COST EFFECTIVENESS OF EUROPEAN DEMONSTRATION PROJECT: I-75 DETROIT

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16. Abstract

The performance of the experimental European pavement section in Detroit, MI was analyzed and compared to the adjacent pavement section (Michigan standard section) and three other pavement sections that were constructed using normal Michigan design methods.

The performance criteria that were analyzed included pavement deflection, traffic/tire noise, traffic loading, pavement friction, ride quality, and pavement distress. A cost comparison was completed to compare the initial construction cost of the European pavement to typical Michigan pavements.

Finally, an economic analysis was done to determine the life cycle costs for a European pavement section and a standard Michigan pavement section. This economic analysis was used to determine whether or not the European section is cost competitive with a standard Michigan section for a prescribed service life period.

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Table of Contents

	Page
DISCLAIMER	iii
EXECUTIVE SUMMARY	iv
INTRODUCTION	1
EUROPEAN AND MICHIGAN DESIGN DIFFERENCES	1
DEFLECTION AND TRAFFIC/TIRE NOISE COMPARISON	3
Deflection Analysis	3
Traffic/Tire Noise Analysis	4
PERFORMANCE RESULTS	6
Friction Number	6
Ride Quality Index	6
International Roughness Index	7
Distress Index	7
Traffic	8
Results	9
PAVEMENT DESIGN COST COMPARISON	17
PROJECTION OF PERFORMANCE INDICATORS	19
ECONOMIC ANALYSIS	20
CONCLUSIONS AND RECOMMENDATIONS	26
Conclusions	26
Recommendations	27

Appendix A
- MDOT European Pavement Design Report
- Figure A.1 - Michigan and Euro Section Cross Sections
- Figure A.2 - Standard Section 1 Cross Sections
- Figure A.3 - Standard Section 2 Cross Sections
- Figure A.4 - Standard Section 3 Cross Sections

Appendix B
- Table B.1 – Maximum Midslab Deflection Measurements
- Table B.2 – Transverse Joint Deflection Measurements
- Figure B.1 – Plan View of Noise Measurement Site
- Figure B.2 – Quarter Car Simulation for IRI

Appendix C
Figure C.1 – Projected Average Ride Quality
Figure C.2 – Projected Distress Index

List of Tables and Figures

Tables

Table 1. Location and Date of Opening for all Analyzed Sections
Table 2. Summary of Pavement Cross-Sections
Table 3. Summary of Average Maximum Midslab Deflections
Table 4. Summary of Average Maximum Deflections and Average LTE
Table 5. Typical Noise Levels at Various Locations
Table 6. Perception Levels for various Noise level Changes
Table 7. Cost Comparison
Table 8. Unit Bid Prices
Table 9. MDOT Pavement Preservation Strategies
Table B.1 – Maximum Midslab Deflection Measurements
Table B.2 – Transverse Joint Deflection Measurements

Figures

Figure 1. Variation in Total Annual Traffic per Section from 1993 to 1999
Figure 2. Cumulative Total Traffic Volume From 1993 to 1999
Figure 3: Friction Number vs. Cumulative Traffic
Figure 4: Average Ride Quality Index vs. Cumulative Traffic
Figure 5: Average International Roughness Index vs. Cumulative Traffic
Figure 6: Distress Index vs. Cumulative Traffic
Figure 6a: Distress Index vs. Cumulative Traffic
Figure A.1 - Michigan and Euro Section Cross Sections
Figure A.2 - Standard Section 1 Cross Sections
Figure A.3 - Standard Section 2 Cross Sections
Figure A.4 - Standard Section 3 Cross Sections
Figure B.1 – Plan View of Noise Measurement Site
Figure B.2 – Quarter Car Simulation for IRI
Figure C.1 – Projected Average Ride Quality
Figure C.2 – Projected Distress Index

DISCLAIMER

EXECUTIVE SUMMARY

In an effort to design and construct concrete pavements with longer service lives the Michigan Department of Transportation (MDOT)and the Federal Highway Administration partnered in 1993 to implement a European pavement design. The pavement project was constructed as a portion of I-75 (Chrysler Freeway) in downtown Detroit, between I-375 and I-94 (Edsel Ford Freeway). The pavement utilized design specifications from both Germany and Austria with adjustments for the climatic, soil, and traffic conditions found in Detroit.

The primary objective of this report was to determine whether the innovative features of typical rigid pavement designs used in European countries is a cost effective alternative to conventional design and construction methods used for rigid pavements in the United States (ie: Michigan). This report addresses the analysis and comparison of the performance of the European pavement cross section with four similar MDOT standard pavement sections located on I-75 in southeast Michigan.

The European pavement was designed on the premise that it would have better overall performance than the standard MDOT pavements. Condition measures to determine relative performance of the pavement sections included slab deflection, traffic/tire noise, Friction Number (FN), Ride Quality Index (RQI), International Roughness Index (IRI), and Distress Index (DI). Cumulative traffic volumes were used as a relative measure of pavement wear.

The following conclusions were drawn from the study:

- The traffic/tire noise level, which was anticipated to favor the European pavement with its exposed aggregate surface, was determined to be equivalent to the Michigan tined texture.

- All the Michigan sections and the European section have acceptable surface friction numbers. The Michigan sections have slightly higher values which was unexpected, as the exposed aggregate surface of the European pavement was supposed to provide higher FN's.

- The ride quality, as measured by RQI and IRI, was better on the three standard comparison sections than either the Michigan control or European sections. This was somewhat unexpected, because of the increased quality control and inspection intensity during construction of the special project.

- All pavement sections exhibit low distress levels since construction as measured by MDOT's distress index. It was expected the DI for the European section would remain very low with its superior design materials and increased structural capacity.

- The Euro Section was much more expensive to build than a conventional Michigan pavement. Analysis by MDOT showed that the conventional pavement was constructed for approximately forty-three percent (43%) of the cost of the Euro pavement (based on the low bidder's estimate, the range for the other bidders was 40-49%).

- There is no definite trend apparent for the measured RQI and DI values since construction for either pavement section. The amount of data are insufficient to make an accurate prediction of when service failure will likely occur.

- Given the MDOT-assumed maintenance schedule for pavements, the Euro pavement could be competitive (on an annualized cost basis) with standard pavements when the Euro's capital cost is no more than approximately 17% higher. (This is subject to several assumptions which are addressed in earlier sections.)

Furthermore, the following recommendation was made:

The analysis done for this report is based on a small sample of data over a very limited time period (relative to the expected service lives of all of the pavements). Simply put, all of the pavements are still performing very well and have not yet approached the distress levels that would signal the need for significant maintenance to be done. It is recommended that the various indicators of pavement wear (e.g., distress index) be monitored on an annual basis. Once trends become clear, a follow-up analysis is recommended. Based on the "typical" service life and distress index deterioration that are assumed in MDOT's pavement preservation strategies, it would seem likely that trends should be notable when the pavement is on the order of 10 years old since the distress index is assumed to reach a level of around nine (9) and require some substantial maintenance after approximately 13 years of service.

INTRODUCTION

A continuing objective of the Michigan Department of Transportation (MDOT) is to lengthen pavement service life by improving the performance of its design, materials, or construction quality. In 1993 this effort led MDOT to design and construct a special pavement reconstruction project. The project is located on I-75 (Chrysler Freeway) in downtown Detroit, between I-375 and I-94 (Edsel Ford Freeway). The special features were adapted from European pavement designs and incorporated into the plans and specifications of Federal Project IM 75-1(420), Michigan Project IM 82251/30613A. A conventional Michigan rigid pavement design was constructed adjacent to the European section as a comparison control section. The design features and construction specifications of each pavement are documented in MDOT's project construction report in Appendix A.

The primary objective of this study was to determine whether the innovative features of typical rigid pavement designs used in European countries are a cost effective alternative to conventional design and construction methods used for rigid pavements in Michigan, which are similar throughout the United States. This report addresses the analysis and comparison of the performance of the European pavement section (Euro Section), the adjacent control section constructed using conventional Michigan design methods (Michigan Section), and three additional reconstruction projects (Standard Sections 1, 2, and 3). Standard Sections 1-3 are along the I-75 corridor south of this study project and have been in service about 3-4 years longer than the study sections.

The study hypothesis was that the Euro Section would have better overall performance than the typical Michigan pavements, as measured by smaller slab deflections, higher surface friction, and lower noise levels.

EUROPEAN AND MICHIGAN DESIGN DIFFERENCES

Table 1 lists the locations and "opening to traffic" dates for the Euro Section, Michigan Section, and Standard Sections 1-3.

The pavement cross section for the approximate one mile long Euro Section was selected according to the procedures followed for a typical German rigid pavement adjusted for the climatic, soil, and traffic conditions found in the Detroit area. The cross section consisted of a 16-inch non-frost susceptible aggregate subbase placed directly on the existing clay subgrade; a 6-inch non-reinforced lean concrete base with plane of weakness joints placed above the subbase; and finally, a 10-inch non-reinforced concrete pavement (JPCP) placed above the lean concrete base. The JPCP was constructed in two layers (2.5 inches and 7.5 inches) with two separate mixtures. The 2.5-inch top layer uses an exposed aggregate layer to texture the pavement that was expected to provide higher friction numbers and lower noise levels as compared to Michigan tined pavements. The Euro Section consists of three or four traveling lanes with a 10.5 feet tied concrete shoulder. The inside travel lanes are 12 feet wide and the outside slab is widen to 13.5 feet (stripped at 12 feet). The outside lanes are wider to provide a superior interior loading condition (lower slab tensile stresses) which reduces the potential of fatigue cracking. The transverse joint spacing is 15 feet. Table 2 is a summary of the pavement cross sections for each section.

Table 1. Location and Date of Opening for all Analyzed Sections

Pavement Section	Date Opened	Location
Euro Section	November 1993	Northbound I-75 between the Warren Avenue exit ramp N'ly to Picquette Avenue
Michigan Section	November 1993	Northbound I-75 between I-375 and the Warren Avenue exit ramp
Standard Section 1	October 1989	Northbound and Southbound I-75 from Dunbar Road N'ly to I-275 in Monroe County
Standard Section 2	September 1990	Northbound and Southbound I-75 from I-275 N'ly to the Wayne County line
Standard Section 3	November 1991	Northbound and Southbound I-75 from Sibley Road N'ly to Goddard Road

Table 2. Summary of Pavement Cross-Sections

	Subbase	Base	Conc. Pavement
Euro	16" non-frost susceptible aggregate	6" non-reinf. lean concrete	10" non-reinf. concrete (2.5" over 7.5")
Michigan	12" sand *	4" cement treated OGDC	11" reinf. concrete
Standard Section 1	10"-12" sand *	4" bit. treated OGDC	11"-12" reinf. concrete
Standard Section 2	10"-12" sand *	4" bit. treated OGDC	11"-12" reinf. concrete
Standard Section 3	10"-12" sand *	4" bit. treated OGDC	11" reinf. concrete

* Sand was existing in-place from original pavement construction

The Michigan Section and Standard Sections 1-3 were conventional MDOT pavement designs. Each pavement cross section consists of a 10-12 inch sand subbase, a 4-inch open graded drainage course (OGDC), and a jointed reinforced concrete pavement (JRCP). The 4-inch OGDC was cement or bituminous treated to increase layer stiffness and reduce segregation during placement. Furthermore, the 4-inch OGDC on Standard Sections 1-3 was constructed using recycled crushed concrete pavement. The JRCP slab thickness is either 11 or 12 inches depending on the anticipated traffic load requirements. The Michigan Section and Standard Sections 1-3 consist of three travel lanes in each direction with a 10 to 12 feet wide tied concrete shoulder. The travel lanes are 12 feet wide and the transverse joint spacing is 41 feet for the Michigan Section and 27 feet for Standard Sections 1-3.

DEFLECTION AND TRAFFIC/TIRE NOISE COMPARISON

Three of the expected advantages of the European pavement design were increased ability to carry heavy axle loads (lower slab deflections), higher surface friction, and a reduction in traffic/tire noise levels. Measurements of deflection and tire noise were only taken on the Michigan Section and the Euro Section.

Deflections Analysis

Deflection testing for the Michigan and Euro Sections was performed twice, first in November 1993 and then in April 1995. The November 1993 measurements were taken during daylight hours prior to the pavement being opened to traffic. In contrast, the April 1995 measurements were taken at night (from 1:00 AM - 5:00 AM). The measurements were taken using MDOT's falling weight deflectometer (FWD) using a 4000 kg (9000 lb) impact load. Each value is an average of three drops.

Table 3 is a summary of the comparison of maximum midslab deflection measurements for the two pavement sections. These data indicate both sections are relatively stiff with minimal change among lanes. As expected, the European Section is slightly stiffer (higher layer modulii values) than the Michigan Section because of its lean concrete base and stiff dense-graded subbase. More complete data are shown in Table B.1 in Appendix B.

Table 3. Summary of Average Maximum Midslab Deflections

Section	Test Date	Average Maximum Midslab Deflection (mils)		
		Inside Lane	Lane Left of Outside Lane	Outside Lane
Euro	November 93	1.27	1.37	1.30
	April 95	1.33	1.32	1.41
Michigan	November 93	2.28	2.13	1.99
	April 95	2.07	2.07	2.05

Table 4 is a summary comparison of deflection values taken in the right wheel path at transverse contraction joints and the calculated load transfer efficiencies (LTE) in 1993 and 1995. More complete data are shown in Table B.2 in Appendix B.

LTEs were calculated by dividing the deflection on the unloaded side of the joint by the deflection (load plate) on the loaded side of the joint and then converting to a percentage. The equation is as follows:

$$LTE_{\delta}\,(\%) = (\delta_{UL}/\delta_{L}) \cdot 100\%$$

δ_{UL} = deflection of the unloaded side
δ_L = deflection of the loaded side

Table 4. Summary of Average Maximum Deflections and Average LTE

Section	Test Date	Lane Left of Outside Lane		Outside Lane	
		Avg. Max. Deflection (mils)	Avg. LTE (%)	Avg. Max. Deflection (mils)	Avg. LTE (%)
Euro	November 93	3.29	79.1	3.39	77.0
	April 95	5.14	61.9	4.85	58.8
Michigan	November 93	3.78	71.6	3.83	67.5
	April 95	6.01	69.5	5.19	69.7

The average LTEs appear to be low for both pavements, especially in 1995 for the European section. The European section was expected to have higher LTEs because of its stiffer lean concrete base and closer spacing (240 mm vs. 300 mm in the outside lane) between dowel bars, which allows for better shear transfer. For a concrete pavement with 15' joint spacing and tied concrete shoulders and doweled joints the LTEs in Table 4 are low. The distress data does not indicate any faulting or spalling which would indicate poor joint performance. The weather data for the study site indicate the lower LTEs for the European pavement may result from moisture warping in the top slab during testing. During the thirty days preceding the test there were many days of recorded rainfall, although little rain occurred during the week before testing. The FWD testing should be repeated under "normal" environment and pavement conditions to verify the postulate.

It should be noted that the actual location relationship between the FWD load plate and the joint's dowel bars was not determined for this testing.

Traffic/Tire Noise Analysis

Noise is a measure of sound pressure that is expressed in decibels (dBA). For comparison, Table 5 contains typical decibel levels for various locations/situations.

Table 5. Typical Noise Levels at Various Locations

Location	**Noise Level (dBA)**
average residential living room	45
typical business office with typing	65
average street traffic at highway speeds	85
average truck traffic at highway speeds	92

There is a significant difference when comparing measured noise levels and the perceived noise levels. A 3 dBA change in the measured noise level correlates to a doubling of the sound pressure, but, the doubling in sound pressure does not correlate to a doubling of the perceived noise level. In fact, a 3 dBA change in noise level is barely perceivable to a person with average hearing. Table 6 lists the perception levels for various changes in noise level.

Table 6. Perception Levels for various Noise level Changes

Change in Noise Level (+/-) in dBA	Perception Level
3	barely perceptible
5 to 6	readily perceptible
10	doubling or halving of the noise level

Noise is often expressed as a weighted average sound level over a period of time, L_{eq}. This measure provides a steady state sound level that has the equivalent energy of a sound with a varying level.

Exposed aggregate surfaces have been used successfully in Europe for several years to reduce the annoying effects of traffic vehicle noise resulting from tire contact with the pavement surface. The exposed aggregate surface on this project was expected to provide similar results.

MDOT made a traffic noise study in June 1994. During the study the southbound pavement was being reconstructed and traffic was detoured to the northbound side of I-75. Northbound traffic was detoured. The noise testing was done after the detour went into effect to avoid background vehicle noise from southbound I-75.

Separate noise measurements of mixed traffic were made simultaneously at two locations adjacent to the European pavement and the Michigan pavement using General Radio and B&K Type I noise level meters and a Nagra IV SJ tape recorder. The measurement locations were 56 feet from the nearest lane of I-75 traffic at a spacing of approximately 1400 feet. The magnetic tape was later analyzed for the spectral composition of the noise. The time period for each measurement was ten minutes. The L_{eq} noise levels for the European pavement were 0.4 dBA quieter (76.0 vs. 76.4) than the Michigan pavement. The instrumentation was capable of measuring noise to +/- 1 dBA. This measurement tolerance shows that there is essentially no difference in measured noise levels between the two pavements. Even if the difference were significant, it would not be perceptible.

The magnetic tape analysis at one octave band intervals showed the European pavement produced slightly more energy at 63 and 16K Hz, but produced less noise at 250, 2K, 4K, and 8K Hz. There was no significant difference for other octave bands.

Noise measurements were also made inside a 1991 Dodge Dynasty traveling at 50 mph with the windows closed and open. With the windows closed, the L_{eq} noise level for the European pavement was 64.5 dBA versus 65.2 dBA for the Michigan pavement. With the windows open, the L_{eq} noise level for the European pavement was 66.8 dBA versus 67.4 dBA for the Michigan pavement. Again the measurement tolerance for the equipment used was +/- 1 dBA. Thus, there is no measurable difference in the noise levels for the European and Michigan pavements.

The study results indicate the exposed aggregate surface does not produce the expected reduction in noise levels that are perceptible to persons residing adjacent to the project or when traveling by car. The complete traffic/tire noise study can be found in the MDOT report, "First Year Performance of the European Concrete Pavement on Northbound I-75, Detroit, Michigan" (1995). A possible reason for the result, which the report discusses, is that the exposed aggregate surface had too much macro-texture from excessive spacing of the large aggregate particles.

PERFORMANCE RESULTS

The performance since construction of all the pavement sections was determined by comparing the Friction Number (FN), Ride Quality Index (RQI), International Ride Index (IRI), and Distress Index (DI) of each pavement section.

Friction Number

The Friction Number (FN) is Michigan's measurement unit for available wet sliding friction on pavement surfaces. The FN values are acquired in the field using a full-scale locked-wheel trailer under controlled test situations. ASTM E-274 is used to establish test parameters and control variables such as tire type, applied water depth, time and sequence of lock-up, sampling procedures, and required reporting. The field values of wet sliding friction are transformed to equivalent standard units (FN) by use of a correlation equation developed at the Field Test and Evaluation Center for Eastern States in East Liberty, Ohio.

Ride Quality Index

The Ride Quality Index is Michigan's measurement unit for pavement ride quality. This value is determined from analyzing the various wavelengths of the longitudinal profile from the right wheel path in the outside driving lane. The profile is measured with MDOT's Rapid Travel Inertial Profilometer, which was initially developed from research conducted by General Motors in the 1960s. The value is calculated by passing the profile through three bandpass filters ranging from 2 to 50 feet and then computing the signal variance of each band. The variances are Log transformed and statistically matched with the user's opinion of pavement ride quality. The RQI value is a unitless number between 1 and 100, with lower RQI values representing pavements with better ride quality. A scale for rating RQI values in subjective terms is:

RQI	Subjective Rating
<31	Excellent
31 to 53	Good
54 to 70	Fair
>70	Poor

MDOT's current ride quality specification for new pavement requires the RQI to be less than 53 to be acceptable. New pavements with a RQI value of less than 45 qualify for a varying incentive payment.

International Roughness Index

The International Roughness Index is the more universal method for measuring road roughness. The IRI is a standard roughness measurement related to measurements obtained by road meters installed on vehicles or trailers. The IRI is a mathematical model applied to a measured profile. The model simulates a quarter-car system (QCS) (Figure B.2, Appendix B), traveling at a constant speed of 80 km/hr. The IRI is computed as the cumulative movement of the suspension of the QCS divided by the traveled distance (Shahin, 1994). A scale for rating IRI values in subjective terms is:

IRI Value, in/mile	Rating
80	Smooth
161	Satisfactory
241	Rough

IRI is related to present serviceability index (PSI) as follows:

IRI Value, in/mile	PSI
80	4.5
120	4.2
210	3.0
310	1.8

Both RQI and IRI ride quality values were determined from the same profile data that was collected after all surface grinding was completed to meet project acceptance for ride quality.

Distress Index

The Distress Index is defined as the sum of the distress points along a project normalized to the project length and compiled in $1/10^{th}$ mile increments. Each distress type is assigned distress points depending on its extent and severity. The DI scale is open-ended, starting at zero for a distress free pavement. A distress level of 50 indicates the pavement is no longer conducive for preventive maintenance treatments. Major rehabilitation or reconstruction then becomes the most cost effective fix alternative.

Traffic

Pavement performance is measured by how well the pavement functions over its intended service life until an unacceptable structural or functional distress condition occurs. Traffic is typically used as the measure of pavement age, or wear, because the majority of deterioration occurs when the pavement is being loaded. Not all traffic loads are of sufficient magnitude to damage the pavement, as automobiles and light commercial vehicles cause relatively little pavement damage. Thus, mixed commercial traffic is converted to Equivalent Single Axle Load (ESAL) for design and evaluation purposes and becomes the preferred measure of pavement age. MDOT data from automatic traffic recorders for the five pavement sections contains variable data in terms of the vehicle classification types. Thus, the number of ESALs can only be approximated, based on total traffic volumes and commercial vehicle volumes or percentages. Moreover, year-to-year variation in commercial vehicle percentages are typically estimated percentages which are not necessarily updated annually. For these reasons, the total volume estimates were used as a measure of pavement age since it was the most consistent estimator of traffic loading.

For the several figures that follow which illustrate trends in performance as measured by the several wear criteria (e.g., friction number), a simple time trend or a cumulative traffic trend is shown. An example of the former would be a plot of friction number versus pavement age in years. An example of the latter would be a plot of friction number versus pavement age in terms cumulative traffic volume. If all sites experienced identical, or nearly identical, annual volumes of traffic (ESALs) then both types of trends should look the same. However, the estimated volumes show substantial variation from site to site, that is, the ADTs at some sites are quite a bit higher than those at others. In addition, there is some variation in ADT from year to year at any given site. Thus, a "year of wear" at site X is not equivalent to a "year of wear" at site Y because the pavements at site X and Y have not been exposed to the same volume. Indeed, if the traffic volumes at site X were consistently 50% higher than at site Y, identical pavements would not last the same amount of time (in terms of actual time) at both sites. Likewise "year 1" of wear at site X may not even be equal to "year 2" of wear at site X if the ADT is steadily increasing over time.

Given the above explanation, a simple time trend for some pavement wear estimator is deemed to be inappropriate as the horizontal axis-time is not measured in units of "equal wear" (unless ADT is equal for every year). However, use of cumulative traffic as the horizontal axis solves this problem. For this study, the Euro and Michigan Sections have been exposed to traffic for fewer years than Standard Sections 1-3. However, the study sections, by virtue of their higher ADTs, have been exposed to approximately the same total traffic volume (ESALs) as the older standard sections.

The cumulative traffic total volumes were derived from MDOT's annual average 24-hour traffic volume maps. A direction factor of 0.50 and a lane distribution factor of 1.0 were used. Figures 1 and 2 show the variation in average total annual traffic per section and the cumulative traffic total volumes from 1993 to 1998, respectively. It should be noted that although the Euro and Michigan Sections are adjacent, their average annual traffic volumes differ. The difference is in the total annual traffic and cumulative total traffic volumes, presented in Figures 1 and 2, represent the difference in annual traffic reported in MDOT's annual average 24-hour traffic volume maps (i.e. the annual average 24-hour traffic volume maps report that the region containing the Euro Section was exposed to more traffic than the region containing the Michigan Section in 1998).

The summary of the performance parameters is shown in Figures 3 - 7. The performance parameters are given as a function of cumulative total traffic.

Results

Friction Number

The analysis of the FN shows that the Michigan Section and Standard Sections 1 and 2 have higher FNs, or more wet sliding friction, then the Euro Section (Figure 3). As stated earlier, this was unexpected. The Michigan Section, Euro Section, and Standard Section 2 show an increase in FN with an increase in cumulative traffic total volume, while Standard Section 1 shows a decrease in FN with an increase in cumulative traffic total volume. For the Michigan and Euro Sections the initial increase in wet sliding friction is likely due to the wearing off of the curing compound. The initial test value was made before the pavement was opened to traffic. After the second test there is no statistical change in the FN for the Michigan and Euro sections. The reason for the change in wet sliding friction for Standard Sections 1 and 2 is unknown. Standard Sections 1 and 2 used a local carbonate coarse aggregate in the concrete mixture which is susceptible to polishing when tested for use in bituminous mixtures. The FN's are at acceptable levels for all sections and should not require any remedial action in the foreseeable future.

Ride Quality Index

The average RQI values for all pavement sections have remained constant and acceptable (less than 50) since construction. The Michigan Section and the Euro Section RQI ratings are approximately the same. A future increasing trend may develop as each pavement section is exposed to additional traffic loading. The lowest change in rate will determine whether the Euro or Michigan Section has the better performance.

International Roughness Index

The analysis of the IRI shows similar results as for RQI. The three Standard Sections and the Michigan Section had an initial IRI rating lower than that of the Euro Section (Figure 5).

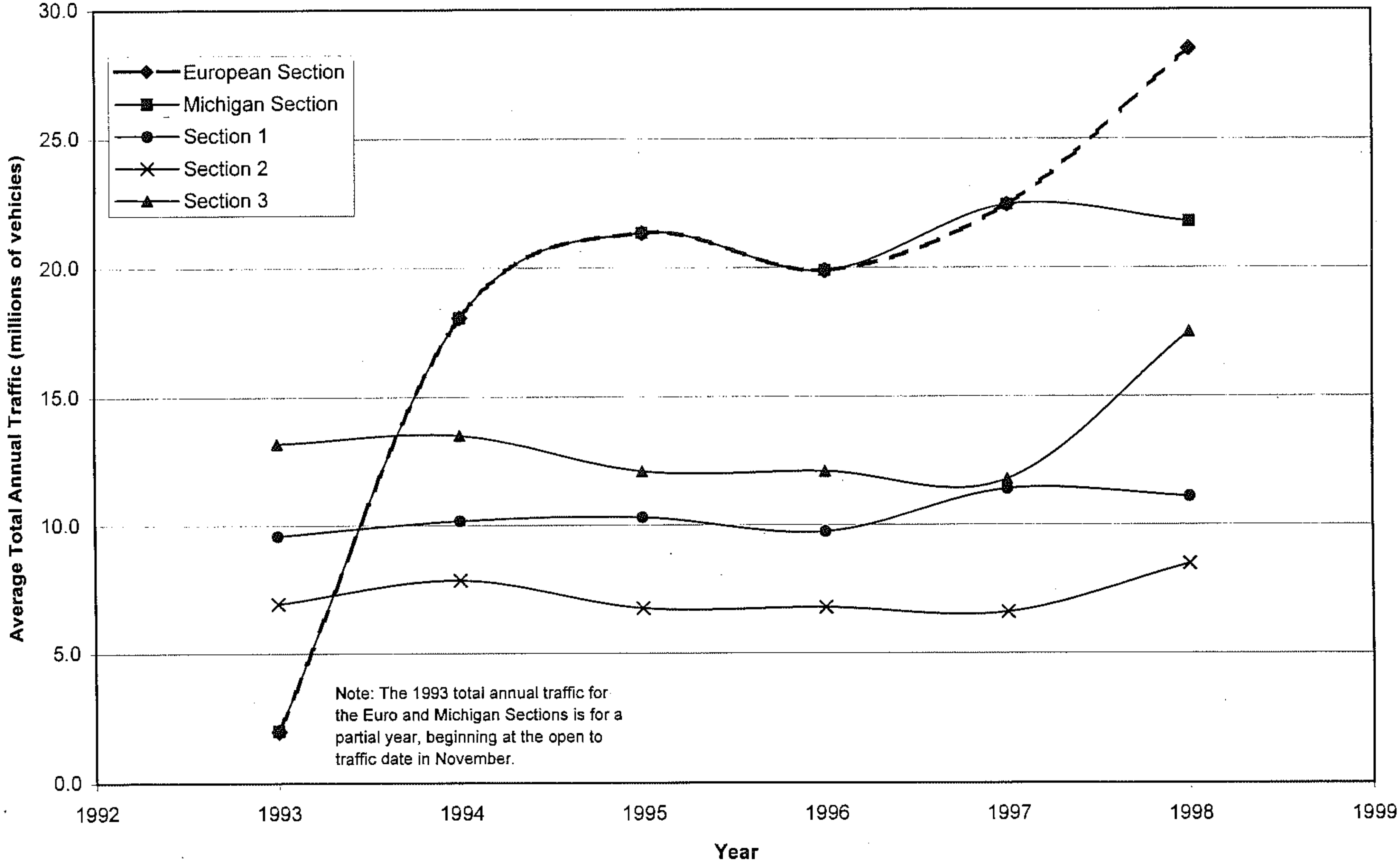

Figure 1: Variation in Total Annual Traffic per Section from 1993 to 1998

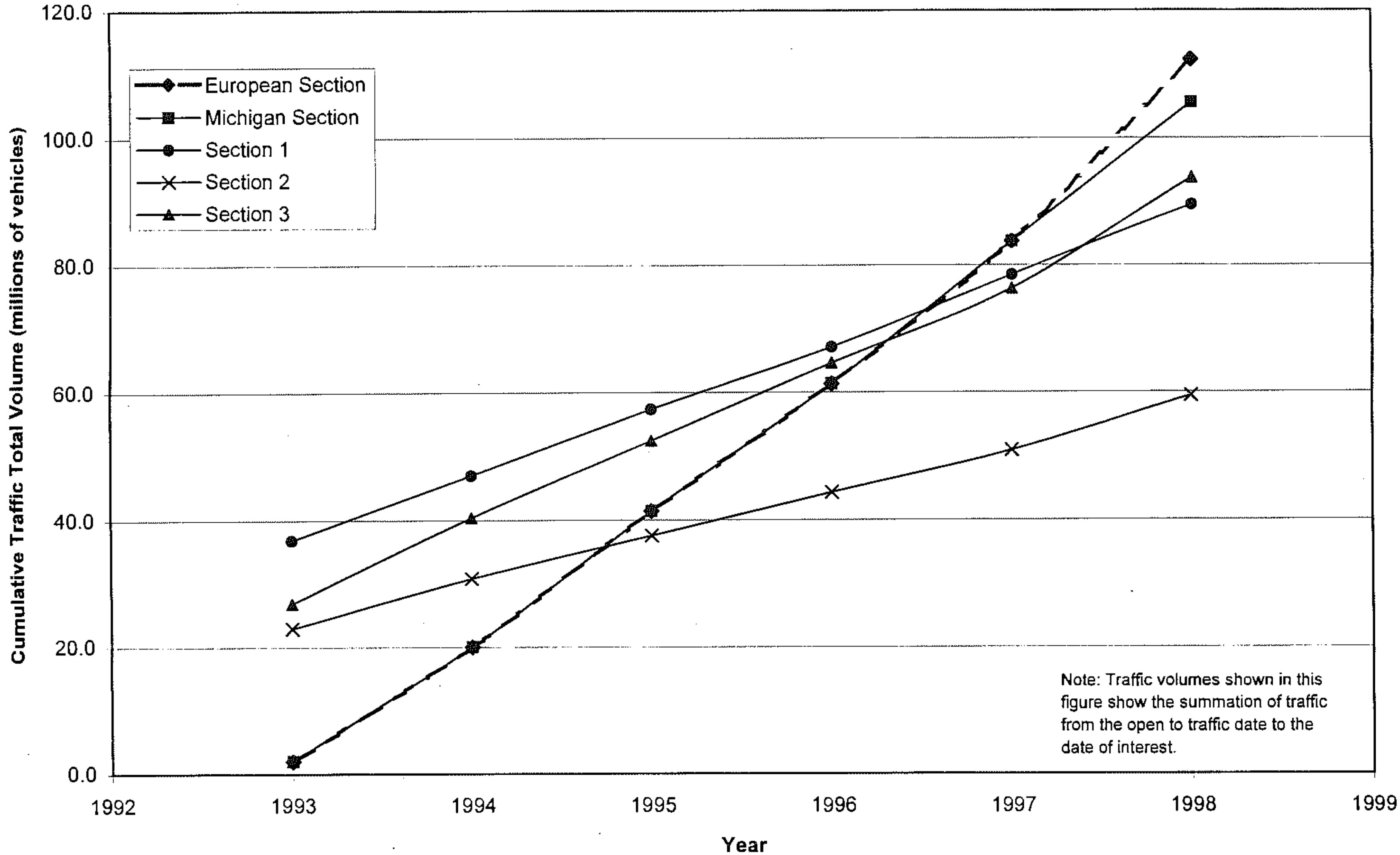

Figure 2: Cumulative Total Traffic Volume from 1993 to 1998

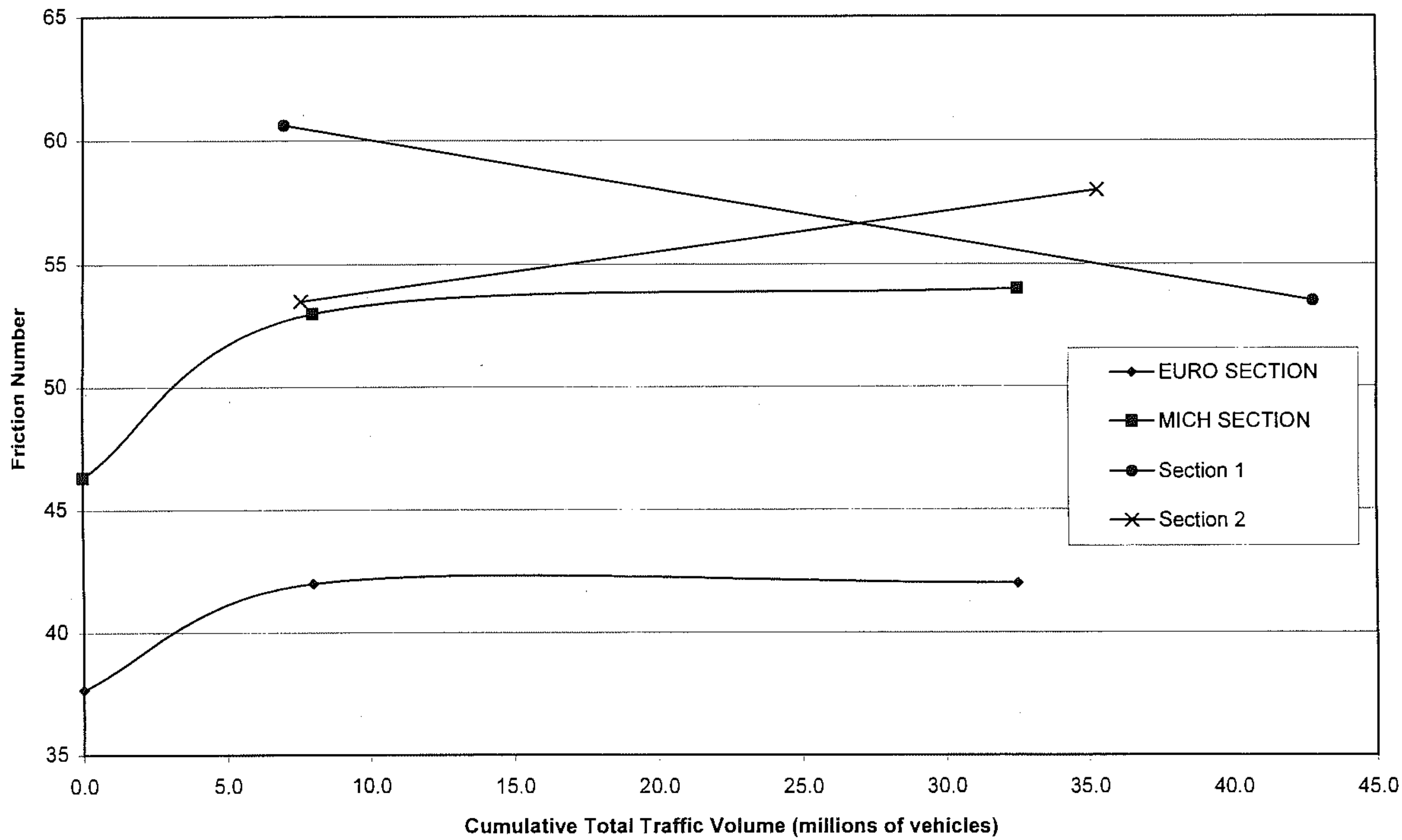

Figure 3: Friction Number (Averaged Over All Lanes) vs. Cumulative Traffic

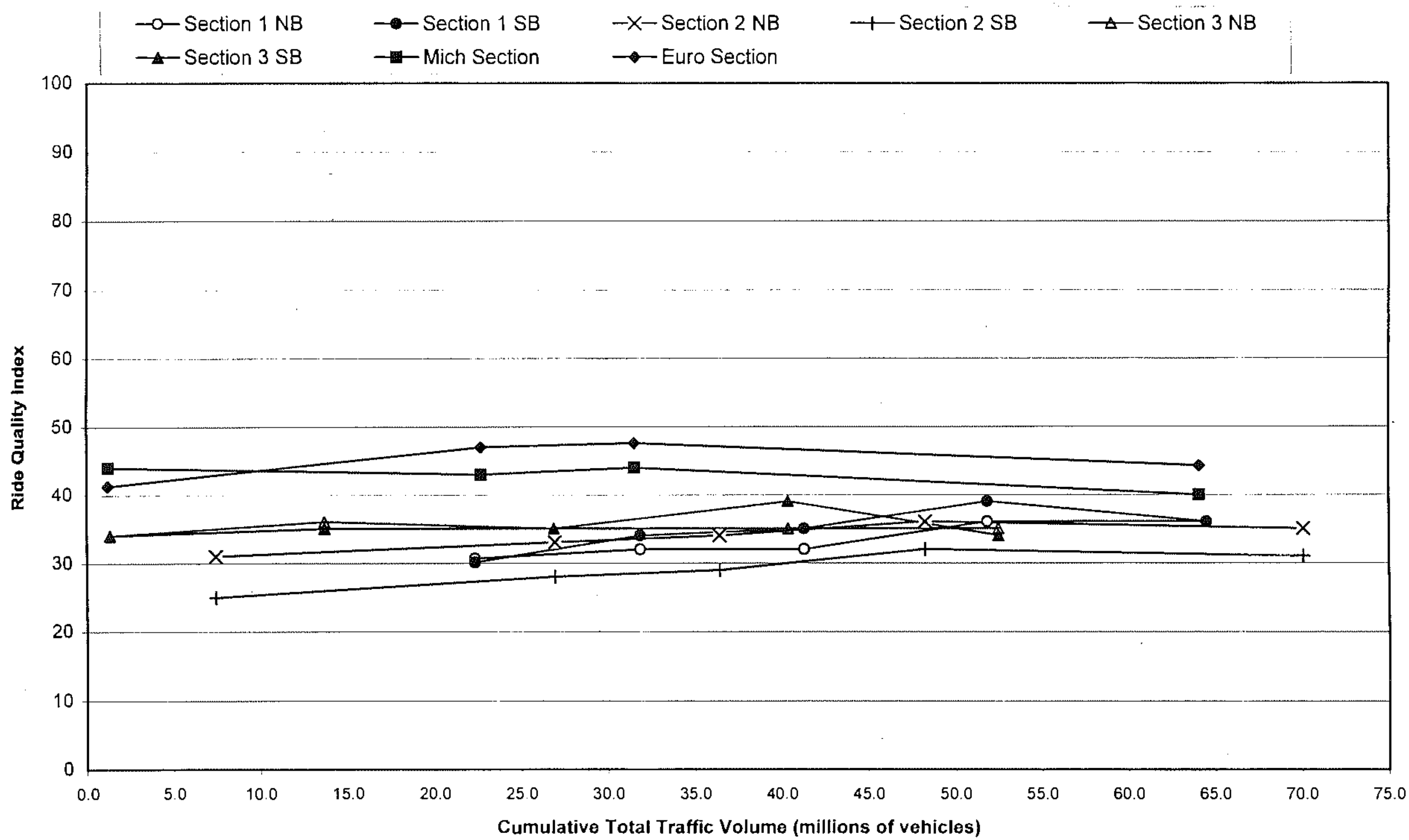

Figure 4: Average Ride Quality Index (over entire section) vs. Cumulative Traffic

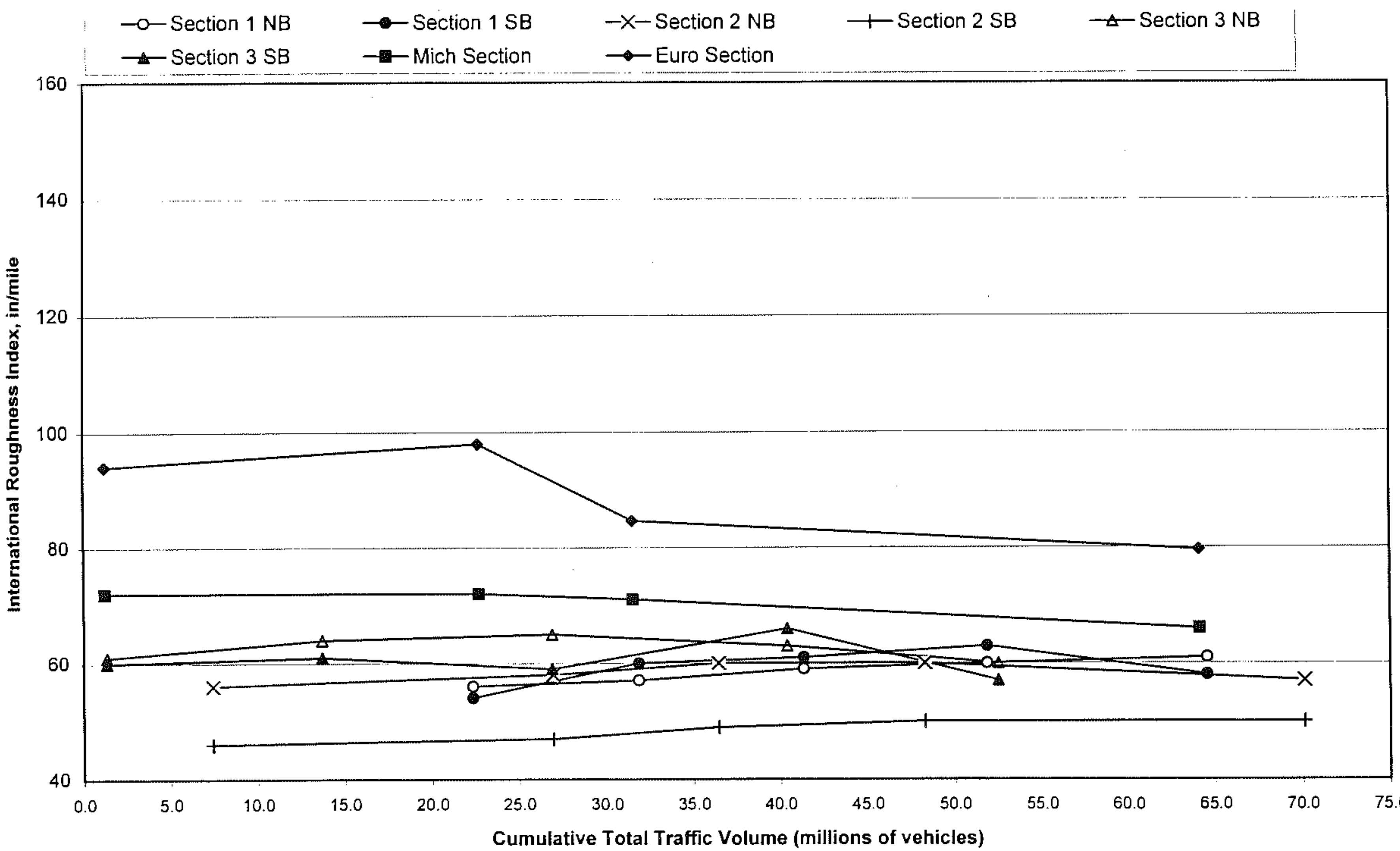

Figure 5: Average International Roughness Index (over entire section) vs. Cumulative Traffic

