. Texas has its share of these problems. Probably a quarter of the state's 70,000 mile road system crosses these active soils.

Identification of the areas of expansive soils must be made. Construction techniques are available if these swelling soils cannot be avoided. They include replacement, deep lime treatment, pressure injection of lime, ponding, electro osmosis and moisture seals. [8,9]

An unusually active example of a San Antonio highway had Plasticity Indices in the 70's. It was opened to traffic in 1968. By October of 1977, a three mile section claimed an estimated 23,500 tons of asphaltic concrete - over 12,000 MBTU's. It's had treatments with a heater planner that burns 800 gallons of propane a day, expending another 2200 MBTU's. The pavement has shown no indication of reaching stability yet. All very energy intensive. All very dollar intensive too.

Before the Arab oil embargo and the cartel, these costs and uses had a different impact. Diesel fuel was 6¢ a gallon - now it's 39¢. Asphaltic concrete has gone from $5 a ton to today's $28 - natural gas from 29¢ an MCF to $2.20. What was feasible with the 6¢ diesel fuel, the $5 asphaltic concrete and the rest demands another analysis today.

WHAT CAN BE DONE

There are several indications that these energy consuming efforts can be reduced. Subgrade stabilization and fabrics are two possibilities.[10] The efforts to control these clays are bearing energy saving fruit.

Ponding has been used effectively on new construction. It apparently minimized those energy demanding repairs. On an expressway just west of San Antonio, a half mile section with the highest potential vertical rise, was ponded for thirty days. A highly expansive clay, the finished subgrade was in a cut whose maximum depth exceeded twenty feet. Lime treated subgrade 15 CM (6 in.) thick was used as a moisture seal following ponding. The results were monitored. [11] A zone of activity from finished grade down 3M (10') was observed. It reflected maximum moisture change and movement of the elevation rods. Another indication was the roadway surface inventory. There is comparatively less repair on the ponded section where maximum movement was predicted than the anticipated less active areas (Figure 1). Ponding does require energy. We can quantify roughly that these expenditures were based on 1 KWHs required to pump 750 gallons. This ponding used 18,831 mille-gallons of water - 25,000 KWHs or 85 MBTU's of energy quantity - equal to 160 tons of asphaltic concrete.

Mississippi reports the same good results on their ponding efforts.[12] They ponded for 100 days after holes were drilled into the clay and backfilled with a pervious material. At last reports these sections required no maintenance while adjacent unponded ones required significant energy consuming repairs.

These results are descendants of McDowell's work on I. H. 35 near Waco. Corings a decade later showed significantly less asphaltic concrete level ups required on the ponding sections.

Another measure of potential savings is on the sand backfilled deep underdrain. On U. S. 90 west of D'Hanis, Hondo and San Antonio, the roadway had claimed many tons of asphaltic concrete for "level ups" plus lime placement in 5' deep holes at 5' centers. The asphaltic concrete and the lime used an estimated 300 MBTU's of energy.

Using the ponding project's zone of activity concept and an Israeli engineering concept of sand serving as a moisture reservoir for the clay a maintenance effort combining the two, was used. A 15 CM (6 inc.) perforated underdrain pipe was placed 2.4 M (8 ft.) deep with a sand backfill along the south crown for 0.4 KM (0.25 mi.). No underdrain was placed along the north crown line (Figure 2). Three years of field measurements indicate that the "underdrain" crown moved only 1/3 as much as the non underdrained. It moved 1/5 as much as the roadway to the west with no underdrains at all.

Minimizing moisture changes in the expansive clays have long been recognized as critical to their control. Today this is also critical to the saving of energy. Horizontal and vertical moisture seals are attracting increased attention. An important arterial street was rebuilt by the State Department of Highways and Public Transportation as an Urban System project. A DuPont TYPAR was offered as the horizontal fabric moisture seal. The clay overlaid had liquid limits to 72 and Plasticity Indices to 47. The fabric covered the most expansive areas with Potential Vertical Rises calculated to be 11.2 CM (4½) - those on the non-protected areas 6.2 CM (2½"0) to 7.5 (3"). Three years later, the field measurements indicate no significant movements in the horizontal fabric seal area or the adjacent control sections. All sections had foundation course, black base and an asphalt riding course.

