

**MICHIGAN DEPARTMENT OF TRANSPORTATION
M•DOT**

**Specifications
for
European Concrete Pavement**

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MATERIALS and TECHNOLOGY DIVISION

**TESTING AND RESEARCH SECTION
CONSTRUCTION AND TECHNOLOGY DIVISION
RESEARCH REPORT NO. R-1463**

**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**

**Michigan Transportation Commission
Barton W. LaBelle, Chairman;
Richard T. White, Vice-Chairman;
Jack L. Gingrass, Robert M. Andrews,
Irving J. Rubin, John C. Kennedy
Patrick M. Nowak, Director
Lansing, August 1993**



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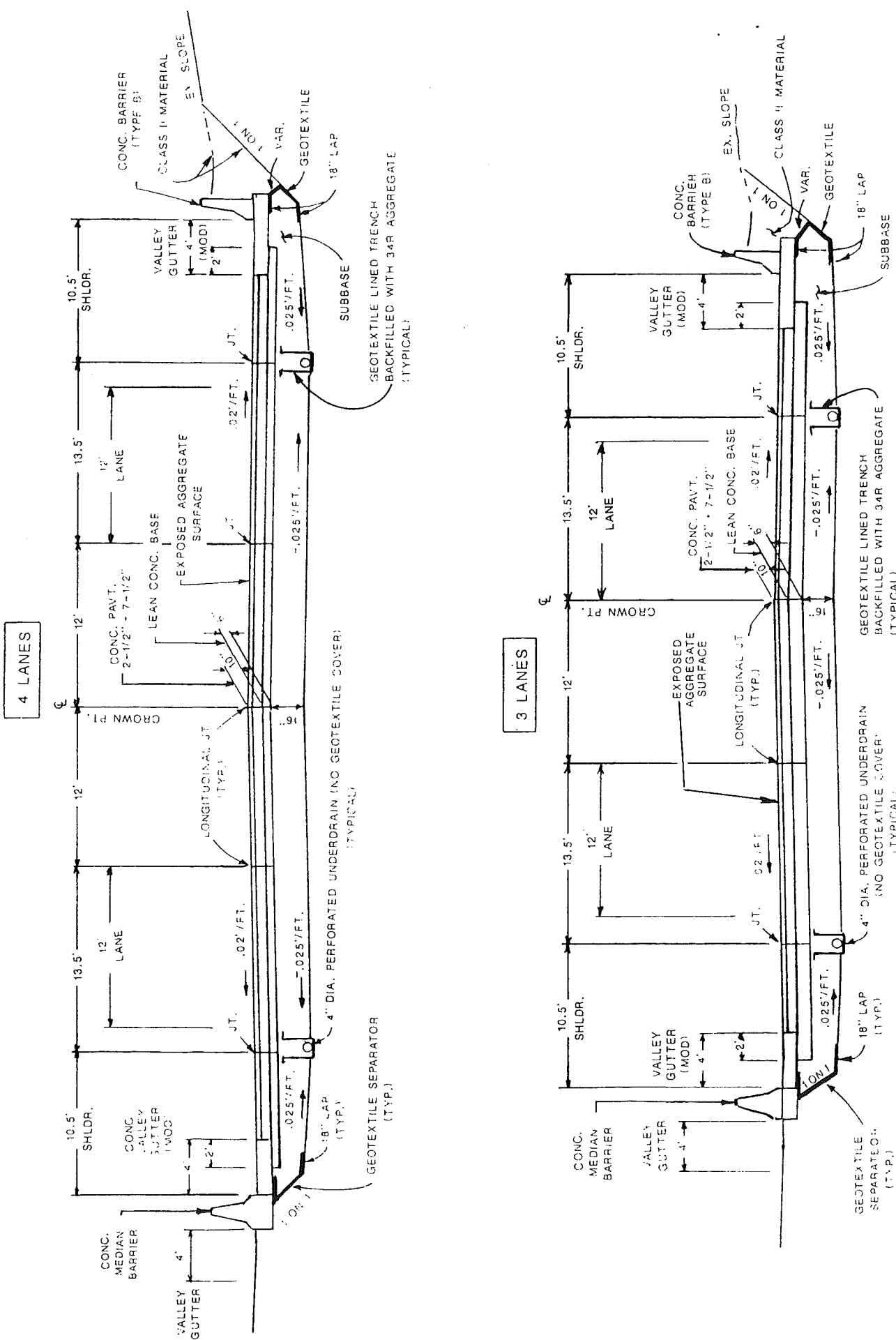


Figure 1. Typical cross-sections trial project.

