5-5110 Implementation Training Workshop for Best Practices for Repairing Spalls in Concrete Pavements

Agenda

January 8, 2008

9:00 Part 1 – Engineers and Planners

- Introductions
- Preparation of Surface
- Materials
- Effect of Thermal Coefficient and Modulus of Elasticity
- Evaluation of Field Repairs
- Environmental and Safety Considerations
- Mixing and Placing
- Material Requirements
- Material Selection Process
- Reference Materials
- Where Do We Go From Here?

11:00 Part 2 – Maintenance Supervisors and Inspectors

- Introductions
- Preparation of Surface
- Materials
- Evaluation of Field Repairs
- Environmental and Safety
- Mixing and Placing
- Summary of Materials
- Reference Materials
- Where Do We Go From Here?

IPR 5-5110
Repair of Spalls in ConcretePavements

Training for Maintenance Supervisors and Inspectors

Training Session for Maintenance

- Part of the implementation effort of 5110
- 5110 was a one-year study that had the objective of identifying appropriate repair materials for spalls in concrete pavements

Objective

- To provide you with the information that will enable you to make repairs of spalls in concrete pavements.

CTR/TTI Support for You

- David Fowler and David Whitney of CTR and Dan Zollinger of TTI will conduct the training sessions and will provide technical support for you.
- We will attend some of the training sessions that you conduct to offer our assistance.
- We will be available to help you at any time during the next year as you implement this research.

Additional Resources

- We will provide you with a notebook that contains:
  - TxDOT specifications
  - Copies of slides for training engineers and maintenance personnel.
  - 5110 report

Outline of Presentation

- Introduction
- Preparation of repair area
- Types of repair materials
- Mixing and placing materials

Preparation of Repair Area

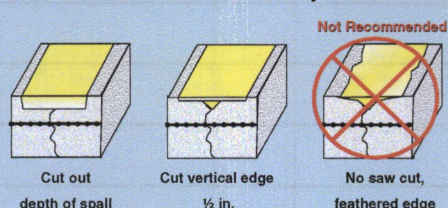
- Remove old concrete or repair material
- Chip with light hammer all loose concrete

Preparation

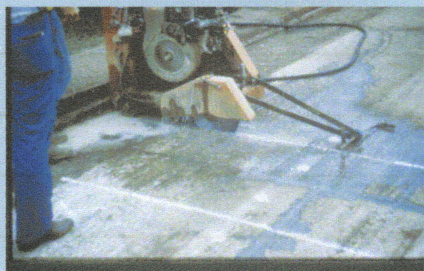
- **Saw Cut vs Non-Saw Cut**
  - Generally the repairs are less likely to spall at the edge if a saw cut is used.
  - Most repair materials, particularly the non-polymers, do not perform well when feather edge is used.
  - TxDOT 720 requires a 1 ½-in. deep vertical cut around repairs when using hydraulic cements.
  - The disadvantage is the extra step in the repair process and associated cost

Surface Preparation

- Saw cut as needed for non hydraulic cements



Saw Cutting



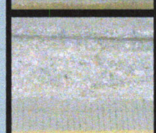
Concrete Removal

- Chipping hammers less than 15 lbs or hydro-demolition equipment should be used.
- Heavier chipping hammers can damage the concrete below the surface or around the perimeter.

Preparation of Repair Area

- Sandblast and blow out spall area

Before



After

Sandblast precautions

- If air compressors are used, care should be taken to ensure that an oil trap is used to prevent an oil film from being placed on the surface of the repair that could prevent good bond.

Steel Replacement

- Clean all rebars of scale or other materials that could reduce bond.
- Replace or lap new rebars when 25% or more of the bar cross section has been lost due to corrosion or cutting.

Preparation of Repair Area

- Prime Surface (If required by manufacturer)
  - Required by:
    - Fibrescreed
    - Delpatch
    - FlexKrete
    - Wabo ElastoPatch
    - Flexpatch – Only if repair is less than 1" deep.

Repair Materials Choices

- **Non-Hydraulic Cement Products-**
  - Must meet TxDOT DMS 6170, Polymeric Materials for Patching Spalls in Concrete Pavement
  - Pre approved list, polyptch, from CST M&P.
- **Hydraulic Cement Products**
  - Must be approved by CST M&P, too.
  - Still working on DMS 4655, Rapid Hardening Cementitious Materials for Patching Concrete Pavement

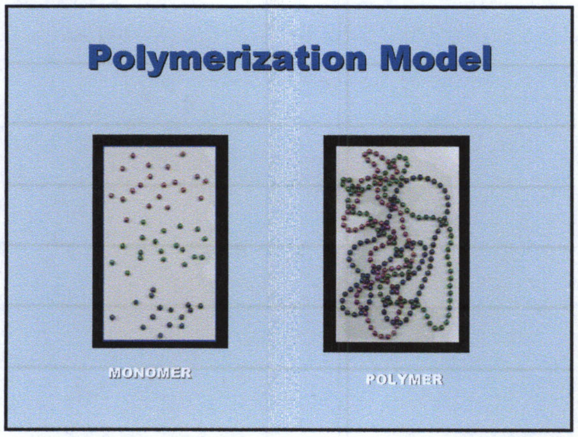
Types of Materials

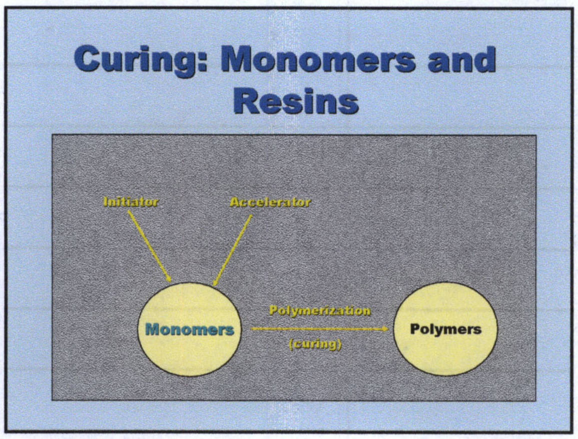
- **Polymeric (Polyurethane, Vinyl Esters, Epoxy)**
- **Many different brand names:**

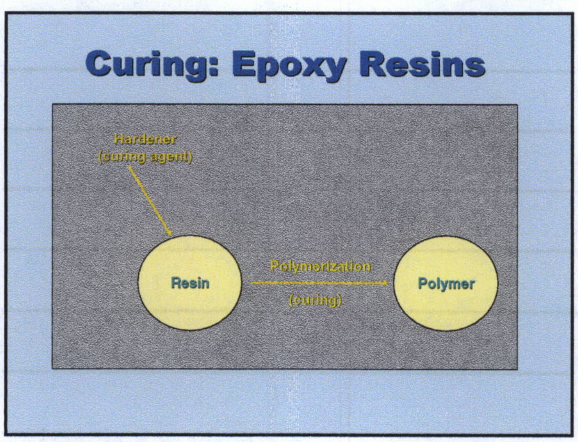
  FlexKrete – Vinyl Ester
  FlexPatch – Epoxy
  Delpatch – Polyurethane
  Wabo ElastoPatch – Polyurethane
  RSP - Polyurethane

What are polymers?

- **They are made from combining two or more chemicals to produce a long chain molecule.**
- **They start as individual molecules, similar to individual beads for a necklace, called resins or monomers.**
- **When they cure, all the molecules link together to form a very long necklace-like chain, with several thousand molecules.**


Polymerization Model
MONOMER
POLYMER


Curing: Monomers and Resins
Initiator
Accelerator
Monomers
Polymerization
(curing)
Polymers


Curing: Epoxy Resins
Hardener
(curing agent)
Resin
Polymerization
(curing)
Polymer

POLYMERIZATION (CURING)

- The key is to get them to link together at just the right speed so the polymer doesn't cure too fast or too slow.
- For repairs, the resins are mixed with curing agents, sometimes called hardeners, and with aggregate, usually sand and sometimes pea gravel.
- Just like concrete, retarders and accelerators can be added to control the curing time

POLYMER CONCRETE

- The resulting material is called polymer concrete—aggregate glued together with polymers, or plastics.
- Polymer concrete is very durable, water tight, and wear resistant.
- It bonds very well to dry concrete—but that is important—usually the aggregate and concrete need to be dry.
- Some of the polyurethanes are different—they can work with wet surfaces and wet aggregate.

POLYMER CONCRETE

- Polymer concrete can be made very flexible (ability to stretch without breaking—think of chewing gum!) which is better for repairs than a very brittle material which cracks easily.
- Most of the polymer concretes we will be talking about are very ductile, but hard enough to wear well.

Polymer Concretes

- But there are no free lunches—polymers cost a lot more than portland cement.
- But their ability to bond and stay in the repair without cracking may make them very cost effective.
- When you make a repair you don't want to be going back any time soon.
- So material costs may not be nearly as important for repairs as for new construction.

Types of Materials

- Modified Bitumen
  - Fibrescreed – a hot applied synthetic polymer modified resin compound containing mineral fillers, chopped fibers, sand and graded granite aggregate.

Requirements

- Fiberscreed requires special equipment to heat the bitumen, similar to making hot mix.
- The repair material is basically asphalt based.
- It will not have the strength or wear resistance of most of the other repair materials.

Types of Materials

- Rapid Setting Cement
  - Rapid Set
    - Chemically 33% calcium sulfo-aluminate and 67% di-calcium silicate.
    - Add water per instructions to activate.

Types of Materials

- Magnesium Phosphate
  - EucoSpeed
  - Pavemend
  - MgKrete

What is magnesium phosphate?

- Magnesium phosphate is a special chemical that reacts with water and sets very quickly.
- It is mixed with aggregate very similar to portland cement.
- In hot weather, it has to be retarded or it will set faster than it can be placed and finished.

Costs

- Material costs
- Labor and installation costs
- Maintenance and life time costs

Cost and Storage life

Material:	Approximate Material Price (per cubic foot)	Storage Life (years)
Wabo ElastoPatch (Elastomeric)	$160.00	1
Delpatch (Elastomeric)	$145.00	2
RSP (Elastomeric)	$52.00	0.5
Fibrescreed (Elastomeric)	$101.00	2
FlexKrete (Semi-Rigid)	$110.00	0.5
FlexPatch (Semi-Rigid)	$115.00	2
RapidSet (Semi-Rigid)	$26.00	1
EucoSpeed (Semi-Rigid)	$43.00	1
Pavemend (Semi-Rigid)	Not Available	3

Results of Field Evaluations

- Houston
- I 35 near Alvarado in Ft. Worth District

Field Evaluation - Houston

Cores taken to determine field bond strength of three different products: WaboCrete, Fibrescreed, Delpatch, FlexPatch


Delpatch hole

Results were inconclusive due to the limited field samples available for testing, and the failure modes. (Only one material failed at the bond line)


Delpatch core

- However, visual evaluations of many repairs over a period of about six years in Houston indicate that the low modulus repair materials, particularly urethanes, have performed extremely well.
- In many, even most, cases, the crack at the bottom of the spall has not reflected through the urethane repair material after several years in place.

Field Evaluation- I-35 Alvarado

- Manufacturers' representatives placed five repair materials in tracks made in fresh concrete pavement by a motorist.
- Original repair material lasted several years, was removed, and new materials were placed in summer 2005
- This evaluation occurred one year after placement.

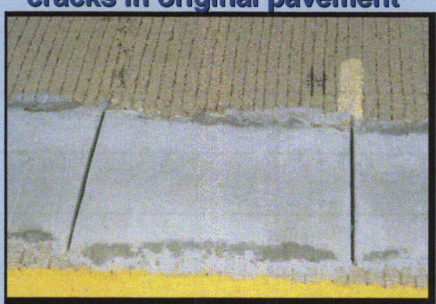
Alvarado Repair Test Section
One year after placement

- Polymer Concretes
  - Delpatch (polyurethane)
  - FlexPatch (epoxy)
- Magnesium Phosphates
  - EucoSpeed
  - Pavemend
  - MgKrete
- Materials placed by manufacturers' reps so that there was no question that they were placed properly.

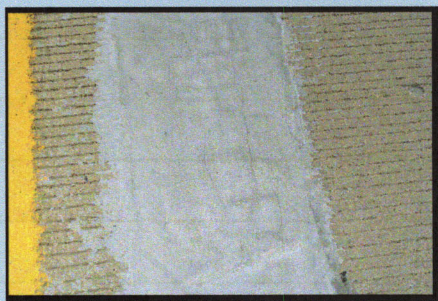
Magnesium Phosphates

- Pavemend
- EucoSpeed
- MgKrete

Pavemend- note formed joints at cracks in original pavement

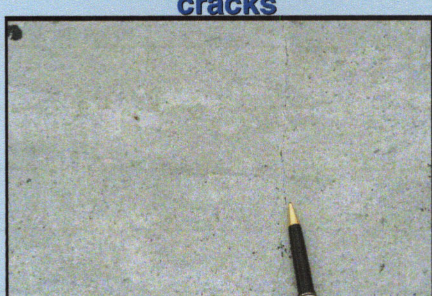


Pavemend- note cracking



Pavemend- cracks at boundary

Pavemend—closely spaced cracks

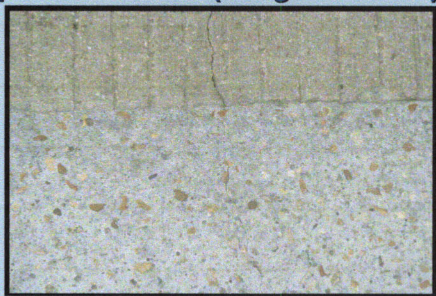


Pavemend- severe cracking

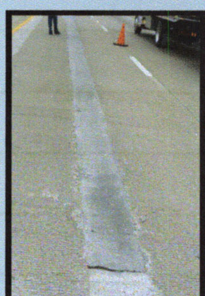
Pavemend- surface spalling

EucoSpeed- placed in rain

EucoSpeed- reflective cracking, placed in rain (rough surface)



EucoSpeed- placed after rain

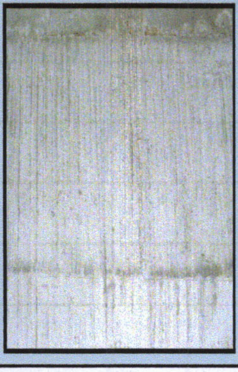


EucoSpeed- note reflective cracking

EucoSpeed- note cracking

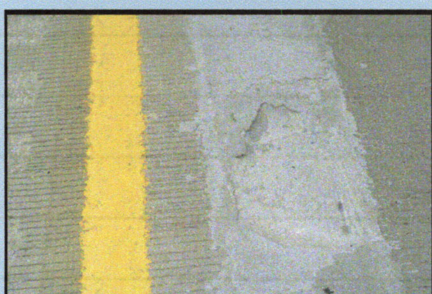
EucoSpeed- cracks at boundaries

MgKrete



MgKrete- note blisters and cracks

MgKrete- severe spalling



MgKrete- cracking and spalling

MgKrete- cracking and spalling

MgKrete- cracking

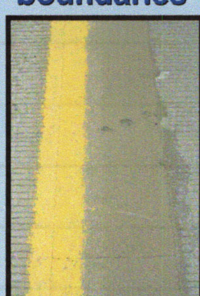
Polymer Concretes

- **FlexPatch**- Epoxy Polymer Concrete
- **Delpatch**- Polyurethane Polymer Concrete

FlexPatch

FlexPatch- in about 100 ft., one transverse crack

FlexPatch- continuous crack at boundaries



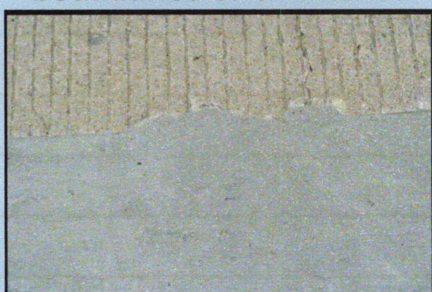
FlexPatch

FlexPatch- crack at intersection with MgKrete

Delpatch

Delpatch- excellent condition

Delpatch- no cracking at boundaries or on interior



Summary of Performance

- **Delpatch**- clearly performed the best. No cracks, spalling or other signs of distress. Estimated life- Minimum of 15-20 years
- **FlexPatch**- only one transverse crack, no spalling or other interior cracking, but continuous cracks at boundaries. Estimated life- 4-5 years
- **EucoSpeed**- developed spalls when installed during rain. Fine cracks in interior and along some boundaries even when installed dry. Estimated life- 4-5 years.

- **Pavemend**- considerable cracking and some surface spalling. Estimated life - 3 to 4 years

- **MgKrete**- Considerable surface spalling; blisters formed on surface during placement and later developed spalls. Considerable cracking. Estimated life - 2 to 3 years

Conclusions

- Polyurethane polymer concrete, Delpatch, clearly outperformed all other materials. This has been confirmed in the Houston District where repairs have been in place for 5 years or more and show no signs of distress. The excellent performance is due to the very low modulus, high elongation and excellent bond.

- The FlexPatch, which is an epoxy polymer concrete, looked very good except for continuous cracks along the boundary which are likely to result in failure within 5 years.

- The magnesuim phosphates developed significant cracking and spalling. The EucoSpeed has finer cracks than the others. MgKrete was clearly the poorest performer of all materials tested at the site. The poor performance of these materials is due to the high modulus and low ductility.

Environmental and Safety Considerations

- Environmental:
  - Clean up:
    - Magnesium Phosphates and Rapid Setting Mixes
      - Clean up with water
    - Delpatch
      - Denatured alcohol
    - Flexkrete
      - Acetone
    - Flexpatch
      - Any solvent such as mineral spirits
    - RSP and Wabo ElastoPatch
      - Not specified

Environmental and Safety Considerations (Continued)

- Proper Disposal of Materials
  - Magnesium Phosphates and Rapid Setting Mixes
    - Normal disposal of unused product
  - Urethanes
    - Special disposal of unmixed product

Environmental and Safety Considerations

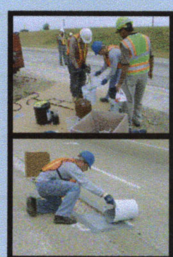
- Safety
  - Hard hats
  - Steel-toed boots
  - Safety glasses
  - Back support belts
- Urethanes
  - Latex gloves
  - Well ventilated area or respirator protection

Effects of Weather

- **Temperature**
  - Cool temperatures retard and slow down cure
  - Warmer temperatures accelerate cure time, and may cause blistering or cracking.
- **Moisture**
  - Urethane materials do not like water contamination. Surface must be kept dry.

Mixing and Placing

- **Delpatch:**
  - Mix 3000 ml part "A" component with 1500ml part "B" component for 10 seconds. Add pre-bagged, very dry aggregate and mix an additional minute
  - Pour material into spall
  - Texture surface with trowel



Mixing and Placing

- **FlexKrete:**
  - **Mix 1gallon of FlexKrete with 1.2 oz of catalyst*. Mix for 30 to 60 seconds. Add 3 to 4 gallons of sand and mix thoroughly for 2 minutes.**
  - **Pour material into spall**
  - **Trowel into place**

*Caution to prevent chemical burns

Mixing and Placing

- WaboElastoPatch:
  - Mix part "A" component with "B" in a 1:1 ratio for 2 minutes. Add packaged aggregate and mix an additional 2 minutes until well blended.
  - Pour material into spall.

Mixing and Placing

- FlexPatch:
  - Mix prepackaged part "A" component with "B" for 3 minutes. Slowly add "C" component (aggregate) and "A-B" liquid until well blended.
  - Pour material into spall.
  - Finish with steel trowel.

Mixing and Placing

- RSP:
  - Place aggregate into spall area.
  - Mix part "A" component with "B" component in 1:1 ratio.
  - Pour material over aggregate in spall.
  - Apply sand to top of repair.

Mixing and Placing

- EucoSpeed:
  - Add 0.4 to 0.5 gallons of water to 50-lb. bag of Material. Mix for 2 minutes. May extend with an additional 30 lbs of pea gravel, mix an additional minute.
  - Pour material into spall.
  - Trowel material, broom finish.

Mixing and Placing

- Pavemend 15:
  - Add 1.0 gallon of water to 45-lb bucket of material. Mix until temperature has reached 95 degrees.
  - Pour material into spall.

Mixing and Placing

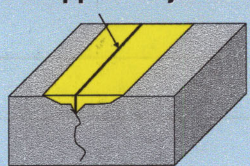
- Rapid Set:
  - Add 3 to 5 quarts of water for each 60-lb bag of material. Mix for 2 minutes. Mix 1 to 3 minutes until of uniform consistency
  - Pour material into spall.
  - Trowel, float or broom finish.

Mixing and Placing

- FibreScreed:
  - Material placed by contractor with proper equipment.
    - Place packaged material in machine.
    - Once material at proper temperature (375 to 380 degrees) apply to spall area in 2" lifts. Add ¾" bulking stone with each lift. Continue until flush with surface.
    - Apply aggregate topping coat for skid resistance. (larger aggregates make for noisier ride)

Mixing And Placing

- Reestablish joint for **Rigid Materials** (saw cutting through depth of patch, then fill with approved joint sealer)



Set Time

- **Many products have additional additives which can speed up, and slow down set times and workability.**
- **Many companies also produce different formulations for different temperatures which affect set time.**

Material:	Initial Set Time (minutes)
Wabo ElastoPatch	22
Delpatch	60
RSP	6
Fibrescreed	**
FlexKrete	8
FlexPatch	63
RapidSet	24
EucoSpeed	17
Pavemend	13

** Not chemically activated, temperature controlled

Curing and Return to Traffic

Material:	Return to traffic at 75 to 80°
Wabo ElastoPatch	1 hr
Delpatch	1 hr
Fibrescreed	15 min – 1 hr
FlexKrete	1.5 hrs
FlexPatch	1 – 2 hrs
RapidSet	1 hr
EucoSpeed	1 hr
Pavemend	1.5 hrs

Summary: Polymer Materials

Material	Flexibility	Moisture Sensitivity	Ready for traffic	Cost, cu. ft.
Wabo EP	Flexible	Yes	1 hr.	$160
Delpatch	Flexible	Yes	1 hr.	$145
RSP	Semi flex	Yes	1 hr.	$52
Flexpatch	Flexible	Some	1-2 hrs.	$115
FlexKrete	Semi flex	Yes	1.5 hrs.	$110

Summary: Mag Phosphate, PCC, Asphalt

Material	Flexibility	Moisture Sensitivity	Set Time	Cost, Cu. ft.
EucoSpeed	Brittle	Yes	1 hr.	$43
Pavemend	Brittle	Yes	1.5 hrs.	N/A
MgKrete	Brittle	Yes	1 hr.	
Rapid Set	Brittle	No	1 hr.	$26
Fibrescreed	Flexible	Yes	¼-1 hr.	$101

Spall Repair Options

Weather	Spall Type	Materials	Comments
(San Diego, CA?) 55F<Temp<95F	Shallow < 3 in.	Type I – Flexible FlexKrete DelPatch WaboElastopatch Flexpatch	FlexKrete, DelPatch, WaboElastopatch: surface must be dry (compressed air) Flexpatch → OK on damp surface
55F<Temp<95F	Deep > 3 in.	Type I – Flexible (listed above) Type II – Rigid Eucospeed Rapid Set	Recommended (extend with CA, but still higher cost) Lower cost alternatives

Table based on studied materials only. Always consult with TxDOT CST P&M for their list of approved materials or to evaluate promising new materials.

Spall Repair Options

Weather Conditions	Spall Type	Material Type	Specify/ Choices
COLD < 55F	Shallow	Type I – Flexible FlexKrete DelPatch WaboElastopatch	surface must be dry (compressed air)
COLD < 55F	Deep	Type I – Flexible FlexKrete DelPatch WaboElastopatch Type II – Rigid Eucospeed, Rapid Set	Recommended with added CA (still more costly) Less expensive alternate

Table based on studied materials only. Always consult with TxDOT CST P&M for their list of approved materials or to evaluate promising new materials.

Spall Repair Options

Weather Conditions	Spall Type	Material Type	Specify/ Choices
HOT>95F	Shallow	Type I – Flexible Flexpatch FlexKrete DelPatch WaboElastoPatch	Dry Surface
HOT>95F	Deep	Type I – Flexible Flexpatch FlexKrete DelPatch WaboElastoPatch Type II – Rigid Eucospeed, Rapid Set	Recommended with added CA (still more costly) Less Costly alternative

For Emergency Repairs

- **Sudden-problem pavement spalls-**
  - Keep small stock of moisture-insensitive, low-modulus, epoxy mortar concrete-patching system for repairs above 55F. Polyurethanes and Polyesters can more easily accommodate dry temperature extremes.
  - For deep spalls keep bags of dried ½-inch coarse aggregate to extend the mortar (as per manufacturers instructions).
  - Cool weather bring matls to room temp. over night.
  - Make repairs at temperatures above 50F on sound, clean, and dry or minimally damp substrates.
- **Use for emergencies on bridge decks, too.**

Questions?

IPR 5-5110
Repair of Spalls in Concrete Pavements

Training for Engineers

Training Session for Engineers

- Purpose: To provide training required to train personnel to select the appropriate repair materials and to specify the repair procedures
- Part of the implementation effort of 5110

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Resources

- You will be given a folder of resource materials:
  - Slides for presentation
  - Handouts
  - Evaluation forms
  - TxDOT specifications

3

Outline of Presentation

- Preparation of repair area
- Materials
- Field tests
- Selection of materials

4

Preparation of Repair Area

- Remove old concrete or repair material
- Chip with light hammer all loose concrete

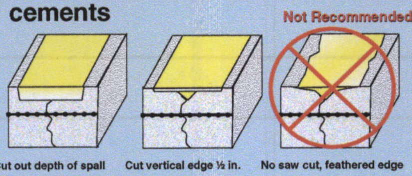
Preparation

- **Saw Cut vs Non-Saw Cut**
  - Generally the repairs are less likely to spall at the edge if a saw cut is used.
  - Most repair materials, particularly the non-polymers, do not perform well when feather edge is used.
  - TxDOT 720 requires a 1 ½-in. deep vertical cut around repairs when using hydraulic cements.
  - The disadvantage is the extra step in the repair process and associated cost

6

Surface Preparation

- Saw cut as needed for non hydraulic cements



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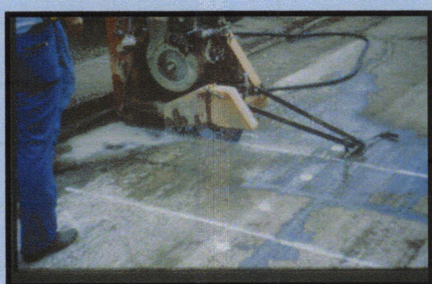
Saw Cutting



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Concete Removal

- Chipping hammers less than 15 lbs or hydrodemolition equipment should be used for removing concrete.
- Heavier chipping hammers can damage the concrete below the surface or around the perimeter.
- Hydrodemolition requires a great deal of water which may have to be captured and will also produce a wet surface that may have to be dried before some materials can be applied.

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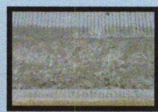
Preparation of Repair Area

- Sandblast and blow out spall area



Before

After

10

Sandblast Precautions

- If air compressors are used, care should be taken to ensure that an oil trap is used to prevent an oil film from being placed on the surface of the repair that could prevent good bond.

11

Moisture Condition of Surface

- Normally the surface should be dry.
- For hydraulic cements (those that have water in the mix) can normally be damp or SSD
- Most polymers should be dry. Blow surface with air or lightly dry with a torch.

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Steel Replacement

- Clean all exposed rebars (if any) of scale or other materials that could reduce bond.
- Replace or lap new rebars when 25% or more of the bar cross section has been lost due to corrosion or cutting.

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Preparation of Repair Area

- Prime Surface (If required by manufacturer)
  - Required by:
    - Fibrescreed
    - Delpatch
    - FlexKrete
    - Wabo ElastoPatch
    - Flexpatch – Only if repair is less than 1" deep.

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Repair Materials

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Types of Materials

- Polymeric (Polyurethane, Vinyl Esters, Epoxy)
- Many different brand names:

FlexKrete – Vinyl Ester
FlexPatch – Epoxy
Delpatch – Polyurethane
Wabo ElastoPatch – Polyurethane
RSP - Polyurethane

16

What are Polymers?

- They are made from combining two or more chemicals to produce a long chain molecule.
- They start as individual molecules, similar to individual beads for a necklace, called resins or monomers.
- When they cure, all the molecules link together to form a very long necklace-like chain, with several thousand molecules.

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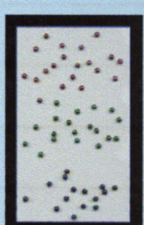
Polymerization Model



MONOMER

POLYMER

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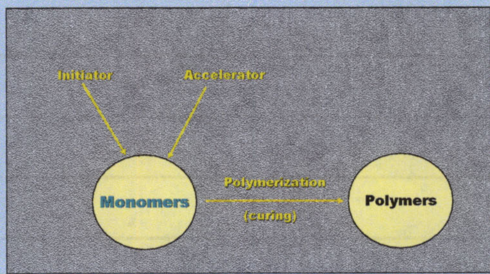
Curing: Monomers and Resins



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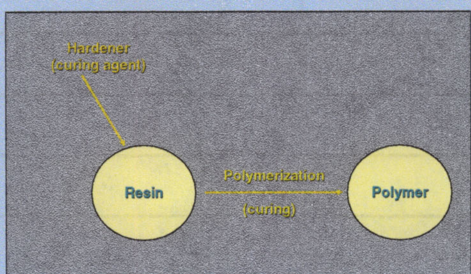
Curing: Epoxy Resins



20

Polymerization (Curing)

- The key is to get them to link together at just the right speed so the polymer doesn't cure too fast or too slow.
- For repairs, the resins are mixed with curing agents, sometimes called hardeners, and with aggregate, usually sand and sometimes pea gravel.
- Just like concrete, retarders and accelerators can be added to control the curing time

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Polymer Concrete

- The resulting material is called polymer concrete—aggregate glued together with polymers, or plastics.
- Polymer concrete is very durable, water tight, and wear resistant.
- It bonds very well to dry concrete—but that is important—usually the aggregate and concrete need to be dry.
- Some of the polyurethanes are different—they can work with wet surfaces and wet aggregate.

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Polymer Concrete

- Polymer concrete can be made very flexible (ability to stretch without breaking—think of chewing gum!) which is better for repairs than a very brittle material which cracks easily.
- Most of the polymer concretes we will be talking about are very ductile, but tough enough to wear well.

23

Polymer Concrete

- But there are no free lunches—polymers cost a lot more than portland cement.
- But their ability to bond and stay in the repair without cracking may make them very cost effective.
- When you make a repair you don't want to be going back any time soon.
- So material costs may not be nearly as important for repairs as for new construction.

24

Types of Materials

- Modified Bitumen
  - **Fibrescreed** – a hot applied synthetic polymer modified resin compound containing mineral fillers, chopped fibers, sand and graded granite aggregate.

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Requirements

- Fiberscreed requires special equipment to heat the bitumen, similar to making hot mix.
- The repair material is basically asphalt based.
- It will not have the strength or wear resistance of most of the other repair materials.

26

Types of Materials

- Rapid Setting Cement
  - **Rapid Set**
    - **Chemically 33% calcium sulfoaluminate and 67% dicalcium silicate.**
- Water is added to mix

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Types of Materials

- Magnesium Phosphate
  - EucoSpeed
  - Pavemend
  - MgKrete

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What is Magnesium Phosphate?

- Magnesium phosphate is a special chemical that reacts with water and sets very quickly.
- It is mixed with aggregate very similar to portland cement.
- In hot weather, it has to be retarded or it will set faster than it can be placed and finished.

