MDOT RC-1527

CONDITION ASSESSMENT AND METHODS OF ABATEMENT OF PRESTRESSED CONCRETE BOX-BEAM DETERIORATION

Phase II

FINAL REPORT
(APPENDICES)

Research

WESTERN MICHIGAN UNIVERSITY

Michigan Tech

Center for Structural Durability
A Michigan DOT Center of Excellence

CONDITION ASSESSMENT AND METHODS OF ABATEMENT OF PRESTRESSED CONCRETE BOX-BEAM DETERIORATION

Phase II

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Submitted to:

MDOT

Submitted by

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APPENDIX A: MATERIAL DATA SHEETS

Construction

Product Data Sheet
Edition 8.2003
Identification no. 539
SikaRepair SHA

SikaRepair® SHA

Fast-setting, one component, cementitious repair mortar with superior high build properties

Description	SikaRepair SHA is a fast-setting, one-component, cementitious ready to use repair mortar. The incorporation of low density aggregates allows high build applications on vertical and overhead surfaces. SikaLatex R or SikaLatex may be used instead of water for a two component, polymer-modified repair mortar.
Where to Use	▪ Fast repairs to overhead and vertical concrete and mortar surfaces on grade, above and below grade. ▪ As a repair material for building facades, parking structures, industrial plants, bridges, etc.
Advantages	▪ Minimal time required between lifts. ▪ Fast finishing time. ▪ Time/labor-saving material; application up to 3 inches on vertical surfaces in one layer. ▪ Easy to use; just add water. ▪ High bond strength ensures excellent adhesion. ▪ Good, early and ultimate strength. ▪ Increased freeze/thaw durability and resistance to deicing salts. ▪ Easy to clean. ▪ Suitable for exterior and interior applications. ▪ Not a vapor barrier.
Yield	0.55 cu. ft./bag
Packaging	Sika Repair SHA: 25 lb. bag, 60/pallet; 50 lb. (22.7 kg.) multi-wall bag. SikaLatex (R): 1 gal. plastic jug; 4/carton, 5 gal. pails.

Typical Data *(Material and curing conditions @ 73°F (23°C) and 50% R.H.)*

Shelf Life	One year in original, unopened bags.	
Storage Conditions	Store dry at 40°-95°F (4°-35°C). **Condition material to 65°-75°F before using.**	
Color	Concrete gray.	
Mixing Ratio	1 50 lb. bag SikaRepair SHA + 3/4 gal. to 1 gal. of liquid	
Density (Wet mix)	106 lbs./cu. ft. (1.70 kg./l)	
Application Time	Approximately 20-30 minutes.	
Finishing Time	30-40 minutes	
Time Between Lifts	Less than 1 hour	
Compressive Strength (ASTM C-109)		**with Latex R**
1 day	2,000 psi (13.8MPa)	2,500 psi (17.2 MPa)
7 days	3,000 psi (20.7 MPa)	3,500 psi (24.1 MPa)
28 days	4,500 psi (31.0 MPa)	5,000 psi (34.5 MPa)
Flexural Strength (ASTM C-293)		
28 days	800 psi (5.5 MPa)	1,100 psi (9.7 MPa)
Bond Strength * (ASTM C-882 modified)		
28 days	1,000 psi (6.8 MPa)	1, 800 psi (12.4 MPa)

*Mortar scrubbed into substrate

How to Use

Substrate Concrete, mortar, and masonry products.

Surface Preparation - **Concrete/Mortar:** Remove all deteriorated concrete, dirt, oil, grease, and all bond-inhibiting materials from surface. Preparation work should be done by high pressure water blast, scabbler or other appropriate mechanical means to obtain an exposed aggregate surface profile of ±1/16-in. (CSP-5). After preparation, substrate strength should be verified prior to patch placement. Substrate should be saturated surface dry (SSD) with no standing water during application.

Reinforcing Steel: Steel reinforcement should be thoroughly prepared by mechanical cleaning to remove all traces of rust. Where corrosion has occurred due to the presence of chlorides, the steel should be high pressure washed with clean water after mechanical cleaning. For priming of reinforcing steel use Sika Armatec 110 EpoCem (consult Technical Data Sheet).

Construction

Concrete Substrate: Prime the prepared substrate with a brush or sprayed applied coat of Sika Armatec 110 EpoCem (consult Technical Data Sheet). Alternately, a scrub coat of Sika Repair SHA can be applied prior to placement of the mortar. The repair mortar has to be applied into the wet scrub coat before it dries.

Mixing

With water: Pour 3/4 of one gallon of water into the mixing container. Add powder while mixing continuously. Mix mechanically with a low-speed drill (400-600 rpm) and mixing paddle or in an appropriate mortar mixer. Add more water to obtain desired consistency of the mortar. Do not exceed one gallon per bag. Mix to uniform consistency, maximum 3 minutes. Manual mixing can be tolerated only for less than a full unit. Thorough mixing and proper proportioning is necessary.

With Latex R: Pour 3/4 gallon of Sika Latex R into the mixing container. Slowly add powder and mix as above.

With diluted Latex R: Sika Latex R may be diluted up to 5:1 (water: Sika Latex R) for projects requiring minimal polymer-modification. Pour 3/4 gallon of the mixture into the mixing container. Slowly add powder and mix as above.

Note: SikaLatex R must be protected from freezing. If frozen, discard.

Application & Finish

The mixed SikaRepair SHA must be worked well into the primed substrate, filling all pores and voids. Compact well. Force material against edge of repair working towards the center. Thoroughly compact the mortar around exposed reinforcement. After filling repair, consolidate, then screed. Finish with steel, wood, plastic floats, or damp sponges, depending on the desired surface texture. Where multiple lifts are required, score top surface on each lift to produce a roughened substrate for next lift. Allow preceding lift to harden before applying fresh material. Saturate surface of the lift with clean water. If previous layers are over 48 hours old, mechanically prepare the substrate and dampen.

Curing

As per ACI recommendations for portland cement concrete, curing is required. Moist cure with wet burlap and polyethylene, a fine mist of water or a water based* compatible curing compound. Curing compounds adversely affect the adhesion of following lifts of mortar, leveling mortar or protective coatings. Moist curing should commence immediately after finishing. Protect freshly applied mortar from direct sunlight, wind, rain and frost.

*Pretesting of curing compound is recommended.

Limitations

- Application thickness: Minimum: With water: 1/4 inch (6 mm). With Latex R: 1/8" (3 mm). Maximum in one lift: 3 inches (75 mm) vertical, 1.5 inches (38 mm) overhead.
- Minimum ambient and surface temperatures 45°F (7°C) and rising at time of application.
- Do not use solvent based curing compounds. As with all cement based materials, avoid contact with aluminum to prevent adverse chemical reaction and possible product failure. Insulate potential areas of contact by coating aluminum bars, rails, posts etc. with an appropriate epoxy such as Sikadur Hi-Mod 32.

Caution

Irritant

Suspect carcinogen - Contains portland cement and sand (crystalline silica). Skin and eye irritant. Avoid contact. Dust may cause respiratory tract irritation. Avoid breathing dust. Use only with adequate ventilation. May cause delayed lung injury (silicosis). IARC lists crystalline silica as having sufficient evidence of carcinogenicity in laboratory animals and limited evidence of carcinogenicity in humans. NTP also lists crystalline silica as a suspect carcinogen. Use of safety goggles and chemical resistant gloves is recommended. If PELs are exceeded, an appropriate NIOSH approved respirator is required. Remove contaminated clothing.

First Aid

In case of skin contact, wash thoroughly with soap and water. For eye contact, flush immediately with plenty of water for at least 15 minutes, and contact a physician. For respiratory problems, remove person to fresh air.

Clean Up

In case of spillage, scoop or vacuum into appropriate container, and dispose of in accordance with current, applicable local, state and federal regulations. Keep container tightly closed and in an upright position to prevent spillage and leakage.

Mixed material: Uncured material can be removed with water. Cured material can only be removed mechanically.

KEEP CONTAINER TIGHTLY CLOSED — KEEP OUT OF REACH OF CHILDREN
NOT FOR INTERNAL CONSUMPTION — FOR INDUSTRIAL USE ONLY
CONSULT MATERIAL SAFETY DATA SHEET FOR MORE INFORMATION

Sika warrants this product for one year from date of installation to be free from manufacturing defects and to meet the technical properties on the current technical data sheet if used as directed within shelf life. User determines suitability of product for intended use and assumes all risks. Buyer's sole remedy shall be limited to the purchase price or replacement of product exclusive of labor or cost of labor.

NO OTHER WARRANTIES EXPRESS OR IMPLIED SHALL APPLY INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. SIKA SHALL NOT BE LIABLE UNDER ANY LEGAL THEORY FOR SPECIAL OR CONSEQUENTIAL DAMAGES.

Visit our website at www.sikausa.com **1-800-933-SIKA NATIONWIDE**

Regional Information and Sales Centers. For the location of your nearest Sika sales office, contact your regional center.

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QUALITY ISO 9001 9002 ACHIEVEMENT

Quality Certification Numbers: Lyndhurst: FM 69711 (ISO 9000), FM 70421 (QS 9000), Marion: FM 69715, Kansas City: FM 69107, Santa Fe Springs: FM 69408

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Product Data Sheet
Edition 8.2003
Identification no. 188
SikaTop 123 *Plus*

Construction

SikaTop® 123 *PLUS*

Two-component, polymer-modified, cementitious, non-sag mortar plus FerroGard 901 penetrating corrosion inhibitor

Description

SikaTop 123 *PLUS* is a two-component, polymer-modified, portland cement, fast-setting, non-sag mortar. It is a high performance repair mortar for vertical and overhead surfaces, and offers the additional benefit of FerroGard 901, a penetrating corrosion inhibitor.

Where to Use

- On grade, above, and below grade on concrete and mortar.
- On vertical and overhead surfaces.
- As a structural repair material for parking structures, industrial plants, water/waste water treatment facilities, roads, walkways, bridges, tunnels, dams, ramps, etc.
- Approved for repairs over cathodic protection systems.

Advantages

- High compressive and flexural strengths.
- High early strengths.
- Increased freeze/thaw durability and resistance to de-icing salts.
- Compatible with coefficient of thermal expansion of concrete - Passes ASTM C-884 (modified).
- Increased density - improved carbon dioxide resistance (carbonation) without adversely affecting water vapor transmission (not a vapor barrier).
- Enhanced with FerroGard 901, a penetrating corrosion inhibitor - reduces corrosion even in the adjacent concrete.
- Not flammable, non-toxic.
- Conforms to ECA/USPHS standards for surface contact with potable water.
- USDA approved.
- ANSI/NSF Standard 61 potable water approved.

Yield

0.39 cu. ft./unit.

Packaging

Component 'A' - 1 gal. plastic jug; 4/carton. **Component 'B'** - 44 lb. multi-wall bag.

Typical Data *(Material and curing conditions @ 73°F (23°C) and 50% R.H.)*

Shelf Life: One year in original, unopened packaging.

Storage Conditions: Store dry at 40°-95°F. **Condition material to 65°-75°F. before using.** Protect Component 'A' from freezing. If frozen, discard.

Color: Concrete gray when mixed.

Mixing Ratio: Plant-proportioned kit.

Application Time: Approximately 15 min. after adding Component 'B' to Component 'A'. Application time is dependent on temperature and relative humidity.

Finishing Time: 20 to 60 min after combining components: depends on temperature, relative humidity, and type of finish desired.

Density (wet Mix): 132 lbs./cu. ft. (2.2 kg./l)

Flexural Strength (ASTM C-293)	**28 days**	2,000 psi (13.8 MPa)
Splitting Tensile Strength (ASTM C-496)	**28 days**	900 psi (6.2 MPa)
Bond Strength* (ASTM C-882 modified)	**28 days**	2,200 psi (15.2 MPa)

Compressive Strength (ASTM C-109)

1 day	3,500 psi	(24.1 MPa)
7 days	6,000 psi	(41.4 MPa)
28 days	7,000 psi	(48.3 MPa)

Permeability (AASHTO T-277)
28 days Approximately 500 Coulombs. Electrical resistivity (ohm-cm) 27,000

Freeze/Thaw Resistance (ASTM C-666) 300 cycles 98%

Corrosion Testing for FerroGard 901

Cracked Beam Corrosion Tests:
Reduced corrosion rates 63% versus control specimens. ASTM G109 modified after 400 days

* Mortar scrubbed into substrate.

Substrate: Concrete, mortar, and masonry products.

Construction

How to Use

Surface Preparation **Concrete/Mortar:** Remove all deteriorated concrete, dirt, oil, grease, and all bond-inhibiting materials from surface. Be sure repair area is not less than 1/8 inch in depth. Preparation work should be done by high pressure water blast, scabbler, or other appropriate mechanical means to obtain an exposed aggregate surface with a minimum surface profile of ±1/16 in. (CSP-5) Saturate surface with clean water. Substrate should be saturated surface dry (SSD) with no standing water during application.
Reinforcing Steel: Steel reinforcement should be thoroughly prepared by mechanical cleaning to remove all traces of rust. Where corrosion has occurred due to the presence of chlorides, the steel should be high-pressure washed with clean water after mechanical cleaning. For priming of reinforcing steel use Sika Armatec 110 EpoCem (consult Technical Data Sheet).

Priming **Concrete Substrate:** Prime the prepared substrate with a brush or sprayed applied coat of Sika Armatec 110 EpoCem (consult Technical Data Sheet). Alternately, a scrub coat of Sika Top 123 can be applied prior to placement of the mortar. The repair mortar has to be applied into the wet scrub coat before it dries.

Mixing Pour Component 'A' into mixing container. Add Component 'B' while mixing continuously. Mix mechanically with a low-speed drill (400 - 600 rpm) and mixing paddle or mortar mixer. Mix to a uniform consistency, maximum 3 minutes. Manual mixing can be tolerated only for less than a full unit. Thorough mixing and proper proportioning of the two components is necessary.

Application & Finish SikaTop 123 *PLUS* **must be scrubbed** into the substrate, filling all pores and voids. Force material against edge of repair, working toward center. After filling repair, consolidate, then screed. Material may be applied in multiple lifts. The thickness of each lift, not to be less than 1/8 inch minimum or more than 1.5 inches maximum. Where multiple lifts are required score top surface of each lift to produce a roughened surface for next lift. Allow preceding lift to reach final set, 30 minutes minimum, before applying fresh material. Saturate surface of the lift with clean water. Scrub fresh mortar into preceding lift. Allow mortar or concrete to set to desired stiffness, then finish with wood or sponge float for a smooth surface.

Curing As per ACI recommendations for portland cement concrete, curing is required. Moist cure with wet burlap and polyethylene, a fine mist of water or a water based*, compatible curing compound. Curing compounds adversely affect the adhesion of following lifts of mortar, leveling mortar or protective coatings. Moist curing should commence immediately after finishing. If necessary protect newly applied material from direct sunlight, wind, rain and frost.
*Pretesting of curing compound is recommended.

Limitations
- **Application thickness:** Minimum 1/8 inch (3 mm). Maximum in one lift - 1.5 in. (38 mm).
- Minimum ambient and surface temperatures 45°F (7°C) and rising at time of application.
- Do not use solvent-based curing compound.
- Size, shape and depth of repair must be carefully considered and consistent with practices recommended by ACI. For additional information, contact Technical Service.
- For additional information on substrate preparation, refer to ICRI Guideline No. 03732 Coatings, and Polymer Overlays".
- If aggressive means of substrate preparation is employed, substrate strength should be tested in accordance with ACI 503 Appendix A prior to the repair application.
- As with all cement based materials, avoid contact with aluminum to prevent adverse chemical reaction and possible product failure. Insulate potential areas of contact by coating aluminum bars, rails, posts etc. with an appropriate epoxy such as Sikadur Hi-Mod 32.

Caution **Component 'A' - Irritant** - May cause skin/eye/respiratory irritation. Avoid breathing vapors. Use with adequate ventilation. Avoid skin and eye contact. Safety goggles and rubber gloves are recommended.
Component 'B' - Irritant; suspect carcinogen - Contains portland cement and sand (crystalline silica). Skin and eye irritant. Avoid contact. Dust may cause respiratory tract irritation. Avoid breathing dust. Use only with adequate ventilation. May cause delayed lung injury (silicosis). IARC lists crystalline silica as having sufficient evidence of carcinogenicity in laboratory animals and limited evidence of carcinogenicity in humans. NTP also lists crystalline silica as a suspect carcinogen. Use of safety goggles and chemical resistant gloves is recommended. If PELs are exceeded, an appropriate, NIOSH approved respirator is required. Remove contaminated clothing.

First Aid In case of skin contact, wash thoroughly with soap and water. For eye contact, flush immediately with plenty of water for at least 15 minutes, and contact a physician. For respiratory problems, remove person to fresh air.

Clean Up In case of spillage, scoop or vacuum into appropriate container, and dispose of in accordance with current, applicable local, state and federal regulations. Keep container tightly closed and in an upright position to prevent spillage and leakage.
Mixed components: Uncured material can be removed with water. Cured material can only be removed mechanically.

KEEP CONTAINER TIGHTLY CLOSED — KEEP OUT OF REACH OF CHILDREN
NOT FOR INTERNAL CONSUMPTION — FOR INDUSTRIAL USE ONLY
CONSULT MATERIAL SAFETY DATA SHEET FOR MORE INFORMATION

Sika warrants this product for one year from date of installation to be free from manufacturing defects and to meet the technical properties on the current technical data sheet if used as directed within shelf life. User determines suitability of product for intended use and assumes all risks. Buyer's sole remedy shall be limited to the purchase price or replacement of product exclusive of labor or cost of labor.

NO OTHER WARRANTIES EXPRESS OR IMPLIED SHALL APPLY INCLUDING ANY WARRANTY OF MERCHANTABILITY OR FITNESS FOR A PARTICULAR PURPOSE. SIKA SHALL NOT BE LIABLE UNDER ANY LEGAL THEORY FOR SPECIAL OR CONSEQUENTIAL DAMAGES.

Visit our website at www.sikausa.com **1-800-933-SIKA NATIONWIDE**

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QUALITY ISO 9001 9002 ACHIEVEMENT

[redacted]

CONSPEC
BY DAYTON SUPERIOR

Conpatch VO

Vertical and overhead repair mortar

PRODUCT DESCRIPTION

Conspec Conpatch V/O is a single component, cement based, polymer modified patching and render repair mortar developed for vertical and overhead, thin to thick surface applications. Conpatch V/O's unique rapid setting, shrinkage compensating formulation offers excellent durability and ease of application without the use of forms. If required the material may be mixed with Corrosion Inhibitor admixture using proven calcium nitrite technology.

USE

Conpatch V/O is specifically formulated to repair vertical and overhead concrete. Surfaces subjected to severe freeze-thaw and de-icing salts such as bridge columns, parking structures columns, spandrels beams, concrete ceilings, tunnels, pipes, pilings and any other vertical or overhead application where excellent durability and strength is required.

BENEFITS

- ◊ Standard product is one-component; just add water
- ◊ Can be used as a two-component repair mortar with approved admixture
- ◊ Excellent resistance to freeze-thaw and de-icing salts
- ◊ Available with proven calcium nitrite corrosion technology
- ◊ Designed for Vertical and Overhead Patching
- ◊ Interior and exterior applications
- ◊ Can be extended for deep patches
- ◊ Rapid set and strength gain for multi-lift and structural repairs
- ◊ Is shrinkage compensated, helping to assure a tight contact with surrounding substrate
- ◊ High bond strength
- ◊ Thermal expansion similar to concrete for long term durability
- ◊ For overhead, vertical and horizontal applications
- ◊ Can be pumped and sprayed through small volume pneumatic equipment

PROPERTIES, TEST DATA

Initial Set 30 minutes
Final Set 60 minutes

Compressive Strength (ASTM C - 109)

24 hours	>4500 psi	(31 MPa)
7 days	>7000 psi	>(48 MPa)
28 days	>8000 psi	>(55 MPa)

Flexural Strength (ASTM C -78)

1 Day	850 psi
7 Day	1,000 psi
28 day	1,200 psi

Splitting Tensile Strength (ASTM C-496)

1 Day	240 psi
7 Day	540 psi
28 Day	650 psi

Direct Tensile Strength (CRD C164)

1 Day	170 psi
7 Day	200 psi
28 Day	240 psi

Modulus of Elasticity (ASTM C469)

28 Days 3.9x106

Bond Strength (ACI 503R Direct Tensile)

1 Day	200 psi
7 Day	245 psi
28 Day	300 psi

Coefficient of Thermal Expansion (CRD C-39 modified)

4.4x10-6

Freeze Thaw Resistance (ASTM C666, Procedure A)

300 cycles >96%

Scaling Resistance (ASTM C672)

50 cycles 0 Rating

Rapid Chloride Permeability (ASTM C1202)

28 Days 430 Coulombs

APPLICATION

Surface Preparation

The concrete must be sound and free of all foreign material, including oil, grease, dust, laitance, or other surface contaminants. We recommend surface prep per ICRI Guideline 03730. Saw cut the perimeter of the repair to a maximum depth of 1/2" (1.3 cm). Best results will be obtained by abrasive blasting the area to be repaired, providing uniform depth, a high surface profile and a firm bonding area. All surfaces to be repaired should be in a saturated-surface-dry (SSD) condition with no standing water on the surface.