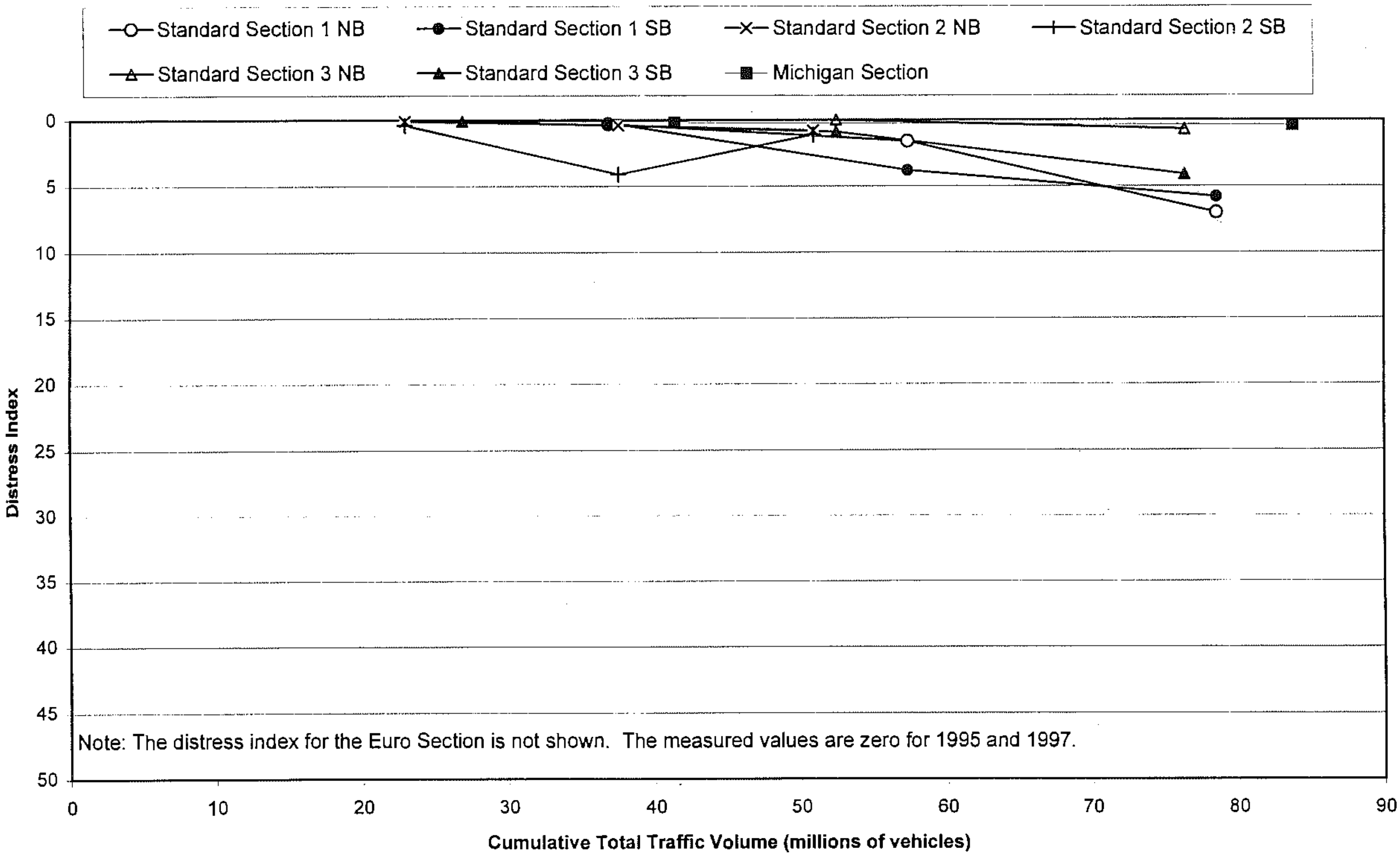

Figure 6: Distress Index (over entire section) vs. Cumulative Traffic

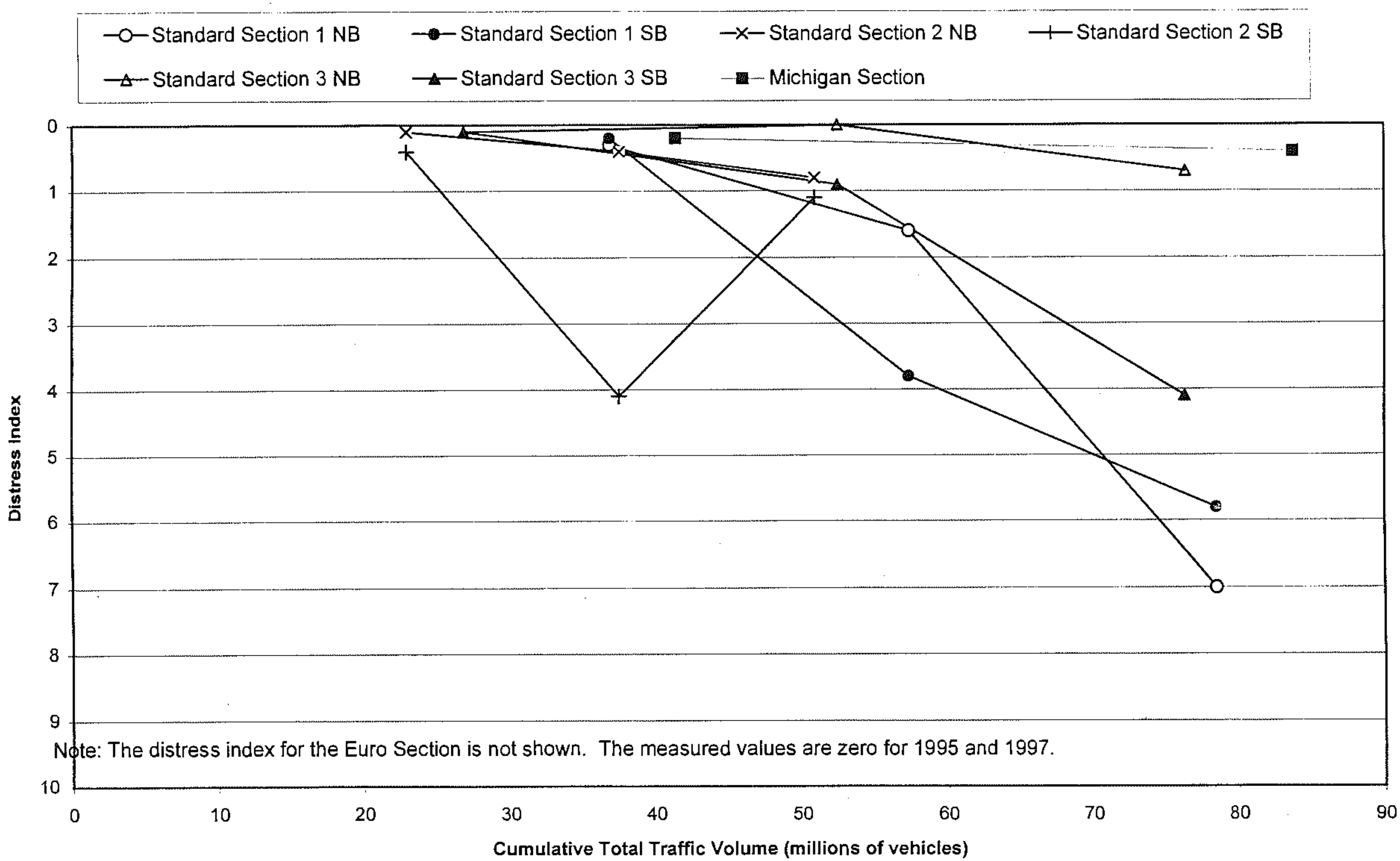

Figure 6a: Distress Index (over entire section) vs. Cumulative Traffic (Scale expanded to show an imaginable trend)

As was the case with the RQI, the IRI value has remained relatively constant since construction. Here again, it is expected that an upward trend may develop as the pavement is exposed to additional traffic loading.

Distress Index

The DI for the Euro Section was zero for 1995 and 1997, which is the latest year of reported distress data in Michigan's Pavement Management System. A visual survey conducted in September 1998 confirmed the reported 1997 DI. The DI values for the Michigan Section and Standard Section 1-3 are all low (<10) relative to the 50 threshold (Figure 6). The relationship between DI and cumulative traffic volume for Standard Section 2 Southbound was not used because the results are inconclusive. Figure 6a provides an expanded distress scale to possibly visualize some "imaginable" trend.

PAVEMENT DESIGN COST COMPARISON

It was expected that the European pavement section would cost more to construct than a typical Michigan section. However, the return on this higher initial investment was expected to be a longer pavement service life with much lower maintenance costs until major rehabilitation is required. Hopefully, these results would equate to a lower life cycle cost for the Euro Section.

The way the bid was structured for the project made it difficult to come up with directly comparable construction costs per mile for the Michigan, European, and Standard Sections 1-3. MDOT had, however, estimated costs per square yard for the European and Michigan pavement designs in their 1994 report on the construction of the project (the full report is provided in appendix A). The cost per square yard includes all bid items of work necessary to construct the typical cross section. These items include any earthwork, the pavement drainage system, shoulders, and miscellaneous paving. Those costs were used to estimate the capital costs for the economic analysis to be done in later sections of the report. The breakdown by bidder (from untitled table, p15, appendix A) is shown in table 7 along with a conversion to costs/lane-mi. and cost/mile for a three-lane section. For purposes of comparison, a constant 3-lane section is assumed. As can be seen in table 7, the ratio of European to Michigan capital costs range (by bidder) from 2.05 to 2.47—i.e., the European section is 2.05-2.47 times as expensive as the standard Michigan section. The low bidder cost (table 7) is used for the analysis which is presented in detail later.

The large difference in pavement quantities and respective items of work would account for part of the price differential. Also, the paving of the Euro Section and the Michigan Section had relative lower production rates than with the Standard Sections. Table 8 gives the actual unit prices for all pavement sections.

Table 7. Cost Comparison

bidder	cost units	European	Michigan	ratio
1	$/sq.yd.	87.76	37.58	2.34
	$/lane-mi.	617,830	264,563	
	$/mi. of 3-lane section	1,853,490	793,689	
2	$/sq.yd.	84.74	40.63	2.09
	$/lane-mi.	596,570	286,035	
	$/mi. of 3-lane section	1,789,710	858,105	
3	$/sq.yd.	99.55	48.47	2.05
	$/lane-mi.	700,832	341,229	
	$/mi. of 3-lane section	2,102,496	1,023,687	
4	$/sq.yd.	127.10	51.40	2.47
	$/lane-mi.	894,784	361,856	
	$/mi. of 3-lane section	2,684,352	1,085,568	

Table 8. Unit Bid Prices

Section	Item	Unit Price ($)	Measure
Euro	Exposed Agg. Surface Treatment	11.12	SYD
	10" Non-reinforced Conc. Pavement	30.10	SYD
	6" Non-reinforced Lean Conc. Base	10.00	SYD
	16" Aggregate Subbase	20.00	CYD
	Longitudinal Joint	3.25	LFT
	Contraction Joint	7.50	LFT
	Geotextile Seperator	0.90	SYD
Michigan	11" Reinforced Concrete Pavement	16.00	SYD
	4" Open Graded Drainage Course	2.85	SYD
	Longitudinal Joint	0.80	LFT
	Contraction Joint	7.75	LFT
	Geotextile Seperator	0.90	SYD
Standard Section 1	11" Reinforced Concrete Pavement	13.34	SYD
	4" Open Graded Drainage Course	2.00	SYD
	Longitudinal Joint	0.50	LFT
	Contraction Joint	6.00	LFT
	Geotextile Seperator	1.40	SYD

Table 8. Unit Bid Prices (continued)

Standard Section 2	11" Reinforced Concrete Pavement	14.00	SYD
	4" Open Graded Drainage Course	1.24	SYD
	Longitudinal Joint	1.10	LFT
	Contraction Joint	5.75	LFT
	Geotextile Seperator	1.75	SYD
Standard Section 3	11" Reinforced Concrete Pavement	15.79	SYD
	4" Open Graded Drainage Course	1.90	SYD
	Longitudinal Joint	0.74	LFT
	Contraction Joint	6.69	LFT
	4" Aggreagte Base Course	1.95	SYD

PROJECTION OF PERFORMANCE INDICATORS

An analysis was undertaken to determine if any predictions could be made concerning the future performance of the pavement sections. The data for the average RQI and DI were projected into the future until they reached their respective threshold values of 70 for RQI and 50 for DI. A pavement at these threshold values is considered to have poor serviceability and requiring major rehabilitation.

A second order polynomial was used to fit the trend line through the measured data points for the DI projection. It should be noted that the results of the DI projection were unchanged by use of higher order polynomial trend fitting equations. A second order polynomial was also used to fit the trend line through the measured RQI data points for all sections except the Euro Section and Standard Section 3. A third order polynomial was used for trend fitting on the Euro Section and Standard Section 3 data. The use of the third order polynomial trend fitting equation resulted in an increase in RQI with an increase in traffic volume, which is expected. The sections which were projected using a second order polynomial trend showed no change in the trend if higher order polynomial trend fitting equations was used to predict RQI. The Euro Section showed a decrease in RQI when fitted with a second order polynomial, but predicted an increase in RQI with an increase in traffic volume for all trend fitting equations that were third order or higher. Standard Section 3 showed a decrease in RQI with an increase in traffic volume for polynomial trend fitting equations of order 2, 4, 5, 6. The third order polynomial trend fitting equation was the only trend fitting equation that produced an increase in RQI with an increase in traffic volume, which is expected.

The predicted time until service failure of the sections in terms of RQI and DI cannot be made at the present time due to insufficient amount of date available. More reasonable predictions may be made as the pavement sustains more traffic volume and RQI and DI measurements are taken.

ECONOMIC ANALYSIS

As noted earlier, one of the key concerns with Euro pavement is the high capital investment relative to that for traditional/standard concrete designs used in Michigan. The argument is that the higher initial cost is offset by a longer service life. One of the objectives of this project was to undertake an economic analysis to determine the validity of this assertion. Unfortunately, since the data obtained for the various pavements being examined here do not support an accurate estimate of expected overall service life (or even time to the need for rehabilitation) of the Euro or other pavements, the economic analysis is more theoretical than had originally been anticipated. The "model" developed and discussed in the following paragraphs can, however, be used to estimate whether the initially higher cost of the Euro design is "worth it" once the service lives of the various pavements become clear.

Any economic analysis requires several pieces of information:

- identification of the alternatives that are to be compared;
- a description of the actions (e.g., initial construction, reconstruction) associated with each alternative and the benefits and/or costs of each action;
- a time-line which indicates when different actions are taken (for each alternative); and
- an analysis period, typically the expected life of the longer-lived alternative.

For the purposes of this analysis, it is assumed that the cash benefits of using a roadway are similar for all pavements (i.e., the economic benefits of having a highway are the same regardless of what kind of pavement is being used). Thus, the problem reduces to one of minimizing the cost of providing a usable roadway (pavement). These costs would include user costs incurred during construction, maintenance, and rehabilitation activities. In this instance, the costs are examined on an annual basis. The costs could also be examined on the basis of their present (or future) worth-the answer, which pavement is best, will be the same regardless. It is assumed that the alternative designs are being considered for the same roadway (i.e., each alternative will be subjected to the same traffic volume over the same length of time).

The two pavement preservation strategies that are used by MDOT are shown in Table 9. The description of actions associated with each alternative (from Table 9) are combined with the time-line to yield what is called a basic cash-flow (CF) diagram. Only one of the strategies is illustrated in the CF diagram (pavement preservation strategy #1) for the sake of simplicity and to illustrate the basic methodology. The methodology would be the same for any number of alternatives. The open dashed lines in the CF diagram indicate the passage of multiple years. The placement of the maintenance activities in the diagram are based directly on the definition shown in table 9, as is the overall "life" to rehabilitation/reconstruction of 37 years.

The CF diagram for pavement preservation strategy #1 is shown immediately following the table.

Table 9. MDOT Pavement Preservation Strategies

Activity (action)	Distress Index (before action)	Distress Index (after action)	Approx. Age (when action ocurs)	Life (years) Extension	RSL (years, after action)	Cost per lane mile[2]	Type of Cost
Strategy 1[1]							
initial construction	0	na	0	na	19	computed computed	agency user cost
maintenance (M1)	9	2	13	4	10	32,180 1,485	agency user cost
maintenance (M2)	23	2	20	7	10	72,405 800	agency user cost
maintenance (M3)	23	2	27	7	10	80,450 800	agency user cost
rehabilitation or reconstruction (R)			37		0	ignored	
Strategy 2[1]							
initial construction	0	na	0	na	19	computed computed	
maintenance (M1)	9	2	13	4	10	32,180 1,485	agency user cost
maintenance (M2)	9	2	17	4	10	32,180 457	agency user cost
maintenance (M3)	9	2	21	4	10	32,180 457	agency user cost
maintenance (M4)	9	2	25	4	10	32,180 457	agency user cost
rehabilitation or reconstruction (R)			37		0	ignored	

source: MDOT

Notes: 1. facility type is freeway/divided highway; fix type is new/reconstruction-jointed concrete pavement (MDOT pavement preservation strategies #1 and #2,)

2. converted from cost per lane-km in original MDOT source document

The CF diagram for the typical Michigan pavement (preservation strategy #1) is shown below.

```
0     1    2   -   12    13    14   -   19    20    21   -   26    27    28   -   36    37
+-----+----+_-__-_+-----+-----+_-___-_+-----+-----+_-___-_+-----+-----+_-_-_-_+-----+
|                        ↓                  ↓                   ↓                   ↓
|                        M1                 M2                  M3                  R
↓
Cstandard
```

The basic assumptions for both the Michigan pavement (above) and the Euro design (below) are:

C_{euro}, $C_{standard}$ = initial (capital) costs of Euro and standard pavements, respectively

M_1 = early (first) maintenance activity extends pavement life by 4 years, done when distress index = 9; assumed to be the same for standard and Euro design pavements

M_2, M_3 = mid-life maintenance activities extends pavement life by 7 years, done when distress index = 23; assumed to be the same for standard and Euro design pavements

R = rehabilitation or reconstruction done at the end of the approximate end of the basic service life; assumed to be the same for standard and Euro design pavements

Based on these assumptions, the nominal CF diagram for the Euro design pavement can be constructed:

```
0     1    2   -    12    13    14   -   19    20    21   -   26    27    28   -   36   37
+-----+----+ -  ___ - +-----+----+ - ___ - +-----+-----+ - ___ - +-----+----+ - ___ - +----+
|                                        ↓                       ↓                     ↓
|                                        M1                      M2                    R
↓
CEuro
```

By way of further explanation, the maintenance activities (e.g., M_1) are defined as being required after the pavement reaches specified distress index levels-e.g., in the first diagram, when the distress index reaches a value of nine (9), M_1 is assumed to occur. It is further assumed that this occurs at the end of year 13 for the standard Michigan design. It should also be noted that this assumption is independent of the traffic volume (and EASLs) and based solely on elapsed time. The maintenance activity is performed in order to extend the life of the pavement. That is, the pavement will last longer than it would if the maintenance activity had not been undertaken.

As illustrated in the second CF diagram, the basic assumption is that the Euro design extends the time until the first maintenance is required. Once that first maintenance is done, the actual remaining service life is the same. Long-term monitoring of the Euro pavement will be required to assess the validity of this assumption. It is also possible, if the maintenance actions beyond the first activity are precisely the same, that the eventual rehabilitation of the Euro pavement would be further extended by seven years (i.e., the Euro pavement would be subjected to an M_1, M_2, M_3 sequence of maintenance treatments as is the standard pavement). If this is the case, then the life of the Euro pavement (and the CF diagram for that alternative) would be longer than the 37 years shown in the example above. That is, the two pavements would have different service lives until rehabilitation/reconstruction was required-the standard MDOT pavement would be 37, the Euro pavement might be as much as 47 (i.e., M3 would be added to the Euro CF diagram, and R would be "put off" for 10 additional years).

The different costs associated with the two alternatives are not necessarily equal. For example, the capital cost (C_{euro}) of the Euro pavement is expected to be considerably greater than that for the standard pavement ($C_{standard}$) used in Michigan and occur only once in the life of the pavement (at the beginning). On the other hand, the maintenance costs associated with both alternatives (M_1, M_2, M_3) may be similar or even assumed (as they are here) to be the same. These costs occur whenever the distress index reaches a certain level. The rehabilitation costs (R) are assumed to be the same but may occur at different points in time (depending on whether the overall service life of the Euro pavement is longer than the standard pavement).

If the absolute lives of the pavements (alternatives) are different, some adjustments must be made so that the analysis period is effectively the same for all alternatives. There are two basic ways to handle the relatively simple assertion that they will not each last the same amount of time (recall that equal traffic volumes over time have already been assumed):

At the (absolute) end of an alternative's service life, it is replaced with a "new" pavement of the same life-e.g., when the absolute end of the Euro pavement's life is reached, it is replaced with another Euro pavement. Likewise, when the standard pavement reaches the absolute end of its life, it is replaced with another standard pavement. This replacement is assumed to occur for both alternatives until a common end point is reached. For example, if alternative X lasts two years and alternative Y lasts three years, the appropriate analysis period would be six years which is equal to three replications of alternative X (3 x 2 = 6) and two of alternative Y (2 x 3 = 6).

The analysis period can be taken as the length of the shortest-lived alternative. The remaining service life of the longer-lived alternative is reflected in the estimate of salvage value.

Current MDOT practice recognizes that there is likely to be some real salvage value for each alternative. The salvage value occurs at the end of an alternative's useful life and would include, for example and in the case of pavements, the value of the recycling the existing pavement. However, because the salvage value occurs so far in the future (30+ years), MDOT's assumption is that it is greatly discounted and does not need to be considered.

Based on the CF diagram shown and the assumptions stated above, the annual the cost of each alternative can be expressed using standard engineering economic nomenclature:

$$(\text{ANNUAL COST})_{standard} = C_{standard}(A/P,i,n_{standard\text{-}life}) + M_1(P/F,i,n_{standard\text{-}M1})(A/P,i,n_{standard\text{-}life})$$

$$+ M_2(P/F,i,n_{standard\text{-}M2})(A/P,i,n_{standard\text{-}life})$$

$$+ M_3(P/F,i,n_{standard\text{-}M3})(A/P,i,n_{standard\text{-}life}) + R(A/F,i,n_{standard\text{-}life})$$

and

$$(\text{ANNUAL COST})_{euro} = C_{euro}(A/P,i,n_{euro\text{-}life}) + M_1(P/F,i,n_{euro\text{-}M1})(A/P,i,n_{euro\text{-}life})$$

$$+ M_2(P/F,i,n_{euro\text{-}M2})(A/P,i,n_{euro\text{-}life}) + R(A/F,i,n_{euro\text{-}life})$$

where: $n_{euro\text{-}life}$, $n_{standard\text{-}life}$ = the length of the service life of the Euro and standard designs (these are initially assumed to be the same, 37 years; this is based on MDOT's pavement preservation strategy #1 where the approximate age to R, "rehabilitation or reconstruction" is specified as 37 years)

$n_{euro\text{-}Mn}$, $n_{standard\text{-}Mn}$ = the length of time to required maintenance operations for the Euro and standard designs, respectively

i = the discount rate, or in general engineering economic terms, the minimum attractive rate of return used for analysis (assumed to be 3%)

$(A/P,i,n)$ = equal payment-series capital-recovery factor-converts a present amount [P] into a series of n equal amounts [A]

$(P/F,i,n)$ = single-payment present-worth factor-converts a single value in the future [F] at the end of year n to its present worth [P]

$(A/F,i,n)$ = equal-payment-series sinking-fund factor-converts a single value in the future [F] at the end of year n into a series of n equal amounts [A]

As noted earlier, the cost associated with the different construction and maintenance activities are assumed to include user costs (e.g., delays during construction).

Given these two overall annual costs, the decision rule is to select the alternative the minimizes the annual cost:

SELECT: minimum{(ANNUAL COST)$_{euro}$, (ANNUAL COST)$_{standard}$}

The effect of the higher cost and longer life to rehabilitation of the Euro design can be illustrated. First, some assumptions:

initial costs: the initial costs for the Euro and standard designs are taken from table 7, \$617,830/lane-mile and \$264,563/lane-mile, respectively (\$1,853,490 and \$793,689, respectively, for the 3-lane section)

maintenance costs: the annual maintenance costs (M_1, M_2, M_3) are taken from table 11 and MDOT's pavement preservation strategy #1 and **include** user costs (\$33,672, \$73,220, and \$81,267 per lane-mile or, converted to cost/lane-mile for a 3-lane cross section, \$101,017, \$219,661, and \$243,801/lane mile, respectively)

rehabilitation costs: the costs of rehabilitation are assumed to be the same (Z) (MDOT makes no assumption for the rehabilitation costs in its pavement preservation strategies); this can also be assumed to be the end of the pavement's useful life-if so, these costs can be ignored

interest rate: assumed to be 3% (MDOT apparently uses 2.9%, 3% is used here for simplicity)

All costs are converted to ***costs/mile with a 3-lane cross-section assumed*** for the maintenance costs and are shown (below) in \$100,000 (i.e., \$4.785 = \$4,785,000). The end-of-life rehabilitation costs are ignored.

$$(AC)_{standard} = \$0.794(A/P,3,37) + \$0.101(P/F,3,13)(A/P,3,37) + \$0.220(P/F,3,20)(A/P,3,37) + \$0.265(P/F,3,27)(A/P,3,37)$$

and

$$(AC)_{euro} = \$1.854(A/P,3,37) + \$0.101(P/F,3,20)(A/P,3,37) + 0.220(P/F,3,27)(A/P,3,37)$$

Noting that the rehabilitation cost at the end of the useful service life is ignored and inserting factor values, the two costs can be calculated:

$$(AC)_{standard} = \$0.794(.0451) + \$0.101(.6810)(.0451) + \$0.220(.5537)(.0451) + \$0.244(.4502)(.0451) = \$0.049 \text{ (or } \sim\$49{,}000\text{)/mile}$$

$$(AC)_{euro} = \$1.854(.0451) + \$0.101(.5537)(.0451) + \$0.220(.4502)(.0451) = \$0.091 \text{ (or } \sim\$91{,}000\text{)/mile}$$

Clearly, the standard pavement is considerably cheaper than the Euro design. As an alternative, if the useful service life of the Euro pavement additional years (assuming that MDOT's pavement preservation strategy is invoked in its entirety for the Euro design), maintenance M_3 is done at year 34 and the rehabilitation is delayed until year 44. Overall, a more realistic assumption. This approach lowers the annual cost of the Euro design to ~$87,000/mile, still considerably higher than the standard design.

There are also some questions regarding whether the capital cost for the Euro design is realistic. This was a "one-off" design and only a short length of pavement was actually bid and constructed with this design. Thus, it could be argued that the capital cost is higher than they would be if an entire job (of several miles) was being constructed. In this context, another example was worked out using a capital cost for the Euro section equal to half of what was used above (i.e., $1,853,490/mile was reduced to $926,745/mile). While the initial and annualized costs of the standard design are assumed not to change ($793,689 and $49,333, respectively), the annualized cost for the Euro design is lowered to ~$49,000 for a 37-year life (assuming only M1 and M2 are done) and ~$48,000 for a 44-year life (assuming the entire sequence of maintenance is done). With the reduced capital cost, the annualized Euro cost is quite comparable to that of the standard Michigan section. This serves to illustrate the sensitivity of the overall annualized cost to the assumptions regarding capital cost—the lower the capital cost of the Euro design, the more "competitive" it is with the standard design. So, a reduction of the initial Euro cost of ~50% makes the annual costs equivalent. Note that even still, the Euro capital cost is still higher than the standard section: ~$927,000 versus ~$794,000 (the Euro is about 17% higher).

At this point, however, based on the observed capital costs and the assumed maintenance schedule and costs from MDOT, the Euro design is not competitive with the control standard design on a cost basis. It should be noted, however, that the calculations shown are theoretical in the sense that time to all maintenance activities are based on MDOT estimates. The field condition data did not permit an accurate assessment of the pavement lives for any of the pavements considered.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The condition analysis of the pavement sections since construction in 1993 shows that the Euro Section is not performing at a superior level to the Michigan Section or Standard Sections 1-3.

- The traffic/tire noise, which was anticipated to decrease for the Euro Section with its exposed aggregate surface, was determined to be equivalent to the Michigan and ~~Euro~~ Standard Sections.

- The FN for the Michigan Section and Standard Sections 1 and 2 are higher than the FN for the Euro Section. The exposed aggregate surface used on the Euro Section did not meet expectations of higher wet sliding friction.

- The analysis of the RQI and IRI shows that the three Standard Sections have demonstrated better, but not exceptional, ride quality than the Michigan and Euro Sections, which were expected to have very low levels from more intensive quality control and inspection during construction of this special project.

- The DI for the non-reinforced Euro Section is zero, while the comparison reinforced sections have some expected transverse cracking that equates to a relative low DI, as compared to MDOT's threshold value of 50.

- The Euro Section was much more expensive to build than a conventional Michigan pavement. Analysis by MDOT showed that the conventional pavement was constructed for approximately forty-three percent (43%) of the cost of the Euro pavement (based on the low bidder's estimate, the range for the other bidders was 40-49%).

- The projection of the average RQI and DI values are based upon a short time period. The data trends are insufficient to make an accurate prediction of when service life will end.

- The life cycle cost, using MDOT's assumed maintenance schedule, of the European design is considerably more expensive than a standard Michigan pavement section.

- Given the MDOT-assumed maintenance schedule for pavements, the Euro pavement could be competitive (on an annualized cost basis) with standard pavements when the Euro's capital cost is no more than approximately 17% higher. (This is subject to several assumptions which are addressed in earlier sections.)

Recommendation

The analysis done for this report is based on a small sample of data over a very limited time period (relative to the expected service lives of all of the pavements). Simply put, all of the pavements are still performing very well and have not yet approached the distress levels that would signal the need for significant maintenance to be done. It is recommended that the various indicators of pavement wear (e.g., distress index) be monitored on an annual basis. Once trends become clear, a follow-up analysis is recommended. Based on the "typical" service life and distress index deterioration that are assumed in MDOT's pavement preservation strategies, it would seem likely that trends should be notable when the pavement is on the order of 10 years old since the distress index is assumed to reach a level of around nine (9) and require some substantial maintenance after approximately 13 years of service.

Appendix A

MDOT European Pavement Design Report

Figure A.1 - Michigan and Euro Section Cross Sections

Figure A.2 - Standard Section 1 Cross Sections

Figure A.3 - Standard Section 2 Cross Sections

Figure A.4 - Standard Section 3 Cross Sections

MICHIGAN DEPARTMENT OF TRANSPORTATION
M•DOT

CONSTRUCTION OF EUROPEAN CONCRETE PAVEMENT ON NORTHBOUND I-75 - DETROIT, MICHIGAN

MICHIGAN DEPARTMENT OF TRANSPORTATION

MATERIALS and TECHNOLOGY DIVISION

MICHIGAN DEPARTMENT OF TRANSPORTATION
M•DOT

CONSTRUCTION OF EUROPEAN CONCRETE PAVEMENT ON NORTHBOUND I-75 - DETROIT, MICHIGAN

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A Research Demonstration Project by the
Michigan Department of Transportation
in Cooperation With the
Federal Highway Administration

Research and Technology Section
Materials and Technology Division
Research Project 92 B-105
Research Report No. R-1333

Lansing, September 1994

INTRODUCTION

This report describes the design and construction of the experimental pavement reconstruction project on I-75 (Chrysler Freeway) in dcwntown Detroit, between I-375 and I-94 (Edsel Ford Freeway). The experimental features were assimilated from European pavement designs and incorporated into the plans and specifications of Federal Project IM 75-1(420), Michigan Project IM 82251/30613A. The experimental rigid pavement section is approximately one mile long and is located on northbound I-75 between the Warren Avenue exit ramp northerly to Piquette Avenue. The location of the project is shown in Figure 1. A conventional Michigan rigid pavement design was used on the remaining portion of the northbound roadway as a control section. On July 7, 1993, the complete project, including the European pavement section on I-75, was awarded to:

Ajax Paving Industries
One Ajax Drive
P.O. Box 317
Madison Heights, Michigan 48071
(313) 398-2300

Construction began on the northbound roadway on July 8, 1993, and was opened to traffic on November 23, 1993. The entire project, including the reconstruction of southbound I-75, is scheduled for completion in November 1994. The European pavement was constructed for the purpose of comparing the European with American pavement designs to demonstrate the applicability of certain European concepts to the United States highway system.

PROJECT DESCRIPTION

The design and construction of the experimental pavement structures on northbound I-75 is similar to the procedures used in Germany and Austria. A typical cross-section of the European test section is shown in Figure 2. A 1.3 mile pavement section directly south of the experimental section is a typical rigid pavement cross-section used by the Michigan Department of Transportation (MDOT). The southbound roadway will also be constructed with MDOT's conventional procedures and materials for concrete pavement sections. The experimental section consists of either three or four driving lanes. The typical cross-section for Michigan's conventional section is shown in Figure 3.

BACKGROUND

The European pavement project on I-75 resulted from a FHWA sponsored technical tour in October 1992, which was an effort to gain insight into European design and construction practices of concrete pavement in

EUROPEAN TEST SECTION LOCATION

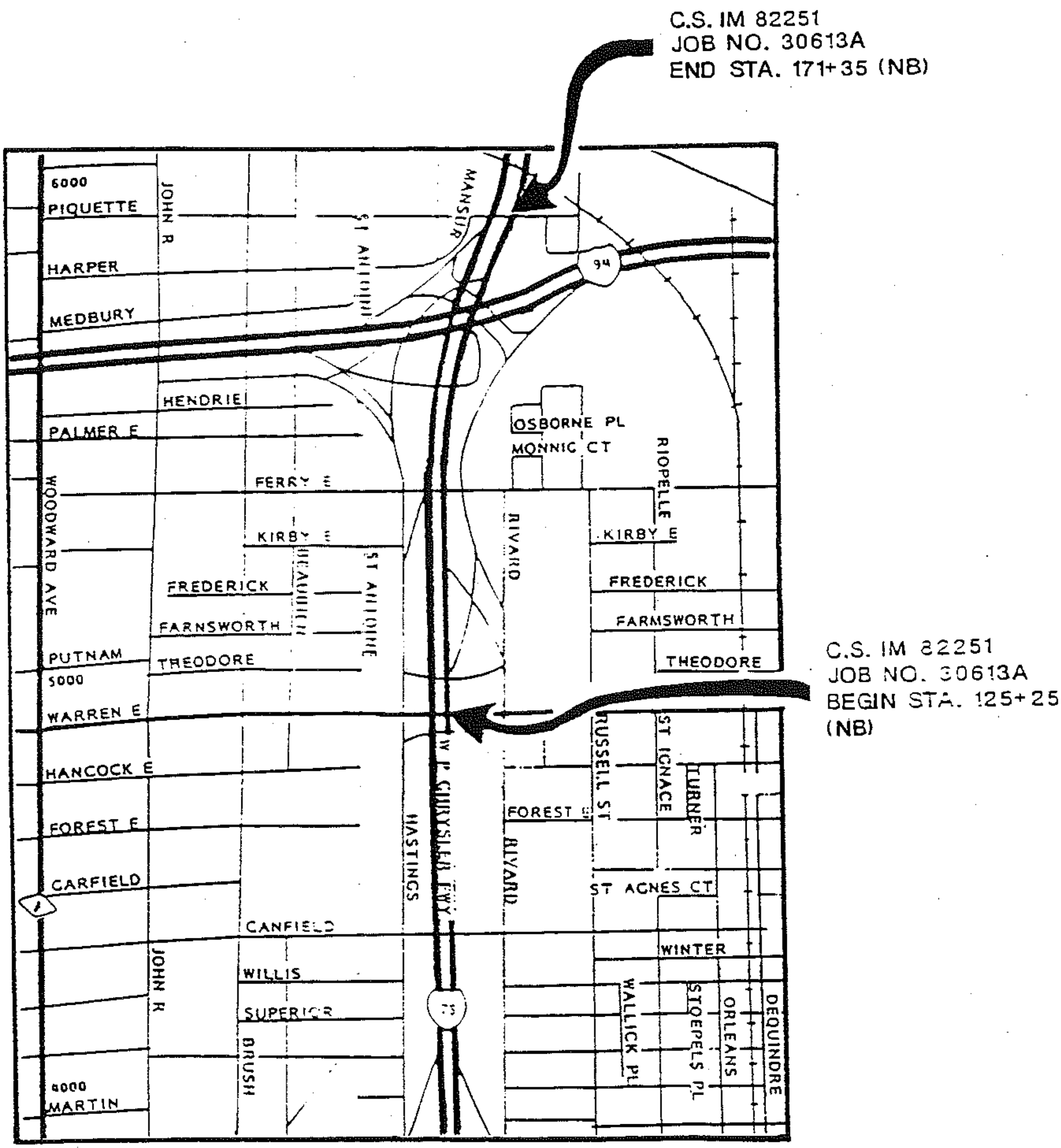
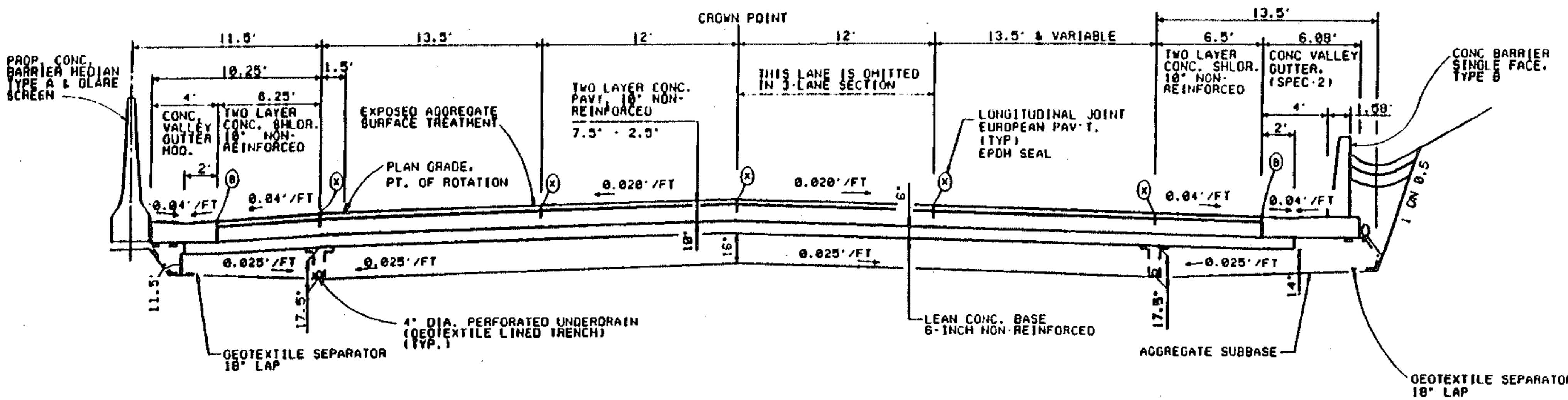


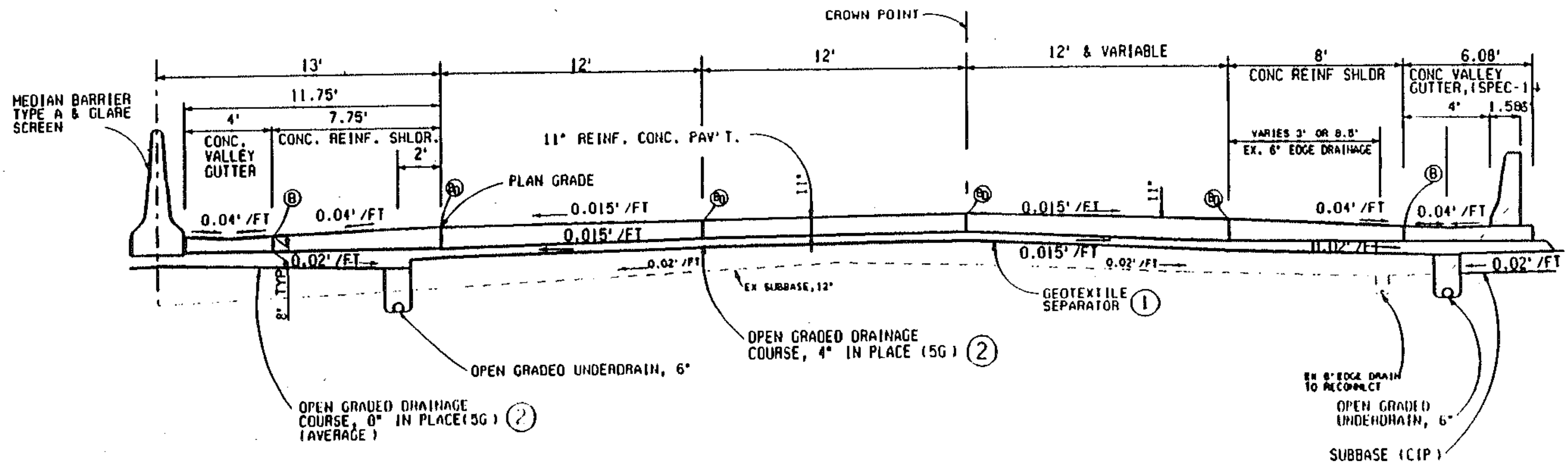
FIGURE 1.



EUROPEAN PAVEMENT SECTION

NBD I-75

Figure 2



MICHIGAN CONVENTIONAL SECTION
NB I-75

NOTES:

(1) GEOTEXTILE SEPARATOR WAS INADVERTENTLY SHOWN TO BE PLACED ACROSS TRENCH OPENING FOR OPEN-GRADED UNDERDRAIN.

(2) CONTRACTOR HAS OPTION BY SPECIFICATION TO COAT 5G AGGREGATE WITH EITHER CEMENT OR ASPHALT.

Figure 3.

Austria and Germany. Seven engineers from the United States returned from a 12 day tour of those countries on October 22, 1992. Three engineers from the Federal Highway administration (Roger Larson, Suneel Vanikar, and Steve Forster), two engineers from the Michigan Department of Transportation (Randy Van Portfliet and Roger Till), one engineer from the New York Department of Transportation (Ray Gemme), and one engineer from the American Concrete Pavers Association (Pat Nolan), were involved in the trip. They visited eight construction sites in Germany and four in Austria.

The tour found pavement designs in Austria and Germany to be typical of others in the European community. For many years, Europeans have emphasized the quality aspects of a pavement's design, materials, and construction without concern for likely higher costs or longer construction time. German pavement designs have been standardized to account for anticipated traffic loading, soil support characteristics, and climate conditions. Typically, European pavement designs use a 30 to 40 year design service life as compared to the United States conventional 20 year design service life. They concentrate their efforts on constructing high quality concrete pavements through a cooperative working relationship between government, contractors, and the material suppliers.

European pavement designs allow for heavier axle loads and larger commercial traffic volumes (typically 40,000 to 60,000 vehicles per day, with 25-40 percent of those trucks). The limit in Germany for a single axle increased from 11.5 metric tons (25.3 kips) to 13 metric tons (28.6 kips) in 1993. The super single tire (125 psi) is also prevalent throughout Europe. The limit for a single axle in Michigan is 18 kips. However, Michigan does allow a maximum gross truck weight of 164,000 lbs when distributed over 11 axles.

The stated advantages of the European design features for United States implementation are:

- Longer and more reliable pavement service lives resulting in fewer traffic closures for maintenance repairs.

- Ability to carry increased axle loads that will contribute to economic growth to help keep the USA globally competitive.

- Higher surface friction values and a reduction in tire noise levels.

To implement these features requires a large increase in initial costs for construction. Therefore, American applied European designs must prove their cost effectiveness over time to be a useful alternative to our current American designs.

The report from the 1992 Technical Tour (Bib. No. 1) established objectives for achieving world class concrete pavement structures in the United States. The FHWA will continue to motivate state agencies to use the most effective designs and construction practices available.

Some of the key report objectives are:

- Commitment to research, innovation, and training by both government and private industry to ensure improvements in designs, materials, and construction technology.

- Develop a conceptual design catalog of the most effective designs and practices used across the United States.

- Establish at a national level, better methods of collecting and disseminating information about pavement technology developments to pavement engineers, researchers, and the construction industry in the United States and other nations.

- Construct experimental projects like I-75, to demonstrate the applicability of certain European concepts to the United States highway system.

- Encourage interaction, to promote better concrete pavement, among highway agency engineers, consultants, researchers, industry, universities, and contractors.

EUROPEAN DESIGN FEATURES

We selected the structural layer thicknesses and respective materials by following the procedures noted in the German design catalog for the climatic, soil, and traffic conditions found in the Detroit area. In 1965, a panel of German pavement experts conceived the design catalog based on the results of AASHO Road Test, and only minor refinements have been made since that time.