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Costs

- Material costs
- Labor and installation costs
- Maintenance and life time costs

30

Laboratory Tests

- A laboratory test program was conducted to evaluate the program.
- Laboratory results were used to better understand the field performance.

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Results – Set Time Comparison

- Many products have additional additives which can speed up, and slow down set times and workability.
- Many companies also produce different formulations for different temperatures which effect set time.

Material:	Initial Set Time (minutes)
Wabo ElastoPatch	23
Delpatch	80
RSP	6
Fibrescreed	Temperature Dependent
FlexKrete	11
FlexPatch	55
RapidSet	23
EucoSpeed	17
Pavemend	13

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Material Classification

Products to Be Tested:	Type of Material	General Properties
RSP	Polyurethane Polymer Concrete	Semi Rigid
Delpatch	Polyurethane Polymer Concrete	Flexible
Wabo ElastoPatch	Polyurethane Polymer Concrete	Flexible
FlexPatch (SSI)	Epoxy Polymer Concrete	Semi Rigid
FlexKrete	Thermosetting Vinyl Polymer Concrete	Semi Rigid
EucoSpeed MP	Magnesium Polyphosphate	Rigid
MgKrete	Magnesium Polyphosphate	Rigid
Pavemend 15	Magnesium Polyphosphate	Rigid
Rapid Set	Hydraulic Cement	Rigid
Fibrescreed	Polymer Modified Bitumen	Flexible

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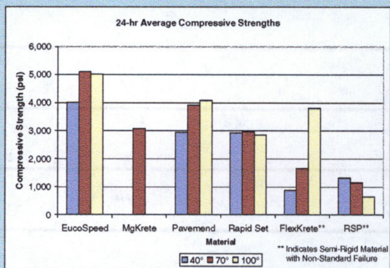
Results – Compressive Strengths

For Rigid and Semi-Rigid Materials at 24 hours



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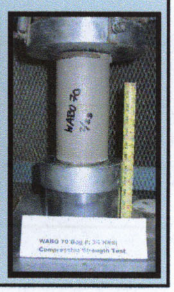
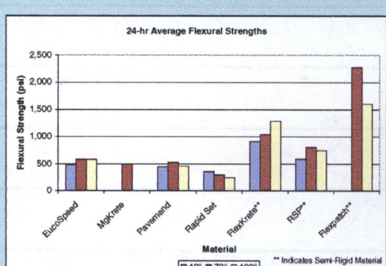
Results – Compressive Strengths

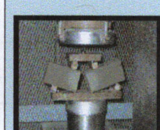
Found that "Flexible" and some "Semi-rigid' materials were too flexible for conventional tests



Results – Flexural Strengths

For Rigid and Semi-Rigid Materials at 24 hours





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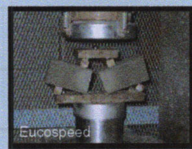
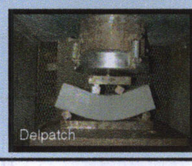
Results – Flexural Strengths

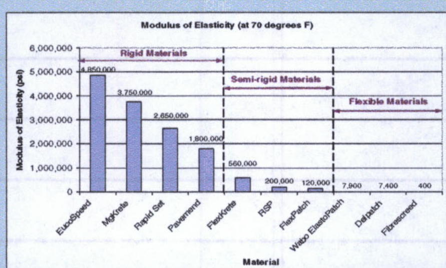
Found that some materials were too flexible for conventional tests

Only able to test 'Rigid' and 'Semi-rigid' materials





Results - Modulus



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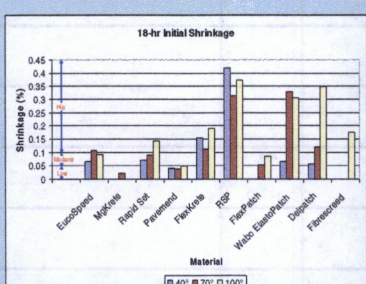
Results – Shrinkage



Rigid materials experienced low to moderate shrinkage values.

Semi-Rigid and flexible materials experienced moderate to high shrinkage values.

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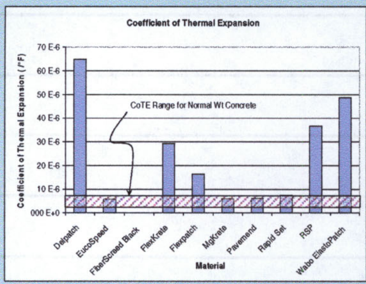
Results - COTE



Rigid materials experienced COTE which were comparable to normal concrete.

Semi-Rigid and flexible materials experienced COTE values which were 3 to 10 times the values of normal concrete.

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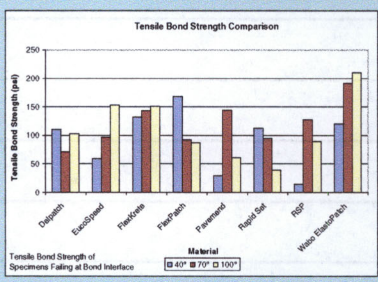
Results – Tensile Bond Strength



Results mixed, in some cases showed good performance from each category of material.

Difficult to get an consistent test of bond strength since bonding surface different for each spall

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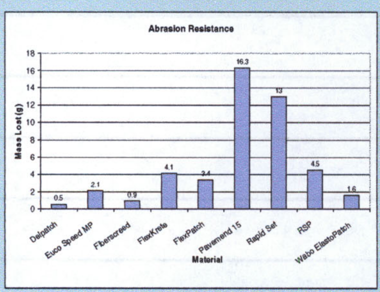
Results – Abrasion Resistance



Polymer concretes showed consistently good performance

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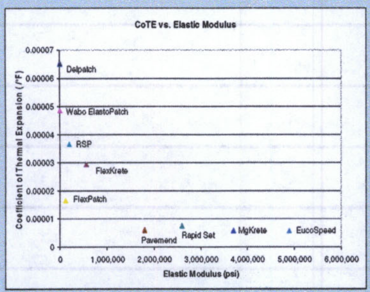
Discussion



Materials with low elastic moduli had correspondingly high COTE, and shrinkage values.

Materials with high elastic moduli had correspondingly low COTE and shrinkage values.

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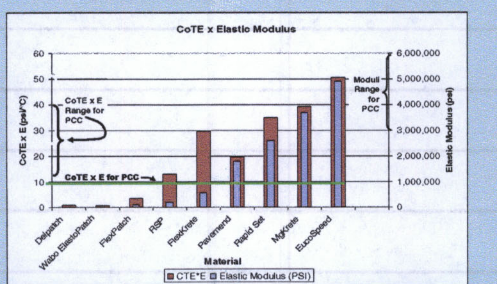
Discussion



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What Does Coefficient of Thermal Expansion and Modulus of Elasticity Have to Do with Repair Materials?

- A lot!
- May be the most important properties for repair materials

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COTE

- Coefficient of thermal expansion (COTE) has the units of inches/inch/degree Fahrenheit
- Concrete has a COTE of 4 to 7×10^{-6} in./in./deg F
- If the COTE, for example, is 6×10^{-6} in./in./deg F, and we increase the temperature 1 degree, a one-inch-long piece of concrete would expand:

6×10^{-6} in./in./deg F x 1 in. x 1 deg. = 6×10^{-6} in.

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- However, if that piece of concrete was held between two pieces of concrete or bonded to the substrate so that it couldn't expand, what would happen?

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- It would be the same thing as letting it expand and then pushing it back to the original position.
- That would require force as a result of stress.
- How would you calculate the stress?

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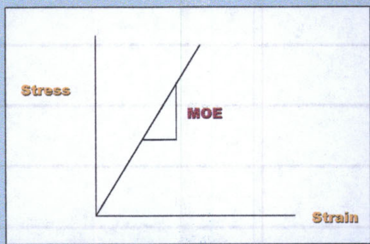
Stress-Strain Diagram



MOE = Stress / Strain or

Stress = Strain * MOE

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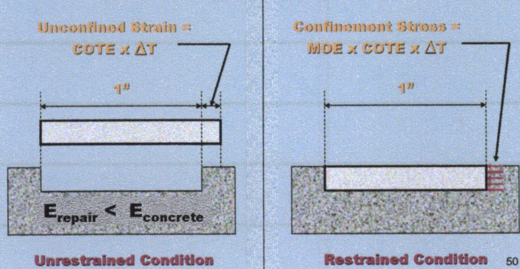
Stress Strain Behavior Modulus and COTE at Work



50

- Note that strain has the units of inches/inch
- That is the unit of COTE per degree F
- So we can find stress due to a material being restrained against movement due to thermal change by multiplying

  COTE x Modulus of elasticity (E) x deg. F

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How Much Stress is Caused by a 1° Temperature Change?

- Limestone aggregate concrete
  - -E = 3 to 4.5 x 10^6 psi
  - -COTE = 4 to 5x10^{-6} in./in./deg F
  - Stress = COTE x E = 12 to 22 psi/deg. F
- Silicious river gravel concrete
  - -E = 4 to 5 x 10^6 psi
  - -COTE = 6 to 7x10^{-6} in./in./deg F
  - Stress = 24 to 35 psi/deg. F

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How Much Stress is Caused in Polymer Repair Materials?

- The COTE is much higher, but the E is much lower so as a result the stress is much lower in many polymer materials
- Stress ranges considerably:
- Delpatch (E=7400 psi, COTE= 65x10^{-6})
  Stress = 7400 x 65x10^{-6} in./in./deg F = 0.48 psi/deg. F
- RSP (E=200,000 psi, COTE= 37x10^{-6})
  Stress = 200,000 x 37x10^{-6} in./in./deg F = 7.4 psi/deg. F

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What Have We Learned about COTE and E?

- From the field tests we have learned that the polymers that had low E performed the best.
- Materials that had a COTE x E less than 10 psi/deg F seemed to perform better than the rigid materials that had a COTE x E greater than 10.
- Does that mean that hydraulic cements are never good repair materials?
  -Probably not, but the research in this study did not identify any that performed nearly as well.

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Example Calculation

- If a temperature drop of 30°F occurs in a MgKrete repair and the coefficient of thermal expansion is $6x10^{-6}$ in/in/°F, the strain is 30 x $6x10^{-6}$ = 0.18 x 10^{-3} in/in.
- If the repair is 100 inches long, the contraction would be 0.18 x 10^{-3} in/in x 100 in. = 0.018 in.

55

- However, if the repair is bonded to concrete on each end and can't move, it would be the same as letting the repair contract and then pulling it back so that it is in the original position.
- The stress required would be the strain times the modulus of elasticity. If the modulus is 3.7 x 10^6 psi, the stress required to keep the repair from contracting is 0.18 x 10^{-3} in/in x 3.7 x 10^6 psi = 666 psi

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- Would the concrete crack if it is restrained against movement?
- The tensile strength of MgKrete can be estimated from its flexural strength which is approximately 500 psi which is less than the tensile stress, 666 psi, caused by the drop in temperature.
- **Cr-a-a-a-ck!!**

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- But let's look at one of the polymer concretes, Delpatch.
- The modulus is 7400 psi (that's right, 7400 psi) and the coefficient of expansion is 65 x10^{-6} in/in/°F. For the same 30°F drop in temperature, the strain would be 30°F x 65 x 10^{-6} in/in/°F = 0.00195 in/in. The stress would be 0.00195 in/in x 7400 psi = 14 psi.
- The tenisile bond strength of these materials is 50 to 100 psi so they would not fail.

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What Have We Learned?

- Even though the coefficient of thermal expansion for some of the polymer concretes may be as much as 10 times greater than concrete, the modulus is about 1/400 or 1/500 of concrete, the stress produced is much smaller and the repair material is much less likely to fail when shrinkage or thermal change occurs
- Now let's see what happened in the field...

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Results of Field Evaluations

- Houston
- I 35 near Alvarado in Ft. Worth District

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Field Evaluation - Houston

Cores taken to determine field bond strength of three different products: WaboCrete, Fibrescreed, Delpatch, FlexPatch

Results were inconclusive due to the limited field samples available for testing, and the failure modes. (Only one material failed at the bond line)

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- However, visual evaluation of many repairs over a period of about six years in Houston indicate that the low modulus repair materials, particularly urethanes, have performed extremely well.
- In many, even most, cases, the crack at the bottom of the spall has not reflected through the urethane repair material after several years in place.

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Field Evaluation- I-35 Alavarado

- Manufacturers' representatives placed five repair materials in tracks made in fresh concrete pavement by a motorist.
- Original repair material lasted several years, was removed, and new materials were placed in summer 2005
- This evaluation occurred one year after placement.

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I-35 Alvarado Repair Test Section

One year after placement

- Polymer Concretes
  - Delpatch (polyurethane)
  - FlexPatch (epoxy)
- Magnesium Phosphates
  - EucoSpeed
  - Pavemend
  - MgKrete
- Materials placed by manufacturers' reps so that there was no question that they were placed properly.

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Magnesium Phosphates

- Pavemend
- EucoSpeed
- MgKrete

65

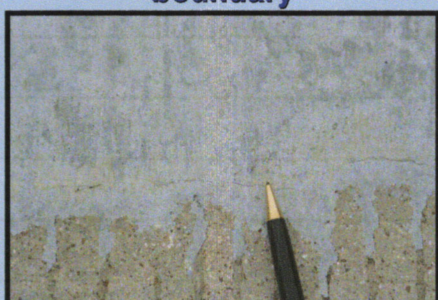
Pavemend- Note formed joints at cracks in original pavement

66

Pavemend- Note cracking

67

Pavemend- Cracks at boundary



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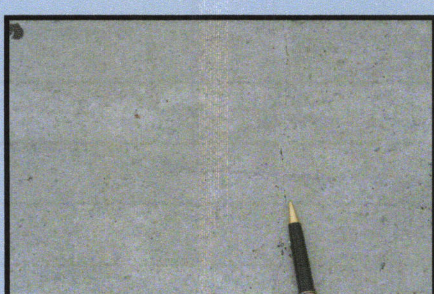
Pavemend- Closely spaced cracks



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Pavemend- Severe cracking

70

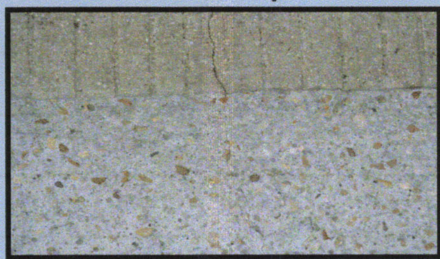
Pavemend- Surface spalling

71

EucoSpeed- Placed in rain

72

EucoSpeed- Reflective cracking, placed in rain (rough surface)



73

EucoSpeed- Placed after rain

74

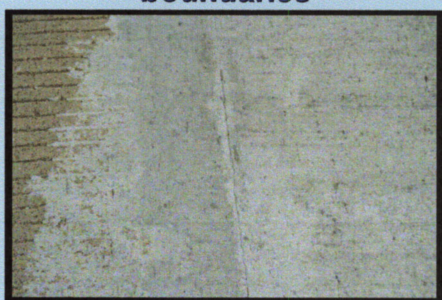
EucoSpeed- Note reflective cracking

75

EucoSpeed- Note cracking

76

EucoSpeed- Cracks at boundaries



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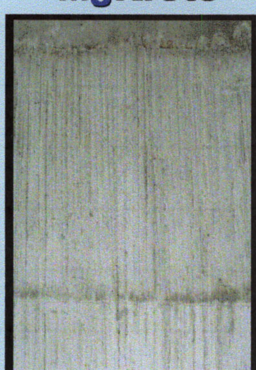
MgKrete



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MgKrete- Note blisters and cracks

79

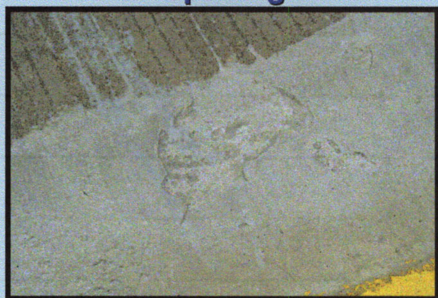
MgKrete- Severe spalling

80

MgKrete- Cracking and spalling

81

MgKrete- Cracking and spalling



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MgKrete- Cracking

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Polymer Concretes

- FlexPatch—Epoxy Polymer Concrete
- Delpatch—Polyurethane Polymer Concrete

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FlexPatch

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FlexPatch- In about 100 ft., one transverse crack

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FlexPatch- Continuous crack at boundaries

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FlexPatch

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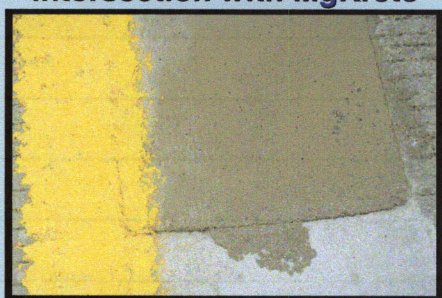
FlexPatch- Crack at intersection with MgKrete



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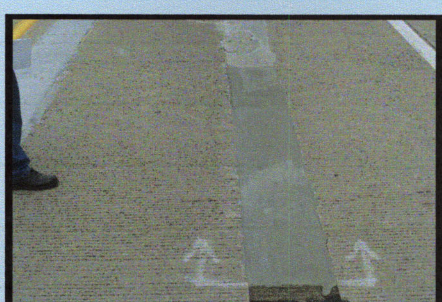
Delpatch



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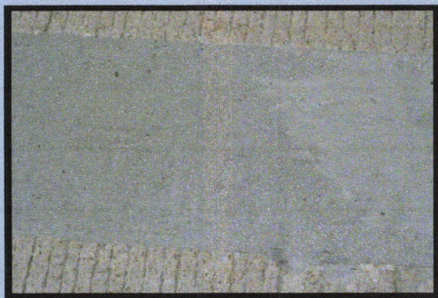
Delpatch- Excellent condition



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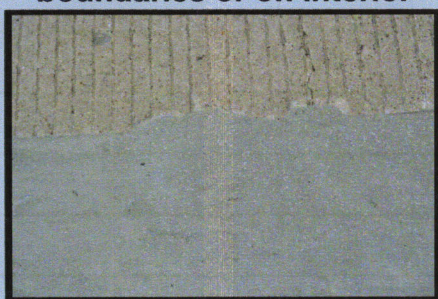
Delpatch- No cracking at boundaries or on interior



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Summary of Performance

- Delpatch—clearly performed the best. No cracks, spalling or other signs of distress. Estimated life—Minimum of 15-20 years
- FlexPatch—only one transverse crack, no spalling or other interior cracking, but continuous cracks at boundaries. Estimated life—4-5 years
- EucoSpeed—developed spalls when installed during rain. Fine cracks in interior and along some boundaries even when installed dry. Estimated life—4-5 years.

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- Pavemend—considerable cracking and some surface spalling. Estimated life: 3-4 years
- MgKrete—Considerable surface spalling; blisters formed on surface during placement and later developed spalls. Considerable cracking. Estimated life—2 to 3 years

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Conclusions

- Polyurethane polymer concrete, Delpatch, clearly outperformed all other materials. This has been confirmed in the Houston District where repairs have been in place for 5 years or more and show no signs of distress. The excellent performance is due to the very low modulus, high elongation and excellent bond.

95

- The FlexPatch, which is an epoxy polymer concrete, looked very good except for continuous cracks along the boundary which are likely to result in failure within 5 years.
- The magnesuim phosphates developed significant cracking and spalling. The EucoSpeed has finer cracks than the others. MgKrete was clearly the poorest performer of all materials tested at the site. The poor performance of these materials is due to the high modulus and low ductility.

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Results - Product Comparison

Product	Time to Traffic	Storage Life (yrs)	Material Cost ($/cft)
Delpatch-(Elastomeric)	1 hour	2	$145.00
RSP- (Elastomeric)	8-10 min	0.5	$52.00
WaboElastoPatch- (Elastomeric)	1 hour	1	$152.00
FlexPatch (SSI)- (Semi-Rigid)	1-2 hours	1	$115.00
FlexKrete- (Semi-Rigid)	45 - 90 min	0.5	$110.00
EucoSpeed MP- (Rigid)	1 hour	1	$43.00
MgKrete- (Rigid)	30 min	0.5	$62.00
Pavemend 15- (Rigid)	1.5 hours	1-3	Not Available
RapidSet- (Rigid)	1 hour	1	$26.00
Fibrescreed- (Elastomeric)	15 – 60 min	2	$101.00

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Are There Any Concerns about Low Modulus Materials?

- Being low modulus they are more likely to rut (asphalt is a low modulus material, particularly at high temperatures) and wear.
- But these materials are more temperature stable than asphalts and have much higher tensile strengths.
- The next slide shows the abrasion resistance for different materials.

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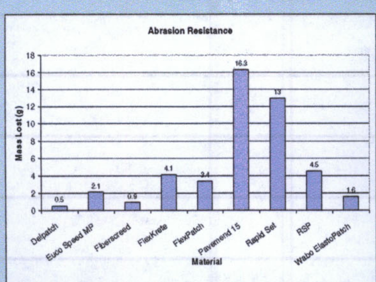
Results – Abrasion Resistance



Polymer concretes showed consistently good performance

99

Environmental and Safety Considerations

100

Environmental and Safety Considerations

- Environmental:
  - Clean up:
    - Magnesium Phosphates and Rapid Setting Mixes
      - Clean up with water
    - Delpatch
      - Denatured alcohol
    - Flexkrete
      - Acetone
    - Flexpatch
      - Any solvent such as mineral spirits
    - RSP and Wabo ElastoPatch
      - Not specified

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Environmental and Safety Considerations

- Proper Disposal of Materials
  - Magnesium Phosphates and Rapid Setting Mixes
    - Normal disposal of unused product
  - Urethanes
    - Special disposal of unmixed product

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Environmental and Safety Considerations

- Safety
  - Hard hats
  - Steel toed boots
  - Safety glasses
  - Urethanes
    - Latex gloves
    - Well ventilated area or respirator protection

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Effects of Weather

- Temperature
  - Cool temperatures retard and slow down cure
  - Warmer temperatures accelerate cure time
- Moisture
  - Urethane materials do not like water contamination. Surface must be kept dry

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Mixing and Placing

105

Mixing and Placing

- **Delpatch:**
  - Mix 3000ml part "A" component with 1500ml part "B" component for 10 seconds. Add pre- bagged aggregate and mix an additional minute
  - Pour material into spall
  - Texture surface with trowel

Mixing and Placing

- FlexKrete:
  - Mix 1gallon of FlexKrete with 1.2 oz of catalyst. Mix for 30 to 60 seconds. Add 3 to 4 gallons of sand and mix thoroughly for 2 minutes.
  - Pour material into spall
  - Trowel into place

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Mixing and Placing

- WaboElastoPatch:
  - Mix part "A" component with "B" in a 1:1 ratio for 2 minutes. Add packaged aggregate and mix an additional 2 minutes until well blended.
  - Pour material into spall.

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Mixing and Placing

- FlexPatch:
  - Mix prepackaged part "A" component with "B" for 3 minutes. Slowly add "C" component (aggregate) and "A-B" liquid until well blended.
  - Pour material into spall.
  - Finish with steel trowel.

09

Mixing and Placing

- **RSP:**
  - Place aggregate into spall area.
  - Mix part "A" component with "B" component in 1:1 ratio.
  - Pour material over aggregate in spall.
  - Apply sand to top of repair.

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Mixing and Placing

- **EucoSpeed:**
  - Add 0.4 to 0.5 gallons of water to 50 lb bag of Material. Mix for 2 minutes. May extend with an additional 30 lbs of pea gravel, mix an additional minute.
  - Pour material into spall.
  - Trowel material, broom finish.

111

Mixing and Placing

- **Pavemend 15:**
  - Add 1.0 gallon of water to 45-lb bucket of material. Mix until temperature has reached 95 degrees.
  - Pour material into spall.

112

Mixing and Placing

- **Rapid Set**:
  - Add 3 to 5 quarts of water for each 60-lb bag of material. Mix for 2 minutes. Mix 1 to 3 minutes until of uniform consistency
  - Pour material into spall.
  - Trowel, float or broom finish.

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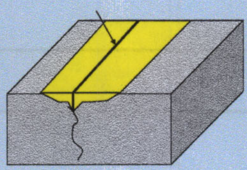
Mixing and Placing

- **FibreScreed:**
  - Material placed by contractor with proper equipment.
    - Place packaged material in machine.
    - Once material at proper temperature (375 to 380 degrees) apply to spall area in 2" lifts. Add ¾" bulking stone with each lift. Continue until flush with surface.
    - Apply top coat for skid resistance.

114

Mixing And Placing

- Reestablish Joint for Rigid Materials, preferably by saw cutting



115

Set Time

- Many products have additional additives which can speed up, and slow down set times and workability.
- Many companies also produce different formulations for different temperatures which effect set time.

Material:	Initial Set Time (minutes)
Wabo ElastoPatch	22
Delpatch	60
RSP	6
Fibrescreed	**
FlexKrete	8
FlexPatch	63
RapidSet	24
EucoSpeed	17
Pavemend	13

** Not chemically activated, temperature controlled

116

Curing and Return to Traffic

Material:	Return to traffic at 75 to 80°
Wabo ElastoPatch	1 hr
Delpatch	1 hr
Fibrescreed	15 min – 1 hr
FlexKrete	1.5 hrs
FlexPatch	1 – 2 hrs
RapidSet	1 hr
EucoSpeed	1 hr
Pavemend	1.5 hrs

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Summary: Polymer Materials

Material	Flexibility	Moisture Sensitivity	Ready for traffic	Cost, cu. ft.
Wabo EP	Flexible	Yes	1 hr.	$160
Delpatch	Flexible	Yes	1 hr.	$145
RSP	Semi flex	Yes	1 hr.	$52
Flexpatch	Flexible	Some	1-2 hrs.	$115
FlexKrete	Semi flex	Yes	1.5 hrs.	$110

118

Summary: Mag Phos, PCC, Asphalt

Material	Flexibility	Moisture Sensitivity	Set Time	Cost, Cu. ft.
EucoSpeed	Brittle	Yes	1 hr.	$43
Pavemend	Brittle	Yes	1.5 hrs.	N/A
MgKrete	Brittle	Yes	1 hr.	
Rapid Set	Brittle	No	1 hr.	$26
Fibrescreed	Flexible	Yes	¼-1 hr.	$101

119

Materials Requirement

- General Requirement
  - Carry traffic in 3 hours of placement
  - Resistance to weather and abrasion
  - Use only aggregates specified by manufacturer
  - Skid resistant surface
  - Reflective finish; color to match concrete
  - Placing temperature of 10°C and above

120

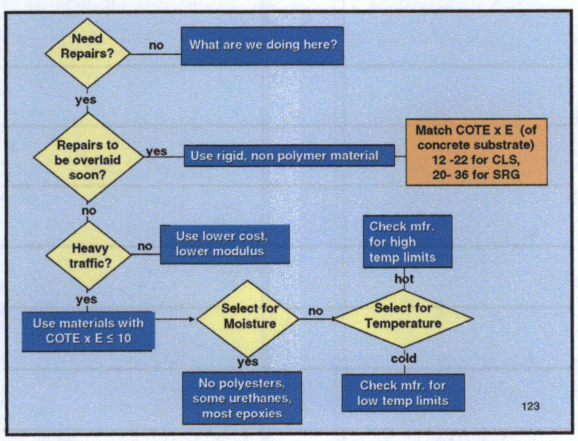
Materials Requirement

- Chemical resistance to:
  - Deicers
  - Motor oil
  - Sodium chloride solution
  - Hydraulic brake fluid
- Physical Requirements
  - Gel time (min)
  - Wet bond strength (psi)
  - Resilience (%)
  - Compressive strength (psi)
  - Thermal/stiffness compatibility

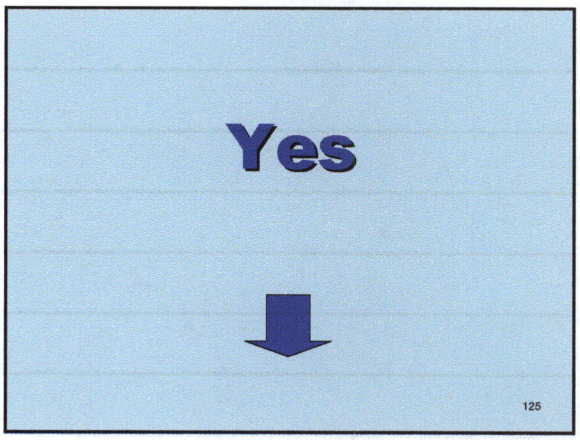
121

Material Selection Process

122




Need Repairs?
124


Yes
125


Repairs to be
overlaid soon?
126

If overlay planned for near future:

- use a rigid non polymer material.

  Match COTE x E (of concrete substrate)

  12-22 for Crushed Limestone (CLS)

  20-36 for Siliceous River Gravel (SRG)

- Make square edge cuts (no feather edges) and
- Make repair below depth of reinforcement

If not, go to traffic decision diamond

127

Heavy traffic?

128

- **For very few heavy trucks use low cost, low modulus repair material**
- **For heavy traffic use materials with COTE x E ≤ 10**

129

Select for Moisture

130

For probable wet seasonal conditions

- Do not consider polyesters
- Check for specific urethanes

When repairs will be made only under dry conditions select for temperature conditions

131

Select for Temperature

132

- For dry temperate conditions most materials on the list will perform well
- For hot, dry conditions check with manufacturer for temperature limits, high temp formulations or retarding additives
- For cold dry conditions check with manufacturer for low temp limits, low temp formulations, or accelerating additives

133

Spall Repair Options

Weather	Spall Type	Materials	Comments
(San Diego, CA?) 55F<Temp<95F	Shallow < 3 in.	Type I – Flexible FlexKrete DelPatch WaboElastopatch Flexpatch	surface must be dry (compressed air) [FlexKrete, DelPatch, WaboElastopatch] OK on damp surface [Flexpatch]
55F<Temp<95F	**Deep > 3 in.**	**Type I – Flexible** (listed above) **Type II – Rigid** Eucospeed Rapid Set	Recommended (extend with CA, but still higher cost) Lower cost alternatives

Table based on studied materials only. Always consult with TxDOT CST P&M for their list of approved materials or to evaluate promising new materials.

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Spall Repair Options

Weather Conditions	Spall Type	Material Type	Specify/ Choices
COLD < 55F	Shallow	Type I – Flexible FlexKrete DelPatch WaboElastopatch	surface must be dry (compressed air)
COLD < 55F	**Deep**	Type I – Flexible FlexKrete DelPatch WaboElastopatch	Recommended with added CA (still more costly)
		Type II – Rigid Eucospeed, Rapid Set	Less expensive alternate

Table based on studied materials only. Always consult with TxDOT CST P&M for their list of approved materials or to evaluate promising new materials.

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Spall Repair Options

Weather Conditions	Spall Type	Material Type	Specify/ Choices
HOT>95F	Shallow	Type I – Flexible Flexpatch FlexKrete DelPatch WaboElastoPatch	Dry Surface
HOT>95F	Deep	Type I – Flexible Flexpatch FlexKrete DelPatch WaboElastoPatch Type II – Rigid Eucospeed, Rapid Set	Recommended with added CA (still more costly) Less Costly alternative

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For Emergency Repairs

- **Sudden-problem pavement spalls-**
  - Keep small stock of moisture-insensitive, low-modulus, epoxy mortar concrete-patching system for repairs above 55F. Polyurethanes and Polyesters can more easily accommodate dry temperature extremes.
  - For deep spalls keep bags of dried ½-inch coarse aggregate to extend the mortar (as per manufacturers instructions).
  - Cool weather bring matls to room temp. over night.
  - Make repairs at temperatures above 50F on sound, clean, and dry or minimally damp substrates.
- **Use for emergencies on bridge decks, too.**

137

Questions?