Mixing

Ratios:

Standard Mix: Add 6.25 - 6.75 pints (2.94-3.19 L) of clean potable water per 50 lb. (22.7 kg) bag or 20-24 oz. (0.59-.70 L) per 10 lbs. (4.5 kg) of Conpatch V/O material.

Acrylic Admix: Add 6.5-6.75 pints (3.08-3.19 L) of Strong Bond diluted 1:1 with clean potable water per 50 lb. (22.7 kg) bag.

Corrosion Inhibitor: 6.5-6.75 pints (3.08-3.19 L) of Special Bond CI neat per 50 lb. (22.7 kg) bag.

Mixing: Mix with a low speed drill or, for larger projects, a mortar mixer. Add recommended amount of clean water or Special Bond CI into the container followed by the Conpatch V/O. Mix 2 to 3 minutes. Mix only what can be applied within the setting period. Work time is approximately 15-25 minutes.

Scrub-coat: Using freshly mixed Conpatch V/O, scrub a thin layer into the SSD substrate with a stiff fiber brush and place the Conpatch V/O before the scrub coat dries. In certain conditions the use of an approved bonding agent, i.e. Spec Bond 100 surface applied epoxy or Special Bond CI integral mix, may be required. Contact technical services for further information.

Application Temperature Range: Ideal installation temperatures are from 50°F (10°C) to 80°F (27°C). Cooler temperatures will slow set-time and strength gain. Hot temperatures will accelerate set time.

Placement

Place the Conpatch V/O by trowel or hand before the scrub coat dries. On patching applications, trowel the Conpatch V/O onto the surface to a minimum thickness of 1/4" (0.6 cm) and a maximum neat thickness of 2". Additional lifts can be placed up to 6 inches and between each lift, the substrate must be left roughened or scarified. Prior to each lift, the surface must be in a SSD condition and a scrub coat applied immediately prior to the next lift being applied.

Curing

Conpatch V/O is self-curing under most conditions. Thin applications will require actions for curing. To assure maximum durability under severe drying conditions (high wind and temperature, low humidity), moist cure or use approved ASTM C-309 Conspec water based curing compound.

Clean Up

Use water when material is wet. Hardened material requires abrasive methods.

WASTE DISPOSAL

Dispose of waste material and empty packaging in accordance with all Federal, State and Local requirements. Refer to the product's MSDS for further information.

ESTIMATED YIELD

0.37 ft^3 (0.01 m^3)

PACKAGING

ITEM #	Package	Weight	
		lb.	kg
300437	Bags	50	22.7

STORAGE

Shelf life of unopened bags, when stored ina dry facility, is 12 months. Excessive temperature differential and/or high humidity can shorten the shelf life expectacy. Store in a cool, dry area free of direct sunlight.

LIMITATIONS

When using less than one bag always dry mix the full bag. Supported patches deeper than 2" (5 cm) may require reinforcement or anchorage. Applications for unsupported repairs exceeding 1" (2.54 cm) in thickness may require anchorage and should be designed in accordance with the provisions of SEI/ASCE 7-02, Section 9.6.1.6. Please consult the engineer of record for special requirements that may be required. DO NOT place at unprotected temperatures below 40°F(5°C) or if the temperature is expected to drop below 40°F(5°C) in the next twenty-four hour period. In hot weather, follow ACI Committee 305 recommended procedures. Do not apply over smooth hard trowelled surfaces without roughening.

PRECAUTIONS

Contains Portland cement and sand. Cement will cause irritation. Avoid contact. Use of a dust respirator, safety goggles and rubber gloves is recommended. Avoid prolonged contact with eyes, immediately flush with water for at least 15 minutes. Get prompt medical attention. DO NOT wear contact lenses when working with this product. DO NOT take internally. Keep out of reach of children. Avoid hazards by following all precautions found in the Material Safety Data Sheet (MSDS), product labels and technical literature. Please read this information prior to using the product.

MANUFACTURER

Conspec a brand of Dayton Superior Corporation
4226 Kansas Avenue
Kansas City, KS 66106
Customer Service: 877-416-3439
Technical Service: 877-416-3439
Website: www.daytonsuperiorchemical.com

WARRANTY

Dayton Superior Corporation ("Dayton") warrants for 12 months from the date of manufacture or for the duration of the published product shelf life, whichever is less, that at the time of shipment by Dayton, the product is free of manufacturing defects and conforms to Dayton's product properties in force on the date of acceptance by Dayton of the order. Dayton shall only be liable under this warranty if the product has been applied, used, and stored in accordance with Dayton's instructions, especially surface preparation and installation, in force on the date of acceptance by Dayton of the order. The purchaser must examine the product when received and promptly notify Dayton in writing of any non-conformity before the product is used and no later than 30 days after such non-conformity is first discovered. If Dayton, in its sole discretion, determines that the product breached the above warranty, it will, in its sole discretion, replace the non-conforming product, refund the purchase price or issue a credit in the amount of the purchase price. This is the sole and exclusive remedy for breach of this warranty. Only a Dayton officer is authorized to modify this warranty. The information in this data sheet supersedes all other sales information received by the customer during the sales process. THE FOREGOING WARRANTY SHALL BE EXCLUSIVE AND IN LIEU OF ANY OTHER WARRANTIES, EXPRESS OR IMPLIED, INCLUDING WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE, AND ALL OTHER WARRANTIES OTHERWISE ARISING BY OPERATION OF LAW, COURSE OF DEALING, CUSTOM, TRADE OR OTHERWISE.

LIMITATION OF LIABILITY

Dayton shall not be liable in contract or in tort (including, without limitation, negligence, strict liability or otherwise) for loss of sales, revenues or profits; cost of capital or funds; business interruption or cost of downtime, loss of use, damage to or loss of use of other property (real or personal); failure to realize expected savings; frustration of economic or business expectations; claims by third parties (other than for bodily injury), or economic losses of any kind; or for any special, incidental, indirect, consequential, punitive or exemplary damages arising in any way out of the performance of, or failure to perform, its obligations under any contract for sale of product, even if Dayton could foresee or has been advised of the possibility of such damages. The Parties expressly agree that these limitations on damages are allocations of risk constituting, in part, the consideration for this contract, and also that such limitations shall survive the determination of any court of competent jurisdiction that any remedy provided in these terms or available at law fails of its essential purpose.

BASF
The Chemical Company

PRODUCT DATA

3 03 01 20 **Concrete Rehabilitation**

HB2 REPAIR MORTAR

Polymer-modified high-build repair mortar

Description

HB2 Repair Mortar is a two-component polymer-modified high-build, lightweight repair mortar. It is designed for repairing vertical and overhead concrete surfaces in deep lifts—up to 3" on vertical and 1-1/2" on overhead surfaces. It can be applied by hand, trowel, or low-velocity wet spraying.

Features	Benefits
• Lightweight	Fast, easy overhead repairs
• Shrinkage compensated	Minimizes shrinkage and stresses on the bond line
• Polymer modified	Enhanced adhesion
• Low permeability	Provides protection against carbon dioxide and chloride intrusion
• Excellent freeze/thaw resistance	Durable repairs in cold temperatures
• Coefficient of thermal expansion similar to concrete	Reduces failures caused by thermal movement

Yield

No. 1 Kit:
0.50 ft³ (0.015 m³ per 45 lb bag)

No. 2 Kit:
2.50 ft³ (0.076 m³ per 225 lb bag)

Packaging

No. 1 Kit
45 lbs (20.4 kg) powder
1 gallon (3.8 L) liquid

No. 2 Kit
225 lbs (102 kg) powder
5 gallon (18.9 L) liquid

Shelf Life

1 year when properly stored

Storage

Store and transport in unopened containers at 60 to 80° F (16 to 27° C) in clean, dry conditions. Do not allow the liquid component to freeze.

Where to Use

APPLICATION

- Structural concrete repairs
- Applications that require high levels of resistance to chlorides and carbon-dioxide
- Parking garages
- Columns and beams
- High-rise buildings

LOCATION

- Vertical and overhead surfaces
- Interior or exterior

SUBSTRATE

- Concrete

How to Apply

Concrete

1. Concrete substrate must be structurally sound. Loose or unsound concrete should be removed.
2. Saw cut the edges of the repair locations to a depth of at least 3/8" (10 mm) to avoid feather-edging and to provide a square edge. Break out the complete repair area to a minimum depth of 3/8" (10 mm) up to the sawn edge.
3. Clean the surface by removing any dust, unsound or contaminated material, oil, paint, greases, and corrosion deposits.
4. Where breaking out is not required, roughen the surface and remove any laitance by mechanical means or high-pressure water wash. Remove oil and grease deposits by steam cleaning, detergent scrubbing, or degreasing.
5. To ensure optimum repair results, assess the effectiveness of decontamination by a pull-off test.

Protection and Repair

Technical Data

Composition

HB2 Repair Mortar is a proprietary blend of cement, graded aggregate, shrinkage-compensating agents, additives, and latex.

Test Data

The following results were obtained with a liquid / powder ratio of 3.7 quarts per 45 lb (3.5 L per 20.5 kg) bag.

PROPERTY	RESULTS	TEST METHODS
Fresh wet density, lb/ft³ (kg/m³)	105 (1,682)	ASTM C 138
Working time, min, at 72° F (22° C), 50% relative humidity	45	
Set time, hrs, at 72° F (22° C), 50% relative humidity		ASTM C 191
Initial	3	
Final	4	
Compressive strength, psi (MPa), 2" (51 mm) cubes		ASTM C 109
1 day	2,300 (15.9)	
7 days	4,500 (31.0)	
28 days	5,800 (40.0)	
Compressive strength, psi (MPa), 3 by 6" (76 by 152 mm) cylinders, at 28 days	5,000 (34.5)	ASTM C 39
Flexural strength, psi (MPa) at 28 days	1,000 (6.9)	ASTM C 348
Slant sheer bond strength, psi (MPa)		ASTM C 882, modified[1]
7 days	2,100 (14.5)	
28 days	2,700 (18.6)	
Splitting tensile strength, psi (MPa)		ASTM C 496
7 days	300 (2.1)	
28 days	590 (4.1)	
Elastic modulus, psi (GPa)	2.0×10^6 (13.8)	ASTM C 469
Coefficient of thermal expansion[2] 1" (25 mm) prisms, in/in/° F (cm/cm/° C)	4.5×10^{-6} (8.1×10^{-6})	CRD C 39
Drying shrinkage, μstrain, at 28 days	350	ASTM C 157
Freeze/thaw resistance, % RDM[3], at 300 cycles	100	ASTM C 666
Rapid chloride permeability, coulombs	941 (very low)	ASTM C 1202

All application and performance values are typical for the material, but may vary with test methods, conditions, and configurations.

[1]No bonding agent scrubbed into prepared surface.

[2]Portland cement concrete, typical range is 4.0 – 8.0 x 10^{-6} in/in/° F (7.2 – 14.4 x 10-6 cm/cm/° C), according to American Concrete Institute.

[3]Relative dynamic modulus

REINFORCING STEEL

1. Remove all oxidation and scale from the exposed reinforcing steel in accordance with ICRI Technical Guideline No. 03730 "Guide for Surface Preparation for the Repair of Deteriorated Concrete Resulting from Reinforcing Steel Corrosion."

2. For additional protection from future corrosion, coat the prepared reinforcing steel with Zincrich Rebar Primer or install Corr-Stops® CM.

Mixing

1. Ensure that HB2 Repair Mortar is thoroughly mixed; a forced action mixer is essential. Do not use free-fall mixers.

2. For the occasional 1 bag mix, using a suitably sized container and an appropriate paddle and variable-speed (400 – 500 rpm) heavy-duty drill is acceptable. Do not mix partial bags. Always mix the material in a clean container.

3. For normal applications, place 3 quarts (2.8 L) of MBT® Polymer Liquid into the clean mixer for each complete 45 lb (20.5 kg) bag of HB2 Repair Mortar. The powder should always be added to the liquid.

4. Mix 3 – 5 minutes until fully homogeneous. Avoid overmixing.

5. Depending on the ambient temperature and the desired consistency, additional MBT® Polymer Liquid may be added, but the maximum liquid content should not exceed 1 gallon (3.8 L) per 45 lb (20.5 kg) bag of HB2 Repair Mortar.

Application

1. Substrate should be saturated surface-dry (SSD) with no standing water.

2. Using a stiff brush, scrub a thin coat of the mixed material thoroughly into the surface to ensure sufficient bonding.

3. Before bond coat dries, thoroughly compact the mortar onto the substrate and around the exposed reinforcement.

4. HB2 Repair Mortar can be applied in single lifts up to 3" (76 mm) in thickness on vertical surfaces and up to 1-1/2" (38 mm) in thickness on overhead surfaces (without the use of form work).

5. Depending on the actual configuration of the repair area and the volume of exposed reinforcing steel, applications can be made in either single or multiple lifts. If multiple lifts are used, lightly rake the surface after initial set and before applying subsequent lifts.

6. If the material sags during application, completely remove HB2 Repair Mortar. Properly reprime the substrate and reapply the mortar at a reduced thickness.

7. Finish HB2 Repair Mortar by striking off with a straight edge and close with a steel trowel. Wooden or plastic floats or sponges may also be used to achieve the desired surface texture. Do not overwork the completed surface.

Curing

1. Proper curing is extremely important. For peak performance of the repair, cure immediately after finishing in accordance with good concrete practices (refer to ACI 308).

2. An ASTM C 309-compliant curing compound may be used in place of moist curing. Apply the curing compound when the surface cannot be marred by the application process.

Clean Up

Remove HB2 Repair Mortar from tools, equipment, and mixers with clean water immediately after use. Cured material can only be removed mechanically. Clean hands and skin immediately with soap and water or industrial hand cleaner.

For Best Performance

- Do not mix partial bags.
- Exposure to heavy rainfall before the final set may result in surface scour.
- In cold conditions down to 40° F (4° C), maintain MBT® Polymer Liquid at 80° F (26° C) to accelerate strength development. Adopt normal precautions for working with cementitious materials in the winter. Do not apply if the temperature is expected to fall below 40° F (4° C) within 24 hours of application. For cold-weather applications, consider using HBA Repair Mortar (see Form No. 1018991).
- At ambient temperatures above 80° F (26° C), store the materials in the shade. Cool MBT® Polymer Liquid to 60° F (16° C) before using.
- Make certain the most current versions of product data sheet and MSDS are being used; call Customer Service (1-800-433-9517) to verify the most current version.
- Proper application is the responsibility of the user. Field visits by BASF personnel are for the purpose of making technical recommendations only and not for supervising or providing quality control on the jobsite.

Health and Safety

HB2 REPAIR MORTAR

Caution

HB2 Repair Mortar contains crystalline silica, and Portland cement.

Risks

Product is alkaline on contact with water and may cause injury to skin or eyes. Ingestion or inhalation of dust may cause irritation. Contains free respirable quartz, which has been listed as a suspected human carcinogen by NTP and IARC. Repeated or prolonged overexposure to free respirable quartz may cause silicosis or other serious and delayed lung injury.

Precautions

KEEP OUT OF THE REACH OF CHILDREN. Prevent contact with skin and eyes. Prevent inhalation of dust. DO NOT take internally. Use only with adequate ventilation. Use impervious gloves, eye protection and if the TLV is exceeded or used in a poorly ventilated area, use NIOSH/MSHA approved respiratory protection in accordance with applicable federal, state and local regulations.

First Aid

In case of eye contact, flush thoroughly with water for at least 15 minutes. SEEK IMMEDIATE MEDICAL ATTENTION. In case of skin contact, wash affected areas with soap and water. If irritation persists, SEEK MEDICAL ATTENTION. Remove and wash contaminated clothing. If inhalation causes physical discomfort, remove to fresh air. If discomfort persists or any breathing difficulty occurs or if swallowed, SEEK IMMEDIATE MEDICAL ATTENTION.

Refer to Material Safety Data Sheet (MSDS) for further information.

Proposition 65

This product contains material listed by the state of California as known to cause cancer, birth defects, or other reproductive harm.

VOC Content

0 lbs/gal or 0 g/L

**For medical emergencies only,
call ChemTrec (1-800-424-9300).**

BASF Building Systems

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Customer Service 800-433-9517
Technical Service 800-243-6739

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BASF
The Chemical Company

PRODUCT DATA

3 03 01 00 **Maintenance of Concrete**

SET® 45 AND SET® 45 HW

Chemical-action repair mortar

Description

Set® 45 is a one-component magnesium phosphate-based patching and repair mortar. This concrete repair and anchoring material sets in approximately 15 minutes and takes rubber-tire traffic in 45 minutes. It comes in two formulations: Set® 45 Regular for ambient temperatures below 85° F (29° C) and Set® 45 Hot Weather for ambient temperatures ranging from 85 to 100° F (29 to 38° C).

Yield

A 50 lb (22.7 kg) bag of mixed with the required amount of water produces a volume of approximately 0.39 ft³ (0.011 m³); 60% extension using 1/2" (13 mm) rounded, sound aggregate produces approximately 0.58 ft³ (0.016 m³).

Packaging

50 lb (22.7 kg) multi-wall bags

Color

Dries to a natural gray color

Shelf Life

1 year when properly stored

Storage

Store in unopened containers in a clean, dry area between 45 and 90° F (7 and 32° C).

Features	Benefits
• Single component	Just add water and mix
• Reaches 2,000 psi compressive strength in 1 hour	Rapidly returns repairs to service
• Wide temperature use range	From below freezing to hot weather exposures
• Superior bonding	Bonds to concrete and masonry without a bonding agent
• Very low drying shrinkage	Improved bond to surrounding concrete
• Resistant to freeze/thaw cycles and deicing chemicals	Usable in most environments
• Only air curing required	Fast, simple curing process
• Thermal expansion and contraction similar to Portland cement concrete	More permanent repairs
• Sulfate resistant	Stable where conventional mortars degrade

Where to Use

APPLICATION

- Heavy industrial repairs
- Dowel bar replacement
- Concrete pavement joint repairs
- Full-depth structural repairs
- Setting of expansion device nosings
- Bridge deck and highway overlays
- Anchoring iron or steel bridge and balcony railings
- Commercial freezer rooms
- Truck docks
- Parking decks and ramps
- Airport runway-light installations

LOCATION

- Horizontal and formed vertical or overhead surfaces
- Indoor and outdoor applications

How to Apply

Surface Preparation

1. A sound substrate is essential for good repairs. Flush the area with clean water to remove all dust.
2. Any surface carbonation in the repair area will inhibit chemical bonding. Apply a pH indicator to the prepared surface to test for carbonation.
3. Air blast with oil-free compressed air to remove all water before placing Set® 45.

Technical Data

Composition

Set® 45 is a magnesium-phosphate patching and repair mortar.

Test Data

PROPERTY	RESULTS	TEST METHODS
Typical Compressive Strengths*, psi (MPa)		ASTM C 109, modified

	Plain Concrete 72° F (22° C)	Set® 45 Regular 72° F (22° C)	Set® 45 Regular 36° F (2° C)	Set® 45 HW 95° F (35° C)
1 hour	—	2,000 (13.8)	—	—
3 hour	—	5,000 (34.5)	—	3,000 (20.7)
6 hour	—	5,000 (34.5)	1,200 (8.3)	5,000 (34.5)
1 day	500 (3.5)	6,000 (41.4)	5,000 (34.5)	6,000 (41.4)
3 day	1,900 (13.1)	7,000 (48.3)	7,000 (48.3)	7,000 (48.3)
28 day	4,000 (27.6)	8,500 (58.6)	8,500 (58.6)	8,500 (55.2)

NOTE: Only Set® 45 Regular formula, tested at 72° F (22° C), obtains 2,000 psi (13.8 MPa) compressive strength in 1 hour.

Modulus of Elasticity, psi (MPa)	**7 days**	**28 days**	ASTM C 469
Set® 45 Regular	4.18×10^6 (2.88×10^4)	4.55×10^6 (3.14×10^4)	
Set® 45 Hot Weather	4.90×10^6 (3.38×10^4)	5.25×10^6 (3.62×10^4)	

PROPERTY	RESULTS	TEST METHODS
Freeze/thaw durability test, % RDM, 300 cycles, for Set® 45 and Set 45® HW	80	ASTM C 666, Procedure A (modified**)
Scaling resistance to deicing chemicals, Set® 45 and Set 45® HW		ASTM C 672
5 cycles	0	
25 cycles	0	
50 cycles	1.5 (slight scaling)	
Sulfate resistance		ASTM C 1012
Set® 45 length change after 52 weeks, %	0.09	
Type V cement mortar after 52 weeks, %	0.20	
Typical setting times, min, for Set® 45 at 72° F (22° C), and Set® 45 Hot Weather at 95° F (35° C)		Gilmore ASTM C 266, modified
Initial set	9 – 15	
Final set	10 – 20	
Coefficient of thermal expansion,*** both Set® 45 Regular and Set® 45 Hot Weather coefficients	7.15×10^{-6}/° F (12.8×10^{-6}/° C)	CRD-C 39
Flexural Strength, psi (MPa), 3 by 4 by 16" (75 by 100 by 406 mm) prisms, 1 day strength,		ASTM C 78, modified
Set® 45 mortar	550 (3.8)	
Set® 45 mortar with 3/8" (9 mm) pea gravel	600 (4.2)	
Set® 45 mortar with 3/8" (9 mm) crushed angular noncalcareous hard aggregate	650 (4.5)	

* All tests were performed with neat material (no aggregate)

**Method discontinues test when 300 cycles or an RDM of 60% is reached.

***Determined using 1 by 1 by 11" (25 mm by 25 mm by 279 mm) bars. Test was run with neat mixes (no aggregate). Extended mixes (with aggregate) produce lower coefficients of thermal expansion.