The European typical section consists of either three or four driving lanes. The middle one or two lanes are constructed 12 feet wide and the outer lanes are 13.5 feet wide with the lane marking placed at 12 feet. The pavement surface is crowned at 0.02 ft/ft grade. The tied concrete shoulders are 10.5 feet wide, which includes a four foot wide concrete valley gutter, and have a 0.04 ft/ft slope. The project specifications for the following cross sectional features are in Appendix A.

Subgrade

Review of the Great Lakes - Geologic map indicated this project lies within the Devonian Series of lake beds. The existing roadbed lies within an approximate 25 foot cut section. The subgrade is predominately lacustrine silty clay. A typical subgrade soil sample consisted of the following average soil type: 31 percent sand and fine gravel, 47 percent silt and 22 percent clay. The average plasticity index for these subgrade soils is 7.0, with a liquid limit of 21 and an average natural moisture content of 12 percent. No groundwater was evident during preliminary investigations of the site. The subgrade density requirement was not less than 95 percent of its maximum unit weight in accordance with Michigan's One-Point T-99 (Proctor) Test.

Aggregate Subbase

A 16 in. thick non-frost susceptible aggregate subbase was placed directly on the clay subgrade. The gradation and physical properties of the granular subbase shown in Table 1 matches typical German specifications.

TABLE 1

Grading Requirements						
MI Series & Class	Sieve Analysis, Total Percent Passing				#30	% Loss By Washing
	1-3/4"	1"	1/2"	#8		
Euro-A1	100	65-95	40-65	40-42	8-30	7.0 Max.

Physical Requirements	
MI Series & Class	Euro-A1
Crushed Material, min.	90%*
Loss, max., Los Angeles Abrasion (AASHTO T96)	45%

*On aggregate >#4 sieve with minimum one fractured face.

The specification required the material be placed in two 8-inch layers and compacted to not less than 100 percent of its maximum unit weight. The material unit weight was determined using the One-Point Michigan Cone Test. The photograph in Figure 4 shows the aggregate subbase in place.

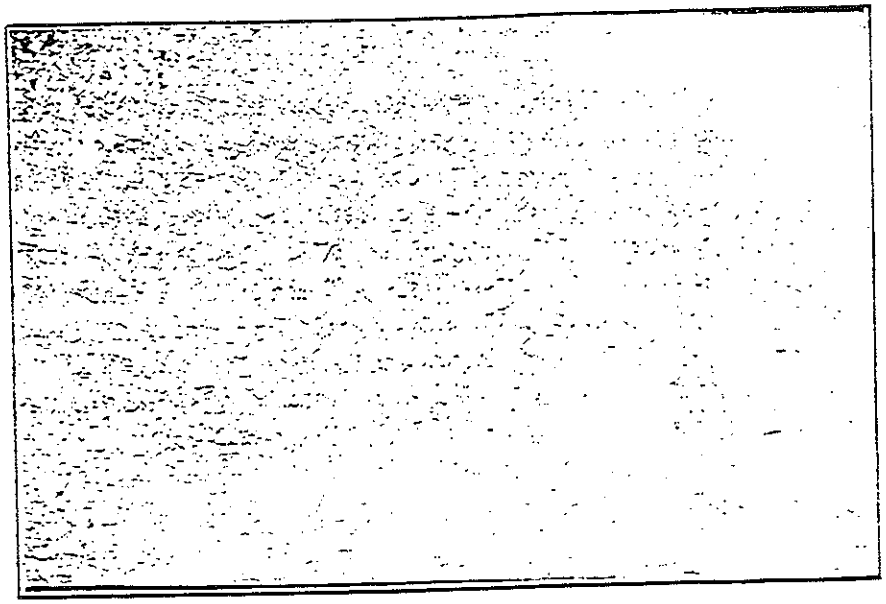


Figure 4:

The typical cross section included drains that are similar to Michigan's open-graded underdrains. The drain consists of a six inch diameter corrugated plastic pipe in a geotextile lined trench with peastone backfill. During design, the permeability of the German gradation for the aggregate subbase was the questioned. Laboratory testing by MDOT (MTM 122-91, Appendix A) in the design phase indicated a permeability of less than one foot per day. Even with such a low permeability it was decided to still use drains in the design, but their primary purpose would be to drain water from the interface between the aggregate subbase and the lean concrete base.

Lean Concrete Base

A six inch thick non-reinforced lean concrete base with plane-of-weakness joints (no load transfer) was placed on the 16-inch thick aggregate subbase. The concrete for the base was specified to be grade 25P, which was to obtain 2,500 psi compressive strength in 28 days. The relief joints were to be sawcut to 0.4(D), where D equals the slab thickness. The lean concrete base extended laterally to the center of the four-foot valley gutter providing a solid, level base for the paver and a smoother ride.

Two Layer Pavement

The surface pavement was designed to be constructed in two layers (2 1/2 in. over 7 1/2 in.) while wet. The concrete for the 2 1/2 in. top layer was specified to be grade 55P while the bottom layer was grade 50P concrete requiring compressive strengths of 5500 psi and 5000 psi, respectively, at 28 days. The coarse aggregate for both layers was specified as Michigan 6AA (1 1/2 in. top size) with a higher durability requirement meeting a maximum freeze-thaw dilation of 0.008 percent per 100 cycles in accordance with

Michigan Test Method (MTM) 115. Michigan's MTM is similar to ASTM C666 Procedure B. The complete MTM is given in Appendix A.

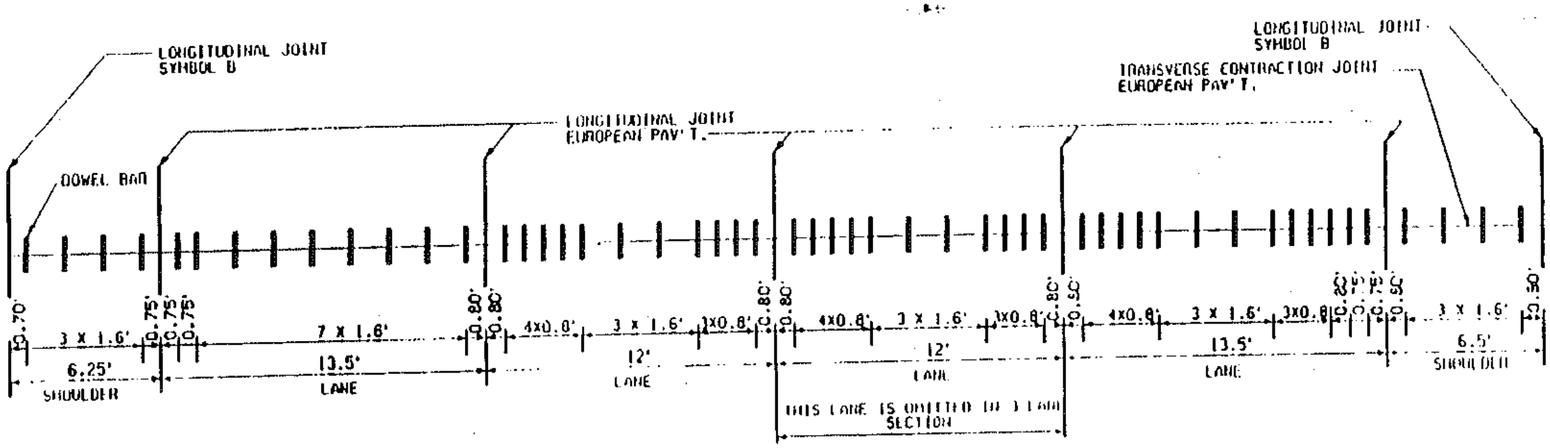
A comparison of the European, 25P, 50P, and 55P, and Michigan pavement concretes is given in Table 2.

TABLE 2

Comparison of European and Michigan Pavement Concretes				
Property	European Test Pavement			Michigan Control Pavement Test Section
	Top Layer	Bottom Layer	Lean Base	
28-Day Compressive Strength	5500 psi	5000 psi	2500 psi	3500 psi
28-Day Flexural Length	—	—	—	650 psi
Maximum Water/Cement Ratio, by Weight	0.40	0.42	0.70	0.50
Minimum Cement Content	752 lb/cu yd	588 lb/cu yd	420 lb/cu yd	550 lb/cu yd
Maximum Slump	3 in.	3 in.	3 in.	3 in.
Air Content	6.5 ± 1.5%	6.5 ± 1.5%	6.5 ± 1.5%	6.5 ± 1.5%

Transverse and Longitudinal Joints

Contraction joints were spaced at 15 foot intervals (not skewed) and designed to match the same joint spacing in the lean concrete base. Expansion joints were used only where the European pavement tied into the conventional or existing pavement. The polyethylene coated dowel bars were 20 inches long by 1 1/4 inch in diameter. The dowel spacing was varied to increase load transfer efficiency in the wheel paths. Figure 5 shows the dowel spacing for the four lane roadway and a photograph of a typical dowel basket assembly. The dowel spacing in the lane tapered areas was 0.8 feet. Dowels were also placed for load transfer in the shoulder transverse joints. Lane ties in the longitudinal joints were 7/8 inch in diameter by 32 inch long deformed epoxy coated bars. There were four ties per 15 foot slab and they were located as shown in Figure 6. Each basket was fastened to the lean concrete base with eight evenly spaced clips using a 1-1/4 inch long ram-set nail.



DOWEL BAR SPACING

ALL BARS SHALL BE 1 ¼" DIA., 20" LONG AND TYPE A COATED INSTALLED AT HALF DEPTH (5")

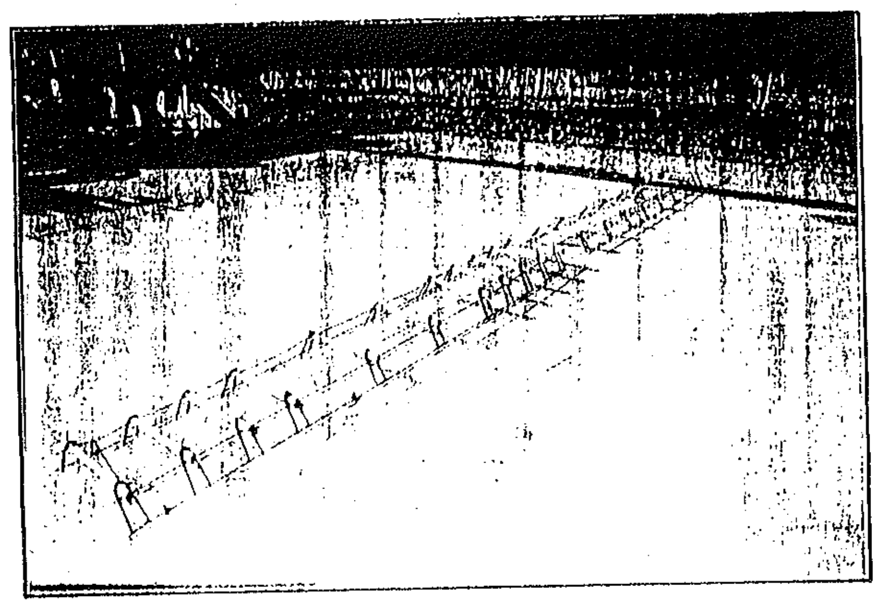


FIGURE 5

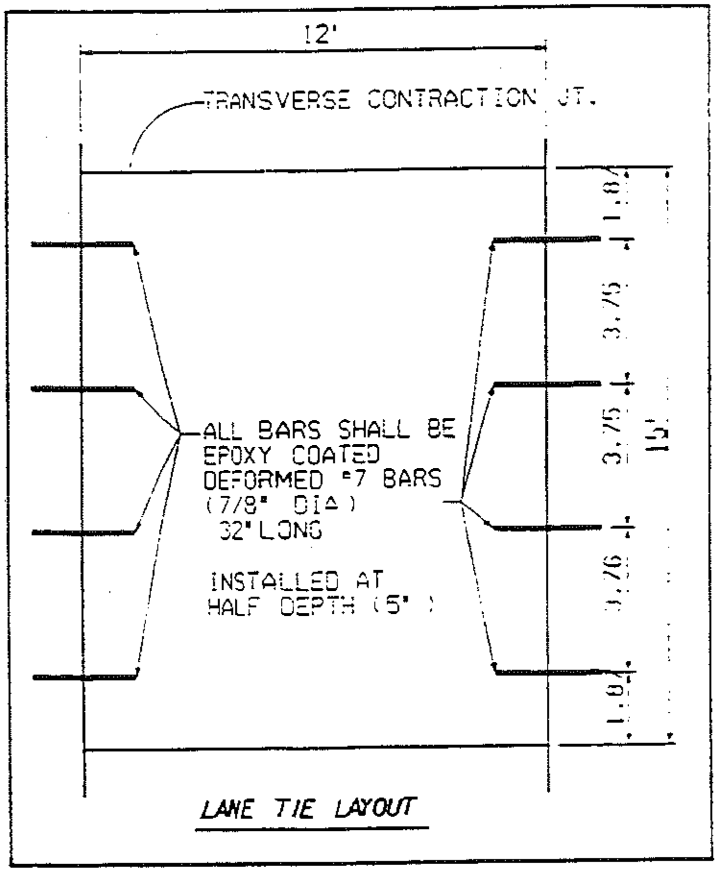


FIGURE 6.

The longitudinal joints in the two layer pavement were specified to be placed within one inch of the longitudinal joint in the lean concrete base. Similarly, the transverse contraction joints were specified to be within two inches of the contraction joints in the lean concrete base. The longitudinal and transverse joints were sealed with an Ethylene Propylene Diene Terpolymer (EPDM) seal, as shown in Figure 7. After the initial cut, the joint was to be cleaned using compressed air. A continuous polyethylene foam backer rod, shown in the photograph in Figure 8, was placed at the bottom of the cut to eliminate any incompressible material from entering the crack below the joint seal. The material and sizes of the EPDM seal in the test section were similar to those used in Germany. The seals were supplied by Phoenix North America, Inc., located in Carteret, New Jersey, which is an affiliate of Phoenix AG of Hamburg, Germany. Phoenix joint EPDM Type M 214-66 and Phoenix EPDM Type M 214-45 were specified to seal the longitudinal and transverse joints, respectively. The stated advantages of using the EPDM seal compared to a neoprene seal are that installation only requires clean but not dry joints, and the Phoenix joint eliminates the need for adhesives. Also, these joint seals are supposedly resistant to liquids found on highway surfaces like hydraulic oils and deicing agents.

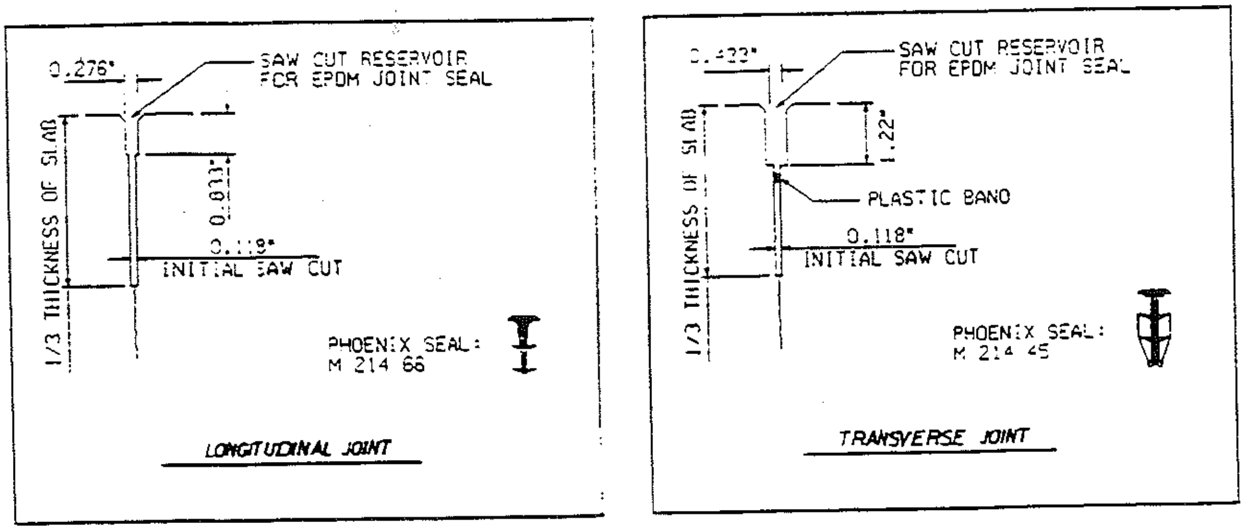


FIGURE 7.

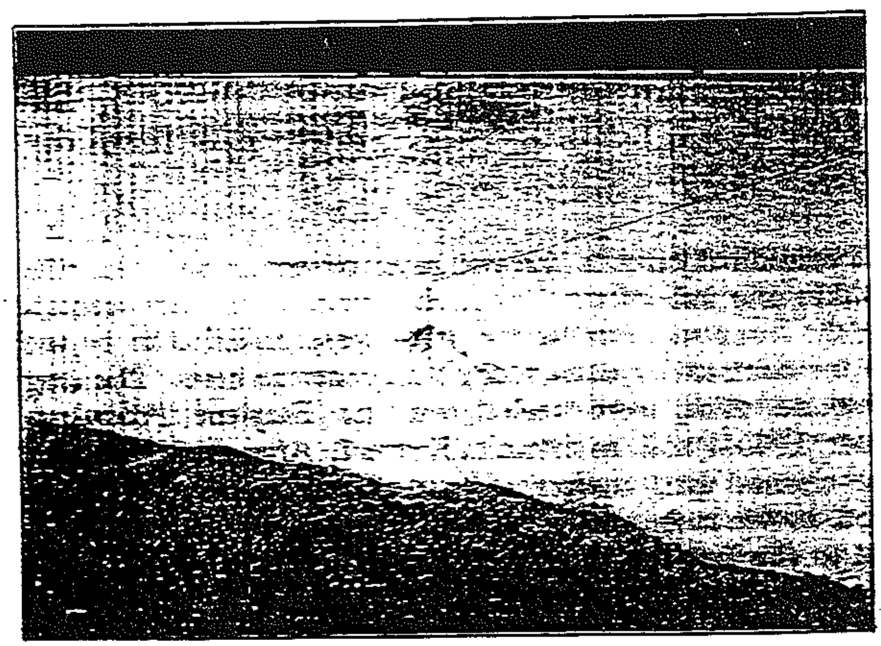


FIGURE 8.

Exposed Aggregate Surface

An exposed aggregate surface was designed to texture the pavement surface. The construction procedure was a specified patented process developed by Robuco, Ltd. of Belgium. The process includes evenly spraying the surface with a setting retarder within 30 minutes of the finishing operation. The retarder was a citric acid admixture containing a green pigment in sufficient quantity to visually verify an even application with a uniform color after it was sprayed onto the pavement surface. The application rate was 0.026 gallons per square yard. Immediately after spraying the retarder, the concrete surface was protected by covering it with a 2 mil plastic waterproof sheeting. Robuco equipment in operation is shown in Figure 9. The sheeting was removed approximately 20 hours after the initial placement. The amount of time that the sheeting remained on the surface was dependent on curing rate, wind, air temperature, and the actual application rate of the retarder.

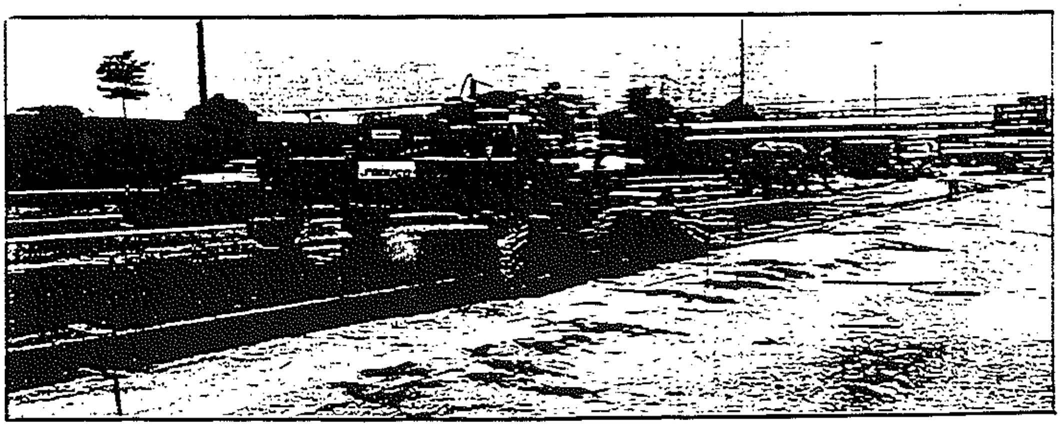


FIGURE 9.

A Robuco representative was on site to determine when the application rate was adequate and to determine the amount of time the plastic sheeting was to remain on the pavement surface. Initial sawcuts for the transverse and longitudinal joints were made through the protective sheeting prior to the brushing operation. Moist strips of burlap were placed immediately over the sawcuts to allow the curing process to continue. The concrete surface was brushed when the Robuco representative determined the concrete had sufficient strength to support the brushing machine. Within four hours after removing the waterproof sheeting and within one hour after completing the brushing operation, a curing compound was sprayed on the exposed aggregate surface. The final texture was verified by a sand patch test based on British Standard BS598 Part 105. The average texture depth was specified to be 1.3 mm plus or minus 0.20 mm (0.05 in. plus or minus 0.008 in.). Figure 10 is a photograph of the sand patch test being performed.

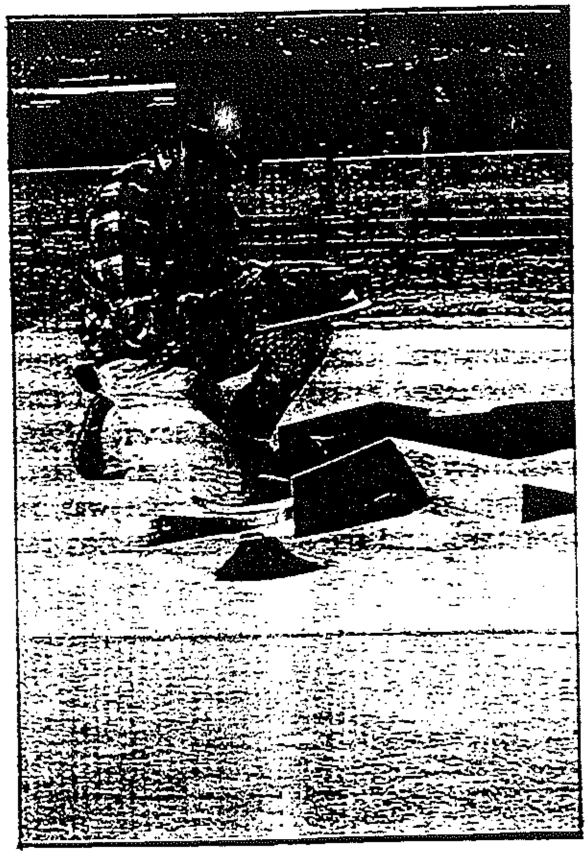


Figure 10.

PAVEMENT DESIGN COST COMPARISON

Before approving the project, MDOT engineers expected the European pavement section would cost more than a typical Michigan freeway design. However, the beneficial return on this higher initial investment is expected to be a longer pavement service life with lower maintenance costs until major rehabilitation is required.

To arrive at a cost comparison between the Michigan and European sections, the costs for the respective items of work applying to each section (including shoulder pavement) were totaled and divided by the total square yards of Michigan pavement, which equaled 98,295 sq yds, versus 25,730 sq yds of European pavement. The breakdown for each of the lowest four project bidders is as follows:

Low Bidder	European ($/sq yd)	Michigan ($/sq yd)	Percent Increase
1	87.76	37.58	133
2	84.74	40.63	109
3	99.55	48.47	105
4	127.10	51.40	147

The large difference in pavement quantities and respective items of work would account for part of the price differential. Actual unit bid prices are shown in Appendix B.

MICHIGAN STANDARD PAVEMENT

The pavement cross section for the Michigan comparison pavement is shown in Figure 3. The pavement thickness is 11 in. with 41 ft joint spacing. The pavement was mesh reinforced in accordance with Michigan Road Standard II-45G. The reinforced concrete shoulder is tied with transverse contraction joint spacing matching the mainline pavement.

The aggregates (Michigan 5G gradation) for the open-graded drainage course (OGDC) were made from crushing the existing I-75 pavement and stabilizing it with approximately 6.0 percent cement, by weight. The OGDC is separated from the 12 in. thick sand subbase (original to I-75) with a geotextile separator. The typical cross section in the plans showed the geotextile separator across the top of the underdrain trench, which is incorrect. The system was constructed and the pavement placed before the error was discovered. Permeability tests ran on the sand subbase samples indicated a satisfactory drainable granular material with an average permeability coefficient equal to 15.5 feet per day. The sand subbase gradation met Michigan's current Class II specification requirements. The locarion and types of underdrains matched the European pavement.

The concrete mixture specifications for the Michigan pavement included a 3500 psi (28 day) compressive strength, a 650 psi (28 day) flexural strength, a maximum 3" slump, a minimum 550 lbs/cyd cement content, and a maximum 0.50 w/c ratio. The same coarse aggregate was specified for the Michigan section and the European section. The coarse aggregates for the southbound I-75 will meet normal M-DOT standards and be a control section to identify any differences in concrete durability performance.

CONSTRUCTION MODIFICATIONS AND DISCUSSION

Subgrade Modifications

After the subgrade was cut to grade, it was inspected for frost susceptible or unstable areas. In these areas, Type I (clay backfill) or Type II (sand backfill) undercuts were set-up. A Type I undercut consists of removing the unacceptable material and replacing it with any natural or other approved clay material that can be compacted to the required density, contains no organic material, and shall have a maximum unit weight of at least 95 pounds per cubic foot. The material must not contain more than 50 percent silt or have a plasticity index of less than 10. A Type II undercut consists of removing the material and backfilling the area with granular material that meets Michigan's Class II requirements.

Type I undercut areas were:

Station	Lane Number*	Depth, in.	Material Excavated (cyd)
137+25 to 138+75	1 and 2	6	72
143+40 to 144+10	1 and 2	6	34
160+00 to 160+50	1	6	13.4
164+75 to 167+25	1 and 2	6	127.3

Type II undercut areas were:

Station	Lane Number*	Depth, ft	Material Excavated (cyd)
132+20 to 132+78	2	1	112.6
134+25 to 135+00	1 and 2	2	240
134+86 to 136+56	Outside Shoulder	1	106
160+50 to 162+90	2	1	140

*Lane no. 1 is the right most driving lane with land no. 2 adjacent to it.

The subgrade was shaped at 0.02 ft/ft for drainage.

Aggregate Subbase

A crushed limestone aggregate was used for the subbase. The tested aggregate at times was found out of specification on the No. 200 sieve and the No. 8 sieve. The percentage passing the No. 200 sieve ranged from 4.8 percent to 8.3 percent, which exceeded the maximum 7 percent specified. The amount passing the No. 8 sieve ranged from 13 percent to 28 percent, and did not initially meet the required specified range of 20 percent to 42 percent passing. Material was taken from station 127+00 to station 135+00, and from station 147+00 to station 159+00, and was mixed by windrowing and then resampled. The material was remixed, windrows were rebuilt, and the material was resampled and tested a third time. Based on test averages and proper remixing of the material on the grade, the aggregate subbase was accepted for the non-specification locations. It was concluded that segregation due to excessive handling of the material, while transferring it several times from the producer to the grade, was the main cause for the erratic gradation results. To correct the segregation problem, the stockpile was mixed, then several one ton "mini" stockpiles were built. Gradation tests performed on material from the "mini" stockpiles fell within the specified gradation requirements. The physical properties met the required specified ranges. Typical maximum dry unit weights ranged from 127 lb/cu ft to 134 lb/cu ft, because of the segregation problem. A typical gradation for the aggregate in place on the grade was:

Table 3

MI Series & Class	Sieve Analysis, Typical Percent Passing				% Loss by Washing
	1 3/4"	1"	1/2"	#8	
Euro-A1	100	88	59	23	6.6

Lean Concrete Base

The minimum cement content for the 25P concrete mix design was revised from 400 pounds to 420 pounds. A 35P concrete mix was used during the later stages of the project to achieve a faster strength gain. The lean concrete base met the specified compressive strengths. However, some minor longitudinal cracking did occur in some pavement slabs. The outside driving lane was cracked from premature loading from construction vehicles. The cracking was fixed by epoxy injection or the slab was removed and replaced. When the slab was replaced, the new base was tied to the existing LCB similarly to the two-layer pavement.

LaFarge Type I cement, a natural 2NS sand with a absorption of 0.7 percent from Koenig Sand and Gravel Pit No. 63-9, and Presque Isle 6AA aggregate from Pit No. 71-47 with an absorption rate of 1.2 percent were used in the concrete mix design. The aggregate subbase and the lean concrete base provided excellent support for construction equipment and the paving train. No special construction methods were required for either operation.

Two-Layer Pavement

The two-layer, wet on wet concrete pavement coupled with the two different concrete mixes created a major change from conventional practices. The contractor used a paving train consisting of four pieces of equipment when paving the inside two lanes (25.5 ft wide). The bottom layer concrete was placed on the lean concrete base with a spreader to initially distribute the concrete. A paver then consolidated and struck off the 7 1/2 in. bottom layer. A second spreader was then used to distribute the 2 1/2 in. top layer concrete for the second paver, which provided the final consolidation and screeding of the pavement. An autofloat was used on the paver during the placement of the 2 1/2 in. top layer. When the contractor paved one lane at a time, two pavers without the spreaders were used. Two spreaders were needed in the 25.5 ft wide paving to distribute the low slump concrete to the edges. Two photographs of the paving operation are shown in Figure 11. The contractor had no problem distributing the concrete with the paver in the one lane wide pass.

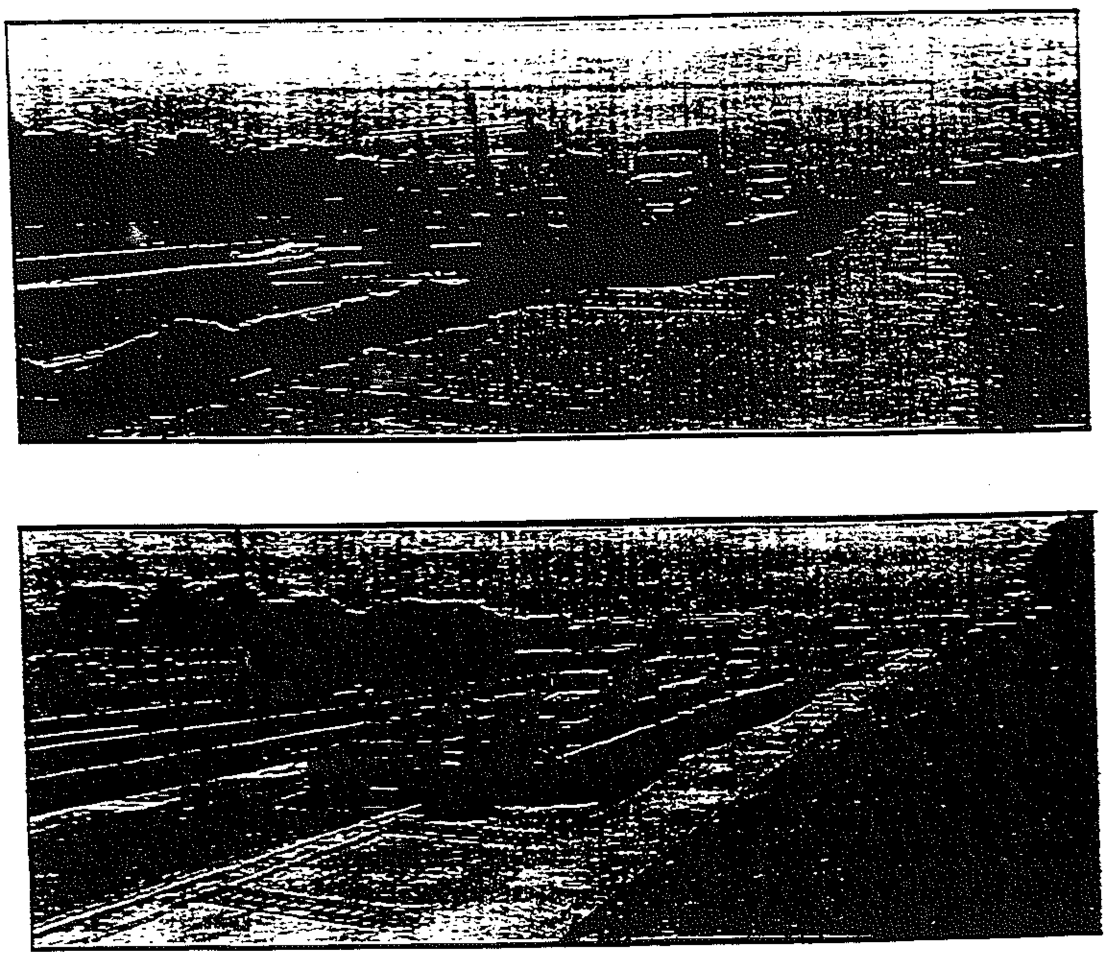


FIGURE 11.

The contractor had to closely monitor the delivery of the different concrete mixes. Ajax produced the concrete mixture for the bottom layer with an Erie Strayer dual drum 12 yard plant and the top layer was produced by Koenig Fuel and Supply, which is a commercial redi-mix plant. The coordination of the delivery and batch times for the different concrete mixtures required special attention.

The contractor successfully managed this problem by using separate hauling units for each concrete mixture. An agitator hauling unit was used for the top layer mixture and a normal dump truck was used for the bottom layer.

The same sources for cement and aggregates were used in the bottom and top layer mixtures as in the lean concrete base mixture, except for the coarse aggregate in the top layer. The top layer coarse aggregate was specified to be a 100 percent crushed basalt rock to meet specification requirements to resist polishing under traffic. The coarse aggregate was supplied by Ontario Trap Rock, Ltd. (Pit No. 95-10) near Bruce Mines, Ontario.

A modification was made in placing the top and bottom layers during construction. The width of the bottom layer was reduced six inches to allow for more efficient equipment travel. The top layer mixture was then extended three inches over each side of the bottom layer that covered the complete edge of the ten inch pavement.

Coring for thickness and strength checks found no evidence of a cold joint between the layers or instances where a mix was placed in the wrong layer. However, there were instances where the top layer was excessively thin (1/2 inch) and monetary penalties were assessed.

The aggregate gradation for the top-layer mixture was revised to allow eight percent passing the No. 5 sieve from three percent passing. This change was made because it had no significant affect on the integrity of the mix design. The mix design was revised to compensate for the increased coarse aggregate quantity as follows:

LaFarge Type I Cement	= 752 lb	Water	= 280 lb
Sand	= 1004 lb	Air Entrainment	= 13.2 oz
Stone	= 1960 lb	Admixture (Catexol - 1000N)	= 22.6 oz

The admixture, Catexol - 1000N, for the 25P, 50P, and the 55P concrete mixtures was a Type A water-reducer supplied by Axim Concrete Technologies.

The actual project mix designs for the grade 55P and 50P mixture are given in Appendix B.

Due to economic considerations, longitudinal lane ties were placed manually in the bottom layer, using a hand-held installation device when the paving was two lanes wide. The dowel bar assembly baskets were specially fabricated for this project because of the non-uniform bar spacing. The dowel bars were supported by a "U" shaped wire versus a normal "V" shaped support wire. The manufacturer (Deighton Superior) claimed this was needed for fabrication because of the non-uniform bar spacing.

The required compressive strengths for the 55P mixture were obtained without any problems. Typical strength results from quality control testing are in Appendix B.

The required compressive strengths for the 50P mixtures were met for over 99 percent of the project area. Four cores from low strength areas were checked for hardened air content according to ASTM C257 to verify if this was the cause of low compressive strengths. Air content was determined on a vertical slice of the core at a depth between 1 1/2 in. to 4 1/2 in. from the top. The hardened air content was determined to be 14.2 percent, which exceeded the required 6.5 percent plus or minus 1.5 percent. The low strength areas were assessed a monetary penalty.

Exposed Aggregate Surface

The texture values for the exposed aggregate surface at several locations ranged from 0.9 mm to 1.0 mm, which was less than the required 1.1 mm to 1.5 mm specification range. Construction personnel noted that in sections where it was necessary to adjust drainage structures, the process of spraying the retarder and placing the plastic sheeting was delayed and perhaps a reason for decreased surface texture numbers. Texture values increased to between 1.0 mm and 1.1 mm, after abrasive blasting was done on the pavement surface. The areas with deficient texture were re-evaluated and accepted based on the method specified for determining the average texture value. These areas will be monitored during the performance period to determine whether any significant differences in surface friction values occur over time.

Transverse and Longitudinal Joints

Typically, the spacing between contraction joints was 15 ft. Occasionally, the spacing was shortened to not less than 12 ft, to avoid having a drainage structure intersecting a joint. The drainage structures were gapped during paving and later enclosed in a 4' x 4' reinforced concrete pavement square.

Joint Sawing and Sealing

There were no problems keeping within the tolerance when aligning the joints in the 10 in. two-layer pavement with the joints in the lean concrete base. The actual size of the reservoir saw cut deviated from the plan dimensions due to field modifications suggested by Phoenix North American Inc. representatives. The revised dimensions of the constructed saw cut joints are shown in Figure 7. The longitudinal joints were sawcut with a 1/4 inch blade and the transverse joints were sawcut with a 3/16 inch blade with spacers. Both the longitudinal and transverse joints were sawcut to a depth of 1/3 the thickness of the slab. By randomly viewing the pavement edge, it appeared the contraction joints cracked, as designed, below the initial saw cut.

A continuous polyethylene foam backer rod was used (placed prior to brushing surface) in place of a rubber band. Representatives from Phoenix North America Inc. supplied a machine for the joint installation, and installed the EPDM seals until Ajax learned the procedure. The seals were placed according to plan and specifications. Occasionally, during the second stage sawing for the seal reservoir, the foam backer rod was cut and pulled from the joint by the saw blade. It is not clear whether this damage had any significant affects on preventing slurry from entering the initial saw cut. No other problems were encountered with the installation.

INITIAL PERFORMANCE TEST RESULTS

Surface Friction

Friction Numbers (FN) are Michigan's measurement unit for available wet sliding friction on pavement surfaces. The values are acquired by field testing using a full scale locked wheel trailer under controlled test parameters. ASTM E-274 is used to establish test parameters and control variables such as tire type, applied water depth, time and sequence of lock-up, sampling procedures, and required reporting. The field values of wet sliding friction are transformed to equivalent standard units (FN) by use of a correlation equation developed at the Field Test and Evaluation Center for Eastern States near East Liberty, Ohio. Table 4 shows the friction number test results for the European design and the Michigan design taken at the time of completion of the pavement, just prior to opening to traffic. At this time the curing compound was still present.

Table 4

Pavement Friction Analysis			
Friction Number (FN)			
Michigan Design		European Design	
Station of Test	FN	Station of Test	FN
NB #3			
64+60	45.4	123+15	42.1
72+67	43.7	131+12	36.1
89+25	46.0	137+41	35.3
93+95	44.6	143+53	36.0
103+19	39.4	150+98	31.3
111+27	42.0	157+47	32.0
		164+86	33.9
		169+61	33.9
Average	43.5		35.1
NB #2			
68+13	38.3	122+41	43.3
81+97	45.8	132+39	34.9
94+11	44.5	141+00	35.1
105+94	50.7	149+45	41.7
114+23	52.0	164+49	39.7
		169+51	33.3
Average	46.3		38.0
NBIL			
62+43	43.4	123+78	36.0
78+43	44.0	131+02	36.1
91+37	56.7	142+79	44.8
105+83	48.9	153+88	43.0
115+60	50.2	164+97	46.6
Average	48.6		41.3
Overall Average	46.1		37.6

NBIL = Lane Closest to Median
NB#2 = 2nd Lane From Median
NB#3 = 3rd Lane From Median

Ride Quality

Ride Quality Index (RQI) is Michigan's measurement unit for pavement ride quality. This value is determined by computer processing the actual pavement profile as measured by the department's Rapid Travel Inertial Profilometer, which was constructed as a result of research conducted by General Motors in the 1960's. The value is a weighted measure of power contained in the profile between wave lengths of 2-50 feet. These wave lengths are known to be those that most affect a persons opinion of pavement ride quality. This power measure is then transformed to RQI based on results of a subjective ride quality study. The RQI value is a unitless number between 1 and 100. Smaller RQI values represent pavements with better ride quality. A scale for rating RQI values in subjective terms is:

RQI Value	Rating
0 -30	Excellent
31 - 50	Good
51 - 70	Fair
>70	Poor

The department's current ride quality specification for new concrete pavement requires a RQI value of less than 49.8 to be acceptable. Pavements with a RQI value between zero and 40.5 receive a varying bonus payment.

International Roughness Index (IRI) is the more universal method for measuring road roughness. The respective RQI and IRI values for each pavement section are shown in Table 5.

Table 5

Ride Quality Analysis											
*RQI in 1/10th Mile Segments						*IRI in 1/10th Mile Segments					
Michigan Design			European Design			Michigan Design			European Design		
NBIL	NB#2	NB#3	NBIL	NB#2	NB#3	NBIL	NB#2	NB#3	NBIL	NB#2	NB#3
66.8	63.8	68.9	52.8	52.8	47.9	144.7	135.9	146.1	117.9	130.1	185.5
45.8	46.8	53.3	45.4	47.1	48.1	83.4	88.7	98.2	65.0	93.2	94.5
52.5	46.4	42.7	48.4	49.9	47.0	91.4	88.7	65.5	98.8	106.1	96.6
48.3	48.7	42.2	49.8	55.9	45.0	64.1	72.6	71.9	95.1	106.5	105.0
41.9	46.9	45.5	42.9	48.3	41.7	70.3	80.2	70.7	88.6	67.3	61.1
38.7	41.4	38.4	48.8	49.3	35.8	60.8	64.6	55.5	74.9	101.3	96.8
42.2	50.0	39.9	42.9	42.7	34.8	73.3	87.4	67.3	70.2	85.4	87.9
42.5	42.2	43.3	39.9	39.4	30.3	74.2	71.7	65.1	62.8	71.4	73.0
38.9	36.4	39.0	52.7	50.8	38.4	63.4	57.8	54.5	83.8	101.4	106.3
32.8	38.1	30.2	47.1	52.3	52.4	56.7	65.3	43.6	113.3	91.2	92.5

Ride Quality Analysis											
*RQI in 1/10th Mile Segments						*IRI in 1/10th Mile Segments					
Michigan Design			European Design			Michigan Design			European Design		
NBIL	NB#2	NB#3	NBIL	NB#2	NB#3	NBIL	NB#2	NB#3	NBIL	NB#2	NB#3
48.7	44.8	37.6				81.6	70.9	57.0			
50.1	47.0	41.1				80.5	76.7	80.6			
AVERAGES											
48.5	49.0	48.5	48.0	49.7	42.4	78.6	80.3	72.4	85.0	95.6	94.0

NBIL = Lane Adjacent to Median
NB#2 = Second Lane From Median
NB#3 = Third Lane From Median
* = Values start at beginning (south end) of pavement section.

Both RQI and IRI ride quality values were determined from profile data collected after all surface grinding was finished to meet project acceptance for ride quality.

Deflection Analysis

Initial deflection measurements with the department's falling-weight-deflectometer (FWD) were taken prior to opening either pavement section to traffic loading. A 9000 lb impact load was used and an average reading was determined from three drops. The deflection basin was measured with the seismometers located at 8, 12, 18, 24, 36, and 60 inches from the load plate. A comparison of mid-slab deflection readings for the European and Michigan pavement sections is shown in Table 6.

Table 6

Mid-Slab Maximum Deflection, mils						
	Inside Lane		Middle Lane		Outside (Driving) Lane	
	European	Michigan	European	Michigan	European	Michigan
Average	1.27	2.28	1.37	2.14	1.30	2.07
Standard Deviation	0.10	0.10	0.08	0.07	0.08	0.08
Maximum	1.42	2.56	1.50	2.55	1.44	2.51
Minimum	1.15	1.98	1.25	1.91	1.15	1.84

The load transfer efficiency across both the transverse and longitudinal joints of the European section was determined. The transverse and longitudinal joints had average efficiencies of 95 percent and 87 percent, respectively. The joint load transfer efficiency was not done for the Michigan pavement, but will be determined for subsequent performance reports.

Special Project Testing by FHWA

The FHWA (Office of Technology Applications) conducted a research project on site during the construction of the European section. Their purpose was to investigate new non-destructive testing equipment. The results of the project have been published (March 1994) in a report entitled; "Demonstration Project No. 75, Michigan Demonstration Project I-75 Detroit, Michigan".

Future Project Evaluation

A vehicle noise study will occur in 1994, once southbound I-75 is switched to northbound for reconstruction of the southbound portion of the freeway. The Michigan Department of Transportation has a commitment to the FHWA to monitor the European test section for a five year period, which includes submitting interim performance reports by December 31, 1994, 1995, and 1996. A final report shall be provided to the FHWA by December 31, 1998.