Included in the Binder

(Binder tabs)

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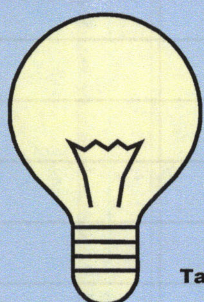
Decision Tree



Tab Number 1

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TxDOT Standard Specifications

Tab Number 2

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DMS 6170
for
Elastomeric
Concrete
Repair Materials

Tab Number 3

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Draft of DMS 4655
for Rapid-Setting
Cementitious
Repair Materials

Tab Number 4

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Previous
TxDOT Job
Specifications

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Qualifying New Materials

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Testing Specifications

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TxDOT Pre-Approved List, MSDS, & Product Data Sheets

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Repair Guidelines

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1-5110 Final Report CD

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Performance And Evaluation

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CDs (training)

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Contact Info for Attendees and Key Personnel

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Session Notes

Tab Number 14

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CDs (training)

Tab Number 12

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Contact Info for Attendees and Key Personnel

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Session Notes

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Session Notes

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CDs (training)

Tab Number 12

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Contact Info for Attendees and Key Personnel

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Session Notes

Tab Number 14

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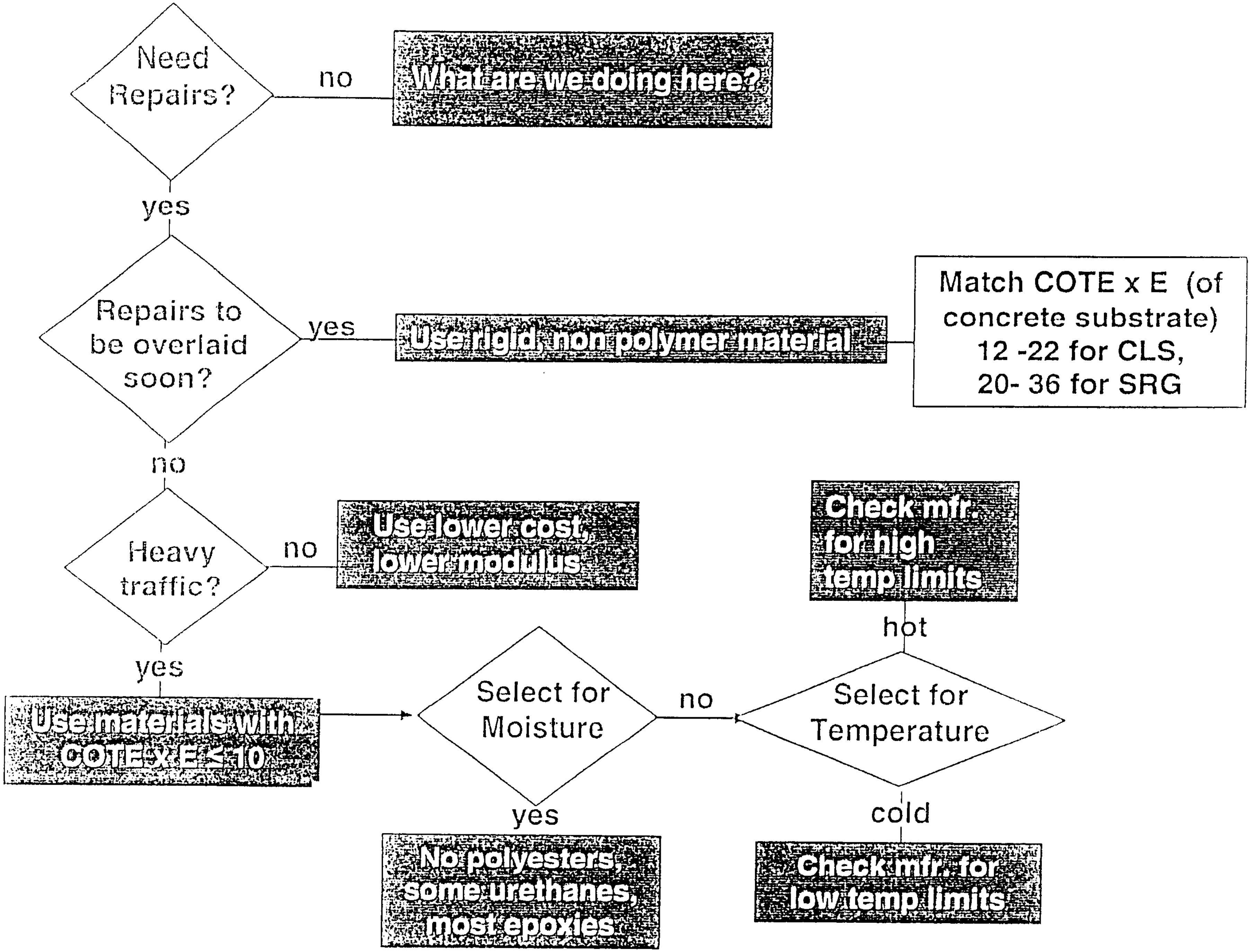
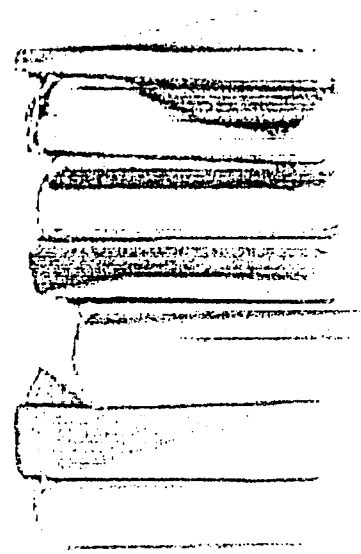

Need Repairs?
no
What are we doing here?
yes
Repairs to be overlaid soon?
yes
Use rigid, non polymer material
Match COTE x E (of concrete substrate) 12 -22 for CLS, 20- 36 for SRG
no
Heavy traffic?
no
Use lower cost, lower modulus
yes
Use materials with COTE x E ≤ 10
Select for Moisture
yes
No polyesters, some urethanes, most epoxies
no
Select for Temperature
hot
Check mfr. for high temp limits
cold
Check mfr. for low temp limits

Relevant Resources

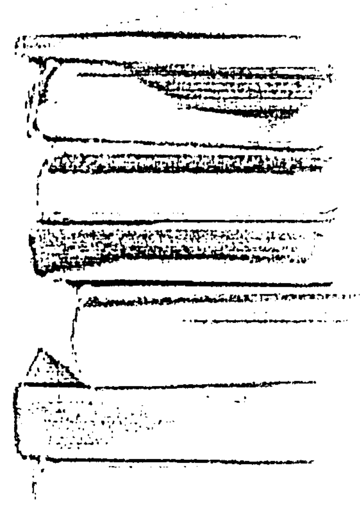
Where can I find them?



List of prequalified materials

TxDOT's

Prequalified Products List for
Polymeric Materials for Patching
Spalls in Concrete Pavement



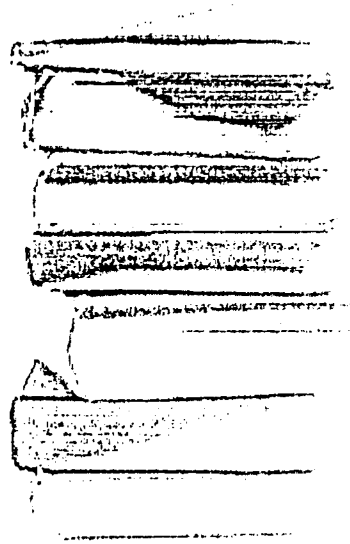
On the web at:

ftp://ftp.dot.state.tx.us/pub/txdot-info/cmd/mpl/polyptch.pdf

DMS-6170, Polymeric Materials for Patching Spalls in Concrete Pavement

On the Web at:

ftp://ftp.dot.state.tx.us/pub/txdot-info/cst/DMS/6000_series/pdfs/6170.pdf

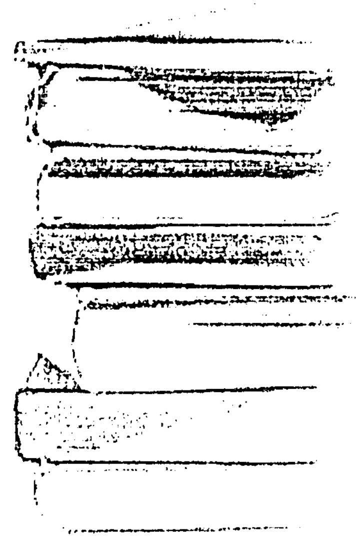


ITEM 720- REPAIR OF SPALLING IN CONCRETE PAVEMENT

Page 984 of the
STANDARD SPECIFICATIONS FOR
CONSTRUCTION AND
MAINTENANCE OF HIGHWAYS,
STREETS,AND BRIDGES

- Also found on the web at:

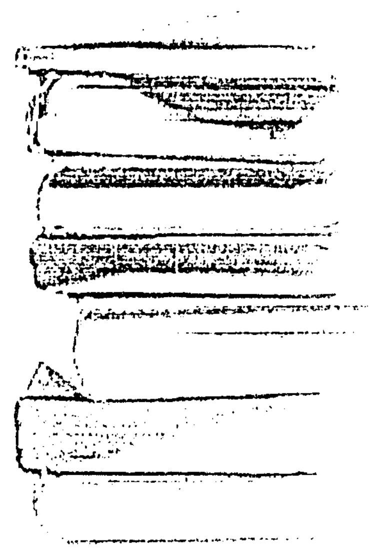
ftp://ftp.dot.state.tx.us/pub/txdot-info/des/specs/specbook.pdf



Test Methods

Tex-418-A Compressive Strength of Cylindrical Concrete Specimens @ ftp://ftp.dot.state.tx.us/pub/txdot-info/cst/TMS/400-A_series/pdfs/cnn418.pdf

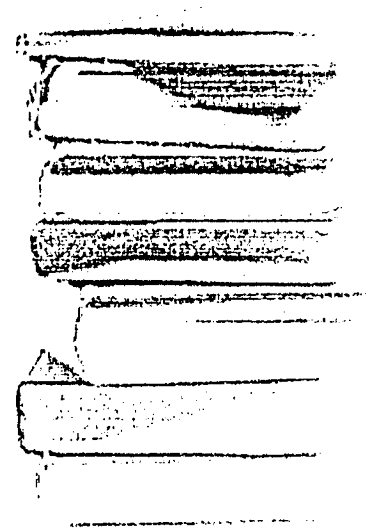
Tex-428-A Determining the Coefficient of Thermal Expansion of Concrete @ ftp://ftp.dot.state.tx.us/pub/txdot-info/cst/TMS/400-A_series/pdfs/cnn428.pdf



Test Methods

- Tex-442-A Determining Compressive Strength of Grouts @ ftp://ftp.dot.state.tx.us/pub/txdot-info/cst/TMS/400-A_series/pdfs/cnn442.pdf

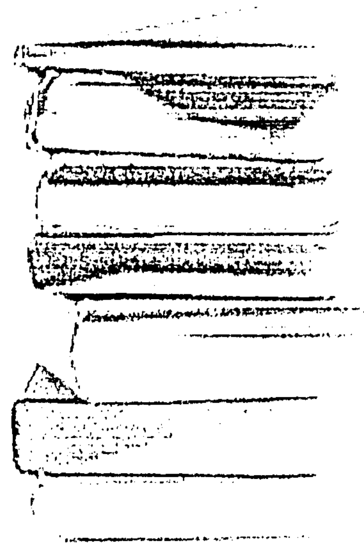
- Tex-446-A Rebound Number of Hardened Concrete @ ftp://ftp.dot.state.tx.us/pub/txdot-info/cst/TMS/400-A_series/pdfs/cnn446.pdf



Test Methods

- Tex-618-J Testing Elastomeric Concrete @ ftp://ftp.dot.state.tx.us/pub/txdot-info/cst/TMS/600-J_series/pdfs/chm618.pdf

- Tex-614-J Testing Epoxy Materials @ ftp://ftp.dot.state.tx.us/pub/txdot-info/cst/TMS/600-J_series/pdfs/chm614.pdf



ITEM 720

REPAIR OF SPALLING IN CONCRETE PAVEMENT

720.1. Description. Repair spalling and partial-depth failures in concrete pavement.

720.2. Materials. Furnish either rapid-set concrete or polymeric patching material unless otherwise shown on the plans.

A. **Rapid-Set Concrete.** Provide concrete that meets DMS-4655, "Rapid-Hardening Cementing Materials for Concrete Repair."

   Use a packaged blend of hydraulic cement, sand, and gravel (maximum size 3/8 in.) which requires the addition of water and has a maximum shrinkage of 0.15% in accordance with ASTM C 928. Do not use chlorides, magnesium or gypsum to accelerate setting time. Before spall repair operations, demonstrate that the mixture achieves flexural strength of at least 425 psi in 5 hr., a minimum compressive strength of 5,100 psi in 7 days, and 6,300 psi in 28 days. Test in accordance with Tex-418-A and Tex-448-A.

B. **Polymeric Patching Material.** Provide polymeric patching material that meets DMS-6170, "Polymeric Materials for Patching Spalls in Concrete Pavement," and matches the color of the pavement.

720.3. Equipment. Furnish equipment in accordance with Item 429, "Concrete Structure Repair," or as approved.

720.4. Work Methods. Repair areas as shown on the plans or as directed. Dispose of debris off the right of way in accordance with federal, state, and local regulations.

A. **Hydraulic Cement Concrete Material.** Saw at least 1 1/2 in. deep around repair area before concrete removal, unless otherwise directed, providing a vertical face around the perimeter of the repair area. Provide a uniform rough surface free of loose particles and suitable for bonding. Remove concrete to a depth of 1 1/2 in. or the depth of deteriorated concrete, whichever is greater. Use chipping hammers not heavier than the nominal 15-lb. class or hydro-demolition equipment for the removal of concrete below 1 1/2 -in. depth. Mix, place, and cure in accordance with manufacturer's recommendations. Do not place concrete if the air temperature is below 40°F. Screed concrete to conform to roadway surface. Provide a rough broom finish.

B. **Polymeric Patching Material.** Submit for approval a statement from the manufacturer identifying the recommended equipment and installation procedures. Remove the deteriorated concrete to the dimensions shown on the plans or as directed. Dry and abrasive-blast the repair area to ensure it is free from moisture, dirt, grease, oil, or other foreign material that may reduce the bond. Remove dust from the abrasive blasting operation. Apply primer to the repair area. Reapply primer if conditions change before placing patching material. Mix, place, and cure in accordance with manufacturer's recommendations. Begin placement of material at the lower end of sloped areas. Screed polymeric patching material to conform to the roadway surface. Provide a non-skid finish with a notched trowel.

720.5. Measurement. This Item will be measured as follows:

A. Hydraulic Cement Concrete Material. By the cubic foot of concrete repair material placed.

B. Polymeric Patching Material. By the gallon of polymeric patching material placed.

720.6. Payment. The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Spalling Repair" of the type (Hydraulic Cement; Polymeric, Flexible; or Polymeric, Semi-rigid) specified. This price is full compensation for sawing, chipping, milling, cleaning, abrasive-blasting, repairing spalled concrete pavement, disposal of materials, materials, equipment, labor, tools, and incidentals.

Section 8

DMS-6170, Polymeric Materials for Patching Spalls in Concrete Pavement

Overview

Effective Date: August 2004 (refer to "Archived Versions" for previous versions).

This Specification governs the quality monitoring program (QMP) for polymeric material for patching spalls in concrete pavement, and describes prequalification, quality monitoring requirements, disqualification and requalification, sampling and testing, and material requirements.

Material Description

Concrete patching material is a thermosetting polymer-based material mixed with aggregate to form a mortar used for patching spalls in concrete pavement.

- Type I is a flexible material with high resilience properties. This material is not intended for use in areas where a concrete asphalt overlay is anticipated.
- Type II is a semirigid material with a high compressive strength. The rigidity of this material is preferred when the concrete pavement will be repaved with a concrete asphalt overlay.

Prequalification

Material Producer List

The Materials and Pavements Section of the Construction Division (CST/M&P) maintains a material producer list (polyptch) of all materials conforming to the requirements of this program. Materials appearing on the material producer list require no further testing unless deemed necessary by the engineer. To obtain a place on the material producer list the producer must be accepted into the QMP.

The material will be prequalified as a complete binder and aggregate system; thus, the list will include the binder and aggregate specified by the manufacturer. The Contractor, supplier, or producer cannot substitute any of the components without prior notice to and approval of CST/M&P.

Materials not appearing on the material producer list require project specific testing and approval before use. Refer to 'Project Specific Testing.'

Prequalification Requests

Submit a written request to the Texas Department of Transportation, Construction Division, Materials and Pavements Section (CP51), 125 E. 11th Street, Austin, Texas 78701-2483, to prequalify your products. Include the following information in the request:

- company name,
- physical and mailing addresses,
- contact person and telephone number, and
- material type.

Performance History

CST/M&P will only accept into the QMP those materials that are determined by the Director of CST/M&P to have an established performance history and compliance with this Specification. Therefore, prospective producers or suppliers may be required to install their material at a test location. The Department must approve test sections before installation. Provide materials and installation for the test site at no cost to the Department. CST/M&P will monitor the test location for a minimum period of 12 mo. unless the material fails prematurely.

Prequalification Procedures

After the producer submits a request for QMP prequalification, CST/M&P will use the following procedure to prequalify the material:

- The producer will provide a laboratory test report that contains data showing compliance of the material in accordance to the requirements in"Material Requirements".
- The producer will submit a minimum of 1 sample (amount of binder components equal to 1 gal. of mixed material and corresponding aggregate) for consideration of each type of patching material.
- CST/M&P will test each sample according to the tests outlined in 'Material Requirements.' CST/M&P will determine if there is an adequate correlation between the producer and CST/M&P test results. CST/M&P will reject the material if a correlation is not established or if the material does not meet the requirements.

CST/M&P will place materials meeting all requirements in the quality monitoring program. After acceptance, any changes in formulation or composition must be reported to CST/M&P. Material changes require resubmission for prequalification.

Quality Monitoring Requirements

The prequalification periods are from January 1st to June 30th and July 1st to December 31st of every year. During each prequalification period, the producer must provide 1 prequalification sample, and monthly quality control testing reports.

Monthly Quality Control Reports

The Department requires that all producers in the QMP perform quality control testing on their material. The Department requires that producers submit monthly quality control testing reports to CST/M&P for every prequalified material. The report must reflect the test data from each batch of prequalified material produced during that month regardless of the destination of the material. The monthly report must contain the following information:

- type of patching material,
- date of manufacture,
- batch number, and
- QM test results.

QM tests are those listed in 'Material Requirements.' Producers must submit reports by the first business day of every month. If no prequalified material is produced for a particular month, then submit a report stating no material was produced.

Prequalification Sample

Submit a sample of each prequalified material for every prequalification period at least 1 mo. before the beginning of the prequalification period to allow sufficient time for testing. Any material not submitted on time may be delayed in posting on the material producer list.

Random Testing and Auditing

The Department reserves the right to conduct random sampling of prequalified materials for testing, and perform random audits of test reports. Department representative may sample material from the manufacturing plant, the project site, and warehouse. Maintain a complete record of all test reports for the previous and current calendar year. CST/M&P reserves the right to inspect and approve the laboratory where the quality control testing is performed to ensure that all criteria for equipment and procedure compliance are met. CST/M&P reserves the right to test samples to verify compliance with "DMS-6170, Polymeric Materials for Patching Spalls in Concrete Pavement."

Disqualification and Requalification

A producer may be disqualified and removed from the quality monitoring program if 1 of the following infractions occurs:

- material tested by CST/M&P fails to meet the requirements stated in this Specification
- the producer fails to properly submit complete monthly quality control testing reports or prequalification samples to CST/M&P or
- the producer fails to report changes in the formulation or composition of the material to CST/M&P.

If a material is disqualified, the producer will not be allowed to supply material to the Department for a period of 6 mo., or as determined by the Director of CST/M&P. After this time has expired, the producer must requalify to regain QMP status. Disqualification will only apply to the patching material type corresponding to the infraction.

To requalify after the 6-mo. disqualification period, the producer must submit a written request to CST/M&P. Include with the request a test report from an independent laboratory with data that certifies that the material meets the requirements in "Material Requirements."After receiving the request and test data, all requirements in 'Prequalification Procedures' will apply.

Sampling and Testing

The Department will sample in accordance with "Tex-734-I, Sampling Epoxy," and will test in accordance with 'Material Requirements.'

Costs of sampling and testing are normally borne by the Department; however, the costs to sample and test materials failing to conform to the requirements of this Specification are borne by the Contractor or supplier. This cost will be assessed at the rate established by the Director of CST/M&P and in effect at the time of testing.

Amounts due the Department will be deducted from monthly or final estimates on Contracts or from partial or final payments on direct purchases by the State.

Project Specific Testing

Materials not appearing on the material producer list require project specific testing and approval before their use. Submit samples to CST/M&P with a certified test report from an independent laboratory with test data verifying that the material meets the requirements stated within this Specification. This material must not be used until testing is complete and material is approved.

Material Requirements

General Requirements

Both types of concrete pavement patching material have the following properties:

- The patching material is able to carry traffic within 3 hr. of placement or as directed by the Engineer.
- Concrete patching material is resistant to weather and abrasion.
- The aggregate type used in the patching material will be those specified by the manufacturer.
- The patching material has a skid-resistant finish (e.g., tining, broadcast sand).
- The patching material has a nonreflective finish with similar color tone to concrete, and

- Concrete patching material must be placed at substrate temperatures of 10°C (50°F) and rising.

Chemical Resistance

Manufacturers must submit a certified report indicating compliance to the following requirements for chemical resistance.

Chemical Resistance

Chemical	Effects
Deicers	None
Motor oil	None
Sodium Chloride Solution (5%)	None
Hydraulic Brake Fluid	None
Standard: ASTM "D 471, Standard Test Method for Rubber Property-Effect of Liquids." 25°C (77°F) after 22 hr.	

Submit report before the material is accepted into the QMP. It is not required as a part of the monthly quality control reports, unless requested by CST/M&P.

Physical Requirements

- Type I

Type I

Test	Method	Requirements
Gel Time, min.	"Tex-614-J, Testing Epoxy Materials"	5 minimum – 60 maximum
Wet Bond Strength to Concrete, psi	"Tex-618-J, Testing Elastomeric Concrete"	100 minimum
Compressive Strength 24 hr. psi	ASTM "C 579, Standard Test Methods for Compressive Strength of Chemical-Resistant Mortars, Grouts, Monolithic Surfacings and Polymer Concretes," Method B	200 minimum
Compressive Stress @ 0.1 in., 7 days, psi	"Tex-618-J, Testing Elastomeric Concrete"	200 minimum
Resilience, %	"Tex-618-J, Testing Elastomeric Concrete"	90 minimum
Thermal Compatibility One cycle is 8 hrs. @ 60°C followed by 16 hrs. @ -21°C Determine results after 9 cycles.	ASTM "C884/ C884M, Standard Test Method for Thermal Compatibility Between Concrete and an Epoxy-Resin Overlay," with modifications	No delamination or cracking

- Type II

Type II

Test	Method	Requirements
Gel Time, min.	"Tex-614-J, Testing Epoxy Materials"	1 minimum – 60 maximum
Wet Bond Strength to Concrete, psi	"Tex-618-J, Testing Elastomeric Concrete"	250 minimum
Compressive Strength 24 hr. psi	ASTM "C 579, Standard Test Methods for Compressive Strength of Chemical-Resistant Mortars, Grouts, Monolithic Surfacings and Polymer Concretes," Method B	2,000 minimum
Compressive Stress @ 0.1 in., 7 days, psi	"Tex-618-J, Testing Elastomeric Concrete"	2,000 minimum
Resilience, %	"Tex-618-J, Testing Elastomeric Concrete"	65 minimum
Thermal Compatibility One cycle is 8 hrs. @ 60°C followed by 16 hrs. @ -21°C. Determine results after 9 cycles.	ASTM "C884/ C884M, Standard Test Method for Thermal Compatibility Between Concrete and an Epoxy-Resin Overlay," with modifications	No delamination or cracking

Packaging and Labeling

Package reactive components in airtight containers and protect from light and moisture. Package aggregates to protect them from moisture. Include instructions for mixing and application of the material, and include all safety information and warnings regarding contact with the components.

Labels must include the following information:

- type of material
- resin or hardener components
- brand name
- name of manufacturer
- ratio of components to be mixed by volume
- unique batch number
- date of manufacture and
- expiration date.

Archived Versions

Archived versions of "DMS 6170, Polymeric Materials for Patching Spalls in Concrete Pavement" are available through the following link:

Click on 6170-0703 for the Specification effective July 2003 through July 2004.

Draft of New Departmental Material Specification

Section - DMS-4655, Rapid-Hardening Cementitious Materials for Patching Spalls in Concrete Pavement

(or from 720 - DMS-4655, Rapid-Hardening Cementing Materials for Concrete Repair.)

Overview

Effective Date: (September 2006 ?)

This Specification governs the quality monitoring program (QMP) for rapid-hardening cementing material for patching spalls in concrete pavement, and describes prequalification, quality monitoring requirements, disqualification and requalification, sampling and testing, and material requirements.

Material Description

This concrete patching material is a rapidly hardening, hydraulic cement-based material mixed with aggregate to form a mortar, grout or concrete used for patching spalls in concrete pavement.

Use a TxDOT-approved, commercially packaged blend of hydraulic cement, and sand (also gravel of maximum size 3/8 in. permissible for spalls deeper than 2 in.) which requires the addition of water and has a maximum shrinkage of 0.15% in accordance with ASTM C 928. Do not use chlorides, magnesium (from Std. Spec. Item 720) or gypsum to accelerate setting time.

This material must form a semi-rigid or rigid material designed to meet a minimum average compressive strength of 2,000 psi in 3 hours. Provide class HES concrete in accordance with Item 421, "Hydraulic Cement Concrete," except that strength over-design is not desirable. Before spall repair operations, demonstrate that the mixture achieves a final modulus of elasticity of less than 4.0×10^6 and minimum average compressive strength of 3,700 psi at 28 days. Test in accordance with Tex-448-A or Tex-418-A. The coefficient of thermal expansion, as determined from Tex-428-A, must be less than 5.0 10^{-6} in/in/degree F. The multiplication product of coefficient of thermal expansion times the modulus of elasticity for repair material must be less than 20.

The rigidity of this material is preferred over elastomeric patching materials for deep repairs required when the concrete pavement will be repaved with a concrete or asphalt overlay within three years from the repair.

Prequalification

Material Producer List

The Materials and Pavements Section of the Construction Division (CST/M&P) maintains a material producer list (rigdptch?) of all prepackaged materials conforming to the requirements of this program. Materials appearing on the material producer list require no further testing unless deemed necessary by the engineer. To obtain a place on the material producer list the producer must be accepted into the QMP.

The material will be prequalified as a complete binder and aggregate system; thus, the list will include the binder and aggregate specified by the manufacturer. The Contractor, supplier, or producer cannot substitute any of the components without prior notice to and approval of CST/M&P.

Materials not appearing on the material producer list require project specific testing and approval before use. Refer to 'Project Specific Testing.'

Prequalification Requests

Submit a written request to the Texas Department of Transportation, Construction Division, Materials and Pavements Section (CP51), 125 E. 11th Street, Austin, Texas 78701-2483, to prequalify your products. Include the following information in the request:

- company name,

- physical and mailing addresses,
- contact person and telephone number, and
- material type.

Performance History

CST/M&P will only accept into the QMP those materials that are determined by the Director of CST/M&P to have an established performance history and compliance with this Specification. Therefore, prospective producers or suppliers may be required to install their material at a test location. The Department must approve test sections before installation. Provide materials and installation for the test site at no cost to the Department. CST/M&P will monitor the test location for a minimum period of 12 mo. unless the material fails prematurely.

Prequalification Procedures

After the producer submits a request for QMP prequalification, CST/M&P will use the following procedure to prequalify the material:

- The producer will provide a laboratory test report that contains data showing compliance of the material in accordance to the requirements in Material Requirements.
- The producer will submit a minimum of 1 sample (amount of binder components equal to 1cu. ft. of mixed material and corresponding aggregate) for consideration of each type of patching material.
- CST/M&P will test each sample according to the tests outlined in 'Material Requirements.' CST/M&P will determine if there is an adequate correlation between the producer and CST/M&P test results. CST/M&P will reject the material if a correlation is not established or if the material does not meet the requirements.

CST/M&P will place materials meeting all requirements in the quality monitoring program. After acceptance, any changes in formulation or composition must be reported to CST/M&P. Material changes require resubmission for prequalification.

Quality Monitoring Requirements

The prequalification periods are from January 1st to June 30th and July 1st to December 31st of every year. During each prequalification period, the producer must provide 1 prequalification sample, and monthly quality control testing reports.

Monthly Quality Control Reports

The Department requires that all producers in the QMP perform quality control testing on their material. The Department requires that producers submit monthly quality control testing reports to CST/M&P for every prequalified material. The report must reflect the test data from each batch of prequalified material produced during that month regardless of the destination of the material. The monthly report must contain the following information:

- type of patching material,
- date of manufacture,
- batch number, and
- QM test results.

QM tests are those listed in 'Material Requirements.' Producers must submit reports by the first business day of every month. If no prequalified material is produced for a particular month, then submit a report stating no material was produced.

Prequalification Sample

Submit a sample of each prequalified material for every prequalification period at least 1 mo. before the beginning of the prequalification period to allow sufficient time for testing. Any material not submitted on time may be delayed in posting on the material producer list.

Random Testing and Auditing

The Department reserves the right to conduct random sampling of prequalified materials for testing, and perform random audits of test reports. Departmental representative may sample material from the manufacturing plant, the project site, and warehouse. Maintain a complete record of all test reports for the previous and current calendar year. CST/M&P reserves the right to inspect and approve the laboratory where the quality control testing is performed to ensure that all criteria for equipment and procedure compliance are met. CST/M&P reserves the right to test samples to verify compliance with "DMS-4655, Rapid-Hardening Cementitious Materials for Patching Spalls in Concrete Pavement."

Disqualification and Requalification

A producer may be disqualified and removed from the quality monitoring program if 1 of the following infractions occurs:

- Material tested by CST/M&P fails to meet the requirements stated in this Specification
- The producer fails to properly submit complete monthly quality control testing reports or prequalification samples to CST/M&P or
- The producer fails to report changes in the formulation or composition of the material to CST/M&P.

If a material is disqualified, the producer will not be allowed to supply material to the Department for a period of 6 mo., or as determined by the Director of CST/M&P. After this time has expired, the producer must requalify to regain QMP status. Disqualification will only apply to the patching material type corresponding to the infraction.

To requalify after the 6-mo. disqualification period, the producer must submit a written request to CST/M&P. Include with the request a test report from an independent laboratory with data that certifies that the material meets the requirements in Material Requirements. After receiving the request and test data, all requirements in 'Prequalification Procedures' will apply.

Sampling and Testing

The Department will sample in accordance with "Tex-407-A, Sampling Freshly Mixed Concrete," and will test in accordance with 'Material Requirements.'

Costs of sampling and testing are normally borne by the Department; however, the costs to sample and test materials failing to conform to the requirements of this Specification are borne by the Contractor or supplier. This cost will be assessed at the rate established by the Director of CST/M&P and in effect at the time of testing.

Amounts due the Department will be deducted from monthly or final estimates on Contracts or from partial or final payments on direct purchases by the State.