Test results are averages obtained under laboratory conditions. Expect reasonable variations.

Mixing

1. Set® 45 must be mixed, placed, and finished within 10 minutes in normal temperatures (72° F [22° C]). Only mix quantities that can be placed in 10 minutes or less.

2. Do not deviate from the following sequence; it is important for reducing mixing time and producing a consistent mix. Use a minimum 1/2" slow-speed drill and mixing paddle or an appropriately sized mortar mixer. Do not mix by hand.

3. Pour clean (potable) water into mixer. Water content is critical. Use a maximum of 4 pts (1.9 L) of water per 50 lb (22.7 kg) bag of Set® 45. Do not deviate from the recommended water content.

4. Add the powder to the water and mix for approximately 1 – 1-1/2 minutes.

5. Use neat material for patches from 1/2 – 2" (6 – 51 mm) in depth or width. For deeper patches, extend a 50 lb (22.7 kg) bag of Set® 45 HW by adding up to 30 lbs (13.6 kg) of properly graded, dust-free, hard, rounded aggregate or noncalcareous crushed angular aggregate, not exceeding 1/2" (6 mm) in accordance with ASTM C 33, #8. If aggregate is damp, reduce water content accordingly. Special procedures must be followed when angular aggregate is used. Contact your local BASF representative for more information. (Do not use calcareous aggregate made from soft limestone. Test aggregate for fizzing with 10% HCL).

Application

1. Immediately place the mixture onto the properly prepared substrate. Work the material firmly into the bottom and sides of the patch to ensure good bond.

2. Level the Set® 45 and screed to the elevation of the existing concrete. Minimal finishing is required. Match the existing concrete texture.

Curing

No curing is required, but protect from rain immediately after placing. Liquid-membrane curing compounds or plastic sheeting may be used to protect the early surface from precipitation, but never wet cure Set® 45.

For Best Performance

- Color variations are not indicators of abnormal product performance.
- Regular Set® 45 will not freeze at temperatures above -20° F (-29° C) when appropriate precautions are taken.
- Do not add sand, fine aggregate, or Portland cement to Set® 45.
- Do not use Set® 45 for patches less than 1/2" (13 mm) deep. For deep patches, use Set® 45 Hot Weather formula extended with aggregate, regardless of the temperature. Consult your BASF representative for further instructions.
- Do not use limestone aggregate.
- Water content is critical. Do not deviate from the recommended water content printed on the bag.
- Precondition these materials to approximately 70° F (21° C) for 24 hours before using.
- Protect repairs from direct sunlight, wind, and other conditions that could cause rapid drying of material.
- When mixing or placing Set® 45 in a closed area, provide adequate ventilation.
- Do not use Set® 45 as a precision nonshrink grout.
- Never featheredge Set® 45; for best results, always sawcut the edges of a patch.
- Prevent any moisture loss during the first 3 hours after placement. Protect Set® 45 with plastic sheeting or a curing compound in rapid-evaporation conditions.
- Do not wet cure.
- Do not place Set® 45 on a hot (90° F [32° C]), dry substrate.
- When using Set® 45 in contact with galvanized steel or aluminum, consult your local BASF sales representative.
- Make certain the most current versions of product data sheet and MSDS are being used; call Customer Service (1-800-433-9517) to verify the most current versions.
- Proper application is the responsibility of the user. Field visits by BASF personnel are for the purpose of making technical recommendations only and not for supervising or providing quality control on the jobsite.

Health and Safety

SET® 45

WARNING!

Contains silica, crystalline quartz, fly ash, magnesium oxide, phosphoric acid, monoammonium salt, iron oxide, silica, amphorous, aluminum oxide, sulfur trioxide.

Risks

Product is alkaline on contact with water and may cause injury to skin or eyes. Ingestion or inhalation of dust may cause irritation. Contains small amount of free respirable quartz which has been listed as a suspected human carcinogen by NTP and IARC. Repeated or prolonged overexposure to free respirable quartz may cause silicosis or other serious and delayed lung injury.

Precautions

Avoid contact with skin, eyes and clothing. Prevent inhalation of dust. Wash thoroughly after handling. Keep container closed when not in use. DO NOT take internally. Use only with adequate ventilation. Use impervious gloves, eye protection and if the TLV is exceeded or used in a poorly ventilated area, use NIOSH/MSHA approved respiratory protection in accordance with applicable Federal, state and local regulations.

First Aid

In case of eye contact, flush thoroughly with water for at least 15 minutes. In case of skin contact, wash affected areas with soap and water. If irritation persists, SEEK MEDICAL ATTENTION. Remove and wash contaminated clothing. If inhalation causes physical discomfort, remove to fresh air. If discomfort persists or any breathing difficulty occurs or if swallowed, SEEK IMMEDIATE MEDICAL ATTENTION.

Waste Disposal Method

This product when discarded or disposed of is not listed as a hazardous waste in federal regulations. Dispose of in a landfill in accordance with local regulations.

For additional information on personal protective equipment, first aid, and emergency procedures, refer to the product Material Safety Data Sheet (MSDS) on the job site or contact the company at the address or phone numbers given below.

Proposition 65

This product contains material listed by the State of California as known to cause cancer, birth defects or other reproductive harm.

VOC Content

0 g/L or 0 lbs/gal less water and exempt solvents.

For medical emergencies only,
call ChemTrec (1-800-424-9300).

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APPENDIX B: REPAIR MATERIAL AND SHEAR KEY GROUT VOLUME REQUIRED FOR EACH TEST

Test	Specimen Size (in)	Volume of Material for 1 Specimen (in^3)	Total Volume of Material (ft^3)	Number of Specimens	Number of Grout Materials	Total Volume of Material (in^3)	Total Volume of Material (ft^3)
Flow test		15	0.00867	1	1	15	0.00867
Air Content		10	0.00578	3	1	30	0.01734
Compressive Strength	2 x 2	8	0.004624	18	1	144	0.083232
Slant Shear Bond Strength	3 x 6	42.39	0.02450142	3	1	127.17	0.07350426
Length Change	1 x 12	12	0.006936	6	1	72	0.041616
Elastic Modulus	3 x 6	42.39	0.02450142	3	1	127.17	0.07350426
Fatigue			0				0
Freeze/thaw	3 x 4 x 16	192	0.110976	3	1	576	0.332928
Rapid Chloride Permeability	4 x 6	75.36	0.04	3	1	226.08	0.13067424
Sorptivity	4 x 6	75.36	0.04355808	2	1	150.72	0.08711616
Air Content of hardened concrete	4 x 6	75.36	0.04355808	1	1	75.36	0.04355808
Restrained Ring Test				3	1		2.1
							2.992143

APPENDIX C: COMPRESSIVE STRENGTH OF REPAIR MATERIALS AND SHEAR KEY GROUTS

Table C-1 SikaTop 123 Plus

Age	Load	Compressive Strength (psi)	Age	Load	Compressive Strength (psi)	Age	Load	Compressive Strength (psi)
1 day	13,000	3250	**7 days**	23,000	5750	**28 days**	27,900	6975
	18,500	4625		20,000	5000		27,100	6775
	6,000	1500		23,000	5750		24,500	6125
	15,500	3875		20,100	5025		26,300	6575
	13,500	3375		13,500	3375		27,200	6800
	14,000	3500		17,500	4375		26,000	6500
	AVG	**3500**		**AVG**	**5381.25**		**AVG**	**6725**
	STDEV	270.03		STDEV	425.92		STDEV	189.57
	COV	7.72		COV	7.91		COV	2.82

Table C-2 SikaRepair SHA

Age	Load	Compressive Strength (psi)	Age	Load	Compressive Strength (psi)	Age	Load	Compressive Strength (psi)
1 day	7,000	1750	**7 days**	16,500	4125	**28 day**	22,700	5675
	9,800	2450		15,750	3937.5		26,200	6550
	10,500	2625		15,000	3750		25,600	6400
	9,500	2375		13,800	3450		24,100	6025
	11,000	2750		17,200	4300		25,500	6375
	9,800	2450		17,350	4337.5		22,000	5500
	AVG	**2530**		**AVG**	**4090**		**AVG**	**6205**
	STDEV	153.50		STDEV	342.57		STDEV	427.42
	COV	6.07		COV	8.38		COV	6.89

Table C-3 Conpatch VO

Age	Load	Compressive Strength (psi)	Age	Load	Compressive Strength (psi)	Age	Load	Compressive Strength (psi)
1 day	15,500	3875	**7 days**	24,500	6125	**28 day**	41,000	10250
	20,800	5200		25,000	6250		41,000	10250
	18,900	4725		24,000	6000		42,200	10550
	16,300	4075		25,000	6250		39,500	9875
	19,900	4975		25,000	6250		37,000	9250
	20,200	5050		24,000	6000		37,500	9375
	AVG	**4805**		**AVG**	**6146**		**AVG**	**9925**
	STDEV	442.79		STDEV	122.90		STDEV	522.02
	COV	9.22		COV	2.00		COV	5.26

Table C-4 HB2 Mortar Repair

Age	Load	Compressive Strength (psi)	Age	Load	Compressive Strength (psi)	Age	Load	Compressive Strength (psi)
1 day	9,500	2375	**7 days**	18,650	4663	**28 day**	26,500	6625
	11,500	2875		19,200	4800		27,000	6750
	10,850	2713		19,900	4975		25,800	6450
	9,250	2313		18,500	4625		25,850	6463
	10,200	2550		18,000	4500		25,000	6250
	11,600	2900		20,100	5025		27,250	6813
	AVG	**2534**		**AVG**	**4766**		**AVG**	**6538**
	STDEV	263.66		STDEV	158.57		STDEV	239.14
	COV	10.40		COV	3.33		COV	3.66

Table C-5 SET 45

Age	Load	Compressive Strength (psi)	Age	Load	Compressive Strength (psi)	Age	Load	Compressive Strength (psi)
1 day	17,000	4250	**7 days**	23,000	5750	**28 days**	27,900	6975
	19,200	4800		20,000	5000		27,500	6875
	16,200	4050		23,000	5750		24,500	6125
	18,200	4550		20,100	5025		26,300	6575
	16,000	4000		13,500	3375		26,850	6712.5
	13,100	3275		17,500	4375		27,450	6862.5
	AVG	**4330**		**AVG**	**5381**		**AVG**	**6688**
	STDEV	340.22		STDEV	425.92		STDEV	381.61
	COV	7.86		COV	7.91		COV	5.71

Table C-6 Type I Cement Grout

Age	Load	Compressive Strength (psi)	Age	Load	Compressive Strength (psi)	Age	Load	Compressive Strength (psi)
1 day	11,600	2900	**7 days**	13,500	3375	**28 days**	18,250	4563
	10,300	2575		14,200	3550		18,000	4500
	10,600	2650		13,900	3475		17,850	4463
	8,600	2150		13,700	3425		18,000	4500
	9,000	2250		13,600	3400		17,900	4475
	8,500	2125		13,600	3400		17,800	4450
	AVG	**2442**		**AVG**	**3450**		**AVG**	**4500**
	STDEV	314.11		STDEV	64.71		STDEV	40.05
	COV	12.86		COV	1.88		COV	0.89

Table C-7 Masonry Cement Grout

Age	Load	Compressive Strength (psi)	Age	Load	Compressive Strength (psi)	Age	Load	Compressive Strength (psi)
1 day	11,600	2900	**7 days**	13,500	3375	**28 days**	18,250	4563
	10,300	2575		14,200	3550		18,000	4500
	10,600	2650		13,900	3475		17,850	4463
	8,600	2150		13,700	3425		18,000	4500
	9,000	2250		13,600	3400		17,900	4475
	8,500	2125		13,600	3400		17,800	4450
	Avg	**2442**		**Avg**	**3450**		**Avg**	**4500**
	SD	314.11		SD	64.71		SD	40.05
	COV	12.86		COV	1.88		COV	0.89

APPENDIX D: SLANT SHEAR BOND STRENGTH

Table D-1 SikaTop 123 Plus

Sample #	Load	Slant Shear Strength 1 day (psi)	Mode of Failure	Sample #	Load	Slant Shear Strength 7 day (psi)	Mode of Failure
1	14600	1033	shear	1	18000	1274	compressive
2	14000	991	shear	2	18800	1331	compressive
3	14000	991	compressive	3	18200	1288	shear
	AVG	1005			**AVG**	1297	
	STDEV	20.02			**STDEV**	24.06	
	COV	1.99			**COV**	1.85	

Table D-2 SikaRepair SHA

Sample #	Load	Slant Shear Strength 1 day (psi)	Mode of Failure	Sample #	Load	Slant Shear Strength 7 day (psi)	Mode of Failure
1	11900	842	shear	1	16500	1168	shear
2	13000	920	compressive	2	15900	1125	shear
3	12200	863	shear	3	17000	1203	shear
	AVG	875			**AVG**	1165	
	STDEV	32.86			**STDEV**	31.83	
	COV	3.75			**COV**	2.73	

Table D-3 Conpatch VO

Sample #	Load	Slant Shear Strength 1 day (psi)	Mode of Failure	Sample #	Load	Slant Shear Strength 7 day (psi)	Mode of Failure
1	15100	1069	compressive	1	19300	1366	shear
2	15100	1069	compressive	2	18900	1338	compressive
3	15000	1062	shear	3	19250	1362	compressive
	AVG	1066			**AVG**	1355	
	STDEV	3.34			**STDEV**	12.59	
	COV	0.31			**COV**	0.93	

Table D-4 HB2 Mortar Repair

Sample #	Load	Slant Shear Strength 1 day (psi)	Mode of Failure	Sample #	Load	Slant Shear Strength 7 day (psi)	Mode of Failure
1	4500	366	shear	1	12800	1041	compressive
2	4200	341	compressive	2	14500	1179	compressive
3	3700	301	compressive	3	15000	1220	compressive
	AVG	336			**AVG**	1146	
	STDEV	26.83			**STDEV**	76.56	
	COV	7.98			**COV**	6.68	

Table D-5 SET 45

Sample #	Load	Slant Shear Strength 7 day (psi)	Mode of Failure	Sample #	Load	Slant Shear Strength 7 day (psi)	Mode of Failure
1	19200	1561	shear	1	23200	1886	compressive
2	18000	1463	shear	2	23300	1894	shear
3	18600	1512	compressive	3	23600	1919	shear
	AVG	1512			**AVG**	1900	
	STDEV	39.83			**STDEV**	13.82	
	COV	2.63			**COV**	0.73	

Table D-6 Type I Cement Grout

Sample #	Load	Slant Shear Strength 7 day (psi)	Mode of Failure	Sample #	Load	Slant Shear Strength 7 day (psi)	Mode of Failure
1	13000	1057	compressive	1	17250	1402	compressive
2	12000	976	shear	2	17500	1423	compressive
3	13500	1098	compressive	3	17000	1382	compressive
	AVG	1043			**AVG**	1402	
	STDEV	50.70			**STDEV**	16.60	
	COV	4.86			**COV**	1.18	

Table D-7 Masonry Cement Grout

Sample #	Load	Slant Shear Strength 7 day (psi)	Mode of Failure	Sample #	Load	Slant Shear Strength 7 day (psi)	Mode of Failure
1	11000	894	compressive	1	14500	1179	shear
2	11500	935	compressive	2	13800	1122	compressive
3	11600	943	compressive	3	14000	1138	compressive
	AVG	924			**AVG**	1146	
	STDEV	21.34			**STDEV**	23.93	
	COV	2.31			**COV**	2.09	