CONCLUSIONS/RECOMMENDATIONS

Construction of the European design was accomplished without any major difficulties. The contractor experienced slower production rates for paving, but this is attributed mostly to this being a demonstration project. More familiarity with the two-layer concrete mixtures and the exposed aggregate surface would increase production rates and likely reduce unit costs. Specific recommendations for similar future projects include:

- The initial saw depth for the longitudinal and transverse joints in the two-layer pavement should be revised. Dr. Leykauf, from the Munich Technical University is now recommending the saw depth for longitudinal joints be 0.4D to 0.45D, where "D" equals the pavement depth. The saw depth for transverse joints should be 0.25D to 0.30D, to reduce the chance of joint spalling from expansion pressures.

- Dr. Leykauf also reports that German research (Ref. in Bib. No. 2) has shown that forming plane-of-weakness joints in the lean concrete base by notching is just as effective as sawing. The notching action pushes aggregate particles to either side to form the plane-of-weakness.

- The variable spacing of dowel bars in a basket assembly should be orientated such that the spacing between bars actually represents a standard "uniform" spacing, but with missing bars. This will reduce fabrication costs for the baskets.

- The top layer of the two-layer pavement should not be designed to be less than 7 cm in thickness to reduce the chance for poor consolidation and a thin surface layer to occur.

- The concrete mixture for the top-layer should be revised to eliminate sand particles larger than 1 mm. The coarser particles in the 2NS gradation prevents the coarse aggregate particles in the mixture from "locking" together when there is an exposed aggregate surface. Also, coarse sand particles wear at an accelerated rate compared to basalt. Romain Buys, President of Robuco, Ltd., reported during the AASHTO I-75 tour that research by Belgium and Austria has shown that tire noise levels are reduced when the coarse aggregate particles are closer together. Both countries specify an average exposure depth of 1.0 to 1.1 mm. The maximum size sand particle should be less than 1.0 mm and 95 percent of the stone particles should be from 4.0 - 7.0 mm with 8.0 mm top size.

- Construction project staff recommend the exposed aggregate specification be revised to include a range of maximum/minimum values for the ten individual texture test results per 150 feet pavement length. This would provide a more uniform texture value and more pleasing appearance. An alternative solution would be to include a maximum standard deviation value to supplement the average test result. They believe some outlier test values are skewing the average test result value. Additional study will be required to determine the proper data acceptance band.

- The environmental ramifications of the dust and slurry from brushing the surface to achieve the exposed aggregate should be clarified during the project design phase. There was excessive dust at times on I-75, but the location was not near a residential area. Disposing of the slurry must meet all local regulations. Testing slurry for environmental damaging chemicals was considered on I-75, but because it was in a new product category, testing was not required.

- Plans need to provide details for lane drop requirements for longitudinal joints, especially dealing with the 13.5 foot lane widths.

- Repair methods need to be developed for exposed aggregate surfaces when the texture depth is determined to be out of the specified range.

REFERENCES

1. Report on the 1992 U.S. Tour of European Concrete Highways, Federal Highway Administration, Publications No. FHCOA-SA-93-012 - 1992.

2. European (German) Concrete Pavement Construction, Munich Technical University, G. Leykauf.

APPENDIX A

MICHIGAN DEPARTMENT OF TRANSPORTATION
M•DOT

Specifications
for
European Concrete Pavement

Demonstration Project
Control Section IM 82251
Job Number 30613A
Letting Date June 14, 1993

Lansing, August 1993

PRINTED ON RECYCLED PAPER

This report authorized by the transportation director, has been prepared to provide technical information and guidance for personnel in the Michigan Department of Transportation, the FHWA, and other reciprocating agencies. The cost of publishing 200 copies of this report at $1.37 per copy is $274.56 and it is printed in accordance with Executive Directive 1991-6.

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION FOR EXPOSED AGGREGATE SURFACE TREATMENT OF CONCRETE PAVEMENTS (EUROPEAN PAVEMENT)

a. Description.-This work shall consist of the removal of the surface mortar from the top of a concrete pavement to produce an exposed aggregate finish. This finish shall be achieved with the help of a setting retarder sprayed on to the surface of the concrete pavement immediately after it has been placed. The retarded mortar shall be removed by wet or dry brushing with steel wire brushes no sooner than 20 hours after placing the concrete pavement.

The process required by this specification is patented by Robuco, Ltd. located in Buggenhout, Belgium (see note 1). Robuco, Ltd. is being represented in the United States by Robuco U.S.A. (see note 2). The Contractor is responsible for making all the necessary arrangements and payments for the use of the patent on this project.

The Contractor shall make arrangements to have a representative from Robuco, Ltd. on site during the exposed aggregate surface treatment operation. Robuco's representative shall advise the Contractor regarding the exposed aggregate surface treatment operation.

b.Materials.-Curing compound materials shall be in accordance with Section 8.24 of the Standard Specifications.

The composition and viscosity of the surface retarder shall be such that it can be spread at an adequate and uniform rate over the surface of the concrete pavement in order to ensure effective and adequate aggregate exposure during the subsequent wire brushing operation.

The surface retarder shall contain a pigment, other than white, in sufficient quantity to give an even and uniform color after it has been sprayed onto the pavement surface at an acceptable rate. The retarder shall be non-hazardous. Material Safety Data Sheets shall be provided to the Engineer before starting this work.

The Contractor shall submit to the Engineer information on the type and composition of the retarder intended for use in order to satisfy these requirements. The use of this retarder shall be subject to the approval of the Engineer.

The protective sheeting shall be made of polyethylene or other plastic that is completely waterproof. This waterproof sheeting shall have a thickness of at least 2 mils (50 microns). Splices in the protective sheeting shall be waterproof and shall be accomplished by using a one-foot minimum overlap with two lines of double faced tape, one tape line near each edge.

c. Construction Methods and Equipment.-The process for the exposed aggregate surface finish includes spraying retarder on the concrete surface, covering the surface with plastic sheeting, removing the plastic sheeting, wire brushing the retarded surface, and applying a curing material to the moistened exposed aggregate surface.

c.1. Application of the Retarder.-The retarder shall be sprayed onto the surface of the wet concrete pavement as soon as possible after the concrete has been placed and shall be sprayed onto the surface within 30 minutes after the final smoothing operation. The rate of application of the retarder shall be determined by the Contractor's trial sections as required in Section f.

The spraying system shall operate in an automated manner that ensures that the retarder is spread evenly in both the transverse and longitudinal directions. To achieve this uniformity of application, the spraying system shall consist of a spray bar, provided with nozzles, mounted on a machine spanning the concrete pavement.

Before commencing work, the height of the spray bar, the rate of retarder delivery from the nozzles of the spray bar, and the forward speed of the machine shall be adjusted so as to achieve the required rate of application.

A manual spraying system shall always be available on the site for emergency use in case of a breakdown of the automated spraying system. The manual spraying system is subject to approval by the Engineer.

c.2. Protection of the Surface After the Application of the Retarder.-Total protection of the applied retarder and concrete shall be provided by covering with waterproof sheeting that is unrolled evenly onto the full width of the concrete surface. This protective sheeting shall be placed over the concrete pavement immediately after the application of the surface retarder.

The laying of the sheeting shall not affect the finish of the concrete surface or the even distribution of the retarder in any way. Air bubbling or blistering under the sheeting shall be eliminated to the extent possible.

This sheeting shall exceed the width of the concrete pavement by a minimum of 18 inches on each side of the newly placed concrete pavement. The sheeting shall be kept in place by ballast that shall be laid only on the extra width overlaps on both sides of the concrete pavement.

When transverse and longitudinal joints in the concrete pavement are saw cut through the protective sheeting, an equivalent protective sheeting shall be immediately placed over the saw cut holes in the sheeting with 6-inch minimum lap each side of the saw cut and held in place by a suitable means.

c.3. Unrolling of the Waterproof Sheeting.-To minimize the effect of wind on the protective waterproof sheeting, the system of unrolling shall be so arranged that the sheeting is released directly above and as close as possible to the concrete surface.

The unrolling system shall include a burlap drag 10 to 15 feet long and shall be attached to the system for the full width of the concrete pavement and towed forward over the laid protective sheeting so that the sheeting is pressed against the concrete surface. This burlap drag shall be sprinkled with water to keep it moist so that it maintains pressure on the waterproof protective sheeting.

c.4. Removing the Waterproof Sheeting and Exposing the Aggregate by Brushing.-Removing the waterproof sheeting and brushing the concrete surface shall be carried out not less than 20 hours after placing the concrete pavement. Wet or dry wire brushing to remove the retarded surface mortar shall be used. In addition, the concrete must have gained sufficient strength for the brushing machine to travel on the slab without causing any damage to the concrete.

The Contractor shall take all necessary steps to complete the aggregate exposure before the retarder used becomes ineffective.

The waterproof sheeting shall be removed in advance of the machining at the same rate as the brushing machine proceeds in successive sections of 250 foot maximum length in order for the protection to remain in place as long as possible.

The waste waterproof protective sheeting and mortar removed from the surface shall be disposed of at a site outside the project limits on a daily basis.

c.5. **Brushing System.**-The brushing machine shall be equipped with one or two rotary brushes fitted with twisted steel wires having a diameter of 0.02 to 0.04 inches. The rotary brushes shall be shrouded to eliminate mortar dust from being discharged into the air.

The length of the brush wires, when new, shall be at least 10 inches, exclusive of the length of attachment. A brush shall be discarded as soon as any of its wires become shorter than 4 inches, exclusive of the length of attachment.

The brushing machine shall be capable of maintaining a brush rotational speed, which in conjunction with the forward travel speed, is sufficient to remove the surface mortar to the desired depth in two or three passes, while leaving the aggregate exposed in place.

If the wet brushing method is used, each brush shall be equipped with a front spray bar for sprinkling water. An additional spray bar shall be mounted at the rear of the machine.

The inclination and height of the brush(es), as well as the extension on both sides of the machine to at least 12 inches outside the tire track, shall be adjustable from the operator's seat.

To help meet the requirement of Section C.4 relating to avoidance of damage to the concrete, the wheels of the brushing machine shall be fitted with wide tires having a low inflation pressure and a shallow tread.

c.6. **Protection of the Exposed Aggregate Surface After Brushing.**-Within four hours after removing the waterproof sheeting and within one hour of completing the brushing operation, a curing compound shall be sprayed mechanically onto the entire exposed aggregate surface of the concrete pavement. The surface shall be cleaned of all foreign material and moistened with water before spraying the curing compound onto the exposed aggregate surface. The application of the curing compound shall be in accordance with Section 4.50 of the Standard Specifications.

d. **Surface Texture Depth.**-The texture depth of the concrete pavement shall be measured by the sand patch test method indicated herein. The average texture depth determined for each 150 foot section of roadway lane tested shall be 1.3 mm ± 0.20 mm (0.05 in. ± 0.008 in.). Surfaces not meeting this texture depth shall be repaired by the Contractor using a method approved by the Engineer.

The Contractor shall be responsible for quality control testing at the rate specified herein to ensure this surface texture is attained. The Department will conduct quality assurance tests at the rate specified herein for acceptance of the surface.

e. **Sand-Patch Test Method.**-The basis of this test method is British Standard BS598 Part 105.

Sand meeting the gradation of Table 1 and 90 percent roundness requirement is available from U. S. Silica, Gradation AFS 50-70 (Phone 800-635-7363).

e.1. **Apparatus.**-Measuring cylinder of 50 ± 1 mL total capacity and 30 mm maximum internal diameter.

A flat, hard disk approximately 25 mm (1 in.) thick and 60 to 75 mm (2.5 to 3.0 in.) in diameter. The bottom surface or face of the disk shall be covered with a hard rubber material and a suitable handle may be attached to the top surface of the disk. An ice hockey puck is considered suitable for use as the hard rubber material.

Washed and dried silica sand with a 90 percent roundness in accordance with ASTM D 1155 and conforming to the grading given in Table 1. Gradation of sand shall be certified by supplier.

Table 1 Grading of Sand for Sand-Patch Test

Sieve Size	Percent Passing, By Weight
600 μm (#30)	100
300 μm (#50)	90 to 100
150 μm (#100)	0 to 15

A standard steel scale 300 mm (12 in.) or greater in length and having 1 mm (0.04 in.) divisions.

e.2. **Measurement of the Surface Texture.**-Measure the surface texture depth as soon as possible after the surfacing has been completed and before the surfacing has been opened to traffic. Curing compound shall be removed from the surface before conducting the test and shall be reapplied to the surface if the concrete has not attained at least 70 percent of its required strength.

The test shall not be carried out on wet or sticky surfaces.

Make test measurements on 150 foot lane lengths randomly spaced along the section. The total length of the 150 foot lane lengths tested shall not be less than one-third of the section length being represented by the tests.

On each 150 foot lane length, take 10 individual test measurements of the texture depth at approximately 15 foot spacing along a diagonal line across the roadway lane width. Do not take measurements within 12 inches of the longitudinal edge of the roadway.

e.3. **Procedure for Carrying out a Single Measurement.**-If necessary, dry the surface to be measured and remove any foreign matter by sweeping.

Fill the cylinder with sand and, taking care not to compact the sand by any vibration, strike off the sand level with the top of the cylinder. Shield from wind if necessary.

Pour the sand into a heap on the surface to be tested and spread the sand over the surface using the disc. Carefully work the disc with its face kept flat to the road surface, in a rotary motion so that the sand is spread into a circular patch with the surface depressions in the road filled with sand to the level of the peaks. The procedure is complete when no further distribution of sand outward is achieved. Shield from wind if necessary.

Measure the diameter of the sand patch to the nearest 1 mm at 4 diameters approximately 45° apart using the steel scale.

e.4. Calculation and Expression of Results.-Calculate the average diameter of the sand patch to the nearest 1 mm.
Calculate the average texture depth (in mm) from the following formula:

$$\frac{63,660}{D^2} = T$$

Where

D is the average diameter of the sand patch.
T is the average texture depth in mm.

Determine the average texture depth for each section of roadway lane tested and the average of each set of 10 individual measurements to the nearest 0.1 mm.

e.5. **Test Report.**-The report shall state that the texture measurements were made in accordance with this section and shall include the following:

(1) The name and address of the testing organization;
(2) A unique serial number for the test report;
(3) The name of the client and project numbers;
(4) Clear identification of the individual test locations, along with the location of each lane length tested;
(5) The individual test results of texture depth and the average texture depths for each 150 foot lane length comprising each section together with the average value for the section;
(6) A statement saying the road surface was newly laid;
(7) The signature of the person accepting technical responsibility for the test report;
(8) The date of each test;
(9) The date of the report.

f. Trial Sections.-The Contractor shall perform exposed aggregate trial sections as described herein under the observation of the Engineer. These trial sections shall form the basis of the production work.

f.1 Test Panels.-Test panels using the top layer concrete, surface retarder, waterproof protective sheeting, and curing compounds that will be used in the production work shall be prepared by the Contractor. These test panels shall demonstrate that the surface retarder, retarder application rate, and elapsed time before mortar removal will provide the desired surface texture. A test panel procedure, including a materials list, shall be submitted to the Engineer for review prior to making the panels. The panels shall be a minimum of 18 inches wide by 18 inches long and shall be 2-1/2 inches thick. Initial spot check measurements of the panel texture depth shall be performed by the Contractor using the sand-patch test method described herein.

f.2 Trial Length and Production Work.-A trial length of concrete pavement shall be constructed by the Contractor in accordance with the Special Provision for Two-Layer Concrete Pavement and Concrete Shoulders (European Pavement). This trial length of concrete pavement shall incorporate the exposed aggregate surface treatment. The same materials and equipment used to construct the trial length shall be used in concrete pavement production. The trial length shall comply with the specifications in all respects. The Contractor shall not proceed with the European concrete pavement production until the trial length has been approved by the Engineer.

During the construction of this trial length of concrete pavement and European concrete pavement production initial spot check measurements of the texture depth shall be carried out by the Contractor as soon as possible after completing the exposure of the aggregate. If, at this stage, the texture depth requirements are not achieved, work shall be stopped immediately and the surface shall be treated by scabbling or other approved methods until the requirements are met. Work shall not be resumed without the approval of the Engineer and until the causes of the observed defects have been investigated and resolved.

Any new observations of inadequate surface texture during the course of the work shall give rise to the same measures of repair and investigation until the required results are achieved.

g. **Measurement and Payment.**-Payment for the work of EXPOSED AGGREGATE SURFACE TREATMENT OF CONCRETE PAVEMENTS (EUROPEAN PAVEMENT) includes royalty fees and all the necessary materials, labor, and equipment to produce the desired surface texture, along with disposal of the waterproof sheeting and waste mortar. Payment shall be made in accordance with the following contract item (pay item).

Pay Item	Pay Unit
Exposed Aggregate Surface Treatment (European Pavement)	Square Yard

Payment for the exposed aggregate trial sections and test panels will not be paid for separately, but shall be considered in the payment of the Exposed Aggregate Surface Treatment (European Pavement).

Note 1: Robuco, Ltd.
Romain Buys, General Manager
Industriepark Gendhof 4
B-9360
Buggenhout
Belgium (Eur.)
Phone 32-52-33-13-03

Note 2: Robuco U.S.A.
Earl Knott
3800 Maiden
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C/APPR/RVP/RGS 4-27-93

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION FOR TWO-LAYER CONCRETE PAVEMENT AND CONCRETE SHOULDERS (EUROPEAN PAVEMENT)

a. **Description.**-This work shall consist of constructing two-layer, wet on wet, concrete pavement and concrete shoulders. Fresh concrete for the top layer shall be placed on the fresh concrete for the bottom layer in one continuous operation. The concrete pavement and concrete shoulder shall be non-reinforced and shall be constructed to the dimensions and limits shown on the plans. This concrete pavement shall have a final finish in accordance with the Special Provision for Exposed Aggregate Surface Treatment of Concrete Pavements (European Pavement). Concrete pavement and concrete shoulders shall be constructed in accordance with the Standard Specifications, except as modified herein and by other Special Provisions.

b. **Concrete Mix Design.**-The Contractor shall be responsible for the concrete mix design as specified in the Special Provision for Furnishing Portland Cement Concrete (Quality Assurance). Concrete properties, characteristics, and acceptance sampling rate shall be as specified herein. Acceptance of the concrete based on these properties and characteristics shall be in accordance with the Special Provision for Furnishing Portland Cement Concrete (Quality Assurance).

This concrete pavement and concrete shoulder is considered a Critical Pay Adjustment Item.

The Contractor shall provide separate and distinct concrete mixtures for the top layer and bottom layer of the two-layer concrete pavement. The Contractor will not be allowed to construct the pavement full depth with the top layer Grade 55P concrete.

b.1. Bottom Layer Concrete.-Concrete for the bottom layer shall meet the following properties and characteristics.

Class Design Strength (28 days, psi)	5000
Verification Strength (28 days, psi)	5500
Retest Limit (28 days, psi)	4500
Maximum Water/Cement Ratio (lb/lb)	0.42
Minimum Cement Content (lb/cyd)	588
Maximum Slump (inches)	3

This concrete is designated as Concrete Grade 50P.

The Initial Sampling Rate for acceptance shall be 5 per lot, the Retest Sampling Rate (minimum) shall be 6 per lot, and the Rejection Limit shall be 10 percent.

Fine aggregate shall meet the requirements of Section 8.02 in the Standard Specifications.

Coarse aggregate shall be a natural gravel or crushed stone and shall meet the requirements of 6AA as stated in the Standard Specifications, with the additional requirement that freeze-thaw dilation (in percent) per 100 cycles shall be 0.008 maximum per MTM 115. Coarse aggregate shall be sampled at the source or dock if the material is shipped to the project by boat and shall be approved before shipment. Each aggregate stockpile shall be sampled by the District as it is constructed at a frequency of 1 sample for each 1000 tons. No material shall be added or removed from a stockpile after a sample is taken until testing is completed. An aggregate source will not be approved by certification for this concrete. All stockpiles shall be clearly identified to this project at both the source and concrete batch plant.

b.2. **Top Layer Concrete.**-Concrete for the top layer shall meet the following properties and characteristics.

Class Design Strength (28 days, psi)	5500
Verification Strength (28 days, psi)	6000
Retest Limit (28 days, psi)	5000
Maximum Water/Cement Ratio (lb/lb)	0.40
Minimum Cement Content (lb/cyd)	752
Maximum Slump (inches)	3

This concrete is designated as Concrete Grade 55P.

The Initial Sampling Rate for acceptance shall be 5 per lot, the Retest Sampling Rate (minimum) shall be 6 per lot, and the Rejection Limit shall be 10 percent.

Fine aggregate shall meet the requirements of Section 8.02 in the Standard Specifications.

Coarse aggregate shall meet the requirements of 6AA as stated in the Standard Specifications, with the additional requirements that the material shall be 100 percent crushed basalt, the freeze-thaw dilation (in percent) per 100 cycles shall be 0.008 maximum per MTM 115, the maximum size shall be 0.31 inches (8 mm), the maximum percent passing the No. 5 (4 mm) sieve shall be 3 percent, the maximum percent passing the No. 200 sieve shall be 2 percent, the Los Angeles Abrasion Loss (in percent) shall be 20 maximum and the Aggregate Wear Index (AWI) value shall be 300 minimum. The coarse aggregate shall be sampled at the source or dock if the material is shipped to the project by boat and shall be approved before shipment. Each aggregate stockpile shall be sampled by the District as it is constructed at a frequency of 1 sample for each 1000 tons. No material shall be added or removed from a stockpile after a sample is taken until testing is completed. An aggregate source will not be approved by certification for this concrete. All stockpiles shall be clearly identified at both the source and concrete batch plant.

c. **Concrete Production.**-The Contractor shall provide separate concrete mixtures for the top layer and bottom layer of the two-layer concrete pavement. Concrete mixtures for the two-layer concrete shoulder shall be the same as the top layer and bottom layer of the concrete pavement, or each layer shall be placed using the concrete mixture for the bottom layer of the concrete pavement.

d. **Equipment.**-Slip form pavers shall be used for constructing the concrete pavement and the concrete shoulder. Lane ties may be hand vibrated into place or placed with an automatic lane tie inserter for longitudinal joints. A separate machine including a concrete spreader, consolidator, and screed shall be used for each layer of the concrete. This shall be accomplished by using a separate paver for each layer or by using a combined two-layer paver. All pavers used shall be capable of maintaining proper line and grade.

Concrete finishing equipment for the top layer concrete shall include an oscillating longitudinal float pan moving perpendicular to the centerline of the roadway that has a smoothing action on the surface and removes any irregularities left by the operation of the paving equipment. The length of longitudinal float pan in the direction parallel to the centerline of the roadway shall be a minimum of six feet. Hand finishing will only be allowed at the edges.

Dowel bars may be set using a joint assembly or an automatic inserter. Equipment used to automatically place dowel bars and lane ties shall be capable of accurately inserting the dowel bars and lane ties into plastic concrete at the location shown on the plans without interrupting the forward movement of the pavers. The installing device shall consolidate the concrete around the dowel bars and lane ties such that no voids exist, without the supplement use of handheld vibrators. The Contractor shall provide a work bridge for use by the Department in order to make wet checks on the location of the dowel bars and lane ties.

If basket assemblies are used, they shall be held in place and attached to the lean concrete base by a method approved by the Engineer.

e. **Construction.**-Concrete pavement and concrete shoulders shall be constructed to the dimensions shown on the plans. Steel reinforcement shall not be placed in the concrete pavement or concrete shoulder. The concrete pavement shall have a final finish in accordance with the Special Provision for Exposed Aggregate Surface Treatment of Concrete Pavements (European Pavement). Concrete shoulders shall be dragged longitudinally with one or two layers of damp burlap or cotton fabric, a stiff fiber artificial grass carpet, or other approved material as soon as the concrete has set sufficiently to maintain texture. This concrete shoulder texturing shall be done in accordance with Subsection 4.50.14 of the Standard Specifications.

Concrete pavement and concrete shoulder shall be placed over a lean concrete base. The surface of the lean concrete base shall be cleaned of all foreign material before placing the concrete pavement or concrete shoulder. Heavy equipment and equipment for concrete paving will not be allowed on the lean concrete base until it reaches a strength of 70 percent of its class design strength.

Transverse joints in the concrete pavement shall be placed within 2 inches from the transverse joint in the lean concrete base. Longitudinal joints in the two-layer concrete pavement shall be placed within 1 inch from the longitudinal joints in the lean concrete base.

If dowel bars and lane ties are placed by an automatic inserter, they shall be inserted into the consolidated bottom layer of concrete prior to placing the top layer of concrete. Tolerances for placing the dowel bars are 3/16 inch in the length of the bar in both the vertical and horizontal planes of the pavement, within 2 inches of the plan longitudinal location, within 1 inch of the plan transverse location, and within 1/2 inch of the plan depth location. Tolerances for placing the lane ties are 1/2 inch in the length of the bar in both the vertical and horizontal planes of the pavement, within 2 inches of the plan transverse location, within 1 inch of the plan longitudinal location, and within 1/2 inch of the plan depth location. All dowel bars and lane ties placed outside these tolerances shall be removed and replaced at the Contractor's expense. The Contractor shall furnish an instrument capable of verifying the final location of the inserted dowel bars and lane ties.

The Contractor shall provide positive control and an approved method of marking the dowel bar locations for correlation to the sawed transverse joints.

Top layer concrete shall be placed within 30 minutes from screeding the bottom layer concrete directly below and within 45 minutes from unloading the bottom layer concrete onto the lean concrete base. The maximum distance during paving between the top layer paver and bottom layer paver shall be 50 feet.

Miscellaneous concrete pavement shall be constructed using the same materials and procedures as used for concrete pavements. Transverse joints in the miscellaneous concrete pavement shall coincide with the adjacent concrete pavement transverse joints.

e.1. Trial Length.-A trial length of concrete pavement, including a final finish in accordance with the Special Provision for Exposed Aggregate Surface Treatment of Concrete Pavements (European Pavement), shall be constructed by the Contractor.

At least one month prior to the construction of the trial length of concrete pavement the Contractor shall submit for the Engineer's approval a detailed description of the proposed materials, plant, equipment, and construction methods. No trials of new materials, plant, equipment, or construction methods; nor any development of them shall be permitted either during the construction of the trial length or in any subsequent paving work, unless they form part of further approved trials.

The Contractor shall demonstrate the materials, plant, equipment, and methods of construction that are proposed for concrete paving by first constructing a trial length of slab at least 500 feet but not more than 1000 feet long. The width of the trial length shall be 12-foot minimum. The trial length shall be constructed in two parts over a period comprising at least part of two separate working days, with a minimum of 250 feet constructed each day. The trial length shall be constructed at a similar rate to that which is proposed for the production paving.

At least two complete transverse joints and one complete longitudinal joint shall be constructed and assessed in the trial length.

The trial length shall comply with the specifications in all respects, with the following additions.

At least 3 cores with a minimum diameter of 4 inches shall be taken at random from the pavement by the Contractor to check the top and bottom layer thickness.

At least 3 cores with a minimum diameter of 4 inches shall be taken at random from the pavement by the Contractor at joints to check the lateral and vertical location of joint grooves and initial saw cut crack inducers.

Alignment of dowel bars shall be checked by the Contractor in any two consecutive transverse joints by drilling cores from the pavement with a minimum diameter of 4 inches. Cores shall be taken at each end of at least 3 dowel bars in each joint. If the position or alignment of the dowel bars at one of these joints does not comply with the tolerances stated herein, but if that joint remains the only one that does not comply after the next three consecutive transverse joints have been inspected, then the method of placing dowels shall be deemed to be satisfactory.

Position and alignment of tie bars shall be checked by the Contractor by drilling cores from the pavement with a minimum diameter of 4 inches. Cores shall be taken at each end of at least one-third of all the tie bars in the trial section.

Approval of the materials, plant, equipment, and construction methods will be given when the trial length complies with the specifications. The Contractor shall not proceed with production work until the trial length has been approved and any earlier defective trial lengths have been removed, unless they can be remedied to the satisfaction of the Engineer. If the Engineer does not notify the Contractor of any deficiencies in any trial length within 10 working days after the completion of that trial length the Contractor may assume that the trial length, and the materials, plant, equipment, and construction methods adopted are all acceptable.

When approval has been given, the materials, plant, equipment, and construction methods shall thereafter not be changed, except for normal adjustments and maintenance of the plant, without the approval of the Engineer. Any changes in materials, plant, equipment, and construction methods shall entitle the Engineer to require the Contractor to construct another trial length as described in this section to demonstrate that the changes will not adversely affect the work.

Trial lengths that do not comply with the specifications, with the exception of areas within the pavement surface that can be remedied to the satisfaction of the Engineer, shall be removed immediately upon notification of deficiencies by the Engineer and the contractor shall construct a further trial length.

f. **Measurement and Payment.**-Payment for the work of TWO-LAYER CONCRETE PAVEMENT AND CONCRETE SHOULDERS (EUROPEAN PAVEMENT) includes all the materials, labor, and equipment necessary to complete the work as described herein. Payment shall be made in accordance with the following contract items (pay items).

Pay Item	**Pay Unit**
Two-Layer Concrete Pavement - 10-inch Non-Reinforced (European Pavement)	Square Yard
Two-Layer Concrete Shoulder - 10-inch Non-Reinforced (European Pavement)	Square Yard
Miscellaneous Two-Layer Concrete Pavement 10-inch Non-Reinforced (European Pavement)	Square Yard

The cost of furnishing and setting dowel bars and lane ties in two-layer concrete pavement transverse joints is included in the payment for Transverse Contraction Joint (European Pavement) and Longitudinal Joint (European Pavement) as described in the Special Provision for Constructing Longitudinal and Transverse Contraction Joints.

Payment for the trial length of concrete pavement will not be paid for separately, but shall be considered included in the payment for Two-Layer Concrete Pavement - 10-inch Non-Reinforced (European Pavement). Cost for removal and replacement of all failing trial lengths shall be at the Contractor's expense.

Coring the concrete pavement for thickness determination and acceptance will be done in accordance with Section 4.50 of the Standard Specifications. Total pavement thickness will be the basis of application to this section. Top layer thickness of ±1/2 inch from the plan dimension shall be cause for removal and replacement. Depth of reinforcement measurements are not applicable.

C/APPR/RVP/RGS 04-02-93

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION FOR LEAN CONCRETE BASE (EUROPEAN PAVEMENT)

a. Description.-This work shall consist of constructing a lean concrete base over a granular subbase. The lean concrete base shall be non-reinforced and shall be constructed to the dimensions and limits as shown on the plans. Lean concrete bases shall be constructed in accordance with concrete base courses as specified in Section 4.50 of the Standard Specifications, except as modified herein. The two-layer concrete pavement and concrete shoulders shall be placed over the lean concrete base.

b. Concrete Mix Design.-The Contractor shall be responsible for the concrete mix design as specified in the Special Provision for Furnishing Portland Cement Concrete (Quality Assurance). Concrete properties, characteristics, and acceptance sampling rate shall be as specified herein. Acceptance of the concrete based on these properties and characteristics shall be in accordance with the Special Provision for Furnishing Portland Cement Concrete (Quality Assurance). This lean concrete base is considered a Critical Pay-Adjustment Item.

b.1. Concrete Properties and Characteristics.-Concrete for the lean concrete base shall meet the following properties and characteristics.

Class Design Strength (28 days, psi) 2500
Verification Strength (28 days, psi) 3000
Retest Limit (28 days, psi) 2000
Maximum Water/Cement Ratio (lb/lb) 0.70
Minimum Cement Content (lb/cyd) 400
Maximum Slump (inches) 3

This concrete is designated as Concrete Grade 25P.

The Initial Sampling Rate for acceptance shall be 5 per lot, the Retest Sampling Rate (minimum) shall be 6 per lot, and the Rejection Limit shall be 10 percent.

Fine aggregate shall meet the requirements of Section 8.02 in the Standard Specifications.

Coarse aggregate shall be a natural gravel or crushed stone and shall meet the requirements of 6AA as stated in the Standard Specifications, with the additional requirement that freeze-thaw dilation (in percent) per 100 cycles shall be 0.008 maximum per MTM 115. No recycled concrete pavement will be allowed in the lean concrete base mixture. Coarse aggregate shall be sampled at the source or dock if the material is shipped to the project by boat and shall be approved before shipment. Each aggregate stockpile shall be sampled by the District as it is constructed at a frequency of 1 sample for each 1000 tons. No material shall be added or removed from a stockpile after a sample is taken. An aggregate source will not be approved by certification for this concrete. All stockpiles shall be clearly identified to this project at both the source and concrete batch plant.

c. **Construction.**-The lean concrete base shall be non-reinforced and shall be constructed over a granular subbase to the dimensions shown on the plans. The two-layer concrete pavement and concrete shoulders shall be placed over the lean concrete base. Equipment used to place the lean concrete base shall be capable of screeding and consolidating the concrete mixture to the proposed line and grade. Transverse and longitudinal plane of weakness joints with a depth of at least 0.4 to 0.45 percent of the thickness shall be placed in the lean concrete base within 24 hours of placing the concrete. These joints shall be made by a vibrating panel placed in the fresh concrete or by saw cutting the hardened concrete. Transverse joints in the lean concrete base shall be placed within 2 inches from the transverse joint in the two-layer concrete pavement. Longitudinal joints in the lean concrete base shall be placed within 1 inch from the longitudinal joint in the two-layer concrete pavement. Load transfer bars shall not be placed in the lean concrete base at the transverse or longitudinal joints.

As soon as the concrete has set sufficiently to maintain texture, the concrete surface shall be dragged longitudinally with one or two layers of damp burlap or cotton fabric, a stiff fiber artificial grass carpet, or other approved material. This texturing shall be done in accordance with Subsection 4.50.14 of the Standard Specifications.

Lean concrete base surfaces shall be kept free of curing compound. These surfaces shall be cured by being kept continuously moist until the concrete has reached an age of at least 7 days. The moist curing shall be started as soon as the concrete has hardened sufficiently to prevent significant marring or water damage.

Heavy equipment, including slip form pavers, will not be permitted on the lean concrete base until the concrete has attained a strength of 70 percent of its class design strength.

The Contractor shall remove and replace all sections of lean concrete base that have full depth cracks between the transverse joints at no cost to the project.

The surface of the lean concrete base shall be cleaned of all foreign material before placing the two-layer concrete pavement or concrete shoulder.

d. **Measurement and Payment.**-Payment for the work of LEAN CONCRETE BASE (EUROPEAN PAVEMENT) includes all the materials, labor, and equipment necessary to complete the work as described herein. Payment shall be made for the following contract item (pay item).

Pay Item	**Pay Unit**
Lean Concrete Base - 6-inch Non-Reinforced (European Pavement)	Square Yard

Coring the lean concrete base for thickness determination and acceptance will be done in accordance with Section 4.50 of the Standard Specifications. Depths of reinforcement measurements are not applicable.

C/APPR/RVP/RGS 3-18-93

determined and found to be within the specified range.

d.6. Test Procedure Specifications.

ASTM

C31 Making and Curing Concrete Test Specimens in the Field
C39 Compressive Strength of Cylindrical Concrete Specimens
C78 Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)
C138 Unit Weight, Yield and Air Content (Gravimetric) of Concrete
C143 Slump of Hydraulic Cement Concrete
C172 Sampling Freshly Mixed Concrete
C173 Air Content of Freshly Mixed Concrete by the Volumetric Method
C231 Air Content of Freshly Mixed Concrete by the Pressure Method
C293 Flexural Strength of Concrete (Using Simple Beam with Center-Point Loading)

The Department's established procedures for sampling and testing are considered acceptable alternatives.

e. **Measurement and Payment.**-Separate payment will not be made for providing and maintaining an effective quality control program, and all costs associated therewith shall be included in the applicable unit prices for the concrete item.

C/APPR/RVP/RGS 3-18-93

NOTICE TO BIDDERS

LETTING OF JUNE 9, 1993

ADDENDUM NO. 1

This Addendum changes the terms of the Bid Proposal. By submitting a bid you accept all changes included in this Addendum.

The following paragraphs and the attached pages will instruct you as to the changes made and how to make them.

CHANGES TO BID ITEM PRICES

When you are instructed to ADD, DELETE, OR MAKE CHANGES to a BID ITEM PAGE OR PAGES, these additions, deletions, or changes MUST be made on the bid item pages you submit with your bidding proposal, whether handwritten or computer generated.

CHANGES TO OTHER PAGES

When you are instructed to DELETE something which is NOT on a Bid Item Page, you may line through the text diagonally and/or print or write the word "DELETE" on the text being deleted. Physically removing the page(s) is not necessary.

When you are instructed to ADD A NON-BID ITEM PAGE(S), OR PORTIONS THEREOF, you MUST CONSIDER it/them in developing your bid, but the physical insertion of the new page(s) into the proposal is not necessary.

FAILURE TO CARRY OUT THE INSTRUCTIONS IN THIS ADDENDUM MAY RESULT IN THE REJECTION OF YOUR BID.

THIS ADDENDUM IS FOR THE FOLLOWING LISTED PROJECTS:

ITEM	PROJECT	JOB NO.	PARTS	FED NO.	FED ITEM
9306 083	IM 82251	30613A		IM 75-1(420)	NP 1417
	IM 82111	30614A		IM 75-1(420)	NP 1417

Prospective bidders on the above noted project are hereby advised of the following changes:

Proposal

1. On Cover Sheet of the proposal, revise the following paragraph "BIDS WILL BE OPENED AT 10:30 A.M., E.D.T., ON WEDNESDAY, JUNE 9, 1993 AT THE HOLIDAY INN SOUTH/CONVENTION CENTER 6820 S. CEDAR ST., LANSING, MICHIGAN" to read "BIDS WILL BE OPENED AT 2:00 P.M., ON MONDAY, JUNE 14, 1993 AT THE SOUTH TRAINING CENTER OF THE TRANSPORTATION BUILDING, 425 WEST OTTAWA, LANSING, MICHIGAN."

2. Replace pages 1 thru 22, titled "BID ITEMS" with pages 1 Revised thru 22 Revised, titled "BID ITEMS."

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION FOR CONSTRUCTING LONGITUDINAL AND TRANSVERSE CONTRACTION JOINTS (EUROPEAN PAVEMENT)

a. Description.-This work shall consist of constructing longitudinal and transverse contraction joints in the two-layer European concrete pavement and associated shoulders and miscellaneous pavement in accordance with the plans and Section 4.50 of the 1990 Standard Specifications with the exceptions contained herein. Both joints shall be sealed with a PHOENIX EPDM joint seal in place of the hot-poured rubber asphalt longitudinal sealant, and in place of the 1-1/4 inch preformed neoprene transverse seal.

b. Materials:

Joint Sealant.-The longitudinal joint seal shall be a Phoenix EPDM type M 214-66. The transverse joint seal shall be a Phoenix EPDM type M 214-45. No other manufacturer for these joints will be allowed. The manufacturer shall provide Type D certification on the EPDM material, as defined in the Michigan Materials Quality Assurance Manual. PHOENIX North America, Inc. shall be notified one week in advance of the pending sealing operation. A representative of Phoenix will be on hand to assist in the installation procedure. The PHOENIX contact person is:

Mr. Scott Poyner
PHOENIX North America, Inc.
1 minue Street
Carteret, New Jersey 07008-9984
Ph: (908) 969-0319

Dowel Bars.-The dowel bars for transverse contraction joints shall meet the requirements of 8.16.08 except as noted. The dowel bars shall be twenty inches long with a diameter of one and one quarter inch (1 1/4"). The transverse dowel spacing shall be as shown on the plans. The dowels are to be inserted in the pavement by a mechanical dowel bar inserter or by dowel basket assemblies. The dowel bar coating shall be Type A for the inserted dowel bars.

Lane Ties.-Lane ties for longitudinal pavement joints shall meet the requirements of Subsection 8.16.10-a of the 1990 Standard Specifications except that the lane ties shall be an epoxy coated, deformed, number seven bar (seven-eighths inch in diameter), thirty two inches in length. The spacing for the lane ties shall be as shown on the plans.

c. **Joint Groove Sawing.**-The joint grooves shall be sawed to the dimensions shown on the plans and as specified in Subsection 4.50.17 of the 1990 Standard Specifications, except that the first stage saw cutting on all joints will be performed within twenty four hours after concrete placement. No sawing shall be permitted until the concrete has obtained sufficient strength to support the saw without damage. After the initial saw cut, a continuous plastic band or tubing shall be inserted into the saw cut to a depth just below the subsequent saw cut that shapes the joint for the Phoenix seal. This plastic band is inserted to prevent slurry, resulting from the second stage saw cutting, from infiltrating into the crack cavity below the joint seal. The diameter of the solid plastic band should be approximately 10% greater than the width of the initial saw cut or if hollow tubing is used, approximately 25% greater. The exposed ends of the plastic band or tubing should be tied or knotted to prevent the band or tubing from contracting into the exposed ends of the saw cut. The saw and saw blade used for cutting the required bevel, as shown on the plan detail, will be supplied by the joint seal manufacturer (Phoenix). Immediately after the final stage sawing, the joint groove shall be cleaned with water having sufficient pressure to remove all slurry and debris from the joint faces and reservoir. The final stage sawing shall follow the completion of work for the aggregate surface treatment.

d. **Joint Repair.**-Prior to sealing, all spalls or voids in the joint area shall be repaired as specified in Subsection 4.50.19 of the 1990 Standard Specifications. Prior to sealing the joint, the repaired areas shall be sandblasted to clean and texture the surface.

e. **Joint Preparation.**-Immediately prior to sealing, the joint shall be cleaned to remove all dust and contamination from the joint faces and reservoir. Cleaning shall consist of abrasive blasting followed by a final cleaning with compressed air, free of oil and water and having a minimum nozzle pressure of 90 psi.

f. **Joint Sealing.**-The EPDM seal shall be installed in accordance with Subsection 4.50.22-b of the 1990 Standard Specifications with the following exceptions. The transverse joint seal shall be installed prior to installing the longitudinal seal. No lubricant-adhesive shall be used. The joint seal shall be installed by a machine supplied by the joint seal manufacturer. The installation operation shall be carried out in such a manner that the longitudinal elongation of the seal does not exceed 5%. The joint seal shall be wiped clean with a water and soap solution as it is being inserted into the installation device. After the transverse joint seals are installed, a U-shaped notch shall be cut into the seals. This cut, at the intersection between the transverse and longitudinal joints, shall be two-thirds of the profile height of the transverse joint. The device used to notch the transverse seals shall be the same machine that bevels the joint edge. The longitudinal seal shall be installed in a similar manner as the transverse joint. The surface contacts for the overlap between the transverse and longitudinal seals shall be glued with Sikaflex 221. Alternatives to this adhesive shall be approved only by the joint seal manufacturer. The placement of any glue shall not extend more than three transverse joints ahead of the longitudinal seal installation.

g. Joint Seal Splicing.-No splicing of the transverse joint seals will be allowed. Splices in the longitudinal joint shall be made only at mid-panel locations to avoid the intersecting point with the transverse joint. At the splice locations, the ends of the abutting members shall be trimmed square and be joined with an application of Sikaflex 221. Both sections of the seal shall then be inserted into the groove using a hammer and flat ended chisel butting the ends tightly together. Hammer and chisel installation of the longitudinal seal will continue for an additional three feet either side of the splice location, before continuing the installation of the seal with the installation machine.

h. Measurement and Payment.-The completed work as measured for CONSTRUCTING LONGITUDINAL AND TRANSVERSE CONTRACTION JOINTS (EUROPEAN PAVEMENT) will be paid for at the contract unit price for the following contract items (pay items).

Pay Item	Pay Unit
Transverse Contraction Joint (European Pavement)	Linear Foot
Longitudinal Joint (European Pavement)	Linear Foot

The payment for Transverse Contraction Joint will include all items provided for in this provision to construct and seal the transverse joints. This pay item includes such items as furnishing and installing dowel bars, all transverse EPDM joint seals required, adhesives, sawing, forming, and cleaning the joints; furnishing and installing the plastic bands; repairing spalls or voids; and furnishing special installation and sawing equipment. The pay item for Longitudinal Joint will include those similar materials and work for constructing transverse joints, as described in this provision, necessary to construct and seal the longitudinal joint.

C/APPR/RVP/RGS 4-2-93

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION FOR HIGH DURABILITY COARSE AGGREGATE FOR CONCRETE PAVEMENTS AND CONCRETE SHOULDERS

a. **Description.**-The coarse aggregate furnished for Grade 35P and Grade 30P concrete for pavements and shoulders on northbound I-75, within the project limits, shall meet the requirements of 6AA as specified in the Standard Specifications, except as modified herein.

Coarse Aggregate 6AA shall be a natural gravel or crushed stone and shall have a maximum freeze-thaw dilation of 0.008 percent per 100 cycles per MTM 115. Coarse aggregate shall be sampled at the source or dock if the material is shipped to the project by boat and shall be approved before shipment. Each aggregate stockpile shall be sampled by the District as it is constructed at a frequency of 1 sample for each 1000 tons. No material shall be added or removed from a stockpile after a sample is taken. An aggregate source will not be approved by certification for this concrete. All stockpiles shall be clearly identified at both the source and concrete batch plant.