Project Specific Testing

Materials not appearing on the material producer list require project specific testing and approval before their use. Submit samples to CST/M&P with a certified test report from an independent laboratory with test data verifying that the material meets the requirements stated within this Specification. This material must not be used until testing is complete and material is approved.

Material Requirements

General Requirements

Rapid-setting cementitious concrete pavement patching material have the following properties:

- The patching material is able to carry traffic within 3 hr. of placement or as directed by the Engineer.
- Concrete patching material is resistant to weather and abrasion.
- The aggregate type used in the patching material will be those specified by the manufacturer.
- The patching material has a skid-resistant finish (e.g., tining, broadcast sand).
- The patching material has a nonreflective finish with similar color tone to concrete, and

- Concrete patching material must be placed at substrate temperatures of 10°C (50°F) and rising.

Chemical Resistance

Manufacturers must submit a certified report indicating compliance to the following requirements for chemical resistance.

Chemical	Effects
Deicers	None
Motor oil	None
Sodium Chloride Solution (5%)	None
Hydraulic Brake Fluid	None

Standard: ASTM "C 267, Standard Test Method for Chemical Resistance of Mortars, Grouts, and Monolithic Surfacings."

Submit report before the material is accepted into the QMP. It is not required as a part of the monthly quality control reports, unless requested by CST/M&P.

Physical Requirements

Test	Method	Requirements
Final Set, min.	"ASTM C 403/C 403M, Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance"	180 maximum
Slant Shear Strength to Concrete, psi	"ASTM C 882, Test Method For Bond Strength Of Epoxy Resin Systems Used With Concrete By Slant Shear" (as modified in Section 8.5 of "ASTM C 928, Standard Specification for Packaged, Dry, Rapid-Hardening Cementitious Materials for Concrete Repairs"	1000 minimum
Compressive Strength	"ASTM C 579, Standard Test Methods for Compressive Strength of Chemical-Resistant	

@ 3 hr., psi	Mortars, Grouts, Monolithic Surfacings and Polymer Concretes," Method B	2,000 minimum
@ 7 days, psi		3,700 minimum
Modulus of Elasticity, psi	"ASTM C 469 – 02, Standard Test Method for Static Modulus of Elasticity and Poisson's Ratio of Concrete in Compression"	4.0×10^{6} maximum
CoTE, in./in./degree F	"Tex-428-A, Determining the Coefficient of Thermal Expansion of Concrete"	5.0×10^{-6} maximum

Packaging and Labeling

Package reactive components in airtight containers and protect from light and moisture. Package aggregates to protect them from moisture. Include instructions for mixing and application of the material, and include all safety information and warnings regarding contact with the components.

Labels must include the following information:

- type of material
- active chemical components
- brand name
- name of manufacturer
- ratio of components to be mixed by volume
- unique batch number
- date of manufacture and
- expiration date.

SPECIAL SPECIFICATION

3408

Crack and Spall Repair (Elastomeric Patching Material)

1. **Description.** This Item shall govern for the furnishing and installation of elastomeric patching material for the repair of random cracks and spalls in existing Portland cement concrete pavement in accordance with the requirements herein and the details shown on the plans.

2. **Materials.** The repair material shall be an elastomeric patching material consisting of a fluid polyurethane base or binder with a sand and with or without fiberglass aggregate system to provide a product that mixes in 5 minutes or less, flows readily, adheres to concrete, and requires no external application of heat for curing. This material shall be Delpatch (TM) and Delcrete (TM) Elastomeric Concrete as manufactured by D. S. Brown Company, or equal, as approved by the Engineer.

   The materials shall meet the following physical properties:

Binder Only

Test		Test Method	Specification
Original Properties (after conditioning at 100 F for 7 days)	Tensile Strength, psi	TEX-618-J	1,100 Min.
	Tensile Stress, psi	TEX-618-J	500 Min.
	Elongation, %	TEX-618-J	200 Min.
	Hardness, Durometer D	ASTM D2240	90 + 3 A
Tensile Properties (after oven aging 7 days @ 158 F ASTM D573	Tensile Strength, psi	TEX-618-J	1,100 Min.
	Tensile Stress, psi	TEX-618-J	500 Min.
	Elongation, %	TEX-618-J	200 Min.
	Hardness, Durometer D	ASTM D2240	90 + 3 A

   Properties for the binder and aggregate shall be submitted by the Manufacturer to the Engineer for approval.

   The size of the aggregate and binder to aggregate ratio shall meet one of the following mix types:

Type 1. The aggregate shall consist of fine silica sand passing the No. 30 sieve size. The composition of the mix shall be approximately 15 lb. of aggregate per 1 gal. of binder.

Type 2. The aggregate shall consist of fine silica sand passing the No. 6 sieve size. The composition of the mix shall be approximately 30 to 40 lb. of aggregate per 1 gal. of binder.

Type 3. The aggregate shall consist of sand of the size selected by the Manufacturer. The composition of the mix shall be approximately 60 lb. of aggregate per 1 gal. of binder.

The type of mix required for the project shall be as indicated on the drawings.

The elastomeric patching material shall be gray in color. The material shall be kept dry and above freezing temperatures. During hot weather the material shall be kept in the shade and/or as directed by the Manufacturer.

3. **Construction Methods.** Prior to beginning operations, the Contractor shall submit a statement from the elastomeric concrete manufacturer showing the recommended equipment and installation procedures to be used. All equipment and procedures will be subject to approval by the Engineer.

The use of any equipment which damages dowels, reinforcing steel, concrete, base, subbase or subgrade shall be discontinued, and the joint and/or crack shall be cleaned by other methods which do not cause such damage.

(A) Crack And Spall Preparation. At the time of sealing, the crack or spall shall be free of all debris, dirt, dust, saw cuttings or other foreign material.

The cracks shall be cleaned by a method approved by the Engineer. Unless otherwise shown on the plans, hand tools, air guns, power routers, abrasive blasting equipment or other equipment may be used to clean the cracks.

Unsound concrete shall be removed to the dimensions indicated on the plans or as directed by the Engineer. Prior to application of the elastomeric patching material, the surface shall be dry and shall be sandblasted to ensure it is free from dirt, grease, oil, laitance or other foreign material which may reduce the bond between the elastomeric patching material and the existing concrete pavement. There shall be no dust from the sand blasting operation in the area to be repaired.

(B) Primer. After sandblasting, a primer supplied by the manufacturer shall be applied to the area to be repaired and allowed to cure for a minimum of 30 minutes before placing the elastomeric patching material. The primer shall be re-applied if 6 hours pass prior to introduction of the elastomeric patching material, or if a rain occurs.

(C) Application. Elastomeric concrete components shall be weighed and mixed in accordance with the manufacturer's recommendations. The material shall be placed into the area to be repaired within 4 minutes of the initial mixing. If there is a sloped condition in the roadway, placement shall begin at the lower end. Upon initial cure, a notched trowel shall be used to provide a non-skid finish to the surface.

An experienced manufacturer's representative or agent of the manufacturer shall be present during the installation of the elastomeric patching material.

4. **Measurement.** This Item will be measured by the mixed gallon of elastomeric patching material, complete in place, of the type specified.

5. **Payment.** The work performed and materials furnished in accordance with this Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Crack and Spall Repair Type 1", "Crack and Spall Repair Type 2" or "Crack and Spall Repair Type 3". This price shall be full compensation for furnishing all materials; for all routing and chipping, removal of loose concrete and cleaning; furnishing and installing "Elastomeric Patching Material and Primer"; and for all manipulations, labor, equipment, tools and incidentals necessary to complete the work.

SPECIAL SPECIFICATION
3096
Fiber Reinforced Polymer Patching Material

1. **Description.** Repair spalled areas, potholes, and joints on concrete decks, and concrete pavements using a fiber reinforced polymer patching material, bulking aggregates and surface course aggregates as specified below.

2. **Material.** The patching material is a dry powder consisting of resin, polymers, graded fillers, granite aggregates, metal fibers, glass fibers and recycled tire rubber that once heated provides an impermeable, voidless mass solid at ambient temperatures. The patching material is formulated according to climatic conditions to provide a durable pavement repair with good fluidty at process temperature, low temperature flexibility and ambient temperature flow resistance.

   Provide material where the binder meets the following requirements:

Binder Properties	Method	Requirement
Bond	ASTM D 5329	Pass, 3 cycles @ -20°F 50% extension
Cone Penetration	ASTM D 5329	15 pen units min @ 39°F
Ductility	AASHTO T51	15.75 in min @ 77°F
Flow	ASTM D 5329	0.12 in max @ 140°F for 5 hours
Resilience	ASTM D 5329	40% min @ 77°F
Softening Point	AASHTO T53	179°F min
Flash Point	AASHTO T48	410°F min

   Bulking Aggregate. Provide single sized bulking aggregate consisting of a crushed, double washed, and dried Grade 1 Granite in accordance with Item 302, "Aggregates for Surface Treatments" or equivalent.

   Final Surface Aggregate. Provide final surface aggregate consisting of a crushed, double washed, and dried Grade 5 aggregate in accordance with Item 302, "Aggregates for Surface Treatments."

3. **Construction.** Place the patching material installation to encompass the damaged / spalled areas as shown on the plans. Variations in depth and width of the repair area can be adjusted in the field by the Engineer.

   The repair/replacement procedure will include the following:

(1) Ensure work is performed by an applicator certified by the material.

(2) Saw cut around the repair area and remove all loose and damaged pavement. Remove the repair area to a depth and width which will allow proper seating of the patching material.

(3) Use a milling machine or jackhammer to develop the depressed seat. Obtain approval for jackhammer size prior to use. Use an approved jackhammer capable of performing the required removal of the existing material without further damaging the surrounding pavement. Thoroughly clean and dry concrete substrate faces using a hot-compressed air lance.

(4) For concrete pavement, prime the area using a primer determined by the manufacturer to prevent moisture intrusion. For concrete pavement repair, apply a layer of heated binder to cover the bottom and sides of the repair area.

(5) Mix and heat the patching material binder on site in a horizontal mixing unit equipped with electronically controlled thermostats. Heat the bulking and final surface aggregates and dry free of any dust in a vented barrel mixer to 300°F or other approved method.

(6) Apply the patching material binder to the repair area. If the repair area is deeper than 2 in., add bulking aggregate at a minimum rate of 15% and maximum rate of 30% by volume as directed. If the repair extends deeper than 2 in., install the heated binder in layers and add the heated bulking aggregates to the repair material at the rate directed above.

(7) Build the patching in successive layers until level with the existing pavement.

(8) Apply a final coat of the heated patching material binder to level the repair area and overlap the edges of the repair area approximately 2 in. to ensure a tight, waterproof seal. The surface of the patch will then be dressed with heated surface aggregate.

(9) Sweep the area and remove all debris from the site.

Do not allow traffic over the material until after it has cooled to the point that it does not permanently deform under pressure as directed and/or as specified by the patching material binder manufactures instructions.

4. **Measurement.** This Item will be measured by the pound of fiber reinforced patching material binder installed.

5. **Payment.** The work performed and materials furnished in accordance with the Item and measured as provided under "Measurement" will be paid for at the unit price bid for "Fiber Reinforced Polymer Patching Material". This price is full compensation for furnishing materials, including bulking and final surface aggregates, patching material binder, and primer; heating and mixing; removal and disposal of existing pavement material; placing and finishing; and labor, equipment, tools and incidentals.

Section Index

TxDOT Concrete Test Specifications

Tex-418-A, Compressive Strength of Cylindrical Concrete Specimens
Tex-428-A, Determining the Coefficient of Thermal Expansion of Concrete
Tex-442-A, Determining Compressive Strength of Grouts
Tex-448-A, Rebound Number of Hardened Concrete
Tex-498-A, Minimum Standards for Acceptance of a Laboratory for Concrete and Aggregate Testing

TxDOT Elastomeric Concrete Specifications

Tex-614-J, Testing Epoxy Materials
Tex-613-J, Testing Elastomeric Concrete

ASTM Methods Cited in TxDOT Elastomeric Testing Specifications

ASTM C 190 (prior to 1991) for reference to molding briquet specimens
ASTM C 579, Standard Test Methods for Compressive Strength of Chemical-Resistant Mortars, Grouts, Monolithic Surfacings, and Polymer Concretes

ASTM D 76, Standard Specifications for Tensile Testing Machines for Textiles
ASTM D 412, Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers-Tension
ASTM D 624, Standard Test Method for Tear Strength of Conventional Vulcanized Rubber and thermoplastic Elastomers
ASTM D 638. Standard Test Method for Tensile Properties of Plastics

Tex-418-A, Compressive Strength of Cylindrical Concrete Specimens

Contents:

Section 1

Overview

Effective Date: June 2006 (refer to 'Archived Versions' for earlier versions).

Part I of this method covers determining compressive strength of cylindrical concrete specimens such as molded cylinders and drilled cores. It is limited to concrete having a unit weight in excess of 800 kg/m^3 (50 lb/ft^3). Except for editorial differences, this test method is identical with ASTM C 39 and AASHTO T 22. Part II discusses the use of neoprene caps during this testing.

Units of Measurement

The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

Section 2

Part I. Determining Compressive Strength of Cylindrical Concrete Specimens

This part determines compressive strength of cylindrical concrete specimens such as molded cylinders and drilled cores. It is limited to concrete having a unit weight in excess of 800 kg/m^3 (50 lb/ft^3).

Significance and Use

Below is information regarding the significance and use of this test method.

Exercise care interpreting the significance of compressive strength determinations by this test method, since strength is not a fundamental or intrinsic property of concrete made from given materials. Values obtained will depend on the size and shape of the specimen, batching, mixing procedures, the methods of sampling, molding, fabrication, age, temperature, and the moisture conditions during curing.

Use this method to determine compressive strength of cylindrical specimens prepared and cured according to test methods "Tex-424-A, Obtaining and Testing Drilled Cores of Concrete, Tex-447-A, Making and Curing Concrete Test Specimens," and/or "Tex-450-A, Capping Cylindrical Concrete Specimens."

The results of this test method may be used as a basis for quality control of concrete proportioning, mixing, and placing operations; determination of compliance with specifications; control for evaluating effectiveness of admixtures and similar uses.

Apparatus

The following apparatus is required:

- Testing Machine, power operated, able to apply a load continuously rather than intermittently, without shock, having sufficient capacity, and capable of providing the rates of loading prescribed herein. If it has only one loading rate, it must be provided with a supplemental means for loading at a rate suitable for verification. This supplemental means of loading may be power or hand operated.
- Elastic calibration device, such as the circular proving ring, with sufficient capacity to cover the potential loading range of the testing machine and which complies with the requirements of ASTM E 74.
- Testing space, large enough to accommodate, in a readable position, an elastic calibration device.
- Bearing Blocks, Upper and Lower, with bearing faces that have a Rockwell hardness not less than 55 HRC, and minimum dimensions at least 3% greater than the diameter of the test specimen. Except for the concentric circles described below, bearing faces shall not depart from a plane by more than 0.025 mm (0.001 in.) in any 152 mm (6 in.) in blocks 152 mm (6 in.) in diameter or larger, or by more than 0.025 mm (0.001 in.) in

diameter of any smaller block. New blocks must be manufactured to one half this tolerance.

- Upper bearing block, a spherically seated block that will bear on the upper surface of the specimen. The maximum diameter of the bearing face of the suspended spherically seated block shall not exceed these values:

Maximum Diameter of Bearing Face	
Diameter of Test Specimens mm (in.)	Maximum Diameter of Bearing Face mm (in.)
51 (2)	102 (4)
76 (3)	127 (5)
102 (4)	165 (6-1/2)
152 (6)	254 (10)
203 (8)	279 (11)

NOTE: Square bearing faces are permissible, provided the diameter of the largest possible inscribed circle does not exceed the above diameter.

The center of the sphere must coincide with the surface of the bearing face within a tolerance of ± 5% of the radius of the sphere. The diameter of the sphere must be at least 75% of the diameter of the specimen to be tested.

When the diameter of the bearing face of the spherically seated block exceeds the diameter of the specimen by more than 13 mm (1/2 in.), inscribe concentric circles not more than 0.8 mm (1/32 in.) deep and not more than 1.2 mm (3/64 in.) wide to facilitate proper centering.

The ball and the socket must be so designed by the manufacturer that the steel in the contact area does not permanently deform under repeated loads up to 82.7 MPa (12,000 psi) on the test specimen. The preferred contact area is in the form of a ring (described as "preferred bearing area") as shown in 'Schematic Sketch of a Typical Spherical Bearing Block.'

"Line Call-Out" Designation

Grade Class — Tensile Strength — Compression Set

M 2 B C 5 14 A14 B14

SI Units — Type — Hardness — Heat Resistance

Type - 100 °C Test Temperature
Class - 120% Maximum Volume Swell
Hardness (Durometer) - 50± 5 points (Duro)
Tensile Strength - 14 Mpa
Heat Resistance - Tested according to Test Method ASTM D 573
Compression Set - Tested according to Test Method ASTM D 395

Figure 1. Schematic Sketch of a Typical Spherical Bearing Block.

The following text refers to the 'Schematic Sketch of a Typical Spherical Bearing Block.'

The curved surfaces of the socket and of the spherical portion shall be kept clean and shall be lubricated with petroleum-type oil such as conventional motor oil, not with pressure type grease. After contacting the specimen and application of small initial load, further tilting of the spherically seated block is not intended and is undesirable.

If the radius of the sphere is smaller than the radius of the largest specimen to be tested, the portion of the bearing face extending beyond the sphere shall have a thickness not less than the difference between the radius of the sphere and radius of the specimen. The least dimension of the bearing face shall be at least as great as the diameter of the sphere.

The movable portion of the bearing block shall be held closely in the spherical seat, but the design shall be such that the bearing face can be rotated freely and tilt at least 4° in any direction.

Make final centering with reference to the upper spherical block. When the lower bearing block is used to assist in centering the specimen, the center of the concentric rings, when provided, or of the block itself, must be directly below the center of the spherical head. Make provisions on the platen to assure such a position.

- Lower bearing block, at least 25 mm (1 in.) thick when new, and at least 22.9 mm (9/10 in.) thick after any resurfacing operations, on which specimens will rest, which provides a machineable surface to maintain the specified surface conditions. Concentric circles, as described above, are optional. The block may be fastened to the platen of the testing machine. If the machine is so designed that the platen itself can be maintained in the specified surface condition, a bottom block is not required.

- Load Indicators
- Dial-type, with a graduated scale that can be read to at least the nearest 0.1% of the indicated load at any given level within the loading range. In no case shall the loading range of a dial be considered to include loads below the value that is 100 times the smallest change of load that can be read on the scale. The scale must be provided with a graduation line equal to zero and so numbered. The dial pointer shall be of sufficient length to reach the graduation marks; the width of the pointer tip must not exceed the clear distance between the smallest graduations. Each dial shall be equipped with a zero adjustment easily accessible from outside the case, with a suitable device that, at all times until reset, will indicate to within 1% accuracy the maximum load being applied.

NOTE: One half of a scale interval is about as close as can reasonably be read (0.50 mm [0.02 in.]) along the arc described by the end of the pointer) or when the spacing on the load indicating mechanism is between 1 mm and 1.6 mm (1/25 in. and 1/16 in). When spacing is between 1.6 mm (1/16 in.) and 3.2 mm (1/8 in), one third of an interval can be read with reasonable certainty. When the spacing is 3.2 mm (1/8 in.) or more, one fourth of a scale interval can be read with reasonable certainty.

- Digital load indicator, with a numerical display large enough to be easily read, and numerical increment equal to or less than 0.10% of the full scale load of a given loading range. In no case shall the verified loading range include loads less than the minimum numerical increment multiplied by 100. The accuracy of the indicated load must be within 1.0% for any value displayed within the verified loading range. Provision must be made for adjusting to indicate true zero at zero load. A maximum load indicator will indicate, within 1% system accuracy, the maximum load applied to the specimen at all times, until reset.

Calibration Requirements

Below are the requirements for verifying calibration of the testing machine:

- Verifying calibration of the testing machine according to ASTM E 4 is required:
  - After an elapsed interval since the previous verification of 18 months maximum, but preferably after an interval of 12 months
  - On original installation or relocation of the machine
  - Immediately after making repairs or adjustments which may in any way affect the operation of the weighing system or the values displayed, except for zero adjustments that compensate for the weight of tooling, or specimen, or both
  - Whenever there is reason to doubt the accuracy of the results, without regard to the time interval since the last verification.
- The accuracy of the testing machine should conform to these provisions:
  - The percentage of error for the loads within the proposed range of use of the testing machine must not exceed ± 1.0% of the indicated load.

- The accuracy of the testing machine should be verified by applying five test loads in four approximately equal increments in ascending order. The difference between any two successive test loads should not exceed one third of the difference between the maximum and minimum test loads.
- The test load as indicated by the testing machine, and the applied load computed from the readings of the verification device, will be recorded at each test point.
- Calculate the error, *E*, and the percentage of error, *Ep*, for each point from these data:

$$E = A - B$$

$$Ep = 100\,(A - B)/B$$

Where:

A = load, N indicated by the machine being verified, and

B = applied load, N as determined by the calibrating device.

- The report on the verification of a testing machine should state within what loading range it was found to conform to specification requirements, rather than reporting a blanket acceptance or rejection. In no case shall the loading range be stated as including loads below the value which is 100 times the smallest change of load that can be estimated on the load-indicating mechanism of the testing machine or loads within that portion of the range below 10% of the maximum range capacity.
- In no case shall the loading range be stated as including loads outside the range of loads applied during the verification test.
- The indicated load of a testing machine should not be corrected either by calculation or by the use of a calibration diagram to obtain values within the required permissible variation.

Specimens

- Specimens shall not be tested if any diameter of a cylinder differs from any other diameter of the same cylinder by more than 2%.

NOTE: This may occur when single use molds are damaged or deformed during shipment, when flexible single use molds are deformed during molding, or when a core drill deflects or shifts during drilling.

- Neither end of compressive test specimens should depart from perpendicularity to the axis by more than 0.5° (3 mm in 300 mm [1/8 in. in 12 in.]).
- Cap the ends of compression test specimens according to Test Method "Tex-450-A, Capping Cylindrical Concrete Specimens."
- Determine the diameter used for calculating the cross-sectional area of the test specimen to the nearest 0.25 mm (0.01 in.) by averaging two diameters measured at right angles to each other at about mid-height of the specimen.

- The number of individual cylinders measured for determining average diameter may be reduced to one for each ten specimens or three specimens per day, whichever is greater, if all cylinders are known to have been made from a single lot of reusable or single-use molds which consistently produce specimens with average diameters within a range of 0.51 mm (0.02 in).
- When the average diameters do not fall within the range of 0.51 mm (0.02 in.) or when the cylinders are not made from a single lot of molds, each cylinder tested must be measured and the value used to calculate the unit compressive strength of that specimen.
- When the diameters are measured at the reduced frequency, the cross-sectional areas of all cylinders tested on that day shall be computed from the average of the diameters of the three or more cylinders representing the group tested that day.
- The length shall be measured to the nearest 0.05*D* when the length to diameter ratio is less than 1.8, or more than 2.2, or when the volume of the cylinder is determined from measured dimensions.

Test Procedure

The following describes the procedure for compression testing of cylindrical concrete specimens:

- Test specimens in a moist condition.
- Perform compression tests of moist cured specimens as soon as practicable after removal from moist storage.
- Keep test specimens moist by any convenient method during the period between removal from moist storage and testing.
- Break all test specimens for a given test age within the permissible time tolerances prescribed:

Time Tolerances	
Test Age	**Permissible Tolerance**
24 h	±0.5 h or 2.1%
3 days	2 h or 2.8%
7 days	6 h or 3.6%
28 days	20 h or 3.0%
90 days	2 days 2.2%

The following table details compression testing cylindrical concrete specimens.

Compression Testing of Cylindrical Concrete Specimens

Step	Action
1	♦ Place the lower bearing block, with its hardened face up, on the table or platen of the testing machine directly under the spherically seated (upper) bearing block. ♦ Clean the bearing faces of the upper and lower bearing blocks and the test specimen and place the test specimen on the lower bearing block. ♦ Carefully align the axis of the specimen with the center of thrust of the spherically seated block. ♦ As the spherically seated block is brought to bear on the specimen, rotate its movable portion gently by hand, so that uniform seating is obtained.
2	♦ Apply the load continuously and without shock. • For testing machines of the screw type, the moving head shall travel at a rate of approximately 1 mm (0.05 in.)/minute when the machine is running idle. • For hydraulically operated machines, the load shall be applied at a rate of movement (platen to cross-head measurement) corresponding to a loading rate on the specimen within the range of 0.14 to 0.34 MPa/s (20 to 50 psi/s). Maintain the designated rate of movement at least during the latter half of the anticipated loading phase of the testing cycle. ♦ During the application of the first half of the anticipated loading phase a higher rate of loading shall be permitted. ♦ Make no adjustment in the rate of movement of the platen at any time while a specimen is yielding rapidly immediately before failure. ♦ Apply the load until the specimen fails, and record the maximum load carried by the specimen during the test. ♦ Note the type of failure and the appearance of the concrete.

Calculations

Use the following calculations to determine the compressive strength of the specimens:

Calculate the compressive strength of the specimen by dividing the maximum load carried by the specimen during the test by the average cross-sectional area determined as previously described and express the result to the nearest 50 kPa (10 psi).

If the specimen length to diameter ratio is less than 1.8, correct the result obtained by multiplying by the appropriate correction factor shown in the following table:

Correction Factors

L/D	1.75	1.50	1.25	1.00
Factor:	0.98	0.96	0.93	0.87

NOTE 8: These correction factors apply to light weight concrete weighing between 1600 and 1920 kg/m^3 (100 and 200 lb/ft^3) and to normal weight concrete. They are applicable to concrete dry or soaked at time of loading. Values not given in the table shall be determined by interpolation (see 'Cylindrical Concrete Specimens Factor Table' in Test Method "Tex-424-A, Obtaining and Testing Drilled Cores of Concrete"). The correction factors are applicable for nominal concrete strengths from 13.8 to 41.4 MPa (2000 to 6000 psi).

Report

Include the following in the report:

- Identification Number
- Diameter (and length, if outside the range of 1.8*D* to 2.2*D*), in inches
- Cross-sectional area, in square millimeters (square inches)
- Maximum load, in Newtons (pounds-force)
- Compressive strength calculated to the nearest 50 kPa (10 psi)
- Type of fracture, if other than the usual cone (see 'Sketches of Types of Fracture')
- Defects in either specimen or caps
- Age of specimen.

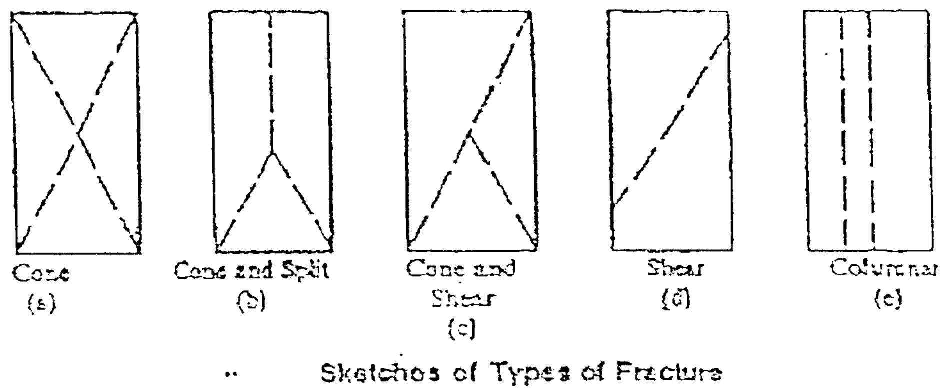


Figure 2. Sketches of Types of Fracture.

Section 3

Part II, Compressive Strength of Cylindrical Concrete

This part discusses the use of unbonded caps during this testing.

Specimens Using Unbonded Caps

'Part II, Compressive Strength of Cylindrical Concrete' discusses the use of unbonded caps with metal extrusion control retainers as a suitable alternate capping procedure to those identified in Test Method "Tex-450-A, Capping Cylindrical Concrete Specimens" to determine the compressive strength of molded cylindrical concrete specimens. Except for editorial differences, this procedure is the same as ASTM C 1231.

Apparatus

The following apparatus is required:

- Steel extrusion control retainers, with cavities which have a depth at least twice the thickness of the pad. The inside diameter of the retaining rings should not be less than 102% or greater than 104% of the diameter of the cylinder. The surfaces of the steel retainer which contact the bearing blocks of the testing machine must be plane to within 0.05 mm (1/500 in.). The bearing surfaces of the retainers should not have gouges, grooves, or indentations greater than 0.25 mm (1/100 in.) deep or 32 mm^2 (1/20 in.^{2}) in surface area.
- Pads made of polyurethane or various other rubbers such as polychloroprene (neoprene) or natural rubber that have a Shore "A" durometer hardness of 50 to 70 have been found acceptable. Shore "A" hardness is determined by ASTM D 2240.

Precautions

The following precaution should be observed when testing cylinders with unbonded caps:

Concrete cylinders tested with unbonded caps rupture more intensely than comparable cylinders tested with sulfur mortar caps. As a safety precaution, the cylinder testing machine should be equipped with a protective cage.

Test Specimens

Test specimen as detailed in 'Part I, Determining Compressive Strength of Cylindrical Concrete Specimens' of this test method, modified as noted:

- Each end of the concrete cylinder must be plane within 3 mm (1/8 in.) across any diameter; i.e., there shall be no depressions in the concrete surface which are deeper than 3 mm (1/8 in.). Do not test cylinders that do not meet this tolerance, unless the surface irregularity is corrected.

- Neither end of the specimen shall depart from perpendicularity to the axis by more than 0.5° (approximately 3 mm in 300 mm [1/8 in. in 12 in.]). No diameter of a cylindr may differ from any other diameter by more than 2%.

Test Procedure

Perform the compression test as detailed in 'Part I, Determining Compressive Strength of Cylindrical Concrete Specimens' of this test method, modified as follows:

- Place an extrusion controller, containing a pad (as described in 'Apparatus'), on the top and bottom surfaces of the concrete cylinder. With the neoprene caps in contact with the concrete cylinder, carefully align the axis of the specimen with the center of thrust of the spherically seated block. Bring the bearing blocks of the machine in contact with both of the extrusion controllers.
- No loose particles shall be trapped between the concrete cylinder and the neoprene caps or between the bearing surfaces of the extrusion controllers and the bearing blocks of the testing machine.
- The same surface of the neoprene cap shall bear on the concrete cylinder for all tests performed with that cap. Do not test more than 100 cylinders with one neoprene cap. Pads exhibiting cracks or splits, regardless of number of uses, must be replaced immediately.

NOTE 1: Deterioration of the pad at the perimeter is normal, however if the thickness is reduced by more than 4 mm (1/8 in.) the pad shall be replaced.

NOTE 2: When used, neoprene caps shall be considered as an acceptable substitute for sulfur-mortar caps without correction for apparent strength differences.

Section 4

Archived Versions

Archived versions of Test Method "Tex-418-A, Compressive Strength of Cylindrical Concrete Specimens" are available through the following links:

- Click on 418-0899 for the test procedure effective August 1999 through May 2000.

Tex-428-A, Determining the Coefficient of Thermal Expansion of Concrete

Contents:

Section 1

Overview

Effective Date: January 2001.

This test method describes the procedure used to determine the linear coefficient of thermal expansion (COTE) of concrete by measuring the change in length of concrete cores or cylinders subjected to a range of temperatures.