APPENDIX E: FREE SHRINKAGE DATA FOR REPAIR MORTAR AND SHEAR KEY GROUTS

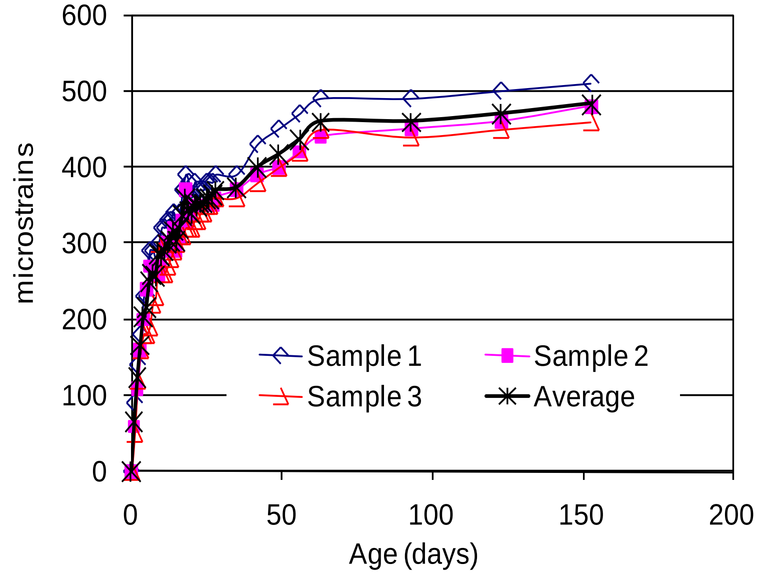


Figure E-1. Development of free shrinkage in Sika Top®123 PLUS in 100 % RH

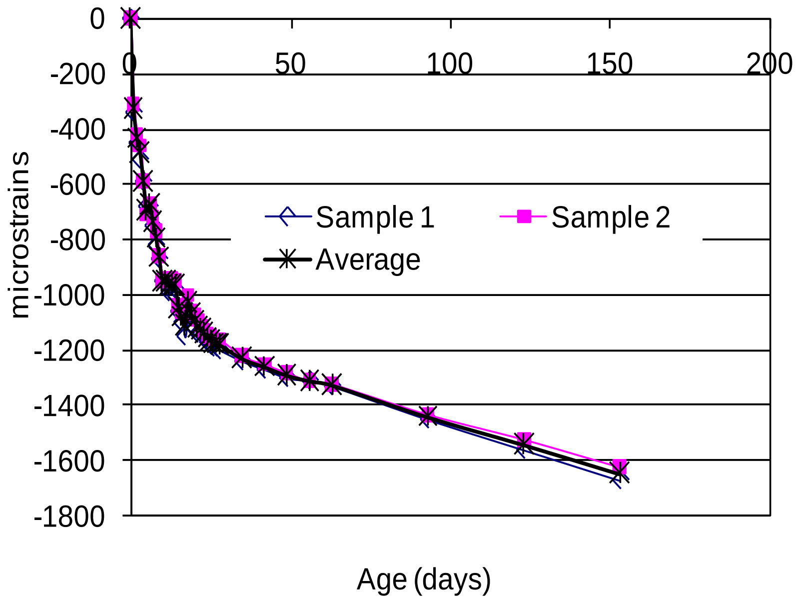


Figure E-2. Development of free shrinkage in Sika Top®123 PLUS in 50 % RH

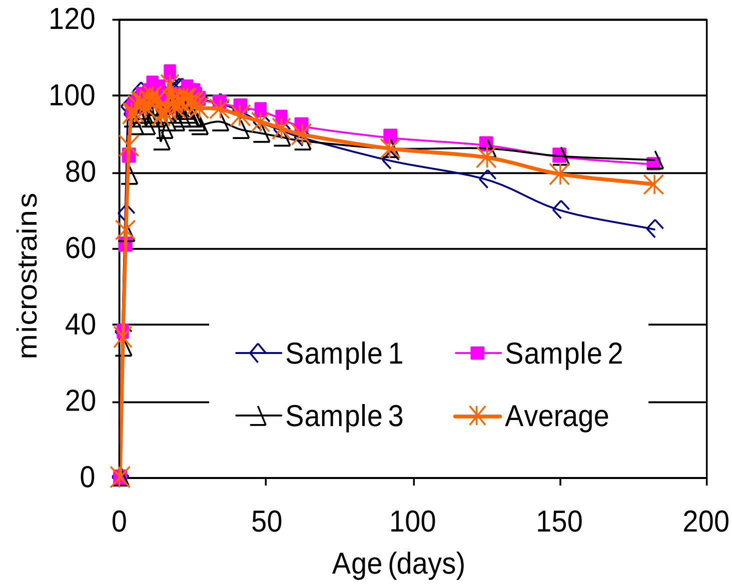


Figure E-3. Development of free shrinkage in Sika Repair ® SHA in 100 % RH

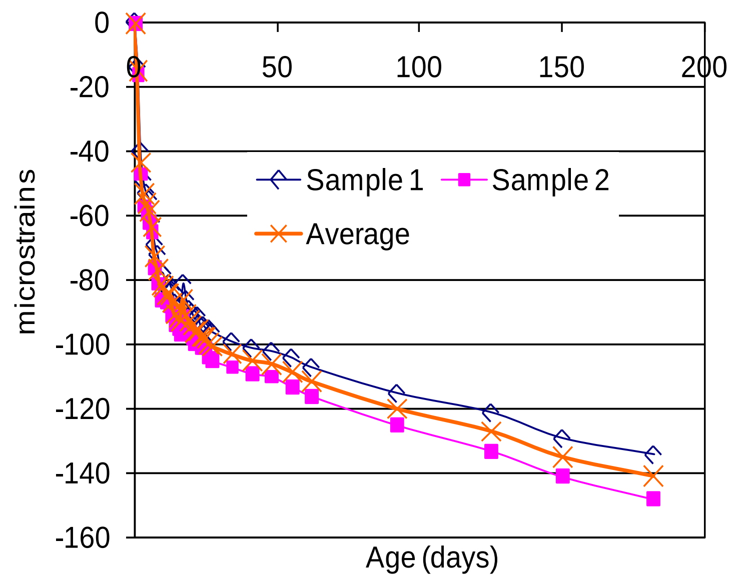


Figure E-4. Development of free shrinkage in Sika Repair ® SHA in 50 % RH

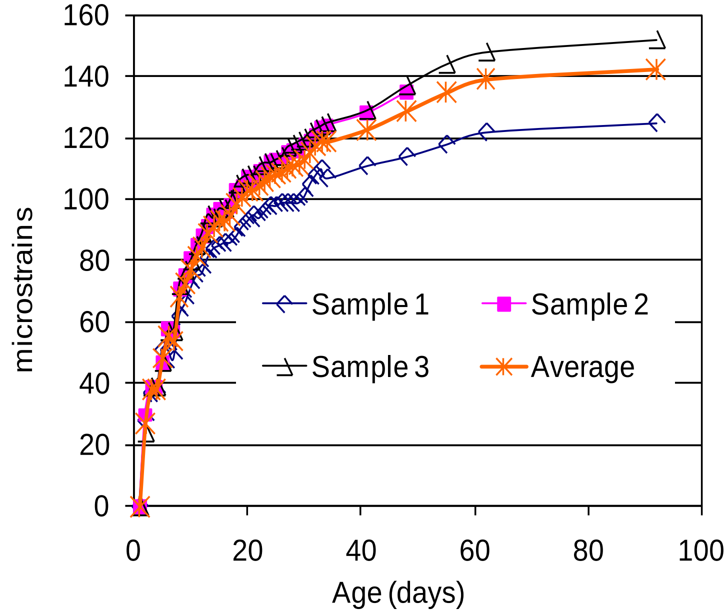


Figure E-5. Development of free shrinkage in HB2 Repair Mortar in 100 % RH

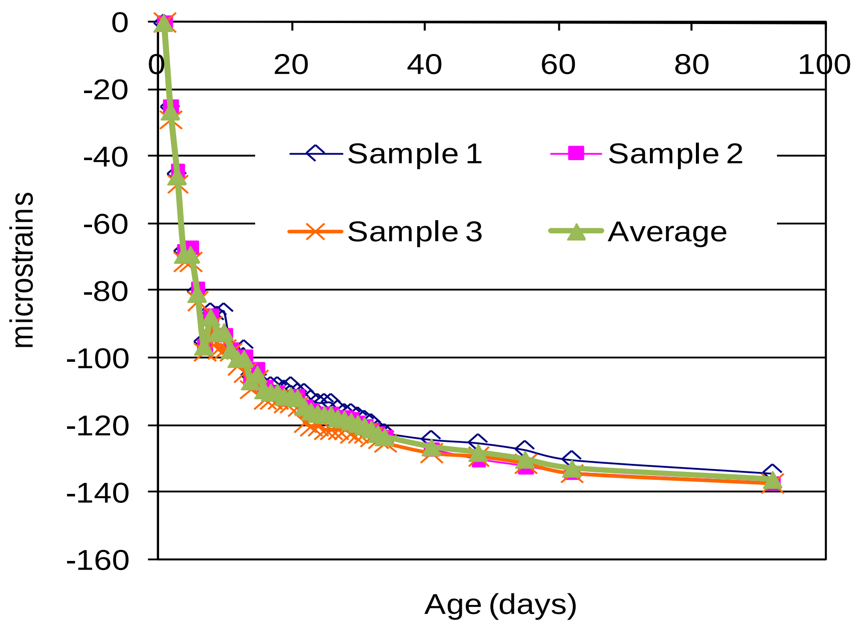


Figure E-6. Development of free shrinkage in HB2 Repair Mortar in 50 % RH

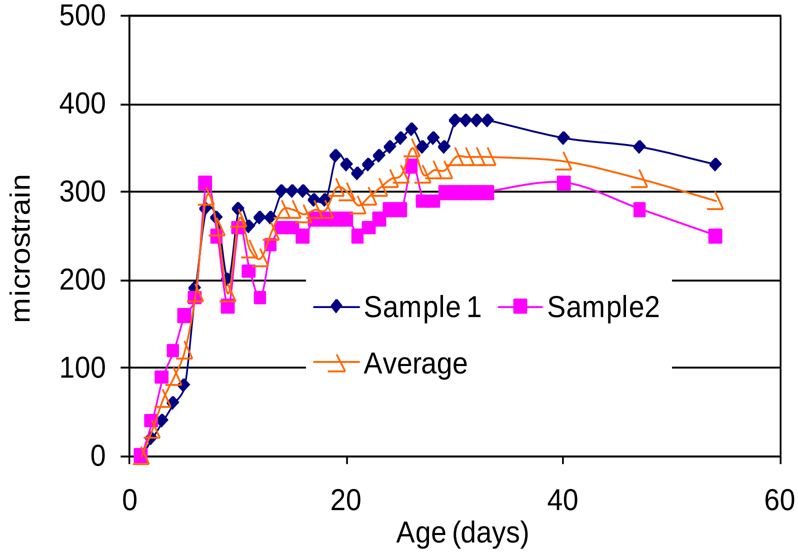


Figure E-7. Development of free shrinkage in Conpatch VO in 100 % RH

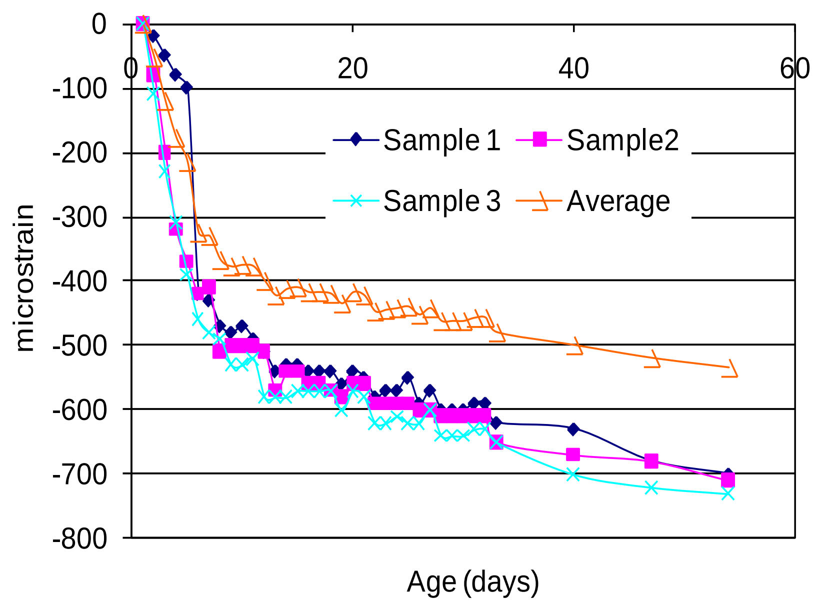


Figure E-8. Development of free shrinkage in Conpatch VO in 50 % RH

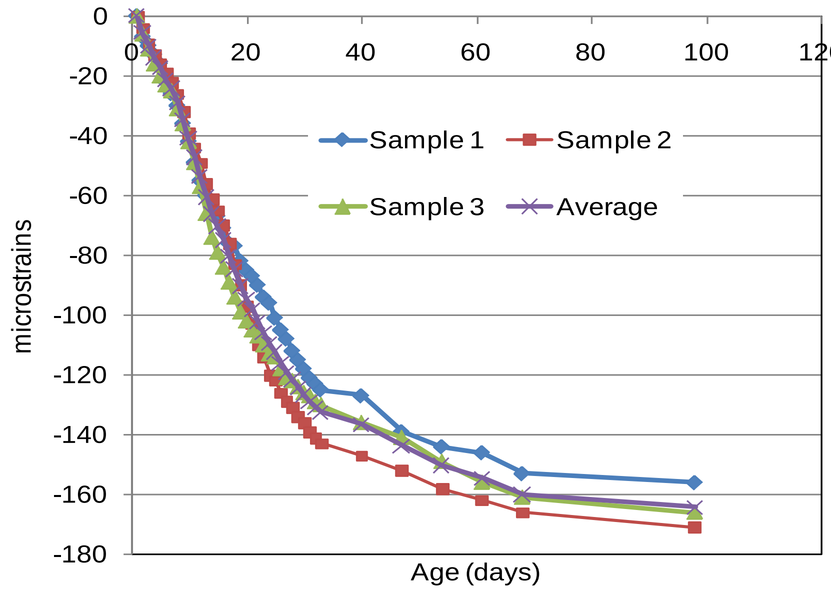


Figure E-9. Development of free shrinkage in SET 45 in 100 % RH

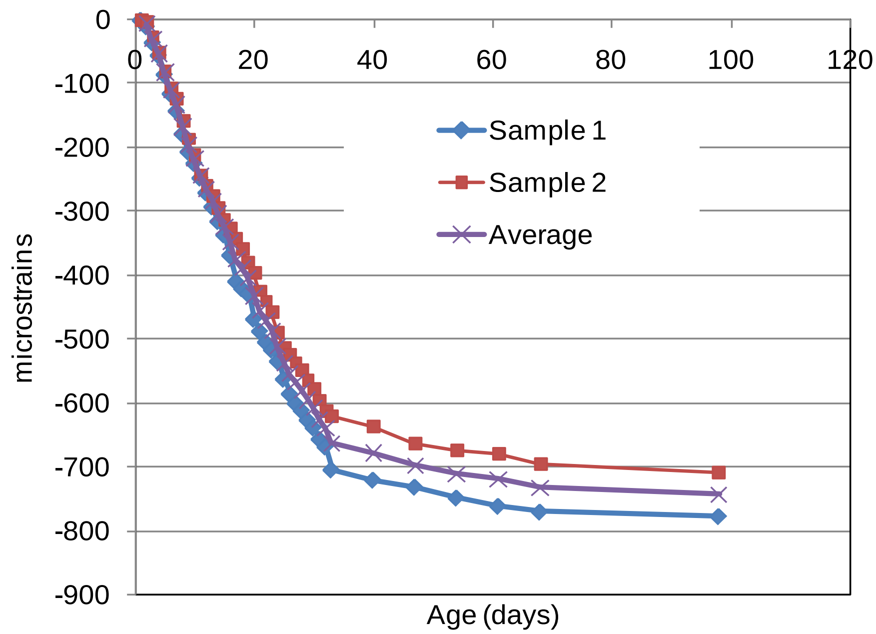


Figure E-10. Development of free shrinkage in SET 45 in 50 % RH

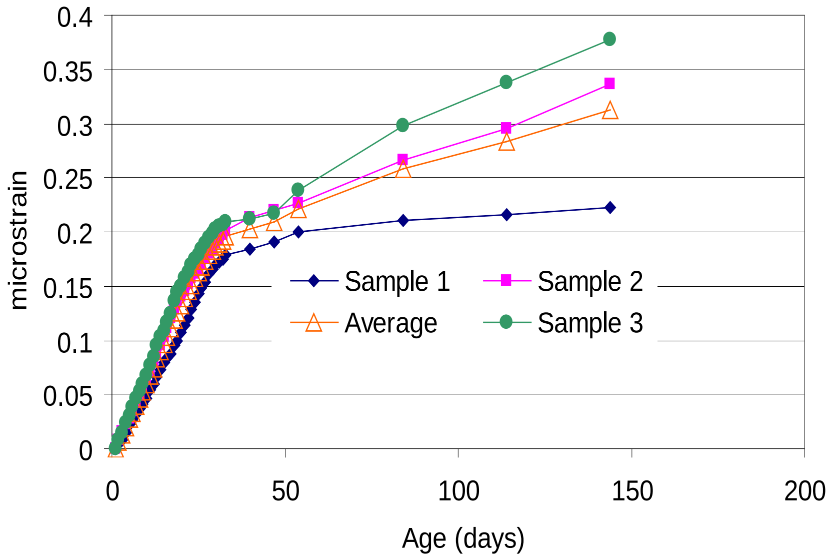


Figure E-11. Development of free shrinkage in Type I Cement Grout in 100 % RH

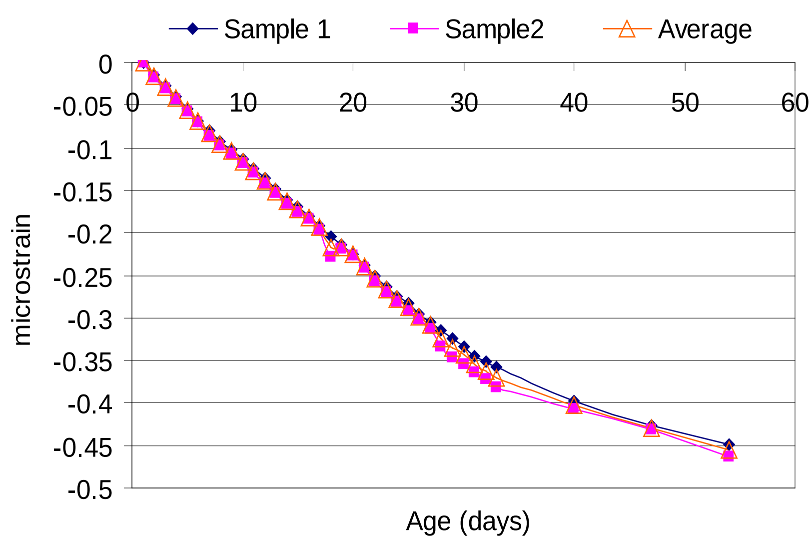


Figure E-12. Development of free shrinkage in Type I Cement Grout in 50 % RH

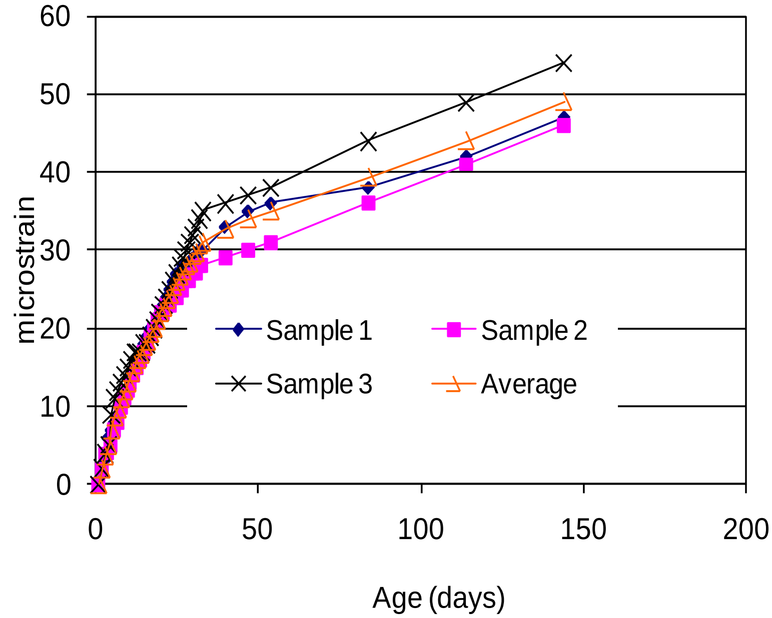


Figure E-13. Development of free shrinkage in Masonry Cement Grout in 100 % RH

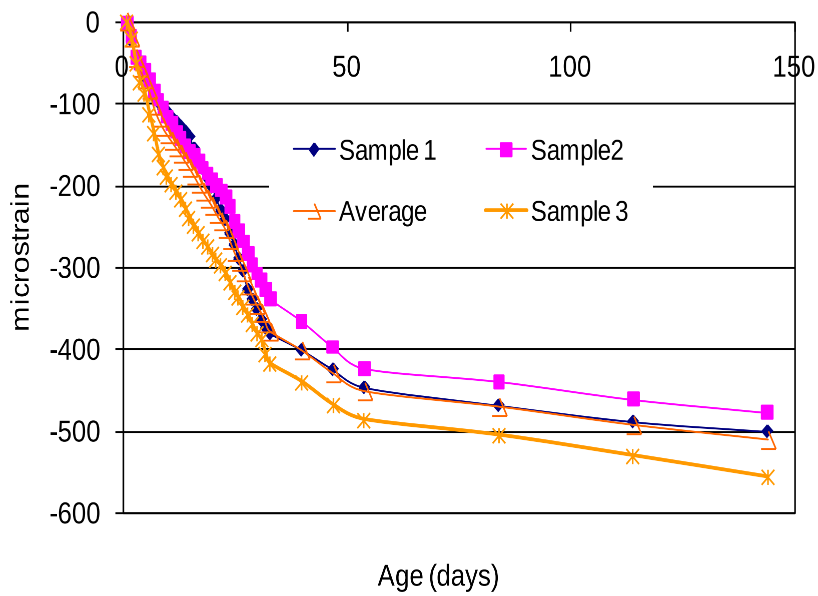


Figure E-14. Development of free shrinkage in Masonry Cement Grout in 50 % RH