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

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

M&T:RDT

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04-27-93

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 $1.3 \text{ mm} \pm 0.20 \text{ mm}$ ($0.05 \text{ in.} \pm 0.008 \text{ in.}$). 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

<u>Sieve Size</u>	<u>Percent Passing, By Weight</u>
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
Waterford, MI 48329
Phone 313-623-9567

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

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

M&T:RDT:RVP

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04-02-93

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 $\pm 1/2$ 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)

M&T:RDT:RVP

1 of 2

03-18-93

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.

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:

<u>ITEM</u>	<u>PROJECT</u>	<u>JOB NO.</u>	<u>PARTS</u>	<u>FED NO.</u>	<u>FED ITEM</u>
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)

M&T:SPB:RVP

1 of 3

04-02-93
IM 82251-30613A

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.

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

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

M&T:RDT:RVP

1 of 1

.03-18-93

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)

M&T:DLS:RVP

1 of 2

03-18-93
IM 82251-30613A

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					%Loss by Washing
	1-3/4"	1"	1/2"	#8	#30	
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 $\pm 3/4$ 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)

M&T:RDT

1 of 17

11-09-92

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 permission 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)

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

In which

Σ = Summation

X_i = 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)

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

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.

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)

Q	Variability-Unknown Procedure									
	Standard Deviation Method									
	Sample Size									
	6									
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)

Q	Standard Deviation Method									
	Sample Size 7									
	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)

Q	Variability-Unknown Procedure									
	Sample Size 8									
	Standard Deviation Method									
	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)

Q	Variability-Unknown Procedure										Standard Deviation Method									
	Sample Size 9																			
	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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	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)

Q	Variability-Unknown Procedure									
	Standard Deviation Method									
	Sample Size									
	10									
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.

MICHIGAN
DEPARTMENT OF TRANSPORTATION
BUREAU OF HIGHWAYS

SPECIAL PROVISION
FOR
PAY ADJUSTMENTS

M&T:RDT

1 of 1

01-27-93

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

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

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:

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

where:

- L_c = 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

<u>Function</u>	<u>Time (Minutes)</u>	<u>Sample Tank Air/Water Temp (°F)</u>	<u>Beam (At Center) Temp (°F)</u>
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
Stop Cooling	100	0	+2
	105	0	+1
Flood Sample Tank	110	0	+0
	112	(Air/Water Transition)	+0
	120	+34	+25
	130	+37	+33
	140	+39	+37
	150	+40	+39
	160	+40	+40
	170	+40	+40
Empty Sample Tank	170	+40	+40
Start Cooling	180	+40	+40

Note: There is a $\pm 3^\circ\text{F}$ 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) = $\frac{E' \times 100}{\text{no. of cycles completed}}$

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

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"
Absorption, %		Soft Particles, %	0.7
24-Hour Soak	1.59	Chert, %	0.2
Vacuum-Saturation	1.81	Sum of Soft & Chert, %	0.9
Crushed Material in sample, %	76	Unit Weight of Agg. (dry, loose)	
Los Angeles Abrasion, % of wear	24	lb/ft ³	95