Another variation of reducing moisture change in the clay will be the use of a deep vertical seal. It will be set on a test section to protect the zone of activity. On Loop 410 Project it will offer another chance to measure energy savings. The northbound lane will have about 3 m (10 ft.) vertical fabric moisture seals on each of its shoulders. This quarter mile section is adjacent to the southbound lane that will be without the moisture seals. Moisture sensors will also be installed. Monitoring of pavement repairs will offer definite energy comparisons (Figure 3).

It is possible that a lime treated subgrade seal would function equally as well.

CONCLUSION

There are definite indications that construction efforts can conserve considerable energy. Transportation facilities over expansive clay soils is one of these particular areas. Control measures have been developed, applicable to existing as well as new facilities. Identification of areas is important as well as recognition of the zone of activity. Ponding, lime treatment, replacement, horizontal and vertical moisture seals can all be of help. Energy conservation is a worldwide problem and can be implemented with beneficial results.

ACKNOWLEDGEMENTS

The writer expresses thanks to the State Department of Highways and Public Transportation personnel who assisten in gathering this data; including District Office personnel, Rick Norwood D-10 Austin Research Section; Fred White, Texas Transportation Institute Research Library, TAMU, and Ms. Blyth Lowery, our secretary for editing and typing.

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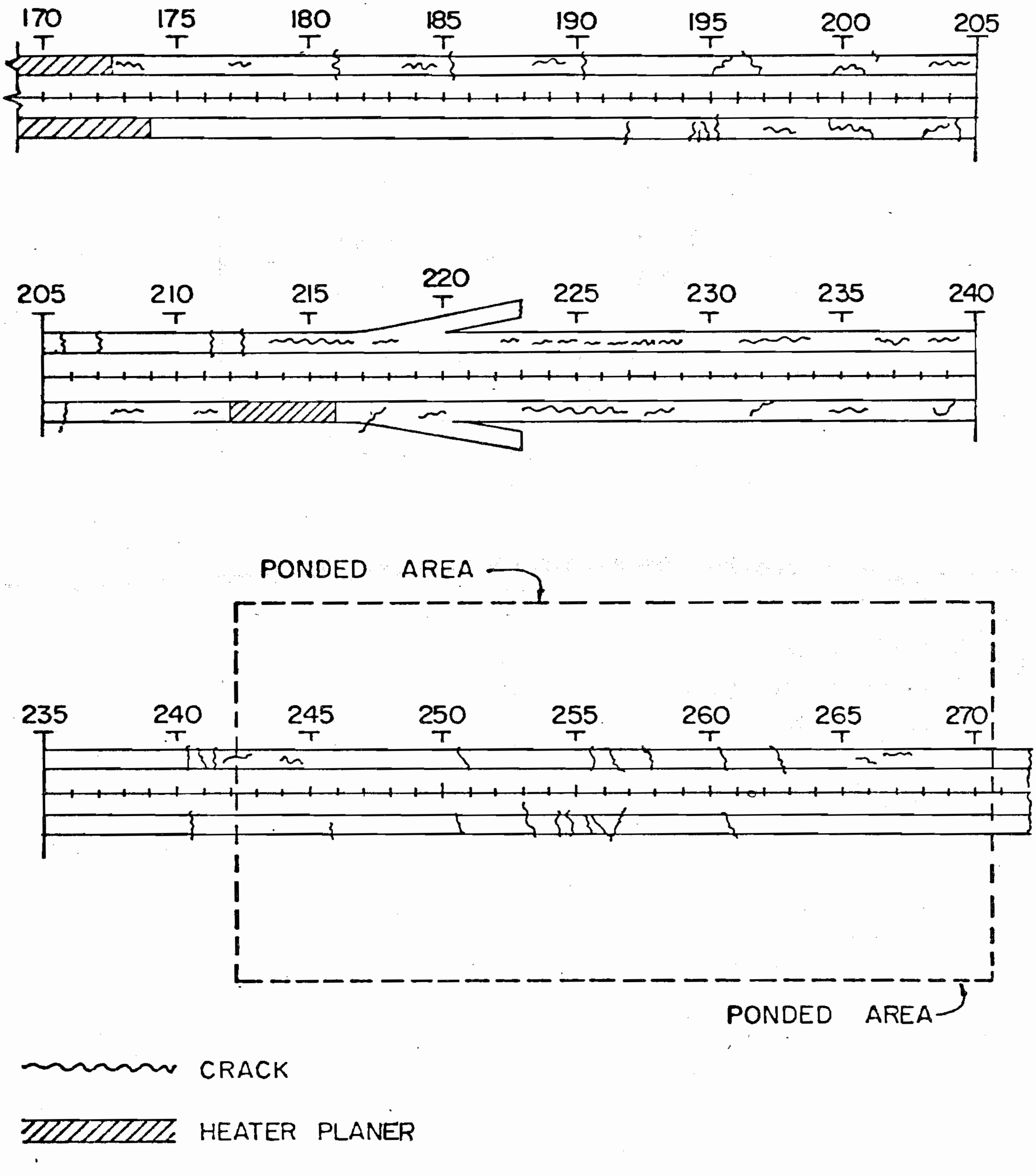