Units of Measurement

The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

Section 2

Apparatus

The following apparatus is required:

- Water Bath – capable of maintaining temperatures of 50 ± 1 °C (122 ± 2 °F) and 10 ± 1 °C (50 ± 2 °F)
- Scale or balance with a capacity of 20 kg (44 lb.). and accurate to 0.1% over its range
- Caliper, comparator or other suitable device to measure the specimen length to the nearest 0.1 mm (0.005 in.)
- Support frame, as described in 'Support Frame'
- Concrete saw, capable of sawing the ends of a cylindrical specimen perpendicular to the axis and parallel to each other
- Four submersible temperature measuring devices with a resolution of 0.1 °C (0.2°F) and accurate to 0.2 °C (0.4 °F)
- Submersible LVDT gage head with excitation source and digital readout, with a minimum resolution of 0.00025 mm (0.00001 in.), and a range suitable for the test (for ease in setting up the apparatus, a range of ± 3 mm (0.1 in.) has been found practical)
- Reference bar, made of 304 stainless steel or other non-corrosive material of known thermal expansion; approximately 180 mm (7 in.) in length and 51 mm (2 in.) in diameter.

Section 3

Test Specimens

Test specimens shall consist of 100 mm (4 in.) or 150 mm (6 in.) nominal diameter cores or cylinders. Cores shall be obtained according to Test Method "Tex-424-A, Obtaining and Testing Drilled Cores of Concrete." Cylinders shall be cast according to Test Method "Tex-447-A, Making and Curing Concrete Test Specimens." The specimens shall be sawed perpendicular to the axis at a standard length of 180 ± 2 mm (7 ± 0.1 in.). The sawed ends shall be flat and parallel.

Section 4

Part I, Determining the Coefficient of Thermal Expansion

Procedure

The following procedure outlines the steps to determine the coefficient of thermal expansion.

Determining the Coefficient of Thermal Expansion	
Step	**Action**
1	♦ Condition the test specimens by submerging in saturated limewater at 23 ± 2 °C (73 ± 4 °F) for not less than 48 hours. ♦ Conditioning is complete when two successive weighings of the surface-dried sample taken at intervals of 24 hours show an increase in weight of less than 0.5%. ♦ Obtain a surface dried sample by removing the surface moisture with a towel.
2	♦ To avoid any sticking at the points of contact with the specimen, put a *very thin* film of silicon grease on the end of the support buttons and LVDT tip. ♦ Place the support frame, with LVDT attached, in the cold water bath.
3	Place the four temperature sensors in the bath at locations that will provide an average temperature for the bath as a whole.
4	♦ Remove the specimen from the saturation tank and measure its length at room temperature to the nearest 0.1 mm (0.004 in.). ♦ Record this length as L_0. *NOTE:* All measurements must be completed within one minute after removing the specimen from the saturation tank.
5	Place the specimen in the measuring apparatus located in the controlled temperature bath, making sure that the lower end of the specimen is firmly seated against the support buttons, and that the LVDT tip is seated against the upper end of the specimen.
6	♦ Set the temperature of the water bath to 10 ± 1 °C (50 ± 2 °F). ♦ Maintain this temperature until thermal equilibrium of the specimen has been reached, as indicated by consistent readings of the LVDT to the nearest 0.00025 mm (0.00001 in.) taken every ten minutes. ♦ Ensure that the specimen is firmly seated against the support buttons, as confirmed by the LVDT reading.
7	♦ Record the temperature readings from the four sensors to the nearest 0.1 °C (0.2 °F). The average of the four temperature readings is the initial temperature, T_1. ♦ Record the LVDT reading to the nearest 0.00025 mm (0.00001 in.). This is the initial length reading, L_1.
8	♦ Set the temperature of the water bath to 50 ± 1 °C (122 ± 2 °F). ♦ Maintain this temperature until thermal equilibrium of the specimen has been reached, as indicated by consistent readings of the LVDT to the nearest 0.00025 mm (0.00001 in.) taken every ten minutes.
9	♦ Record the temperature readings from the four sensors to the nearest 0.1 °C (0.2 °F). The average of the four temperature readings is the second temperature, T_2. ♦ Record the LVDT reading to the nearest 0.00025 mm (0.00001 in.). This is the second reading, L_2.
10	♦ Set the temperature of the water bath to 10 ± 1 °C (50 ± 2 °F). ♦ Maintain this temperature until thermal equilibrium of the specimen has been reached,

Determining the Coefficient of Thermal Expansion	
Step	Action
	as indicated by consistent readings of the LVDT to the nearest 0.00025 mm (0.00001 in.) taken every ten minutes over a one-half hour time period.
11	• Record the temperature readings from the four sensors to the nearest 0.1 °C (0.2 °F). The average of the four temperature readings is the third temperature, T_3. • Record the LVDT reading to the nearest 0.00025 mm (0.00001 in.). This is the third reading, L_3.

Calculations

An average coefficient of thermal expansion (COTE) will be obtained by determining the individual COTE for both Steps 6-9 and for Steps 8-11. A correction factor (C_f) is needed to eliminate any effect caused by thermal expansions or contractions of the measuring apparatus and support frame. The calculation of the correction factor is described in Part II of this test method.

The COTE for the first segment is determined as described below.

$$COTE_1 = \frac{(L_2 - L_1) + [C_f \bullet L_0 \bullet (T_2 - T_1)]}{L_0 \bullet (T_2 - T_1)}$$

The COTE for the second segment is calculated as:

$$COTE_2 = \frac{(L_2 - L_3) + [C_f \bullet L_0 \bullet (T_2 - T_3)]}{L_0 \bullet (T_2 - T_3)}$$

The average of COTE1 and COTE2 shall be the COTE of the specimen.

NOTE: The difference between COTE1 and COTE2 must be less than or equal to 0.5 micro strains/°C (0.3 micro strains/°F). If this tolerance is exceeded, one or more additional test segments should be completed until two successive test segments yield COTE values within allowable tolerances.

Report

Report the average COTE to three significant digits.

Example:

$$COTE = 17.3 \times 10^{-6} / {}^\circ C$$

Section 5
Part II, Determining Correction Factor

Procedure

The following table outlines the steps to determine the correction factor.

Determining Correction Factor	
Step	**Action**
1	Conduct Steps 3-8 from the 'Determining the Coefficient of Thermal Expansion' procedure using the reference bar as the test specimen. NOTE: The reference bar should be kept in a clean, dry location and will not be placed in the saturation tank.
2	Calculate the measured length change (ΔL_{msd}) of the reference bar during the temperature change using the following equation: $$\Delta L_{msd} = L_2 - L_1$$
3	Calculate the actual length change (ΔL_{act}) of the reference bar during the temperature change using the following equation: $$\Delta L_{act} = L_B \times \alpha_c \times (T_2 - T_1)$$ Where: ♦ L_B = length of the reference bar ♦ α_c = coefficient of thermal expansion of reference bar, /°C (17.3×10^{-6}/°C, for 304 SS).
4	Calculate the correction factor (C_f) as follows and record to three significant digits: $$C_f = \frac{\Delta L_{act} - \Delta L_{msd}}{L_B(T_2 - T_1)}$$

Support Frame

The frame shall be made of non-corroding material to minimize the effects of being submerged in a water bath. Vertical members shall be made of Invar, a low thermally expansive material. All other components shall be made of 304 stainless steel.

The threaded measurement tip shall have a threadlocker (example, Loctite 242) applied to prevent loosening during a test. The frame may be designed to be adjustable to accommodate different sample lengths; however, calibrations will be required after each adjustment.

Baseplate Dia. - 10" or Rectangular 10" x 5"

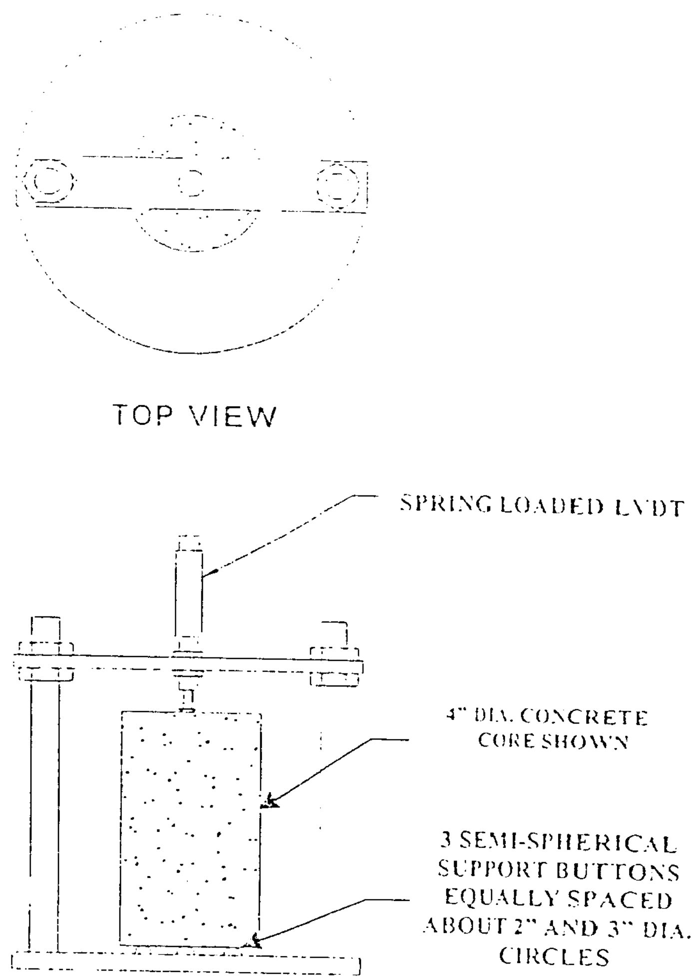


Figure 1. Support Frame.

Tex-442-A, Determining Compressive Strength of Grouts

Contents:

Section 1

Overview

Effective date: June 2003.

This test method determines the compressive strength of grout cubes. Grout is formed in cubes, cured, and compressed.

This procedure is identical to ASTM C 942.

Units Disclaimer

The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

Section 2

Apparatus

The following apparatus is required:

- glass graduates
- three-gang molds, for 2 in. cube specimens
- baseplates
- trowel
- testing machine as specified in "Tex-418-A, Compressive Strength of Cylindrical Concrete Specimens"
- cover plates for specimen molds, capable of supporting a 15-lb. mass
- mass of 15 lb. for holding down cover plates
- release agent.

Section 3

Test Sample

The grout field-test sample will consist of approximately 1500 mL and will be representative of the sample in the mixer.

Section 4

Procedure

The following table describes the compressive strength test.

Compressive Strength Test	
Step	Action
1	Grease molds with release agent.
2	Mold sets of cube specimens. ♦ A 3-gang cube mold will constitute 1 test set. ♦ Provide at least 2 sets.
3	♦ Fill each mold halfway. ♦ Puddle each with a gloved finger 5 times to release entrapped air. ♦ Fill the mold and puddle again. ♦ Bring the excess grout to the center and finish the surface by cutting off the excess with the straight edge of a trowel held vertically and drawn across the top of the mold with a sawing motion.
4	♦ Place the cover plate over the mold, taking care that the grout or loose grains of sand do not prevent seating of the plate. ♦ Place a mass of 15 lb. on each cover plate.
5	Store field specimens according to "Tex-447-A, Making and Curing Concrete Test Specimens."
6	♦ Determine the average compressive strength of 3 cube specimens a minimum of 7 days. ♦ Test the final set of cubes, if needed, at 28 days.
7	♦ Wipe each specimen to a surface dry condition, and remove any loose sand grains from the faces that will be in contact with the bearing blocks of the testing machine. ♦ Check the faces with a straightedge. ♦ Plane curved surfaces by grinding or discard specimen. ♦ Make a check of the cross-sectional area of the specimens.
8	Apply the load to specimen faces that were in contact with the true plane surfaces of the mold.
9	♦ Place the specimen in the testing machine below the center of the upper bearing block. ♦ Use no cushioning or bedding materials.
10	♦ Bring the spherically seated block into uniform contact with the surface of the specimen. ♦ Apply the load rate at a relative rate of movement between the upper and lower platens corresponding to a loading on the specimen with the range of 200 to 400 lb./sec.
11	♦ Record the maximum load indicated by the testing machine. ♦ Calculate the compressive strength of the cube. ♦ Take an average of the set of cubes.

Section 5

Calculations

Determine the compressive strength as follows:

$F_m = P/A$

Where:

- F_m = compressive strength (psi)
- P = total maximum load (lb.)
- A = area of loaded surface (in.^{2}).

Determine the average of the 3 cubes as follows:

$$Avg = \frac{C_1 + C_2 + C_3}{3}$$

Where:

- Avg = Average compressive strength of 3 cubes (psi)
- C_1 = compressive strength of cube 1 (psi)
- C_2 = compressive strength of cube 2 (psi)
- C_3 = compressive strength of cube 3 (psi).

Tex-446-A, Rebound Number of Hardened Concrete

Contents:

Section 1

Overview

This test method covers the determining of a rebound number of hardened concrete using a spring-driven steel hammer. The rebound number may be used to assess the uniformity of concrete in situ, and delineate areas of poor quality or deteriorated concrete.

The rebound hammer is most useful for rapidly surveying large areas of similar concrete in the construction under consideration. This test method is not intended as an alternative for strength determination of concrete and may only be used as an aid in locating suspect concrete.

Section 2

Apparatus and Procedure

The apparatus and procedures are identical to ASTM C 805.

Tex-498-A, Minimum Standards for Acceptance of a Laboratory for Concrete and Aggregate Testing

Contents:

Section 1

Overview

Overview

Use this procedure to determine if a laboratory meets the minimum standards for concrete and aggregate testing. The scope of a laboratory's qualification may include only those test procedures relevant to its operations or which may be required under contract. All applicable equipment shall be calibrated or verified at the specified intervals. In addition to requirements shown below, each apparatus required to perform each test method must be available in the laboratory.

Units of Measurement

The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

Section 2

Documentation

Laboratories shall maintain records for all calibrated or verified equipment. Miscellaneous items such as trowels, pans, scoops, spatulas, straightedges, funnels, brushes, containers, etc. are excluded. Such records/worksheets shall include the following information for each piece of equipment:

- description of equipment
- serial number, or other ID
- frequency of calibration
- calibrating technician
- date of calibration
- date of last calibration
- date of next calibration
- procedure used to calibrate equipment
- detailed results of calibration work

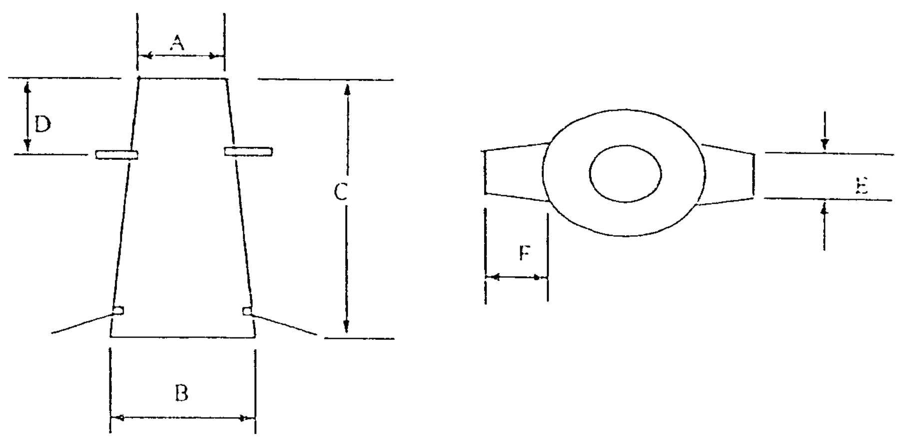
See 'Calibration/Verification Worksheet' for an example of a typical worksheet used to document calibration and verification of equipment.

Texas Department of Transportation

TEXAS DEPARTMENT OF TRANSPORTATION
EQUIPMENT CALIBRATION RECORD

SLUMP CONE (Tex-415-E)

Manufacturer:	Model/Serial No.
Date:	Calibrated by:
Previous Calibration Date:	Next Due:
Frequency: 12 months	Location:
Action recommended: Repair _______ Replace _______ None _______ Other	
Calibration Equipment	**Equipment I.D.**
Ruler, readable to 1/16"	
Measuring Tape, readable to 1/16"	



SLUMP CONE						
	A	B	C	D	E	F
Dimensions	4 ± 1/8"	8 ± 1/8"	12 ± 1/8"	4"	3"	3"
Results						

Is the slump cone free of concrete buildup? ______________
Is the slump cone free of indentations? ______________
Is the slump cone equipped with foot pieces? ______________
Is interior of cone free from projections? ______________
REMARKS: ____

____

____

Section 3

Equipment Calibration and Verification

Moved Equipment – In addition to the intervals specified below, the following equipment must be re-calibrated or verified each time it is moved prior to being used again: balances/scales, beam breakers (check zero and adjust as needed), compression machines, thermometers (check for broken mercury column), and ovens.

Sieves – In addition to the noted six-month visual inspections, results from annual soils and aggregates proficiency samples can be used to verify the accuracy of sieves.

- "Tex-401-A, Sieve Analysis of Fine and Coarse Aggregate"

Tex-401-A, Sieve Analysis of Fine and Course Aggregates			
Equipment	Requirements	Procedure	Interval (Months)
Sieves, as listed in procedure	Check physical condition Check accuracy	Tex-907-K Proficiency Sample	6 12
Quartering machine, sample splitter, or quartering cloth	Visual inspection	NA	12
Mechanical Shaker	Verify sieving thoroughness	Procedure 10-2	12
Balance, accurate and readable to 0.1g or 0.1% of the mass of the test sample	Verify calibration records	Tex-901-K	12
Drying oven, maintained at 230±9°F (110±5°C)	Verify temperature setting	Procedure 10-1	4
Pans, scoops, brushes, etc.	Visual inspection	NA	12

- "Tex-402-A, Fineness Modulus of Fine Aggregate"

Tex-402-A, Fineness Modulus of Fine Aggregate			
Equipment	Requirements	Procedure	Interval (Months)
Apparatus specified in Test Method Tex-401-A	Same as Tex-401-A	Same as Tex-401-A	Same as Tex-401-A

- "Tex-403-A, Saturated Surface-Dry Specific Gravity and Absorption of Aggregates"

Tex-403-A, Saturated Surface-Dry Specific Gravity and Absorption of Aggregates			
Equipment	Requirements	Procedure	Interval (Months)
Glass jar (pycnometer), 0.5gal (2L), and pycnometer cap	Calibrate & check physical condition	Tex-403-A	Each use
Balance, minimum capacity of 4000g, with an accuracy and readability of 0.5g or 0.1% of the mass of the test sample, whichever is greater	Verify calibration records	Tex-901-K	12

Drying oven, maintained at 230±9°F (110±5°C)	Verify temperature setting	Procedure 10-1 or Tex-927-K	4
Funnel, wide mouthed	Visual inspection	NA	12
Sieves, as listed in procedure	Check physical condition Check accuracy	Tex-907-K Proficiency Sample	6 12
Pans, 12 in. in diameter	Visual inspection	NA	12
Small Trowel	Visual inspection	NA	12
Syringe or rubber bulb	Visual inspection	NA	12
Quartering machine, sample splitter, or quartering cloth	Visual inspection	NA	12
Lint free cloth or towel	Visual inspection	NA	12
Sample container	Visual inspection	NA	12
Suspended Apparatus, as described in procedure	Visual inspection	NA	12
Water tank	Visual inspection	NA	12
Metal cone and tamper	Verify dimensions	Tex-406-A	12

- "Tex-404-A, Determining Unit Mass (Weight) of Aggregates"

Tex-404-A, Determination of Unit Mass (Weight) of Aggregates

Equipment	Requirements	Procedure	Interval (Months)
Scoops, one medium and one small, having square points	Visual inspection	NA	12
Quartering cloth or large flat metal pan	Visual inspection	NA	12
Balance, accurate to within 0.1% of the test sample and readable to 5g for fine aggregate and 10g for coarse aggregate	Verify calibration records	Tex-901-K	12
Metal straightedge	Visual inspection	NA	12
Volume measures; volumes of 0.1 and 0.5 cubic feet	Verify calibration records	Tex-905-K	12
Denim cloth sleeve	Verify measurements	Tex-404-A	12
Tamping rod	Verify measurements	Tex-404-A	12

- "Tex-405-A, Determining Percent Solids and Voids in Concrete Aggregate"

Tex-405-A, Determination of Percent Solids and Voids in Concrete Aggregate

Equipment	Requirements	Procedure	Interval (Months)
Apparatus specified in Test Method Tex-403-A	Same as Tex-403-A	Same as Tex-403-A	Same as Tex-403-A
Apparatus specified in Test Method Tex-404-A	Same as Tex-404-A	Same as Tex-404-A	Same as Tex-404-A

- "Tex-466-A, Material Finer than the75mm (No. 200) Sieve in Mineral Aggregates (Decantation Test for Concrete Aggregates)"

Tex-466-A, Material Finer than the 75mm (No. 200) Sieve in Mineral Aggregates (Decantation Test for Concrete Aggregates)			
Equipment	Requirements	Procedure	Interval (Months)
Balance, minimum capacity of 6000g, accurate and readable to 0.5g or 0.1% of the mass of the test sample, whichever is greater	Verify calibration records	Tex-901-K	12
Drying oven, maintained at 140±9°F (60±5°C)	Verify temperature	Procedure 10-1 or Tex-927-K	4
Drying oven, maintained at 230±9°F (110±5°C)	Verify temperature	Procedure 10-1 or Tex-907-K	4
Sieves, as listed in procedure	Check physical condition Check accuracy	Tex-907-K Proficiency Sample	6 12
Pans	Visual inspection	NA	12
Sample splitter, or quartering cloth	Visual inspection	NA	12
Plaster of paris molds with filter paper	Visual inspection	NA	12
Part II (in addition)			
Wide mouth funnel	Visual inspection	NA	12
Pycnometer; 0.5gal (2L) glass mason jar with a pycnometer cap	Calibrate & check physical condition	Tex-403-A	Each use
Part III (pct.limestone)			
Dessicator, with indicating type silica-gel dessicant	Visual inspection	NA	12
Analytical balance, suitable for rapid weighing, minimum capacity of 100g, accurate and readabale to 0.01g	Verify calibration records	Tex-901-K	12
400ml beaker	Visual inspection	NA	12
Stirrer, magnetic type, with a teflon-covered bar	Visual inspection	NA	12
Burette, class A, 50ml capacity, graduated to 0.1ml	Visual inspection	NA	12
pH meter, having an accuracy of ±0.1 pH unit or better, within a temperature range of 32°F to 212°F (0°C to 100°C). The meter shall have either a manual or automatic temperature compensator.	Check fluid level in probe and standardize the meter as per the manufacturer's recommendations.	NA	Each use

- "Tex-407-A, Sampling Freshly Mixed Concrete"

Tex-407-A, Sampling Freshly Mixed Concrete			
Equipment	Requirements	Procedure	Interval (Months)

Sampling container buggy (wheel barrow or a suitable surface)	Clean and non-absorbent	NA	Each use
Covering material	Non-absorbent and impervious material	NA	Each use
Shovel or scoop	As needed	NA	Each use

- "Tex-408-A, Organic Impurities in Fine Aggregate for Concrete'

Tex-408-A, Organic Impurities in Fine Aggregate for Concrete			
Equipment	Requirements	Procedure	Interval (Months)
Glass bottles, 12-16 oz., clear glass	Visual inspection	NA	12
3% sodium hydroxide solution	Visual inspection	NA	12
Glass color standard, mounted in a plastic holder with jive organic color numbers, 1through 5 (Gardner color standard numbers 5, 8, 11, 14, and 16, ASTM 1544)	Visual inspection	NA	12

- "Tex-409-A, Free moisture and Water Absorption in Aggregates for Concrete"
  - Part I

Tex-409-A, Free moisture and Water Absorption in Aggregates for Concrete- Part I			
Equipment	Requirements	Procedure	Interval (Months)
Balance, minimum capacity of 2000g, accurate and readable to at least 0.5g or 0.1% of the mass of the test sample	Verify calibration records	Tex-901-K	12
Pycnometer; 0.5gal (2 L) glass mason jar with a pycnometer cap	Calibrate & check physical condition	Tex-403-A	Each use
Towel or lint-free cloth	Visual inspection	NA	12

- Part II

Tex-409-A, Free moisture and Water Absorption in Aggregates for Concrete- Part II			
Equipment	Requirements	Procedure	Interval (Months)
Balance, minimum capacity of 4,000g, accurate and readable to 0.5g	Verify calibration records	Tex-901-K	12
Pan, approximately 12 in. in diameter	Visual inspection	NA	12
Towel or lint-free cloth	Visual inspection	NA	12

- "Tex-410-A, Abrasion of Coarse Aggregates Using the Los Angeles Machine"

Tex-410-A, Abrasion of Coarse Aggregates Using the Los Angeles Machine			
Equipment	Requirements	Procedure	Interval (Months)

Sieves, as listed in procedure	Check physical condition Check accuracy	Tex-907-K Proficiency Sample	6 12
Balance or scale, accurate within 0.1% of the test load over range required for this test	Verify calibration records	Tex-901-K	12
Drying oven, maintained at 230±9°F (110±5°C)	Verify temperature	Procedure 10-1 or Tex-927-K	4
Los Angeles Abrasion Machine and spheres	Verify dimensions and RPM	ASTM C-131	12

- "Tex-411-A, Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate"

Tex-411-A, Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate			
Equipment	Requirements	Procedure	Interval (Months)
Sieves, as listed in procedure	Check physical condition Check accuracy	Tex-907-K Proficiency Sample	6 12
Drying oven, maintained at 230±9°F (110±5°C), with an evaporation rate of at least 25 g/hr for 4 hrs while the doors of the oven are closed	Verify temperature and evaporation rate	Procedure 10-1 or Tex-927-K ; Procedure 10-3	4
Tanks, non-corrosive and non-reactive	Visual inspection	NA	12
Perforated containers, of a non-corrosive material, for immersion of samples	Visual inspection	NA	12
Sulfate solution	Verify temperature and specific gravity of solution	NA	Weekly
Solution temperature control device	Visual inspection	NA	12
Balance, accurate and readable to 0.1g	Verify calibration records	Tex-901-K	12
Hydrometer, conforming to the requirements of ASTM E 100	Verify dimensions	ASTM E 100	24
Potable water	NA	NA	NA
Barium chloride (0.2 molar)	Visual inspection	NA	12

- "Tex-412-A, Lightweight Pieces in Aggregate"

Tex-412-A, Lightweight Pieces in Aggregate			
Equipment	Requirements	Procedure	Interval (Months)
As specified in ASTM C 123	As specified in ASTM C 123	ASTM C 123	See ASTM C 123

- "Tex-413-A, Determining Deleterious Materials in Mineral Aggregate"

Tex-413-A, Determining Deleterious Materials in Mineral Aggregate			
Equipment	Requirements	Procedure	Interval (Months)
A standard U.S. No.4 (4.75mm) sieve	Check physical condition Check accuracy	Tex-907-K Proficiency Sample	6 12
Drying oven, maintained at 230±9°F (110±5°C)	Verify temperature	Procedure 1-1 or Tex-907-K	4
Balance, minimum capacity of 4000g, accurate and readable to either 0.5g or 0.1% of the test load, whichever is greater	Verify calibration records	Tex-901-K	12
Pan	Visual inspection	NA	12
Small spatula having a blade 4 in. long and ¾ in. wide	Visual inspection	NA	12
Sample splitter, quartering cloth, or quartering machine	Visual inspection	NA	12

- "Tex-414-A, Air Content of Freshly Mixed Concrete by the Volumetric Method"

Tex-414-A, Air Content of Freshly Mixed Concrete by the Volumetric Method			
Equipment	Requirements	Procedure	Interval (Months)
Air meter with a bowl and top section	Verify bowl volume & dimensions; verify accuracy of graduations in neck of top section	Tex-414-A	12
Funnel	Verify discharge will not disturb sample	Procedure 1-1	12
Tamping rod	Verify length, diameter and tip	Procedure 1-2	12
Strike-off bar	Verify length, thickness and width	Procedure 1-3	12
Bulb syringe	Availability	NA	12
Pouring vessel, capacity approx. 1 qt. (1 L)	Availability	NA	12
Measuring cup, capacity equal to 1.03 ± 0.04% of the volume of the bowl of the air meter	Verify volume	Tex-414-A	12
Scoop	Small	NA	12
Trowel	Visual inspection	NA	12
Isopropyl alcohol	70% Isopropyl alcohol	NA	Each use
Mallet (rubber or rawhide)	Verify weight	3-4	12

- "Tex-415-A. Slump of Portland Cement Concrete"

Tex-415-A, Slump of Portland Cement Concrete			
Equipment	Requirements	Procedure	Interval (Months)
Slump cone (metal)	Verify dimensions and smoothness of interior	Procedure 2-2	12
Tamping rod	Verify length, diameter and tip	Procedure 2-2	12
Wide mouth funnel	Visual inspection	NA	12
Scoop	Small	NA	Each use
Rule	Minimum graduations 3 mm (1/8 in.)	NA	Each use

- "Tex-416-A. Air Content of Freshly Mixed Concrete by the Pressure Method"

Tex-416-A, Air Content of Freshly Mixed Concrete by the Pressure Method			
Equipment	Requirements	Procedure	Interval (Months)
Air meter with a measuring bowl and top section	Verify bowl volume & dimensions	"ex-416-A.	3
Calibration vessel	Calibrate	Tex-416-A	3
Tamping rod	Verify length, diameter and tip	Procedure 3-1	12
Mallet	Verify weight	Procedure 3-2	12
Strike-off plate	Verify length, thickness, width and surface smoothness	Procedure 3-4	12
Strike-off bar	Verify length, thickness and width	Procedure 3-3	12
Trowel	Standard brick mason's	NA	12
Container for water	Minimum 1 L (1 qt.)	NA	Each use
Vibrator	Verify diameter, length, vibration frequency and shaft	3-1	12
Scoop	Small	NA	Each use

- "Tex-417-A, Unit Weight, Yield, and Air Content (Gravimetric) of Concrete"

Tex-417-A, Unit Weight, Yield, and Air Content (Gravimetric) of Concrete			
Equipment	Requirements	Procedure	Interval (Months)
Balance (accurate to 0.3% of test load)	Verify capacity and calibration sticker date	Tex-901-K	12
Tamping rod	Verify length, diameter and tip	3-1	12
Vibrator	Verify length, diameter and vibration frequency	3-5	12
Volume Measure (cylindrical made of steel)	Verify calibration sticker and check calibration report	Tex-905-K	12
Strike-off plate	Verify dimensions	3-4	12
Mallet (rubber, rawhide)	Verify weight	3-2	12

- "Tex-418-A, Compressive Strength of Cylindrical Concrete Specimens"

Tex-418-A, Compressive Strength of Cylindrical Concrete Specimens			
Equipment	**Requirements**	**Procedure**	**Interval (Months)**
Compression testing machine	Verify calibration records	Tex-902-K, Tex-418-A	12
Bearing blocks (upper, spherical, seated and lower)	Verify minimum dimensions	4-1	12
Part II - Using Neoprene Caps			
Steel retainers	Verify size and bearing surface smoothness	4-2	12
Pads	Verify composition and size	Procedure 4-2	Upon receipt

- "Tex-421-A, Splitting Tensile Strength of Cylindrical Concrete Specimens"

Tex-421-A, Splitting Tensile Strength of Cylindrical Concrete Specimens			
Equipment	**Requirements**	**Procedure**	**Interval (Months)**
Compression testing machine	Verify calibration records	Tex-902-K	12
Supplementary bearing bar or plate	Verify dimensions	5-1	12
Bearing strips	Verify dimensions	5-2	Each purchase

- "Tex-422-A, Measuring Temperature of Freshly-Mixed Portland Cement Concrete"