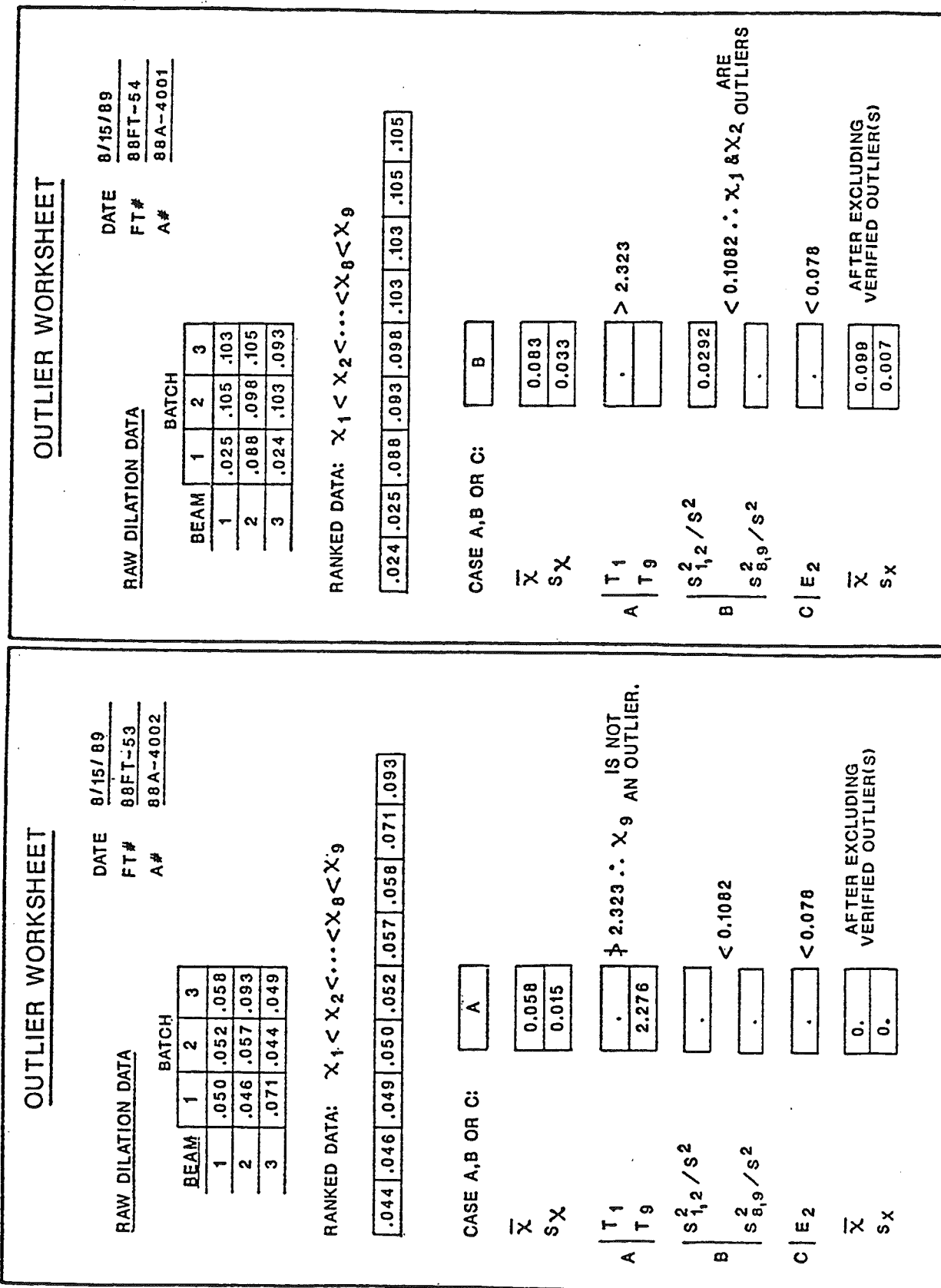
CONCRETE MIX DATA	BATCH NUMBER			
	1	2	3	Average
Date Made	6/9/87	6/11/87	6/16/87	
Slump, Inches	2-1/2	2-1/2	3	2-3/4
Unit Weight of Concrete, lb/ft ³	144.5	145.6	143.7	144.6
Actual Cement Content, lb/yd ³	514	517	513	515
Water-Cement Ratio, by weight	0.46	0.45	0.44	0.45
Air Content, %	7.6	7.4	7.6	7.5

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



(a)

(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 its 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, Cm².