APPENDIX F: RESISTANCE TO FREEZING AND THAWING

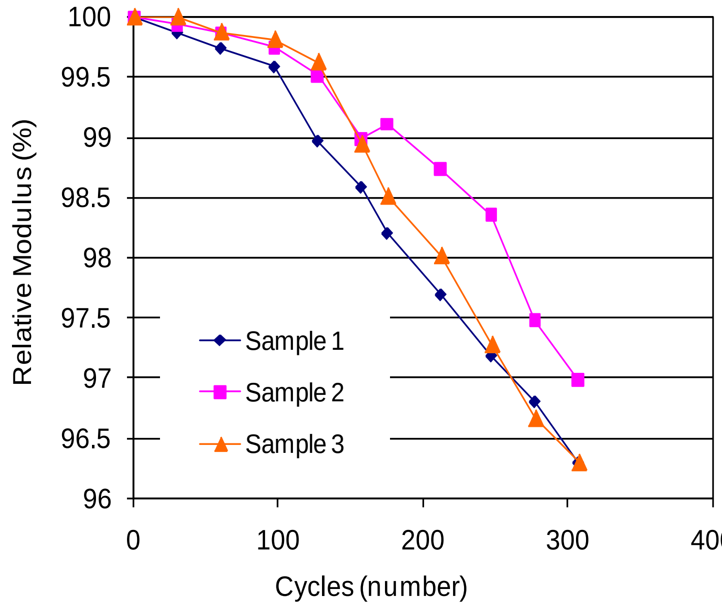


Figure F-1. Relative Dynamic Modulus of Sika Top®123 PLUS over 300 cycles

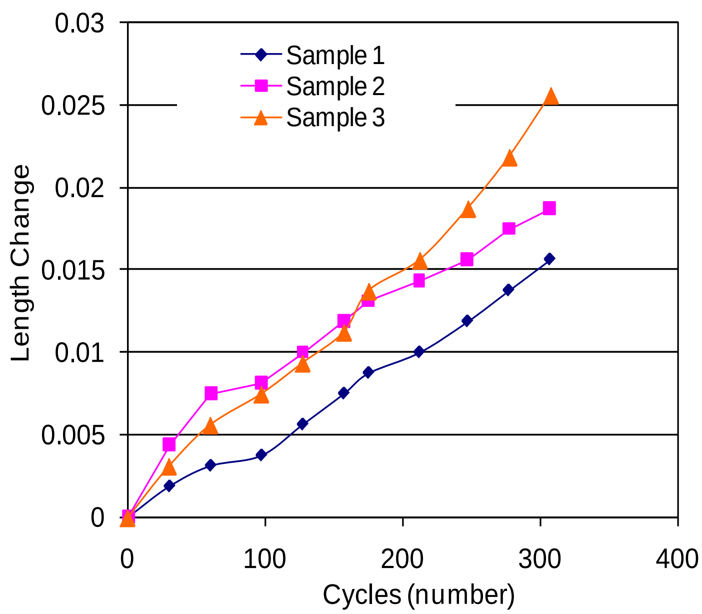


Figure F-2. Length Change in Sika Top®123 PLUS over 300 cycles

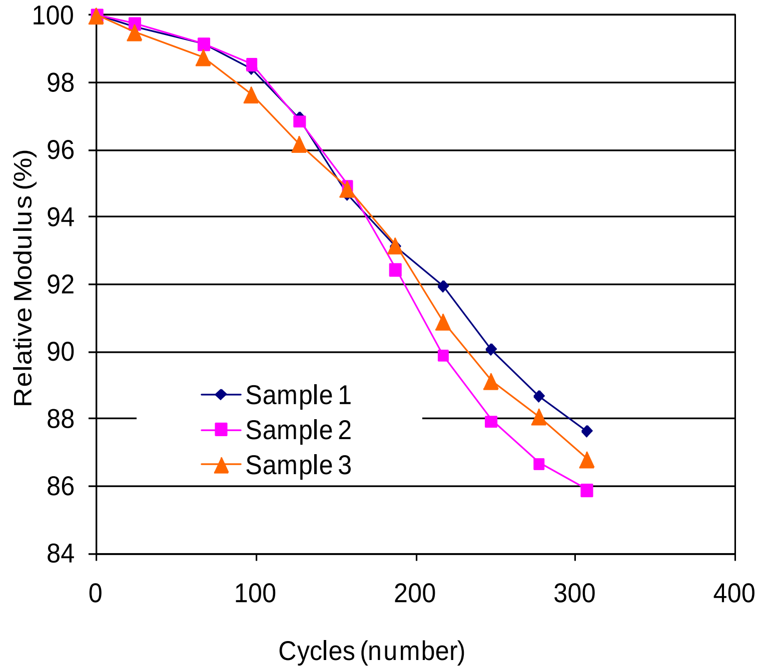


Figure F-3. Relative Dynamic Modulus of Sika Repair ® SHA over 300 cycles

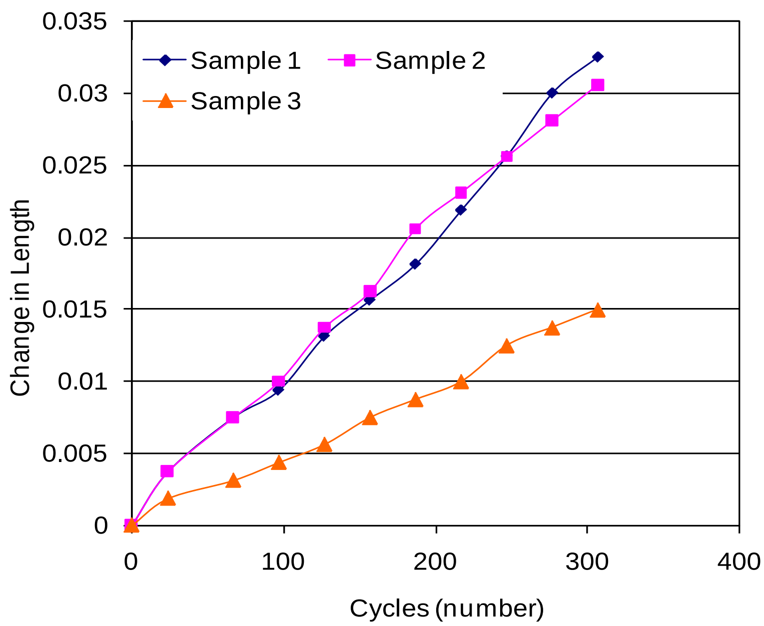


Figure F-4. Length Change in Sika Repair ® SHA over 300 cycles

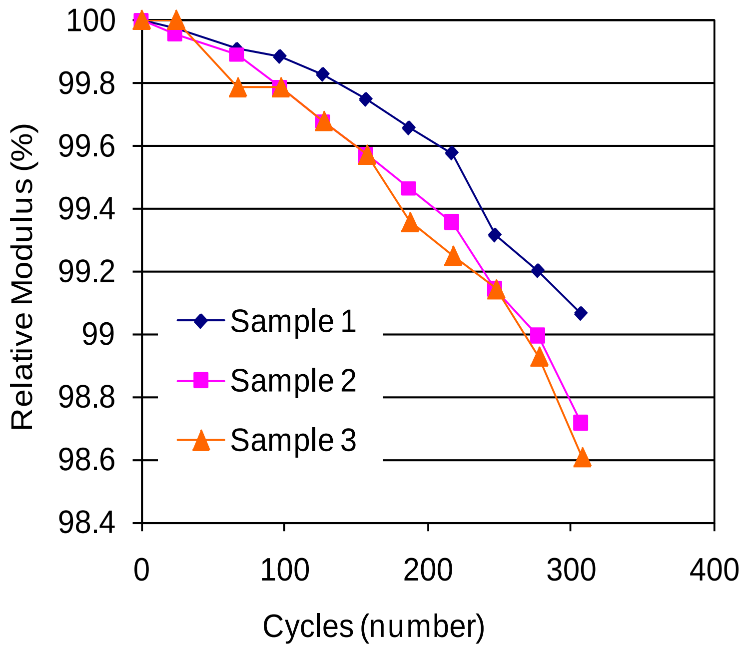


Figure F-5. Relative Dynamic Modulus of Conpatch VO over 300 Cycles

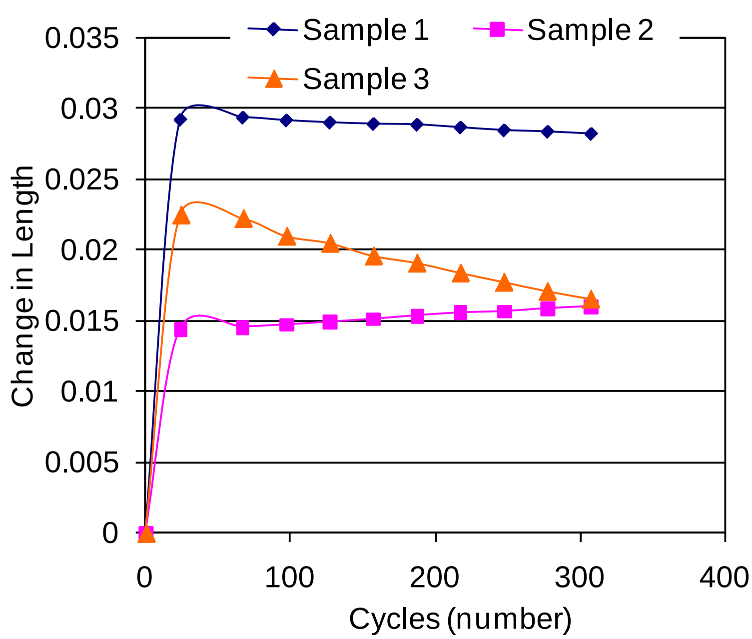


Figure F-6. Length Change in Conpatch VO over 300 cycles

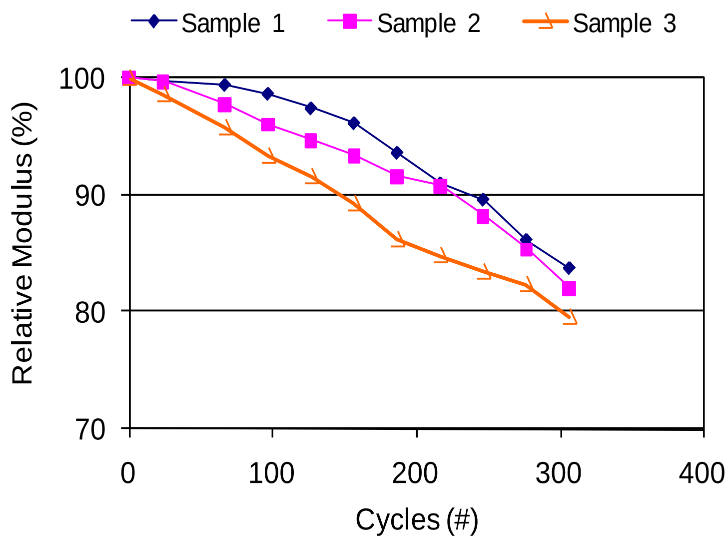


Figure F-7. Development of free shrinkage in SET 45 in 100 % RH

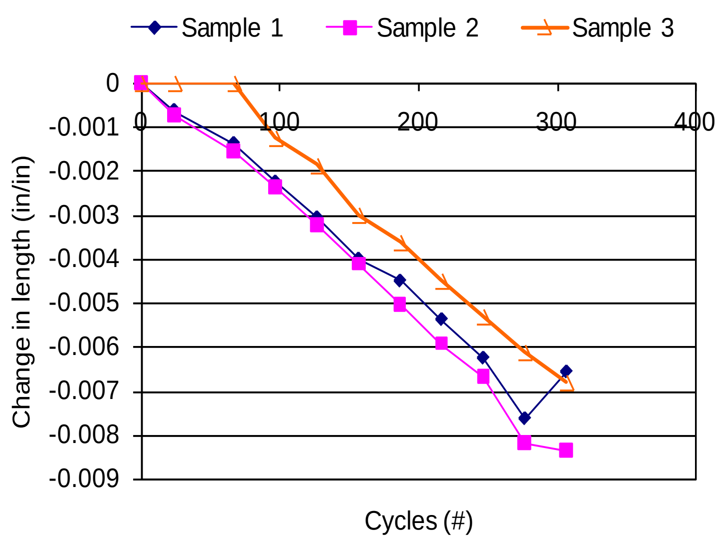


Figure F-8. Development of free shrinkage in SET 45 in 50 % RH

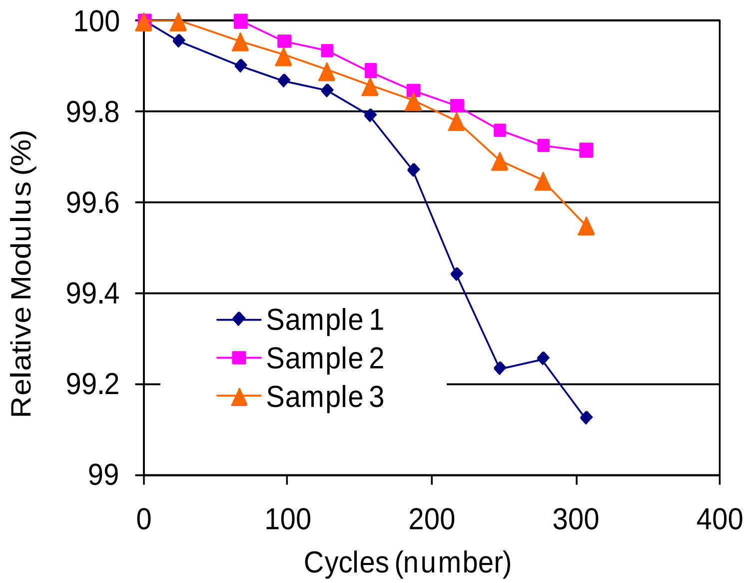


Figure F-9. Development of free shrinkage in Type I Cement Grout in 100 % RH

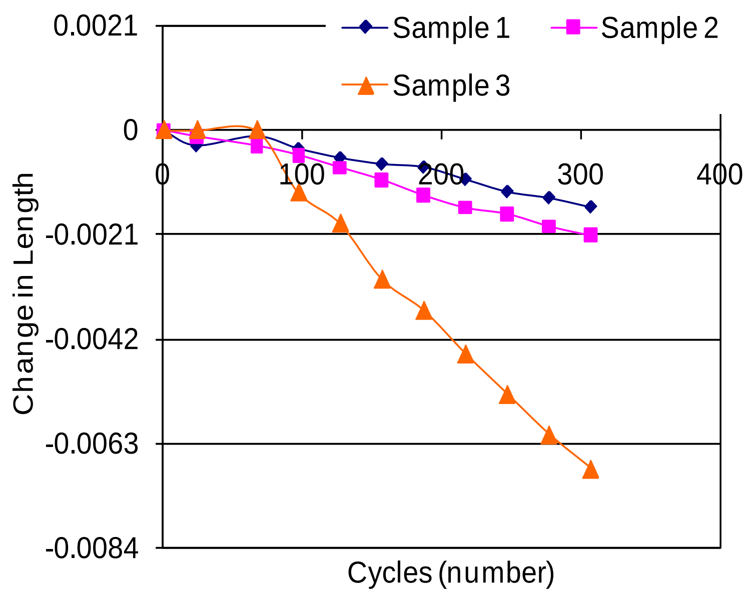


Figure F-10. Development of free shrinkage in Type I Cement Grout in 50 % RH

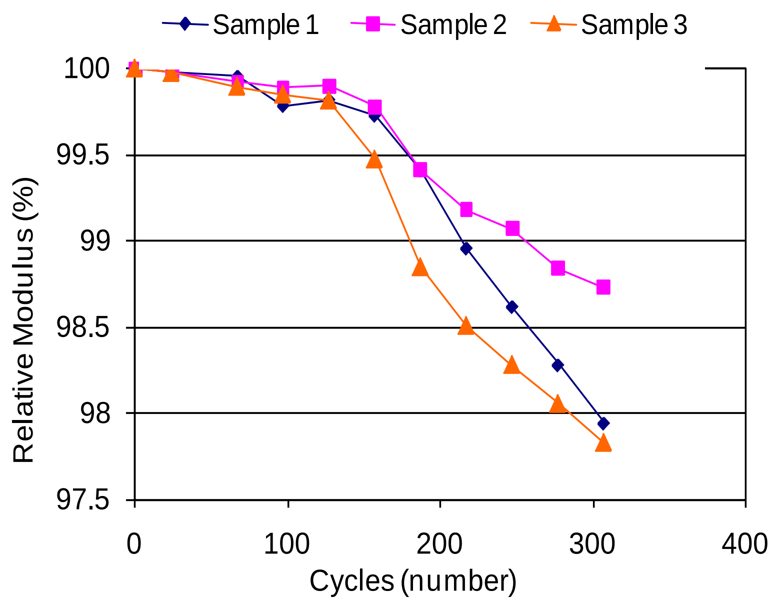


Figure F-11. Development of free shrinkage in Masonry Cement Grout in 100 % RH

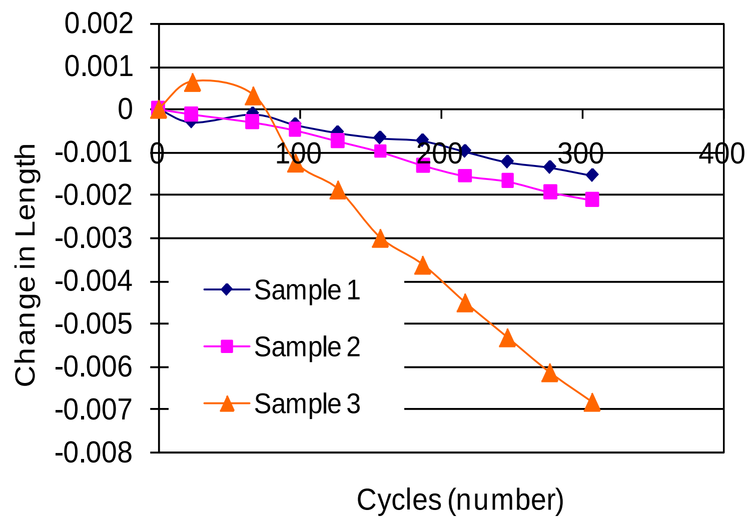


Figure F-12. Development of free shrinkage in Masonry Cement Grout in 50 % RH

Figure F-13. Photograph of Sika Top 123 PLUS at the End of 300 Cycles of Freezing and Thawing

Figure F-14. Photograph of Sika Repair SHA at the End of 300 Cycles of Freezing and Thawing

Figure F-15. Photograph of Conpatch VO at the End of 300 Cycles of Freezing and Thawing

