Report No. CDOT-R-SM-95-15

EPS, FLOW FILL AND STRUCTURE FILL

FOR

BRIDGE ABUTMENT BACKFILL

Shan-Tai Yeh
C. K. Su
Colorado Department of Transportation
Staff Construction and Materials Branch
4340 East Louisiana Avenue
Denver, CO 80222

Final Report
August 1995

Prepared on cooperation with the
U.S. Department of Transportation
Federal Highway Administration

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Technical Report Documentation Page

1. Report No. CDOT-R-SM-95-15	2. Government Accession No.	3. Recipient's Catalog No.
4. Title and Subtitle EPS, Flowfill, and Structural Fill for Bridge Abutment Highway Backfill		5. Report Date August, 1995 6. Performing Organization Code 76.94
7. Author(s) Shan -Tai Yeh and C. K. Su		8. Performing Organization Rpt.No. CDOT-R-SM-95-15
9. Performing Organization Name and Address Staff Materials Laboratory, Colorado DOT 4201 East Arkansas Avenue Denver, CO 80222		10. Work Unit No. (TRAIS) 11. Contract or Grant No.
12. Sponsoring Agency Name and Address Colorado Department of Transportation 4201 E. Arkansas Ave. Denver, Colorado 80222		13. Type of Rpt. and Period Covered Final 14. Sponsoring Agency Code 76.94
15. Supplementary Notes Prepared in Cooperation with the U.S. Department of Transportation Federal Highway Administration		

16. Abstract

Three methods were tested in full-scale highway construction for their effectiveness at reducing the bump at the end of the bridge: expanded polystyrene, flowfill, and and structural backfill. Vertical settlement, lateral movement, and soil pressure behind the abutments were monitor during and after construction. Based on finding of this study flowfill material has the best performance among the three in controlling lateral pressure and movement behind the bridge abutments. Further flowfill shows the least post-construction compression and provides a better ride than the other two two materials tested.

Implementation:

Based on this study it is recommended that CDOT use flowfill for its bridge approaches to mitigate the bump at the end of bridges.

17. Key Words		18. Distribution Statement	
EPS, Expanded Polystyrene, Bridge Approach, Flowfill		No Restrictions: This report is available to the public through the National Technical Info. Service. Springfield, VA 22161	
19.Security Classif. (report) Unclassified	20.Security Classif. (page) Unclassified	21. No. of Pages 17	22. Price

ACKNOWLEDGMENTS

The authors would like to express their appreciation to many people who assisted in the geotechnical monitoring and installation of the instrumentation for this study. These included Ed Belknap, George Pavlick, Larry Conilogue, Louie Lopez, Allen Shade and Paul Lane of the Staff Geotechnical Section.

Brandy Gilmore and Bob Barrett of the Geotechnical group provided many technical suggestions during the review of the report. The CDOT Research Panel provided many excellent comments and suggestions in the course of this study. The panel included Larry McKenzie, Skip Hlad and Michael Hodgson of Region 6 Construction; Jim Bumanglag of Region 6 Design; Gerry Peterson of Region 1; Ron Akin of Staff Bridge; Ken Mauro of Staff Design; and Gust Chocas of FHWA. Their contributions are also greatly appreciated.

The authors also acknowledge the support of the Research Branch of the Division of Transportation Development for sponsoring preparation of this report.

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1.0 INTRODUCTION

The notorious bridge "bump" not only causes an uncomfortable ride but also creates hazardous driving conditions. The bump often requires costly and frequent repair work and thus causes many unnecessary traffic delays. To eliminate this undesirable condition, numerous research studies have been undertaken by Transportation Departments in many states for several decades (4)(5)(7)(9). These studies have concluded that the causes of differential settlement induced bumps are: uneven approach and bridge foundation settlements, compression of the approach embankment and backfill, erosion of material around the abutment, expansion and contraction of the bridge decks, lateral displacement of approach fill, and possible spreading of the backfill. Furthermore, the use of inadequate backfill materials, improper compaction of the embankment, and inappropriate construction sequences were also identified to contribute to the construction-related causes for approach settlement. Types of bridge foundation and abutments were also documented to have influence on the performance of the bridge approaches.

A number of remedial measures for reducing the bridge bump were recommended by these researches. Remedies in alleviating approach settlement due to primary and secondary compression of the foundation include: treatment of the subsurface materials, removal and replacement of the approaches, surcharge with or without waiting period, wick or sand drains, etc.. The recommendations for reducing compression of the approach embankment fill included the improvement of access for compaction equipment near abutments, early placement of the approach embankment prior to bridge construction, and use of high quality, and/or lightweight fill. Lengthening the bridge structure to minimize the size of embankment was also suggested. However, the effectiveness of these improvements to reduce bridge approach settlement was not researched.

Other measures related to the design of bridge structure itself were also studied. It was found that less differential settlement was noted for abutments supported by shallow foundation than abutments supported by deep foundation (2). Use of reinforced approach slabs is common to prevent the differential settlements in bridge approaches (6). Geotextile reinforced embankments and walls beneath the approach slabs have been proven to reduce the approach settlement and to limit the magnitude of lateral earth pressures against abutment walls (3).

Design and construction precautions to reduce the amount of differential settlement for Colorado state highway bridge approaches have been in existence for many years. In 1987, a study (1) to investigate the causes of bridge approach settlement was conducted by the Colorado Department of Transportation (CDOT). A total of 100 existing bridges with moderate to severe approach settlements were surveyed and inspected by the Staff Bridge Branch. Ten bridges with the most severe settlement problems were chosen for further investigation to find the most probable causes. Based on this study, most of the approach settlements were attributed to compressions of the embankment foundation, the embankment itself or the backfill.

As a result, many measures were recommended for implementation. The precautions included extension of wing walls along the roadway shoulder, the use of approach slabs and well-graded granular backfill (Class I Structure Backfill) behind the abutments. However, these design and construction precautions were considered insufficient to eliminate the bridge bump. To further study the problem, an experimental project was developed to investigate the performance of approaches by using different backfill materials. Three types of backfill were chosen for this study. They were super-light Expanded Polystyrene (EPS) fill (8), flow fill and conventional Class 1 Structure Backfill material.

To examine the performance of these backfill materials, instruments were installed at the beginning of the construction. The instrumentation consisted of liquid settlement transducers, earth pressure cells, and extensometers. Parameters measured by the instruments included magnitude of settlements in the approach embankment and foundation, temperature induced lateral movement and lateral earth pressure behind the abutments. A summary of the measurements and a discussion of the results are presented.

2.0 SITE CONDITIONS AND SUBSURFACE EXPLORATION

2.1 Site Conditions

The project site selected for the experimental study is located on Interstate 76 (I-76) near Interstate 25 (I-25) in northwest Denver, Colorado as shown in Figure 1. In the past, bridges constructed in this general area and supported either by pile foundations or shallow foundations suffered various degrees of approach settlement problems. Mudjacking has been used to lift the approach slabs and to stabilize the abutment backfill. Since the geological conditions are similar in this general area, the I-76 and I-25 site was selected for this study.

The experimental site consisted of six bridges over Broadway Street. The center two bridges are for I-76 mainline structures, the northern two bridges are used for the on-ramp structures from south- and northbound I-25, and the remaining two southern bridges are used for the departing I-76 traffic to I-25. The topography of the test site is relatively flat to gently rolling. Clear Creek is located approximately 1/4 mile north of the site and the subsurface material consists of terrace deposits of alluvial silty sand, gravel and cobbles. Bedrock in the area is relatively shallow and uniform, and consists of shale. Geotechnical recommendations for these bridges included spread footings placed on the terrace sand and gravel or steel H-piles driven into bedrock. The latter was selected by the structural engineer for the support of bridges in this area.

2.2 Subsurface Exploration

Fifteen test holes were drilled for the bridge foundations at the site. Subsurface materials consisted of 24 feet to 30 feet (7.32 m to 9.14 m) of granular materials overlying shale bedrock. The natural granular materials included medium dense to very dense gravelly sand and sandy gravel with some cobbles. Figure 2 shows a typical geological profile and the results of Standard Penetration Tests (ASTM D-1586). The shale bedrock encountered beneath the granular materials was hard to very hard gray to dark gray, and weathered near the bedrock surface. The groundwater table is approximately seven feet (2.13 m) below the existing ground surface.