In cases where this Special Provision is in conflict with another Special Provision, this Special Provision will prevail.

b. **Measurement and Payment.**-Separate payment will not be made for providing this coarse aggregate. All costs associated therewith shall be included in the applicable unit price for the concrete item.

C/APPR/RVP/RGS 3-18-93

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION FOR AGGREGATE SUBBASE (CIP) (European Pavement)

a. **Description.**-This work shall consist of furnishing and placing an aggregate on a prepared subgrade in accordance with the details shown on the plans and as specified in Sections 2.08, 2.11, and 8.02 of the 1990 Standard Specifications with the exceptions and additions specified herein.

b. **Materials.**-The materials shall meet the requirements specified herein. The aggregate for the subbase shall be a natural aggregate meeting the following grading and physical requirements:

Grading Requirements

MI Series & Class	Sieve Analysis, Total Percent Passing 1-3/4"	1"	1/2"	#8	#30	%Loss by Washing
Euro-A1	100	65-95	40-65	20-42	8-30	7.0 Max.

Physical Requirements

MI Series & Class	Euro-A1
Crushed Material, min.	90%(*)
Loss, max., Los Angeles Abrasion (AASHTO T96)	45%

*The percentage of crushed material will be determined on that portion of the sample retained on all sieves down to and including the No. 4 sieve.

c. **Construction Methods.**-Prior to placing the aggregate subbase, the subgrade shall be prepared in accordance with Section 2.08.

The aggregate material shall be placed in accordance with Section 2.11, except as modified herein. The aggregate material shall be placed and compacted in two layers of approximately equal thickness. Each layer shall be compacted to not less than 100 percent of its maximum unit weight.

The surface of the Aggregate Subbase shall be finished to the specified grade and cross-section within a tolerance of ±3/4 inch. The finished surface shall be smooth and uniform in appearance, and be free of holes, depressions, ruts, and ridges.

d. **Testing and Acceptance.**-The material will be sampled and tested for gradation acceptance and physical requirements prior to placing and compacting. The Contractor shall make adequate allowance for degradation or segregation of the aggregate so that it will meet specification requirements after being compacted-in-place.

e. **Measurement and Payment.**-The completed work as measured for AGGREGATE SUBBASE (CIP) will be paid for at the contract unit price for the following contract item (pay item).

Pay Item	Pay Unit
Aggregate Subbase (CIP) (European Pavement)	Cubic Yard

Aggregate subbase (CIP) will be measured by area in cubic yards in place in accordance with the methods specified for measuring sand subbase in Subsection 2.11.04 of the 1990 Standard Specifications. Payment for the item Aggregate Subbase (CIP) includes payment for furnishing, placing, spreading, shaping, compacting, and maintaining the new aggregate material.

C/APPR/RVP/RGS 3-18-93

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION FOR FURNISHING PORTLAND CEMENT CONCRETE (QUALITY ASSURANCE)

a. **Description.**-This specification sets forth the requirements for furnishing portland cement concrete and the procedures that will be used for acceptance of the concrete product. All concrete furnished for pavements, structures (except prestressed concrete), and appurtenant highway items that are concrete will be governed by this specification. Provisions for furnishing concrete shall be in accordance with the appropriate sections of the 1990 Standard Specifications for Construction, except as modified herein. Latex modified concrete, concrete repair mixtures, concrete patching mixture, mortar, grout, and concrete grade 35HE are not covered by this specification. In cases where this Special Provision is in conflict with another Special Provision, this Special Provision will prevail.

b. **Mix Design Proportioning and Verification.**-It is the responsibility of the Contractor to provide a concrete mix design such that the specified temperature, slump, air-entrainment, and compressive strength of concrete will be attained.

b.1. **Mix Design Proportioning.**-The designs shall be computed and set up in accordance with ACI Standard 211.1 as applicable. The mix design basis for bulk volume, dry loose or dry rodded method, of coarse aggregate per unit volume of concrete shall be between 65 and 75 percent, inclusive. Dry loose or dry rodded unit weight of coarse aggregate shall be determined in accordance with ASTM C 29 shoveling procedure and rodding procedure, respectively. The material shall be dried before testing.

b.2. **Mix Design Verification.**-The Contractor shall submit mix designs for the various grades of concrete required to the Engineer for review, along with documentation indicating that the proposed mix design will meet the verification strength requirements listed in Table 1. Compressive strength of concrete at an age of seven days that equals or exceeds 90 percent of the verification strength listed in Table 1 will be considered an acceptable mix design. The documentation may be from past experience with the same materials and the same mix design, past experience with similar materials and a similar mix design, or from trial batches.

Mix design documentation using the same materials and the same mix design shall include traceable test results of compressive strength and air content.

Mix design documentation based on past experience with similar materials and similar mix design shall be restricted to changes of aggregate sources. Coarse aggregate sources will be allowed to be substituted provided the new source is within the same source type as the original aggregate, that is, natural gravel, quarried stone, and slag. Substitution of the fine aggregate source will be permitted. Proportions of the proposed mix design shall be adjusted based on the differences in specific gravity and absorption of the fine and coarse aggregate to produce a theoretical yield of 100 percent. This mix adjustment shall be done by an approved testing laboratory. Traceable test results of compressive strength and air content shall be included in the documentation for the original mix design, along with calculations showing how the mix proportions were adjusted.

Mix design documentation using trial batches shall be based on the same materials and proportions proposed for use on the project. Trial batches shall be prepared at least 30 days prior to the start of concrete placement. Tests on the trial batch shall be performed by an approved testing laboratory.

At the Department's option, verification may be done on an annual basis for a concrete plant rather than on a project-to-project basis provided the properties and proportions of the materials do not change. If the job is the continuation of work in progress during the previous construction season and written verification is submitted that the same source and character of materials are to be used, the Engineer may waive the requirement for the design and verification of previously approved mixes.

b.3. **Mix Designs Using Fly Ash.**-If fly ash is added to concrete, the restrictions cited in Subsection 7.01.04 of the Standard Specifications regarding the maximum weight of cement replaced by fly ash and the maximum substitution ratio do not apply. If the Contractor elects to use concrete containing a separate addition of fly ash, the Contractor shall provide a concrete mix design as described herein, except that fly ash shall not be greater than 30 percent of the cementitious material. The combined weight of fly ash and cement content shall be used to determine compliance with the cement factor and water-cement ratio requirements listed in Table 1.

b.4. **Laboratory Requirements.**-Private testing laboratory shall conform to ASTM C 1077 and must demonstrate that they are equipped, staffed, and managed so as to be capable of batching and testing portland cement concrete in accordance with the applicable ASTM/AASHTO methods of testing. A means of demonstrating such ability of the laboratory is by submission of a copy of their latest report of inspection by the Cement and Concrete Reference Laboratory, National Institute of Standards and Technology, along with a letter detailing the actions taken to correct any deficiencies noted therein.

b.5. **Review of Mix Designs.**-Each mix design shall be submitted on portland cement concrete mix design forms acceptable to the Department, giving the source of materials, specific gravity of constituents, aggregate absorption, dry weights used, dry loose or dry rodded unit weight of coarse aggregate (whichever one is used as basis for design), batch weights, and test data. The test data shall include compressive strength, concrete age at the time of strength testing, and air content. When trial batches are used, the test data shall also include the slump of the concrete and the compressive strength of at least two molded cylinders. The average strength of these cylinders must meet the verification strength requirements.

When mix design documentation is based on past experience with similar materials and similar mix design the above information shall be submitted for the original mix design and the proposed mix design, along with calculations showing how the mix proportions were adjusted to produce a theoretical yield of 100 percent.

b.6. **Changes in Materials and Proportions.**-Concrete furnished on the project shall conform to the approved mix design. If another previously approved mix design is to be used, the Engineer shall be notified prior to such change.

Changes in the sources, types, or proportions of materials shall not be made until the requirements for the verification strengths specified herein have been satisfied. Minor adjustments in the approved mix design proportions will be permitted in accordance with Section 7 of the Standard Specifications. The requirement to verify a new design as a result of a change in the type of portland cement may be waived only by the Engineer.

Concrete may be designed to achieve early strength requirements by increasing the cement content. Alternatively, an existing approved mix design may serve as a high-early-strength mix.

c. **Concrete Production.**-The Contractor shall provide quality control measures for the concrete in accordance with the Special Provision for Contractor Quality Control for Concrete.

d. **Acceptance Testing Procedures for Temperature, Slump, and Air-Entrainment.**-The Engineer will perform sampling and testing for temperature, slump, and air-entrainment.

Concrete temperature shall be in accordance with the Standard Specifications and is a basis of acceptance.

Slump and air-entrainment tests are at the rate specified for strength tests in Table 2 and are performed on the same samples of material from which the compressive test cylinders are molded. The Engineer may perform additional unscheduled slump and air-entrainment tests. These tests will be a basis of acceptance. While these tests are being performed, discharge from the truck is to be halted.

Concrete must pass temperature, slump, and air-entrainment tests before cylinders for strength tests are molded.

e. **General Acceptance Testing Requirements for Strength.**-The Contractor shall be responsible for sampling, molding, 28-day curing, and transporting the concrete cylinders for testing, under the observation and direction of the Engineer. The 28-day, fully cured concrete cylinders shall be transported to the District Testing Laboratory to which the project is assigned. These fully cured concrete cylinders shall be delivered to the Testing Laboratory 28 days after molding the specimens. Metal tags will be inserted a maximum of 1/2-inch into the top surface of the molded cylinders by the Engineer for identification purposes. The air content and slump of the concrete represented by the cylinders will be noted on these tags. Random sampling techniques will be used by the Engineer to determine the samples selected for testing. Any high early strength concrete used intermittently on a project shall not be included in the sampling of that grade of concrete to determine acceptance of a lot. High early strength concrete shall not be used for critical pay adjustment items unless written permision from the Engineer is received. The Engineer reserves the right to sample and test any high early strength concrete used on the project to determine acceptance of that concrete.

The Department will cap the fully cured concrete cylinders and perform the strength tests. Metal tags for identification will be clipped off the cylinders by the Department prior to strength testing. Results of the strength test, along with the recorded slump and air content, will be provided to the Contractor and concrete supplier.

Curing of concrete test cylinders for 28 days, as required by ASTM C31, shall be provided by the Contractor.

The Contractor shall furnish a sufficient number of 6-inch by 12-inch cylinder molds to permit making the number of test specimens required for the volume of concrete produced. A shortage of molds will result in a stoppage in the placement operations.

The Contractor shall be responsible for making additional cylinder or beam specimens required for form removal and opening to traffic strengths. Curing of these specimens shall be provided by the Contractor and shall be in the same environment as the concrete item that they represent. These work progress test specimens shall be tested by the Contractor on the project site and the testing shall be witnessed by the Engineer.

An initial strength test result is defined as the average of two 6-inch by 12-inch compression test cylinders, cured for 28 days in accordance with applicable ASTM Standards, and tested in the Department's Laboratory. The required rate of sampling and the acceptance testing criteria of Table 2 must be met. If a batch of concrete is rejected because it fails to meet the temperature, slump, or air-entrainment requirements of this specification, the cylinders for strength tests shall not be molded.

The Engineer may direct additional unscheduled compression cylinders to be taken. These cylinders will be included with the regularly scheduled compression cylinders and the lot will be evaluated on the basis of the increased number of tests.

f. **Acceptance Testing for Strength for Critical Pay-Adjustment Items.**-The list of critical concrete pay items that are subject to pay adjustment and their base prices may be found in the Special Provision for Pay Adjustments.

The amount of pay adjustment in dollars is the product of the item base price times the lot quantity times the percent pay adjustment. The percent pay adjustment is given by Equation (1).

Equation (1):

$$PPA = 2.0 - 0.2\ PD$$

In which

PPA = Percent Pay Adjustment
PD = Percent Defective (Estimate of percent of lot below the class design strength by the use of Equation (2) and Table 3

Equation (2):

$$Q = (\text{Average Lot Strength} - \text{Class Design Strength}) \div S$$

In which

Q = Quality index for pay adjustment computations
S = Standard deviation of the strength test results for the lot as computed by Equation (3)

Equation (3)

$$S = \left[\frac{\Sigma(Xi - ALS)^2}{(N - 1)} \right]^{1/2}$$

In which

Σ = Summation
Xi = Individual test result (Average strength of a test cylinder pair)
ALS = Average lot strength
N = Number of test results for the lot

NOTE - When only a single test result is available, the standard deviation is assumed to be S = 400 psi.

When it is necessary to estimate the percentage of material below the retest limit to check the rejection criteria in Table 2, Equation (4) is used with Table

3. All other terms are as previously defined.

Equation (4)

$$Q_{reject} = (\text{Average Lot Strength} - \text{Retest Limit}) \div S$$

Provided that no initial test result (average strength of two test cylinders) falls below the retest limit (psi) listed in Table 2, the acceptability of a lot is based upon the estimated percentage of concrete having a 28-day compressive strength less than the class design strength specified in Table 1. To be eligible for 100 percent payment, a lot must have no more than 10 percent of the material below the class design strength.

For lots with percent defective levels less than 10 percent, Equation (1) awards positive pay adjustments to be added to the contract price. For lots having percent defective levels greater than 10 percent (when the percent defective is determined using Equation (2) and class design strength) but not exceeding the rejection limit in Table 2 (when the percent defective is determined using Equation (4) and the retest limit), Equation (1) assesses pay adjustments to be subtracted from the contract price.

Whenever an initial test result falls below the retest limit in Table 2, the concrete will be re-evaluated by coring or non-destructive testing.

When re-evaluation is accomplished by a method other than coring, the results will be used only to determine what further action is to be taken. If any non-destructive test results are below the class design strength, the Engineer has the option to core. If this option is waived, the Contractor may elect to core, at no cost to the Department, or to accept the pay adjustment computed from the initial cylinder tests. If the Contractor elects to core, the coring shall be performed as directed and must be submitted to the Department within 45 days from the concrete placement. Cores shall not be taken within two feet of transverse joints, within two feet of longitudinal joints, or within two feet of free edges for critical pay-adjustment items, one-foot clearance in all other cases. The Department will test the cores. If none of the non-destructive test results is below the class design strength, the Engineer may elect either to core or to accept the lot at 100 percent payment.

When cores are taken, final disposition of the lot is based on the core results. Pay adjustment will be computed using the core test results provided that the percentage of material below the retest limit does not exceed the rejection limit percentage in Table 2. If this maximum allowable percentage is exceeded, the Engineer may:

(1) Require the Contractor to remove and replace the defective lot at no cost to the Department. New initial tests shall be obtained and the evaluation procedure repeated.

(2) Allow the Contractor to leave the defective lot in place and receive a percent pay adjustment (PPA) of minus 50 percent, or

(3) Allow the Contractor to submit a plan, for approval, for corrective action to be performed at no cost to the Department. If the plan for corrective action is not approved, either Option (1) or (2) may be applied.

g. **Acceptance Testing for Strength for Non-Critical Pay-Adjustment Items.**-This section applies to all other concrete items, which are subject to pay adjustment, not covered in Section (f), and that are not accepted on the basis of Certificates of Compliance. The lot is eligible for 100 percent payment provided that all initial test results equal or exceed the retest limit for non-critical pay-adjustment items in Table 2. Whenever one or more individual test results fall below the retest limit, the lot will be re-evaluated by coring or other suitable means and is subject to pay adjustment and all other provisions in accordance with Section (f), except that the amount of pay adjustment is the product of the unit bid price times the lot quantity times the percent pay adjustment given by Equation (1).

h. **Combined Pay Adjustments.**-When a contract price requires adjustment for reasons other than strength, the lot of concrete accepted based on strength requirements may have varying contract price adjustments (for other reasons) within that lot. The total pay adjustment for the item shall be calculated using the summation of the pay adjustments involved. The base price or unit bid price, whichever case applies, shall be used in determining the pay adjustment for strength.

i. **Sampling and Testing.**-Sampling and testing will be performed in accordance with the following:

ASTM
C29 Unit Weight and Voids in Aggregate
C31 Making and Curing Concrete Test Specimens in the Field
C39 Compressive Strength of Cylindrical Concrete Specimens
C42 Obtaining and Testing Drilled Cores and Sawed Beams of Concrete
C127 Specific Gravity and Absorption of Coarse Aggregate
C128 Specific Gravity and Absorption of Fine Aggregate
C138 Unit Weight, Yield and Air Content (Gravimetric) of Concrete
C143 Slump of Hydraulic Cement Concrete
C172 Sampling Freshly Mixed Concrete
C173 Air Content of Freshly Mixed Concrete by the Volumetric Method
C192 Making and Curing Concrete Test Specimens in the Laboratory
C231 Air Content of Freshly Mixed Concrete by the Pressure Method

The Department's established procedures for sampling are considered acceptable alternatives.

The Contractor's personnel performing designated sampling and testing shall be certified as a Concrete Technician Michigan Level I or II through a program certified by the Michigan Concrete Association. The Contractor shall furnish the name(s) of the concrete technician(s) to the Engineer prior to sampling and testing.

j. **Measurement and Payment.**-The completed work as measured for FURNISHING PORTLAND CEMENT CONCRETE (QUALITY ASSURANCE) will be paid for at the contract unit price for the following contract item (pay item).

Pay Item	**Pay Unit**
Concrete Quality Assurance Cylinders	Each

Payment for Concrete Quality Assurance Cylinders includes all the necessary materials, labor, and equipment necessary to furnish each fully cured concrete cylinder to the Department for acceptance testing. An initial strength test result consists of the average of two test cylinders, and will be paid for as two Concrete Quality Assurance Cylinders.

Separate payment will not be made for the work required to provide an acceptable concrete mix design, for providing work progress tests, or for providing and maintaining an effective concrete quality control program. These costs shall be considered included in the applicable unit price for the concrete item.

Table 1
Mix Design Requirements

	Grade of Concrete				
	45D	40S	35T	35P 35S	30P 30S
Class Design Strength (28 days, psi)	4500[1]	4000	3500	3500	3000
Verification Strength (28 days, psi)	5000	4500	4500	4000	3500
Maximum Water/Cement Ratio lb/lb	0.44	0.50	0.50	0.50	0.50
Minimum Cement Content lb/cy	650	600[2]	550[2]	550[2]	500[2]

Note 1 - Water reducing or water reducing retarding admixtures shall be used.

Note 2 - Cement content may be decreased by five percent if a water reducing or water reducing retarding admixture is used.

Table 2
Lot Sizes, Sampling Rates, Retest and Rejection Limits

	Grade of Concrete				
	45D	40S	35T	35P 35S	30P 30S
Lot Size, Maximum	One Day's Production				
Critical Pay-Adjustment Items					
Initial Sampling Rate	6/Lot	5/Lot	4/Lot	5/Lot	4/Lot
Retest Limit, psi	4000	3500	3000	3000	2500
Retest Sampling Rate, Min.	6/Lot	6/Lot	6/Lot	6/Lot	6/Lot
Rejection Limit, percent	10	10	10	10	15
Non-Critical Pay-Adjustment Items					
Initial Sampling Rate	3/Lot	3/Lot	3/Lot	3/Lot	3/Lot
Retest Limit, psi	4500	4000	3500	3500	3000

Note 1 - The lot sizes are maximums and, at the option of the Engineer, any lot may be subdivided into two or more smaller lots. When such a subdivision is made, the specified sampling rate applies to each of the smaller lots.

Note 2 - A retest result is defined as the strength of an individual test result obtained by coring or other suitable means.

Note 3 - The specified sampling rates shall apply except that no more than one test per truckload or batch of concrete will be required. At the option of the Engineer, lots consisting of fewer than three truckloads or batches, or containing 20 cubic yards or less, may be accepted without strength tests.

Note 4 - No lot shall include more than one grade of concrete, nor include concrete of the same grade having different specified levels of slump or air-entrainment, nor include concrete of the same grade having a different mix design.

Table 3
Estimation of Lot Percent Defective

Variability-Known Procedure — Standard Deviation Method

Sample Size
1

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	48.98	47.96	46.94	45.92	44.90	43.88	42.86	41.84	40.82
0.1	39.80	38.78	37.76	36.73	35.71	34.69	33.67	32.65	31.63	30.61
0.2	29.59	28.57	27.55	26.53	25.51	24.49	23.47	22.45	21.43	20.41
0.3	19.39	18.37	17.35	16.33	15.31	14.29	13.27	12.24	11.22	10.20
0.4	9.18	8.16	7.14	6.12	5.10	4.08	3.06	2.04	1.02	0.00

Note 1 - Numbers in the body of the table are estimates of lot percent defective corresponding to specific values of Q, the Quality Index. For values of Q greater than or equal to zero, the estimate of percent defective is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100.

Note 2 - This empirically derived table is suitable only for use with this specification.

Variability-Unknown Procedure — Standard Deviation Method

Sample Size
2

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.66	49.33	48.99	48.66	48.32	47.99	47.65	47.32	46.98
0.1	46.64	46.31	45.97	45.64	45.30	44.97	44.63	44.30	43.96	43.62
0.2	43.29	42.95	42.62	42.28	41.95	41.61	41.28	40.94	40.60	40.27
0.3	39.93	39.60	39.26	38.93	38.59	38.26	37.92	37.58	37.25	36.91
0.4	36.58	36.24	35.91	35.57	35.23	34.90	34.56	34.23	33.89	33.56
0.5	33.22	32.89	32.55	32.21	31.88	31.54	31.21	30.87	30.54	30.20
0.6	29.87	29.53	29.19	28.86	28.52	28.19	27.85	27.52	27.18	26.85
0.7	26.51	26.17	25.84	25.50	25.17	24.83	24.50	24.16	23.83	23.49
0.8	23.15	22.82	22.48	22.15	21.81	21.48	21.14	20.81	20.47	20.13
0.9	19.80	19.46	19.13	18.79	18.46	18.12	17.79	17.45	17.11	16.78
1.0	16.44	16.11	15.77	15.44	15.10	14.77	14.43	14.09	13.76	13.42
1.1	13.09	12.75	12.42	12.08	11.75	11.41	11.07	10.74	10.40	10.07
1.2	9.73	9.40	9.06	8.72	8.39	8.05	7.72	7.38	7.05	6.71
1.3	6.38	6.04	5.70	5.37	5.03	4.70	4.36	4.03	3.69	3.36
1.4	3.02	2.68	2.35	2.01	1.68	1.34	1.01	0.67	0.34	0.00

Note 1 - Numbers in the body of the table are estimates of lot percent defective corresponding to specific values of Q, the Quality Index. For values of Q greater than or equal to zero, the estimate of percent defective is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100.

Note 2 - This empirically derived table is suitable only for use with this specification.

Table 3 (Continued)

Variability-Unknown Procedure Standard Deviation Method

Sample Size
3

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.72	49.45	49.17	48.90	48.62	48.35	48.07	47.79	47.52
0.1	47.24	46.96	46.69	46.41	46.13	45.85	45.58	45.30	45.02	44.74
0.2	44.46	44.18	43.90	43.62	43.34	43.05	42.77	42.49	42.20	41.92
0.3	41.63	41.35	41.06	40.77	40.49	40.20	39.91	39.62	39.33	39.03
0.4	38.74	38.45	38.15	37.85	37.56	37.26	36.96	36.66	36.35	36.05
0.5	35.75	35.44	35.13	34.82	34.51	34.20	33.88	33.57	33.25	32.93
0.6	32.61	32.28	31.96	31.63	31.30	30.97	30.63	30.30	29.96	29.61
0.7	29.27	28.92	28.57	28.22	27.86	27.50	27.13	26.76	26.39	26.02
0.8	25.64	25.25	24.86	24.47	24.07	23.67	23.26	22.84	22.42	21.99
0.9	21.55	21.11	20.66	20.19	19.73	19.25	18.75	18.25	17.74	17.21
1.0	16.67	16.11	15.53	14.93	14.31	13.66	12.98	12.27	11.51	10.71
1.1	9.84	8.89	7.82	6.60	5.08	2.87	0.00	0.00	0.00	0.00

Note 1 - Numbers in the body of the table are estimates of lot percent defective corresponding to specific values of Q, the Quality Index. For values of Q greater than or equal to zero, the estimate of percent defective is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100.

Variability-Unknown Procedure Standard Deviation Method

Sample Size
4

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.67	49.33	49.00	48.67	48.33	48.00	47.67	47.33	47.00
0.1	46.67	46.33	46.00	45.67	45.33	45.00	44.67	44.33	44.00	43.67
0.2	43.33	43.00	42.67	42.33	42.00	41.67	41.33	41.00	40.67	40.33
0.3	40.00	39.67	39.33	39.00	38.67	38.33	38.00	37.67	37.33	37.00
0.4	36.67	36.33	36.00	35.67	35.33	35.00	34.67	34.33	34.00	33.67
0.5	33.33	33.00	32.67	32.33	32.00	31.67	31.33	31.00	30.67	30.33
0.6	30.00	29.67	29.33	29.00	28.67	28.33	28.00	27.67	27.33	27.00
0.7	26.67	26.33	26.00	25.67	25.33	25.00	24.67	24.33	24.00	23.67
0.8	23.33	23.00	22.67	22.33	22.00	21.67	21.33	21.00	20.67	20.33
0.9	20.00	19.67	19.33	19.00	18.67	18.33	18.00	17.67	17.33	17.00
1.0	16.67	16.33	16.00	15.67	15.33	15.00	14.67	14.33	14.00	13.67
1.1	13.33	13.00	12.67	12.33	12.00	11.67	11.33	11.00	10.67	10.33
1.2	10.00	9.67	9.33	9.00	8.67	8.33	8.00	7.67	7.33	7.00
1.3	6.67	6.33	6.00	5.67	5.33	5.00	4.67	4.33	4.00	3.67
1.4	3.33	3.00	2.67	2.33	2.00	1.67	1.33	1.00	0.67	0.33
1.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note 1 - Numbers in the body of the table are estimates of lot percent defective corresponding to specific values of Q, the Quality Index. For values of Q greater than or equal to zero, the estimate of percent defective is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100.

Table 3 (Continued)

Variability-Unknown Procedure Standard Deviation Method

Sample Size
5

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.64	49.29	48.93	48.58	48.22	47.86	47.51	47.15	46.80
0.1	46.44	46.09	45.73	45.38	45.02	44.67	44.31	43.96	43.60	43.25
0.2	42.90	42.54	42.19	41.84	41.48	41.13	40.78	40.43	40.08	39.72
0.3	39.37	39.02	38.67	38.32	37.97	37.62	37.28	36.93	36.58	36.23
0.4	35.88	35.54	35.19	34.85	34.50	34.16	33.81	33.47	33.12	32.78
0.5	32.44	32.10	31.76	31.42	31.08	30.74	30.40	30.06	29.73	29.39
0.6	29.05	28.72	28.39	28.05	27.72	27.39	27.06	26.73	26.40	26.07
0.7	25.74	25.41	25.09	24.76	24.44	24.11	23.79	23.47	23.15	22.83
0.8	22.51	22.19	21.87	21.56	21.24	20.93	20.62	20.31	20.00	19.69
0.9	19.38	19.07	18.77	18.46	18.16	17.86	17.55	17.25	16.96	16.66
1.0	16.36	16.07	15.78	15.48	15.19	14.91	14.62	14.33	14.05	13.76
1.1	13.48	13.20	12.93	12.65	12.37	12.10	11.83	11.56	11.29	11.02
1.2	10.76	10.50	10.23	9.97	9.72	9.46	9.21	8.96	8.71	8.46
1.3	8.21	7.97	7.73	7.49	7.25	7.02	6.79	6.56	6.33	6.10
1.4	5.88	5.66	5.44	5.23	5.02	4.81	4.60	4.39	4.19	3.99
1.5	3.80	3.61	3.42	3.23	3.05	2.87	2.69	2.52	2.35	2.19
1.6	2.03	1.87	1.72	1.57	1.42	1.28	1.15	1.02	0.89	0.77
1.7	0.66	0.55	0.45	0.36	0.27	0.19	0.12	0.06	0.02	0.00

Note 1 - Numbers in the body of the table are estimates of lot percent defective corresponding to specific values of Q, the Quality Index. For values of Q greater than or equal to zero, the estimate of percent defective is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100.

Table 3 (Continued)

Variability-Unknown Procedure Standard Deviation Method

Sample Size
6

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.63	49.27	48.90	48.53	48.16	47.80	47.43	47.06	46.70
0.1	46.33	45.96	45.60	45.23	44.86	44.50	44.13	43.77	43.40	43.04
0.2	42.68	42.31	41.95	41.59	41.22	40.86	40.50	40.14	39.78	39.42
0.3	39.06	38.70	38.34	37.98	37.62	37.27	36.91	36.55	36.20	35.84
0.4	35.49	35.14	34.79	34.43	34.08	33.73	33.38	33.04	32.69	32.34
0.5	32.00	31.65	31.31	30.96	30.62	30.28	29.94	29.60	29.26	28.93
0.6	28.59	28.25	27.92	27.59	27.26	26.92	26.60	26.27	25.94	25.61
0.7	25.29	24.96	24.64	24.32	24.00	23.68	23.37	23.05	22.74	22.42
0.8	22.11	21.80	21.49	21.18	20.88	20.57	20.27	19.97	19.67	19.37
0.9	19.07	18.78	18.49	18.19	17.90	17.61	17.33	17.04	16.76	16.48
1.0	16.20	15.92	15.64	15.37	15.09	14.82	14.55	14.29	14.02	13.76
1.1	13.50	13.24	12.98	12.72	12.47	12.22	11.97	11.72	11.47	11.23
1.2	10.99	10.75	10.51	10.28	10.04	9.81	9.58	9.36	9.13	8.91
1.3	8.69	8.48	8.26	8.05	7.84	7.63	7.42	7.22	7.02	6.82
1.4	6.63	6.43	6.24	6.05	5.87	5.68	5.50	5.33	5.15	4.98
1.5	4.81	4.64	4.47	4.31	4.15	4.00	3.84	3.69	3.54	3.40
1.6	3.25	3.11	2.97	2.84	2.71	2.58	2.45	2.33	2.21	2.09
1.7	1.98	1.87	1.76	1.66	1.55	1.45	1.36	1.27	1.18	1.09
1.8	1.01	0.93	0.85	0.78	0.71	0.64	0.57	0.51	0.46	0.40
1.9	0.35	0.30	0.26	0.22	0.18	0.15	0.12	0.09	0.07	0.05
2.0	0.03	0.02	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note 1 - Numbers in the body of the table are estimates of lot percent defective corresponding to specific values of Q, the Quality Index. For values of Q greater than or equal to zero, the estimate of percent defective is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100.

Table 3 (Continued)

Variability-Unknown Procedure | Standard Deviation Method

Sample Size
7

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.63	49.25	48.88	48.50	48.13	47.75	47.38	47.01	46.63
0.1	46.26	45.89	45.51	45.14	44.77	44.40	44.03	43.65	43.28	42.91
0.2	42.54	42.17	41.80	41.44	41.07	40.70	40.33	39.97	39.60	39.23
0.3	38.87	38.50	38.14	37.78	37.42	37.05	36.69	36.33	35.98	35.62
0.4	35.26	34.90	34.55	34.19	33.84	33.49	33.13	32.78	32.43	32.08
0.5	31.74	31.39	31.04	30.70	30.36	30.01	29.67	29.33	28.99	28.66
0.6	28.32	27.98	27.65	27.32	26.99	26.66	26.33	26.00	25.68	25.35
0.7	25.03	24.71	24.39	24.07	23.75	23.44	23.12	22.81	22.50	22.19
0.8	21.88	21.58	21.27	20.97	20.67	20.37	20.07	19.78	19.48	19.19
0.9	18.90	18.61	18.33	18.04	17.76	17.48	17.20	16.92	16.65	16.37
1.0	16.10	15.83	15.56	15.30	15.03	14.77	14.51	14.26	14.00	13.75
1.1	13.49	13.25	13.00	12.75	12.51	12.27	12.03	11.79	11.56	11.33
1.2	11.10	10.87	10.65	10.42	10.20	9.98	9.77	9.55	9.34	9.13
1.3	8.93	8.72	8.52	8.32	8.12	7.92	7.73	7.54	7.35	7.17
1.4	6.98	6.80	6.62	6.45	6.27	6.10	5.93	5.77	5.60	5.44
1.5	5.28	5.13	4.97	4.82	4.67	4.52	4.38	4.24	4.10	3.96
1.6	3.83	3.69	3.57	3.44	3.31	3.19	3.07	2.95	2.84	2.73
1.7	2.62	2.51	2.41	2.30	2.20	2.11	2.01	1.92	1.83	1.74
1.8	1.65	1.57	1.49	1.41	1.34	1.26	1.19	1.12	1.06	0.99
1.9	0.93	0.87	0.81	0.76	0.70	0.65	0.60	0.56	0.51	0.47
2.0	0.43	0.39	0.36	0.32	0.29	0.26	0.23	0.21	0.18	0.16
2.1	0.14	0.12	0.10	0.08	0.07	0.06	0.05	0.04	0.03	0.02
2.2	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note 1 - Numbers in the body of the table are estimates of lot percent defective corresponding to specific values of Q, the Quality Index. For values of Q greater than or equal to zero, the estimate of percent defective is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100.

Table 3 (Continued)

Variability-Unknown Procedure Standard Deviation Method

Sample Size
8

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.62	49.24	48.86	48.49	48.11	47.73	47.35	46.97	46.59
0.1	46.22	45.84	45.46	45.08	44.71	44.33	43.96	43.58	43.21	42.83
0.2	42.46	42.08	41.71	41.34	40.97	40.59	40.22	39.85	39.48	39.11
0.3	38.75	38.38	38.01	37.65	37.28	36.92	36.55	36.19	35.83	35.47
0.4	35.11	34.75	34.39	34.04	33.68	33.33	32.97	32.62	32.27	31.92
0.5	31.57	31.22	30.87	30.53	30.18	29.84	29.50	29.16	28.82	28.48
0.6	28.15	27.81	27.48	27.15	26.82	26.49	26.16	25.83	25.51	25.19
0.7	24.86	24.54	24.23	23.91	23.59	23.28	22.97	22.66	22.35	22.04
0.8	21.74	21.44	21.14	20.84	20.54	20.24	19.95	19.66	19.37	19.08
0.9	18.79	18.51	18.23	17.95	17.67	17.39	17.12	16.85	16.57	16.31
1.0	16.04	15.78	15.51	15.25	15.00	14.74	14.49	14.24	13.99	13.74
1.1	13.49	13.25	13.01	12.77	12.54	12.30	12.07	11.84	11.61	11.39
1.2	11.17	10.94	10.73	10.51	10.30	10.09	9.88	9.67	9.47	9.26
1.3	9.06	8.87	8.67	8.48	8.29	8.10	7.91	7.73	7.55	7.37
1.4	7.19	7.02	6.85	6.68	6.51	6.35	6.19	6.03	5.87	5.71
1.5	5.56	5.41	5.26	5.12	4.97	4.83	4.69	4.56	4.42	4.29
1.6	4.16	4.03	3.91	3.79	3.67	3.55	3.43	3.32	3.21	3.10
1.7	2.99	2.89	2.79	2.69	2.59	2.49	2.40	2.31	2.22	2.13
1.8	2.04	1.96	1.88	1.80	1.72	1.65	1.58	1.51	1.44	1.37
1.9	1.31	1.24	1.18	1.12	1.07	1.01	0.96	0.91	0.86	0.81
2.0	0.76	0.72	0.67	0.63	0.59	0.55	0.52	0.48	0.45	0.42
2.1	0.39	0.36	0.33	0.30	0.28	0.26	0.23	0.21	0.19	0.17
2.2	0.16	0.14	0.13	0.11	0.10	0.09	0.08	0.07	0.06	0.05
2.3	0.04	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.01	0.00

Note 1 - Numbers in the body of the table are estimates of lot percent defective corresponding to specific values of Q, the Quality Index. For values of Q greater than or equal to zero, the estimate of percent defective is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100.

Table 3 (Continued)

Variability-Unknown Procedure

Standard Deviation Method

Sample Size
9

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.62	49.24	48.85	48.47	48.09	47.71	47.33	46.95	46.57
0.1	46.18	45.80	45.42	45.04	44.66	44.29	43.91	43.53	43.15	42.77
0.2	42.40	42.02	41.64	41.27	40.89	40.52	40.15	39.77	39.40	39.03
0.3	38.66	38.29	37.92	37.55	37.19	36.82	36.46	36.09	35.73	35.37
0.4	35.00	34.64	34.29	33.93	33.57	33.21	32.86	32.51	32.15	31.80
0.5	31.45	31.10	30.76	30.41	30.07	29.72	29.38	29.04	28.70	28.36
0.6	28.03	27.69	27.36	27.03	26.70	26.37	26.04	25.72	25.39	25.07
0.7	24.75	24.43	24.11	23.80	23.49	23.17	22.86	22.56	22.25	21.94
0.8	21.64	21.34	21.04	20.75	20.45	20.16	19.87	19.58	19.29	19.00
0.9	18.72	18.44	18.16	17.88	17.61	17.33	17.06	16.79	16.53	16.26
1.0	16.00	15.74	15.48	15.23	14.97	14.72	14.47	14.22	13.98	13.73
1.1	13.49	13.26	13.02	12.79	12.55	12.32	12.10	11.87	11.65	11.43
1.2	11.21	10.99	10.78	10.57	10.36	10.15	9.95	9.75	9.55	9.35
1.3	9.16	8.96	8.77	8.59	8.40	8.22	8.04	7.86	7.68	7.51
1.4	7.33	7.17	7.00	6.83	6.67	6.51	6.35	6.20	6.04	5.89
1.5	5.74	5.60	5.45	5.31	5.17	5.03	4.90	4.77	4.64	4.51
1.6	4.38	4.26	4.14	4.02	3.90	3.78	3.67	3.56	3.45	3.34
1.7	3.24	3.14	3.03	2.94	2.84	2.75	2.65	2.56	2.47	2.39
1.8	2.30	2.22	2.14	2.06	1.98	1.91	1.84	1.76	1.70	1.63
1.9	1.56	1.50	1.44	1.37	1.32	1.26	1.20	1.15	1.10	1.05
2.0	1.00	0.95	0.90	0.86	0.82	0.77	0.73	0.70	0.66	0.62
2.1	0.59	0.55	0.52	0.49	0.46	0.43	0.41	0.38	0.36	0.33
2.2	0.31	0.29	0.27	0.25	0.23	0.21	0.20	0.18	0.17	0.15
2.3	0.14	0.13	0.11	0.10	0.09	0.08	0.08	0.07	0.06	0.05
2.4	0.05	0.04	0.04	0.03	0.03	0.02	0.02	0.02	0.01	0.01
2.5	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note 1 - Numbers in the body of the table are estimates of lot percent defective corresponding to specific values of Q, the Quality Index. For values of Q greater than or equal to zero, the estimate of percent defective is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100.

Table 3 (continued)

Variability-Unknown Procedure Standard Deviation Method

Sample Size
10

Q	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	50.00	49.62	49.23	48.85	48.46	48.08	47.70	47.31	46.93	46.54
0.1	46.16	45.78	45.40	45.01	44.63	44.25	43.87	43.49	43.11	42.73
0.2	42.35	41.97	41.60	41.22	40.84	40.47	40.09	39.72	39.34	38.97
0.3	38.60	38.23	37.86	37.49	37.12	36.75	36.38	36.02	35.65	35.29
0.4	34.93	34.57	34.21	33.85	33.49	33.13	32.78	32.42	32.07	31.72
0.5	31.37	31.02	30.67	30.32	29.98	29.64	29.29	28.95	28.61	28.28
0.6	27.94	27.60	27.27	26.94	26.61	26.28	25.96	25.63	25.31	24.99
0.7	24.67	24.35	24.03	23.72	23.41	23.10	22.79	22.48	22.18	21.87
0.8	21.57	21.27	20.98	20.68	20.39	20.10	19.81	19.52	19.23	18.95
0.9	18.67	18.39	18.11	17.84	17.56	17.29	17.03	16.76	16.49	16.23
1.0	15.97	15.72	15.46	15.21	14.96	14.71	14.46	14.22	13.97	13.73
1.1	13.50	13.26	13.03	12.80	12.57	12.34	12.12	11.90	11.68	11.46
1.2	11.24	11.03	10.82	10.61	10.41	10.21	10.00	9.81	9.61	9.42
1.3	9.22	9.03	8.85	8.66	8.48	8.30	8.12	7.95	7.77	7.60
1.4	7.44	7.27	7.10	6.94	6.78	6.63	6.47	6.32	6.17	6.02
1.5	5.87	5.73	5.59	5.45	5.31	5.18	5.05	4.92	4.79	4.66
1.6	4.54	4.41	4.30	4.18	4.06	3.95	3.84	3.73	3.62	3.52
1.7	3.41	3.31	3.21	3.11	3.02	2.93	2.83	2.74	2.66	2.57
1.8	2.49	2.40	2.32	2.25	2.17	2.09	2.02	1.95	1.88	1.81
1.9	1.75	1.68	1.62	1.56	1.50	1.44	1.38	1.33	1.27	1.22
2.0	1.17	1.12	1.07	1.03	0.98	0.94	0.90	0.86	0.82	0.78
2.1	0.74	0.71	0.67	0.64	0.61	0.58	0.55	0.52	0.49	0.46
2.2	0.44	0.41	0.39	0.37	0.34	0.32	0.30	0.29	0.27	0.25
2.3	0.23	0.22	0.20	0.19	0.18	0.16	0.15	0.14	0.13	0.12
2.4	0.11	0.10	0.09	0.08	0.08	0.07	0.06	0.06	0.05	0.05
2.5	0.04	0.04	0.03	0.03	0.03	0.02	0.02	0.02	0.01	0.01
2.6	0.01	0.01	0.01	0.01	0.01	0.00	0.00	0.00	0.00	0.00

Note 1 - Numbers in the body of the table are estimates of lot percent defective corresponding to specific values of Q, the Quality Index. For values of Q greater than or equal to zero, the estimate of percent defective is read directly from the table. For values of Q less than zero, the table value must be subtracted from 100.

C/APPR/RVP/RGS 2-4-93

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION FOR PAY ADJUSTMENTS

a. **Description.**-This specification sets forth the base price of critical concrete items as referenced in the Special Provision for Furnishing Portland Cement Concrete (Quality Assurance). This base price is used in determining the pay adjustment for these items.

b. **Base Prices.**-The following pay items and corresponding base price are critical pay-adjustment items:

Pay Item	Item Code Number	Unit	Base Price
Concrete Pavement Reinforced 11"	4500025	Syd	$ 16.00
Miscellaneous Concrete Pavement-Reinforced 9"	4500075	Syd	$ 22.00
Miscellaneous Concrete Pavement-Reinforced 10"	4500080	Syd	$ 24.00
Miscellaneous Concrete Pavement-Reinforced 11"	4500085	Syd	$ 26.00
Substructure Concrete	5030023	Cyd	$ 300.00
Superstructure Concrete	5030024	Cyd	$ 140.00
Two-Layer Concrete Pavement 10-inch Non-Reinforced (European Pavement)	4507001	Syd	$ 34.00
Miscellaneous Two-Layer Concrete Pavement 10-inch Non-Reinforced (European Pavement)	4507004	Syd	$ 44.00
Two-Layer Concrete Shoulder 10-inch Non-Reinforced (European Pavement)	4507002	Syd	$ 30.00
Lean Concrete Base 6-inch Non-Reinforced (European Pavement)	4507003	Syd	$ 12.00

C/APPR/RVP/RGS 2-9-93

METHOD OF TESTING CONCRETE FOR DURABILITY BY RAPID FREEZING IN AIR AND THAWING IN WATER

Michigan Test Method 115-90

1. SCOPE

1.1 This method describes the procedure for testing concrete beams to evaluate their durability in rapid freezing and thawing, specifically for the evaluation of coarse aggregate used in the concrete. The method uses concrete beam specimens prepared according to MTM 114 and describes the freeze-thaw cycling and evaluation of the beams by the length change (dilation) procedure. This method conforms to the general requirements of ASTM C 666, Procedure B.

2. APPLICABLE DOCUMENTS

2.1 ASTM Standards:

C 490 Specification for Apparatus for Use in Measurement of Length Change of Hardened Cement Paste, Mortar, and Concrete

C 666 Test Method for Resistance of Concrete to Rapid Freezing and Thawing

E 178 Practice for Dealing with Outlying Observations

2.2 MDOT Publications:

MTM 113 Method of Selection and Preparation of Coarse Aggregate Samples for Freeze-Thaw Testing

MTM 114 Method for Making Concrete Specimens for Freeze-Thaw Testing of Concrete Coarse Aggregate

3. APPARATUS

3.1 The equipment for freeze-thaw testing shall be as described in ASTM C 666, including an automatic freezing-and-thawing apparatus as necessary for testing by Procedure B (without specimen containers), temperature-measuring equipment, length change comparator, and tempering tank.