Figure F-16. Photograph of HB2 Repair Mortar Sample Cast for F/T Testing

APPENDIX G: AIR CONTENT OF REPAIR MATERIALS AND SHEAR KEY GROUTS

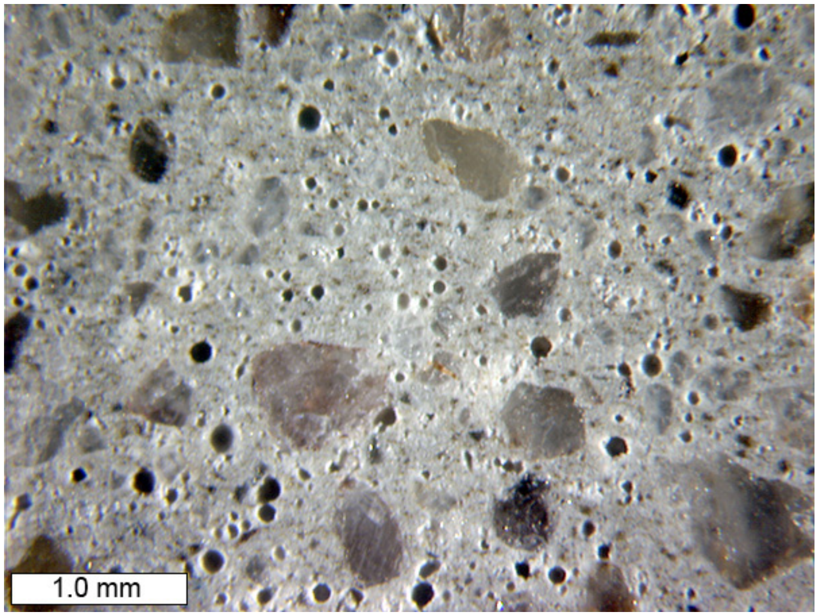


Figure G-1. Stereo Image of Sika Top 123 PLUS Mortar

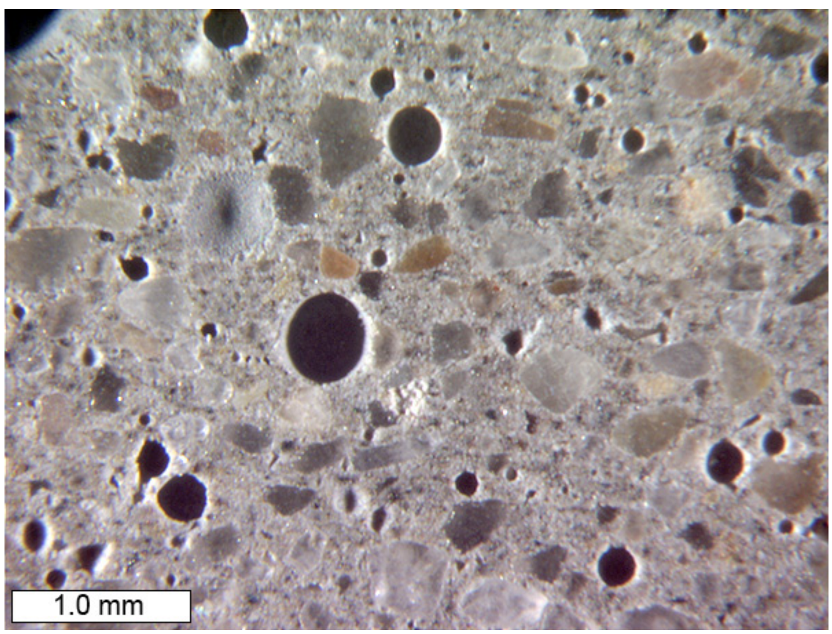


Figure G-2. Stereo Image of Sika Repair SHA Mortar

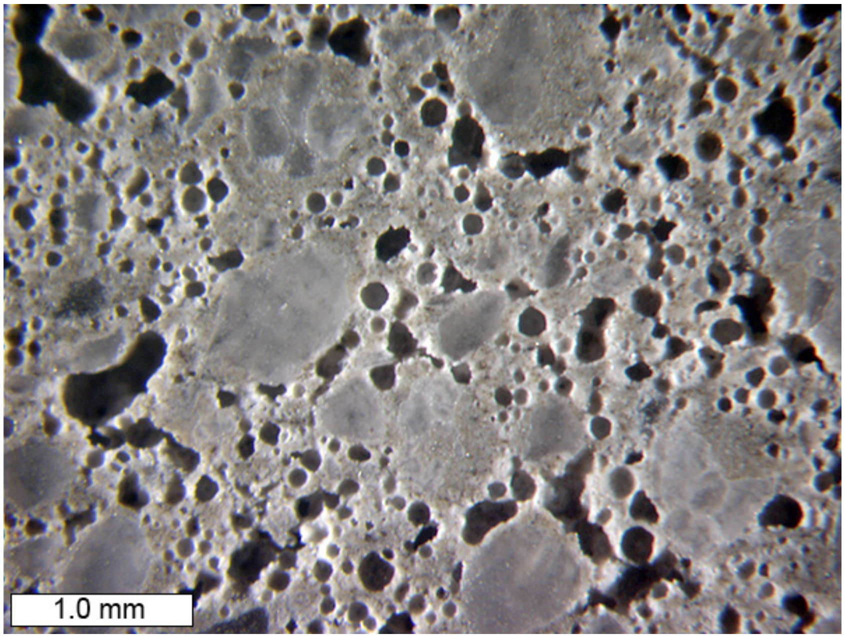


Figure G-3. Stereo Image of HB2 Repair Mortar

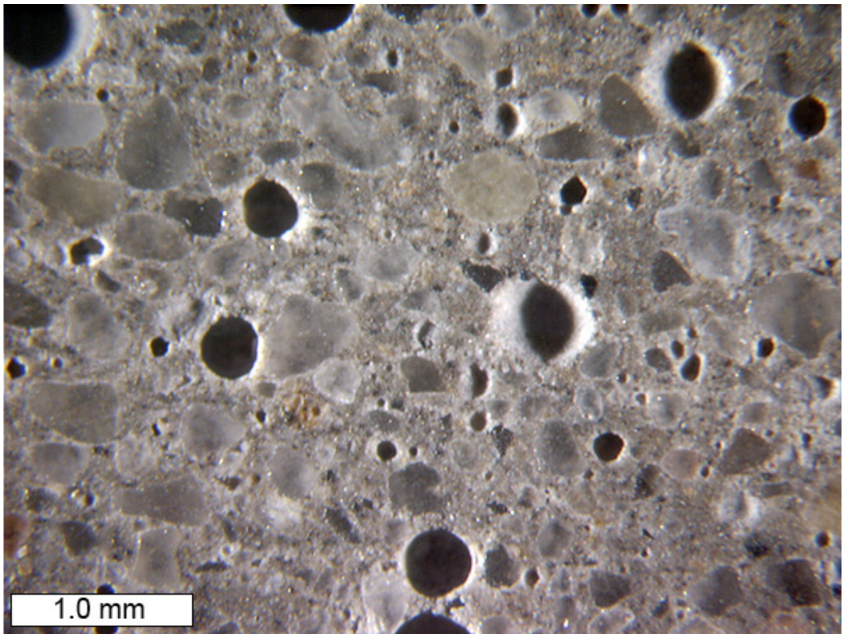


Figure G-4. Stereo Image of Conpatch VO Mortar

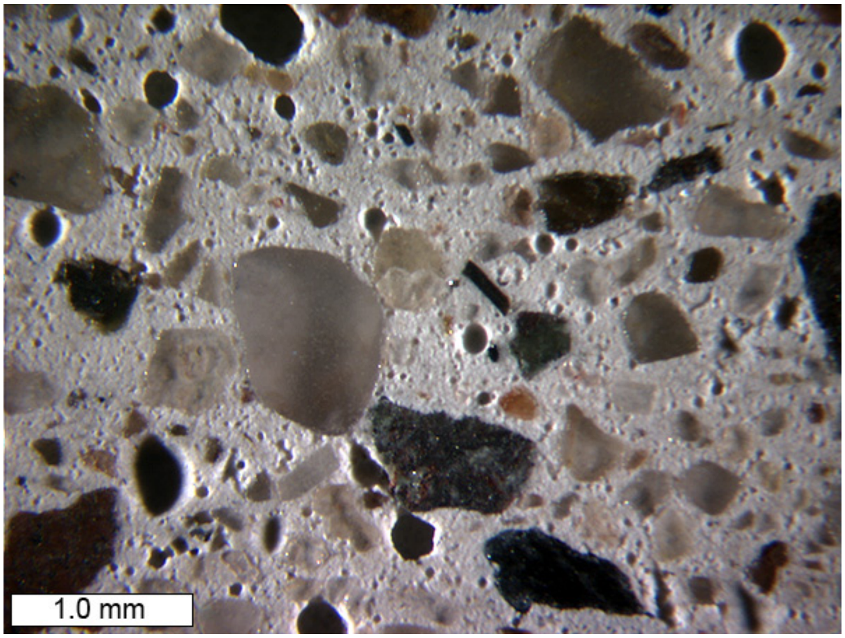


Figure G-5. Stereo Image of Type I Cement Shear Key Grout

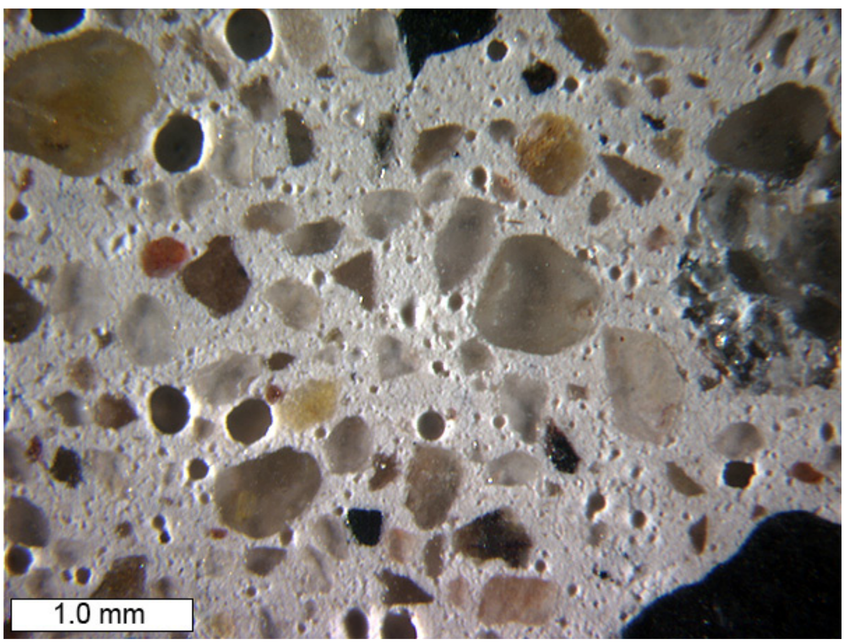


Figure G-6. Stereo Image of Masonry Cement Shear key Grout

APPENDIX H: COEEFICIENT OF THERMAL EXPANSION

Table H-1. CTE analysis for Repair Mortar and Shear key Grouts

Material	CTE for Sample 1 (mm/mm/°C)	Age (days)	CTE for Sample 2 (mm/mm/°C)	Age (days)	Average CTE (mm/mm/°C)	SD	COV
Substrate Concrete	1.32E-05	28	13.24E-6	30	1.32E-05	2.11E-08	0.16
Sika Top 123 PLUS	18.88E-6	7	18.88E-6	11	1.89E-05	0.00E+00	0.00
Sika Repair SHA	15.34E-6	7	14.26E-6	9	1.48E-05	7.59E-07	5.13
HB2 Repair Mortar	11.78E-6	7	9.98E-06	11	1.09E-05	1.27E-06	11.71
Conpatch VO	13.58E-6	7	13.74E-6	9	1.37E-05	1.08E-07	0.79
SET 45	12.59E-6	28	12.38E-6	28	1.25E-05	1.43E-07	1.15
Type I Cement Grout	10.78E-6	28	9.87E-6	28	1.03E-05	6.44E-07	6.24
Masonry Cement Grout	9.41E-6	28	9.73E-6	28	9.57E-06	2.28E-07	2.38

APPENDIX I: SORPTIVITY

Table I-1 Sorptivity Analysis of Repair Mortar and Shear Key Grouts

Material	Initial Rate of Absorption (mm*s$^{-1/2}$)	Regression Coefficient	Secondary Rate of Absorption (mm*s$^{-1/2}$)	Regression Coefficient	Average Initial Rate of Absorption (mm*s$^{-1/2}$)	Average Secondary Rate of Absorption (mm*s$^{-1/2}$)	COV of Initial Rate of Absorption	COV Secondary Rate of Absorption
Sika Top 123 PLUS	7.00E-6	0.9882	6.00E-7	0.97	5.50E-06	8.00E-07	38.57	35.36
	4.00E-6	0.9903	1.00E-6	0.99				
Sika Repair SHA	4.00E-6	0.9728	7.00E-6	0.9846	3.00E-06	5.00E-06	47.14	56.57
	2.00E-6	0.9717	3.00E-6	0.9921				
HB2 Repair Mortar	3.00E-7	0.5495	8.00E-7	0.98	6.00E-07	8.00E-07	70.71	0.00
	9.00E-7	0.8405	8.00E-7	0.98				
Conpatch VO	7.00E-6	0.9756	2.00E-6	0.9943	7.50E-06	3.00E-06	9.43	47.14
	8.00E-6	0.9815	4.00E-6	0.989				
SET 45	30.00E-6	0.976	5.00E-6	0.9849	3.00E-05	3.00E-06	0.00	94.28
	30.00E-6	0.9893	1.00E-6	0.9905				
Type I Cement Grout	40.00E-6	0.984	7.00E-6	0.9944	2.50E-05	8.00E-06	84.85	17.68
	10.00E-6	0.9915	9.00E-6	0.9905				
Masonry Cement Grout	30.00E-6	0.976	5.00E-6	0.9849	3.00E-05	3.00E-06	0.00	94.28
	30.00E-6	0.9893	1.00E-6	0.9905				