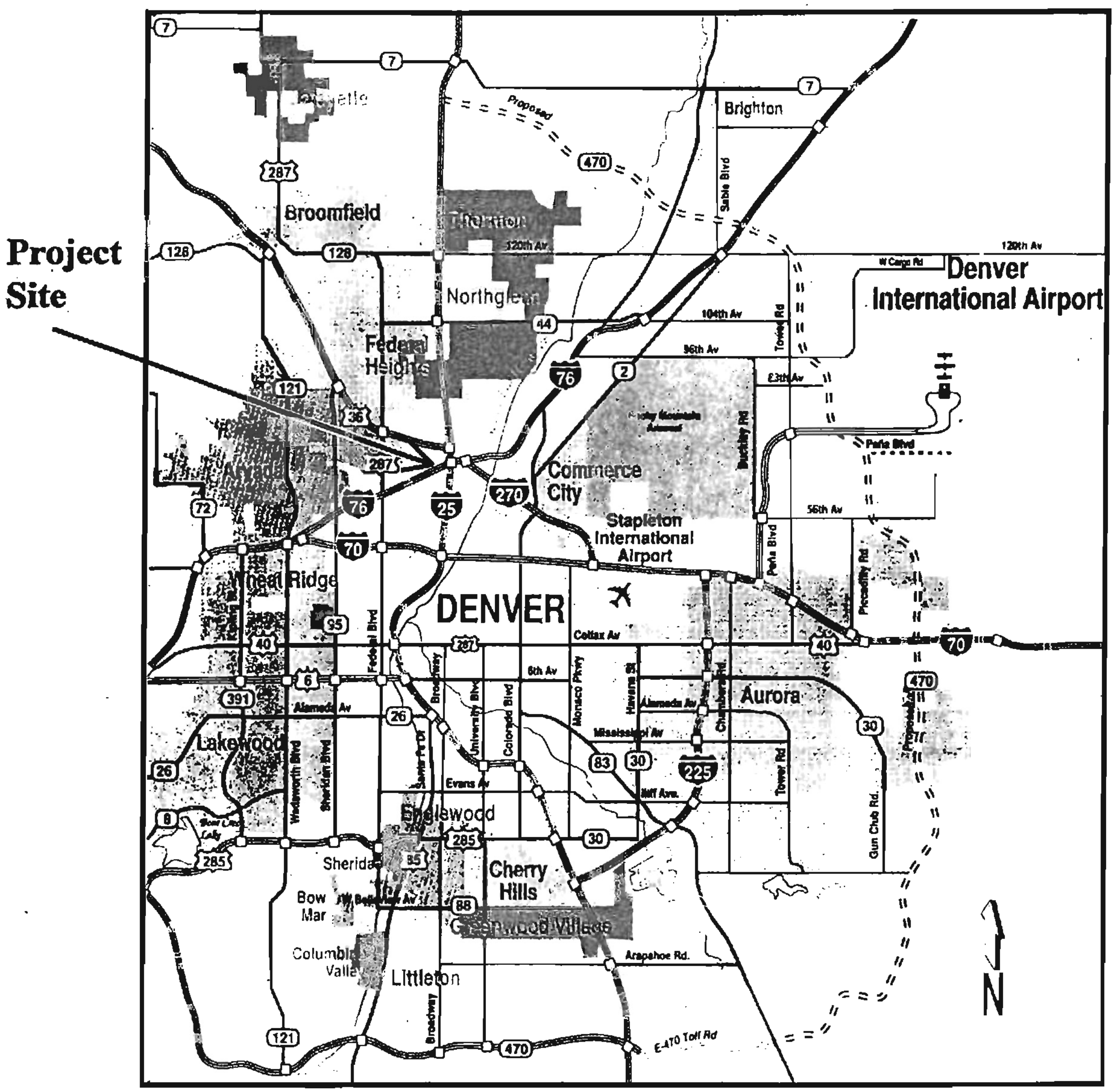


Figure 1: Project Site for the Experimental Study

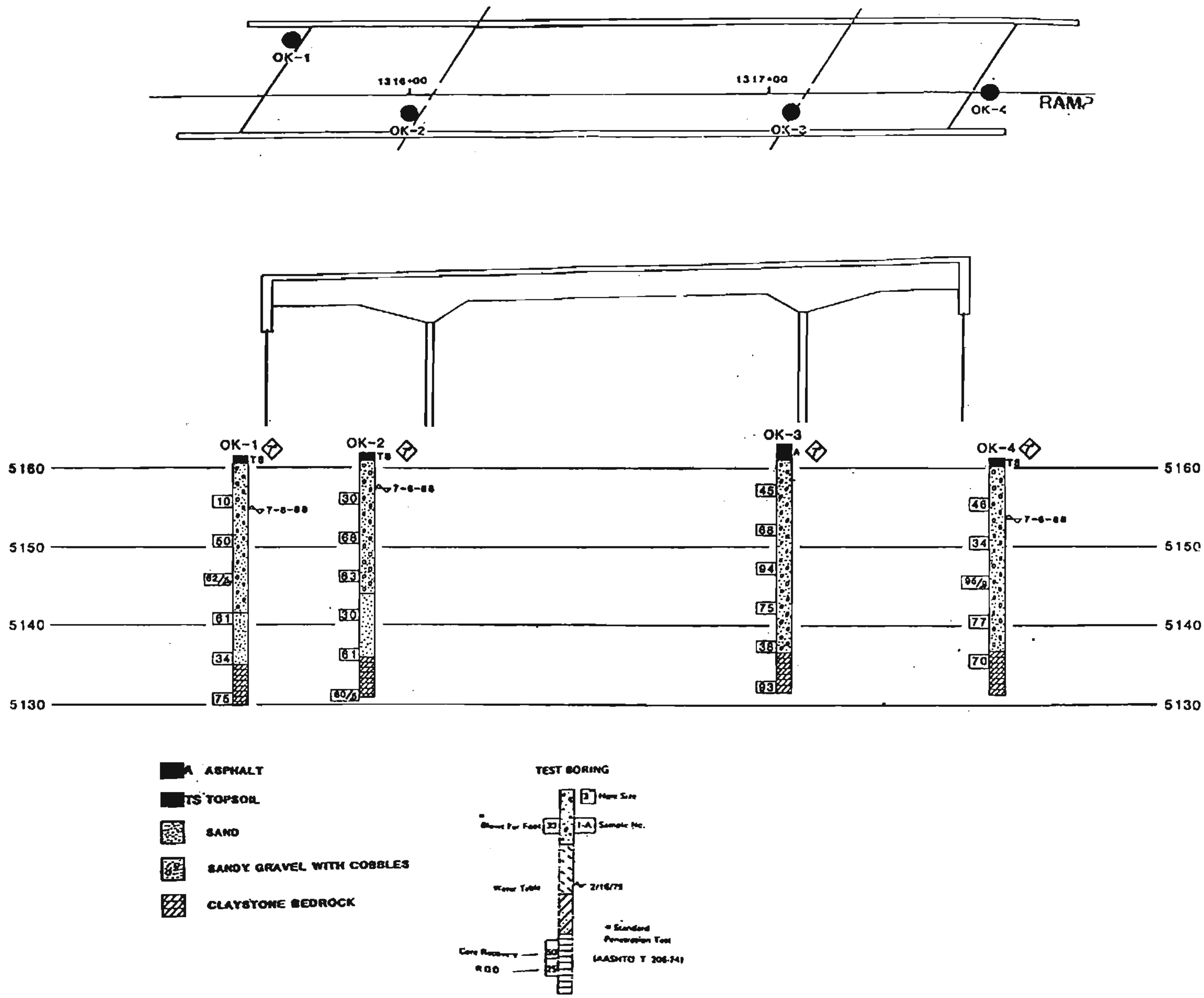


Figure 2: A Typical Geological Profile

3.0 BACKFILL MATERIALS AND CONSTRUCTION

Figure 3 illustrates a standard profile for the CDOT bridge abutment, abutment backfill and approach embankment in a bridge design plan. Bridge approaches are normally constructed over natural material at the site. Backfill behind the abutment between two wingwalls is Class 1 Structure Backfill, typically considered as free-draining granular material. The backfill materials chosen for this study were super-light Expanded Polystyrene (EPS), flow fill and the conventional Class 1 Structure Backfill.

3.1 Expanded Polystyrene (EPS)

CDOT previously used a super-light expanded polystyrene material to repair a failed embankment slope in southwestern Colorado in 1987. The EPS used for the slide repair had a density of 1.25 lb/ft^3 (0.196 kN/m^3) and, the performance of this material to date has been excellent. Due to the extreme light weight of the EPS, this material was chosen to replace typical embankment. A 1.5 lb/ft^3 (0.236 kN/m^3) density EPS material was selected for the experimental study. The following Table 1 lists the physical properties of the EPS:

Table 1: Physical Properties of Expanded Polystyrene (EPS) Material

Density	1.50 lb/ft^3
Compressive Strength (at 10% Deformation) (ASTM D1621)	15.0 psi
Flexural Strength (ASTM C203)	40.0 psi
Shear Strength (ASTM D732)	26.0 psi
Shear Modulus	450.0 psi
Modulus of Elasticity	320.0 psi
Water Absorption (ASTM)	less than 2.5% of volume
Coefficient of Thermal Expansion (ASTM D696)	3.5×10^{-5}

1 lb/ft^3 = 0.1572 kN/m^3; 1 psi = 6.895 kN/m^2

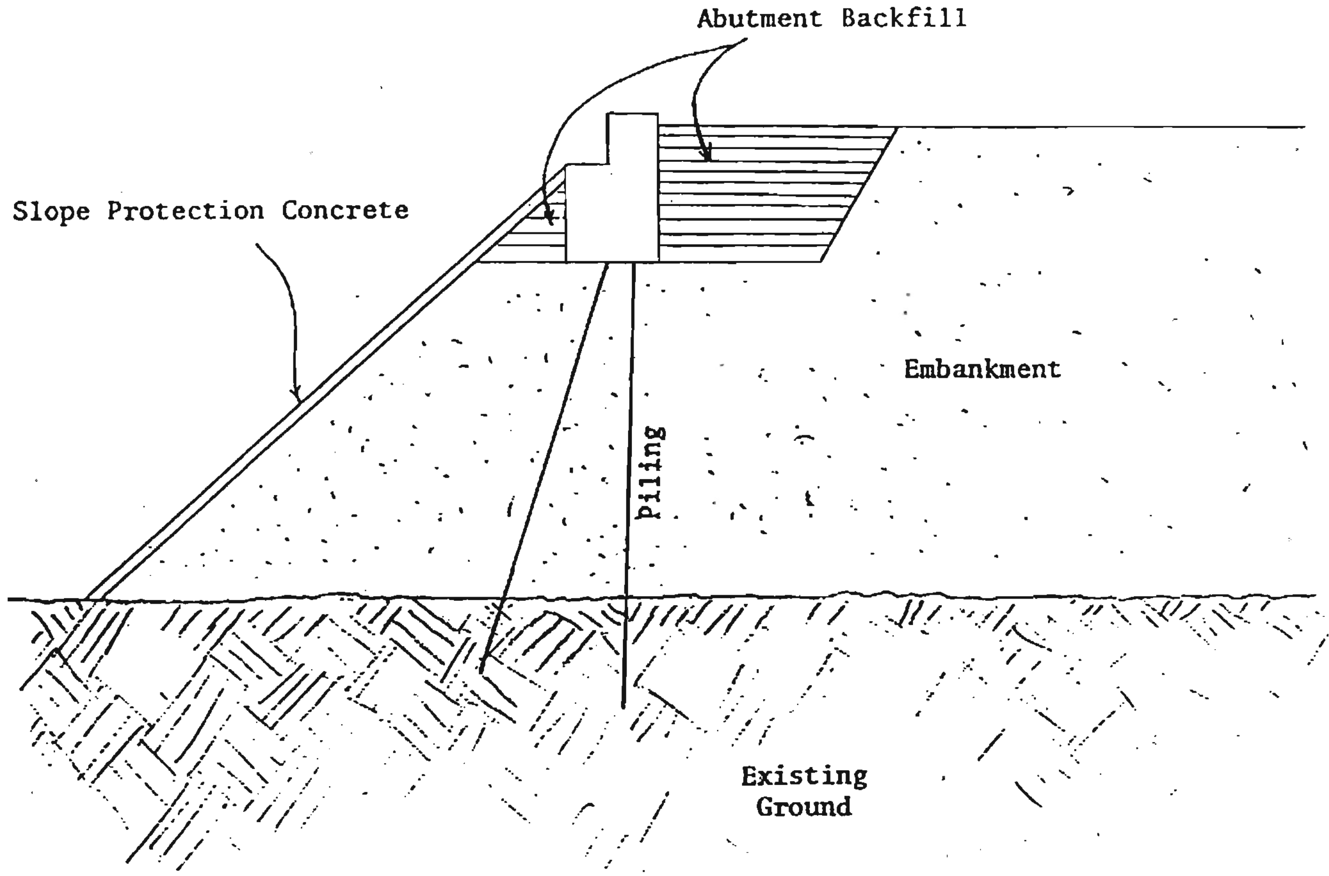


Figure 3: A Typical Bridge Approach Profile

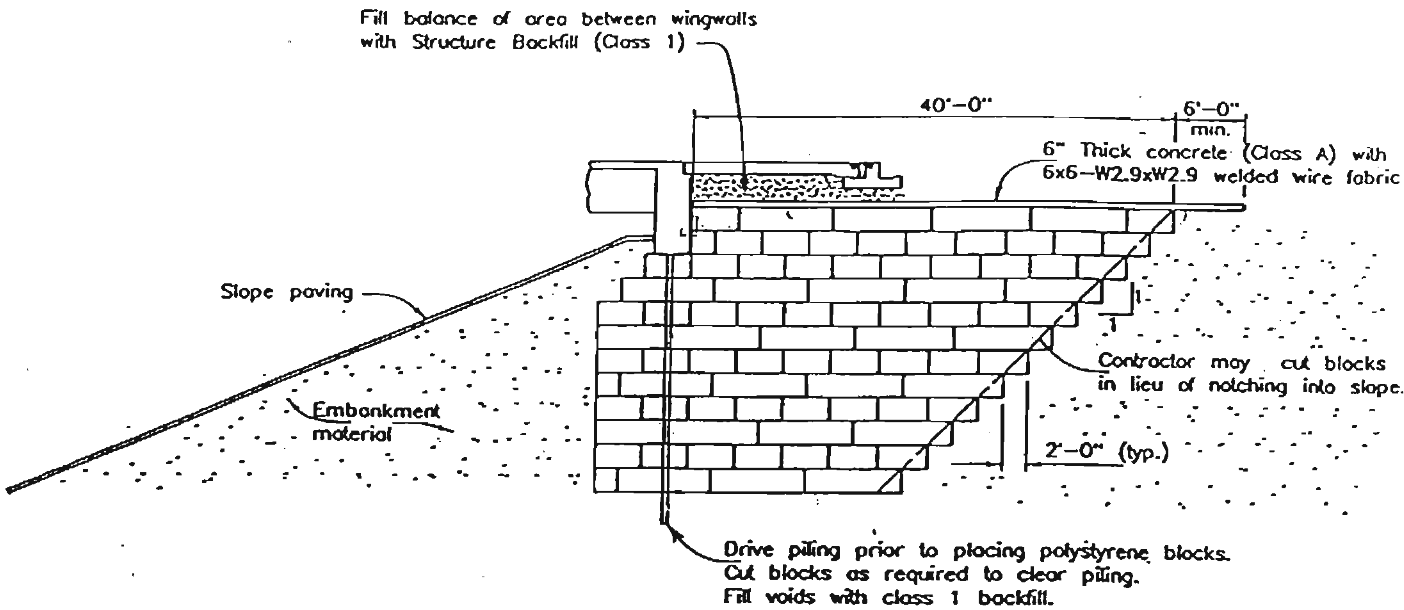
Figure 4 shows the schematic of the EPS fill design. A total of 12 layers of EPS blocks were designed in a reverse trapezoidal shape. The top layer has a dimension of 40 feet by 40 feet (12.2 m x 12.2 m) and the bottom layer has a dimension of 26 feet by 40 feet (7.9 m x 12.2 m). It has been recognized that diesel fuel will cause the EPS material to dissolve. In order to protect the EPS from diesel spills, a 6-inch (15.2 cm) concrete cap with a compressive strength of 3000 psi (20,685 kN/m^2) was installed on top of the EPS. A three foot (0.91 m) granular fill was placed between the concrete cap and the 12-inch (30.48 cm) reinforced concrete approach slab.

Construction of the EPS embankment began in November of 1991 after foundation pile driving at the west approach for the bridge abutment was completed (Photo 1). The EPS blocks were staggered with each lift and placed in a direction perpendicular to those above and below. The formation of continuous joints in the same layer is avoided by staggering the blocks, as shown in Figure 5. A double sided timber fastener was used to reduce potential sliding between layers. Voids between the EPS blocks were filled with sand.