3.2 The length change comparator shall conform to the requirements of ASTM C 490, except that the comparator and reference bar shall be set for a nominal overall length of 16 inches (13.5-inch gage length). Dial gage micrometers for use on the length change comparator shall meet the graduation interval and accuracy requirements for C 490 for the inch calibration requirements. Prior to the start of measurements on any specimens, fix the comparator at an appropriate length to accommodate all of the specimens to be monitored for length change.

4. FREEZING-AND-THAWING CYCLE

4.1 The nominal freezing-and-thawing cycle for this method shall consist of alternately lowering the temperature of the specimens from 40 F to 0 F and raising it from 0 F to 40 F, within the

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NOTE: This method prepared by the Structural Services Unit, Testing Laboratory Section. Approved February 7, 1984. Revised and Re-approved November 23, 1987, June 8, 1989, and April 17, 1990.

temperature limitations of ASTM C 666. The nominal cycle length shall be 3 hours. Table 1 is a tabulation of temperature versus time that is achieved by MDOT equipment.

4.2 The thawing portion of the cycle may be extended when necessary in order to use the freeze-thaw chamber as a tempering tank while testing specimens.

5. TEST SPECIMENS

5.1 The specimens for use in this test shall be beams made and cured according to MTM 114. Three beams from each of 3 batches of concrete shall constitute a test, or a minimum of 7 beams (with no more than 1 damaged beam per batch) if there should be mechanical damage to specimens.

6. TEST PROCEDURE

6.1 Except as otherwise stated herein, all testing shall be according to ASTM C 666. So that the freezing-and-thawing apparatus works under constant load at all times, fill all spaces with either test beams, control beams, or dummy beams.

6.2 On the day prior to starting the beams in freeze-thaw, place them in a 40 F ± 1 F waterbath for approximately 16 hours before being placed in the machine and determine the initial length comparator reading for each specimen in accordance with ASTM C 490.

6.3 Start freezing-and-thawing tests by placing the specimens in the freeze-thaw apparatus during the thawing cycle. Remove the specimens approximately 24 hours after the start of freezing and thawing (approximately 8 cycles) and test for length change. Subsequently, test the specimens for length change twice weekly.

6.4 Continue freezing and thawing until the specimens have been exposed to 300 cycles, or until the length change reaches 0.100%, whichever occurs first. Determine the final length comparator reading of the specimen at the end point. For beams failing before 300 cycles (i.e., reaching 0.100% total dilation), use the number of cycles at that point to calculate dilation per 100 cycles. For beams tested to over 300 cycles (due to holidays or weekends, etc.), interpolate for total dilation at 300 cycles for the value to be used in calculating dilation per 100 cycles.

6.5 Record the values of length change, number of cycles, and location in the freeze-and-thaw apparatus on a worksheet as shown in Figure 1.

7. CALCULATIONS

7.1 Length Change - Calculate the length change in inches and in percent as indicated in Figure 1. At the end of test calculate the average expansion per 100 cycles as:

$$L_e = \frac{E' \times 100}{n}$$

where:

L_e = length change at end of test per 100 cycles, %

E' = total length change in percent

n = number of cycles at end of test

7.2 Outlier Tests - Evaluate any suspected outliers according to the methods of ASTM E 178 for possible elimination in the average length change calculations. See attached Annex A.1, Identification of Outliers in Freeze-Thaw Dilation Results, for proper application.

8. REPORT

8.1 Report the following data on the "Report of Test - Freeze-Thaw Durability in Concrete" as shown in Figure 2, for each beam and the average of the nine beams in the test (less any excluded according to 7.2, or due to mechanical damage) where indicated.

8.1.1 Expansion per 100 cycles in percent, individual values and average.

8.2 Combine the results of testing under this method with the results obtained under MTM 113 and 114 to provide a complete report on the aggregate being tested, as shown in Figure 2.

TABLE 1: TEMPERATURE VERSUS TIME CYCLING

Function	Time (Minutes)	Sample Tank Air/Water Temp (°F)	Beam (At Center) Temp (°F)
Start Cooling	0	+40	+40
	10	+8	+31
	20	+4	+25
	30	+3	+21
	40	+2	+17
	50	+1	+13
	60	0	+10
	70	0	+8
	80	0	+6
	90	0	+4
	100	0	+2
Stop Cooling	105	0	+1
	110	0	+0
Flood Sample Tank	112	(Air/Water Transition)	+0
	120	+34	+25
	130	+37	+33
	140	+39	+37
	150	+40	+39
	160	+40	+40
Empty Sample Tank	170	+40	+40
Start Cooling	180	+40	+40

Note: There is a ± 3°F tolerance band around the above temperature curves.

FREEZE-THAW DURABILITY EXPANSION WORKSHEET

LAB. NO. 87A 569-2-2 BEAM NO. 17

IDENTIFICATION: ABC Gravel Co. Pit No. 89-23

BATCH MADE: 6-11-87 STARTING DATE: 6-25-87

GAGE LENGTH: 13.5 inches
ALL MEASUREMENTS TO BE MADE AT 40°F (4°C)
COMPARATOR READING — REFERENCE BAR = 0.1900 (RR)

Date	Time	Number of Cycles (n)	Comparator Reading Specimen (RS)	Expansion (+) or Contraction (-) (E)	Percent Expansion (E')		Space Number
6/25	8:00	0	0.1733	—	—	↑	9
6/26	8:00	8	0.1737	0.0004	0.003	↓	23
6/30	8:00	40	0.1739	0.0006	0.004	↑	37
7/7	8:00	96	0.1739	0.0006	0.004	↓	50
7/10	8:00	120	0.1742	0.0009	0.007	↑	31
7/14	8:00	152	0.1739	0.0006	0.004	↓	4
7/17	8:00	176	0.1745	0.0012	0.009	↑	23
7/21	8:00	208	0.1742	0.0009	0.007	↓	21
7/24	8:00	232	0.1751	0.0018	0.013	↑	58
7/28	8:00	264	0.1752	0.0019	0.014	↓	28
7/31	8:00	288	0.1752	0.0019	0.014	↑	45
8/3	8:00	312	0.1760	0.0027	0.020	↓	—
						↑	
						↓	
—	—	300	—	—	0.017	↑	—
						↓	
						↑	
						↓	
						↑	
						↓	
						↑	

EXPANSION, in. (E) = RS_n - RS EXPANSION, % (E') = (E/13.5)100

LENGTH CHANGE, LC (per 100 cycles) = $\frac{E' \times 100}{\text{no. of cycles completed}}$

$$L_C = \frac{0.017 \times 100}{300} = 0.006\ \%$$

calculated by TW

checked by JS

Figure 1. Expansion Worksheet

ANNEX
(Mandatory Information)

A1 IDENTIFICATION OF OUTLIERS IN FREEZE-THAW DILATION RESULTS

A1.1 Identify outliers according to ASTM E 178. Type of outliers and method of analysis are as follows:

A1.1.1 Case A is the most common case where the smallest or the largest observation in the set of nine dilation values appears to be an outlier. Use the one-sided T test.

A1.1.2 Case B is the case where the two smallest or two largest observations appear to be outliers. Use the Grubbs test.

A1.1.3 Case C is the least frequent case where the smallest and the largest observation appear to be outliers. Use the Tietjen-Moore statistic.

Note A1.1 All three of these methods are explained in ASTM E 178.

A1.2 For Case A, use the critical value of 2.323 from Table 1 for n = 9 observations and an upper 1% significance level. If the suspected outlier is on the low end, T_1 is the comparison statistic while for the high end, T_9 is used. The smallest observation x_1 is an outlier provided that T_1 is greater than the critical value. The largest observation x_9 is an outlier if T_9 is greater than the critical value.

A1.3 For Case B, use the critical value of 0.1082 from Table 4 for n = 9 observations and an upper 1% significance level. The two smallest observations x_1 and x_2 are outliers if $S^2_{1,2}/S^2$ is less than the critical value. The two largest observations x_8 and x_9 are outliers if $S^2_{8,9}/S^2$ is less than the critical value.

A1.4 For Case C, use the critical value of 0.078 from Table 14 for n = 9, alpha = 0.01 as a comparison with the calculated E_2 value. The original smallest observation x_1 and largest observation x_9 are outliers provided E_2 is smaller than the critical value.

A1.5 The appropriate critical value must be applied for a given value of (n) observations. The number of observations may vary from n = 7 to n = 9. If, however, it is determined that less than seven observations remain after eliminating outliers, a new set of dilations will be determined from the same aggregate source.

A1.6 Several test reports have been analyzed. The attached worksheet (Figure A1.1) identifies the outliers and shows the resulting overall dilation results after excluding the verified outliers. This outlier test will be performed as part of the test report preparation by the Structural Services Unit. Some statistical judgment is required to determine which of the three cases characterizes the given data set in question and calculations may have to be made in more than one case. Calculations for the three cases above are performed by the Freeze-Thaw Dilation Program (FTD) in the Structural Services Unit.

REPORT OF TEST

Freeze-Thaw Durability In Concrete

Freeze-Thaw No.	87 FT-100
Job No.	General
Laboratory No.	87A-569
Date	August 4, 1987

Report on sample of: COARSE AGGREGATE (Gravel)
Date sampled: May 5, 1987 Date received: May 8, 1987
Source of material: ABC Gravel Company, Pit No. 89-23
Sampled from: Source Quantity represented:
Submitted by: J. Doakes, Eng. Tech.
Intended use: Portland Cement Concrete Specification: Grade 6A, 1984 Std. Specs.

PROPERTIES OF COARSE AGGREGATE

Bulk Specific Gravity (dry basis)	2.68	Deleterious Particles (gradation range)	1"-3/8"
		Soft Particles, %	0.7
Absorption, %		Chert, %	0.2
24-Hour Soak	1.59	Sum of Soft & Chert, %	0.9
Vacuum-Saturation	1.81		
Crushed Material in sample, %	76	Unit Weight of Agg. (dry, loose) lb/ft³	95
Los Angeles Abrasion, % of wear	24		

CONCRETE MIX DATA		BATCH NUMBER 1	2	3	Average
Date Made		6/9/87	6/11/87	6/16/87	
Slump, inches		2-1/2	2-1/2	3	2-3/4
Unit Weight of Concrete, lb/ft³		144.5	145.6	143.7	144.6
Actual Cement Content, lb/yd³		514	517	513	515
Water-Cement Ratio, by weight		0.46	0.45	0.44	0.45
Air Content, %		7.6	7.4	7.6	7.5
Compressive Strength, psi	7 days	3090	3400	3060	3180
	28 days	3960	4530	4140	4210
Freeze-Thaw Durability, Expansion per 100 cycles, %	Beam 1	0.012	0.004	0.010	
	Beam 2	0.015	0.006	0.003	
	Beam 3	0.013	0.003	0.005	
	Average	0.013	0.004	0.006	0.008

REMARKS: Tested for Information
Freeze-Thaw testing conducted in _____ machine.

Signed_______________________
Assistant Engineer of Testing

Figure 2 - Report of Test

OUTLIER WORKSHEET

DATE 8/15/88
FT# 88FT-53
A# 88A-4002

RAW DILATION DATA

BEAM	BATCH 1	BATCH 2	BATCH 3
1	.050	.052	.058
2	.046	.057	.093
3	.071	.044	.049

RANKED DATA: $X_1 < X_2 < \cdots < X_8 < X_9$

.044	.046	.049	.050	.052	.057	.058	.071	.093

CASE A,B OR C: A

$\bar{X}$ 0.058
s_X 0.015

A | T_1 . ; T_9 2.276 — $\not> 2.323 \therefore X_9$ IS NOT AN OUTLIER.

B | $s^2_{1,2}/s^2$. ; $s^2_{8,9}/s^2$. — < 0.1082

C | E_2 . — < 0.078

$\bar{X}$ 0.
s_X 0.
AFTER EXCLUDING VERIFIED OUTLIER(S)

(a)

OUTLIER WORKSHEET

DATE 8/15/88
FT# 88FT-54
A# 88A-4001

RAW DILATION DATA

BEAM	BATCH 1	BATCH 2	BATCH 3
1	.025	.105	.103
2	.088	.098	.105
3	.024	.103	.093

RANKED DATA: $X_1 < X_2 < \cdots < X_8 < X_9$

.024	.025	.088	.093	.098	.103	.103	.105	.105

CASE A,B OR C: B

$\bar{X}$ 0.083
s_X 0.033

A | T_1 . ; T_9 — > 2.323

B | $s^2_{1,2}/s^2$ 0.0282 ; $s^2_{8,9}/s^2$. — $< 0.1082 \therefore X_1$ & X_2 ARE OUTLIERS

C | E_2 . — < 0.078

$\bar{X}$ 0.099
s_X 0.007
AFTER EXCLUDING VERIFIED OUTLIER(S)

(b)

Figure A1.1 Calculations for outliers

TEST METHOD FOR DETERMINATION OF THE DRAINABILITY CHARACTERISTICS OF GRANULAR MATERIALS

Michigan Test Method 122-91

1. SCOPE

1.1 This test method describes the procedure used to determine the various drainability characteristics of granular materials including permeability, effective porosity, and drained percent saturation attained by gravity.

2. TERMINOLOGY

2.1 Permeability - The rate at which water can be conducted by a material.

2.2 Effective Porosity - The ratio of the volume of the voids of a soil mass that can be drained by gravity to the total volume of the mass.

2.3 Percent Saturation - The percent of voids in a compacted sample that are filled with water.

3. APPARATUS

3.1 A permeability test assembly as shown in Fig. 1 consisting of a test cylinder with a 4-inch inside diameter, 6 inches long, with top and bottom extensions, a rigid frame, and a test stand.

3.2 Compaction assembly as shown in Fig. 2 consisting of a permeability test cylinder, top retaining ring, and a bottom support plate.

3.3 Compaction equipment including a T-180 rammer, wood block, and strike off bar.

3.4 A 100-ml graduate, a 250-ml graduate, and two 250-ml beakers.

3.5 A stopwatch or electric timer.

3.6 A balance with 3000g capacity and accurate to the nearest 0.1g.

3.7 A Speedy moisture meter.

3.8 A standard Michigan sand cone and pounding block as described in the MDOT Density Control Handbook.

3.9 Miscellaneous hand tools, such as pans, scoops, spoons, and brushes.

NOTE: This method prepared by Pavement Technical Unit, Research Laboratory Section. Approved September 9, 1991.

4. SAMPLE

4.1 Obtain a representative sample of at least 50 lbs. If the material is above or near 100% saturation dry it until it becomes friable. Drying may be done in air or by use of a suitable drying apparatus, but the temperature of the sample should not exceed 140 F.

4.2 Sieve the entire sample over a 3/4-inch sieve, and discard the coarse material retained on the 3/4-inch sieve.

5. PROCEDURE

5.1 Determine the materials maximum density and optimum moisture content using the standard one-point Michigan Cone Test Method described in the MDOT Density Control Handbook. If these values have been determined in the field for density control, then the field values can be used.

5.2 Adjust the moisture content of the material to approximately 1 or 2 percent below optimum by air drying or adding water as needed. If water is added be sure to completely mix the sample to insure a uniform moisture content.

5.3 Place the compaction assembly on the wood pounding block provided with the Michigan cone equipment. The block must rest on a rigid foundation, such as a concrete cube weighing not less than 200 lbs., or on a concrete floor. Form a specimen by compacting the material in five equal layers to give a total compacted depth of about 6-1/2 inches. Compact each layer with 25 uniformly distributed blows from the 10 lb. T-180 rammer dropping free from a height of 18 inches above the elevation of the soil. Scarify the surface of each layer before placing the next layer. Half way through the compaction procedure determine the moisture content of the remaining material with a Speedy moisture meter and record results on the data sheet. Following compaction remove the extension collar and carefully trim the compacted soil even with the top of the mold by means of a straight edge. Remove the mold from the base plate, weigh to the nearest 0.1g., and record results on the data sheet. Determine the percent compaction of the molded specimen based on the one-point cone maximum density. The specimen must be between 95-100 percent compaction. If the specimen is outside of this range it must be remolded by first adjusting the moisture content and then increasing (higher density) or decreasing (lower density) the number of layers as required.

5.4 Place the molded specimen in the permeability test assembly and place assembly on the test stand.

5.5 Saturate the sample from the top by slowly flooding the surface of the sample with de-aired water taking care not to erode the surface. If de-aired water is not available draw a supply of hot tap water and allow it to sit at room temperature for at least 12 hours before using. Continue to increase the supply of water until the overflow outlet is reached, then adjust the supply until a constant amount of water overflow is maintained. The sample is saturated when discharge appears. If no discharge appears within 30 minutes, the material can be considered impermeable and the test can be discontinued.

5.6 Place a beaker under the sample and observe the discharge flow rate. When the discharge flow rate appears to be constant begin collecting the water at one minute intervals. Take at least three consecutive 1-minute readings of constant flow and record both the elapsed time and quantity of water for each time interval on the data sheet. The flow is considered constant if the individual values are within ±2 percent of the average value. If the quantity of water collected in one minute is less than 10cc then the time interval can be increased as needed and must be noted on the data sheet. If no water passes through the sample after 30 minutes it is considered essentially impermeable, the test is terminated, and it is so noted on the data sheet.

5.7 After all flow readings are taken, shut off the water supply, pour the excess water from the top of the sample, and allow the sample to gravity drain. When the length of time between drops of water coming out of the bottom of the sample is greater than one minute the sample is considered gravity drained. Immediately remove the sample from the mold and determine it's moisture content from a sample obtained from the middle of the specimen. Record this moisture content on the data sheet where indicated.

6. CALCULATIONS

Perform the following calculations and record the results on the data sheet where indicated.

6.1 Permeability, K (Ft/Day)

$$K = \frac{(Q_t)(L)}{(h)(A)(T_t)} \times C$$

Q_t = Total quantity of water measured, c.c.

L = Length of sample, Cm.

h = Head of water on sample, Cm.
(Measured from the overflow spout to the top of the porous stone)

A = Cross section area of sample, Cm^2.

T_t = Total time, min.

C = 47.24, conversion factor to change Cm/min to Ft/Day.

6.2 Volume of Solids, V_s

$$V_s = \frac{d}{G_s}$$

d = Dry density of test sample, g/cc

G_s = Specific gravity of test material
(Assumed to be 2.68 unless determined by testing to be otherwise.)

6.3 Volume of Water after Gravity Drained, V_w

$$V_w = d \times W_c$$

W_c = Gravity drained moisture content expressed as A decimal.

6.4 Volume of Voids, V_v

$$V_v = 1 - V_s$$

6.5 Gravity Drained Percent Saturation, % Sat.

$$\% \text{ Sat.} = \frac{V_w}{V_v} \times 100$$

6.6 Effective Porosity, N_e

$$N_e = 1 - V_s [(G_s \times W_e) + 1]$$

6.7 Permeability, Effective Porosity Ratio

$$\text{Ratio} = \frac{K}{N_e}$$

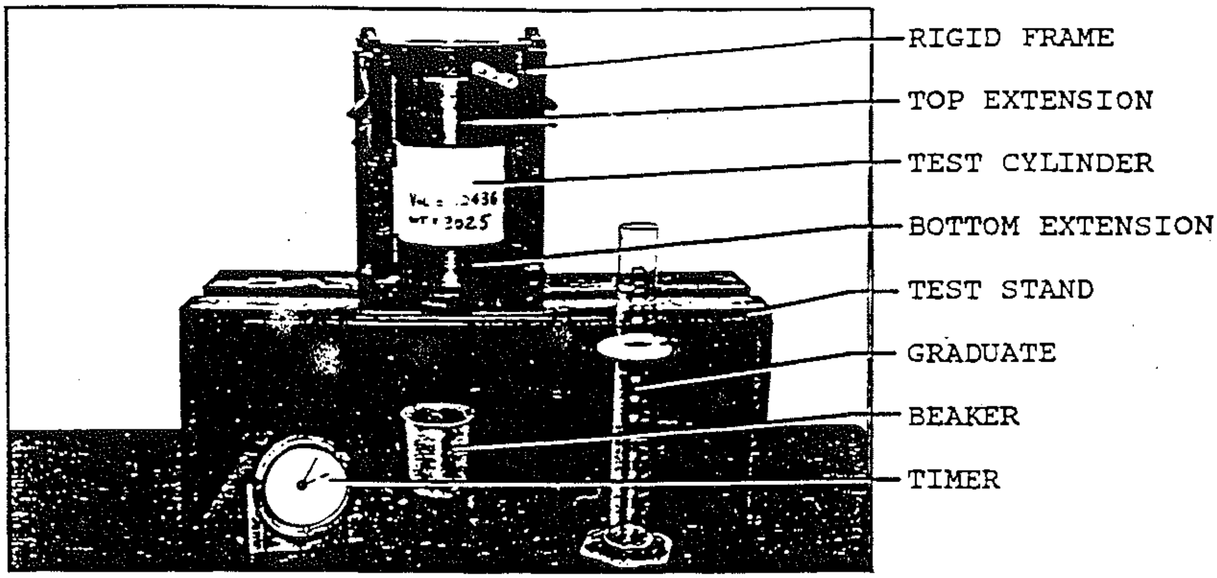

Figure 1. Permeability test assembly.

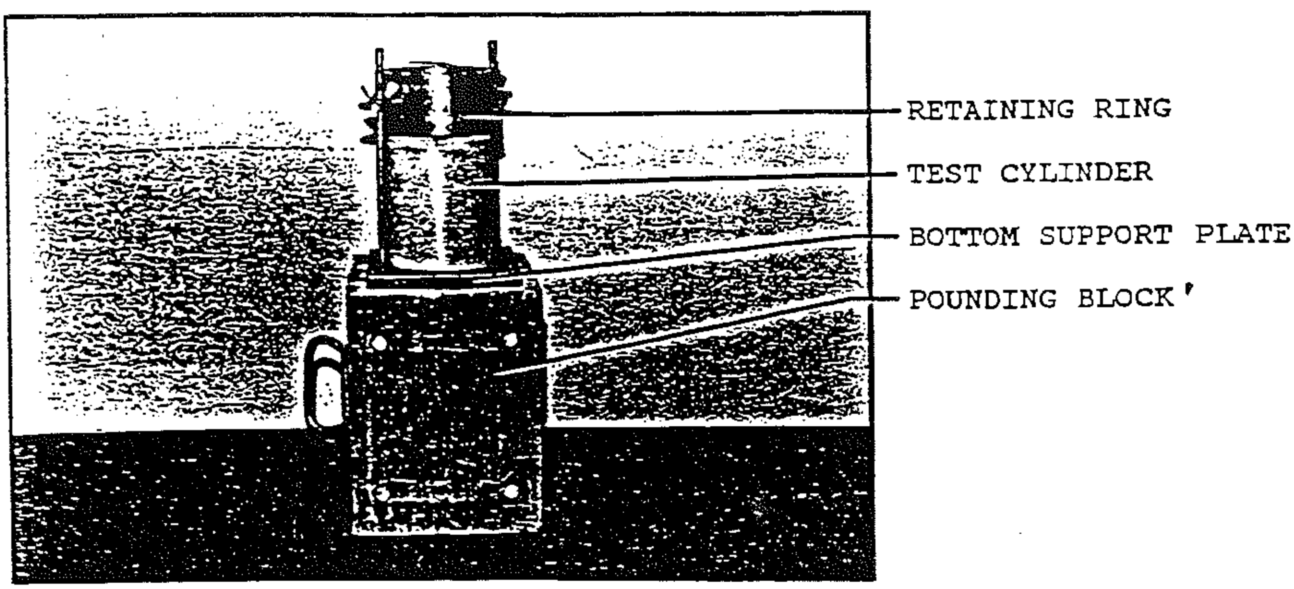

Figure 2. Permeability compaction assembly.

APPENDIX B

·1304 (1/89)
REPORT NO. 128

PROPOSAL 93-06083

SET 2
PAGE 1

TABULATION OF BIDS

hereby certify that this is a true and correct copy of the bids received, read, and tabulated for this project.

[signature]
Administrator, Financial Services

RECEIVED AT	LANSING	ON	JUNE 9 1993	AT	10:30 A.M.
WORK TYPE & LOCATION		FEDERAL PROJECT NO.	CONTROL	SECTION	JOB NO.
1.1 MILE OF CONCRETE PAV'T REPAIR, BIT RESURFACING & CUSHION WALL; 2.3 MILES OF CONCRETE RECONSTRUCTION, STORM SEWER, X-LEAD REPLACEMENT, SIGNING & LIGHTING REPLACEMENT, WEIGHT-IN MOTION DETECTION DEVICE INC 1.0 MILE OF EUROPEAN PAV'T SECT ON I-75 FROM I-375 NORTHERLY TO PIQUETTE AVE EUROPEAN SECT FROM WARREN AVE EXIT RAMP NORTHERLY TO SO OF PIQUETTE AVE (NB ONLY) AND ON I-375 FROM JEFFERSON AVE RAMP NORTHERLY TO THE FISHER FWY INTERCHANGE IN DETROIT, WAYNE COUNTY.		IM 75-1(420)	IM	82251	30613A
20% DBE 0% WBE		IM 75-1(420)	IM	82111	30614A

WORK ITEM DESCRIPTION	CODE	QUANTITY	TONY ANGELO CEMENT CONSTRUCTION COMPANY, NOVI MI 0520 UNIT PRICE	AMOUNT	CHAMPAGNE-WEBBER INC MICHIGAN, FRASER MI 0051 UNIT PRICE	AMOUNT	OTHER CONTRACTORS UNIT PRICE	AMOUNT
01							MIDWEST BRIDGE COMPANY	
REMOVING SEWER	2060006	4,465.00 LFT	8.8000	39,292.00	8.8000	39,292.00	19,383,866.40	
SEWER ABANDOMENT (SPECIAL) 12"	2067001	900.00 LFT	4.0000	3,600.00	4.0000	3,600.00		
REMOVING PAVEMENT	2070002	163,239.00 SYD	5.2000	848,842.80	6.2000	1012,081.80		
REMOVING CURB AND GUTTER	2070005	11,555.00 LFT	2.5000	28,887.50	2.5000	28,887.50		
REMOVING MASONRY AND CONCRETE STRUCTURES	2070007	310.00 CYD	40.2800	12,486.80	40.2800	12,486.80		
REMOVING BEAM GUARDRAIL	2070009	500.00 LFT	2.0000	1,000.00	3.0000	1,500.00		
REMOVING FENCE	2070012	300.00 LFT	1.5000	450.00	1.2000	360.00		
REMOVING DRAINAGE STRUCTURE	2070015	167.00 EACH	50.0000	8,350.00	50.0000	8,350.00		
ABANDONING DRAINAGE STRUCTURE	2070016	52.00 EACH	100.0000	5,200.00	100.0000	5,200.00		
REMOVING CONCRETE MEDIAN BARRIER WITH CONCRETE GLARE SCREEN	2077001	11,195.00 LFT	6.0000	67,170.00	6.0000	67,170.00		
REMOVING CONCRETE BARRIER SINGLE FACE	2077003	4,160.00 LFT	6.0000	24,960.00	6.0000	24,960.00		
REMOVING CONCRETE FILLET	2077005	4,355.00 LFT	2.0000	8,710.00	2.0000	8,710.00		
EARTH EXCAVATION	2080001	63,185.00 CYD	5.3000	334,880.50	5.3000	334,880.50		
STATION GRADING	2080015	221.00 STA	900.0000	198,900.00	900.0000	198,900.00		
EMBANKMENT (CIP)	2080021	500.00 CYD	3.0000	1,500.00	3.0000	1,500.00		
SUBGRADE UNDERCUTTING TYPE I	2080030	400.00 CYD	4.0000	1,600.00	4.0000	1,600.00		
SUBGRADE UNDERCUTTING TYPE II	2080031	1,600.00 CYD	13.0000	20,800.00	13.0000	20,800.00		
STRUCTURE BACKFILL (CIP)	2090005	6,325.00 CYD	11.7000	74,002.50	11.7000	74,002.50		
SUBBASE (CIP)	2110002	2,700.00 CYD	11.7000	31,590.00	11.7000	31,590.00		
SUBBASE (LM)	2110003	10,475.00 CYD	6.0000	62,850.00	6.0000	62,850.00		
AGGREGATE SUBBASE (CIP)	2117001	18,270.00 CYD	20.0000	365,400.00	20.0000	365,400.00		
SEDIMENT TRAP	2130002	26.00 EACH	100.0000	2,600.00	100.0000	2,600.00		
TEMPORARY PIPE	2130006	384.00 LFT	24.3000	9,331.20	24.3000	9,331.20		
SEDIMENT EXCAVATION - MAINTENANCE	2130014	75.00 CYD	1.0000	75.00	1.0000	75.00		
SILT FENCE	2130015	500.00 LFT	1.0000	500.00	1.0000	500.00		
OPEN-GRADED DRAINAGE COURSE, STABILIZED, 4" IN PLACE	3010040	132,020.00 SYD	3.8500	508,277.00	2.7500	363,055.00		
GEOTEXTILE SEPARATOR	3017001	149,487.00 SYD	1.2500	186,858.75	.7500	112,115.25		
OPEN GRADED DRAINAGE COURSE, STABILIZED, 8" IN PLACE	3017005	24,065.00 SYD	8.2500	198,536.25	5.6500	135,967.25		
REMOVING BITUMINOUS PATCHES	4000002	135.00 SYD	10.0000	1,350.00	10.0000	1,350.00		
COLD-MILLING BITUMINOUS SURFACE	4000004	460.00 TON	25.0000	11,500.00	25.0000	11,500.00		

1304 (1/89)
REPORT NO. 128

PROPOSAL 93-06083

SET 2
PAGE 2

TABULATION OF BIDS

RECEIVED AT LANSING	ON JUNE 9 1993 AT 10:30 A.M.
WORK TYPE & LOCATION	

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20% DBE 0% WBE

FEDERAL PROJECT NO.	CONTROL SECTION		JOB NO.
IM 75-1(420)	IM	82251	30613A
IM 75-1(420)	IM	82111	30614A

I hereby certify that this is a true and correct copy of the bids received, read, and tabulated for this project.

Administrator, Financial Services

WORK ITEM DESCRIPTION	CODE	QUANTITY	TONY ANGELO CEMENT CONSTRUCTION COMPANY, NOVI MI 0520 UNIT PRICE	AMOUNT	CHAMPAGNE-WEBBER INC MICHIGAN, FRASER MI 0051 UNIT PRICE	AMOUNT	OTHER CONTRACTORS UNIT PRICE	AMOUNT
01								
COLD MILLING BITUMINOUS SURFACE	4000005	350.00 SYD	10.0000	3,500.00	10.0000	3,500.00		
CHIPPING CONCRETE PAVEMENT FOR JOINTS	4000010	366.00 SYD	6.0000	2,196.00	6.0000	2,196.00		
LONGITUDINAL JOINT REPAIR	4000012	200.00 LFT	1.0000	200.00	1.0000	200.00		
HAND PATCHING	4000015	312.00 TON	50.0000	15,600.00	50.0000	15,600.00		
JOINT AND CRACK CLEANOUT	4000017	10,030.00 LFT	1.0000	10,030.00	1.0000	10,030.00		
REPAIRING PAVEMENT JOINTS AND CRACKS, DETAIL 7	4000020	8,130.00 LFT	.6000	4,878.00	.6000	4,878.00		
REPAIRING PAVEMENT JOINTS AND CRACKS, DETAIL 8	4000021	6,760.00 LFT	.6000	4,056.00	.6000	4,056.00		
BITUMINOUS MIXTURE - 11A	4000041	3,304.00 TON	31.5000	104,076.00	31.5000	104,076.00		
BITUMINOUS MIXTURE - 3B	4000046	5,568.00 TON	24.5000	136,416.00	24.5000	136,416.00		
BITUMINOUS MIXTURE - 4C	4000049	1,230.00 TON	36.4000	44,772.00	36.4000	44,772.00		
BITUMINOUS MIXTURE - 4C (MODIFIED)	4007003	3,890.00 TON	35.0000	136,150.00	35.0000	136,150.00		
QUALITY CONTROL TESTING	4007005	11,759.00 TON	.5000	5,879.50	.5000	5,879.50		
CONCRETE PAVEMENT - REINFORCED 11"	4500025	90,365.00 SYD	22.5000	2033,212.50	24.0000	2168,760.00		
MISCELLANEOUS CONCRETE PAVEMENT - REINFORCED 11"	4500085	7,930.00 SYD	26.0000	206,180.00	36.0000	285,480.00		
CONCRETE BASE COURSE - REINFORCED 10"	4500200	676.00 SYD	53.8500	36,402.60	31.0000	20,956.00		
CEMENT	4500250	43.00 TON	100.0000	4,300.00	65.0000	2,795.00		
CONCRETE SHOULDERS - REINFORCED	4500252	33,600.00 SYD	21.5000	722,400.00	36.0000	1209,600.00		
CONTRACTION JOINT C	4500270	21,200.00 LFT	6.2500	132,500.00	8.5000	180,200.00		
CONTRACTION JOINT C3	4500272	8,100.00 LFT	3.2500	26,325.00	5.6500	45,765.00		
EXPANSION JOINT E2	4500275	2,700.00 LFT	7.5000	20,250.00	9.2500	24,975.00		
EXPANSION JOINT E4	4500277	400.00 LFT	4.5000	1,800.00	5.5000	2,200.00		
EXTERNAL LONGITUDINAL PAVEMENT JOINT	4500290	42,000.00 LFT	1.0000	42,000.00	1.7000	71,400.00		
COLD-MILLING CONCRETE PAVEMENT	4500318	50.00 SYD	50.0000	2,500.00	20.0000	1,000.00		
PAVEMENT RIDING QUALITY	4500350	116,864.00 SYD	.7500	87,648.00	.7500	87,648.00		
PAVEMENT RIDING QUALITY MEASUREMENT	4500351	17.00 LNMI	250.0000	4,250.00	450.0000	7,650.00		
BUMP CUTTING	4500352	500.00 SYD	10.0000	5,000.00	30.0000	15,000.00		
TWO LAYER CONCRETE-10" NON-REINFORCED (EUROPEAN PAVEMENT)	4507001	23,525.00 SYD	34.0000	799,850.00	47.3000	1112,732.50		

1304 (1/88)
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PROPOSAL 93-06083

SET 2
PAGE 3

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[illegible]
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20% DBE 0% WBE

FEDERAL PROJECT NO.	CONTROL	SECTION	JOB NO.
IM 75-1(420)	IM	82251	30613A
IM 75-1(420)	IM	82111	30614A

WORK ITEM DESCRIPTION	CODE	QUANTITY	TONY ANGELO CEMENT CONSTRUCTION COMPANY, NOVI MI 0520 UNIT PRICE	AMOUNT	CHAMPAGNE-WEBBER INC MICHIGAN, FRASER MI 0051 UNIT PRICE	AMOUNT	OTHER CONTRACTORS UNIT PRICE	AMOUNT
01								
TWO LAYER CONCRETE SHOULDER-10" NON-REINFORCED (EUROPEAN PAVEMENT)	4507002	7,355.00 SYD	30.0000	220,650.00	24.0000	176,520.00		
LEAN CONCRETE BASE-6" NON-REINFORCED (EUROPEAN PAVEMENT)	4507003	32,915.00 SYD	12.0000	394,980.00	29.0000	954,535.00		
MISCELLANEOUS TWO LAYER CONCRETE PAVEMENT-10" NON-REINFORCED (EUROPEAN PAVEMENT)	4507004	2,205.00 SYD	44.0000	97,020.00	38.0000	83,700.00		
TRANSVERSE CONTRACTION JOINT (EUROPEAN PAVEMENT)	4507005	14,600.00 LFT	8.0000	116,800.00	8.0000	116,800.00		
LONGITUDINAL JOINT (EUROPEAN PAVEMENT)	4507006	18,500.00 LFT	3.1000	57,350.00	3.0000	55,500.00		
EXPOSED AGGREGATE SURFACE TREATMENT (EUROPEAN PAVEMENT)	4507007	23,525.00 SYD	12.0000	282,300.00	10.0000	235,250.00		
CONCRETE QUALITY ASSURANCE CYLINDERS	4507009	300.00 EACH	65.0000	19,500.00	25.0000	7,500.00		
MOVING FROM REPAIR TO REPAIR	4520001	238.00 EACH	1.0000	238.00	1.0000	238.00		
REMOVING PAVEMENT (REPAIR)	4520002	4,096.00 SYD	33.1500	135,782.40	33.1500	135,782.40		
INTERMEDIATE SAW CUTS	4520003	1,773.00 LFT	2.7000	4,787.10	2.7000	4,787.10		
CALCIUM CHLORIDE	4520030	1,700.00 LBS	.6000	1,020.00	.6000	1,020.00		
EXPANSION JOINT Er	4520036	48.00 LFT	8.4000	403.20	8.4000	403.20		
CONTRACTION JOINT Crg	4520039	4,080.00 LFT	5.1000	20,808.00	5.1000	20,808.00		
EXPANSION JOINT Erg	4520040	204.00 LFT	9.0000	1,836.00	9.0000	1,836.00		
TIED JOINT Trg	4520041	1,101.00 LFT	5.0000	5,505.00	5.0000	5,505.00		
LANE TIE, PAVEMENT REPAIR	4520045	216.00 EACH	5.0000	1,080.00	5.0000	1,080.00		
STEEL REINFORCEMENT, EPOXY COATED	5030031	3,580.00 LBS	1.4000	5,012.00	.6000	2,148.00		
HAND CHIPPING - OTHER THAN DECK	5090007	200.00 CFT	100.0000	20,000.00	50.0000	10,000.00		
PATCHING MORTAR OR CONCRETE	5090015	200.00 CFT	75.0000	15,000.00	25.0000	5,000.00		
FORMING FOR PATCHES	5090017	300.00 SFT	45.0000	13,500.00	15.0000	4,500.00		
EPOXY ANCHORED BOLT, 3/4"	5090037	84.00 EACH	7.0000	588.00	9.0000	756.00		
FILLER WALL CONCRETE	5090087	142.00 CYD	360.0000	51,120.00	500.0000	71,000.00		
CLASS C76-II SEWER, 12", TRENCH DETAIL B	5130249	8,003.00 LFT	35.0000	280,105.00	35.0000	280,105.00		
CLASS C76-II SEWER, 15", TRENCH DETAIL B	5130250	600.00 LFT	42.0000	25,200.00	42.0000	25,200.00		
CLASS C76-II SEWER, 18", TRENCH DETAIL B	5130251	200.00 LFT	43.0000	8,600.00	43.0000	8,600.00		

'1304 (1/89)
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SET 2
PAGE 4

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RECEIVED AT LANSING	ON JUNE 9 1993	AT 10:30 A.M.