FIGURE 1

Ponded and Nonponded Area

U. S. 90W

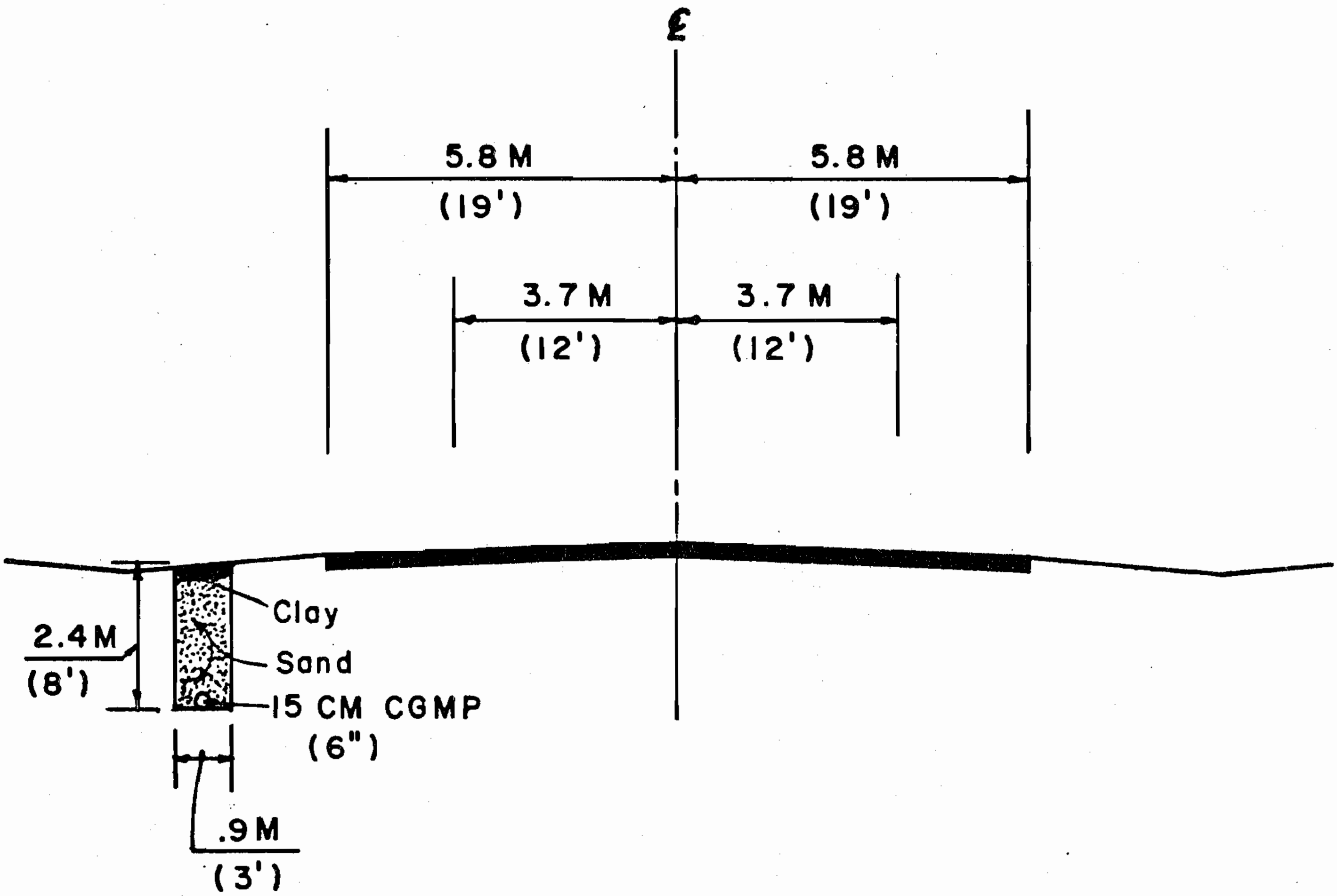

Figure 2