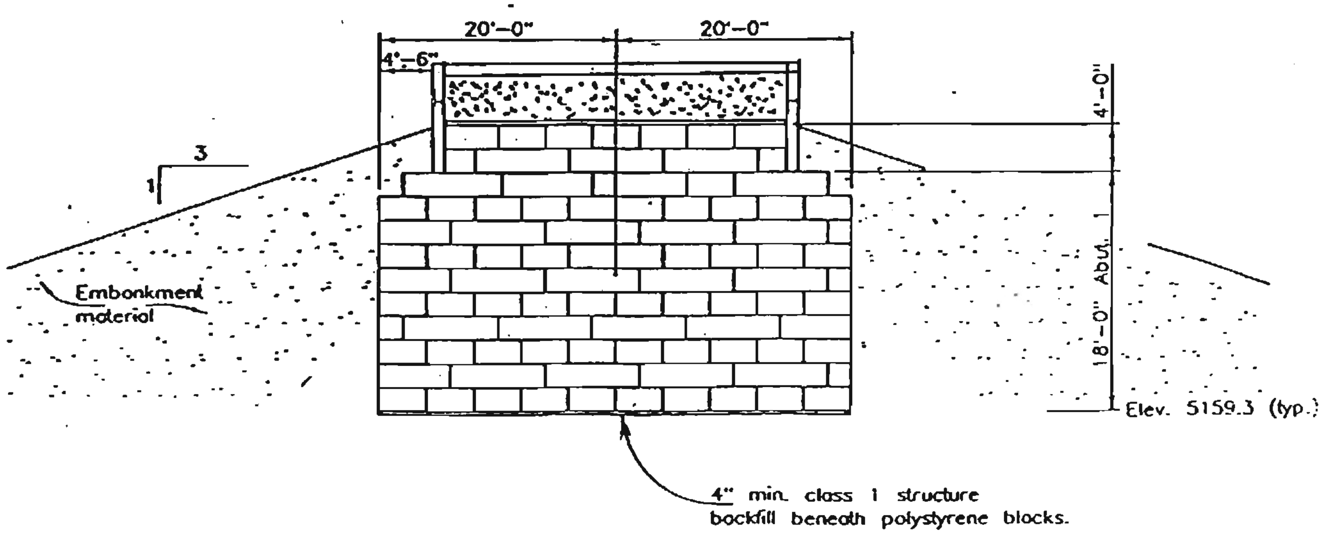
According to the construction specifications, the contractor was required to provide a copy of "certificate of compliance" of the EPS material to the CDOT prior to material delivery to the site. Unfortunately, the laboratory testing conducted on the samples near the end of EPS placement indicated that the material on site did not meet the specifications. As a remedy, the top two layers (4 feet) of the EPS embankment were replaced by a 2.0 lb/ft^3 (0.314 kN/m^3) density material.

3.2 Flow Fill

Flow fill, which is a low strength concrete mix, was introduced in recent years for trench backfill. It has the advantages of high strength without compaction. This material was selected to eliminate the need for backfill compaction and to reduce the effect of bridge expansion and contraction which were considered major causes of the approach settlement.

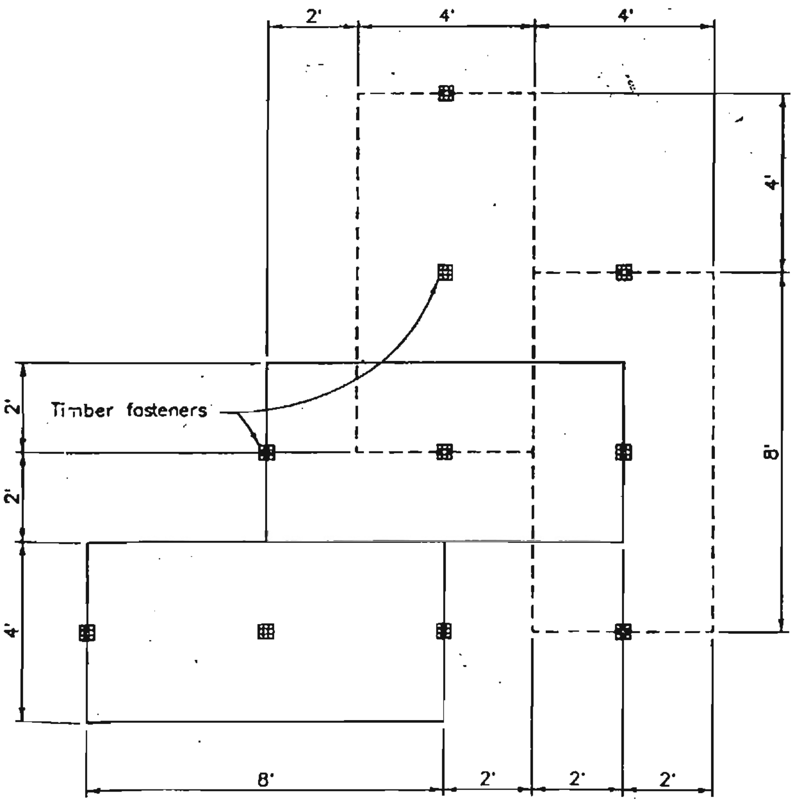


LONGITUDINAL SECTION



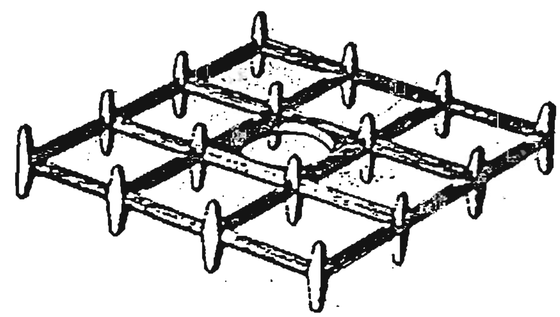
TRANSVERSE SECTION

Figure 4: Schematic of EPS Embankment Fill



Expanded polystyrene blocks shall be laid in a bond pattern which changes direction from one layer to the next in order to avoid continuous joints.

BLOCK PLACEMENT DETAIL



Size 4 1/8" x 4 1/8", 1" deep. Bolt Size to 1". Fits between two flat members.

TIMBER FASTENER DETAIL

Figure 5: Details of EPS Blocks and Timber Fastener

The flow fill used in the study is an aggregate and fine mix based on AASHTO M43, No. 57 gradation with a maximum 28-day compressive strength of 60 psi (413.7 kN/m^2). The specified ingredients for the flow fill are listed in Table 2 and the gradation of the mix is shown in Table 3.

Table 2: Specified Ingredients for Flow Fill

Ingredients	lb/cu. yd.
Cement (0.45 sack)	42
Water (39 gallons)	325
Coarse Aggregate (Size No. 57)	1700
Sand(ASTM C-33)	1845

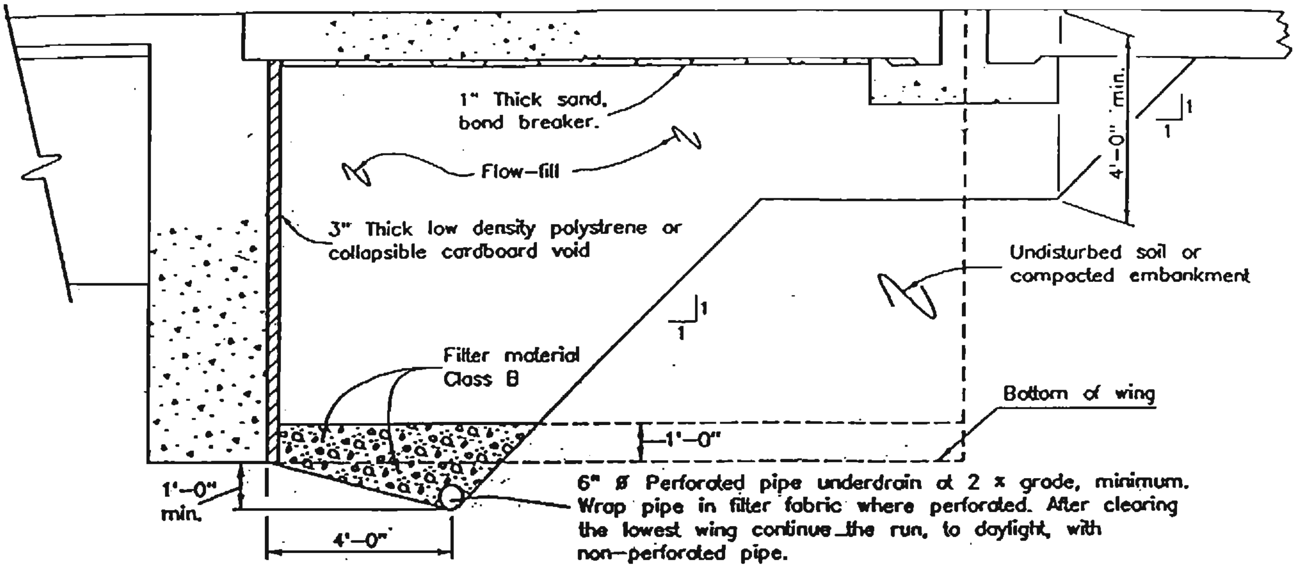
1 lb/cu. yd. = 0.5933 kg/m^3

Table 3: Gradation of Aggregates

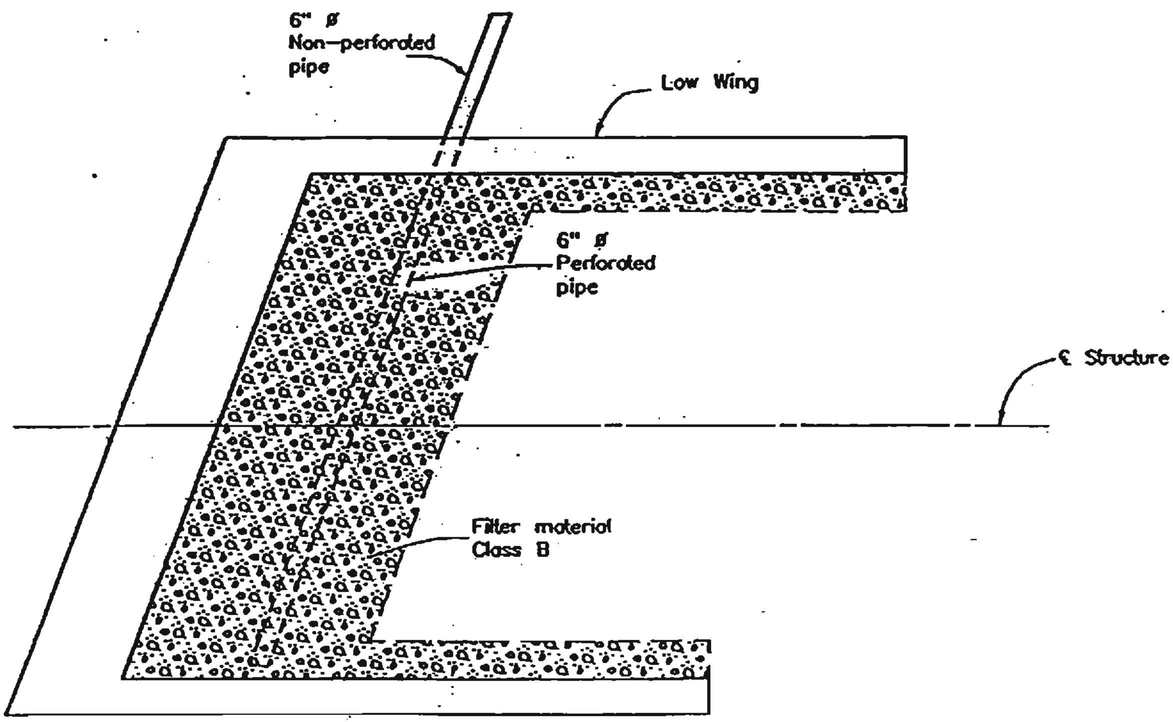
Sieve Size	% by Weight Passing Square Mesh Sieves
1-1/2 inch	100
1 inch	95-100
1/2 inch	25-60
No. #4	0-10
No. #8	0-5

1 inch = 2.54 cm

Figure 6 shows the schematic design of the flow fill. To provide an adequate drainage system behind the abutment and wingwalls, a layer of filter material (Class B) was constructed before the placement of the flow fill. A six-inch diameter perforated pipe was installed at the bottom to collect any excess water. This water, in turn was carried by a non-perforated pipe which daylights through the wing wall. A three-inch (7.62 cm) thick low density polystyrene mat was also placed at the back side of the abutment wall. The placement of the flow fill is shown in Photo 2. The maximum lift thickness for the flow fill was limited to three feet. A 12-inch (30.48 cm) reinforced concrete approach slab and a sleeper slab were constructed on top of the flow fill as shown in Photo 3.