WORK TYPE & LOCATION
1.1 MILE OF CONCRETE PAV'T REPAIR, BIT RESURFACING & CUSHION WALL; 2.3 MILES OF CONCRETE RECONSTRUCTION, STORM SEWER, X-LEAD REPLACEMENT, SIGNING & LIGHTING REPLACEMENT, WEIGHT-IN-MOTION DETECTION DEVICE INC 1.0 MILE OF EUROPEAN PAV'T SECT ON I-75 FROM I-375 NORTHERLY TO PIQUETTE AVE EUROPEAN SECT FROM WARREN AVE EXIT RAMP NORTHERLY TO SO OF PIQUETTE AVE (NB ONLY) AND ON I-375 FROM JEFFERSON AVE RAMP NORTHERLY TO THE FISHER FWY INTERCHANGE IN DETROIT, WAYNE COUNTY.
20% DBE 0% WBE

FEDERAL PROJECT NO.	CONTROL	SECTION	JOB NO.
IM 75-1(420)	IM	82251	30613A
IM 75-1(420)	IM	82111	30614A

Bidders: TONY ANGELO CEMENT CONSTRUCTION COMPANY, NOVI MI 0520; CHAMPAGNE-WEBBER INC MICHIGAN, FRASER MI Q051; OTHER CONTRACTORS

WORK ITEM DESCRIPTION	CODE	QUANTITY	Tony Angelo UNIT PRICE	Tony Angelo AMOUNT	Champagne-Webber UNIT PRICE	Champagne-Webber AMOUNT	Other UNIT PRICE	Other AMOUNT
01								
CLASS C76-II SEWER, 24", TRENCH DETAIL B	5130253	200.00 LFT	66.0000	13,200.00	66.0000	13,200.00		
CLASS C76-II SEWER, 30", TRENCH DETAIL B	5130255	200.00 LFT	75.0000	15,000.00	75.0000	15,000.00		
CLASS C76-II SEWER, 36", TRENCH DETAIL B	5130256	400.00 LFT	87.0000	34,800.00	87.0000	34,800.00		
CLASS C76-II SEWER, 42", TRENCH DETAIL B	5130257	20.00 LFT	95.0000	1,900.00	95.0000	1,900.00		
SEWER TAP, 6"	5130621	6.00 EACH	150.0000	900.00	150.0000	900.00		
SEWER BULKHEAD, 12"	5130655	124.00 EACH	40.0000	4,960.00	40.0000	4,960.00		
TRENCH UNDERCUT AND BACKFILL	5130700	100.00 CYD	15.0000	1,500.00	15.0000	1,500.00		
RESEALING SEWER JOINTS, OPEN CUT,12"	5137001	30.00 EACH	51.0000	1,530.00	51.0000	1,530.00		
RESEALING SEWER JOINTS, OPEN CUT,15"	5137003	50.00 EACH	51.0000	2,550.00	51.0000	2,550.00		
RESEALING SEWER JOINTS, OPEN CUT,18"	5137005	30.00 EACH	51.0000	1,530.00	51.0000	1,530.00		
RESEALING SEWER JOINTS, OPEN CUT,21"	5137007	30.00 EACH	69.0000	2,070.00	69.0000	2,070.00		
RESEALING SEWER JOINTS, OPEN CUT,24"	5137009	30.00 EACH	69.0000	2,070.00	69.0000	2,070.00		
RESEALING SEWER JOINTS, OPEN CUT,27"	5137011	30.00 EACH	69.0000	2,070.00	69.0000	2,070.00		
RESEALING SEWER JOINTS, OPEN CUT,30"	5137013	30.00 EACH	91.0000	2,730.00	91.0000	2,730.00		
RESEALING SEWER JOINTS, OPEN CUT,36"	5137015	50.00 EACH	93.0000	4,650.00	93.0000	4,650.00		
RESEALING SEWER JOINTS, OPEN CUT,42"	5137017	5.00 EACH	96.0000	480.00	96.0000	480.00		
CLASS C76-II SEWER, 21", TRENCH DETAIL B	5137019	200.00 LFT	61.0000	12,200.00	61.0000	12,200.00		
CLEANING CATCH BASIN LEADS	5137020	12,000.00 LFT	3.7400	44,880.00	3.7400	44,880.00		
CLASS C76-II SEWER, 27", TRENCH DETAIL B	5137021	200.00 LFT	66.0000	13,200.00	66.0000	13,200.00		
RESEALING SEWER JOINTS, CHEMICAL,12"	5137023	10.00 EACH	147.0000	1,470.00	147.0000	1,470.00		

·1304 (1/89)
REPORT NO. 128

PROPOSAL 93-06083

SET 2
PAGE 5

TABULATION OF BIDS

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20% DBE 0% WBE

FEDERAL PROJECT NO.	CONTROL	SECTION	JOB NO.
IM 75-1(420)	IM	82251	30613A
IM 75-1(420)	IM	82111	30614A

WORK ITEM DESCRIPTION	CODE	QUANTITY	TONY ANGELO CEMENT CONSTRUCTION COMPANY, NOVI MI 0520 — UNIT PRICE	AMOUNT	CHAMPAGNE-WEBBER INC MICHIGAN, FRASER MI 0051 — UNIT PRICE	AMOUNT	OTHER CONTRACTORS — UNIT PRICE	AMOUNT
01								
RESEALING SEWER JOINTS, CHEMICAL, 15"	5137026	20.00 EACH	149.0000	2,980.00	149.0000	2,980.00		
RESEALING SEWER JOINTS, CHEMICAL, 18"	5137027	10.00 EACH	154.0000	1,540.00	154.0000	1,540.00		
RESEALING SEWER JOINTS, CHEMICAL, 21"	5137029	10.00 EACH	159.0000	1,590.00	159.0000	1,590.00		
RESEALING SEWER JOINTS, CHEMICAL, 24"	5137031	10.00 EACH	163.0000	1,630.00	163.0000	1,630.00		
RESEALING SEWER JOINTS, CHEMICAL, 27"	5137033	10.00 EACH	167.0000	1,670.00	167.0000	1,670.00		
RESEALING SEWER JOINTS, CHEMICAL, 30"	5137035	10.00 EACH	171.0000	1,710.00	171.0000	1,710.00		
RESEALING SEWER JOINTS, CHEMICAL, 36"	5137037	20.00 EACH	175.0000	3,500.00	175.0000	3,500.00		
RESEALING SEWER JOINTS, CHEMICAL, 42"	5137039	4.00 EACH	192.0000	768.00	192.0000	768.00		
RELINING 12" SEWER, INVERSION PROCESS	5137041	100.00 LFT	54.0000	5,400.00	54.0000	5,400.00		
RELINING 15" SEWER, INVERSION PROCESS	5137043	200.00 LFT	75.0000	15,000.00	75.0000	15,000.00		
RELINING 18" SEWER, INVERSION PROCESS	5137045	100.00 LFT	96.0000	9,600.00	96.0000	9,600.00		
RELINING 21" SEWER, INVERSION PROCESS	5137047	100.00 LFT	117.0000	11,700.00	117.0000	11,700.00		
RELINING 24" SEWER, INVERSION PROCESS	5137049	100.00 LFT	138.0000	13,800.00	138.0000	13,800.00		
RELINING 27" SEWER, INVERSION PROCESS	5137051	100.00 LFT	159.0000	15,900.00	159.0000	15,900.00		
RELINING 30" SEWER, INVERSION PROCESS	5137053	100.00 LFT	180.0000	18,000.00	180.0000	18,000.00		
RELINING 36" SEWER, INVERSION PROCESS	5137055	200.00 LFT	222.0000	44,400.00	222.0000	44,400.00		
RELINING 42" SEWER, INVERSION PROCESS	5137057	10.00 LFT	265.0000	2,650.00	265.0000	2,650.00		
DRAINAGE STRUCTURE, 4' DIAMETER	5140001	149.00 EACH	840.0000	125,160.00	840.0000	125,160.00		

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IM 75-1(420)	IM	82111	30614A

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01								
DRAINAGE STRUCTURE, 2' DIAMETER	5140005	120.00 EACH	550.0000	66,000.00	550.0000	66,000.00		
DRAINAGE STRUCTURE COVER	5140042	206,645.00 LBS	.5500	113,654.75	.5500	113,654.75		
ADJUSTING DRAINAGE STRUCTURE COVER, CASE 1	5140045	130.00 EACH	462.0000	60,060.00	462.0000	60,060.00		
RECONSTRUCTING DRAINAGE STRUCTURE, CASE 1	5140047	62.00 FT	350.0000	21,700.00	350.0000	21,700.00		
RECONSTRUCTING DRAINAGE STRUCTURES - SPECIAL CASE 1	5147001	28.00 EACH	770.0000	21,560.00	770.0000	21,560.00		
DRAINAGE STRUCTURE RECONSTRUCTION (SPECIAL), CASE 2	5147003	20.00 EACH	660.0000	13,200.00	660.0000	13,200.00		
CLEANING PUMPHOUSE WETWELLS	5147005	4.00 EACH	2000.0000	8,000.00	2000.0000	8,000.00		
RECONSTRUCTING DRAINAGE STRUCTURE COVER, CASE 1, (SPECIAL)	5147007	50.00 EACH	650.0000	32,500.00	650.0000	32,500.00		
CLEANING CATCH BASINS	5147010	145.00 EACH	74.0000	10,730.00	74.0000	10,730.00		
COVERS FOR EXISTING CATCH BASIN	5147011	48.00 EACH	250.0000	12,000.00	250.0000	12,000.00		
SLOTTED DRAIN	5147012	655.00 LFT	50.0000	32,750.00	50.0000	32,750.00		
ADJUSTING DRAINAGE STRUCTURE COVER, CASE 1 (SPECIAL)	5147013	16.00 EACH	295.0000	4,720.00	295.0000	4,720.00		
SLOPE PAVING, CONCRETE	6010003	1,350.00 SYD	25.0000	33,750.00	18.0000	24,300.00		
SUBBASE UNDERDRAIN, 6"	6020051	900.00 LFT	7.7500	6,975.00	2.7000	2,430.00		
OPEN-GRADED UNDERDRAIN PIPE, 4"	6020060	10,010.00 LFT	4.1500	41,541.50	2.7900	27,927.90		
OPEN-GRADED UNDERDRAIN PIPE, 6"	6020061	52,450.00 LFT	5.5000	288,475.00	2.9900	156,825.50		
FOUNDATION UNDERDRAIN, 4"	6020120	16,670.00 LFT	1.8000	30,006.00	1.8000	30,006.00		
UNDERDRAIN OUTLET, 6"	6020137	150.00 LFT	10.0000	1,500.00	7.1500	1,072.50		
CONCRETE CURB AND GUTTER, DETAIL B3	6090019	5,580.00 LFT	10.5000	58,590.00	10.3000	57,474.00		
CONCRETE CURB AND GUTTER, DETAIL D3	6090031	540.00 LFT	11.0000	5,940.00	10.3000	5,562.00		
CONCRETE VALLEY GUTTER	6090036	22,835.00 LFT	8.7500	199,806.25	6.1000	139,293.50		
CONCRETE VALLEY GUTTER SPECIAL	6097001	13,075.00 LFT	13.0000	169,975.00	7.9000	103,292.50		
VALLEY GUTTER CONCRETE MODIFIED	6097003	6,765.00 LFT	10.7500	72,723.75	6.7000	45,325.50		
VALLEY GUTTER CONCRETE MODIFIED SPECIAL	6097005	2,975.00 LFT	15.0000	44,625.00	9.5000	28,262.50		
CONCRETE SIDEWALK, 4"	6110002	7,005.00 SFT	2.7500	19,263.75	3.3000	23,116.50		
CONCRETE BARRIER - SINGLE FACE, TYPE B	6120002	19,015.00 LFT	16.7500	318,501.25	10.5000	199,657.50		
CONCRETE BARRIER-SINGLE FACE, TYPE C	6120003	770.00 LFT	28.0000	21,560.00	40.0000	30,800.00		

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01								
CONCRETE BARRIER - DOUBLE FACE, TYPE A	6120005	8,185.00 LFT	22.2500	182,116.25	16.0000	130,960.00		
CONCRETE BARRIER - SPLIT, TYPE A	6120009	3,130.00 LFT	53.0000	165,890.00	32.0000	100,160.00		
CONCRETE BARRIER - SPECIAL	6120013	1,240.00 LFT	35.0000	43,400.00	30.0000	37,200.00		
LIGHT STANDARD FOUNDATION - CB	6120020	31.00 EACH	1900.0000	58,900.00	2500.0000	77,500.00		
GLARE SCREEN - CONCRETE	6120022	9,285.00 LFT	5.7500	53,388.75	7.0000	64,995.00		
GLARE SCREEN, CONCRETE - SPLIT	6120023	3,130.00 LFT	17.2500	53,992.50	7.0000	21,910.00		
SIGN SUPPORT FOUNDATION - CB, TRUSS TYPE C	6120026	2.00 EACH	8900.0000	17,800.00	3600.0000	7,200.00		
CONCRETE BARRIER BACKFILL (CIP)	6120035	1,570.00 CYD	12.2500	19,232.50	18.2500	28,652.50		
CONCRETE BARRIER SINGLE FACE SPECIAL	6127001	140.00 LFT	35.0000	4,900.00	30.0000	4,200.00		
INSTALL IMPACT ATTENUATOR	6127005	4.00 EACH	3500.0000	14,000.00	3500.0000	14,000.00		
REMOVE IMPACT ATTENUATOR	6127007	4.00 EACH	1900.0000	7,600.00	1900.0000	7,600.00		
REMOVE ATTENUATOR PAD	6127008	5.00 CYD	495.0000	2,475.00	495.0000	2,475.00		
SAND MODULE IMPACT ATTENUATOR (TEMPORARY)	6127013	48.00 EACH	495.0000	23,760.00	495.0000	23,760.00		
SAND MODULE IMPACT ATTENUATOR (RELOCATE)	6127015	12.00 EACH	195.0000	2,340.00	195.0000	2,340.00		
SAND MODULE IMPACT ATTENUATOR (REPLACEMENT)	6127017	12.00 EACH	495.0000	5,940.00	495.0000	5,940.00		
GREAT ATTENUATOR (8 BAYS) FURNISHED	6127019	3.00 EACH	35550.0000	106,650.00	35550.0000	106,650.00		
CHAIN LINK FENCE, 48"	6210011	500.00 LFT	5.2500	2,625.00	13.0000	6,500.00		
GATE, 12', FOR CHAIN LINK FENCE, 48"	6210047	19.00 EACH	500.0000	9,500.00	500.0000	9,500.00		
FIELD OFFICE	6220001	18.00 MOS	1000.0000	18,000.00	500.0000	9,000.00		
OVERHEAD TRUSS, TYPE C, 50'	6260016	2.00 EACH	27637.0000	55,274.00	27635.0000	55,270.00		
TRUSS FOUNDATION, TYPE C	6260028	4.00 EACH	5600.0000	22,400.00	5600.0000	22,400.00		
TRUSS FOUNDATION, TYPE D	6260035	2.00 EACH	5800.0000	11,600.00	5800.0000	11,600.00		
CANTILEVER, TYPE H	6260078	5.00 EACH	19000.0000	95,000.00	18000.0000	95,000.00		
CANTILEVER FOUNDATION, TYPE H-3	6260081	5.00 EACH	7900.0000	39,500.00	7900.0000	39,500.00		
WOOD POST, 4" X 6"	6260106	150.00 LFT	21.0000	3,150.00	21.0000	3,150.00		
WOOD POST, 6" X 8"	6260107	40.00 LFT	25.0000	1,000.00	25.0000	1,000.00		
SIGN, TYPE IA	6260114	6,969.00 SFT	18.0000	125,442.00	18.0000	125,442.00		
SIGN, TYPE IIA	6260115	509.00 SFT	14.5000	7,380.50	14.5000	7,380.50		

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SET 2
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01								
SIGN, TYPE IIIA	6260116	33.00 SFT	10.5000	346.50	10.5000	346.50		
SIGN, TYPE IB	6260118	821.00 SFT	16.7500	13,751.75	16.7500	13,751.75		
SIGN, TYPE IIB	6260119	272.00 SFT	14.5000	3,944.00	14.5000	3,944.00		
SIGN, TYPE IIIB	6260120	37.00 SFT	9.5000	351.50	9.5000	351.50		
BRIDGE CONNECTION, TYPE A	6260130	22.00 EACH	425.0000	9,350.00	425.0000	9,350.00		
BRIDGE CONNECTION, TYPE C	6260132	5.00 EACH	950.0000	4,750.00	950.0000	4,750.00		
REMOVAL OF SIGN, TYPE I	6260150	54.00 EACH	125.0000	6,750.00	125.0000	6,750.00		
REMOVAL OF SIGN, TYPE II	6260151	32.00 EACH	15.0000	480.00	15.0000	480.00		
REMOVAL OF SIGN, TYPE III	6260152	12.00 EACH	5.0000	60.00	5.0000	60.00		
REMOVAL OF WOOD SUPPORT FOUNDATION	6260159	6.00 EACH	75.0000	450.00	75.0000	450.00		
REMOVAL OF CANTILEVER FOUNDATION	6260161	4.00 EACH	1500.0000	6,000.00	1500.0000	6,000.00		
REMOVAL OF TRUSS FOUNDATION	6260162	10.00 EACH	1250.0000	12,500.00	1250.0000	12,500.00		
REMOVAL OF CANTILEVER	6260163	4.00 EACH	1000.0000	4,000.00	1000.0000	4,000.00		
REMOVAL OF TRUSS	6260170	5.00 EACH	1200.0000	6,000.00	1200.0000	6,000.00		
REMOVAL OF BRIDGE CONNECTION, TYPE A	6260180	16.00 EACH	150.0000	2,400.00	150.0000	2,400.00		
REMOVAL OF BRIDGE CONNECTION, TYPE C	6260182	4.00 EACH	450.0000	1,800.00	450.0000	1,800.00		
BOLT REPLACEMENT IN BRIDGE CONNECTIONS	6267007	58.00 EACH	200.0000	11,600.00	200.0000	11,600.00		
THERMOPLASTIC PAVEMENT MARKING, 4", WHITE	6290212	15,940.00 LFT	.6500	10,361.00	.6500	10,361.00		
THERMOPLASTIC PAVEMENT MARKING, 4", YELLOW	6290213	14,040.00 LFT	.6500	9,126.00	.6500	9,126.00		
THERMOPLASTIC PAVEMENT MARKING, 12", YELLOW	6290216	2,800.00 LFT	2.7500	7,700.00	2.7500	7,700.00		
THERMOPLASTIC PAVEMENT MARKING, 12", WHITE	6290217	6,900.00 LFT	2.7500	18,975.00	2.7500	18,975.00		
REMOVING CURING COMPOUND, LONGITUDINAL MARKINGS	6290300	69,000.00 LFT	.3500	24,150.00	.3500	24,150.00		
OVERLAY COLD PLASTIC PAVEMENT MARKING, 4", WHITE	6290350	41,600.00 LFT	1.5500	64,480.00	1.5500	64,480.00		
OVERLAY COLD PLASTIC PAVEMENT MARKING, 4", YELLOW	6290351	23,300.00 LFT	1.5500	36,115.00	1.5500	36,115.00		
OVERLAY COLD PLASTIC PAVEMENT MARKING, 12", WHITE	6290356	4,160.00 LFT	5.2500	21,840.00	5.2500	21,840.00		

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IM 75-1(420)	IM	82111	30614A

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01								
LIGHTED ARROW, TYPE A - FURNISHED	6310011	21.00 EACH	1400.0000	29,400.00	10.0000	210.00		
LIGHTED ARROW, TYPE A - OPERATED	6310012	11.00 EACH	2710.0000	29,810.00	600.0000	5,500.00		
BARRICADE, TYPE II, LIGHTED - FURNISHED	6310026	675.00 EACH	35.0000	23,625.00	35.0000	23,625.00		
BARRICADE, TYPE II, LIGHTED - OPERATED	6310027	430.00 EACH	70.0000	30,100.00	70.0000	30,100.00		
BARRICADE, TYPE III, LIGHTED - FURNISHED	6310036	115.00 EACH	100.0000	11,500.00	100.0000	11,500.00		
BARRICADE, TYPE III, LIGHTED - OPERATED	6310037	70.00 EACH	250.0000	17,500.00	250.0000	17,500.00		
VEHICLE MOUNTED ATTENUATOR - FURNISHED	6310038	2.00 EACH	14850.0000	29,700.00	4000.0000	8,000.00		
VEHICLE MOUNTED ATTENUATOR - OPERATED	6310039	2.00 EACH	5000.0000	10,000.00	2000.0000	4,000.00		
TEMPORARY CONCRETE BARRIER	6310049	23,000.00 LFT	18.2500	419,750.00	10.0000	230,000.00		
SIGN, TYPE A TEMPORARY	6310056	250.00 SFT	25.0000	6,250.00	25.0000	6,250.00		
SIGN, TYPE B TEMPORARY	6310057	3,070.00 SFT	12.0000	36,840.00	12.0000	36,840.00		
TEMPORARY PAVEMENT MARKING, TYPE R, 4", WHITE	6310085	23,200.00 LFT	1.5500	35,960.00	1.8000	41,760.00		
TEMPORARY PAVEMENT MARKING, TYPE R, 4", YELLOW	6310086	30,650.00 LFT	1.5500	47,507.50	1.8000	55,170.00		
TEMPORARY PAVEMENT MARKING, TYPE NR, TAPE, 4", WHITE	6310087	450.00 LFT	.4500	202.50	.3000	135.00		
TEMPORARY PAVEMENT MARKING, TYPE NR, TAPE, 4", YELLOW	6310088	15,050.00 LFT	.4500	6,772.50	.3000	4,515.00		
REMOVING PAVEMENT MARKING, LONGITUDINAL	6310139	41,750.00 LFT	.7500	31,312.50	.9000	37,575.00		
SIGN, TYPE B TEMPORARY, SPECIAL	6317001	4,800.00 SFT	29.7500	142,800.00	35.0000	168,000.00		
FURNISH AND INSTALL VERTICAL PANEL	6317007	650.00 EACH	12.5000	8,125.00	25.0000	16,250.00		
BARRIER REFLECTOR	6317009	75.00 EACH	10.0000	750.00	10.0000	750.00		
WATER	6530003	100.00 UNIT	60.0000	6,000.00	60.0000	6,000.00		
CHEMICAL FERTILIZER NUTRIENT	6530010	1,700.00 LBS	.6200	1,054.00	.6200	1,054.00		
TOPSOIL SURFACE, 5"	6530016	32,760.00 SYD	1.0000	32,760.00	1.0000	32,760.00		
ROADSIDE SEEDING - MODIFIED	6530035	2,725.00 LBS	2.7000	7,357.50	2.7000	7,357.50		
MULCH BLANKETS	6530037	32,760.00 SYD	.9000	29,484.00	.9000	29,484.00		

ON JUNE 9 1993 AT 10:30 A.M.

TABULATION OF BIDS

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WORK TYPE & LOCATION
1.1 MILE OF CONCRETE PAV'T REPAIR, BIT RESURFACING & CUSHION WALL; 2.3 MILES OF CONCRETE RECONSTRUCTION, STORM SEWER, X-LEAD REPLACEMENT, SIGNING & LIGHTING REPLACEMENT, WEIGHT-IN-MOTION DETECTION DEVICE INC 1.0 MILE OF EUROPEAN PAV'T SECT ON I-75 FROM I-375 NORTHERLY TO PIQUETTE AVE EUROPEAN SECT FROM WARREN AVE EXIT RAMP NORTHERLY TO SO OF PIQUETTE AVE (NB ONLY) AND ON I-375 FROM JEFFERSON AVE RAMP NORTHERLY TO THE FISHER FWY INTERCHANGE IN DETROIT, WAYNE COUNTY.
20% DBE 0% WBE

FEDERAL PROJECT NO.	CONTROL SECTION		JOB NO.
IM 75-1(420)	IM	82251	30613A
IM 75-1(420)	IM	82111	30614A

WORK ITEM DESCRIPTION	CODE	QUANTITY	TONY ANGELO CEMENT CONSTRUCTION COMPANY, NOVI MI, 0520 — UNIT PRICE	AMOUNT	CHAMPAGNE-WEBBER INC MICHIGAN, FRASER MI, 0051 — UNIT PRICE	AMOUNT	OTHER CONTRACTORS — UNIT PRICE	AMOUNT
01								
REMOVE HANDHOLE - ELECTRICAL	6900001	67.00 EACH	260.0000	17,420.00	260.0000	17,420.00		
REMOVE LUMINAIRE	6900006	54.00 EACH	26.0000	1,404.00	26.0000	1,404.00		
REMOVE FOUNDATION	6900007	3.00 EACH	120.0000	360.00	120.0000	360.00		
DIRECT BURIAL CONDUIT, 1-3"	6900062	14,220.00 LFT	3.7000	52,614.00	3.7000	52,614.00		
DIRECT BURIAL CONDUIT, 1-2"	6900063	165.00 LFT	3.2000	528.00	3.2000	528.00		
DIRECT BURIAL CONDUIT, 2-2"	6900064	20.00 LFT	7.0000	140.00	7.0000	140.00		
JUNCTION BOX IN BARRIER WALL	6900090	5.00 EACH	340.0000	1,700.00	340.0000	1,700.00		
HANDHOLE, HEAVY DUTY COVER	6900092	64.00 EACH	610.0000	39,040.00	610.0000	39,040.00		
600V 2-1/C #6 DIRECT BURIAL CABLE IN CONDUIT	6900128	1,360.00 LFT	2.2000	2,992.00	2.2000	2,992.00		
600V 3-1/C #6 DIRECT BURIAL CABLE IN CONDUIT	6900129	5,190.00 LFT	3.1000	16,089.00	3.1000	16,089.00		
600V 6-1/C #6 DIRECT BURIAL CABLE IN CONDUIT	6900132	110.00 LFT	5.4000	594.00	5.4000	594.00		
600V 3-1/C #4 DIRECT BURIAL CABLE IN CONDUIT	6900134	7,405.00 LFT	3.4000	25,177.00	3.4000	25,177.00		
600V 6-1/C #4 DIRECT BURIAL CABLE IN CONDUIT	6900137	1,890.00 LFT	6.5000	12,285.00	6.5000	12,285.00		
600V 3-1/C #2 DIRECT BURIAL CABLE IN CONDUIT	6900139	2,890.00 LFT	4.8000	13,872.00	4.8000	13,872.00		
3 #6 OVERHEAD LINE	6900212	570.00 LFT	1.4000	798.00	1.4000	798.00		
3 #4 OVERHEAD LINE	6900215	10,445.00 LFT	2.2000	22,979.00	2.2000	22,979.00		
3 #2 OVERHEAD LINE	6900217	770.00 LFT	2.4000	1,848.00	2.4000	1,848.00		
LIGHT STANDARD 30' MOUNTING HEIGHT WITH 12' ARM ON NEW FOUNDATION	6900318	4.00 EACH	1750.0000	7,000.00	1750.0000	7,000.00		
LIGHT STANDARD 45' MOUNTING HEIGHT WITH 12' DOUBLE ARM ON MEDIAN WALL	6900523	29.00 EACH	1576.0000	45,704.00	1576.0000	45,704.00		
250W HIGH PRESSURE SODIUM LUMINAIRE	6900612	4.00 EACH	180.0000	720.00	180.0000	720.00		
400W HIGH PRESSURE SODIUM LUMINAIRE	6900613	58.00 EACH	190.0000	11,020.00	190.0000	11,020.00		
REMOVE LIGHT STANDARD,45' MOUNTING HEIGHT WITH 12' DOUBLE ARM ON MEDIAN BARRIER	6907001	30.00 EACH	162.0000	4,860.00	162.0000	4,860.00		
REMOVE LIGHT STANDARD 30' MOUNTING HEIGHT WITH 12' ARM ON FRANGIBLE TRANSFORMER BASE & FOUNDATION	6907002	2.00 EACH	270.0000	540.00	270.0000	540.00		

P1304 (1/89)
REPORT NO. 128

PROPOSAL 93-06083

SET 2
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FEDERAL PROJECT NO.	CONTROL SECTION	JOB NO.
IM 75-1(420)	IM 82251	30613A
IM 75-1(420)	IM 82111	30614A

WORK TYPE & LOCATION
1.1 MILE OF CONCRETE PAV'T REPAIR, BIT RESURFACING & CUSHION WALL; 2.3 MILES OF CONCRETE RECONSTRUCTION, STORM SEWER, X-LEAD REPLACEMENT, SIGNING & LIGHTING REPLACEMENT, WEIGHT-IN-MOTION DETECTION DEVICE INC 1.0 MILE OF EUROPEAN PAV'T SECT ON I-75 FROM I-375 NORTHERLY TO PIQUETTE AVE EUROPEAN SECT FROM WARREN AVE EXIT RAMP NORTHERLY TO SO OF PIQUETTE AVE (NB ONLY) AND ON I-375 FROM JEFFERSON AVE RAMP NORTHERLY TO THE FISHER FWY INTERCHANGE IN DETROIT, WAYNE COUNTY.
20% DBE 0% WBE

WORK ITEM DESCRIPTION	CODE	QUANTITY	TONY ANGELO CEMENT CONSTRUCTION COMPANY NOVI MI 0520 UNIT PRICE	AMOUNT	CHAMPAGNE-WEBBER INC MICHIGAN FRASER MI 0051 UNIT PRICE	AMOUNT	OTHER CONTRACTORS UNIT PRICE	AMOUNT
01								
REMOVE LIGHT STANDARD 30' MOUNTING HEIGHT WITH 12' ARM	6907003	2.00 EACH	120.0000	240.00	120.0000	240.00		
REMOVE TEMPORARY LIGHTING UNIT	6907005	52.00 EACH	138.0000	7,176.00	138.0000	7,176.00		
TEMPORARY LIGHTING UNITS - SINGLE ARM	6907007	47.00 EACH	710.0000	33,370.00	710.0000	33,370.00		
DIRECT BURIAL CONDUIT 4-4"	6907009	75.00 LFT	9.8000	735.00	9.8000	735.00		
DIRECT BURIAL CONDUIT, 6-3"	6907011	95.00 LFT	11.4000	1,083.00	11.4000	1,083.00		
STEEL MESSENGER ATTACHED TO STRUCTURE	6907015	362.00 LFT	4.0000	1,448.00	4.0000	1,448.00		
REMOVE STEEL MESSENGER ATTACHED TO STRUCTURE	6907017	362.00 LFT	1.5000	543.00	1.5000	543.00		
3 #6 & 6 #4 OVERHEAD LINE	6907019	130.00 LFT	11.2000	1,456.00	11.2000	1,456.00		
FIT UP WODD POLE AS A TEMPORARY SERVICE POLE	6907021	13.00 EACH	1283.0000	16,679.00	1283.0000	16,679.00		
REMOVE TEMPORARY SERVICE POLE	6907023	10.00 EACH	270.0000	2,700.00	270.0000	2,700.00		
LIGHT STANDARD FOUNDATION	6907025	4.00 EACH	480.0000	1,920.00	480.0000	1,920.00		
RF TRANSMISSION CABLE	6907052	13,570.00 LFT	3.0000	40,710.00	3.0000	40,710.00		
SHIELDED PAIR COMMS CABLE	6907054	20,330.00 LFT	1.3000	26,429.00	1.3000	26,429.00		
MULTICONDUCTOR SIGNAL AND AUDIO CABLE	6907056	14,260.00 LFT	2.2000	31,372.00	2.2000	31,372.00		
3/C POWER CABLE	6907058	4,735.00 LFT	2.0000	9,470.00	2.0000	9,470.00		
1-3"CONDUIT UNDER PAVEMENT	6907060	1,985.00 LFT	4.2000	8,337.00	4.2000	8,337.00		
2-3"CONDUIT UNDER PAVEMENT	6907062	1,030.00 LFT	5.1000	5,253.00	5.1000	5,253.00		
4-3"CONDUIT UNDER PAVEMENT	6907064	3,905.00 LFT	6.0000	23,430.00	6.0000	23,430.00		
#8 AWG I/C EQUIPMENT GROUNDING CONDUCTOR	6907071	9,465.00 LFT	.6000	5,679.00	.6000	5,679.00		
#6 AWG I/C EQUIPMENT GROUNDING CONDUCTOR	6907072	1,040.00 LFT	.7500	780.00	.7500	780.00		
REMOVE HANDHOLE	6910176	24.00 EACH	210.0000	5,040.00	210.0000	5,040.00		
HANDHOLE (TYPE "D")	6910447	16.00 EACH	1450.0000	23,200.00	1450.0000	23,200.00		
TRAFFIC DETECTOR LOOP TYPE III	6917005	9.00 EACH	1145.0000	10,305.00	1145.0000	10,305.00		
REMOVING BITUMINOUS PATCHES	6917012	135.00 SYD	10.0000	1,350.00	10.0000	1,350.00		
IMPEDANCE MATCHING TRANSFORMER	6917013	250.00 EACH	35.0000	8,750.00	35.0000	8,750.00		
4 - 3" SCHEDULE 80 CONDUIT HUNG TO STRUCTURES	6917015	1,700.00 LFT	11.2500	19,125.00	11.2500	19,125.00		

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20% DBE 0% WBE

			TONY ANGELO CEMENT CONSTRUCTION COMPANY NOVI MI 0520		CHAMPAGNE-WEBBER INC MICHIGAN FRASER MI 0051		OTHER CONTRACTORS	
WORK ITEM DESCRIPTION	CODE	QUANTITY	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT	UNIT PRICE	AMOUNT
01								
HANDHOLE (TYPE"D") (REMOVAL AND SALVAGE)	6917017	29.00 EACH	315.0000	9,135.00	315.0000	9,135.00		
INSTALL HANDHOLE - TYPE "D" (SALVAGED)	6917019	18.00 EACH	1130.0000	20,340.00	1130.0000	20,340.00		
HANDHOLE (TYPE III) WITH HEAVY DUTY COVER	6917021	3.00 EACH	940.0000	2,820.00	940.0000	2,820.00		
HANDHOLE (TYPE "D") MODIFIED	6917023	3.00 EACH	2356.0000	7,068.00	2356.0000	7,068.00		
HANDHOLE (TYPE III)	6917025	4.00 EACH	658.0000	2,632.00	658.0000	2,632.00		
TRAFFIC DETECTOR LOOP TYPE II	6917103	48.00 EACH	775.0000	37,200.00	775.0000	37,200.00		
TRAFFIC DETECTOR LOOP TYPE I	6917105	18.00 EACH	250.0000	4,500.00	250.0000	4,500.00		
TRAFFIC DETECTOR LOOP TYPE IV	6917107	76.00 EACH	750.0000	57,000.00	750.0000	57,000.00		
ON THE JOB TRAINING	6920002	7,500.00 HRS	1.0000	7,500.00	1.0000	7,500.00		
PHOTOIONIZATION DETECTOR	2077007	1.00 EACH	6000.0000	6,000.00	4900.0000	4,900.00		
MAGNETIC LOCATOR	2077009	1.00 EACH	2000.0000	2,000.00	2000.0000	2,000.00		
PROJECT CLEANUP	2140001	1.00 LSUM	5000.0000	5,000.00	15000.0000	15,000.00		
REMOVE AND REPLACE CUSHIONING WALL	6127011	1.00 LSUM	537400.0000	537,400.00	537400.0000	537,400.00		
HEX - FOAM ATTENUATOR (8-BAY NARROW), FURNISHED	6127021	1.00 EACH	28895.0000	28,895.00	28895.0000	28,895.00		
MOBILIZATION	6230001	1.00 LSUM	1537125.0000	1537,125.00	1500000.0000	1500,000.00		
OVERHEAD TRUSS, TYPE C, 75'	6260021	1.00 EACH	34500.0000	34,500.00	34500.0000	34,500.00		
MINOR TRAFFIC DEVICES	6310054	1.00 LSUM	67570.0000	67,570.00	2500.0000	2,500.00		
FLAG CONTROL	6310056	1.00 LSUM	36500.0000	36,500.00	45000.0000	45,000.00		
LIGHTING FOR NIGHT PAVING	6317010	1.00 LSUM	10000.0000	10,000.00	1.0000	1.00		
INSTALL NEW FRANGIBLE TRANSFORMER BASE	6900590	1.00 EACH	450.0000	450.00	450.0000	450.00		
WIM Equipment Furnished (North Bound I-75)	6917113	1.00 LSUM	88100.0000	88,100.00	82741.5000	82,741.50		
WIM Equipment Furnished (South Bound I-75)	6917115	1.00 LSUM	88100.0000	88,100.00	82741.5000	82,741.50		
WIM Equipment Placed (North Bound I-75)	6917117	1.00 LSUM	22180.0000	22,180.00	13180.0000	13,180.00		
WIM Equipment Placed (South Bound I-75)	6917119	1.00 LSUM	22180.0000	22,180.00	13180.0000	13,180.00		
CONCRETE PAVEMENT REPAIR - REINFORCED 11"	4520013	4,230.00 SYD	33.0000	139,590.00	33.0000	139,590.00		

P1304 (1/89)
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FEDERAL PROJECT NO.	CONTROL SECTION		JOB NO.
IM 75-1(420)	IM	82251	30613A
IM 75-1(420)	IM	82111	30614A

WORK ITEM DESCRIPTION	CODE	QUANTITY	TONY ANGELO CEMENT CONSTRUCTION COMPANY, NOVI MI 0520 UNIT PRICE	AMOUNT	CHAMPAGNE-WEBBER INC MICHIGAN, FRASER MI 0051 UNIT PRICE	AMOUNT	OTHER CONTRACTORS UNIT PRICE	AMOUNT
01 GALVANIZED STEEL OVERHEAD TRUSS, TYPE D, 105'	6267001	1.00 EACH	37500.0000	37,500.00	37500.0000	37,500.00		
	PART 01	SUBTOTAL		17,384,495.60		17,893,038.40		
		TOTAL		17,384,495.60		17,893,038.40		

CONTROL SEC IM 82251
JOB NUMBER 30613A
GRADE CONC. 35P

CONCRETE QA

Design Strength 3500

SPECIMEN ID #		STRENGTH, PSI		INIT. STRENGTH TEST, PSI	LOT AVERAGE	STD DEV	Q	PD	% PAY ADJ	NOTE
LOT NO	1502	4379	4344	4361.5						08-23-93
		5319	5656	5487.5						35P-1
				0						
				0						
				0						
				0						
					4924.5	796.202	1.789	0	2	
LOT NO	1501	4805	5018	4911.5				G		08-24-93
		4680	4539	4609.5						35P-2
		4539	4397	4468						
		4894	5000	4947						
		4751	5071	4911						
				0						
					4769.4	216.907	5.852	0	2	
LOT NO	1515	4866	4919	4892.5						08-25-93
		5414	5485	5449.5						35P-3
		4795	4830	4812.5						
		4282	4211	4246.5						
		4069	4016	4042.5						
				0						
					4688.7	558.746	2.127	0	2	
1401	1401	3769	3804	3786.5						08-26-93
				0						35P-4
				0						
				0						
				0						
				0						
					3786.5	400	0.716	0	2	

CONCRETE QA

CONTROL SEC IM 82251
JOB NUMBER 30613A
GRADE CONC. 35P

Design Strength 3500

SPECIMEN ID #		STRENGTH, PSI		INIT. STRENGTH TEST, PSI	LOT AVERAGE	STD DEV	Q	PD	% PAY ADJ	NOTE
LOT NO	1545	4105	4140	4122.5					–	09-07-93
				0						35P-5
				0						
				0						
				0						
				0						
					4122.5	400	1.556	0	2	
LOT NO	1557	3928	3786	3857						09-09-93
				0						35P-6
				0						
				0						
				0						
				0						
					3857	400	0.892	0	2	
LOT NO	1437	4200	4230	4215						09-25-93
		4620	4900	4760						35P-7
		6400	6500	6450						
				0						
				0						
				0						
					5141.666	1165.35	1.408	0	2	
LOT NO	1438	6370	5220	5795						09-26-93
		5920	6010	5965						35P-8
		5380	5270	5325						
		5310	4690	5000						
				0						
				0						
					5521.25	440.480	4.588	0	2	

CONCRETE QA

CONTROL SEC IM 82251
JOB NUMBER 30613A
GRADE CONC. 35P

Design Strength 3500

SPECIMEN ID #		STRENGTH, PSI		INIT. STRENGTH TEST, PSI	LOT AVERAGE	STD DEV	Q	PD	% PAY ADJ	NOTE
LOT NO	1403	6600	6320	6460						09-28-93 35P-9
		6470	6550	6510						
		6220	6260	6240						
		5410	5480	5445						
				0						
				0						
					6163.75	493.311	5.399	0	2	
		4740	4650	4695						10-19-93 35P-10
		5100	5110	5105						
		4670	5310	4990						
		5520	5380	5450						
		5730	5660	5695						
				0						
					5187	392.055	4.302	0	2	
LOT NO	1851	5320	5800	5560						10-20-93 35P-11
		4390	4370	4380						
		5490	5930	5710						
		4770	4740	4755						
		6190	6300	6245						
				0						
					5330	752.935	2.430	0	2	
LOT NO	1823	4490	4600	4545						10-22-93 35P-12
		4940	4990	4965						
		4880	4810	4845						
		4340	4160	4250						
		4105	4090	4097.5						
				0						
					4540.5	372.014	2.796	0	2	

CONCRETE QA

CONTROL SEC IM 82251
JOB NUMBER 30613A
GRADE CONC. 35P

Design Strength: 3500

SPECIMEN ID #		STRENGTH, PSI		INIT. STRENGTH TEST, PSI	LOT AVERAGE	STD DEV	Q	PD	% PAY ADJ	NOTE
LOT NO	2098	4441	4900	4670.5						10-23-93 35P-13
		5149	4777	4963						
		5821	5131	5476						
		5202	4423	4812.5						
				0						
				0						
					4980.5	351.259	4.214	0	2	
LOT NO	1925	5570	5680	5625						11-01-93 35P-14
		5600	6720	6160						
		6086	6020	6053						
				0						
				0						
				0						
					5946	283.095	8.640	0	2	
LOT NO	1913	6180	6320	6250						11-03-93 35P-15
		5310	5200	5255						
		5750	5940	5845						
				0						
				0						
				0						
					5783.333	500.358	4.563	0	2	
LOT NO	803	6420	6720	6570						11-05-93 35P-16
		6140	6170	6155						
				0						
				0						
				0						
				0						
					6362.5	293.449	9.754	0	2	

CONCRETE QA

CONTROL SEC IM 82251
JOB NUMBER 30613A
GRADE CONC. 35P

SPECIMEN ID #		STRENGTH, PSI		INIT. STRENGTH TEST, PSI (Design Strength)	LOT AVERAGE (3500)	STD DEV	Q	PD	% PAY ADJ	NOTE
LOT NO	824	3008	3804	3406						11-06-93
		4636	4565	4600.5						35P-17
		4423	4565	4494						
				0						
				0						
				0						
					4166.833	661.049	1.008	16.11	-1.222	
LOT NO	833	4210	4070	4140						11-08-93
		3720	3680	3700						35P-18
		4990	5170	5080						
				0						
				0						
				0						
					4306.666	704.934	1.144	0	2	
LOT NO	855	5570	5930	5750						11-09-93
		5380	5410	5395						35P-19
		5240	5130	5185						
				0						
				0						
				0						
					5443.333	285.584	6.804	0	2	
LOT NO	893	5750	5870	5810						11-12-93
		4320	4260	4290						35P-20
		5660	5390	5525						
		5110	5250	5180						
		6280	6300	6290						
				0						
					5419	750.752	2.556	0	2	

CONCRETE QA

CONTROL SEC IM 82251
JOB NUMBER 30613A
GRADE CONC. 35P

Design Strength: 3500

SPECIMEN ID #		STRENGTH, PSI		INIT. STRENGTH TEST, PSI	LOT AVERAGE	STD DEV	Q	PD	% PAY ADJ	NOTE
LOT NO	213	4460 6440 6420	4950 6370 6230	4705 6405 6325 0 0 0						11-15-93 35P-21
					5811.666	959.235	2.409	0	2	
				0 0 0 0 0 0						
					ERR	0	ERR		2	
				0 0 0 0 0 0						
					ERR	0	ERR		2	
				0 0 0 0 0 0						
					ERR	0	ERR		2	

CONCRETE QA

CONTROL SEC IM82251
JOB NUMBER 30613A
GRADE CONC. 25P

SPECIMEN ID #		STRENGTH, PSI		INIT. STRENGTH TEST, PSI (Design Strength)	LOT AVERAGE (2500)	STD DEV	Q	PD	% PAY ADJ	NOTE
		3981	4158	4069.5						9-9-93 25P-1
		4140	3822	3981						
		4069	4282	4175.5						
		3362	3379	3370.5						
		3769	3715	3742						
				0						
					3867.7	320.667	4.265	0	2	
		3520	3610	3565						9-18-93 25P-2
		3878	3645	3761.5						
		3574	3574	3574						
				0						
				0						
				0						
					3633.5	110.942	10.21	0	2	
		4122	4458	4290						9-20-93 25P-3
		4335	3963	4149						
		4388	4210	4299						
				0						
				0						
				0						
					4246	84.1249	20.75	0	2	
		3680	3680	3680						9-23-93 25P-4
		4459	4441	4450						
		4459	4423	4441						
		4370	4423	4396.5						
		4246	4335	4290.5						
				0						
					4251.6	325.757	5.377	0	2	

CONCRETE QA

CONTROL SEC IM82251
JOB NUMBER 30613A
GRADE CONC. 25P

Design Strength 2500

SPECIMEN ID #		STRENGTH, PSI		INIT. STRENGTH TEST, PSI	LOT AVERAGE	STD DEV	Q	PD	% PAY ADJ	NOTE
		4104	3980	4042						10-27-93 25P-5
				0						
				0						
				0						
				0						
				0						
					4042	400	3.855	0	2	
		4810	4880	4845						11-8-93 25P-6
		4780	4900	4840						
		4105	4110	4107.5						
		6020	5800	5910						
				0						
				0						
					4925.625	742.103	3.268	0	2	
		3630	3660	3645						11-9-93 25P-7
		4140	4420	4280						
		4250	4300	4275						
		3890	3930	3910						
		3880	3890	3885						
				0						
					3999	274.485	5.461	0	2	
				0						
				0						
				0						
				0						
				0						
				0						
					ERR	0	ERR		2	

CONCRETE QA

CONTROL SEC IM82251
JOB NUMBER 30613A
GRADE CONC. 50P

Design Strength: 5000

SPECIMEN ID #		STRENGTH, PSI		INIT. STRENGTH TEST, PSI	LOT AVERAGE	STD DEV	Q	PD	% PAY ADJ	NOTE
		5010	5130	5070						11-23-93
		4770	4970	4870						LOT50-P-19
		5060	5060	5060						
				0						
				0						
				0						
					5000	112.694	0	50	-8	
		5700	5790	5745						11-24-93
		5910	5800	5855						50-P-20
		5630	5790	5710						
				0						
				0						
				0						
					5770	75.6637	10.17	0	2	
				0						
				0						
				0						
				0						
				0						
				0						
					ERR	0	ERR		2	
				0						
				0						
				0						
				0						
				0						
				0						
					ERR	0	ERR		2	

CONCRETE QA

CONTROL SEC IM 82251

JOB NUMBER 30613A

GRADE CONC. 55P

Design Strength 5500

SPECIMEN ID #		STRENGTH, PSI		INIT. STRENGTH TEST, PSI	LOT AVERAGE	STD DEV	Q	PD	% PAY ADJ	NOTE
LAB NO	1418	6180	6370	6275 0 0 0 0 0						9-30-93 LOT 55P-1 816 SYD
					6275	400	1.937	0	2	
LAB NO	1421 1422	7113	6936	7024.5 0 0 0 0 0						10-02-93 LOT 55P-2
					7024.5	400	3.811	0	2	
LAB NO	1499	6720 6650 6940 6510 6230	7150 7010 6990 7200 6940	6935 6830 6965 6855 6585 0						10-05-93 LOT 55P-3
					6834	149.849	8.902	0	2	
LAB NO	1485	6420	6480	6450 0 0 0 0 0						10-07-93 55P-4
					6450	400	2.375	0	2	

CONCRETE QA

CONTROL SEC IM 82251
JOB NUMBER 30613A
GRADE CONC. 55P

Design Strength 5500

SPECIMEN ID #		STRENGTH, PSI		INIT. STRENGTH TEST, PSI	LOT AVERAGE	STD DEV	Q	PD	% PAY ADJ	NOTE
LOT NO	1815	7010	6900	6955						11-05-93
		7080	6810	6945						55P-13
		6260	6260	6260						
		6950	7020	6985						
		6620	6640	6630						
				0						
					6755	312.109	4.021	0	2	
				0						
				0						
				0						
				0						
				0						
				0						
					ERR	0	ERR		2	
				0						
				0						
				0						
				0						
				0						
				0						
					ERR	0	ERR		2	
				0						
				0						
				0						
				0						
				0						
				0						
					ERR	0	ERR		2	

CONCRETE QA

CONTROL SEC IM 82251
JOB NUMBER 30613A
GRADE CONC. 55P

Design Strength: 5500

SPECIMEN ID #		STRENGTH, PSI		INIT. STRENGTH TEST, PSI	LOT AVERAGE	STD DEV	Q	PD	% PAY ADJ	NOTE
LOT NO	1452	7020	5680	6350						10-08-93
		6300	5840	6070						55P-5
		6370	6810	6590						
		7080	6670	6875						
		5840	5840	5840						
				0						
					6345	409.756	2.062	0	2	
LOT NO	1879	6880	7110	6995						10-12-93
		7080	6790	6935						55P-6
		6720	7080	6900						
		6760	7094	6927						
				0						
				0						
					6939.25	40.0697	35.91	0	2	
LOT NO	1815	6460	6330	6395						10-14-93
		7220	7080	7150						55P-7
		7250	7110	7180						
				0						
				0						
				0						
					6908.333	444.812	3.166	0	2	
LOT NO	1813	7340	7140	7240						10-15-93
		6640	6480	6560						55P-8
		6760	6550	6655						
		6330	6070	6200						
		6700	6750	6725						
				0						
					6676	374.489	3.140	0	2	

CONCRETE QA

CONTROL SEC IM 82251
JOB NUMBER 30613A
GRADE CONC. 55P

Design Strength 5500

SPECIMEN ID #		STRENGTH, PSI		INIT. STRENGTH TEST, PSI	LOT AVERAGE	STD DEV	Q	PD	% PAY ADJ	NOTE
LOT NO	2018	6759	6909	6834						10-23-93
		6706	6883	6794.5						55P-9
		5697	5732	5714.5						
		6369	7502	6935.5						
		7413	7608	7510.5						
				0						
					6757.8	650.723	1.932	0	2	
LOT NO	2019	5800	5640	5720						10-25-93
		6440	6170	6305						55P-10
		6510	6404	6457						
		6700	6260	6480						
		6260	6400	6330						
				0						
					6258.4	310.532	2.442	0	2	
LOT NO	1924	6630	6390	6510						11-01-93
		6400	7160	6780						55P-11
		7220	7110	7165						
		7040	7150	7095						
				0						
				0						
					6887.5	302.282	4.590	0	2	
LOT NO	100	5960	5920	5940						11-13-93
		6380	6420	6400						55P-12
				0						
				0						
				0						
				0						
					6170	325.269	2.059	0	2	

2. *Layer-One*

Layer-One was placed over the lean concrete base once it obtained the required strength and completed the wet cure. Specifications required the lean concrete base to be wet cured for seven days. Some areas were cured less than 7 days with the approval of the engineer. Prior to placement all foreign materials were removed and the surface thoroughly cleaned. The first layer was batched, delivered, placed, and finished prior to layer-two being placed.