Tex-422-A, Measuring Temperature of Freshly-Mixed Portland Cement Concrete			
Equipment	Requirements	Procedure	Interval (Months)
Container	Verify minimum dimensions	6-1	Each use
Temperature device	Verify required accuracy and minimum range	6-2	12

- "Tex-423-A, Determining Pavement Thickness by Direct Measurement"

Tex-423-A, Determining Pavement Thickness by Direct Measurement			
Equipment	Requirements	Procedure	Interval (Months)
Straight steel rod 4 in. (100 mm) longer than the depth of pavement with blunt end	Verify minimum dimensions	NA	Each use
Standard tape measure readable to 1/16 in. (1 mm)	Verify required accuracy and minimum range	NA	Each use

- "Tex-424-A, Obtaining and Testing Drilled Cores of Concrete"
  - Part I

Tex-424-A, Obtaining and Testing Drilled Cores of Concrete (Part I)			
Equipment	Requirements	Procedure	Interval (Months)
Core drill	Shot or diamond drill as described in procedure	NA	12

  - Part II

Tex-424-A, Obtaining and Testing Drilled Cores of Concrete (Part II)			
Supports	Made of hardened steel. Verify dimensions	NA	12
Scale with accurately spaced graduations	Spacing of the graduations should be 0.1 in. or a decimal part thereof	NA	12
Measuring rod	Verify dimensions	NA	12
Calipering device	Verify device meets minimum requirement	Procedure 7-1	12

  - Part III

Tex-424-A, Obtaining and Testing Drilled Cores of Concrete (Part III)			
Core drill	Visual inspection	NA	12
Water storage (lime saturated water)	Visual inspection Verify temperature.	NA	Each use
Wet blanket of burlap or other suitable absorbent fabric	Visual inspection	NA	12

Compressive testing machine	Verify calibration records	NA	12
Rubber pads, sulfur caps or gypsum caps	Visual inspection	NA	12
Capping table	Visual inspection	NA	12
Level	Visual inspection	NA	12
Wet saw	Visual inspection	NA	12
Calipering device	Verify device meets minimum requirement	Procedure 7-1	12

- "Tex-425-A, Determining Moisture Content in Fine Aggregate by the 'Speedy' Moisture Method"

Tex-425-A, Determining Moisture Content in Fine Aggregate by the "Speedy" Moisture Method			
Equipment	**Requirements**	**Procedure**	**Interval (Months)**
Calcium carbide pressure tester set	Visual inspection	NA	12
Small scoop	Visual inspection	NA	12
Brush and cloth	Visual inspection	NA	12
Apparatus, as listed in Tex-103-E,	Same as Tex-103-E	Same as Tex-103-E	Same as Tex-103-E
Supply of calcium carbide	Visual inspection	NA	12
Standard U.S. No. 4 (4.75 mm) sieve	Check physical condition Check accuracy	Tex-907-K Proficiency Sample	6 12

- "Tex-426-A. Estimating Concrete Strength by the Maturity Method"

Tex-426-A, Estimating Concrete Strength by the Maturity Method			
Equipment	**Requirements**	**Procedure**	**Interval (Months)**
Maturity meter, commercial battery-powered which automatically computes and displays maturity index in terms of a temperature-time factor, or both a temperature-time factor and equivalent age	Verify proper value of datum temperature is selected Verify calibration	NA Procedure 10-1	Each use Each use and at min. every 12 mos.
Thermocouple wire grade ≥ 20 awg.	Visual inspection	NA	Each use
Batteries	Verify adequately charged	NA	Each use

- "Tex-429-A, Determining the Percent Solids and Voids in Lightweight Coarse Aggregate"

Tex-429-A, Determining the Percent Solids and Voids in Lightweight Coarse Aggregate			
Equipment	Requirements	Procedure	Interval (Months)
Apparatus outlined in Test Method Tex-403-A	Same as Tex-403-A	Same as Tex-403-A	Same as Tex-403-A
Apparatus outlined in Test Method Tex-404-A	Same as Tex-404-A	Same as Tex-404-A	Same as Tex-404-A

- "Tex-431-A, Pressure Slaking Test of Synthetic Coarse Aggregate"

Equipment	Requirements	Procedure	Interval (Months)
Sieves, as listed in procedure	Check physical condition Check accuracy	Tex-907-K Proficiency Sample	6 12
Drying oven, maintained at 230±9°F (110±5°C)	Verify temperature	Procedure 10-1 or Tex-927-K	4
Balance, minimum capacity of 4000g, accurate and readable to 0.1g or 0.1% of the mass of the test sample.	Verify calibration records	Tex-901-K	12
Mechanical Sieve Shaker	Verify sieving thoroughness	Procedure 10-2	12
Pressure cooker, approximately 6 qt (6L) capacity with 15 psi regulator	Visual inspection	NA	12
Heavy duty shaker, Equipoise model No.5855 or equivalent	Visual inspection	NA	12
Heat source	Visual inspection	NA	12
Beaker, 250 ml	Visual inspection	NA	12
Distilled or de-ionized water	Visual inspection	NA	12
Centrifuge bottles, 500ml Pyrex	Visual inspection	NA	12

- "Tex-432-A, Coarse Aggregate Freeze-Thaw Test"

Tex-432-A, Coarse Aggregate Freeze-Thaw Test			
Equipment	Requirements	Procedure	Interval (Months)
Sieves, as listed in procedure	Check physical condition Check accuracy	Tex-907-K Proficiency Sample	6 12
Drying oven, maintained at 230±9°F (110±5°C)	Verify temperature	Procedure 10-1 or Tex-927-K	4
Balance, minimum capacity of 800g, accurate and readable to 0.1g or 0.1% of the mass of the test sample	Verify calibration records	Tex-901-K	12

Freezing chamber, maintained at – 15°F (9.5°C)	Verify temperature setting	Procedure 10-1	4
Trays or other containers suitable to hold the samples in a single layer	Visual inspection	NA	12

- "Tex-433-A, Absorption and Dry Bulk Specific Gravity of Lightweight Coarse Aggregate"

Tex-433-A, Absorption and Dry Bulk Specific Gravity of Lightweight Coarse Aggregate

Equipment	Requirements	Procedure	Interval (Months)
Balance, minimum capacity of 4000g, accurate and readable to 0.5g or 0.1% of the test load	Verify calibration records	Tex-901-K	12
Drying oven, maintained at 230±9°F (110±5°C)	Verify temperature	Procedure 10-1 or Tex-927-K	4
Glass jar (pycnometer), 0.5gal (2L), with a pycnometer cap	Calibrate & check physical condition	Tex-403-A	Each use
Standard U.S. No. 5/8 (16 mm) and No. 8 (2.36 mm) sieves	Check physical condition Check accuracy	Tex-907-K Proficiency Sample	6 12
Funnel, wide mouthed	Visual inspection	NA	12
Dessicator	Visual inspection	NA	12
Timing device (stopwatch)	Verify accuracy	Tex-924-K	6
Syringe or rubber bulb	Visual inspection	NA	12
Distilled or de-ionized water	Visual inspection	NA	12

- "Tex-436-A, Measuring Texture Depth by the Sand Patch Method"

Tex-436-A, Measuring Texture Depth by the Sand Patch Method

Equipment	Requirements	Procedure	Interval (Months)
Sand spreading tool 2.5 in. (63 mm) diameter flat wooden disc with a 5/8 in. (16 mm) thick hard rubber disc attached to one face and short dowel handle on other face	Visual inspection	NA	12
Metal measuring cylinder volume approx. 1.5 in^3 (24.6 m^3)	Verify capacity (calibrate)	NA	12
Natural silica sand	Verify gradation	NA	12
Ruler 12 in. (300 mm) marked in divisions of 1/10 in. (1 mm)	Visual inspection	NA	12
Wire brush	Visual inspection	NA	12
Soft hand brush	Visual inspection	NA	12

♦ "Tex-437-A, Test for Flow of Grout Mixtures (Flow Cone Method)"

Tex-437-A, Test for Flow of Grout Mixtures (Flow Cone Method)			
Equipment	Requirements	Procedure	Interval (Months)
Flow Cone	Visual inspection	NA	12
Container minimum capacity of 68 fl. oz. (2000 mL)		NA	12
Ring stand	Visual inspection	NA	12
Level, carpenter's or similar	Visual inspection	NA	12
Stop watch able to read 0.2s	Visual inspection	NA	12
Grout mixer	Visual inspection	NA	12

♦ "Tex-438-A, Accelerated Polish Test for Coarse Aggregate"

Tex-438-A, Accelerated Polish Test for Coarse Aggregate			
Equipment	Requirements	Procedure	Interval (Months)
Wessex Accelerated Polishing Machine	Check rpm, feed rate, water	NA	Weekly
British Pendulum Tester	Verify calibration records	NA	3
Rubber sliders, new, conditioned for the BPT	Visual inspection	NA	Each slider
Height measuring dial gauge, accurate to 0.001in (0.025mm)	Verify calibration records	NA	12
O-rings, rubber 14in diameter with a thickness of 0.125in	Visual inspection	NA	12
Drying oven, maintained at 230±9°F (110±5°C)	Verify temperature	Procedure 10-1	4
Metal molds, to form test coupons	Visual inspection	NA	12

♦ "Tex-447-A, Making and Curing Concrete Test Specimens"

Tex-447-A, Making and Curing Concrete Test Specimens			
Equipment	Requirements	Procedure	Interval (Months)
Vibrator	Verify length, diameter and vibrator frequency	Procedure 3-5	12
Tamping rod	Verify length, diameter and tip	Procedure 3-3	12
Small tools (shovel, pails, trowels, wood floats, scoops & rubber gloves)	Verify availability	NA	12
Mallet (rubber or rawhide)	Verify weight	Procedure 3-4	12
Cotton mats	Verify availability	NA	Each use
Moist room or storage tank, with recording thermometer	Verify water temperature and lime content	Procedure 8-1	Daily
Molds (single use and reusable) and caps	Verify dimensions	Procedure 802	Upon receipt

- "Tex-448-A, Flexural Strength of Concrete using Simple Beam Third-Point Loading"

Tex-448-A, Flexural Strength of Concrete using Simple Beam Third-Point Loading			
Equipment	Requirements	Procedure	Interval (Months)
Testing machine	Verify calibration sticker and certification certificate	NA	12
Leather shims	Verify dimensions	Procedure 9-4	12
Feeler gauges (2 each)	Verify sizes	Procedure 9-5	12
Ruler or tape measure	Verify increment capability (1/16 in.)	NA	12
Small square and straight edge	Verify availability	NA	12

- "Tex-450-A, Capping Cylindrical Concrete Specimens"

Tex-450-A, Capping Cylindrical Concrete Specimens			
Equipment	Requirements	Procedure	Interval (Months)
Capping plates and capping materials	Verify plate material type, dimensions, smoothness and strength of capping material	Procedure 9-1	12
Guide bars (alignment bars)	Verify perpendicularity to capping plate	Procedure 9-2	12
Melting pots	Verify type of heating (peripheral)	Procedure 9-3	Initially
Feeler gauge	Verify size (.002 in.)	NA	12
Metal rods	Availability	NA	12
Ladle, large	Availability	NA	12
Straight edge	Availability	NA	12

- "Tex-460-A, Determining Crushed Face Particle Count"

Tex-460-A, Determining Crushed Face Particle Count			
Equipment	Requirements	Procedure	Interval (Months)
Drying oven, maintained at 230±9°F (110±5°C)	Verify temperature	Procedure 10-1 or Tex-927-K	4
A standard U.S. No.4 (4.75mm) sieve	Check physical condition Check accuracy	Tex-907-K Proficiency Sample	6 12

Section 4

Procedures

The following procedures correspond to and detail the procedure indicated in each of the tables under 'Requirements.'

1-1, Funnel

Funnel with a spout of a size permitting it to be inserted through the neck of the top section and long enough to extend to a point just above the bottom of the top section. The discharge end of the spout shall be so constructed that when water is added to the container there will be a minimum disturbance to the concrete.

1-2, Tamping Rod

Round, steel, or plastic, straight 5/8 in. diameter x 12 in. long (16 mm x 300 mm) with both ends rounded to hemispherical tip of the same diameter.

1-3, Strike-Off Bar

Flat, straight, at least:

- 1/8 in. (3 mm) thick for steel bars or 1/4 in. (6 mm) thick for plastic bars
- 3/4 in. (20 mm) wide
- 12 in. (300 mm) long.

2-1, Slump Cone

Metal molds, not readily attacked by cement paste, and not thinner than No. 16 gauge (BWG). If formed by the spinning process, there shall be no point at which the thickness is less than 0.045 in (1.14 mm).

The mold shall conform to the following dimensions:

- Top opening – 4 ± 1/8 in. (100 mm ± 3 mm)
- Bottom opening – 8 ± 1/8 in. (200 mm ± 3 mm)
- Height – 12 ± 1/8 in. (300 mm ± 3 mm).

The base and top shall be open, parallel and at right angles to the axis of the cone, have foot pieces, handles, and an interior which is smooth and free from projections such as rivets, and free from dents.

2-2. Tamping Rod

Round, straight steel. 5/8 in diameter x 24 in. long (16 mm x 600 mm). Tamping end to have hemispherical tip of same diameter.

3-1, Tamping Rod

Round, straight steel rod having a tamping end rounded to a hemispherical tip the diameter of the rod:

- - 5/8 in. diameter x 16 in. long (16 mm x 400 mm) for Test Method "Tex-416-A, Air Content of Freshly Mixed Concrete by the Pressure Method"
- - 24 in. (600 mm) long for "Tex-417-A, Unit Weight, Yield, and Air Content (Gravimetric) of Concrete."

3-2, Mallet

Rawhide or rubber 1.25 lbs. ± .50 lbs. (0.57 kg ± 0.23 kg).

3-3, Strike-Off Bar, Steel or other suitable metal, at least:

Length – 12 in. (300 mm)

Thickness – 1/8 in. (3 mm)

Width – 3/4 in. (20 mm).

3-4, Strike-Off Plate

Strike-Off Plate, flat rectangular metal, at least 1/4 in. (6 mm) thick, or glass or acrylic, at least 1/2 in. (13 mm) thick with a length and width at least 2 in. (51 mm) greater than the diameter of the measure with which it is to be used. The edges of the plate shall be straight and smooth within a tolerance of 1/16 in. (1.5 mm).

3-5, Vibrator

Refer to the 'Apparatus' section of Part I of "Tex-447-A, Making and Curing Concrete Test Specimens."

4-1, Bearing Blocks

Refer to the *Bearing Blocks, Upper and Lower* listed under 'Apparatus' of 'Part I' of "Tex-418-A, Compressive Strength of Cylindrical Concrete Specimens."

4-2, Steel Retainers and Caps

Refer to the *Steel Extrusion Control Retainers and Pads* listed under 'Apparatus' of 'Part II' of "Tex-418-A, Compressive Strength of Cylindrical Concrete Specimens."

5-1, Supplementary Bearing Bar or Plate

Refer to the *Supplementary Bearing Bar or Plate* listed under 'Apparatus' of "Tex-421-A, Splitting Tensile Strength of Cylindrical Concrete Specimens."

5-2, Bearing Strips

Refer to *Bearing Strips* listed under 'Apparatus' of "Tex-421-A, Splitting Tensile Strength of Cylindrical Concrete Specimens."

6-1, Container

Container shall be made of non-absorptive material and large enough to provide at least 3 in. (75 mm) of concrete in all directions around the sensor of the temperature measuring device; concrete cover must also be at least three times the nominal maximum size of the coarse aggregate.

6-2, Temperature Device

Temperature measuring device, capable of measuring the temperature of the freshly mixed concrete to ± 1°F (± 0.5°C) throughout the entire temperature range likely to be encountered in the fresh concrete and having a range from 0 to 120°F (-18 to 49°C). The calibration of thermometers shall take place in a water bath capable of maintaining the set temperature within ± 0.5°F (± 0.25°C). Digital thermometers shall be calibrated at three points and all other thermometers at two points over a minimum range of 30°F (15°C).

Other thermometers of the required accuracy, including the metal immersion type, are acceptable. Partial, immersion liquid-in-glass thermometers (and possibly other types) shall have a permanent mark to which the device must be immersed without applying a correction factor.

Acceptable certificates of calibration include a manufacturer's calibration report or certificates issued by the Materials and Pavements Section or the District Laboratory indicating successful calibration according "Tex-926-K, Thermometer Calibration Using Controlled Temperature Baths." All certificates must have a date of issuance within the last 6-month period.

7-1, Calipering Device

Refer to the *Calipering Device* listed under 'Apparatus' of 'Part II, Measuring Length of Drilled Concrete Cores' of "Tex-424-A, Obtaining and Testing Drilled Cores of Concrete."

8-1, Storage Tanks

Refer to *Water Storage Tanks* listed under 'Requirements' of "Tex-447-A, Making and Curing Concrete Specimens."

8-2, Molds (Single use and Reusable)

Refer to the 'Apparatus' of "Tex-447-A, Making and Curing Concrete Specimens" for the following:

- *Cylinder Molds*, 'Part I, Compressive Strength Specimens'
- *Beam Molds*, 'Part II, Flexure Strength Specimens (Beams).'

9-1, Capping Plates and Capping Material

Refer to *Capping Plates* listed under 'Apparatus' of "Tex-450-A, Capping Cylindrical Concrete Specimens."

Refer to 'Materials' of "Tex-450-A, Capping Cylindrical Concrete Specimens."

9-2, Guide Bars (Alignment Bars)

Refer to *Alignment Devices* listed under 'Apparatus' of "Tex-450-A, Capping Cylindrical Concrete Specimens."

9-3, Melting Pot (Sulfur Caps)

Refer to the *Caution* under 'Apparatus' of "Tex-450-A, , Capping Cylindrical Concrete Specimens."

9-4, Leather Shims

Thickness – 1/4 in.

Width – 1 to 2 in.

Length – 6-1/4 in.

9-5, Feeler Gauges

1 ea., 0.004 in. (0.1 mm)

1 ea., 0.015 in. (0.4 mm)

10-1, Ovens

Apparatus

- A calibrated digital thermometer graduated in 2°F (1°C), having a range including the temperature range to be checked.
  - When using the calibrated digital thermometer, place the thermocouple probe on the shelf where the samples are normally placed.
  - Take the first reading at least 1 hour after closing the oven (oven should remain undisturbed). Take as many readings as necessary to determine if the temperature range is within the specified tolerance (three consecutive readings, taken no less than □ hour apart and within the tolerance allowed, are required).
  - Adjust the temperature of the oven if an observed temperature reading is outside the specified tolerance (allow at least □ hour for the temperature to stabilize between each adjustment).
  - Repeat Steps 3 and 4 as necessary.

-OR-

- A calibrated thermometer graduated in 2°F (1.0°C) increments, having a range including the temperature range to be checked.
  - When using the calibrated thermometer, place it inside the brass well with the clothespin attached to the thermometer.Position the thermometer on the shelf where the samples are normally placed.Take the first reading at least 1 hour after closing the oven (oven should remain undisturbed).Take as many readings as necessary to determine if the temperature range is within the specified tolerance (three consecutive readings, taken no less than □ hour apart and within the tolerance allowed, are required).
  - Adjust the temperature of the oven if an observed temperature reading is outside the specified tolerance (allow at least □ hour for the temperature to stabilize between each adjustment).
  - Repeat Steps 3 and 4 as necessary.
- A brass thermometer well to retain heat while the oven door is open. This is essential for a constant temperature reading.
- A clothespin to hold the thermometer in such a manner as to enable the operator to read the scale easily from outside or inside the oven.

10-2, Mechanical Shaker

Match the sieve and aggregate such that a minimum of ten percent of the total sample weight is retained on each sieve. After sieving on the mechanical shaker for a given time, the thoroughness of sieving shall be checked by hand shaking each sieve with a lateral and vertical motion, accompanied by a jarring action so as to keep the material moving continuously over the surface of the sieve. If hand shaking shows more than 1% passing any given sieve, then shaking time should be increased and the check repeated until all screens show less than 1% by weight passing a given sieve.

10-3, Oven Evaporation Rate Check

Place 500 g of water at 70±3°F in each of 5 one-liter low-form beakers. Position one beaker in each corner and one in the center of one oven shelf. At the end of four hours weigh each beaker and determine the evaporation rate for each location. Repeat for each shelf. The evaporation rate for each location shall be at least 25g/hr for four hours.

10-4, Water Bath

Place a calibrated thermometer in center of the water bath for 1 hour to verify temperature setting.

NOTE: Check setting at which the water bath is used.

Tex-614-J, Testing Epoxy Materials

Contents:

Section 1

Overview

Effective Date: July 2006

This test method covers various test procedures for epoxy materials specified in "DMS-6100, Epoxies and Adhesives." The tests performed depend upon the requirements set forth for each particular material.

This test method includes the following test procedures:

- Compressive Strength
- Viscosity of Mixed Components
- Difference in Viscosity
- Stability
- Gel Time
- Tensile Bond
- Tensile Bond for Type I Epoxy
- Thixotropy
- Tensile Shear Strength
- Impact Strength
- Wet Strength
- Wet Pullout Strength
- Grind
- Bond Strength of fresh concrete to cured concrete
- Old Concrete to New Grout Mix
- Hiding Power
- Water Gain
- Contact Time.

Units of Measurement

The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

Section 2

Component Ratios

Determine the weight per gallon/liter of each component according to ASTM D 1475, "Standard Test Method for Density of Liquid Coatings, Inks, and Related Products." For all tests performed on the mixed epoxy, determine the proper weight ratio of resin and hardener components based on the weight per gallon/liter and the specified volume ratio.

Section 3

Procedures

Compressive Strength

The following procedure applies to epoxies types I and IV.

Apparatus

Use the following apparatus:

- PVC tubing, 1 in. × 2 in. (25 mm × 50 mm) in length for use as molds
- machine lathe
- mold release grease
- plastic film and rubber bands to seal bottoms of the molds
- metal ointment can, 6 fl. oz. (170 mL) size
- balance, with minimum capacity of 2000 g, which meets the requirements of "Tex-901-K, Verifying the Calibration of Weighing Devices used for Laboratory Testing"
- compression testing machine as described in Section 5.1 of ASTM D 695, "Standard Test Method for Compressive Properties of Rigid Plastics," capable of a constant rate of crosshead movement of 0.05 in./min. and capable of applying a maximum load of at least 10,000 lbf. Use compression plates that are flat and parallel to each other in a plane normal to the vertical loading axis.

Procedure

Use the following procedure to determine the compressive strength of epoxy types I and IV.

Compressive Strength Test

Step	Action
1	Set up the molds. ♦ Set up at least 3 of the PVC molds for each test sample. ♦ Coat the inside of the molds with release grease. ♦ Seal the bottom of the molds with a plastic film to prevent leakage. *NOTE:* For type I epoxy, set up 2 sets of 3 molds.
2	Cast the epoxy specimens. ♦ Use the component ratios to determine the amount of each component necessary to make 200 g of mixed epoxy. ♦ Weigh the components into a metal can.

Compressive Strength Test

Step	Action
	♦ Mix components for 3 min. ♦ Fill the molds with the epoxy.
3	Condition the epoxy specimens. ♦ For type I epoxy, allow specimens to cure at the temperature specified. Cure one set of specimen for 24 hr. and the second set for 48 hr. ♦ For type IV epoxy, allow the specimen to cure for 48 hr. at 77°F (25°C).
4	Test the epoxy specimens. ♦ Compress specimens in a compression-testing machine. ♦ Test specimen at a rate of 0.05 in. (1.3 mm) per min. ♦ Record the load at failure or at 0.1 in. (2.5 mm) crosshead travel, whichever occurs first.
5	Calculate the compressive strength. ♦ Use the calculations listed under "Calculations." ♦ Average the results from all the specimens. ♦ Report results in psi (kPa).

Calculations

Use the following calculation to determine compressive strength.

$$(C_s = L/\pi r^2 \text{, psi})$$

Where:

- C_s = compressive strength, psi (kPa)
- L = load, lb. (N)
- r = radius of the specimen, in. (m).

Viscosity of Mixed Components

The following procedure applies to epoxies types III, IV, V, VII, and IX.

Apparatus

Use the following apparatus:

- Brookfield viscometer
- friction top cans, 1 pt. (500 mL) and 1 qt. (1 L)

- thermometer, range 66 to 80°F (19 to 27°C), 0.2 division (F17 thermometer as shown in ASTM E 1, "Standard Specification for ASTM Liquid-in-Glass Thermometers")
- spatula
- balance, with minimum capacity of 2000 g, which meets the requirements of Tex-901-K
- stopwatch.

Procedure

The following procedure describes the viscosity test.

Viscosity of Mixed Components Test

Step	Action
1	♦ Set up the viscometer according to manufacturer's instructions. ♦ Level the instrument. ♦ Set the speed control at 20 rpm. *NOTE:* Set the speed control at 10 rpm if the viscosity of the material is greater than 1200 poise. ♦ Choose the proper spindle for the viscosity measurement and attach the spindle to the viscometer. *NOTE:* Type of spindle is dependent on measured viscosity range and type of viscometer.
2	Mix the epoxy. ♦ Measure the temperature of each component of epoxy and ensure the temperature of each is 77 ±2°F (25 ±1°C). ♦ Using the mixing ratios, determine the amount of resin and hardener needed to make 400 g of mixed epoxy. ♦ Weigh components into a 1 pt. (500 mL) can. ♦ Mix the epoxy for 3 min.
3	Immerse the spindle into the epoxy. ♦ Adjust the height of the viscometer to bring the liquid level to the indention in the spindle. ♦ Ensure that there is at least a 1 in. (25 mm) clearance between the bottom and sides of the spindle and the container when immersing the spindle to the proper depth in the sample. *NOTE:* With disk type spindles, first immerse the spindle in the liquid at an angle to eliminate air bubbles, and then attach the spindle to the shaft.
4	Measure the viscosity. ♦ Start the viscometer. ♦ Allow the reading to stabilize. ♦ Record the viscosity.

Difference in Viscosity

The following procedure applies to epoxy type II.

Apparatus

Use the following apparatus:

- Brookfield viscometer
- friction top cans, 1 pt. (500 mL)
- thermometer, range 66 to 80°F (19 to 27°C), 0.2 division (F17 thermometer as shown in ASTM E 1)
- spatula
- balance, with minimum capacity of 2000 g, which meets the requirements of Tex-901-K
- stopwatch.

Procedure

The following procedure describes the viscosity test for type II epoxy.

Difference in Viscosity Test	
Step	Action
1	Set up the viscometer according to manufacturer's instructions. ♦ Level the instrument. ♦ Set the speed control at 20 rpm. *NOTE:* Set the speed control at 10 rpm if the viscosity of the material is greater than 1200 poise. ♦ Choose the proper spindle for the viscosity measurement and attach the spindle to the viscometer. *NOTE:* Type of spindle is dependent of measured viscosity range and type of viscometer.
2	Prepare the epoxy. ♦ Measure the temperature of each component of the epoxy and ensure the temperature of each is 77 ±2°F (25 ±1°C). ♦ Place 400 g of each component into separate 1 pt. (500 mL) cans.
3	Immerse the spindle into one of the components. ♦ Adjust the height of the viscometer to bring the liquid level to the indention in the spindle. ♦ Ensure that there is at least a 1 in. (25 mm) clearance between the bottom and sides of the spindle and the container when immersing the spindle to the proper depth in the sample.
4	Measure the viscosity. ♦ Start the viscometer. ♦ Allow the reading to stabilize. ♦ Record the viscosity.
5	Repeat measurement for the second component. ♦ Stop the viscometer.

Difference in Viscosity Test	
Step	Action
	♦ Clean the spindle. ♦ Repeat the procedure beginning at Step 2.
6	Use the 2 measurements to calculate and report the difference in viscosity.

Calculations

$$\text{Difference in viscosity} = \frac{v_2 - v_1}{v_1}(100)$$

Where:

- v1 = lower viscosity reading
- v2 = higher viscosity reading.

Stability

The stability test applies to epoxy types II, V, VII, and VIII.

- For the stability on type II epoxy, measure the viscosity of the individual components.
- For the stability on types V, VII, and VIII epoxy, measure the viscosity on the mixed epoxy.

Apparatus

Use the following apparatus:

- Brookfield viscometer
- friction top cans, 1 pt. (500 mL) and 1 qt. (1 L)
- thermometer, range 66 to 80°F (19 to 27°C), 0.2 division (F17 thermometer as shown in ASTM E 1)
- oven capable of maintaining a temperature of 120°F (49°C).
- metal spatula
- balance, with minimum capacity of 2000 g, which meets the requirements of Tex-901-K
- stopwatch.

Procedure

The following procedure describes the stability test after 14 day heat aging at 120°F (49°C) for epoxy types II, V, VII, and VIII.

Stability Test

Step	Action
1	♦ Fill separate 1 qt. (1 L) cans with resin and hardener. ♦ Place the resin and hardener in the oven, set at 120°F (49°C), for 14 days.
2	Remove epoxy from oven and allow the material to cool to 77 ±2°F (25 ±1°C).
3	Set up the viscometer according to manufacturer's instructions. ♦ Level the instrument. ♦ Set the speed control at 20 rpm. *NOTE:* Set the speed control at 10 rpm if the viscosity of the material is greater than 1200 poise. ♦ Choose the proper spindle for the viscosity measurement and attach the spindle to the viscometer. *NOTE:* Type of spindle is dependent of measured viscosity range and type of viscometer.
4	Prepare the epoxy. ♦ Measure the temperature of each component of the epoxy, and ensure the temperature of each is 77 ±2°F (25 ±1°C). ♦ For type II epoxy, place 400 g of each component into separate 1 pt. (500 mL) cans. ♦ For types V, VII, and VIII epoxy, use the mixing ratios and measure 400g of resin and hardener into a 1 pt. (500 mL) can. Then mix the epoxy for 3 min.
5	Immerse the spindle into the epoxy. ♦ Adjust the height of the viscometer to bring the liquid level to the indention in the spindle. ♦ Ensure that there is at least a 1 in. (25 mm) clearance between the bottom and sides of the spindle and the container, when immersing the spindle to the proper depth in the sample. *NOTE:* With disk type spindles, first immerse the spindle in the liquid at an angle to eliminate air bubbles, and then attach the spindle to the shaft.
6	Measure the viscosity. ♦ Start the viscometer. ♦ Allow the reading to stabilize. ♦ Record the viscosity. ♦ For type II epoxy, repeat Steps 5 and 6 for the second component.
7	Use the stability calculation to determine the stability. ♦ For type II epoxy, use the viscosities determined from the difference in viscosity test as the viscosity of original material. ♦ For types V, VII, and VIII epoxy, use the viscosities determined from the viscosity of mixed components test as the viscosity of original material.

Calculations

$$Stability = \frac{v_2 - v_1}{v_1}(100)$$

Where:

- v1 = viscosity of original material
- v2 = viscosity of aged material.

Gel Time Tests

The following procedures apply all types of epoxy.

Apparatus (Except Type X)

Use the following apparatus:

- thermometer, range 66 to 80°F (19 to 27°C) (F17 thermometer as shown in ASTM E 1)
- balance, with minimum capacity of 2000 g, which meets the requirements of Tex-901-K
- metal ointment can, 6 fl. oz. (170 mL) size
- metal spatula
- wooden block, minimum thickness of 1 in. (25 mm)
- round, wooden toothpick
- stopwatch.

Procedure

The following procedure describes the gel time test except for type X.

Gel Time Test (Except for Type X)

Step	Action
1	Test Preparation. ♦ Measure the temperature of each component of the epoxy and ensure the temperature of each is 77 ±2°F (25 ±1°C). ♦ Using the component ratios, determine the amount of each component necessary to make a total 100 g of mixed adhesive. *NOTE:* Condition the type I epoxy to the specified temperature.
2	Weigh the components. Weigh 100 g total of adhesive into a 6 fl. oz. (170 mL) metal ointment can.