SECTION PERPENDICULAR TO ABUTMENT



Plan View of Abutment

Figure 6: Schematic of Flow Fill and Abutment

Photo 1: EPS Construction on West Bridge Abutment Approach

Photo 2: Placement of Flow Fill Behind of Abutment

Photo 3: Reinforced Concrete Approach Slab and Sleeper

3.3 Conventional Class 1 Structure Backfill

Based on a standard design plan, the approach slabs for this project were placed on an eight-foot (2.44 m) high structural backfill confined by the abutment and wingwalls. The structural backfill was in turn placed on top of the embankment material. The gradation for Class 1 Structure Backfill is listed in Table 4. This material has a Liquid Limit (LL) of less than 35 and a Plasticity Index (PI) of less than six (6). Based on the construction requirements, structure backfill should be compacted to a density of not less than 95 percent of the maximum dry density determined in accordance with AASHTO T-180. Lift thickness was limited to six inches.

Table 4: Gradation of Class 1 Structure Backfill

Sieve Size	% by Weight Passing Square Mesh Sieves
2 inch	100
N0. 4	30-100
No. 50	10-60
No. 200	5-20

1 inch = 2.54 cm

4.0 FIELD INSTRUMENTATION

A monitoring and instrumentation program was planned and designed. The plan view of the locations of the various instruments for abutments and embankment is shown in Figure 7. Two profiles (Center line Stations 372+08 and 374+38) across the abutments and one profile (Station 370+50) across the embankment were selected for instrumentation. The profile at Station 372+08 consisted of five instrumented abutments, while at Station 374+38 only four abutments were instrumented. The profile at Station 370+50 consisted of five embankments.

Three types of measurements were included in the monitoring program. They were: (1) settlements in the embankment and foundation, (2) lateral pressures behind the abutments, and (3) lateral movements between the backfill and the abutment. Liquid settlement transducers were used for measurement of the settlement in embankment and foundation. Measurements of the lateral pressures were taken using earth pressure cells. Extensometers were installed for monitoring the lateral movements between the backfill and abutment. All measurements were taken during and after construction.

4.1 Liquid Settlement Transducers

A total of 46 liquid settlement transducers were installed at the top and bottom of the embankment. Twenty three of them were located two feet (0.61 m) below the original ground surface to monitor foundation movement. The remaining 23 transducers were placed at the same location but three feet (0.91 m) beneath the concrete approach slab. The top transducers were installed to measure the amount of compression in the approach fill. The compression of the fill can be estimated by the difference of the movement between the bottom and top transducers. A liquid settlement transducer is shown in Photo 4. The bottom transducers were installed in December, 1991 while the top transducers were completed in November, 1992. Initial readings were taken on all liquid settlement transducers, and all the transducers were in good working condition after the installation.

4.2 Earth Pressure Cells

The earth pressure cells were installed at the back face of the abutments to monitor the magnitude of earth pressures from the different backfills due to thermal expansion/contraction of the bridge.

The earth pressure cell consisted of a nine-inch. (22.86 cm) diameter by 0.43 inch.(1.09 cm) thick steel bladder fitted with a pneumatic piezometer made by the Slope Indicator Company. The earth pressures at abutments backfilled by all three tested materials were measured. Eight earth pressure cells were installed on the back face of the four abutments with two pressure cells installed on the mid line of each abutment wall. As shown in Photo 5, the earth pressure cell was glued to the wall. All earth pressure cells were completed and functioning properly by September 25, 1992.

4.3 Extensometers

Earth pressure behind the abutment is strongly related to the movement of the abutment itself and the type of backfill material used. The movement, in turn is determined by the variations of temperature which affect the elongation or contraction of the bridge decks. Temperature reading and lateral movement measurement devices were therefore needed.

Lateral movements between the abutment and backfill material were monitored by five extensometers. As illustrated in Figure 8, an extensometer is used for the measurement of the relative movement between abutment and backfill materials. A remote electrical sensing head was used in the extensometer system. The strain element in the extensometer consisted of a groutable anchor and a fiberglass rod protected by a plastic conduit which terminated in a reference header tube. A picture of the extensometer is shown in Photo 6. The plastic conduit terminated in a reference header tube was slightly modified in the field during this study.

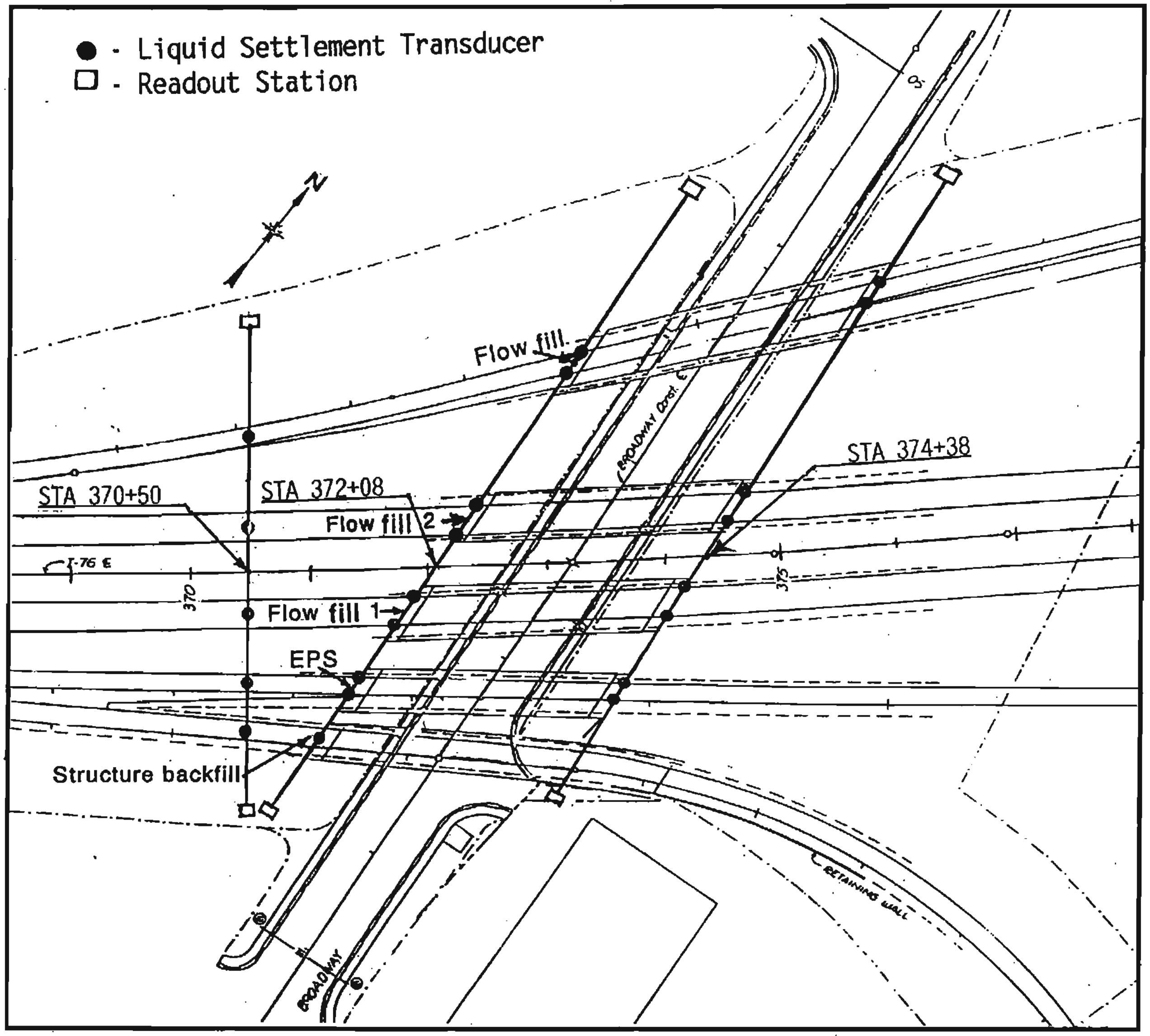


Figure 7: Location of Instrumentation

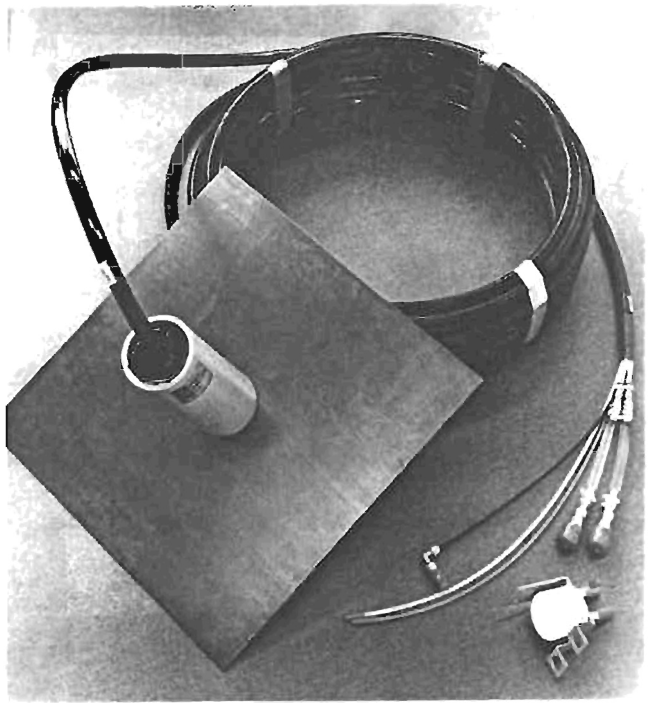


Photo 4: A Liquid Settlement Transducer Device

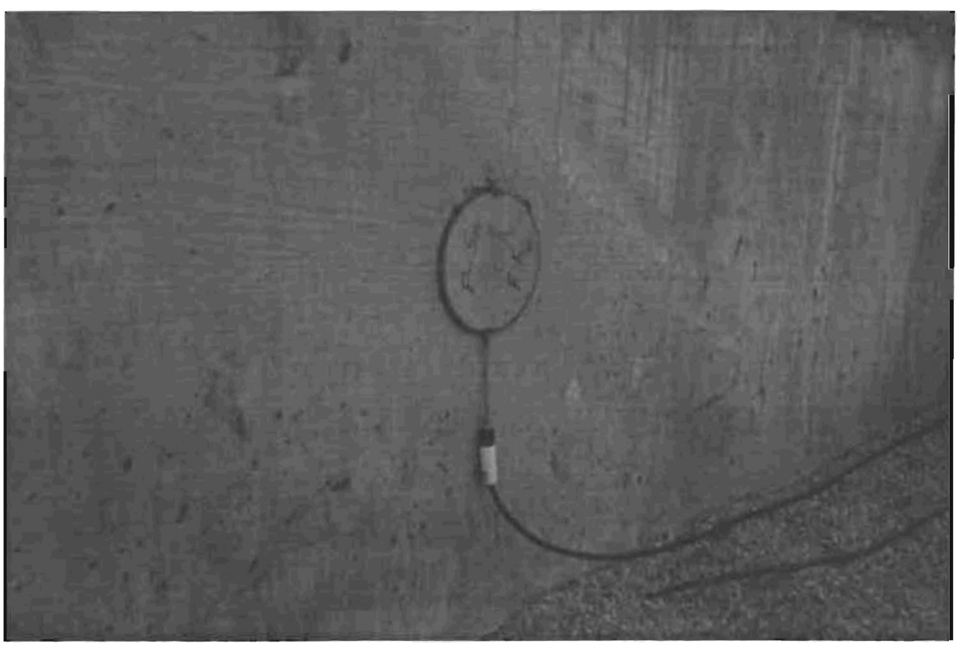


Photo 5: An Installed Earth Pressure Cell on Abutment Wall

The extensometer was installed at the center of each abutment at the same elevation as the earth pressure cell. The installation of the four extensometers was completed in September, 1992. All extensometers were in good working condition. Photo 7 shows an extensometer tube placed on top of the EPS.