Class 50P Layer-One f'(c) = 5000 PSI

CONTRACTOR: Ajax Paving
PROJECT : I-75 European Pavement
SOURCE OF CONCRETE: Ajax Paving
CONSTRUCTION TYPE: Bottom-Layer
PLACEMENT : Slip Form

WEIGHTS PER CUBIC YARD	(SATURATED, SURFACE-DRY)	YIELD, CU FT
Cement-Lafarge Type I, LB	588	2.99
F.A.-Federal Marine Pit No. 95-9, 2NS, LB	1305	7.86
C.A.-Presque Isle Pit No.71-47, 6AA LS, LB	1705	10.51
WATER, LB (GAL-US)	243 (29.2)	3.91
TOTAL AIR, %	6.5 +/- 1.5	1.76
	TOTAL	27.00
Water Reducing Admixture - Type A, OZ	17.64	
Air Entrainment, OZ-US	7.4	
WATER/CEMENT RATIO, LBS/LB	0.41	
SLUMP, IN	1.50	
CONCRETE UNIT WEIGHT, PCF	142.2	

Specification: Slump Range 0-3"
Air Content 6.5 +/- 1.5
Max. W/C Ratio 0.42
Absorption: CA 1.2, FA 0.7

3. *Layer-Two*

The concrete for layer-two was produced at a separate batch plant then delivered and placed after the finishing operation of layer-one. The intent of the wet on wet construction was to provide a good bond between both layers. The elapsed time between screeding the bottom layer and placement of the top layer should not exceed 30 minutes. The maximum time after unloading the bottom layer and placement of the top layer should be less than 45 minutes.

Class 55P Layer-Two f'(c) = 5500 PSI

CONTRACTOR: Ajax Paving
PROJECT : I-75 European Pavement
SOURCE OF CONCRETE: Koenig Fuel & Supply
CONSTRUCTION TYPE: Top-Layer Exposed Aggregate Surface
PLACEMENT : Slip Form

WEIGHTS PER CUBIC YARD (SATURATED, SURFACE-DRY)

		YIELD, CU FT
Cement-Lafarge Type I, LB	752	3.83
F.A.-Koenig Sand & Gravel - 2NS Nat., LB	1004	6.09
C.A.-Ontario Trap Rock - 6AA Modified, LB	1960	10.87
WATER, LB (GAL-US)	280 (33.6)	4.49
TOTAL AIR, %	6.5 +/- 1.5	1.76
	TOTAL	27.03

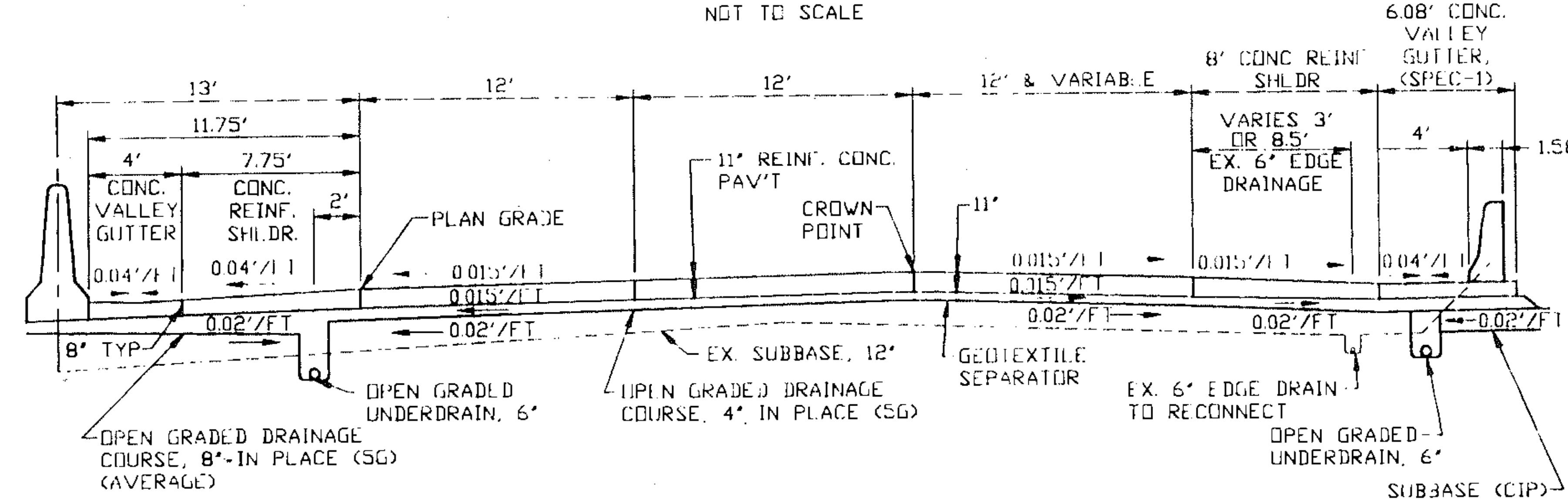
Water Reducing Admixture - Type A, OZ-US	22.56
Air Entrainment, OZ-US	13.2
WATER/CEMENT RATIO, LBS/LB	0.37
SLUMP, IN	1.50
CONCRETE UNIT WEIGHT, PCF	147.8

Specification: Slump Range 0-3"
Air Content 6.5 +/- 1.5
Max. W/C Ratio 0.40
Absorption: CA 0.5, FA 0.7

6AA Modified: 100 percent crushed basalt
Maximum size 0.31 (8 mm)
Maximum passing the No.5 (4 mm) sieve shall be 3%
Maximum passing the No. 200 sieve shall be 2%
Aggregate Wear Index (AWI) shall be 300 minimum

MICHIGAN SECTION NB I-75
(I-375 N'LY TO WARREN AVE. EXIT RAMP)

NOT TO SCALE



EURO SECTION NB I-75
(WARREN AVE. EXITRAMP N'LY TO PICQUETTE AVE.)

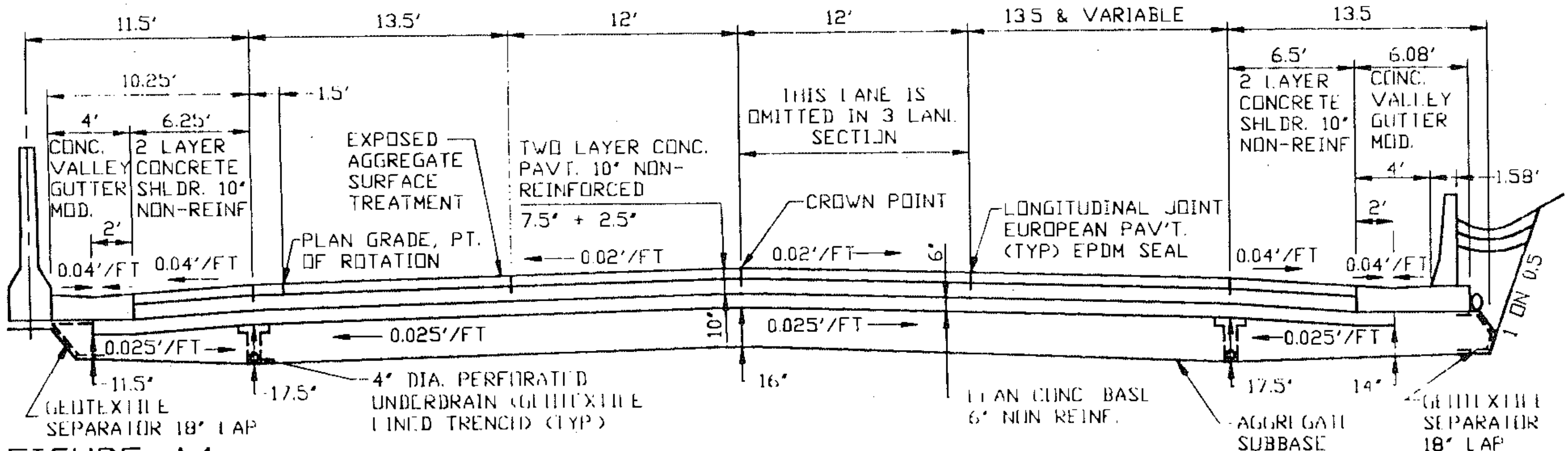
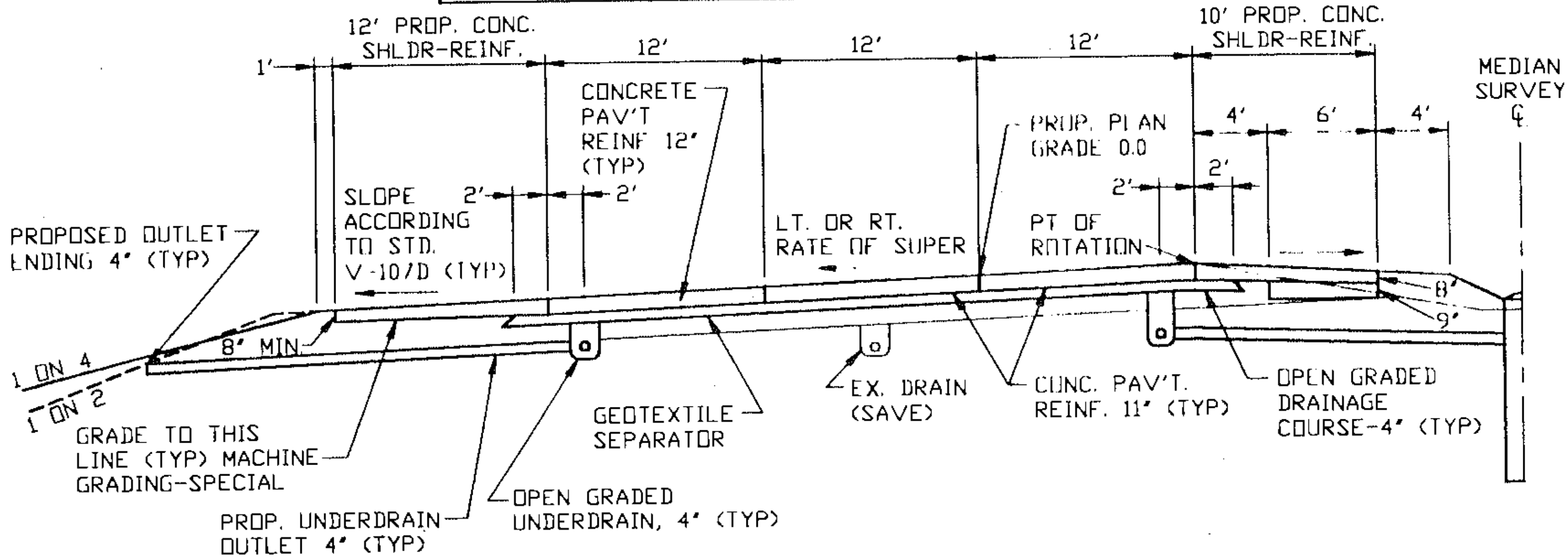


FIGURE A.1

STANDARD SECTI 1 (DUNBAR R N'LY TO I-275)

NORTHBOUND TYPICAL SECTION
NOT TO SCALE



SOUTHBOUND TYPICAL SECTION
NOT TO SCALE

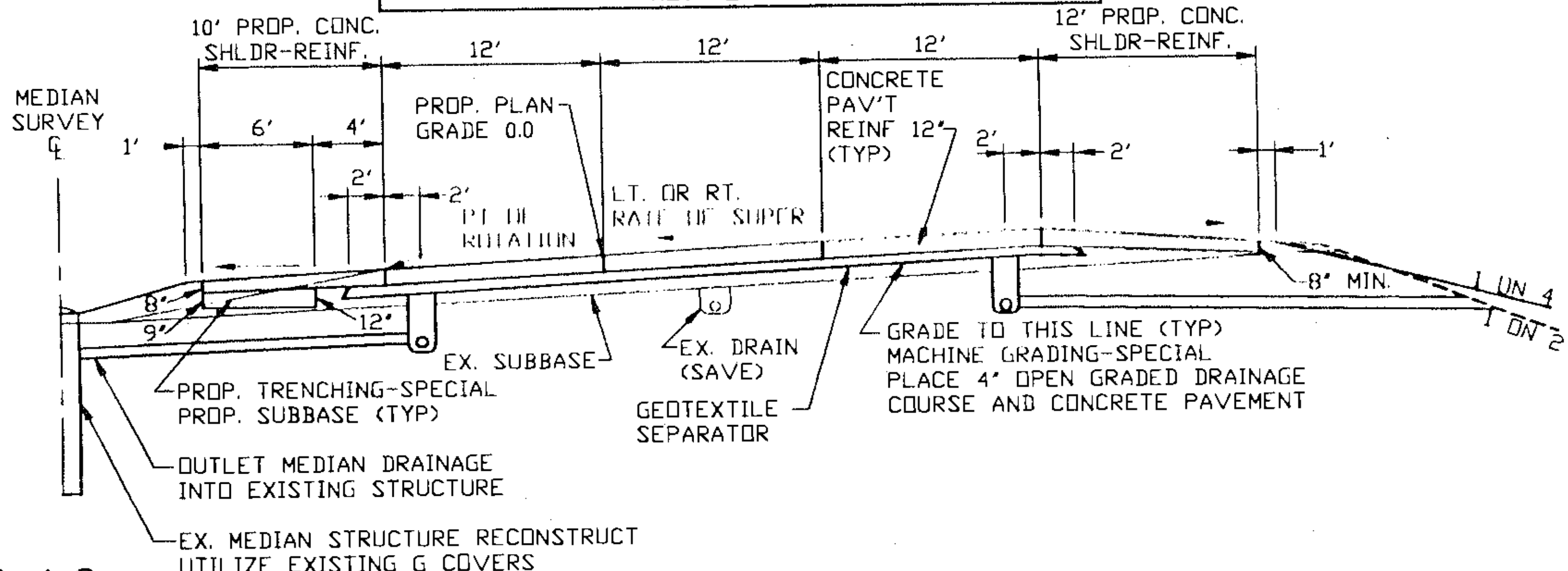
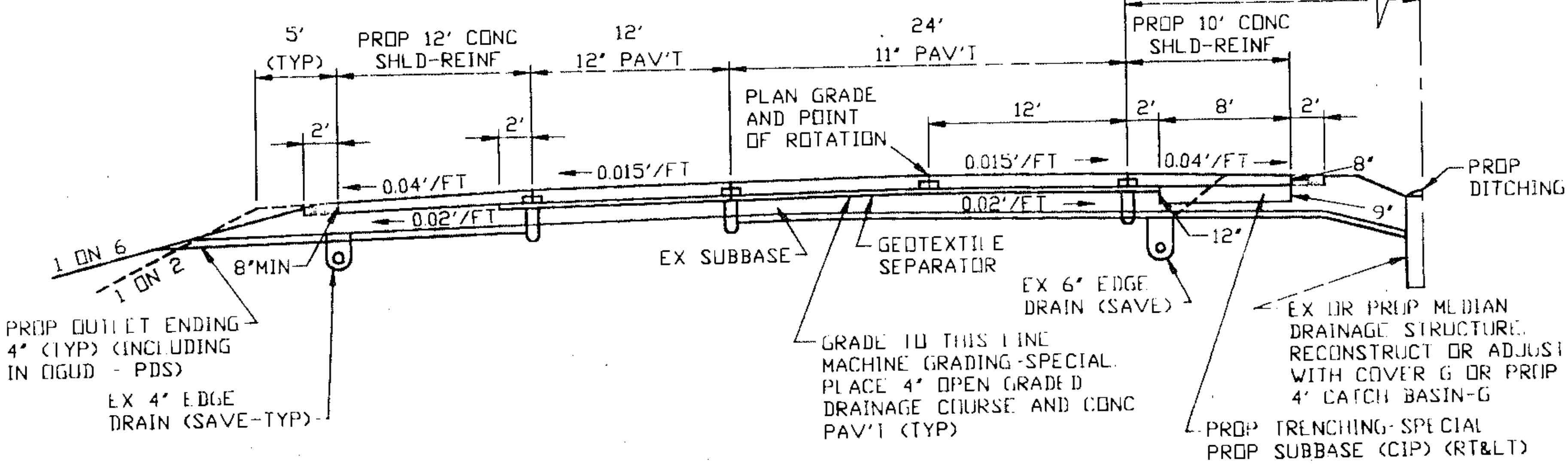


FIGURE A.2

STANDARD SECTION
(I-275 N'LY TO THE WAYNE COUNTY LINE)

NORTHBOUND TYPICAL SECTION
NOT TO SCALE



SOUTHBOUND TYPICAL SECTION
NOT TO SCALE

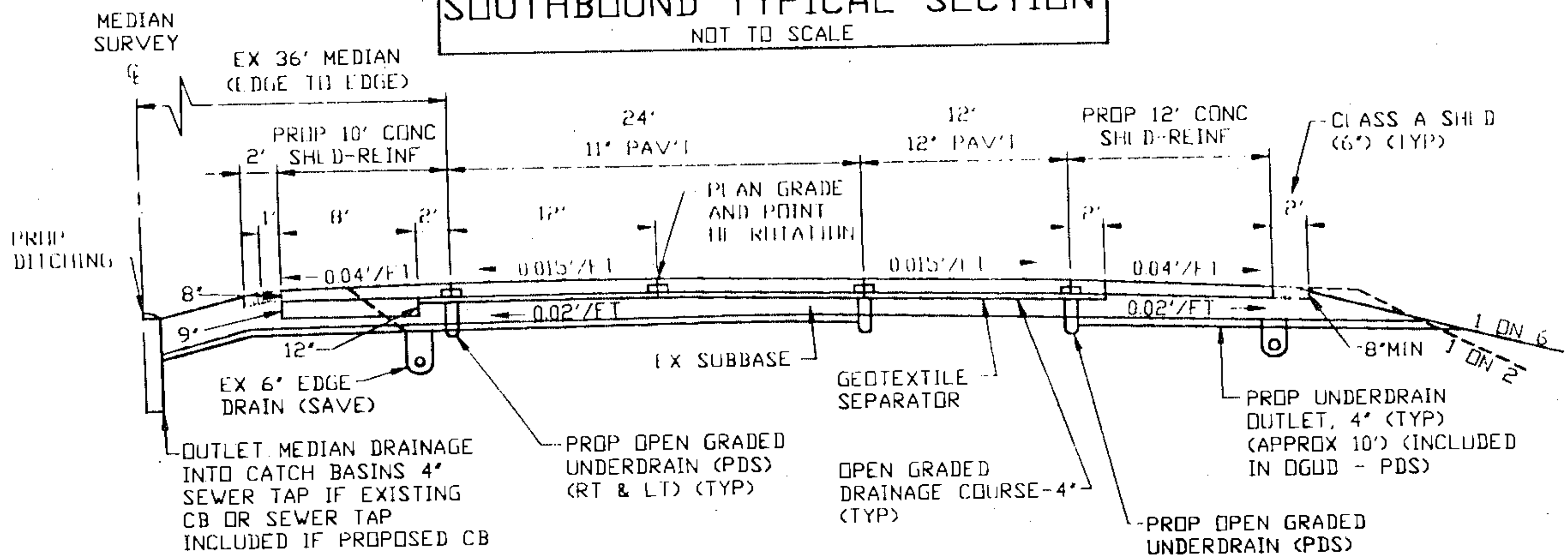
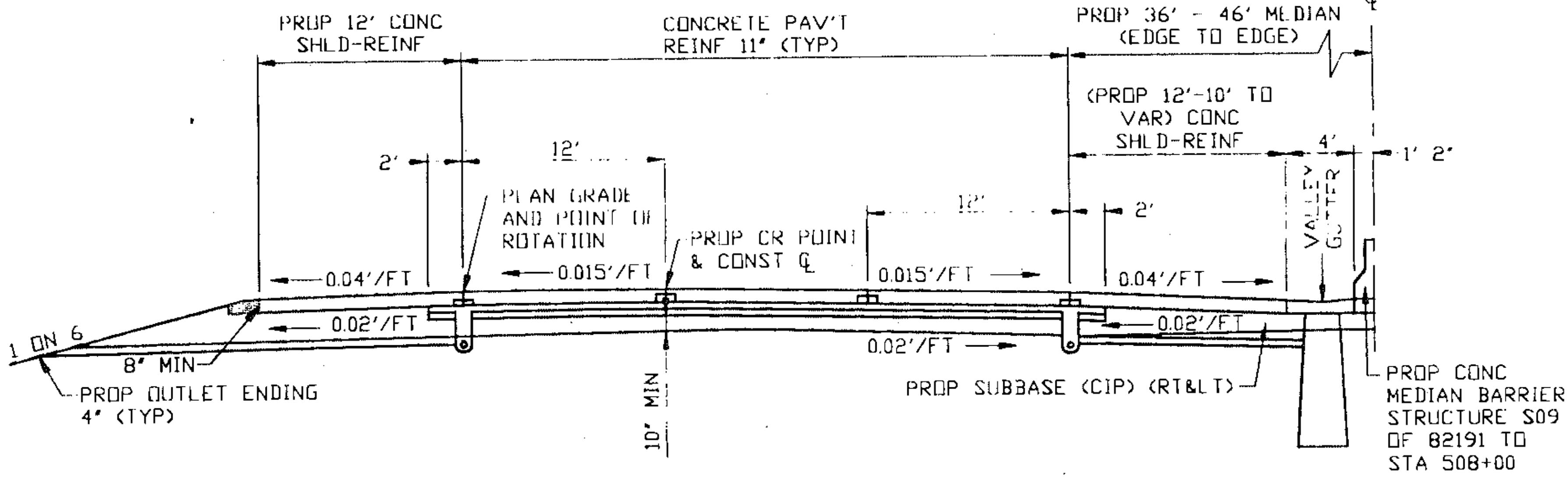


FIGURE A.3

STANDARD S[illegible]TION 3 (SIBLY RD. [illegible]Y TO GODDARD RD.)

NORTHBOUND TYPICAL SECTION

NOT TO SCALE



SOUTHBOUND TYPICAL SECTION

NOT TO SCALE

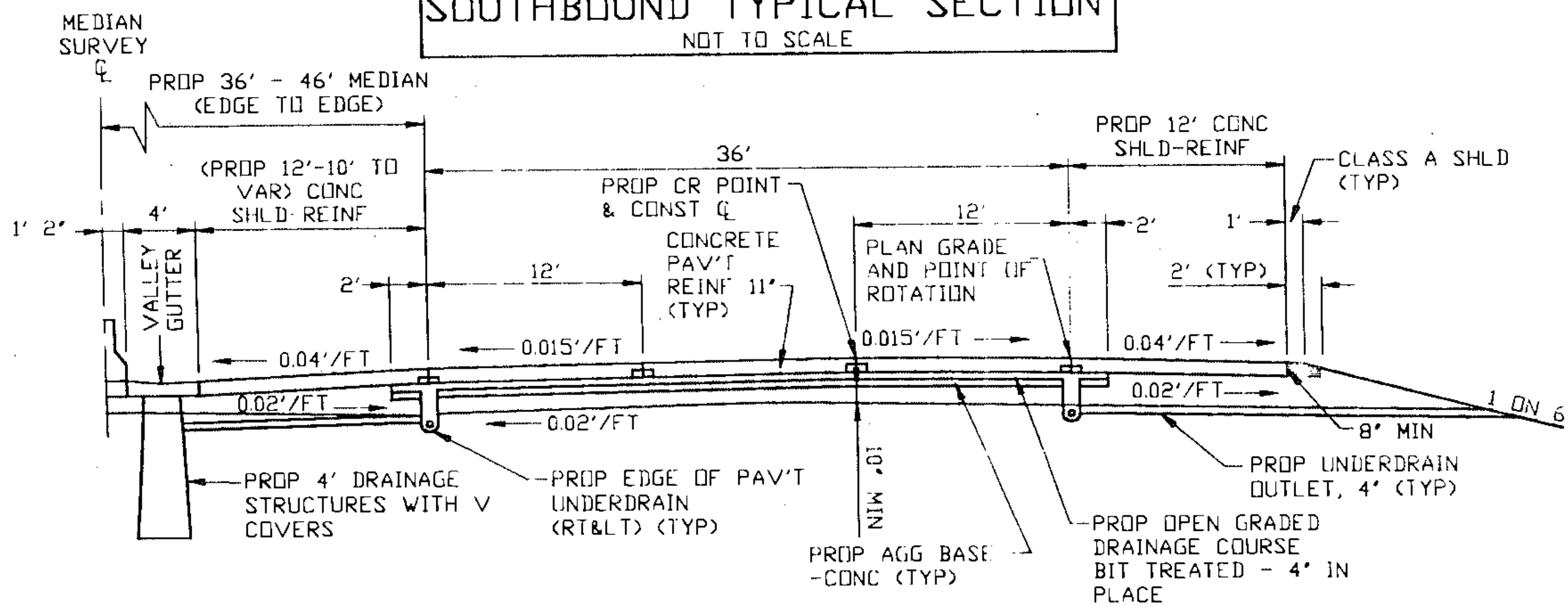


FIGURE A.4

Appendix B

Table B.1 – Maximum Midslab Deflection Measurements

Table B.2 – Transverse Joint Deflection Measurements

Figure B.1 – Plan View of Noise Measurement Site

Figure B.2 – Quarter Car Simulation for IRI

Table B.1 Maximum Midslab Deflection Measurements

Michigan Section

Lane	NBIL		NB2		NBOL	
Year	Nov. 93	Apr. 95	Nov. 93	Apr. 95	Nov. 93	Apr. 95
Age (mon)	0	29	0	29	0	29
Unit	mils	mils	mils	mils	mils	mils
Average	2.28	2.07	2.13	2.07	1.99	2.05
Std. Dev.	0.18	0.16	0.16	0.22	0.22	0.24
Max.	2.56	2.33	2.55	2.50	2.51	2.57
Min.	1.98	1.82	1.91	1.66	1.36	1.66
Count	11	10	24	22	46	13
Temp. (F)	43	44	43	43	46	43

Euro Section

Lane	NBIL		NB2		NBOL	
Year	Nov. 93	Apr. 95	Nov. 93	Apr. 95	Nov. 93	Apr. 95
Age (mon)	0	29	0	29	0	29
Unit	mils	mils	mils	mils	mils	mils
Average	1.27	1.33	1.37	1.32	1.30	1.41
Std. Dev.	0.10	0.23	0.08	0.23	0.08	0.15
Max.	1.42	1.97	1.50	1.81	1.44	1.85
Min.	1.15	1.10	1.25	1.18	1.15	1.17
Count	18	24	28	20	50	27
Temp. (F)	45	44	45	42	43	44

NOTE: All tests taken on the outside wheelpaths (owp).

Temp (F) - Is pavement surface temperature taken at the time of test.

NB2 - First lane left of outside lane

WEATHER INFORMATION		
	Nov. 93	Apr. 95
Average Air Temp. 5 Days prior to Tests (F)	44	54
Total Precipitation 5 Days Prior to Tests (in)	0.37	0.07
Total Precipitation 30 Days Prior to Tests (in)	1.2	2.6

Table B.2 Transverse Joint Deflection Measurements

Michigan Section								
Lane	NB2				NBOL			
DATE	Nov. 93		Apr. 95		Nov. 93		Apr. 95	
Age (mon)	0		29		0		29	
Test	Max. Def.	LTE	Max. Def.	LTE	Max. Def.	LTE	Max. Def.	LTE
Unit	mils	%	mils	%	mils	%	mils	%
Average	3.78	71.60	6.01	69.50	3.83	67.50	5.19	69.70
Std. Dev.	0.28	6.10	0.72	8.40	0.50	9.50	1.50	6.60
Max.	4.07	77.00	6.88	80.00	6.06	92.30	7.20	84.30
Min.	3.27	61.10	4.20	48.20	3.17	39.90	1.99	61.70
Count	6		11		40		8	
Temp. (F)	41		42		43		43	

Euro Section								
Lane	NB2				NBOL			
DATE	Nov. 93		Apr. 95		Nov. 93		Apr. 95	
Age (mon)	0		29		0		29	
Test	Max. Def.	LTE	Max. Def.	LTE	Max. Def.	LTE	Max. Def.	LTE
Unit	mils	%	mils	%	mils	%	mils	%
Average	3.29	79.10	5.14	61.90	3.39	77.00	4.85	58.80
Std. Dev.	0.46	6.60	1.01	4.10	0.50	9.10	0.61	4.60
Max.	4.21	88.10	7.75	69.70	4.28	90.30	6.01	69.00
Min.	2.35	67.90	3.61	54.70	2.47	56.90	3.75	51.50
Count	15		15		11		15	
Temp. (F)	48		43		41		43	

NOTE: All tests taken on the outside wheelpaths (owp).
LTE=D5/DO*100 (DO sensor load plate with transverse joint between DO and D5)
Temp (F) - Is pavement surface temperature taken at the time of test.
1993 testing done during daytime and before roadway was open to traffic
1995 testing done between 1:00 a.m. - 5:00 a.m. at night
NB2 - First lane left of outside lane

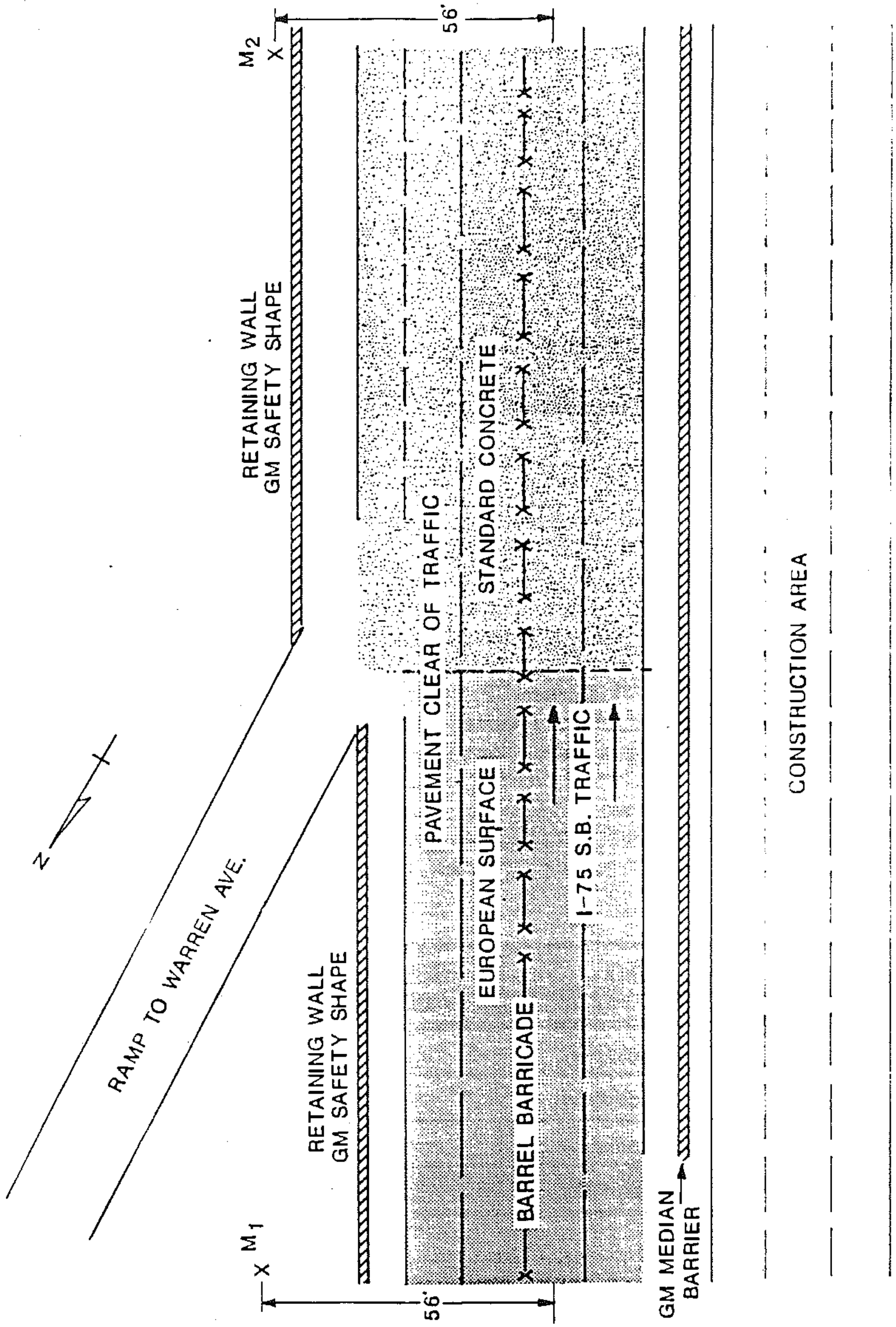


Figure B.1: Plan View of Noise Measurement Site

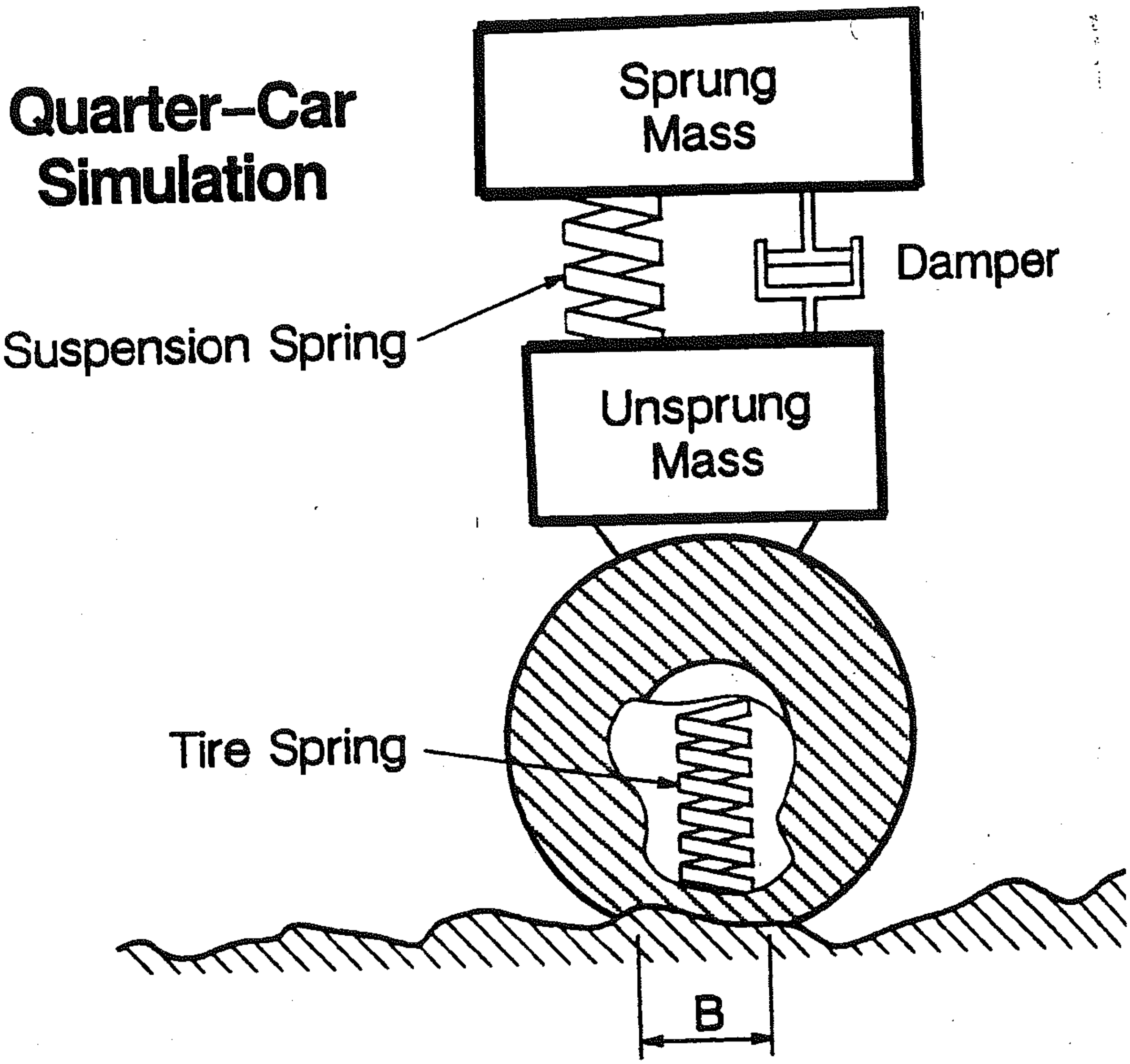


Figure B.2: Quarter Car Simulation for IRI

Appendix C

Figure C.1 – Projected Average Ride Quality

Figure C.2 – Projected Distress Index

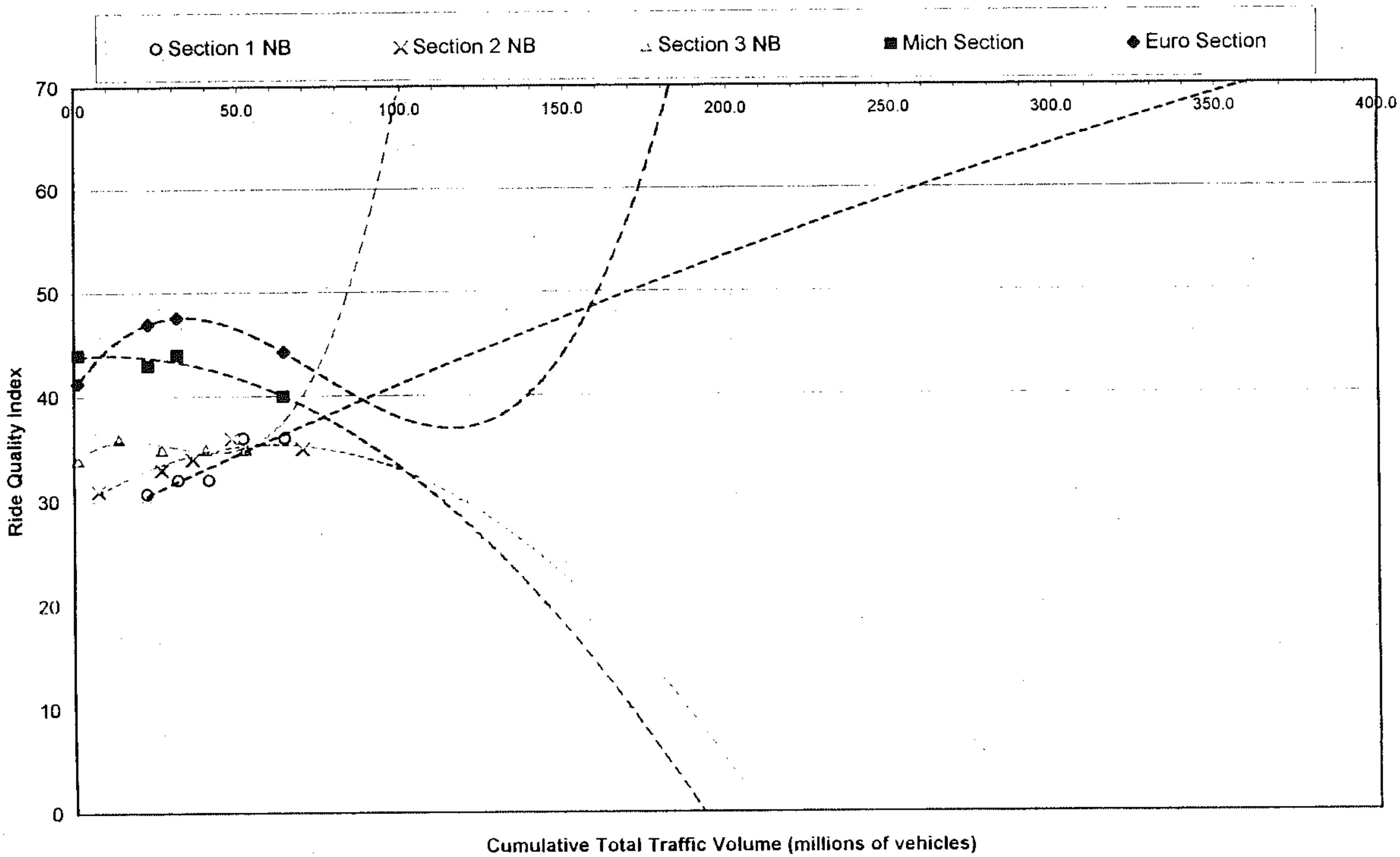


Figure C.1: Projected Average Ride Quality Index vs. Cumulative Traffic

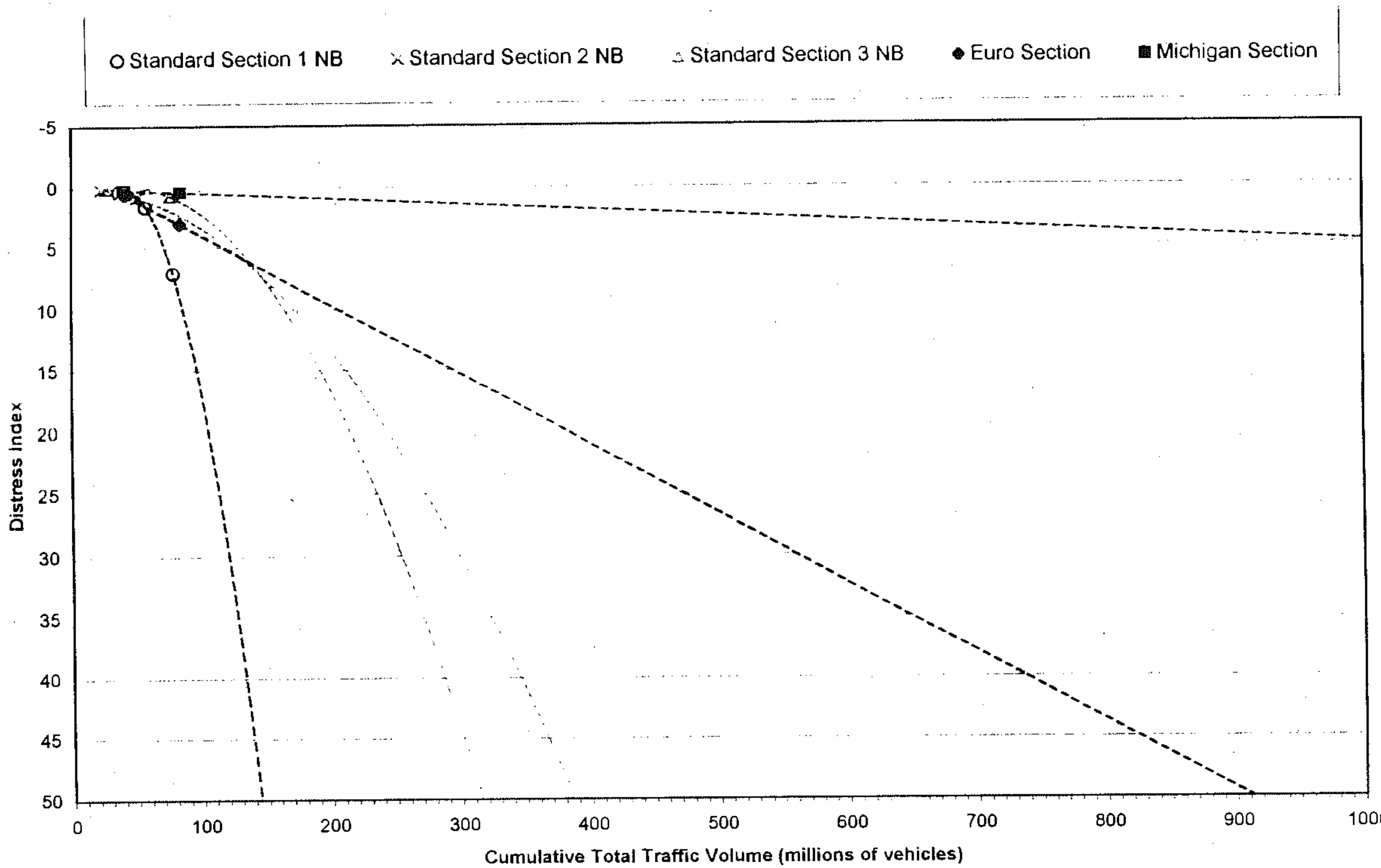


Figure C.2: Projected Distress Index vs. Cumulative Traffic