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

$$N_e = 1 - V_v [(G_v \times W_e) + 1]$$

6.7 Permeability, Effective Porosity Ratio

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

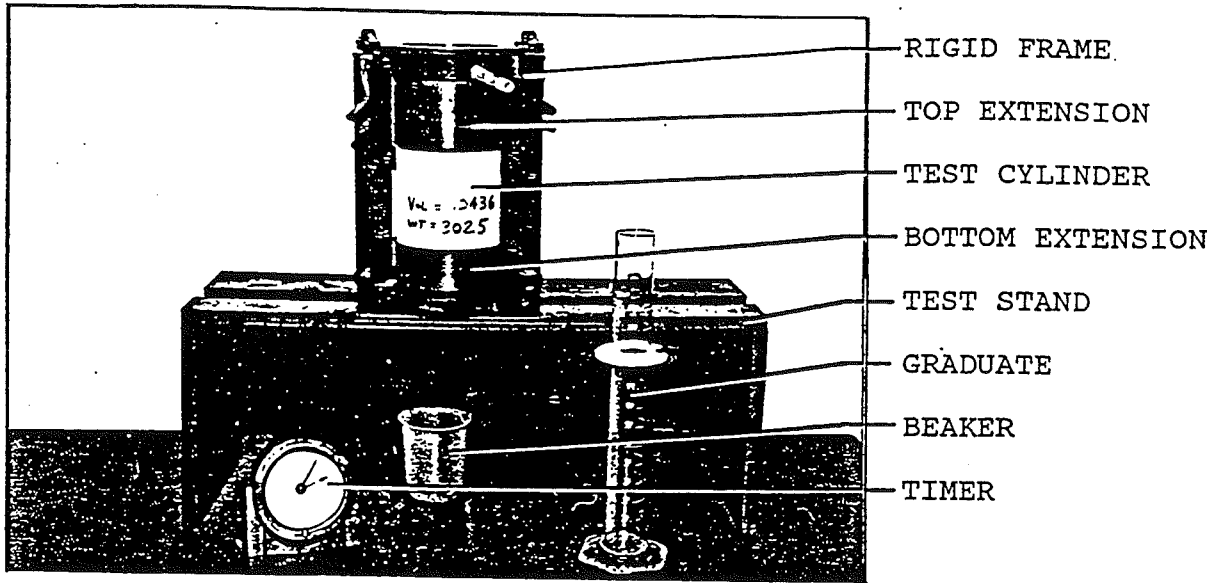


Figure 1. Permeability test assembly.

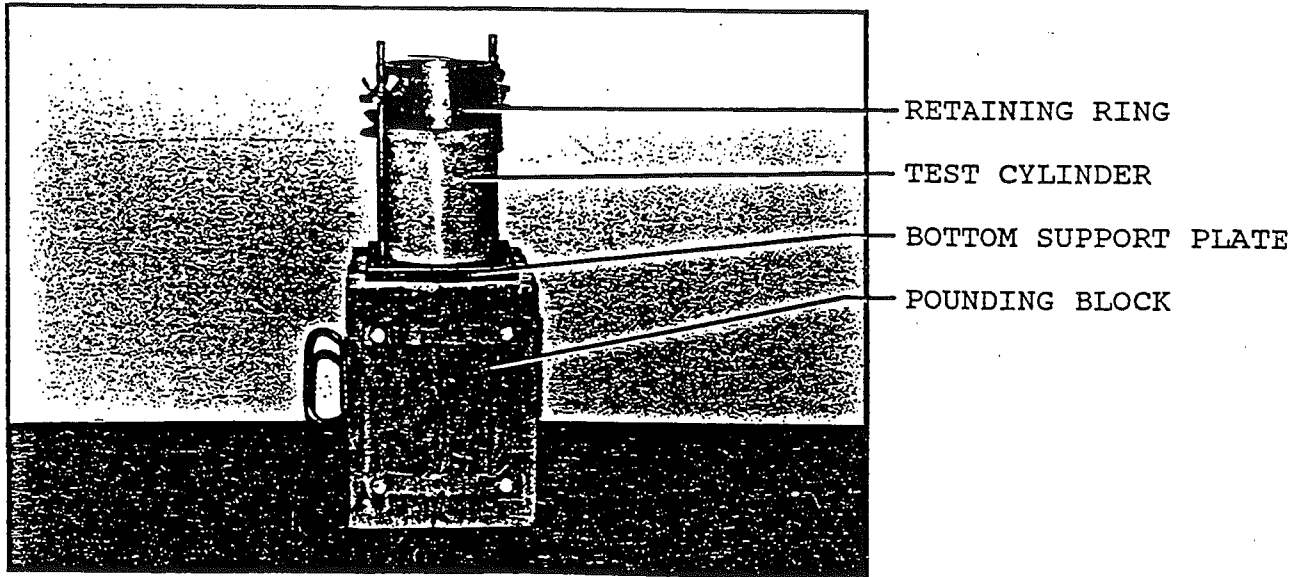


Figure 2. Permeability compaction assembly.