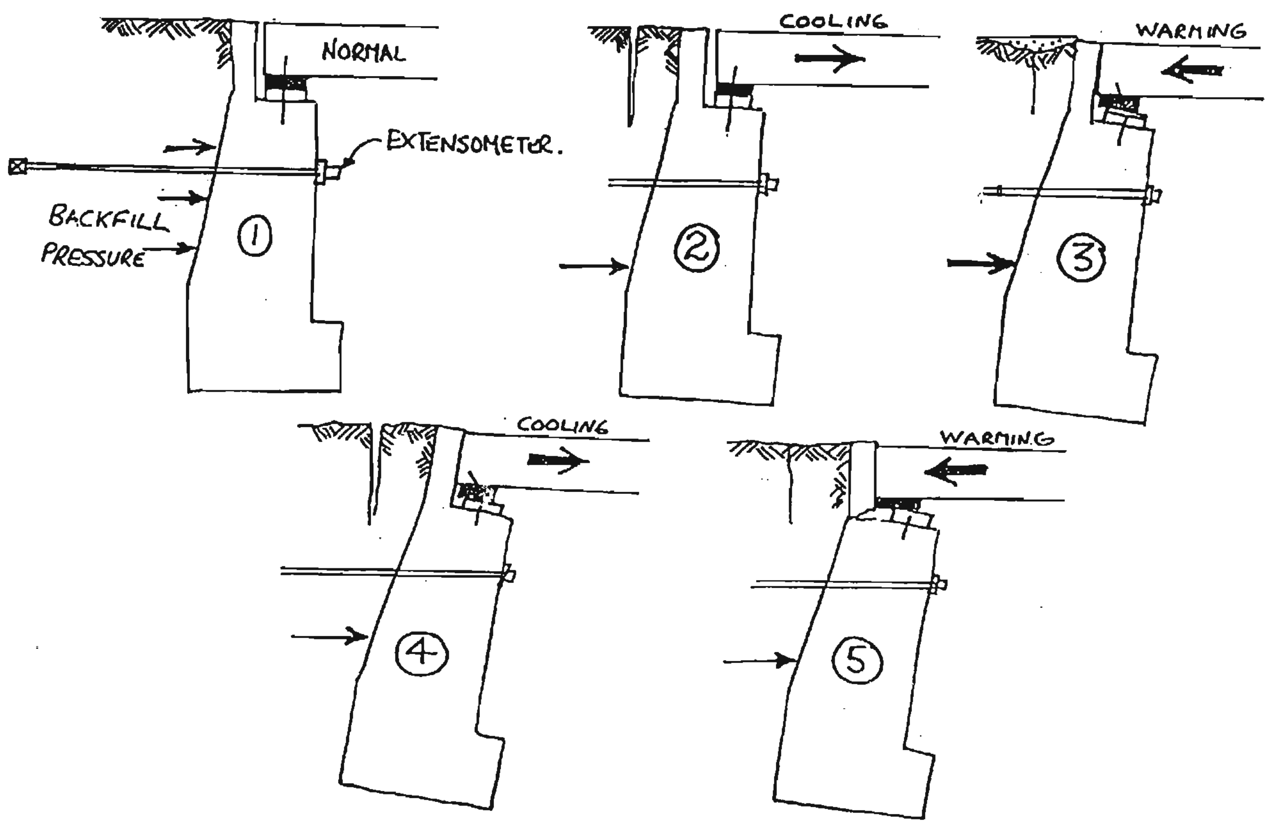


Figure 8: Extensometers for Monitoring Lateral Movements Between Backfill and Abutment

Photo 6: An Extensometer Electrical Sensor Head Installed at an Abutment Wall

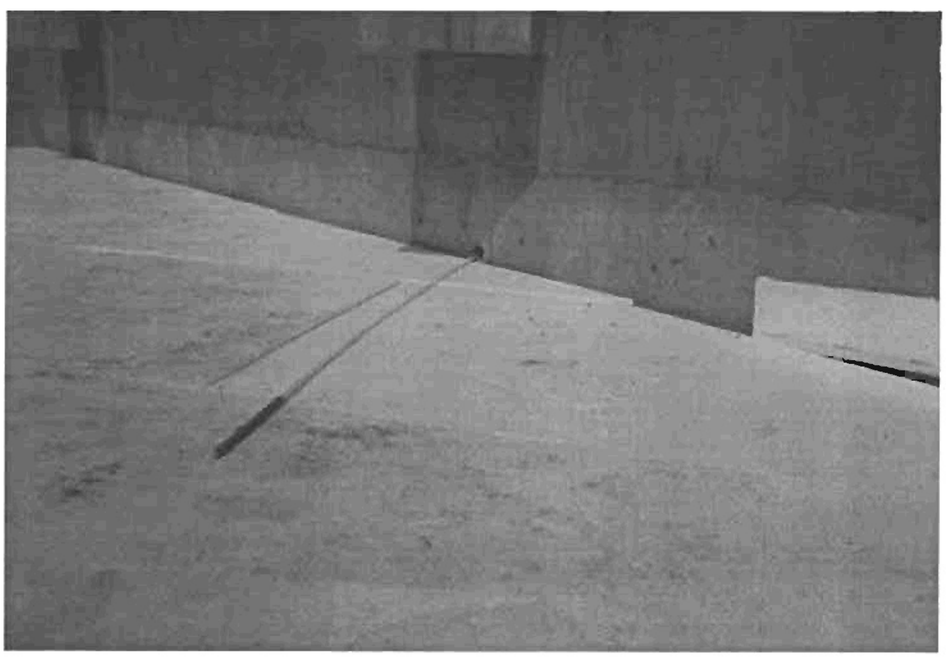


Photo 7: An Extensometer Fiberglass Rod Placed on the top of EPS Blocks

5.0 RESULTS OF MEASUREMENTS AND DISCUSSION

Measured field data is presented under the following categories: (A) settlement measurements; (B) earth pressure measurements; (C) lateral movements.

5.1 Settlement Measurements

The embankment material used except in the EPS area was predominantly silty clay and ranged from 20 to 25 feet (6.09 to 7.61 m) in height. The foundation soils beneath the embankment consisted of 24 feet to 30 feet (7.32 m to 9.14 m) of granular materials overlying shale bedrock. Based on the subsurface conditions, it was anticipated that the foundation soil would be consolidated shortly after it was loaded and the foundation material movement would be stabilized by the time the road surface is paved.

Construction of the embankment began in November, 1991. All approach slabs were installed after September 1992. Thus, there had been a time lapse of approximately 10 months between the time the embankment was completed and the time the approach slabs were constructed. This was considered sufficient time for the consolidation of the foundation material.

The curves shown on Figures 9 to 11 indicate the amount of foundation settlement versus the height of fill placed at the location of the settlement transducers as shown on various cross sections. The first measurement was taken on December 18, 1991, when there was six to eight feet (1.83 m to 2.44 m) of fill placed at the site. Subsequent measurements were made at an embankment height of between 12 and 24 feet (3.66 and 7.32 m). The recorded data shows a correlation between fill height and the amount of foundation movement. The total foundation settlement measured ranged from 2.0 to 4.0 inches (5.08 to 10.16 cm) after the completion of 24 feet (7.32 m) of embankment fill. The results, as expected, indicate that the EPS backfill induces the least foundation settlement due to its extreme light weight.