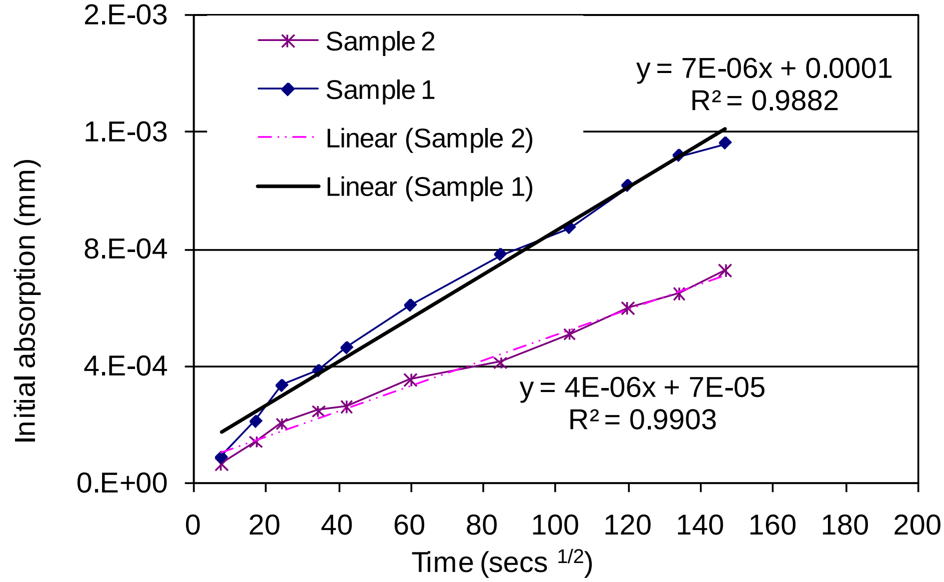


Figure I-1. Initial Absorption Curves for Sika Top 123 PLUS

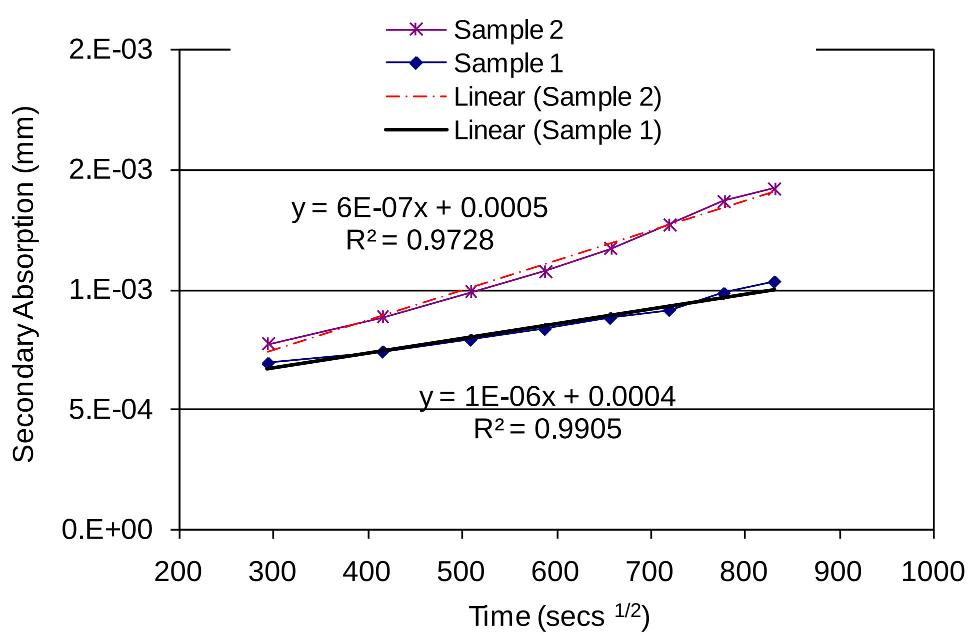


Figure I-2. Secondary Absorption Curves for Sika Top 123 PLUS

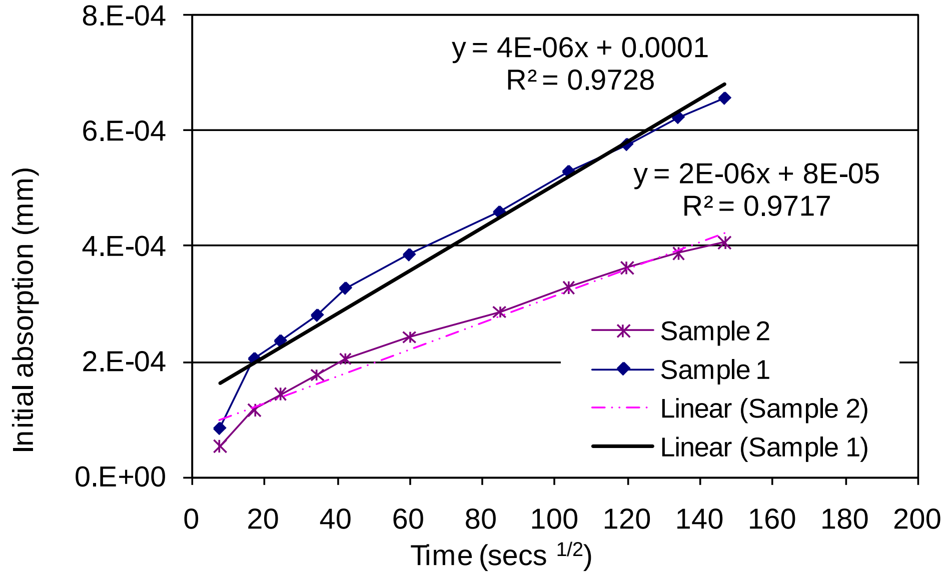


Figure I-3. Initial Absorption Curves for Sika Repair SHA

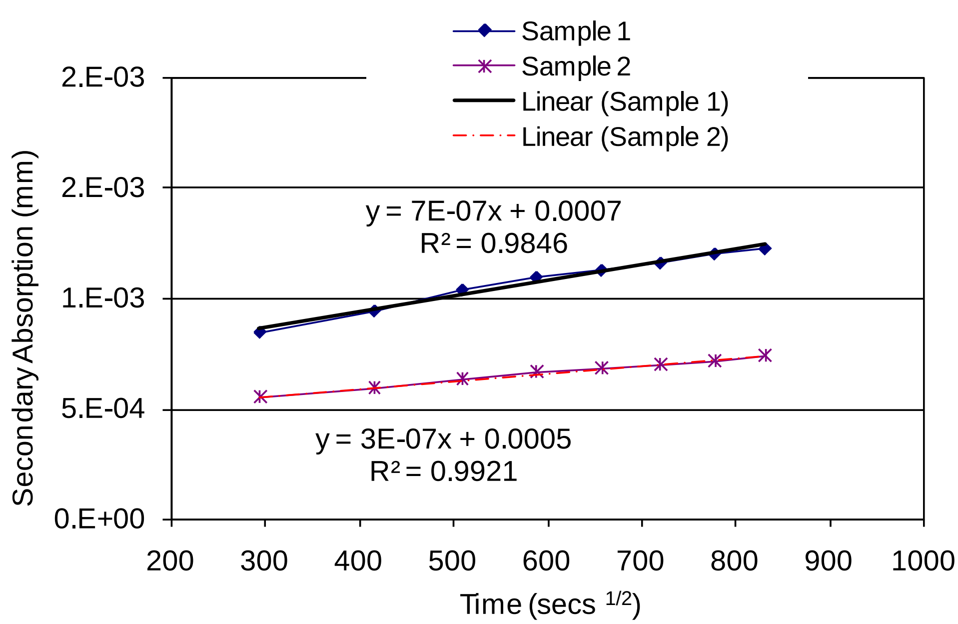


Figure I-4. Secondary Absorption Curves for Sika Repair SHA

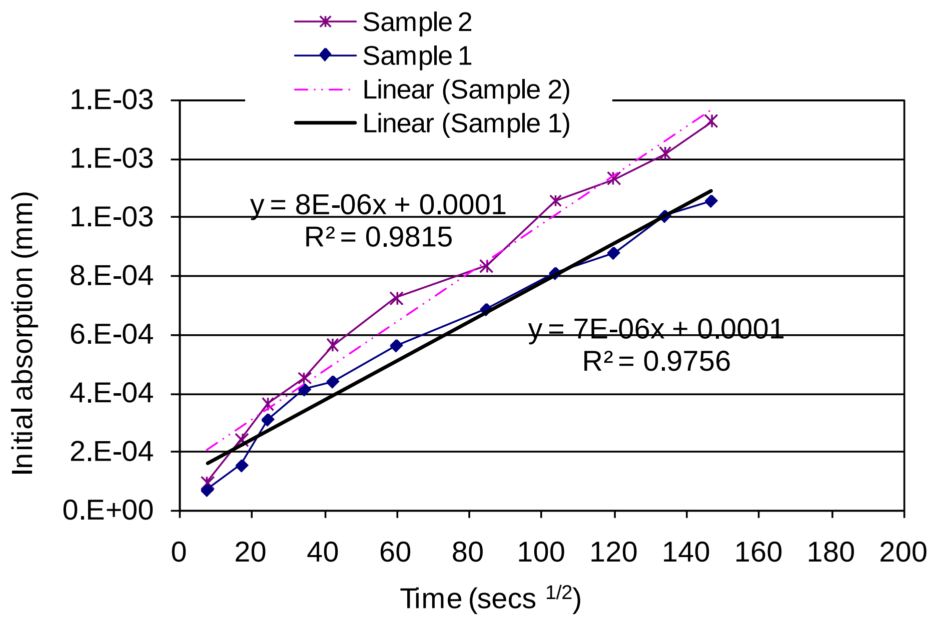


Figure I-5. Initial Absorption Curves for Conpatch VO

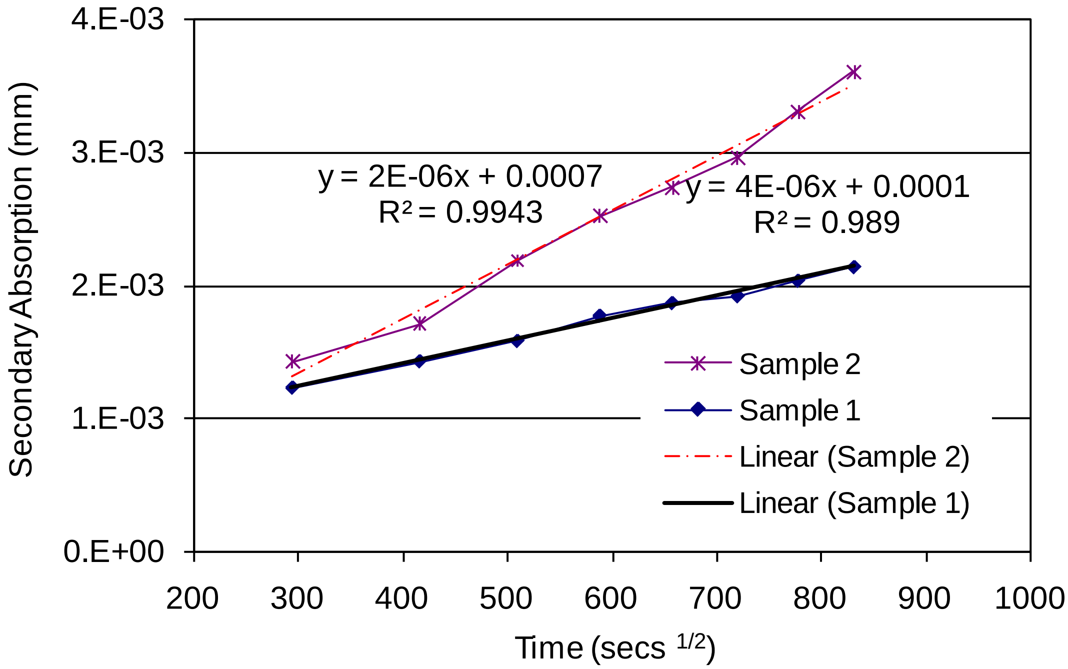


Figure I-6. Secondary Absorption Curves for Conpatch VO

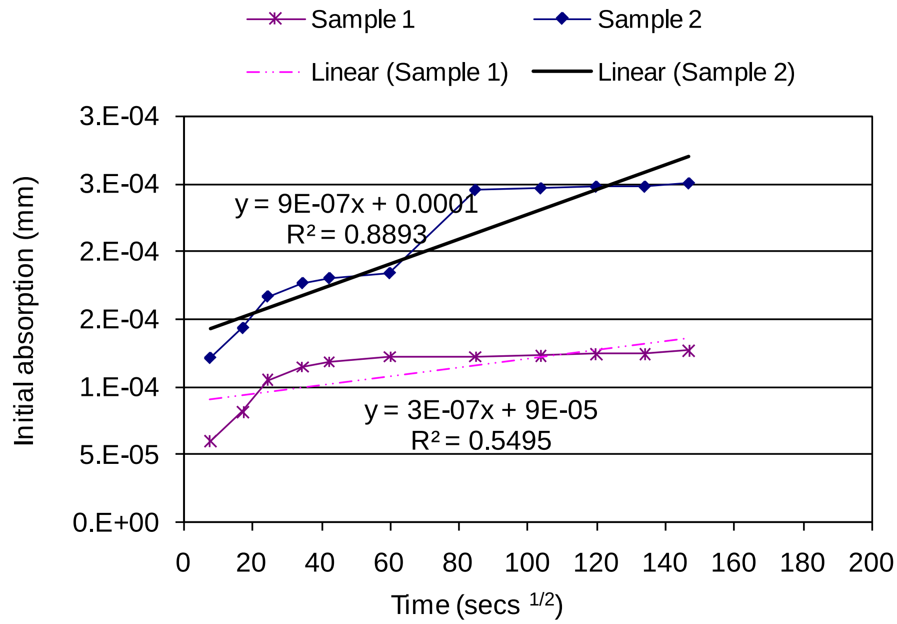


Figure I-7. Initial Absorption Curves for HB2 Repair Mortar

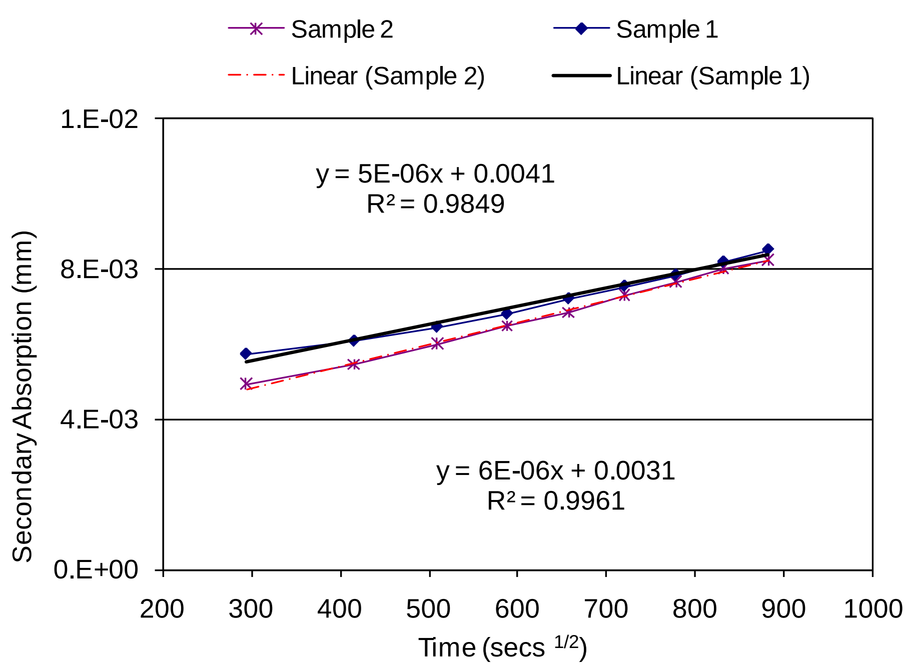


Figure I-8. Secondary Absorption Curves for HB2 Repair Mortar

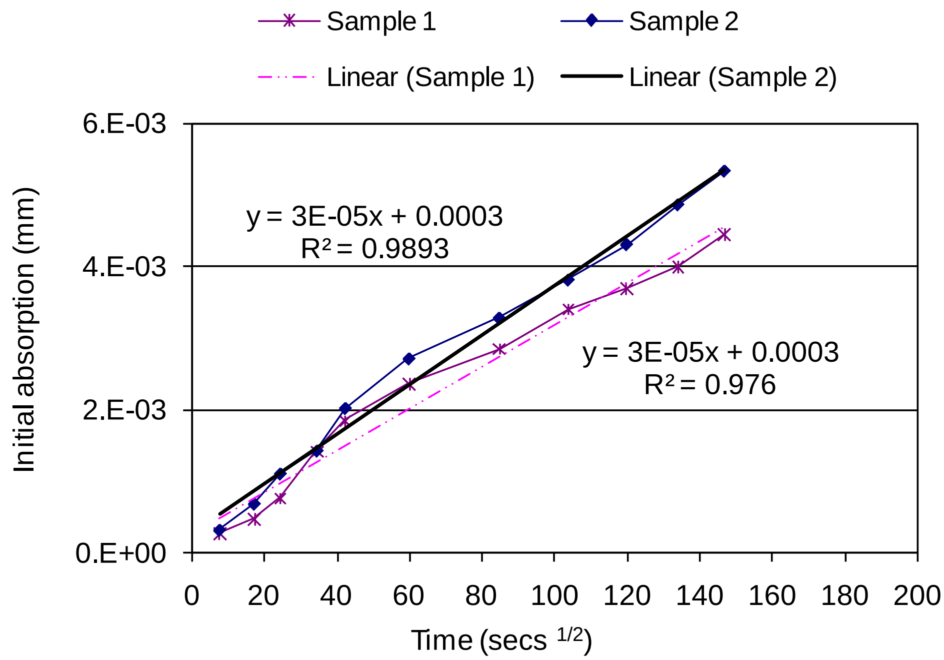


Figure I-9. Initial Absorption Curves for SET 45

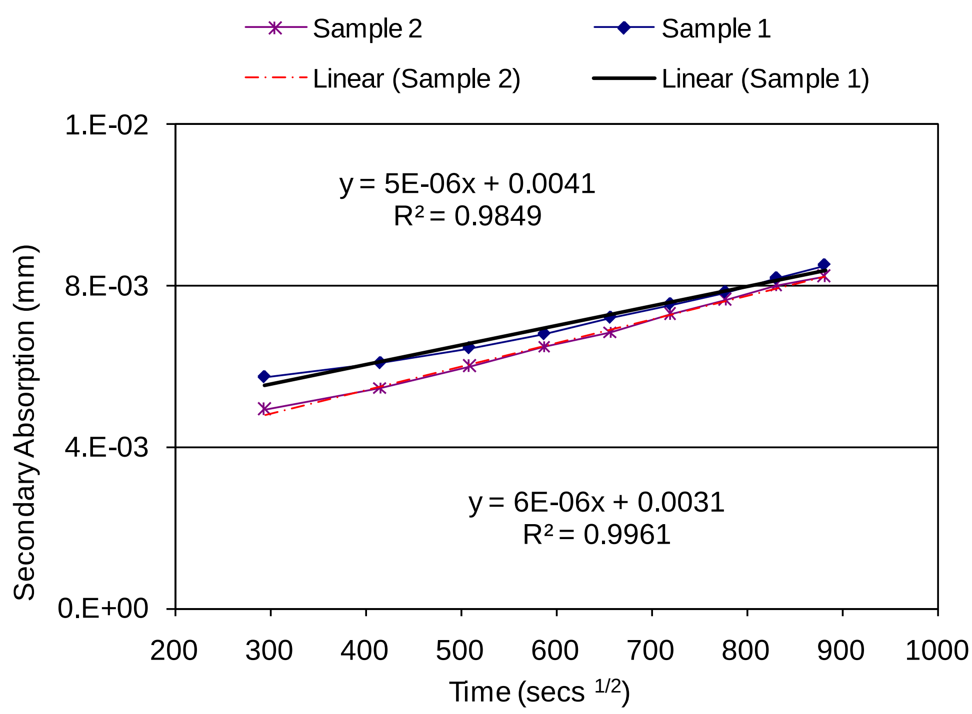


Figure I-10. Secondary Absorption Curves for SET 45

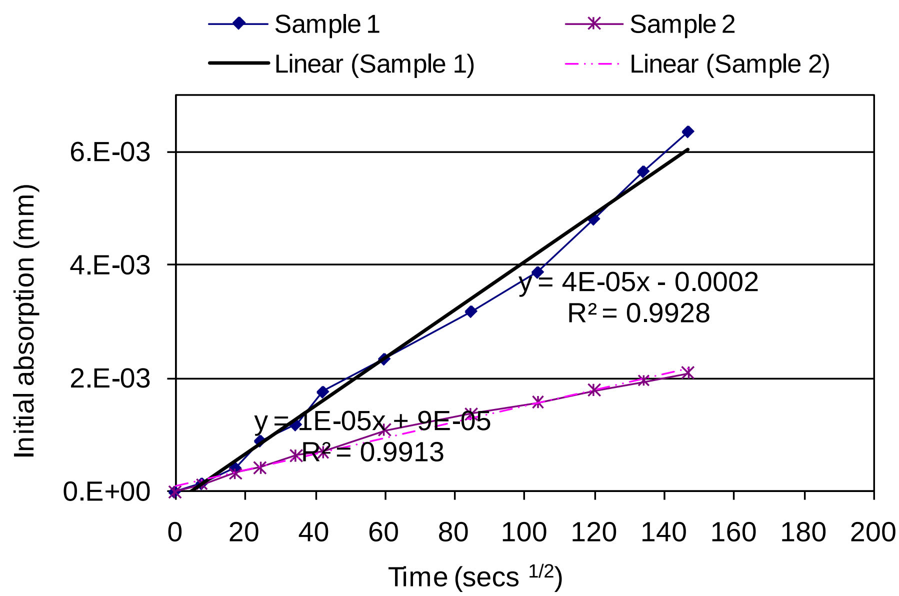


Figure I-11. Initial Absorption Curves for Type I Cement Grout

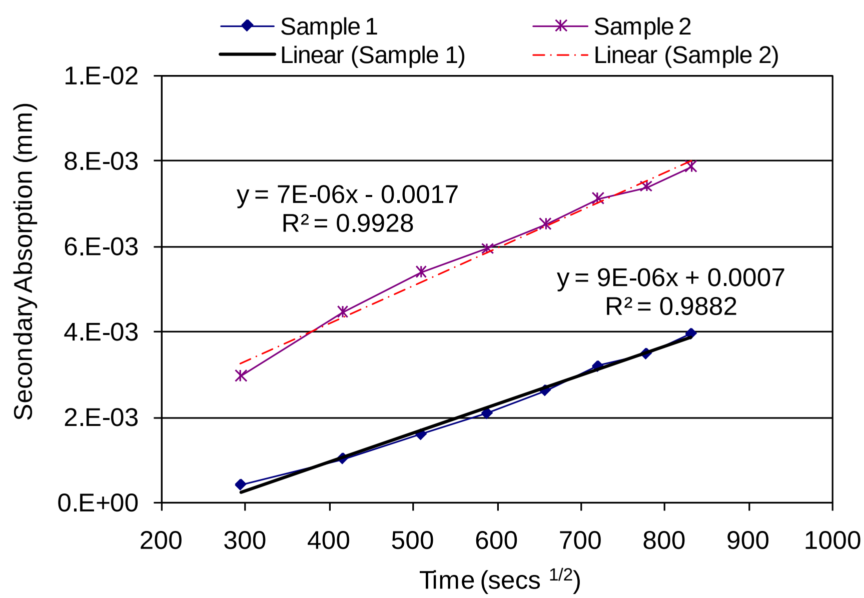


Figure I-12. Secondary Absorption Curves for Type I Cement Grout

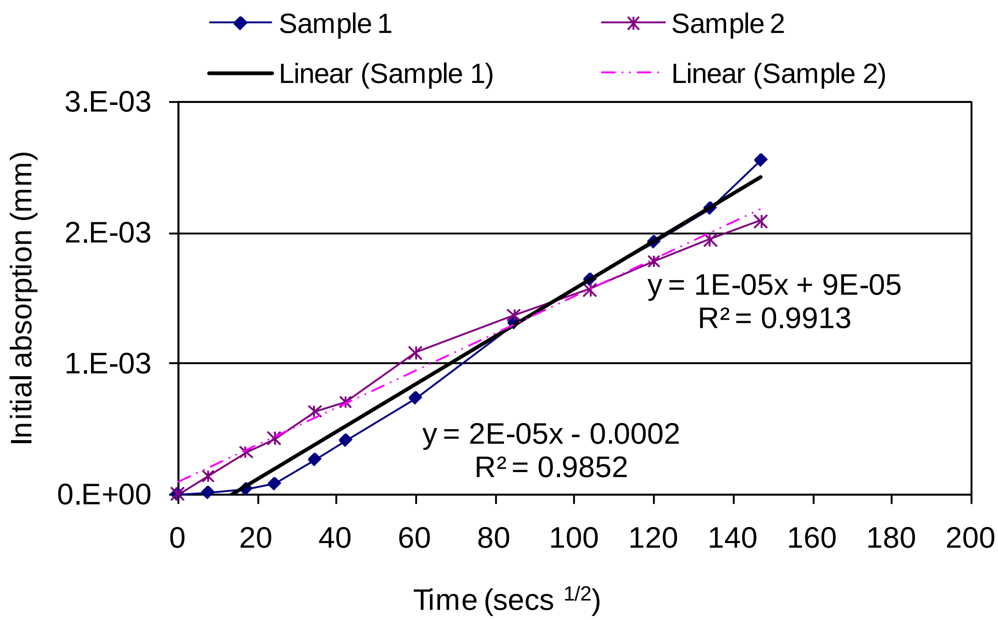


Figure I-15. Initial Absorption Curves for Mortar Cement Grout

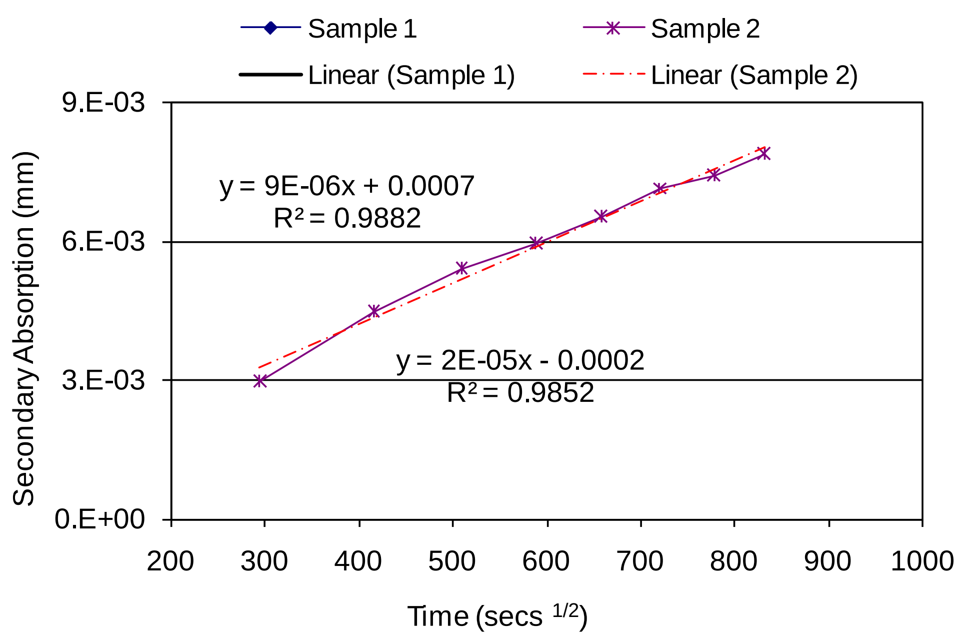


Figure I-16. Secondary Absorption Curves for Mortar Cement Grout

APPENDIX J: RATIONAL TRANSVERSE POSTTENSION DESIGN

TABLE J-1 Averaged Transverse Moment, N-m/m (in-lb/in)

Row No.	Shear key location m (in.)	End Diaphragm Moment Averaged within 1.91m (75 in.)						Intermediate Diaphragm Moment Averaged within 3.81 m (150 in.)						Midspan Diaphragm Moment Averaged within 3.81 m (150 in.)					
		Loads						Loads						Loads					
		Deck (a)	Barrier (b)	1 truck (c)	1 lane (d)	2 trucks (e)	2 lanes (f)	Deck (g)	Barrier (h)	1 truck (i)	1 lane (j)	2 trucks (k)	2 lanes (l)	Deck (m)	Barrier (n)	1 truck (o)	1 lane (p)	2 trucks (q)	2 lanes (r)
1	0.95 (37.5)	**-730 (-164)**	**-2982 (-670)**	**-2728 (-613)**	**-547 (-123)**	-1838 (-413)	-263 (-59)	2283 (513)	-2332 (-524)	8669 (1948)	2532 (569)	7432 (1670)	2078 (467)	3039 (683)	-2554 (-574)	10992 (2470)	3244 (729)	9372 (2106)	2657 (597)
2	1.94 (76.5)	779 (175)	-2439 (-548)	739 (166)	863 (194)	988 (222)	828 (186)	3974 (893)	-4303 (-967)	10805 (2428)	3872 (870)	9919 (2229)	3453 (776)	5224 (1174)	-5006 (-1125)	14098 (3168)	4873 (1095)	13087 (2941)	4406 (990)
3	2.93 (115.5)	1460 (328)	**-2194 (-493)**	1833 (412)	1095 (246)	**2390 (537)**	**1077 (242)**	5002 (1124)	**-5304 (-1192)**	**13025 (2927)**	**3484 (783)**	14374 (3230)	3698 (831)	6501 (1461)	**-6439 (-1447)**	**16105 (3619)**	**4388 (986)**	18165 (4082)	4810 (1081)
4	3.92 (154.5)	**1606 (371)**	-2140 (-481)	1384 (311)	360 (81)	2768 (622)	721 (162)	**5345 (1201)**	-5611 (-1261)	5994 (1347)	1571 (353)	11988 (2694)	3142 (706)	**6920 (1555)**	-6906 (-1552)	7939 (1784)	2145 (482)	15878 (3568)	4294 (965)
5	4.91 (193.5)	1460 (328)	-2194 (-493)	552 (124)	-18 (-4)	2390 (537)	1077 (242)	5002 (1124)	-5304 (-1192)	1348 (303)	209 (47)	14374 (3230)	3698 (831)	6501 (1461)	-6439 (-1447)	2060 (463)	423 (95)	18165 (4082)	4810 (1081)
6	5.91 (232.5)	779 (175)	-2439 (-548)	249 (56)	-36 (-8)	988 (222)	828 (186)	3974 (893)	**-4303 (-967)**	**-886 (-199)**	**-414 (-93)**	9919 (2229)	3453 (776)	5224 (1174)	**-5006 (-1125)**	**-1010 (-227)**	**-467 (-105)**	13087 (2941)	4406 (990)
7	6.9 (271.5)	-730 (-164)	-2982 (-670)	890 (200)	285 (64)	-1838 (-413)	-263 (-59)	2283 (513)	-2332 (-524)	-1237 (-278)	-454 (-102)	7432 (1670)	2078 (467)	3039 (683)	-2554 (-574)	-1620 (-364)	-587 (-132)	9372 (2106)	2657 (597)

Note: Negative (-) moments develop tension on top of the deck
Highlighted cells contain the critical moments for AASHTO LRFD (*15*) Service I combination

Design of Transverse Posttension Force

The design calculations for transverse posttension are included in detail. The sign convention in these calculations is: tension negative (-) and compression positive (+). Additionally, using the common moment sign convention negative moment develops tension at the top.

Step 1: First Stage Posttension (before Cast-in-Place Deck Placement)

Cast-in-place concrete deck weight is applied as a dead load to the analysis model with stiffness properties of RVE without a deck.

Step 1.1: Moments at End Diaphragm

Maximum averaged negative moment = -730 N-m/m *(-164 lb-in/in)* (Table J-1: row 1, column a)
Maximum nominal negative moment (M_1) = -730 (N-m/m) × 1.9 m = -1.387 kN-m (-*1.0 ft-kips)*
Maximum averaged positive moment = 1606 N-m/m *(371 lb-in/in)* (Table J-1: row 4, column a)
Maximum nominal positive moment (M_2) = 1606 (N-m/m) × 1.9 m = 3.051 kN-m (2.3 *ft-kips)*

Step 1.2: Stresses at End Diaphragm

Moment of inertia (I) = 1.708 × 10^{10} mm^4 (Table J-2: row 2, column a)
Neutral axis depth (y) = 343 mm (Table J-2: row 3, column a)

Stress at the top fiber due to M_1

$$f_{1,top} = \frac{M_1 y}{I} = \frac{-1.387\ (kN-m)\ \times\ 343\ (mm)}{1.708 \times\ 10^{10}(mm^4)}$$
$$= -2.8 \times 10^{-2} MPa\ (-4.1 \times 10^{-3}\ ksi)$$

Stress at the bottom fiber due to M_1

$$f_{1,bot} = 2.8 \times 10^{-2} MPa\ (4.1 \times 10^{-3}\ ksi)$$

Stress at the top fiber due to M_2

$$f_{2,top} = \frac{M_2 y}{I} = \frac{3.051\ (kN-m)\ \times\ 343\ (mm)}{1.708 \times\ 10^{10}(mm^4)} = 6.1 \times 10^{-2} MPa\ (8.9 \times 10^{-3}\ ksi)$$

Stress at the bottom fiber due to M_2

$$f_{2,bot} = -6.1 \times 10^{-2} MPa\ (-8.9\ \times 10^{-3}\ ksi)$$

Step 1.3: Moment at Intermediate Diaphragm

Maximum averaged positive moment = 5345 N-m/m *(1201 lb-in/in)* (Table J-1: row 4, column g)

Maximum nominal positive moment (M) = 5345 (N-m/m) × 3.81 m = 20.365 kN-m (15.0 *ft-kips)*

Step 1.4: Stresses at Intermediate Diaphragm

Moment of inertia (I) = 9.557 × 10^9 mm^4 (Table J-2: row 2, column b)
Neutral axis depth (y) = 343 mm (Table J-2: row 3, column b)

Stress at the top fiber due to M

$$f_{top} = \frac{My}{I} = \frac{20.365\ (kN - m)\ \times\ 343\ (mm)}{9.557 \times\ 10^9 (mm^4)} = 7.309 \times 10^{-1} MPa\ (1.06 \times 10^{-1}\ ksi)$$

Stress at the bottom fiber due to M

$$f_{bot} = -7.309 \times 10^{-1} MPa\ (-1.06 \times 10^{-1}\ ksi)$$

Step 1.5: Moment at Mid Diaphragm

Maximum averaged positive moment = 6920 N-m/m *(1555 lb-in/in)* (Table J-1: row 4, column m)

Maximum nominal positive moment (M) = 6920 (N-m/m) × 3.81 m = 26.365 kN-m (19.4 *ft-kips)*

Step 1.6: Stresses at Mid Diaphragm

Moment of inertia (I) = 9.557 × 10^9 mm^4 (Table J-2: row 2, column b)
Neutral axis depth (y) = 343 mm (Table J-2: row 3, column a)

Stress at the top fiber due to M

$$f_{top} = \frac{My}{I} = \frac{26.365\ (kN - m)\ \times\ 343\ (mm)}{9.557 \times\ 10^9 (mm^4)} = 9.462 \times 10^{-1} MPa\ (1.37 \times 10^{-1}\ ksi)$$

Stress at the bottom fiber due to M

$$f_{bot} = -9.462 \times 10^{-1} MPa\ (-1.37 \times 10^{-1}\ ksi)$$

Step 1.7: Required Posttension Force before 6-in. Cast-in-Place Concrete Deck Placement

AASHTO LRFD (*15*) Service I limit state is implemented. Posttension force is calculated based on no tension criterion. It is assumed that the posttension stress is uniformly distributed across the diaphragm cross-section.