Deep Sand Back-Filled Underdrain

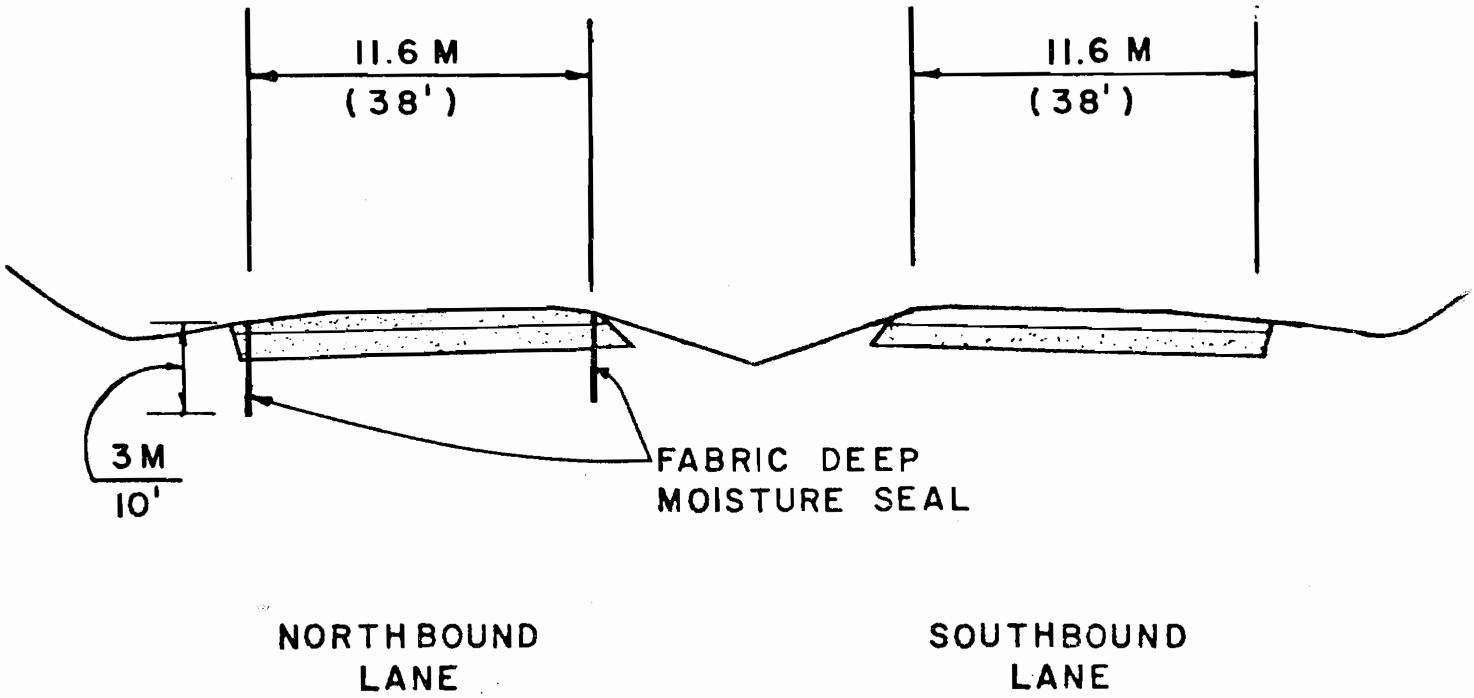

Figure 3

Vertical Fabric Moisture Seal Test Section