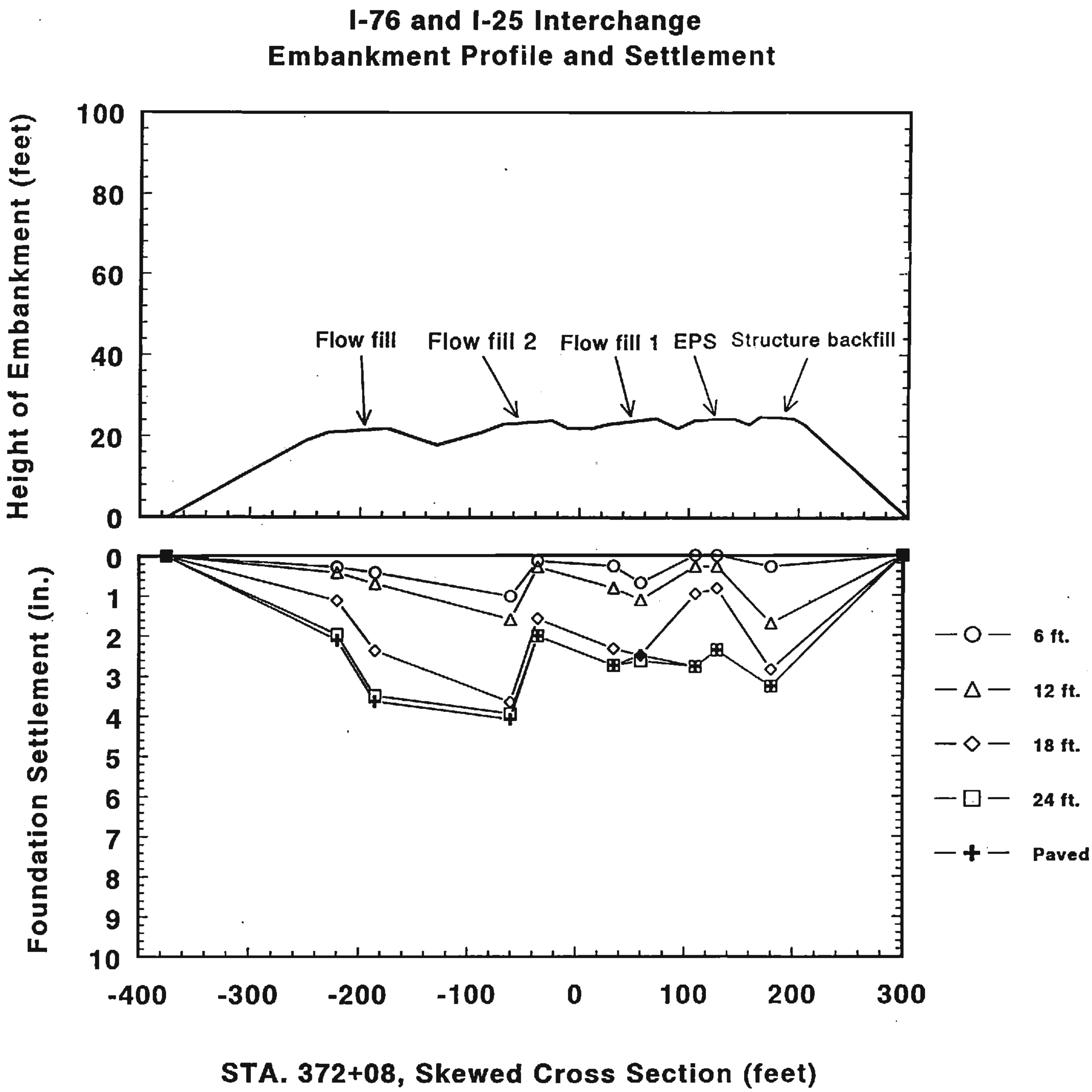


Figure 9: Foundation Settlements Versus Height of Fill at Station 372+08

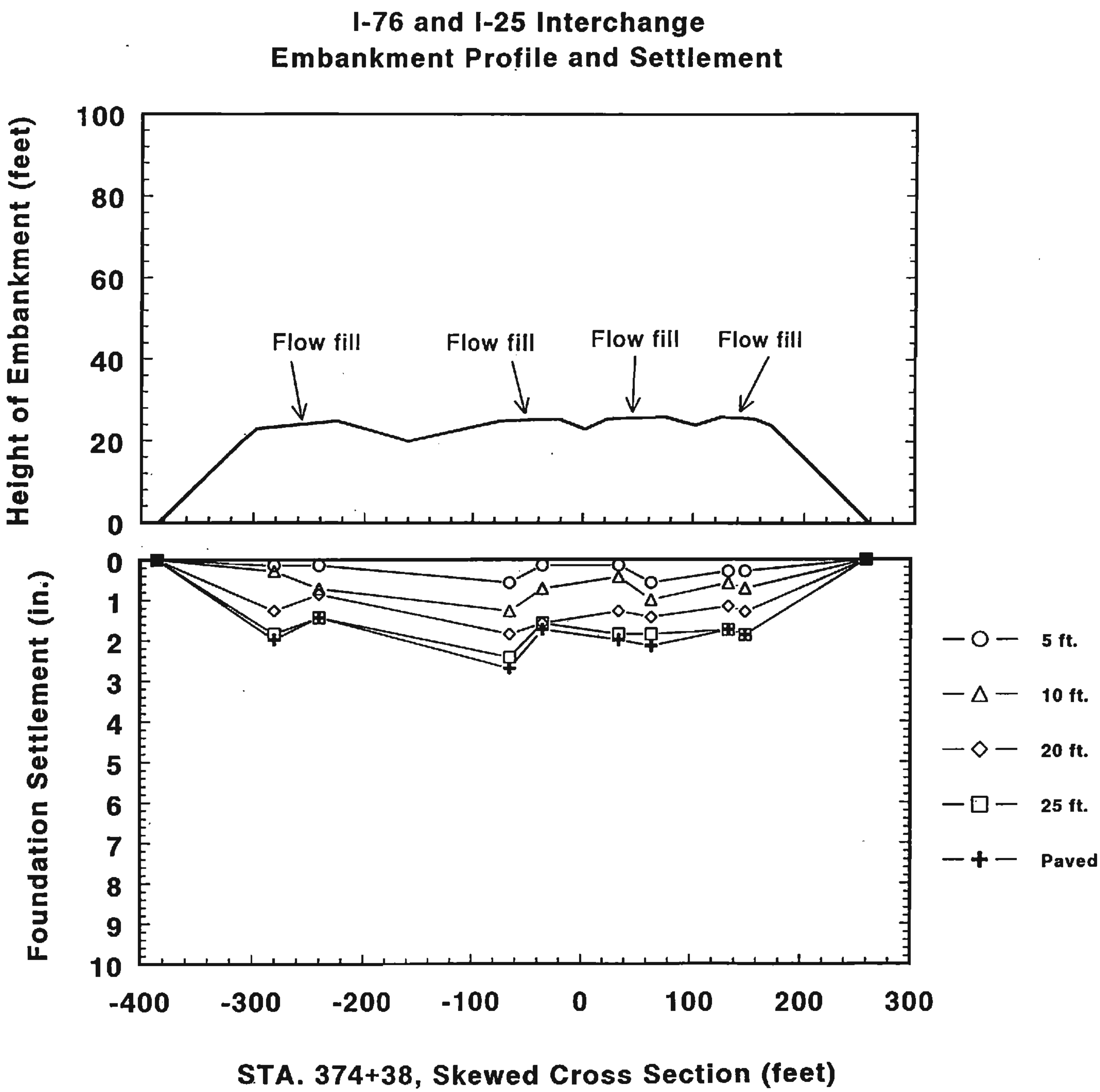


Figure 10: Foundation Settlements Versus Height of Fill at Station 374+38

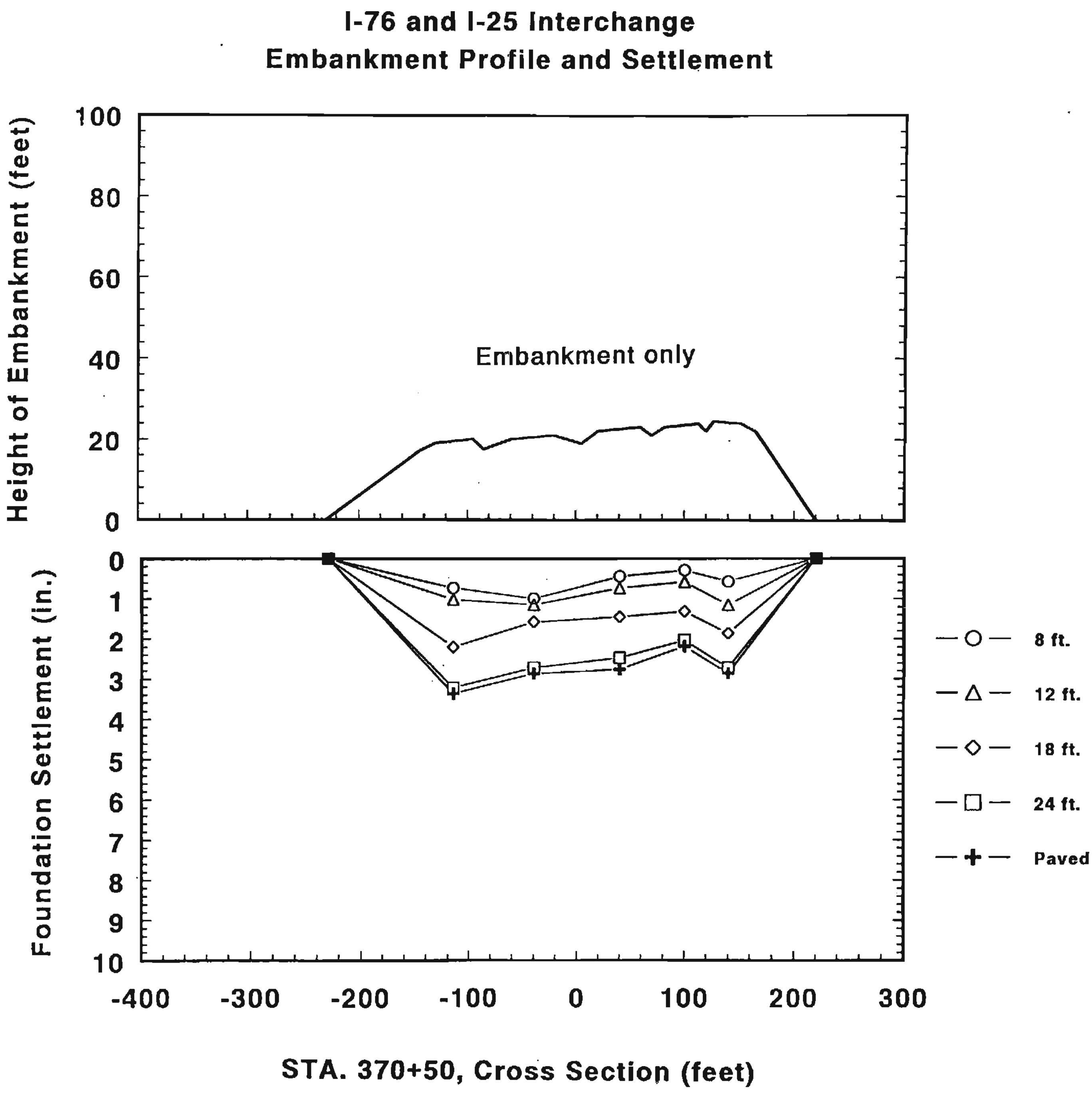


Figure 11: Foundation Settlements Versus Height of Fill at Station 370+50

The results also indicate that the primary compression of the foundation soils is nearly complete at the time the approach slab is constructed in November, 1992. Nil to less than 0.2 inches (0.51 cm) settlement was detected between the last measurement of settlement after the completion of the embankment and the placement of approach slabs. It can be concluded that most of the future approach settlement will be the compression of the embankment or backfill materials and the consolidation of the foundation soils will be minimal.

Measurements of the compression of the embankment were taken from the top transducers. The results as shown on Figures 12 to 14 indicate that the combined compression from the embankment and backfill ranged from 1.4 to 2.0 inches (3.56 to 5.08 cm).

Interstate 76 at the test area was opened to traffic in September of 1993. The amount of settlement six months after opening was again measured. As indicated on Figure 15, up to 1.5 inches (3.8 cm) of differential settlement has occurred across Station 372+08. It appears that a larger embankment compression has occurred at areas backfilled by the Class 1 structural fill and EPS. Contrary to our expectation, the approaches backfilled by the flow fill experience the least compression and the area backfilled by the EPS suffers the most compression.

The approach areas were also examined by personal driving at a speed of 55 mph (90 km per hour). As confirmed by the collected settlement data, the areas constructed with the flow fill appear to provide a better ride.