The posttension force required at the end diaphragm is determined using the maximum tensile stress calculated in step 1.2. Posttension force is calculated multiplying the tensile stress (step 1.2) and the intermediate diaphragm cross-section area (Table J-2: row 1, column a).

$$Post\ Tension\ Force\ Required = 6.1 \times 10^{-2} MPa \times 4.356 \times 10^5 (mm^2) = 26.6\ kN \cong \mathbf{30\ kN}\ (\mathbf{6.8\ kips})$$

The posttension force required at the intermediate diaphragm is determined using the maximum tensile stress calculated in step 1.4. Posttension force is calculated multiplying the tensile stress (step 1.4) and the end diaphragm cross-section area (Table J-2: row 1, column b).

$$Post\ Tension\ Force\ Required = 7.309 \times 10^{-1} MPa \times 2.442 \times 10^{5} (mm^2)$$
$$= 178.5\ kN \cong \mathbf{180\ kN}\ (\mathbf{40.5\ kips})$$

The posttension force required at the midspan diaphragm is determined using the maximum tensile stress calculated in step 1.6. Posttension force is calculated multiplying the tensile stress (step 1.6) and the midspan diaphragm cross-section area (Table J-2: row 1, column b).

$$Post\ Tension\ Force\ Required = 9.462 \times 10^{-1} MPa \times 2.442 \times 10^{5} (mm^2)$$
$$= 231.1\ kN \cong \mathbf{232\ kN}\ (\mathbf{52\ kips})$$

Step 2: Second Stage Posttension (after Cast-in-Place Deck Placement)

Barrier and HL-93 (lane and HS-20 truck) load are applied to the analysis model with stiffness properties of RVE with deck. Truck and lane loads are positioned considering one and two-loaded lanes.

AASHTO LRFD (*15*) service I limit state is considered. Multiple presence factors of 1.2 and 1.0 for one and two-lane cases are included in the calculations. The dynamic allowance factor of 1.75 for deck joints is considered.

Step 2.1: Moments at End Diaphragm

The maximum service I nominal negative moment is a result of applying barrier load and single-lane truck and lane loads (Table J-1: row 1, column b, c, d)

The averaged moment due to
barrier load = -2982 N-m/m *(-670 lb-in/in)* (Table J-1: row 1, column b)
single truck load = -2728 N-m/m *(-613 lb-in/in)* (Table J-1: row 1, column c)
single lane load = -547 N-m/m *(-123 lb-in/in)* (Table J-1: row 1, column d).

The nominal moment due to
barrier load = -2982 (N-m/m) × 1.9 m = -5.666 kN-m (*-4.2 ft-kips)*
single truck load = -2728 (N-m/m) × 1.2× 1.75 × 1.9 m = -10.885 kN-m (*-8.0 ft-kips)*
single lane load = -547 (N-m/m) × 1.2× 1.9 m = -1.247 kN-m (*-0.92 ft-kips).*

The maximum service I nominal negative moment

$$M_1 = -5.666 - 1.0\,[10.885 + 1.247] = -17.8\ kN - m\ (\text{-13.12 ft-k})$$

The maximum service I nominal positive moment is a result of applying truck and lane loads on to both lanes of the structure in conjunction with the barrier load (Table J-1: row 3, column b, e, f)

The averaged moment due to
barrier load = -2194 N-m/m *(-493 lb-in/in)* (Table J-1: row 3, column b)
two-truck load = 2390 N-m/m *(537 lb-in/in)* (Table J-1: row 3, column e)

two-lane load = 1077 N-m/m *(242 lb-in/in)* (Table J-1: row 3, column f).

The nominal moment due to

barrier load = -2194 (N-m/m) × 1.9 m = -4.169 kN-m (*-3.1 ft-kips)*

single truck load = 2390 (N-m/m) × 1.0× 1.75 × 1.9 m = 7.947 kN-m *(5.86 ft-kips)*

single lane load = 1077 (N-m/m) × 1.0× 1.9 m = 2.046 kN-m (*1.5ft-kips)*.

The maximum service I nominal positive moment

$$M_2 = -4.169 + 1.0\,[7.947 + 2.046] = 5.824 \; kN - m \text{ (4.3 ft-k)}$$

Step 2.2: Stresses at End Diaphragm

Moment of inertia (I) = 3.114 × 10^{10} mm^4 (Table J-2: row 5, column a)
Neutral axis depth (y_t) = 419 mm (Table J-2: row 6)

Stress at the top fiber due to M_1

$$f_{1,top} = \frac{M_1 y}{I} = \frac{-17.8\;(kN-m)\;\times\;419\;(mm)}{3.114\times\;10^{10}(mm^4)}$$
$$= -2.4\times 10^{-1} MPa\;(-3.4\times 10^{-2}\;ksi)$$

Stress at the bottom fiber due to M_1

$$f_{1,bot} = 2.4\times 10^{-1} MPa\;(3.4\times 10^{-2}\;ksi)$$

Stress at the top fiber due to M_2

$$f_{2,top} = \frac{M_2 y}{I} = \frac{5.824\;(kN-m)\;\times\;419\;(mm)}{3.114\times\;10^{10}(mm^4)} = 7.8\times 10^{-2} MPa\;(1.14\times 10^{-2}\;ksi)$$

Stress at the bottom fiber due to M_2

$$f_{2,bot} = -7.8\times 10^{-2} MPa\;(-1.14\;\times 10^{-2}\;ksi)$$

Step 2.3: Moments at Intermediate Diaphragm

The maximum service I nominal negative moment is a result of applying barrier load and single-lane truck and lane loads (Table J-1: row 6, column h, i, j).

The averaged moment due to

barrier load = -4303 N-m/m *(-967 lb-in/in)* (Table J-1: row 6, column h)

single truck load = -886 N-m/m *(-199 lb-in/in)* (Table J-1: row 6, column i)

single lane load = -414 N-m/m *(-93 lb-in/in)* (Table J-1: row 6, column j).

The nominal moment due to

barrier load = -4303 (N-m/m) × 3.81 m = -16.4 kN-m (*-12.1 ft-kips)*

single truck load = -886 (N-m/m) × 1.2× 1.75 × 3.81 m = -7.1 kN-m (*-5.2 ft-kips)*

single lane load = -414 (N-m/m) × 1.2× 3.81 m = -1.9 kN-m (*-1.4 ft-kips)*.

The maximum service I nominal negative moment

$$M_1 = -16.4 - 1.0\,[7.1 + 1.9] = -25.4\,kN - m \text{ (-18.73 ft-k)}$$

The maximum service I nominal positive moment is a result of applying barrier load and single-lane truck and lane loads (Table J-1: row 3, column h, i, j).

The averaged moment due to

barrier load = -5304 N-m/m *(-1192 lb-in/in)* (Table J-1: row 3, column h)

single truck load = 13025 N-m/m *(2927 lb-in/in)* (Table J-1: row 3, column i)
single lane load = 3484 N-m/m *(783 lb-in/in)* (Table J-1: row 3, column j).

The nominal moment due to

barrier load = -5304 (N-m/m) × 3.81 m = -20.21 kN-m (*-15.0 ft-kips)*
single truck load = 13025 (N-m/m) × 1.2× 1.75 × 3.81 m = 104.2 kN-m *(76.8 ft-kips)*
single lane load = 3484 (N-m/m) × 1.2× 3.81 m = 16.0 kN-m (11.74 *ft-kips).*

The maximum service I nominal positive moment

$$M_2 = -20.21 + 1.0\,[104.2 + 16] = 100 \;\; kN - m \text{ (73.7 ft-k)}$$

Step 2.4: Stresses at Intermediate Diaphragm

Moment of inertia (I) = 1.746 × 10^{10} mm^4 (Table J-2: row 5, column b)
Neutral axis depth (y_t) = 419 mm (Table J-2: row 6)

Stress at the top fiber due to M_1

$$f_{1,top} = \frac{M_1 y}{I} = \frac{-25.4\ (kN - m)\ \times\ 419\ (mm)}{1.746 \times\ 10^{10}(mm^4)}$$
$$= -6.1 \times 10^{-1} MPa\ (-8.8 \times 10^{-2}\ ksi)$$

Stress at the bottom fiber due to M_1

$$f_{1,bot} = 6.1 \times 10^{-1} MPa\ (8.8 \times 10^{-2}\ ksi)$$

Stress at the top fiber due to M_2

$$f_{2,top} = \frac{M_2 y}{I} = \frac{100\ (kN - m) \times 419\ (mm)}{1.746 \times 10^{10}(mm^4)} = 2.4\ MPa\ (3.5 \times 10^{-1}\ ksi)$$

Stress at the bottom fiber due to M_2

$$f_{2,bot} = -2.4\ MPa\ (-3.5 \times 10^{-1}\ ksi)$$

Step 2.5: Moments at Midspan Diaphragm

The maximum service I nominal negative moment is a result of applying barrier load and single-lane truck and lane loads (Table J-1: row 6, column n, o, p).

The averaged moment due to

barrier load = -5006 N-m/m *(-1125 lb-in/in)* (Table J-1: row 6, column n)
single truck load = -1010 N-m/m *(-227 lb-in/in)* (Table J-1: row 6, column o)
single lane load = -467 N-m/m *(-105 lb-in/in)* (Table J-1: row 6, column p).

The nominal moment due to

barrier load = -5006 (N-m/m) × 3.81 m = -19.1 kN-m (*-14.1 ft-kips)*
single truck load = -1010 (N-m/m) × 1.2× 1.75 × 3.81 m = -8.1 kN-m (*-6.0 ft-kips)*
single lane load = -467 (N-m/m) × 1.2× 3.81 m = -2.1 kN-m (*-1.6 ft-kips).*

The maximum service I nominal negative moment

$$M_1 = -19.1\ - 1.0\,[8.1 + 2.1] = -29.3\ kN - m \text{ (-21.6 ft-k)}$$

The maximum service I nominal positive moment is a result of applying barrier load and single-lane truck and lane loads (Table J-1: row 3, column n, o, p).

The averaged moment due to

barrier load = -6439 N-m/m *(-1447 lb-in/in)* (Table J-1: row 3, column n)
single truck load = 16105 N-m/m *(3619 lb-in/in)* (Table J-1: row 3, column 0)
single lane load = 4388 N-m/m *(986 lb-in/in)* (Table J-1: row 3, column p).

The nominal moment due to

barrier load = -6439 (N-m/m) × 3.81 m = -24.53 kN-m (*-18.1 ft-kips)*
single truck load = 16105 (N-m/m) × 1.2× 1.75 × 3.81 m = 129.0 kN-m *(95.0 ft-kips)*
single lane load = 4388 (N-m/m) × 1.2× 3.81 m = 20.1 kN-m (14.8 *ft-kips).*

The maximum service I nominal positive moment

$$M_2 = -24.53 + 1.0\,[129 + 20.1] = 124.6\ kN - m \text{ (91.8 ft-k)}$$

Step 2.6: Stresses at Midspan Diaphragm

Moment of inertia (I) = 1.746 × 10^{10} mm^4 (Table J-2: row 5, column b)
Neutral axis depth (y_t) = 419 mm (Table J-2: row 6)

Stress at the top fiber due to M_1

$$f_{1,top} = \frac{M_1 y}{I} = \frac{-29.3\ (kN - m)\ \times\ 419\ (mm)}{1.746 \times\ 10^{10}(mm^4)}$$
$$= -7.0 \times 10^{-1} MPa\ (-1.0 \times 10^{-1}\ ksi)$$

Stress at the bottom fiber due to M_1

$$f_{1,bot} = 7.0 \times 10^{-1} MPa\ (1.0 \times 10^{-1}\ ksi)$$

Stress at the top fiber due to M_2

$$f_{2,top} = \frac{M_2 y}{I} = \frac{124.6\ (kN - m) \times 419\ (mm)}{1.746 \times 10^{10}\ (mm^4)} = 3.0\ MPa\ (4.3 \times 10^{-1}\ ksi)$$

Stress at the bottom fiber due to M_2

$$f_{1,bot} = -3.0\ MPa\ (-4.3 \times 10^{-1}\ ksi)$$

Step 2.7: Required Posttension Force after 6-in. Cast-in-Place Concrete Deck Placement

The posttension force required at end diaphragm is calculated in order to suppress the maximum tensile stress developed at the top or bottom fiber due to applied loads. The maximum tensile stress is calculated in step 2.2 as 0.24 MPa. Resultant posttension force is eccentric to the neutral axis of the deck-beam composite section and develops a moment as shown in Table J-2: row 6.

Other variables used in the calculations are defined in Table J-2.

$for\ f_{top} > 0$

$$Post\ Tension\ Force \geq \frac{f_{top}}{\left(\frac{1}{A} - \frac{(y_2 - y_1)}{2I} y_t\right)} = \frac{2.4 \times 10^{-1}\ (MPa)}{\left(\frac{1}{5.321 \times 10^5 (mm^2)} - \frac{(241 - 89)(mm) \times 419\ (mm)}{2 \times 3.114 \times 10^{10}\ (mm^4)}\right)}$$

$$Post\ Tension\ Force \geq \mathbf{281\ kN}\ (63\ kips)$$

With the level of applied posttension, grout close to the beam bottom fiber is subjected to the highest level of compression. It is required to check if the grout capacity is adequate to carry the level of stress exerted by the posttension force.

$$f_{bot}\,(P = 281\ kN) = \frac{P}{A} + \frac{P\,(y_2 - y_1)\,y_t}{2I} = \frac{281\ (kN)}{5.321\times10^{5}(mm^2)} + \frac{281\ (kN)\times(241-89)\ (mm)\times419\ (mm)}{2\times3.114\times10^{10}\ (mm^4)}$$

$f_{bot}\,(P = 281\ kN) = 815\ kPa$ << grout compressive strength

The posttension required at intermediate diaphragm is calculated to suppress the tensile stresses calculated in step 2.4.

The maximum tensile stress at the top fiber = $6.1 \times 10^{-1} MPa$
The maximum tensile stress at the bottom fiber = $2.4\ MPa$

$for\ f_{top} > 0$

$$Post\ Tension\ Force \geq \frac{f_{top}}{\left(\frac{1}{A} - \frac{(y_2 - y_1)}{2I} y_t\right)} = \frac{6.1\times10^{-1}\ (MPa)}{\left(\frac{1}{2.983\times10^{5}(mm^{2})} - \frac{(241-89)(mm)\times419\ (mm)}{2\times1.746\times10^{10}\ (mm^{4})}\right)}$$

$$Post\ Tension\ Force \geq 400\ kN\ (90\ kips)$$

$for\ f_{bot} > 0$

$$Post\ Tension\ Force \geq \frac{f_{bot}}{\left(\frac{1}{A} + \frac{(y_2 - y_1)}{2I} y_t\right)} = \frac{2.4\ (MPa)}{\left(\frac{1}{2.983\times10^{5}(mm^{2})} + \frac{(241-89)(mm)\times419\ (mm)}{2\times1.746\times10^{10}\ (mm^{4})}\right)}$$

$$Post\ Tension\ Force \geq \mathbf{464\ kN}\ (105\ kips)$$

Under service conditions, stress in grout is in a safe range, much smaller than the compressive strength.

The posttension required at midspan diaphragm is calculated to suppress the tensile stresses calculated in step 2.6.

The maximum tensile stress at the top fiber = $= 7.0 \times 10^{-1} MPa$
The maximum tensile stress at the bottom fiber = $3.0\ MPa$

$for\ f_{top} > 0$

$$Post\ Tension\ Force \geq \frac{f_{top}}{\left(\frac{1}{A} - \frac{(y_2 - y_1)}{2I} y_t\right)} = \frac{7\times10^{-1}\ (MPa)}{\left(\frac{1}{2.983\times10^{5}(mm^{2})} - \frac{(241-89)(mm)\times419\ (mm)}{2\times1.746\times10^{10}\ (mm^{4})}\right)}$$

$$Post\ Tension\ Force \geq 458\ kN\ (103\ kips)$$

$for\ f_{bot} > 0$

$$Post\ Tension\ Force \geq \frac{f_{bot}}{\left(\frac{1}{A} + \frac{(y_2 - y_1)}{2I} y_t\right)} = \frac{3.0\ (MPa)}{\left(\frac{1}{2.983\times10^{5}(mm^{2})} + \frac{(241-89)(mm)\times419\ (mm)}{2\times1.746\times10^{10}\ (mm^{4})}\right)}$$

$$Post\ Tension\ Force \geq \mathbf{580\ kN}\ (130\ kips)$$

Under service conditions, stress in grout is in a safe range, much smaller than the compressive strength.

The transverse posttension force requirements calculated in step 1.7 and 2.7 are summarized in Table J-3.

Table J-2 Geometric Parameters of Diaphragms and Transverse Posttension Locations along the Beam Height

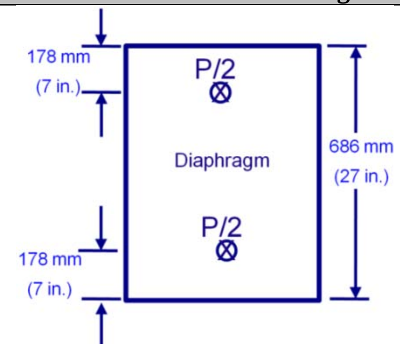
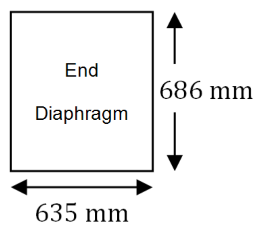
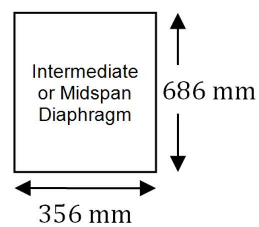
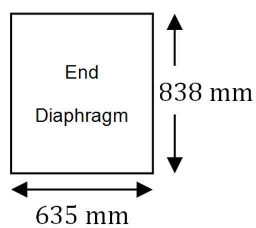
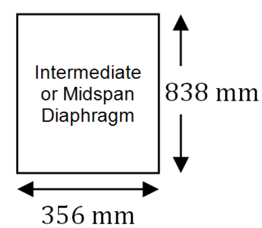
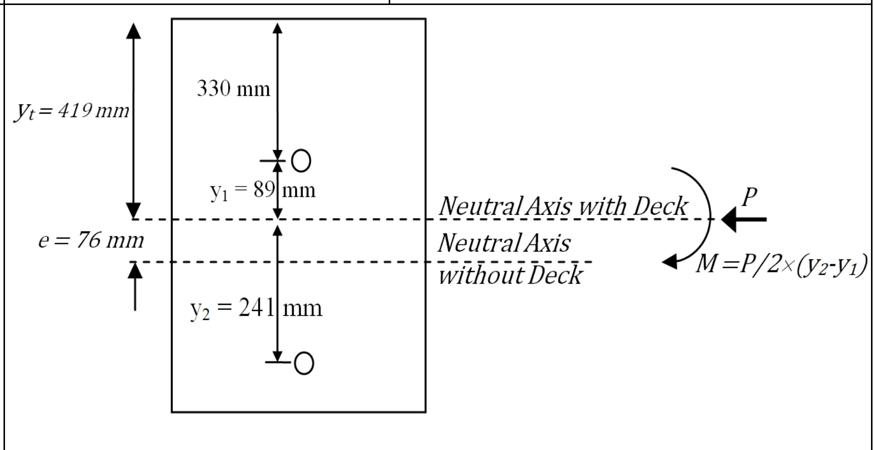
	Transverse Posttension Locations along Beam Height	
		
	Diaphragm Cross-Section without Deck	
	End Diaphragm (a)	Intermediate and Midspan Diaphragms (b)
		
1. Cross-Section Area (A) mm^2	4.356×10^5	2.442×10^5
2. Moment of Inertia (I) mm^4	1.708×10^{10}	9.557×10^9
3. Neutral Axis Depth (y) mm	343	343
	Diaphragm Cross-Section with Deck	
		
4. Cross-Section Area (A) mm^2	5.321×10^5	2.983×10^5
5. Moment of Inertia (I) mm^4	3.114×10^{10}	1.746×10^{10}
6. Miscellaneous Parameters		

TABLE J-3 Posttension Force Requirement for the Sample Bridge

	Posttension Force at Diaphragm, kN (kips)		
	End Diaphragm	Intermediate Diaphragm	Middle Diaphragm
Before deck placement	30 (7)	180 (41)	232 (52)
After deck placement	281 (63)	464 (105)	580 (130)
Total	311 (70)	644 (146)	812 (182)