Gel Time Test (Except for Type X)

Step	Action
3	Start the stopwatch and begin mixing. ♦ Mix the 2 components for 3 min. with a spatula. ♦ During the mixing, scrape the sides and bottom of the can periodically. *NOTE:* For adhesives that gel in less than 3 min., mix the components for 1 min.
4	After mixing, let the adhesive set. ♦ Place the can with the mixed adhesive on a wooden block. ♦ Insert toothpick in the center of mixed material.
5	Probe the material to determine the gel time. ♦ If adhesive has a gel time less than 20 min., probe adhesive every minute until it gels. ♦ If adhesive has a gel time above 20 min., probe the mixed adhesive every min. starting 16 min. from the initiation of mixing until center of material gels. *NOTE:* An adhesive reaches its gel point when a ball of cured material forms in the center.
6	Record the elapsed time as the gel time.

Apparatus for Epoxy Type X

Use the following apparatus:

- thermometer, range 66 to 80°F (19 to 27°C) (F17 thermometer as shown in ASTM E 1)
- balance, with minimum capacity of 2000 g, which meets the requirements of Tex-901-K
- friction top can, 1 pt. (500 mL), with friction lip removed
- metal spatula
- wooden block, minimum thickness of 1 in. (25 mm)
- glass stirring rod
- stopwatch.

Procedure

The following procedure describes the gel time test for epoxy type X

Gel Time Test For Epoxy Type X

Step	Action
1	Test Preparation. ♦ Measure the temperature of each component of the epoxy and ensure the temperature of each is 77 ±2°F (25 ±1°C).

Gel Time Test For Epoxy Type X

Step	Action
1	♦ Using the component ratios, determine the amount of each component necessary to make a total 300 g of mixed epoxy.
2	Weigh the components. Weigh a total of 300 g of epoxy into a 1 pt. (500 mL) can.
3	Start the stopwatch and begin mixing. ♦ Mix the 2 components for 5 min. with a spatula. ♦ During the mixing, scrape the sides and bottom of the can periodically.
4	After mixing, set aside the epoxy. ♦ Place the can on a wooden block. ♦ Allow mixed material to sit for 35 min.
5	Determine the gel time. ♦ Probe mixed material every 5 min. with a glass-stirring rod until it gels. ♦ Record the elapsed time as the gel time. *NOTE:* An epoxy reaches its gel point when a ball of cured material forms in the center.

Tensile Bond

The tensile bond test requires the use of cement mortar briquettes. The procedure applies to epoxy types II, III, V, VII, and VIII.

Apparatus

Use the following apparatus:

- metal spatula
- metal ointment can, 6 fl. oz. (170 mL)
- oven capable of maintaining a temperature of 120°F (49°C)
- a constant rate of crosshead movement testing machine as described in Section 5.1 of ASTM D 638, "Standard Test Method for Tensile Properties of Plastics," capable of maintaining a constant rate of travel of 0.05 in./min. (1.3 mm/min.) and applying a tensile force of at least 500 lbf. (2.2 kN) Use grips to hold specimens as described in Section 4.7 of ASTM C 190, "Standard Test Method For Tensile Strength Of Hydraulic Cement Mortars," (Discontinued 1991; No Replacement)
- cement (Type III)
- washed river sand aggregate sieved though a No. 4 sieve
- molds as described in ASTM C 190

- metal shims, 1 in. (25.4 mm) square and 0.037 ±0.003 in. (0.94 ±0.08 mm) thick
- trowel with a steel blade 4 to 6 in. (100 to 150 mm) in length with straight edges
- rubber tamper with a cross section of 1/2 × 1 in. (13 × 25 mm) and a length of 5 to 6 in. (120 to 150 mm). The tamping face must be flat and at right angles to the length of the tamper.
- moist cabinet or room conforming to the requirements of ASTM C 511, "Standard Specification for Mixing Rooms, Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cements and Concretes"
- water storage tank, conforming to the requirements of ASTM C 511
- glass graduate, conforming to the requirements of ASTM C 190
- balance, with minimum capacity of 2000 g, which meets the requirements of Tex-901-K

Prepare Mortar Briquettes

The following procedure describes the preparation of mortar briquettes

Preparing Mortar Briquettes

Step	Action
1	Prepare molds. ♦ Obtain molds as described in ASTM C 190. ♦ Place a shim vertically in the 1 in. waistline of each briquette mold. ♦ Coat the inside of the molds in release material. ♦ Set the mold on top of an ungreased sheet of glass.
2	Obtain components for making the cement mortar. ♦ The mortar is 1-part cement to 3-parts aggregate. ♦ Weigh 750 g of river sand. ♦ Weigh 250 g of cement. ♦ Measure 125 mL of water.
3	Mix components to make the mortar.. ♦ Thoroughly mix sand and cement. ♦ Create a crater in the center of the sand and cement mixture. ♦ Pour water into the center of the crater. ♦ Scoop the material from the sides into the crater over the top of the water within 30 sec. of adding the water. ♦ For the next 30 sec., trowel the dry mortar around the outside of the cone over the remaining mortar for the absorption of water. ♦ Complete the operation with vigorous mixing, squeezing, and kneading the mortar by hand for 1.5 min. During the mixing operation, protect hands with rubber gloves.

Preparing Mortar Briquettes

Step	Action
4	Fill the molds with concrete on both sides of the shim. Compact the concrete using the following procedure: ♦ Press the mortar firmly with the rubber tamper, applying a force of approximately 15 to 20 lbf. Tamp each briquette 12 times. ♦ Add more mortar and compact again until mold is complete. ♦ Heap more mortar above the mold and smooth it off with a trowel.
5	Condition the briquettes. ♦ Place the mold with the briquettes in a moist cabinet and cure for 24 hr. ♦ After 24 hr., remove the briquettes from the mold and immerse them in the water storage tank for 6 days.
6	Remove the briquettes from the water storage tank, and allow the briquettes to dry before use.

Procedure

The following procedure describes the tensile bond test.

Tensile Bond Test

Step	Action
1	Prepare the briquettes. ♦ Divide the briquettes into sets of 6 briquettes. ♦ Sandblast the bonding face of each mortar briquette to remove the laitance on the surface. ♦ After sandblasting, clean the bonding faces of the briquettes with compressed air. *NOTE:* Do not touch bonding faces after sandblasting.
2	Mix the epoxy. ♦ Ensure that the initial temperature of each epoxy component is 77 ±2°F (25 ±1°C). ♦ Using the component ratios, determine the amount of each component necessary to make a total 50 g of mixed epoxy. ♦ Weigh 50 g of total epoxy components into a metal ointment can. ♦ Mix with a spatula for 3 min.
3	Prepare the specimen. ♦ Place a small amount of epoxy on the bonding face of each briquette. ♦ Use a spatula to spread the epoxy uniformly across the bonding face. ♦ Adhere the faces of 2 briquettes together with light pressure, and repeat for the remaining briquettes. ♦ Remove the excess epoxy from the edges of the bonded area with a spatula and stand upright. ♦ Make 1 set of 3 specimens for epoxy types II, V, VII, and VIII. ♦ Make 2 sets of 3 specimens for epoxy type III. *NOTE:* Allow no more than 10 min. to elapse during preparation of the specimens. For type II, allow no more than 6 min.

4	Cure and condition specimens. All specimens are cured in air. ♦ For type II, cure the specimens for 2 hr. at 77 ±2°F (25 ±1°C). ♦ For type III, cure 1 set of 3 specimens for 6 hr. at 77 ±2°F (25 ±1°C). Cure the second set for 48 hr. at 77 ±2°F (25 ±1°C), and then place the specimens in the oven for 1 hr. at 120 ±2°F (49 ±1°C). ♦ For types V and VII, cure the specimens for 6 hr. at 77 ±2°F (25 ±1°C). ♦ For type VIII class A, cure the specimens for 24 hr. at 77 ±2°F (25 ±1°C). ♦ For type VIII class B, cure the specimens for 6 hr. at 77 ±2°F (25 ±1°C).
5	Set up the tensile machine for testing. ♦ Start up tensile machine according to manufacturer's instructions. ♦ Balance and calibrate the tensile machine. ♦ Place the grips on the machine. ♦ Set the crosshead speed to 0.05 in./min. (1.3 mm/min.)
6	Test the specimen. ♦ Load a briquette into the tensile machine. ♦ Start the testing machine and load until break. ♦ Record the load at break. ♦ Repeat test for the remaining specimen. ♦ For type III set of specimen cured at 120°F (49°C), test each specimen, one at a time, immediately after removing it from the oven.
7	Report the average load at break as the tensile bond strength.

Tensile Bond for Type I Epoxy

Apparatus

Use the following apparatus.

- metal spatula
- metal ointment can, 6 fl. oz. (170 mL)
- balance, with minimum capacity of 2000 g, which meets the requirements of Tex-901-K
- third-point loading apparatus as described in ASTM C 78, "Standard Test Method for Flexural Strength of Concrete (Using Simple Beam with Third-Point Loading)"
- environmental chamber, capable of maintaining temperatures of 60 ±2°F (16 ±1°C), 80 ±2°F (27 ±1°C), and 105 ±2°F (41 ±1°C)

Procedure

The following procedure describes the tensile bond test (third-point loading test) for type I epoxy.

Tensile Bond Test for Type I Epoxy	
Step	Action
1	Prepare the blocks. ♦ Prepare and cure flexural concrete specimens as described in ASTM C 78. ♦ Cut 2 cured concrete beams in half.
2	Mix the epoxy. ♦ Ensure that the ambient temperature in the chamber and the initial temperature of each epoxy component is the temperature specified. ♦ Using the component ratios, determine the amount of each component necessary to make a total 100 g of mixed epoxy. ♦ Weigh 100 g of epoxy components into a metal ointment can. ♦ Mix with a spatula for 3 min.
3	Prepare the specimen. ♦ Place a layer of epoxy on the bonding face of each block. The bonding face is the side opposite to the cut. ♦ Use a spatula to spread the epoxy uniformly across the bonding face. ♦ Adhere the faces of 2 halves together to make a complete block.
4	Allow the blocks to cure for 24 hr. at the specified temperature.
5	Test the specimen. ♦ Test the blocks in the third point loading apparatus as described in ASTM C 78. ♦ Report the average of the 2 blocks.

Thixotropy

The thixotropy test applies to the following epoxy types: I, II, III, VIII, and X.

Thixotropy Test (Except Type X)

Refer to the following table to determine the conditioning temperatures, the form thickness, and measurement type required for each type of epoxy.

Thixotropy Test Parameters				
Testing Parameter	Type I	Type II	Type III	Type VIII
Conditioning Temperature	As specified 60 ±2°F (16 ±1°C) 80 ±2°F (27 ±1°C) or 105 ±2°F (41 ±1°C)	120 ±2°F (49 ±1°C)	120 ±2°F (49 ±1°C)	77 ±2°F (25 ±1°C)
Form Thickness	0.1 in. (2.5 mm)	0.1 in. (2.5 mm)	0.05 in. (1.3 mm)	0.25 in. (6.4 mm)
Measurement Type	Sag	Sag	Thickness Retained	Sag
Special Instructions	-	-	-	Test with epoxy and sand mixture

- Apparatus

Use the following apparatus:

- forced-draft oven, capable of maintaining temperatures of 120 ±2°F (49 ±1°C)
- environmental chamber, capable of maintaining temperatures of 60 ±2°F (16 ±1°C), 80 ±2°F (27 ±1°C), and 105 ±2°F (41 ±1°C) [Type I only]
- thickness gauge, with a resolution of at least 0.00005 in. (0.001 mm)
- calipers with a resolution of at least 0.001 in. (0.03 mm)
- smooth, clean metal plate 3 in. × 6 in.(76 mm × 152 mm) approximately 0.1 in. (2.5 mm) thick
- steel forms 3 in. × 6 in. (76 mm × 152 mm) with 2 in. × 4 in. (51 mm × 102 mm) cutout in the center of the following thicknesses: 0.1 in. (2.5 mm), 0.05 in. (1.3 mm), and 0.25 in. (6.4 mm)
- metal spatula
- metal ointment cans, 3 fl. oz. (85 mL)
- balance, with minimum capacity of 2000 g, which meets the requirements of Tex-901-K.

- Procedure

The following procedure describes the thixotropy test for epoxy types I, II, III, and VIII.

Thixotropy Test

Step	Action
1	Obtain the epoxy. ♦ Using the component ratios, determine the amount of each component necessary to produce 50 g of mixed epoxy. ♦ Measure each component into separate 3 fl. oz. (85 mL) metal ointment cans.
2	Obtain the metal plate and form. ♦ Obtain the 3 in. × 6 in. (76 mm × 152 mm) metal plate and the 3 in. × 6 in. (76 mm × 152 mm) metal form with a 2 in. × 4 in. (51 mm × 102 mm) cutout in the center. Use a form of the thickness specified. ♦ If measuring the amount of sag, scribe a mark across the metal plate 1 in. from the edge and parallel to the 3 in. (76 mm) side. The mark will correspond with 1 end of the 2 in. × 4 in. (51 mm × 102 mm) cutout in the steel form.
3	Condition the epoxy components, metal plate, steel form, and a spatula at the temperature specified.
NOTE: For type II epoxy, perform Steps 4–7 within 2 min.	
4	Mix the epoxy. ♦ Remove the epoxy components and a spatula from the oven or environmental chamber if necessary. ♦ Transfer the resin to the hardener can and mix with a spatula for 3 min.

Thixotropy Test

Step	Action
	NOTE: Mix heated epoxy for only 1 min.
5	Set up the metal plate and form. ♦ Remove the steel plate and form from the oven or the environmental chamber if necessary. ♦ Place them on a horizontal surface with 2 or 3 sheets of paper or a piece of thin cardboard under the steel plate. ♦ Place the form on the plate, and align the sides of the plate and the form. ♦ If measuring the amount of sag, align the scribed mark with 1 side of the 2 in. × 4 in (51 mm × 102 mm) cutout in the form. Make note of where the mark is.
6	Form the epoxy panel. ♦ Pour an excess of mixed adhesive immediately into the form. ♦ Use a spatula to screed adhesive on the top surface of the form. *NOTE:* Be careful not to allow the form to shift during the screeding process. ♦ Slowly lift the form upward. *NOTE:* This will leave a 2 in. × 4 in. (51 mm × 102 mm) panel of epoxy on the plate.
7	Stand the steel plate vertically. ♦ The 6 in. (152 mm) sides of the plate are vertical and the 3 in. (76 mm) sides are on the top and bottom. ♦ If measuring the amount of sag, make sure the scribed end of the plate is at the bottom. ♦ Condition the plate at the temperature specified until the epoxy has hardened.
8	To determine the amount of sag, perform the following: ♦ After the adhesive has hardened, remove the plate from the oven or environmental chamber if necessary. ♦ Measure the distance the epoxy sagged over the edge of scribed line. ♦ Take 3 measurements, one at the center and one at each edge. ♦ Average the 3 measurements. ♦ Report the average to the nearest 0.01 in. (0.5 mm).
9	To measure the amount of thickness retained by the epoxy, perform the following: ♦ Remove the plate with the epoxy panel from the oven. ♦ Allow the plate to cool to room temperature. ♦ Using the thickness gage, take 8 measurements, 4 on each side of the epoxy layer. • Before taking each thickness reading, zero the thickness gauge by measuring the thickness of steel plate next to the 4 readings on each side. • Start measuring the epoxy thickness at 0.5 in. (13 mm) from the top and sides, then read down 1 in. (25.4 mm) apart and 0.5 in. (13 mm) from side. ♦ Average all readings and report to the nearest 0.001 in. (0.05 mm).

Thixotropy Test for Epoxy Type X

- Apparatus

Use the following apparatus:

- balance, with minimum capacity of 2000 g, which meets the requirements of Tex-901-K
- thermometer, range 66 to 80°F (19 to 27°C) (F17 thermometer as shown in ASTM E 1)
- thickness gauge, with a resolution of at least 0.00005 in. (0.001 mm)
- smooth steel plates 5 in. × 8 in. × 0.1 in. (127 mm × 203 mm × 2.5 mm)
- adjustable film former, such as a Boston Bradley draw-down gauge with a path at least 3 in. wide and the opening set at approximately 16 mils.
- metal ointment can, 6 fl. oz. (170 mL)
- metal spatula.

- Procedure

The following procedure describes thixotropy for epoxy type X.

Thixotropy Test

Step	Action
1	Determine the thickness of the metal plate. ◆ Determine the average thickness to the nearest 0.001 in. (0.03 mm) of a 2 in. × 4 in. (51 mm × 102 mm) area on a smooth, clean 5 in. × 8 in. (127 mm × 203 mm) steel plate. ◆ The 2 in. × 4 in. (51 mm × 102 mm) area is defined as 3 in. (76 mm) from the top and 1 in. (25 mm) from the bottom along the 8 in. (203 mm) dimension, and 1.5 in. (38 mm) from each side along the 5 in. (127 mm) dimension of the plate. ◆ Using the thickness gage, take 8 random readings, and record the average.
2	Mix the epoxy. ◆ Ensure that the initial temperature of each epoxy component is 77 ±2°F (25 ±1°C). ◆ Using the component ratios, determine the amount of each component necessary to produce 100 g of mixed epoxy. ◆ Weigh out the components into a metal can. ◆ Stir the 2 components of the epoxy coating for 5 min.
3	Form the epoxy panel. ◆ Using approximately half of the mixed material, apply the epoxy on the plate in 2 lines of equal amounts, one at top and other at center of the steel plate. ◆ Draw a 16-mil film down the length of the steel plate using the film former.
4	Stand the steel plate vertically. ◆ After forming the epoxy film, stand the steel panel in a vertical position on its short edge. ◆ Make sure that no more than 10 min. elapse between the mixing time and the placing of the steel panel in the vertical position. ◆ Let stand overnight.
5	Measure the thickness retained by the epoxy.

Thixotropy Test

Step	Action
	♦ After the epoxy has hardened, measure the average thickness of coating covering the 2 in. × 4 in. (51 mm × 102 mm) area of the steel plate defined in Step 1. ♦ Take 8 random readings.
6	Determine the average cured coating thickness by subtracting the average steel panel thickness from the average of total panel plus coating thickness.

Adhesive Shear Strength

Apparatus

Use the following apparatus:

- steel specimens 1 in. × 6.5 in. × 0.064 in. (25 mm × 165 mm × 1.6 mm)
- sandblasting machine
- garnet blasting abrasive, 36 mesh
- A testing machine as described in Section 5 of ASTM D 1002, "Standard Test Method for Apparent Shear Strength of Single-Lap-Joint Adhesively Bonded Metal Specimens by Tension Loading (Metal-to-Metal)."

Procedure

The following procedure describes the adhesive shear strength test for type II epoxy.

Adhesive Shear Strength

Step	Action
1	Follow the procedure outlined in ASTM D 1002, "Standard Test Method for Apparent Shear Strength of Single-Lap-Joint Adhesively Bonded Metal Specimens by Tension Loading (Metal-to-Metal)."
2	Prepare the surfaces of the individual precut specimens by sandblasting to white metal.
3	Clean blasted ends with compressed air.
4	Cure the test specimens for 7 days at 70 to 80°F (21 to 27°C) before testing.

Impact Strength

Apparatus

Use the following apparatus:

- balance, with minimum capacity of 2000 g, which meets the requirements of Tex-901-K
- disk mold to make a 2.5 ±0.5 in. (64 ±1 mm) diameter by 0.37 ±0.01 in. (9.5 ±0.3 mm) thick disk
- sanding lathe
- machined steel plate, 6 × 6 × 0.5 in. (152 × 152 ×13 mm)
- steel pipe, 2 in. (51 mm) inside diameter, approximately 3 ft. (1 m) in length
- steel ball, 1 lb. (454 g)
- metal ointment can, 6 fl. oz. (170 mL).

Procedure

The following procedure describes the impact strength test for type II epoxy.

Impact Strength

Step	Action
1	Obtain at least 3 disk molds to make 2.5 ±0.5 in. (64 ±1 mm) diameter by 0.37 ±0.01 in. (9.5 ±0.3 mm) thick disks.
2	Mix the epoxy. ♦ Ensure that the initial temperature of each epoxy component is 77 ±2°F (25 ±1°C). ♦ Using the component ratios, determine the amount of each component necessary to produce 200 g of mixed epoxy. ♦ Weigh out the components into a metal can. ♦ Mix the epoxy for 3 min.
3	Make the epoxy disks. ♦ Pour the epoxy into the disk molds. ♦ Carefully tap disks on countertop to level material and remove bubbles. ♦ Cure the disks for 7 days at 70 to 80°F (21 to 27°C).
4	Prepare the epoxy disks. ♦ Remove the epoxy disks from the molds. ♦ Grind or machine the plane surfaces of the disks flat and parallel. ♦ The thickness of the finished disks is 0.30 ±0.02 in. (8 ±0.5 mm). ♦ Smooth the specimens with a No. 180 grit sandpaper. ♦ Blow clean the disks with oil-free compressed air. *NOTE:* Be careful not to heat the disks above 120°F (49°C) when machining or grinding..

Impact Strength

Step	Action
5	Set up the impact resistance test. ♦ Place the finished specimens on a machined steel plate securely attached to a concrete slab. ♦ Place the 3 ft. (1 m) steel pipe above the machined steel plate such that the top of the pipe is 5 ft. (1.5 m) above the plate. ♦ Place the epoxy disk on the steel plate directly below the pipe. ♦ The pipe acts as a guide for the ball to fall on the epoxy disk.
6	Perform the impact resistance test. ♦ Drop a 1 lb. (454 g) ball onto the center of the disks from an initial height of 5 ft. (1.5 m) ♦ Increase the height of the pipe by 6 in. (152 mm) for each successive drop until the specimen fails by cracking or shattering or until reaching a maximum height of 7 ft. (2.1 m). ♦ Record the height of the drop at which the failure occurs. ♦ Repeat for the rest of the specimens. *NOTE:* Do not allow the ball to strike the disk after rebounding from the test drop.
7	Report the average to the nearest 0.5 ft. lb. (0.7 joule).

Wet Strength

The wet strength test is required for type II, IV, and IX.

Apparatus

Use the following apparatus:

- balance, with minimum capacity of 2000 g, which meets the requirements of Tex-901-K
- metal spatula
- metal ointment can, 6 fl. oz. (170 mL)
- mortar briquettes
- water bath, capable of maintaining 100 ±2°F (38 ±1°C)
- water bath, capable of maintaining 73 ±2°F (23 ±1°C)
- a constant rate of crosshead movement testing machine as described in Section 5.1 of ASTM D 638 capable of maintaining a constant rate of travel of 0.05 in./min. (1.3 mm/min.) and applying a tensile force of at least 500 lbf. (2.2 kN) Use grips to hold specimens as described in Section 4.7 of ASTM C 190.

Procedure

The following procedure describes the wet strength test for epoxy types II, IV, and IX.

Wet Strength Test

Step	Action
1	Prepare briquettes ♦ Obtain 3 sets of mortar briquettes made in accordance with "Prepare mortar briquettes" of the "Tensile Bond" procedure. ♦ Sandblast the bonding face of each mortar briquette. ♦ Clean the bonding faces of 3 sets of briquettes with compressed air. ♦ For type IX epoxy: • Soak the briquettes in distilled or deionized water at 77 ±2°F (25 ±1°C) for 24 hr. • Remove the briquettes from the water bath and blow the bonding faces dry with oil-free compressed air. *NOTE:* Do not touch bonding faces after sandblasting.
2	Mix the epoxy. ♦ Ensure that the initial temperature of each epoxy component is 77 ±2°F (25 ±1°C) ♦ Using the component ratios, determine the amount of each component necessary to make a total 50 g of mixed epoxy. ♦ Weigh 50 g of epoxy components in a metal can. ♦ Mix with a spatula for 3 min.
3	Prepare the specimen. ♦ Place a small amount of epoxy on the bonding face of each briquette. ♦ Use a spatula to spread the epoxy uniformly across the bonding face. ♦ Place the faces of 2 briquettes halves together with light pressure, and repeat for the remaining briquettes. ♦ Remove the excess epoxy from the edges of the bonded area with a spatula and stand upright. *NOTE:* For type II epoxy, allow no more than 6 min. to elapse during preparation of the specimens.
4	Condition the specimen. ♦ Allow the briquettes to cure for 24 hr. at 77 ±2°F (25 ±1°C). ♦ Immediately transfer the briquettes to an oven at 120 ±2°F (49 ±1°C) for 48 hr. ♦ Immerse the cured specimens in a distilled or deionized water bath maintained at 100 ±2°F (38 ±1°C) for 4 days. ♦ Remove specimens and place them in a distilled or deionized water bath at 73 ±2°F (23 ±1°C) for 1 hr.
5	Set up the tensile machine for testing. ♦ Start up tensile machine according to manufacturer's instructions. ♦ Balance and calibrate the tensile machine. ♦ Place the grips on the machine. ♦ Set the crosshead speed to 0.05 in./min. (1.3 mm/min.).
6	Test the specimen. ♦ Load a briquette into the tensile machine. ♦ Start the testing machine and load until break.

Wet Strength Test

Step	Action
	♦ Record the load at break. ♦ Repeat the test for the remaining specimen.
7	Report the average load at break as the wet bond strength.
8	Test one more set of specimens if any of the tested briquettes fail in the mortar at strengths below 270 psi (1862 kPa).

Wet Pullout Strength

Apparatus

Use the following apparatus:

- balance, with minimum capacity of 2000 g, which meets the requirements of Tex-901-K
- rebar, grade 60, #3, 30 in. (760 mm) in length
- concrete block with a minimum size of 6 in. × 6 in. × 8 in. (150 mm × 150 mm × 200 mm) or a concrete cylinder with a minimum size of 6 in. (150 mm) diameter and 8 in. (200 mm) high. The block or cylinder must be compression rated at 5,000 ±500 lb. (22.3 ±2.2 kN)
- water bath at 77 ±3°F (25 ±2 °C)
- carbide tip masonry drill bit, 6 in. × 5/8 in. diameter (150 mm × 13 mm)
- hammer drill
- metal ointment can, 6 fl. oz. (170 mL)
- a constant rate of crosshead movement testing machine as described in Section 5.1 of ASTM D 638 capable of maintaining a constant rate of travel of 0.2 in./min. (5 mm/min.) and applying a tensile force of at least 10,000 lbf. (44.5 kN).
- mechanical wedge grips, use wedge grips with v-shaped jaw faces to grab the rebar end of the pullout specimen.

- Use the fixture shown in Figure 1 to hold the concrete block end of the pullout specimen. This apparatus consists of the following: 1 steel plate, 4 steel rods with threading on both ends, and 4 bolts. The plate must be 10.75 in. × 8.75 in. × 0.5 in. (273 mm × 222 mm × 13 mm). The plate must have 5 holes: four 0.8 in. (20 mm) diameter holes, one in each corner, and one 1.75 in. (44 mm) diameter hole in the center. The 4 steel rods must be 13.75 in. (350 mm) long and 0.77 in. (20 mm) in diameter with 2.25 in. (57 mm) of threading on each end. The threading must be able to fasten into the bottom plate of the testing machine on one end and fasten into the bolts on the other end. The dimensions may be altered to accommodate other testing machines.

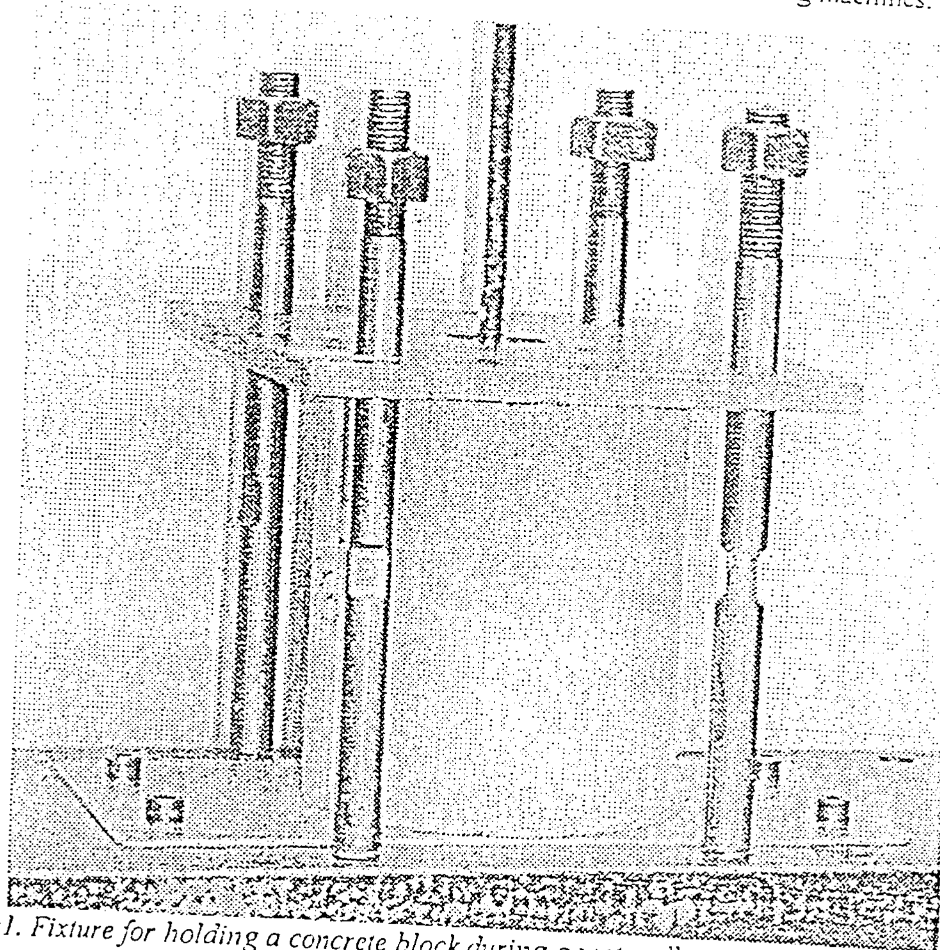


Figure1. Fixture for holding a concrete block during a wet pullout test.

Procedure

The following outlines the procedure for wet pullout strength.

Wet Pullout Strength Test

Step	Action
1	Prepare the concrete block. ♦ Drill a hole, 5/8 in. (13 mm) diameter and 3.5 in. (90 mm) in depth, located at the center of the top surface of the concrete block or cylinder. ♦ Remove debris and dust from the hole using moisture-free compressed air. ♦ Ensure the rebar fits without binding.
2	Mix the epoxy. ♦ Ensure that the initial temperature of each epoxy component is 77 ±2°F (25 ±1°C) ♦ Using the component ratios, determine the amount of each component necessary to make a total 50 g of mixed epoxy. ♦ Weigh 50 g of epoxy components into a metal can. ♦ Mix with a spatula for 3 min.
3	Prepare the specimen. ♦ Place the epoxy in the hole. ♦ Insert the rebar the entire depth of the hole. ♦ Rotate the rebar several times to ensure that the epoxy adequately coats the rebar and to remove air pockets in the epoxy. ♦ Repeat filling the hole and inserting the rebar as necessary until the hole is full. ♦ Remove excess epoxy from the surface of the cylinder. ♦ *NOTE:* To ensure a valid test, the rebar must remain plumb and centrally located in the hole.
4	Cure the specimen. ♦ Cure the specimen in air for 24 hr. at 77 ±3°F (25 ±2°C). ♦ Submerge the block into a water-bath at 77 ±3°F (25 ±2°C) in an upright position for 6 days.
5	Set up the tensile machine for testing. ♦ Start up tensile machine according to manufacturer's instructions. ♦ Balance and calibrate the tensile machine. ♦ Place a wedge grip on the testing machine as the top fixture. ♦ Screw the four rods into the bottom plate of the testing machine. ♦ Set the crosshead speed to 0.2 in./min. (5 mm/min.)
6	Load the specimen in the testing machine. ♦ Place the specimen in between the rods. ♦ Place the steel plate over the block. Fit the rebar through the center hole and the 4 rods through the 4 holes at the corners of the plate. ♦ Grip the rebar in the wedge grip. ♦ Lift the block 2 in. and adjust the block to ensure the rebar is pulling straight. With the block lifted, tighten the 4 nuts to the steel plate.
7	Test the specimen. ♦ Start the testing machine and load until break.