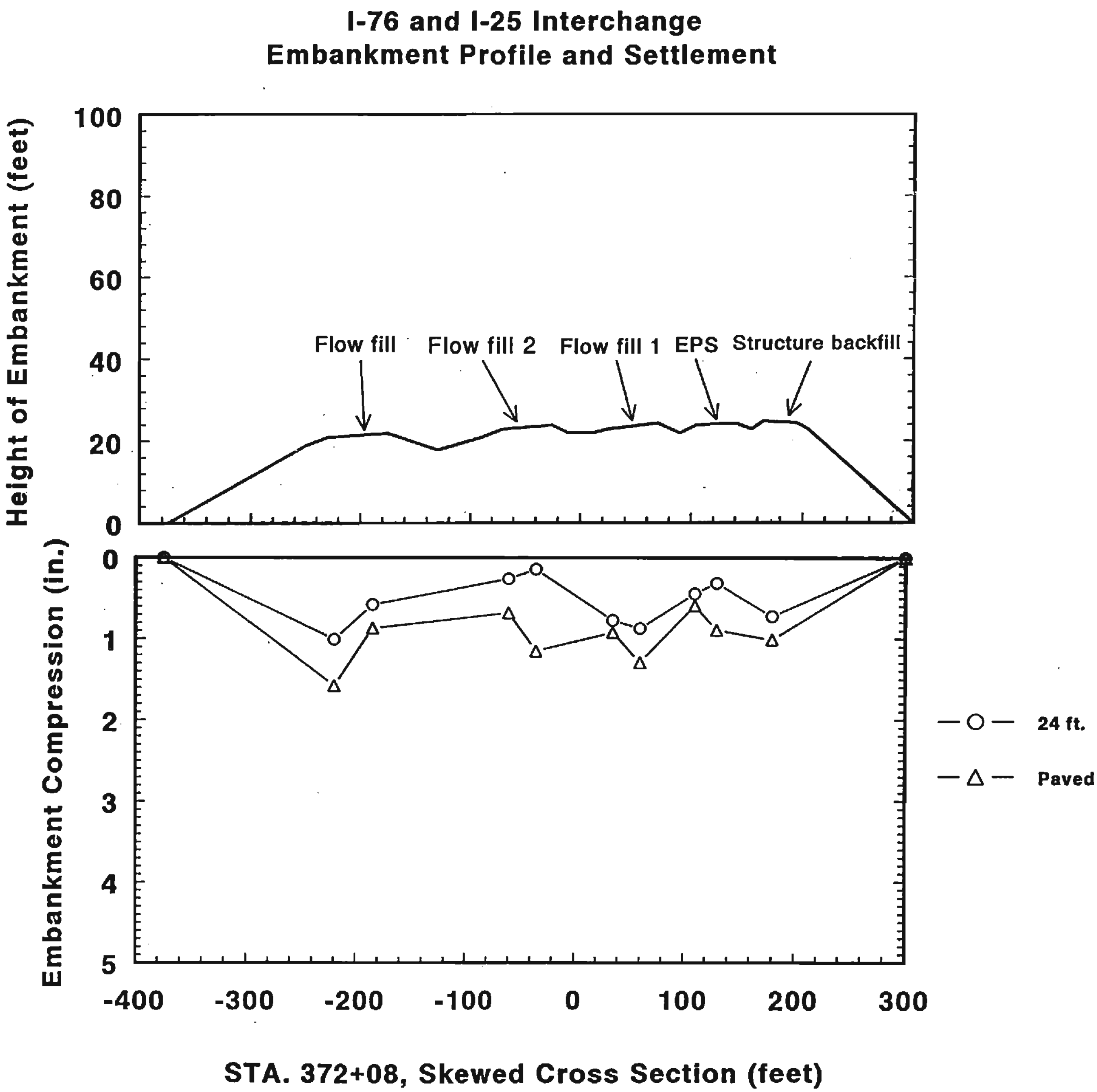


Figure 12: Embankment Compression at Station 372+08

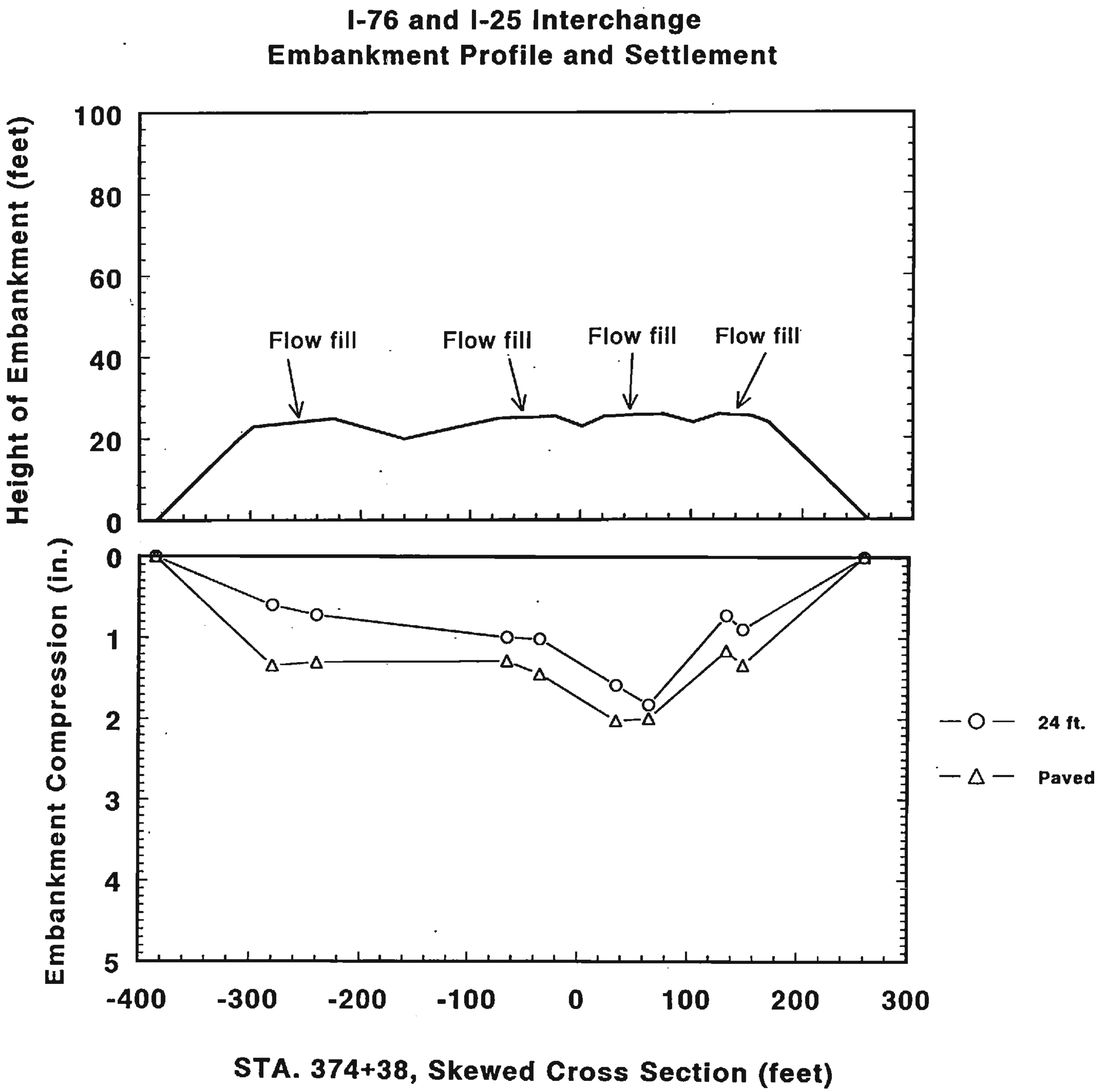


Figure 13: Embankment Compression at Station 374+38

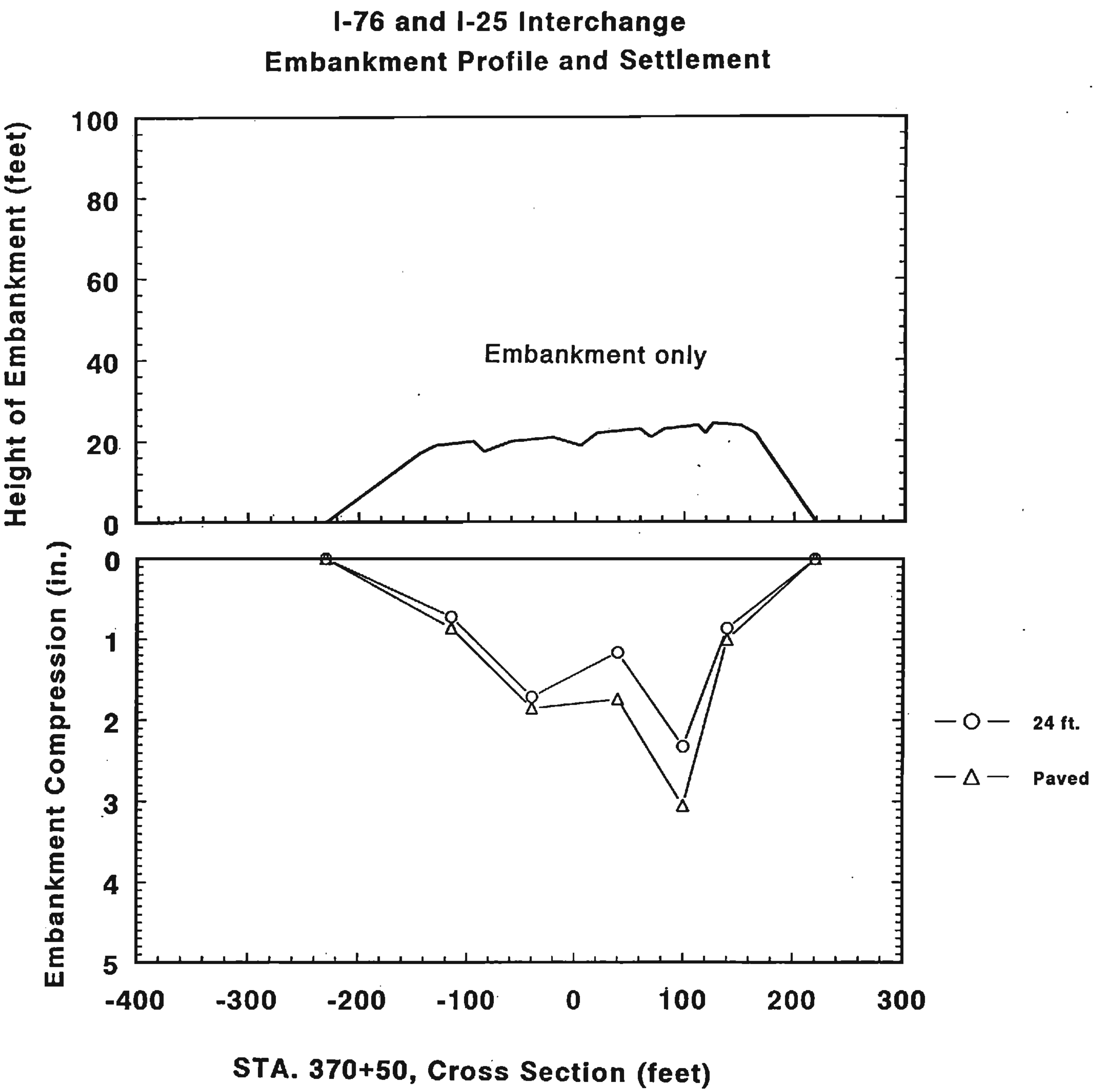


Figure 14: Embankment Compression at Station 370+50

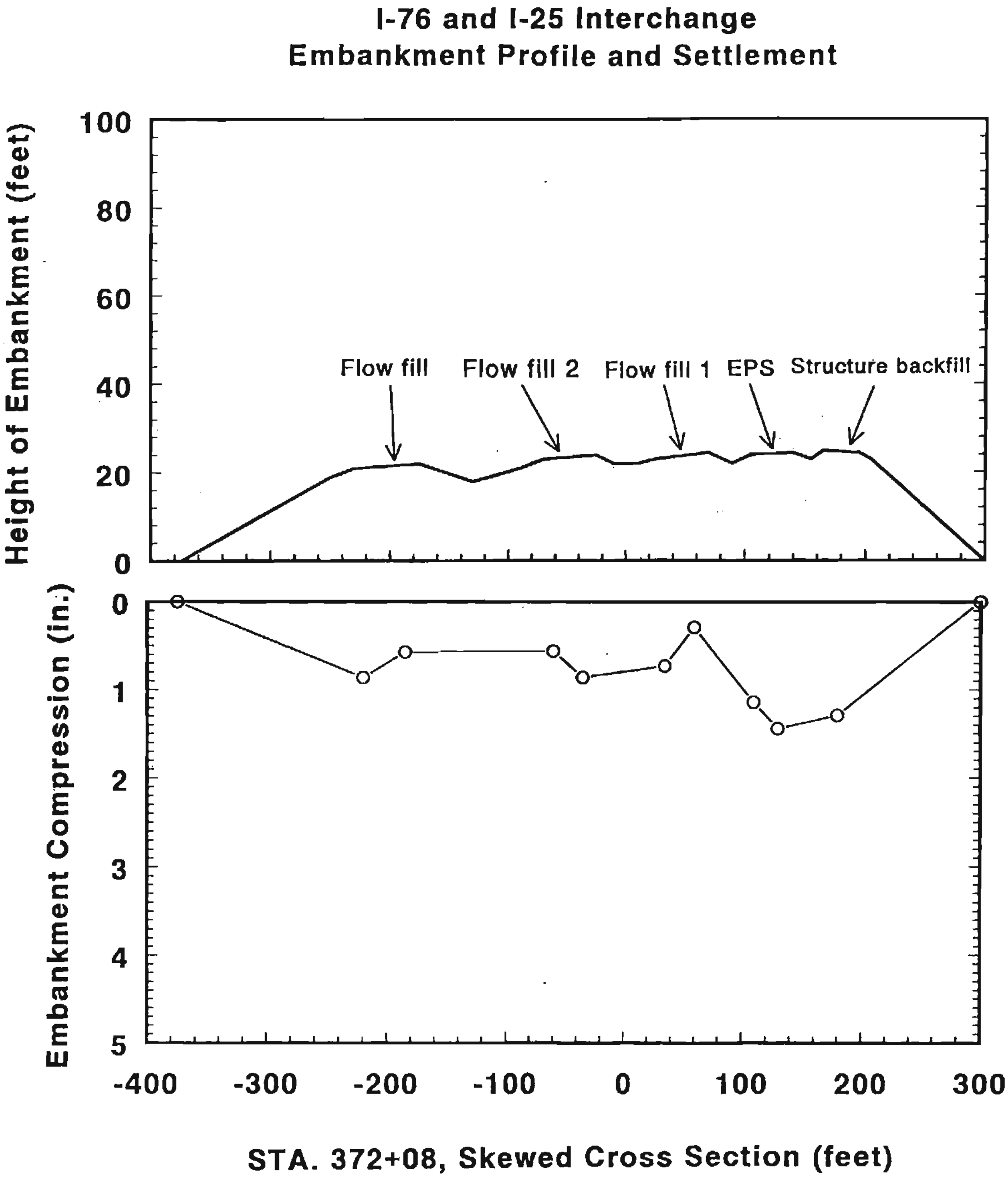


Figure 15: Embankment Compression at Station 372+08 After Opening to Traffic

5.2 Lateral Pressure Measurements

The initial readings for the lateral pressure measurements were taken in August, 1992. Figure 16 presents the relationship between the ground temperature and the earth pressure monitored at the four abutment walls at a depth of four feet (1.22 m). The ground temperature was taken as the average of the temperature measured at the bridge surface and under the bridge. Results of the measurement indicated that ground temperature has significant effects on the magnitude of the lateral earth pressure behind all abutments. In general, a higher temperature will cause the bridge to expand and a higher lateral pressure against the abutments is expected. The maximum lateral pressure measured on the abutment wall occurred at a ground temperature of 90° Fahrenheit (F) for all four types of backfill. On the other hand, a lower ground temperature will cause the bridge deck to contract and a lower earth pressure behind the abutment is expected. At a temperature near 34° F, the lateral pressures in all abutments were very similar and the intensity was relatively low.

The responses of the abutments using various backfill material were also examined. For abutments backfilled with the EPS, the lateral pressure appears to increase negligibly to slightly with increase of temperature and can be considered very minimal. On the contrary, the effect of the temperature is significant for abutments backfilled with Class 1 Structure Backfill. The earth pressure measured was eight psi (55.16 kN/m^2) at a temperature of 90° F. This is equivalent to a passive earth pressure condition (Kp) at a location of four feet (1.22 m) below the approach slab.

For abutments constructed with flow fill, the lateral pressure also increased linearly with the increase of temperature. The effect of the temperature at the lower end of the range is relatively insignificant. The maximum lateral pressures measured were on the order of four to six psi (27.58 to 41.37 kN/m^2) at a temperature of 90 degree F. The average lateral pressures obtained from the paired earth pressure cells plotted against the ground temperatures is shown on Figure 17.

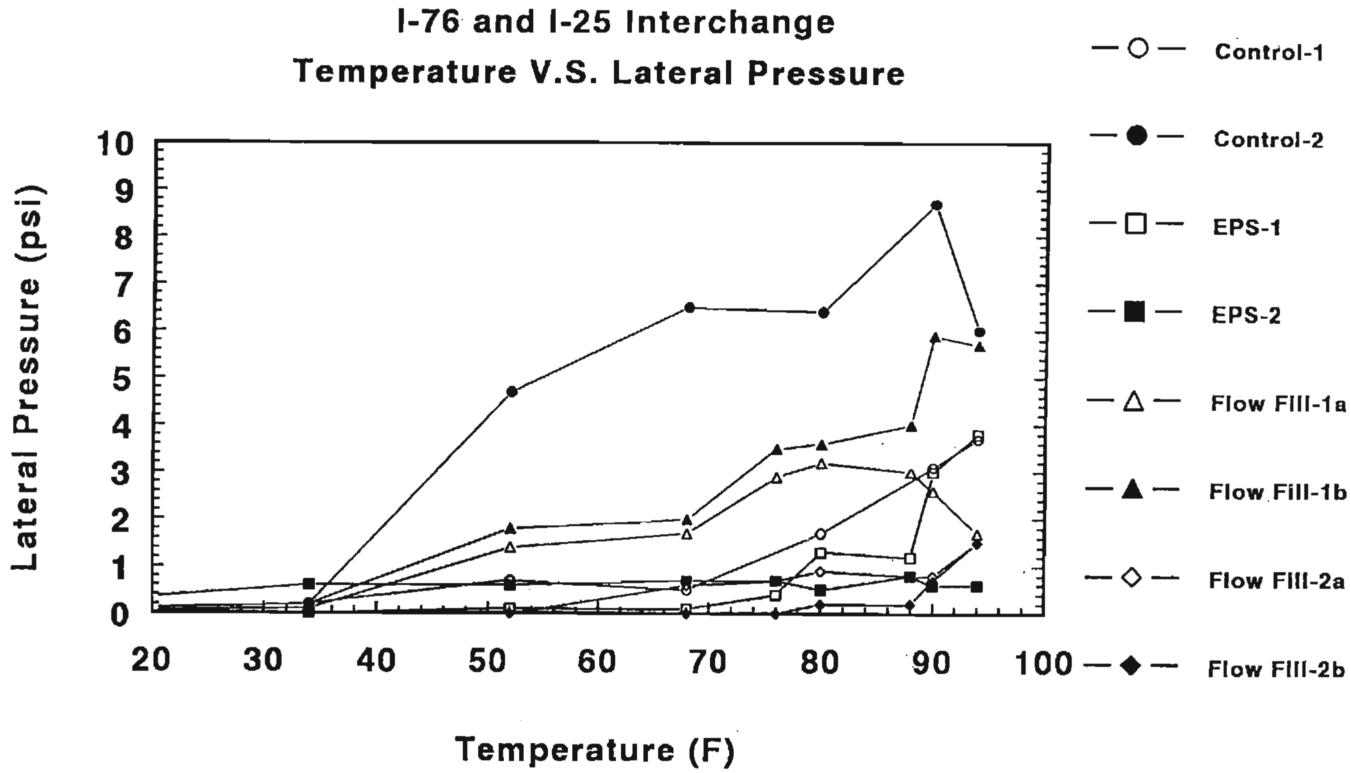


Figure 16: Lateral Pressure Versus Temperature for Abutments Near Station 372+08

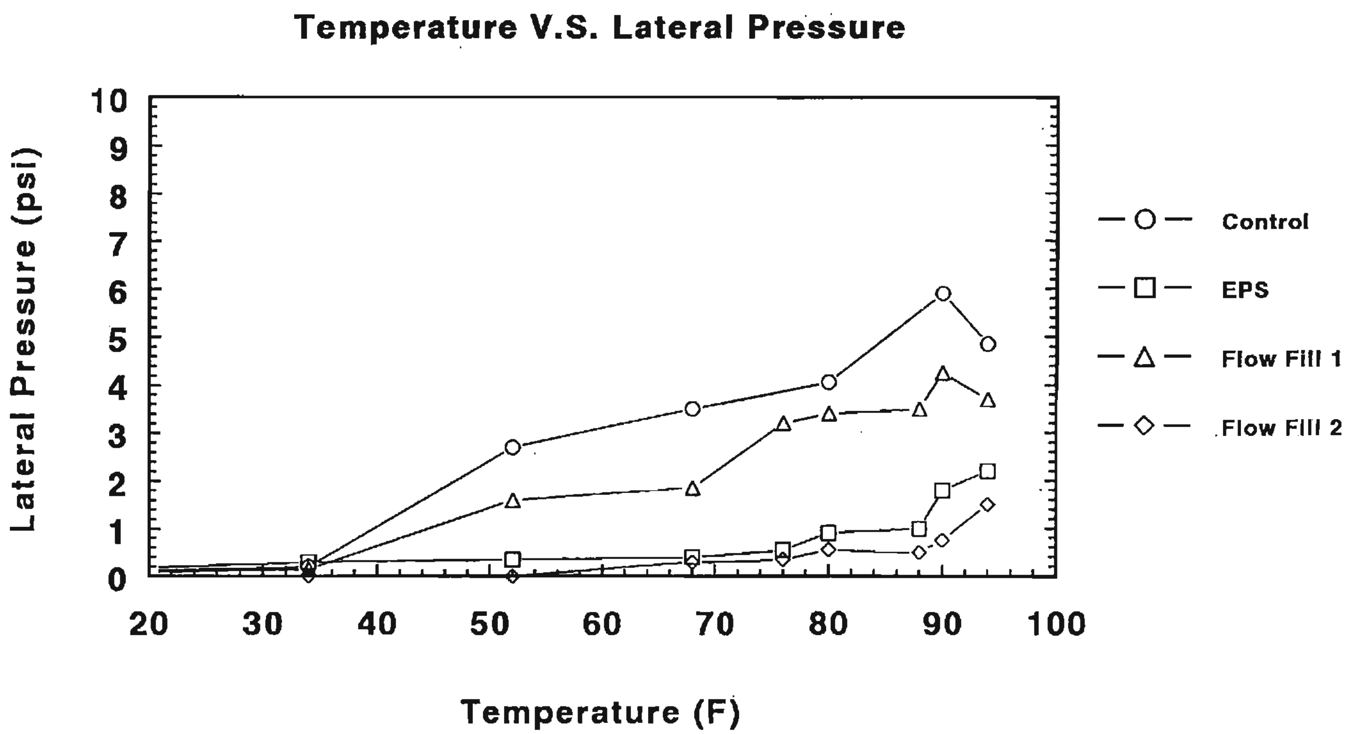


Figure 17: Average Lateral Pressure Versus Temperature for Abutments Near Station 372+08

5.3 Lateral Movement

The initial readings were taken in September, 1992. Figure 18 presents the results of the extensometer measurements at four abutments with the extensometers located at a depth of four feet (1.22 m) below the approach slab. The lateral movement shown on the figure has been calibrated to a reference temperature of 52° F. The calibration were made so that the readings could be compared. In general, the measured movements represent the abutment wall movements recorded between the temperature-induced movements and the zero readings taken at a temperature of 52° F.

A positive movement reading as shown on Figure 18 indicates that the abutment wall moved toward the backfill as the bridge expanded at a higher temperature on warm days. On the other hand, a negative movement reading indicates the wall moved away from the backfill when the bridge contracted at a lower temperature in cool weather.

The results shown in Figure 18 indicate that temperature has significant effects on the lateral movement of the abutment. The higher temperature gives more positive lateral movement induced by thermal expansion of the structure toward the abutment. The negative lateral movement of the abutment wall occurred at a low temperature of 34° F for all four abutments.

For the EPS fill abutment, the lateral movement increases somewhat proportionally with the increase in temperature. The effect of temperature on lateral movement of the abutment in the EPS fill appears to be more significant than the others. This implies that the EPS fill has less resistance to the movement of the abutment wall due to the bridge thermal expansion. A smaller lateral earth pressure was therefore measured.

For the abutment backfilled with Class 1 Structure Backfill, the lateral movement becomes relatively small. It appears that the Class 1 Structural Backfill generate higher earth pressure against the facing of the abutment wall. A positive lateral movement was measured on the facing of the abutment at a higher temperature. It is believed that the structural fill material has been falling into the voids created between the backfill and the abutment by the contraction of the bridge. This restrains the movement of the wall from bridge expansion at higher temperatures. Consequently, a larger earth pressure is measured.

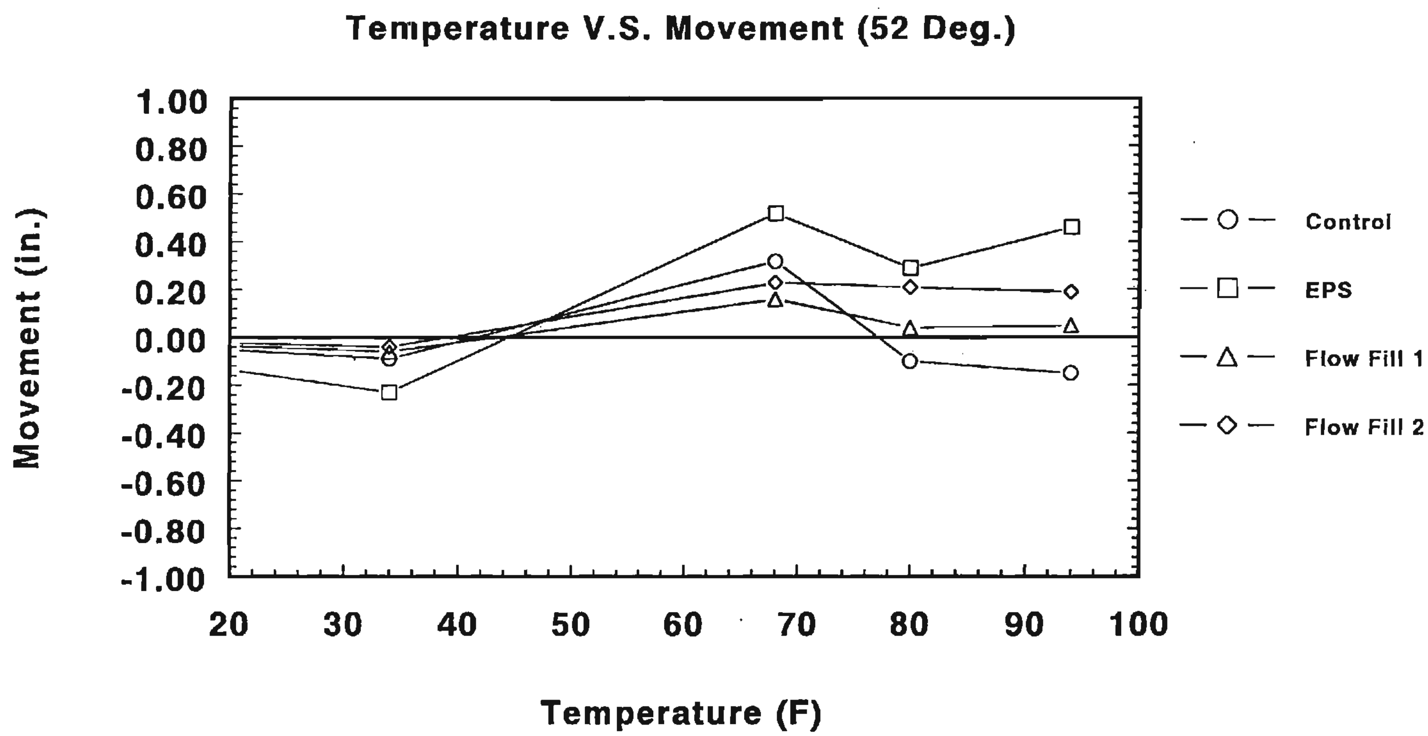


Figure 18: Lateral Movement of Abutment Versus Temperature for Abutments Near Station 372+08

6.0 SUMMARY AND CONCLUSIONS

6.1 Summary

Many investigations for the bridge approach settlement have concluded that, while the bridge "bump" is a very common problem throughout the United States, there is no single cause to attribute to this problem. In other words, individual or a combination of factors have contributed to the observed settlement. Consequently, it is not feasible to have a standard design developed to eliminate all causes.

A comprehensive experimental study was proposed and undertaken in 1987 to investigate the causes of the Colorado highway bridge approach settlement and to study a few feasible solutions. Findings of the investigation were concluded and remedial measures were suggested to alleviate the problem of the approach settlement. Design and construction of the bridge approaches were modified and implemented to minimize settlement problems. However, the performance of the conventional Class 1 Structure Backfill has been poor and the practice of using Class 1 Structure Backfill to reduce bridge approach settlement is not effective.

In an attempt to alleviate the bridge approach settlement problems, an experimental project was developed to evaluate other available backfill materials. The emphasis of the study has been focused on the compression of the embankment and the abutment backfill, rather than the consolidation of the foundation soils. Since the performance of various backfill materials has not been researched, this study provided an opportunity to examine the potentials of various backfill materials.

Five bridge abutments at I-76 were instrumented and monitored to study the behaviors of three different kinds of backfill behind the bridge abutments. The three backfills selected consisted of super-light expanded polystyrene (EPS), Class 1 Structure Backfill and flow fill. The test site was fully instrumented with liquid settlement transducers, earth pressure cells, and extensometers. Measurements during this investigation included settlements in the embankment and foundation, temperature variation, lateral pressure and movement behind the abutments. Most instruments performed satisfactorily and readings were consistent with the predictions. Comparisons of field measurements for the performance of various backfills behind abutments were made.

6.2 Conclusions

The results of this research indicated the following:

1. Foundation settlement of the bridge approach embankments at this test site is insignificant because the subsurface material is mainly granular. Sufficient construction time has allowed initial consolidation of the foundation material to be completed.

2. Results of the field tests indicate that the super-light expanded polystyrene (EPS) backfill has less immediate foundation settlement than other backfills at this site.

3. Compression of the approach embankment and backfill is the most significant factor in contributing to approach settlement problems at this site.

4. Results of the field tests indicate that temperature variations significantly affected the lateral pressure and lateral movement of the bridge abutments.

5. Results of the measurements indicate that Class 1 Structural Backfill used behind the abutment wall is ineffective in reducing lateral earth pressure induced by the bridge expansion. On the contrary, the EPS backfill and flow fill produce the least lateral pressure against the abutment walls.

6. Based on the findings of this study, it appears that flow fill material has the best performance among the three in controlling lateral pressure and movement behind the bridge abutments.

7. It also appears that the bridge approaches backfilled with flow fill show the least post construction embankment compression and provide a better ride than approaches backfilled with the other two types of backfill.

8. To evaluate the long-term behaviors of these backfills, monitoring of settlement, lateral pressure and movement should be continued.

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