Wet Pullout Strength Test

Step	Action
	♦ Record the load at break.
8	Report the load at break as the wet pullout strength.

Grind – Epoxy X

The grind test is only required for epoxy type X.

Apparatus

Use the following apparatus:

- balance, with minimum capacity of 2000 g, which meets the requirements of Tex-901-K
- metal spatula
- metal ointment can, 3 fl. oz. (85 mL)
- tapered gage, a hardened steel, stainless steel, or chrome-plated steel block approximately 7.5 in. (190 mm) in length, 3.5 in. (90 mm) in width, and 1 in. (25 mm) in thickness. The top surface of the block is ground smooth and planar and contains a 5 in. (127 mm) long by 2 in. (50 mm) wide path. The path is tapered uniformly in depth lengthwise from about 4 mils (100 µm) at 0.4 in. (10 mm) from one end to zero depth at the other with intermediate calibrations in accordance with the depth at those points. The preferred calibration is Hegman units.
- scraper, a double edged hardened steel, stainless steel, or chrome-plated steel blade 3.75 in. (95 mm) long, 1.5 in. (40 mm) wide, and 0.25 in. (6.4 mm) thick. The two edges on the 3.75 in. sides are rounded to a radius of 0.015 in. (0.38 mm).

Procedure

The following procedure describes the grind test for epoxy type X.

Grind Test

Step	Action
1	Prepare the epoxy. ♦ Weigh 10 g of the resin component into a metal can. ♦ Add 2 g of xylene. ♦ Stir until it is a homogeneous mixture.
2	Perform the grind test on the epoxy resin according to ASTM D 1210, "Standard Test Method for Fineness of Dispersion of Pigment-Vehicle Systems by Hegman-Type Gage."

Grind Test

Step	Action
3	Record the results. *NOTE:* Refer to ASTM D 1210 for guidance on interpretation of test results.

Bond Strength of Fresh Concrete to Cured Concrete

This test method applies to types V and VII epoxy.

Apparatus

Use the following apparatus:

- balance, with minimum capacity of 2000 g, which meets the requirements of Tex-901-K
- metal spatula
- metal ointment can, 3 fl. oz. (85 mL)
- mortar briquettes
- sand and cement to prepare mortar as described in ASTM C 190
- briquette molds as described in ASTM C 190
- a constant rate of crosshead movement testing machine as described in Section 5.1 of ASTM D 638 capable of maintaining a constant rate of travel of 0.05 in./min. (1.3 mm/min.) and applying a tensile force of at least 500 lbf. (2.2 kN). Use grips to hold specimens as described in Section 4.7 of ASTM C 190.

Procedure

The following procedure describes the bonding fresh to cured concrete test.

Bonding Fresh Concrete to Cured Concrete Test

Step	Action
1	Prepare briquettes ♦ Obtain briquettes made in accordance with "Prepare Mortar Briquette" of the "Tensile Bond" procedure. ♦ Sandblast the bonding face of each mortar briquette. ♦ Clean the bonding faces of the briquettes with compressed air. *NOTE:* Do not touch bonding faces after sandblasting.
2	Mix the epoxy. ♦ Ensure that the initial temperature of each epoxy component is 77 ±2°F (25 ±1°C) ♦ Using the component ratios, determine the amount of each component necessary to make a

Bonding Fresh Concrete to Cured Concrete Test

Step	Action
	total 50 g of mixed epoxy. ♦ Weigh 50 g of epoxy components into a metal ointment can. ♦ Mix with a spatula for 3 min.
3	Apply epoxy to the briquettes. ♦ Take one of the briquettes and place a small amount of epoxy on the bonding face. ♦ Use a spatula to spread the epoxy uniformly across the surface. ♦ Repeat for the remaining briquettes.
4	Mold new mortar to the briquettes to make complete tensile specimen. ♦ Prepare new mortar as described in the 'Tensile Bond' procedure. ♦ Place each briquette into a briquette mold. ♦ Mold the new mortar against each of the 3 briquettes to form 3 complete tensile specimens. ♦ Cure the specimen for 7 days, according to ASTM C 190.
5	Set up the tensile machine for testing. ♦ Start up tensile machine according to manufacturer's instructions. ♦ Balance and calibrate the tensile machine. ♦ Place the grips on the machine. ♦ Set the crosshead speed to 0.05 in./min. (1.3 mm/min.)
6	Test the tensile specimen. ♦ Load a specimen into the tensile machine. ♦ Start the testing machine and load until break. ♦ Record the load at break. ♦ Repeat the test for the remaining specimen.
7	♦ Report the average load at break as the bond strength. ♦ Test one more set of specimens if any of the tested specimens fail in the mortar at strengths below 270 psi (1862 kPa).

Old Concrete to New Grout Mix

This test procedure applies to type VIII epoxy only.

Apparatus

Use the following apparatus:

- balance, with minimum capacity of 2000 g, which meets the requirements of Tex-901-K
- metal spatula
- friction top can, 1 pt. (500 mL), with friction lip removed
- mortar briquettes

- briquette molds as described in ASTM C 190
- a constant rate of crosshead movement testing machine as described in Section 5.1 of ASTM D 638 capable of maintaining a constant rate of travel of 0.05 in./min. (1.3 mm/min.) and applying a tensile force of at least 500 lbf. (2.2 kN) Use grips to hold specimens as described in Section 4.7 of ASTM C 190.

Procedure

The following procedure describes old concrete to new grout test for type VIII epoxy.

Old Concrete to New Grout Test

Step	Action
1	Prepare the briquettes. ◆ Obtain 3 briquettes made in accordance with "Prepare Mortar Briquette" of the "Tensile Bond" procedure. ◆ Sandblast the bonding face of each mortar briquette. ◆ Clean the bonding faces of the briquettes with compressed air. *NOTE:* Do not touch bonding faces after sandblasting.
2	Mix the epoxy grout. ◆ Ensure that the initial temperature of each epoxy component is 77 ±2°F (25 ±1°C). ◆ Using the component ratios, determine the amount of each component necessary to make a total 250 g of mixed grout. ◆ Weigh the grout components in a 1 pt. (500 mL) can. ◆ Mix with a spatula for 3 min.
3	Mold epoxy grout to the briquettes to make complete tensile specimen.. ◆ Place each briquette into a briquette mold. ◆ Mold the epoxy grout against each of the 3 briquettes to form 3 complete tensile specimens. ◆ Cure the specimen for 7 days at 77 ±2°F (25 ±1°C).
4	Set up the tensile machine for testing. ◆ Start up tensile machine according to manufacturer's instructions. ◆ Balance and calibrate the tensile machine. ◆ Place the grips on the machine. ◆ Set the crosshead speed to 0.05 in./min. (1.3 mm/min.)
5	Test the tensile specimen. ◆ Load a specimen into the tensile machine. ◆ Start the testing machine and load until break. ◆ Record the load at break. ◆ Repeat the test for the remaining specimen.
6	◆ Report the average load at break as the bond strength. ◆ Test one more set of specimens if any of the tested specimen fail in the cement mortar at strengths below 270 psi (1862 kPa).

Hiding Power

This test procedure applies to type X epoxy only.

Apparatus

Use the following apparatus:

- balance, with minimum capacity of 2000 g, which meets the requirements of Tex-901-K
- black and white paper charts that are smooth and level, and impervious to paint liquids. The black area must have a maximum reflectance of 1% and the white area a minimum reflectance of 78%. The white area must be nonflourescent.
- draw down gauge, 5 mil
- vacuum platter or other suitable device
- reflectance measurement instrument that allows diffusely reflected, radiant flux to be incident upon the measuring element. It must employ a photometric system, including source, filters, and receptor, that provides a response closely similar to the product of the spectral luminous efficiency function of the CIE standard observer and source C. It must provide readings to at least the third decimal place and permit estimation to the fourth.
- metal ointment can, 6 fl. oz. (170 mL).

Procedure

The following procedure describes the hiding power test for epoxy type X.

Hiding Power

Step	Action
1	Mix the epoxy. ♦ Ensure that the initial temperature of each epoxy component is 77 ±2°F (25 ±1°C). ♦ Using the component ratios, determine the amount of each component necessary to make a total 50 g of mixed epoxy. ♦ Weigh the components into a metal can. ♦ Mix with a spatula for 5 min.
2	Draw down a 5 mil thick film on the black and white paper chart. ♦ Place the black and white paper chart on a flat surface. ♦ Pour 2 horizontal lines of mixed epoxy on the black and white paper, one on each color. ♦ Make the lines the width of the draw down gage. ♦ Put the draw down gage at the top of the paper, and draw it down at approximately 2.4 in./sec. (61 mm/sec.).
3	Allow the film to dry. ♦ Place the black and white paper chart in a well-ventilated dust free location.

Step	Action
	♦ Allow to dry overnight.
4	Measure the reflectance and determine the contrast ratio. ♦ Measure the reflectance at 3 random points on each color. ♦ Calculate the contrast ratio by dividing the reflectance on white substrate (Y_w) into the reflectance on black substrate (Y_b).

Water Gain

This test procedure applies to type VIII epoxy only.

Apparatus

Use the following apparatus:

- disk mold to make a 2.5 ±0.5 in. (64 ±1 mm) diameter by 0.37 ±0.01 in. (9.5 ±0.3 mm) thick disk
- distilled or deionized water
- glass container, approximately 6 to 10 in. (152 to 254 mm) deep and 4 to 5 in. (102 to 127 mm) in diameter
- silicon carbide sandpaper No. 180 grit
- machine lathe
- analytical balance with a minimum capacity of 100 g, which meets the requirements of Tex-901-K.

Procedure

The following procedure describes the water gain test.

Water Gain Test

Step	Action
1	Obtain 3 molds to make 2.5 ±0.5 in. (64 ±1 mm) diameter by 0.37 ±0.01 in. (9.5 ±0.3 mm) thick disks.
2	Prepare the epoxy. ♦ Ensure that the initial temperature of each epoxy component is 77 ±2°F (25 ±1°C). ♦ Using the component ratios, determine the amount of each component necessary to produce 200 g of mixed epoxy. ♦ Weigh out the components into a metal can. ♦ Mix the epoxy for 3 min.
3	Cast and cure the epoxy disks.

Step	Water Gain Test Action
	• Pour the epoxy into the disk molds. • Carefully tap disks on countertop to level material and remove bubbles. • Cure the disks for 7 days at 70 to 80°F (21 to 27°C).
4	Prepare the epoxy disks. • Remove the epoxy disks from the molds. • Grind or machine the plane surfaces of the disks flat and parallel. • The thickness of the finished disks must be 0.30 ±0.02 in. (8 ±0.5 mm). • Smooth the specimens with No. 180 grit sandpaper. • Blow clean the disks with oil-free compressed air. *NOTE:* Be careful not to heat the disks above 120°F (49°C) when machining or grinding.
5	Weigh the disks on an analytical balance to the nearest 0.001 g.
6	Immerse the disks in a water bath. • Fill a water bath with distilled or deionized water. • Ensure the water temperature is maintained at 77 ±4°F (25 ±2°C). • Immerse the disks in the water bath for 24 hr.
7	Weigh the saturated disks to determine the water gain. • Remove one of the disks from the water bath. • Wipe the surface water off with a dry cloth. • Immediately weigh the disk to the nearest 0.001g. • Repeat for the other 2 disks.
8	Calculate the percent increase in weight of each disk. Average the results and report to the nearest 0.1%.

Calculations

Increase in weight

$$\text{Increase in weight, \%} = \frac{\text{wet weight - conditioned weight}}{\text{conditioned weight}} \times 100$$

Where:

- increase in weight, % = percent increase in the weight of the sample
- wet weight = weight in grams of the sample after soaking in water
- conditioned weight = weight in grams of the conditioned sample before soaking in water.

Contact Time

This test procedure applies to type I epoxy only.

Apparatus

Use the following apparatus:

- balance, with minimum capacity of 2000 g, which meets the requirements of Tex-901-K
- metal spatula
- metal ointment can, 6 fl. oz. (170 mL)
- mortar briquettes.

Procedure

The following procedure describes the contact time test.

Contact Time Test	
Step	**Action**
1	Prepare the briquettes. ◆ Obtain 3 sets of mortar briquettes made in accordance with "Prepare Mortar Briquette" of the "Tensile Bond" procedure. ◆ Sandblast the bonding face of each mortar briquette. ◆ Clean the bonding faces of the briquettes with compressed air. *NOTE:* Do not touch bonding faces after sandblasting.
2	Mix the epoxy. ◆ Condition epoxy components to the temperature specified. ◆ Using the component ratios, determine the amount of each component necessary to make a total 50 g of mixed epoxy. ◆ Weigh 50 g of epoxy components in a metal can. ◆ Mix with a spatula for 3 min.
3	Prepare the specimen. ◆ Take one of the briquettes and place a small amount of epoxy on the bonding face. ◆ Use a spatula to spread the epoxy uniformly across the surface. ◆ Repeat for remaining briquettes. ◆ Let the briquette halves sit for 60 min. at the temperature specified.
4	After 60 min., put 2 briquette halves together. If the briquettes adhere together, the epoxy meets the 60 min. contact time requirement. If the epoxy has hardened and the briquettes do not stick together, the epoxy does not meet the 60 min. contact time requirement.

Section 4

Archived Versions

The following archived versions of Test Method "Tex-614-J, Testing Epoxy Materials" are available:

- 614-0899 for the test procedure effective August 1999 through May 2000.
- 614-0600 for the test procedure effective June 2000 through December 2000.
- 614-0101 for the test procedure effective January 2001 through July 2002.
- 614-0802 for the test procedure effective August 2002 through June 2006.

Tex-618-J, Testing Elastomeric Concrete

Contents:

Section 1

Overview

Effective Date: August 2002 (refer to 'Archived Versions' for earlier versions).

The method includes procedures for preparing and testing elastomeric concrete specimens as specified under "DMS-6140, Elastomeric Concrete for Bridge Joints." Tests are performed on binder components alone, and on the complete mixture of binder and aggregate. Refer to DMS-6140 for a description of the two types of elastomeric concrete and the tests performed on each type.

- Tests on Elastomeric Binder Only
  - Impact Strength
  - Tensile Strength
  - Tensile Stress
  - Ultimate Elongation
  - Tear Resistance.
- Tests on Complete Elastomeric Concrete
  - Wet Bond Strength to Concrete
  - 24-hour Compressive Strength
  - Compressive Stress
  - Resilience.

Units of Measurement

The values given in parentheses (if provided) are not standard and may not be exact mathematical conversions. Use each system of units separately. Combining values from the two systems may result in nonconformance with the standard.

Section 2

Preparing Samples

The following describes the required steps to prepare samples.

Preparing Samples	
Step	**Action**
1	♦ Allow material to stabilize at a temperature of 25 ± 2 °C (77 ± 4 °F). ♦ Measure components in the ratios specified by the manufacturer. ♦ Convert volume ratios to weight ratios using the gallon weight of the components.
2	Thoroughly mix the components. For tests that use aggregate, make sure the aggregate is mixed well with the binder.
3	Use Teflon or lubricant coated metal as mold surface.
4	Pour binder mixtures into molds as soon as possible after thorough mixing. NOTE: To minimize entrained air during mixing, use physical means or pass a soft flame over the surface.
5	Allow specimens to cure sufficiently so they will not be damaged by removal from molds

Section 3

Procedures

Impact Strength

Apparatus

The following apparatus is required:

- discs with a 64 ± 1 mm (2.50 ± 0.05 in.) diameter and a 9.5 ± 0.3 mm (0.37 ± 0.01 in.) thickness
- sanding lathe
- water bath capable of maintaining 0 °C (32 °F)
- pipe no more than 4.5 feet in height and 2 inches in diameter
- 1 pound steel ball no more than 2 inches in diameter.

Procedure

The following describes the impact strength test.

Impact Strength	
Step	Action
1	Obtain at least three discs with a 64 ± 1 mm (2.50 ± 0.05 in.) diameter and a 9.5 ± 0.3 mm (0.37 ± 0.01 in.) thickness. NOTE: Lining the discs with release grease helps.
2	♦ Using the weight mixing ratios, measure out sufficient binder material to fill the three discs. ♦ Thoroughly mix the material and pour into the discs. ♦ Set the discs aside to cure.
3	After seven days cure at 25 ± 2 °C (77 ± 4 °F), sand flat the faces of the disc, and immerse the specimen in ice water to condition it to 0 °C (32 °F).
4	Remove the specimen from the ice water, towel dry, and place them on a dry machined steel plate.
5	♦ Immediately after placing on the plate, drop a one-pound steel ball onto the center of the specimen from a height of 1.5 m (5 ft.). ♦ Use the pipe for a better aim.
6	Increase the drop height in 152 mm (0.5 ft.) intervals until the specimen fails by cracking.
7	Report the average value of three specimens in Joule (ft./lb.).

Tensile Strength

Apparatus

The following apparatus is required:

- tensile specimen mold conforming to ASTM D 638, Type IV with dimension WO of 25 mm (1 in.)

- dial gauge or caliper
- tensile testing machine, constant-rate-of-extension (CRE) type, with automatic recording conforming to the requirements of ASTM D 76
- testing clamps with 25 mm x 50 mm (1 in. x 2 in.) serrated jaws, and appropriate clamping power to prevent slipping or crushing.

Procedure

The following describes the tensile strength test.

Tensile Strength	
Step	Action
1	♦ Perform the tensile strength test according to ASTM D 638-84 using the Type IV specimen with dimension WO of 25 mm (1 in). ♦ This corresponds to Die C of ASTM D 412.
2	♦ Using the weight ratios, measure a sufficient amount of the binder components to fill the mold. ♦ Thoroughly mix the components, and pour into the mold. ♦ Cast at least three specimens. ♦ Remove any entrained air using a soft flame or physical methods.
3	Perform test after seven days of curing at 25 ± 2 °C (77 ± 4 °F). Carefully remove the specimen from the mold. Remove excess material and smooth the edges.
4	Measure the thickness and width of the specimen neck with a dial gauge or caliper and determine the cross-sectional area.
5	♦ Use an initial test machine jaw separation of 51 mm (2 in) and a cross-head speed of 51 mm (2 in.) per minute. ♦ Calibrate and set an extensiometer on the sample with an initial gage length of 25 mm (1 in.).
6	Load the specimen to failure and use the maximum load to determine the tensile strength.
7	♦ Report the average results from the three specimens in MPa (psi). ♦ Discard any with obvious flaws.

Tensile Stress

Perform this test according to the methods of 'Tensile Strength' using the same specimens.

Tensile Stress is measured at 13 mm (1/2 in.) elongation based on cross-head travel. Report the average result from the three specimens in MPa (psi).

Ultimate Elongation

Perform this test according to the methods of 'Tensile Strength' using the same specimens.

Determine ultimate elongation from initial gage length and the final amount of extension at failure. Calculate the ultimate elongation as a percent of the original gage length. Report the average result from the three specimens.

Tear Resistance

Apparatus

The following apparatus is required:

- tensile testing machine, constant-rate-of-extension (CRE) type, with automatic recorder
- testing clamps with 25 mm x 50 mm (1 in. x 2 in.) serrated jaws, and appropriate clamping power to prevent slipping or crushing
- stamping die conforming to ASTM D 624, Die C
- dial gauge or calipers to measure thickness.

Procedure

The following describes the tear resistance test.

Tear Resistance	
Step	Action
1	♦ Obtain a mold of a sheet measuring 4.5 in. x 6.5 in. with a 0.063 in. thickness. ♦ Using the weight ratios, measure out a sufficient amount of binder components to fill the mold. ♦ Thoroughly mix the components and pour into the mold. Remove entrained air using a soft flame or physical methods. ♦ Let the sheet cure at 25 ± 2 °C (77 ± 4 °F).
2	♦ Once the sheet of material has sufficiently cured, stamp the specimens for Tear Resistance test using the Die C specimen of ASTM D 624. ♦ Stamp at least four specimens. ♦ Sand the specimens to remove irregularities and provide true surfaces.
3	Continue the test after a total of seven days cure at 25 ± 2 °C (77 ± 4 °F).
4	Determine the thickness of the specimen at the point of tear with a dial gauge or caliper.
5	Use an initial test machine jaw separation of 51 mm (2 in.) and a cross-head speed of 51 mm (2 in.) per minute.
6	♦ Measure the maximum load as the specimen is tearing. ♦ Record the average of the four specimens in N/m (lb./in.).

Wet Bond Strength to Concrete

Apparatus

The following apparatus is required:

- tensile testing machine, constant-rate-of-extension (CRE) type, with automatic recorder conforming to the requirements of ASTM D 76
- briquette mold as described in ASTM C 190 (discontinued 1991)
- water bath capable of maintaining 25 °C (77 °F).

Procedure

The following describes the wet bond strength to concrete test.

Wet Bond Strength to Concrete	
Step	Action
1	For wet bond strength to concrete test, obtain mortar briquette halves prepared according to 'Preparing Mortar Briquettes' of Test Method "Tex-614-J, Testing Epoxy Materials."
2	Using the same molds used to make the briquettes, place a briquette half in the mold. Make sure the surface of the briquette is clean. NOTE: If recommended by the manufacturer, coat the side of the briquette with primer. Let the primer dry.
3	♦ Using the weight ratios, measure sufficient binder and aggregate to fill the three briquette halves. ♦ Thoroughly mix the three components. ♦ Fill the other half of the briquette molds with complete elastomeric concrete. ♦ Make at least three specimens.
4	Let the briquettes cure for 5 days in air at 25 ± 2 °C (77 ± 4 °F).
5	Immerse the specimens in 25 ± 2 °C (77 ± 4 °F) water for two days in a horizontal position.
6	Remove the specimens from the water, blot dry, and subject them to tensile loading while still damp.
7	♦ Determine the average tensile breaking stress based on a 25 mm^2 (1 $in.^2$) cross-sectional area. ♦ Record the average of the three specimens in MPa (psi).

24-hour Compressive Strength

Perform test as described in ASTM C 579.

Form three specimens and cure for 24 hours at 25 ± 2 °C (77 ± 4 °F).

Compress samples in a compression machine, and measure the maximum load.

Calculate stress from max load and report the average of the three specimens in MPa (psi).

Compressive Stress

Apparatus

The following apparatus is required:

- compression testing machine, constant-rate-of-extension (CRE) type, with automatic recorder conforming to the requirements of ASTM D 76
- molds to cast 2 in. cubes
- dial gauge or calipers.

Procedure

The following describes the compressive stress test.

Compressive Stress	
Step	Action
1	♦ Obtain molds to cast three 51 mm (2 in.) cubes. ♦ Line the inside of the molds with release grease.
2	♦ Using the weight mixing ratios, measure sufficient binder and aggregate material to fill the three cubes. ♦ Thoroughly mix the three specimens.
3	♦ Pour the mixture into the molds in two lifts and tamp the material after each lift. ♦ Screed off any excess material on top of the blocks. ♦ Cure specimen for seven days at 25 ± 2 °C (77 ± 4 °F).
4	Using a dial gauge or caliper, determine the original height of the specimen within 0.03 mm (0.001 in.) without a load.
5	Place the specimen in the compression machine, zero the dial gauge, and apply a 445 N (100 lb.) load.
6	♦ Load the specimen at a rate of 4 mm/min. (0.15 in./min.) until deflection of 2.5 mm (0.10 in.) is reached. ♦ Record load at 2.5 mm (0.10 in.).
7	♦ Calculate the compressive stress based on the original 2580 mm^2 area (4 $in.^2$). ♦ Report the average of the three specimens in MPa (psi).

Resilience

The resilience test is a continuation of the 'Compressive Stress' test.

After removal of the load, allow the specimen to recover for five minutes.

Remeasure the height, and calculate the resilience as a percentage of recovered height:

$$\text{Re}\,silience = \frac{s + f - i}{s}$$

where:

- s = max displacement of cross-head (2.5 mm or 0.1 in.)
- f = final height of cube
- i = initial height of cube

Report the average of the three specimens.

Section 4

Archived Versions

Archived versions of Test Method "Tex-618-J, Testing Elastomeric Concrete" are available through the following links:

- Click on 618-0899 for the test procedure effective August 1999 through July 2002.

Prequalified Products List for Polymeric Materials for Patching Spalls in Concrete Pavement

General

The following products have met the requirements of DMS-6170, "Polymeric Materials for Patching Spalls in Concrete Pavement."

The Department reserves the right to conduct random sampling of prequalified materials for testing and to perform random audits of test reports. Department representatives may sample material from the manufacturing plant, the project site, and the warehouse. CST/M&P reserves the right to test samples to verify compliance with DMS-6170, "Polymeric Materials for Patching Spalls in Concrete Pavement."

Prequalified Producers of Polymeric Patching Materials

Type	Product Name	Producer	Contact Information	Lab Number	Tested	Expires
Type I	Delpatch	DS Brown	Ben Jacobus North Baltimore, OH 419-257-3561	J06482725	1/18/07	12/31/07
Type I	ElastoPatch	Crafco	Vern Thompson Chandler,AZ (800) 528-8242	J07481294		12/31/07
Type II	FlexKrete 102	FlexKrete Technologies	Roy Perrin McKinney, TX 972-964-8707	J07480319	02/21/07	12/31/07
Type II	Flexpatch*	Silicone Specialists Inc. 99242	Richard Waters Ft. Worth, TX 817-731-7890	J07482018	12/19/07	12/31/08
Type II	Pavesaver	DS Brown	Ben Jacobus 300 E. Cherry St. North Baltimore, Ohio 45872 419-257-1600	J06482660	12/20/06	12/31/07

*Materials should arrive prepackaged with a two component binder and aggregate.

Insert MSDS and Product Data Sheets here for the candidate systems for your future projects

Guidelines for Repair Procedures

The following guidelines are provided to summarize good practices associated with successful repair techniques. Since many of the requirements are specific for certain material types, it is important to determine exactly what is required by the manufacture before the final product is selected. In some cases, because of time or seasonal temperature constraints, particular requirements for a given product might preclude its use in the spall repair project under consideration.

Preparation for spall repairs are typically begun by cleaning all contaminants and unsound concrete from the spalled area. Depending on the type of contaminant this may even require some chipping with a light jack hammer or bush-milling. Many materials also require that the edges be well defined and of a minimum depth to avoid feathered edges that often ravel. For materials with this requirement the spalled edges are typically sawed 1/4 in. to ½ in. deep before sandblasting. Other materials, like epoxy or vinyl-ester systems may not require any special edge preparation and may only need the area to be sandblasted or dry air blasted. Other common concerns to keep in mind are listed below.

- Clean Rebar (If required) - When the depth of the spall is such that rebar is exposed, repair material manufacturers may recommend or require that the rebar be cleaned (sandblasted, shotblasted or wire brushed) down to clean white-metal condition. This is particularly true for hydraulic cement repair materials, such as Rapid Set, Euco Speed, Pavemend, and MGKrete..

- Prime Surface (If required by manufacturer) - Some of the materials depend upon a little extra effort to ensure proper wet out or bond advantages to the substrate. The manufacturers of these materials require that a primer be applied to the cleaned spall before it is filled with their repair material. If this little extra step insures minimal maintenance on the repairs in the coming years it is well worth the effort.

  Priming is required by:
  - Fibrescreed
  - Delpatch
  - FlexKrete
  - Wabo ElastoPatch
  - Flexpatch – Only if repair is less than 1" deep.

help control the working and curing times. Some epoxy systems are custom batched at the factory to accommodate a specific ambient temperature range.

This type of repair material is called polymer concrete, which simply means aggregates glued together with polymers, or plastics. Polymer concrete is very durable, water tight, and wear resistant. It bonds very well to dry aggregates and dry concrete—but this is important—usually the aggregate and concrete need to be dry. Some epoxies and polyurethanes are different in that they can work with wet surfaces and possibly even damp aggregate.

Polymer concrete can be made very flexible, so that they have the ability to stretch without breaking (think of chewing gum). This makes them better for repairs than a very brittle material which cracks easily. Most of the polymer concretes considered for repairing pavement spalls are very ductile, but still hard enough to wear well. Generally speaking, the more resin-rich repair matrix gives more elastomeric properties, and filling the matrix with more clean, dry sand or clean, dry coarse aggregate makes it more rigid. It is important to note that polymers cost a lot more than portland cement, but their ability to bond and stay in the repair without cracking may make them very cost effective. When making a repair, it is a good thing to not have to return for re-repairs any time soon. So, initial material costs in a labor intensive job may not be nearly as important for repairs as for new construction.

Polymer concrete brand names:
FlexKrete – Vinyl Ester
FlexPatch – Epoxy
Delpatch – Polyurethane
Wabo ElastoPatch – Polyurethane
RSP - Polyurethane

- **Modified Bitumen**

This binder system, basically an asphalt upgraded with polymers, requires special equipment to heat the bitumen, similar to making hot mix. That renders it a material available for large contracted jobs. It does not have the strength or wear resistance of most of the other repair materials, but it has remained in the spall where it has been applied.

Fibrescreed – a hot applied synthetic polymer modified resin and bitumen compound containing mineral fillers, chopped fibers, sand and graded granite aggregate.

- **Rapid Setting HydraulicCement**

These systems are physically similar to normal portland cement concrete, grouts or mortars. They cost considerably more but they set much more quickly to accommodate early return-to-traffic times. Because they are brittle, edge sawing is typically required.

Rapid Set- Chemically, this material is 33% calcium sulfo-aluminate and 67% di-calcium silicate.

- **Magnesium phosphate**

This binder system is a special chemical that reacts with water and sets very quickly in a rigid binder system. It is mixed with aggregate very similarly to portland cement. In hot weather, it must be retarded or it will set faster than it can be placed and finished. It rapidly cures to a relatively brittle material.

- FibreScreed:
  - Material placed by contractor with proper equipment.
    - Place packaged material in machine.
    - Once material at proper temperature (375-380 degrees) apply to spall area in 2" lifts. Add ¾" bulking stone with each lift. Continue until flush with surface.
    - Apply top coat for skid resistance.

The table below is provided for quick reference regarding the type and times for each of the materials evaluated in this research project.

Material:	Initial Set Time (minutes)	Return to traffic	Type
Wabo ElastoPatch	22	1 hr	Elastomeric Polyurethane
Delpatch	60	1 hr	Elastomeric Polyurethane
RSP	6	1 hr	Elastomeric Polyurethane
Fibrescreed	**	15 min – 1 hr	Visco-Elastic Polymer-modified bitumen
FlexKrete	8	1.5 hrs	Semi-Rigid Vinyl Ester
FlexPatch	63	1 – 2 hrs	Semi-Rigid Epoxy
RapidSet	24	1 hr	Rigid Hydraulic Cement
EucoSpeed	17	1 hr	Rigid Magnesium Phosphate
Pavemend	13	1.5 hrs	Rigid Magnesium Phosphate
MG Krete	?	?	Rigid Magnesium Phosphate

** Not chemically activated, temperature controlled

Keep in mind that many products have additional additives which can speed up, and slow down working times and set times. Some companies also produce different formulations for different temperatures which effect critical times.

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