

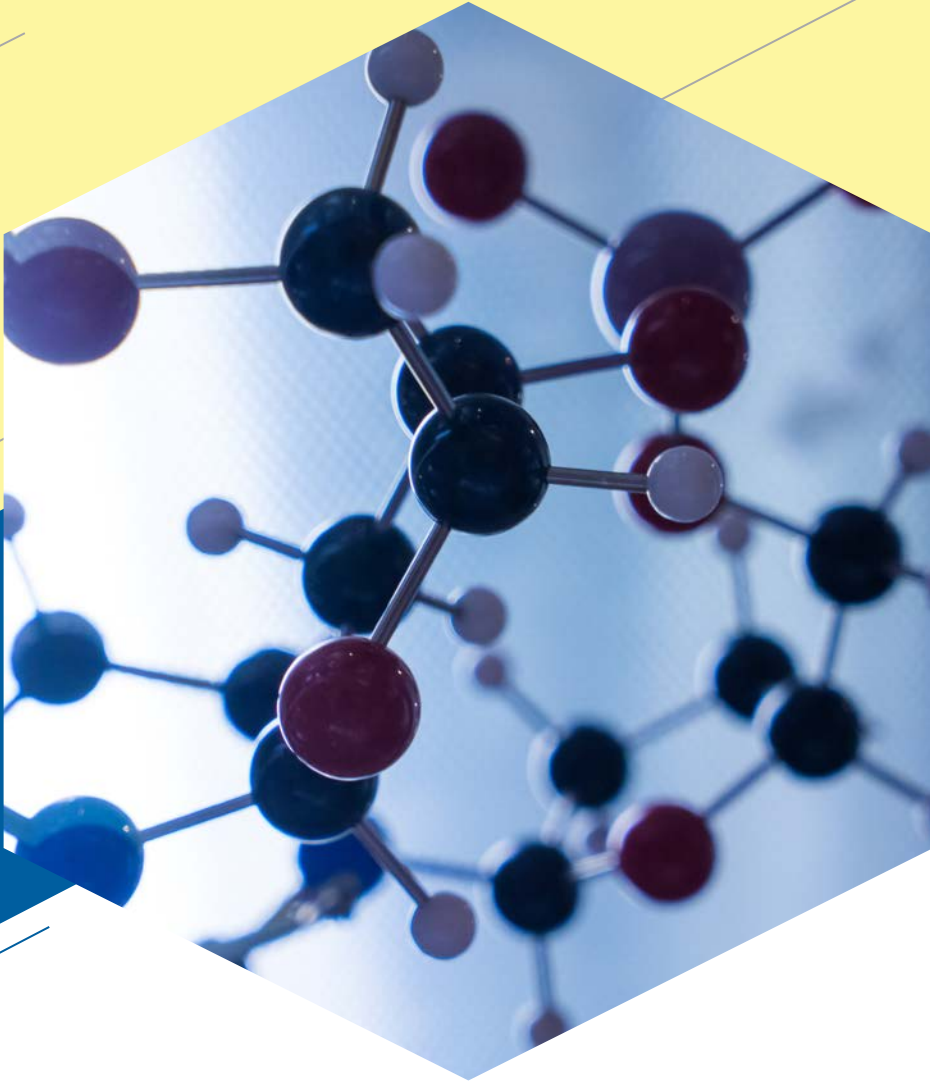


# The Pipeliners Association of Houston

Specifying the Correct Epoxy  
Grout For The Application

# Agenda

- FasTrac Construction Products
- Selecting Grouts
- Technical Aspects of Grout, Grouting Practices, and Techniques



# Grout Types

# What is Grout

**API 686** (American Petroleum Institute)

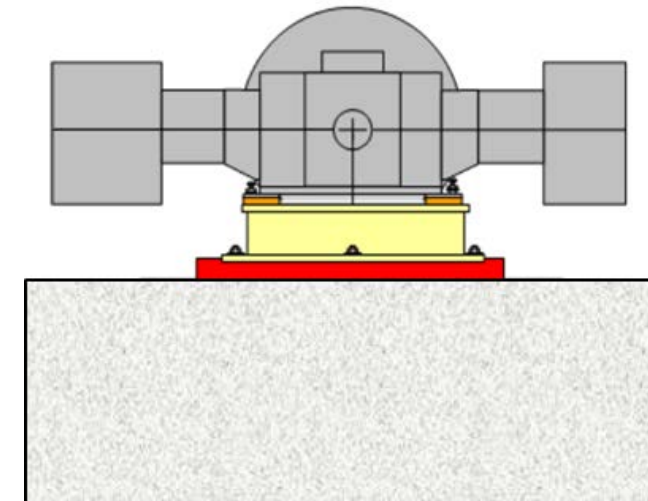
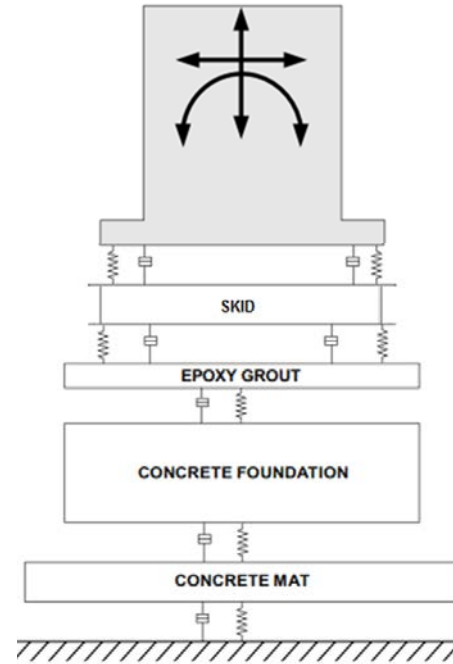
- Grout provides uniform support & a load-transfer link between the equipment and its foundation.

**ACI 351** (American Concrete Institute)

- Grout that is used in the space between plates or machinery & the underlying foundation that is expected to maintain sufficient contact with the base to maintain uniform support

## Static & Dynamic Loads

- Equipment, Fatigue, and Vibration
- $\text{Vibration} = \text{Dynamic Force} \times \text{Dynamic Flexibility}$
- Load Path Transfer



# What is Grout?

## API 686

- Cementitious Grout – Any type of grout material that is cement based
- Epoxy Grout – A type of grout material that consists of a resin base that is mixed with a curing agent (hardener) & usually an aggregate filler

## Grout Reduces Vibration

- Rigid Body Motion
- Flexible Body Motion
- 6 Degrees of Freedom
  - $X$ ,  $Y$ ,  $Z$ ,  $ROT_x$ ,  $ROT_y$ , &  $ROT_z$

## ACI 351

- Grout – A mixture of cementitious materials & water, with or without aggregate, proportioned to produce a pourable consistency without segregation
- Epoxy Grout – A mixture of commercially available ingredients consisting of an epoxy bonding system, aggregate or fillers, & possibly other proprietary materials

# Grout Selection – Epoxy or Cement

## Epoxy

- Equipment over 50 hp
- Compressive Strength
  - 14,000-18,000 psi
  - 96-128 MPa
- Pour depth
  - 38.1mm - 457.2mm (1.5" - 18")
- Dynamic & critical equipment
- Rotating, reciprocating, impact, or impulsive
- High early strength
- Chemical & oil resistance
- Vibration damping
- Monolithic structure
- Rehab or repair
- Some can be pumped with counsel from suppliers

## Non-shrink Cement

- Equipment under 50 hp
- Compressive Strength
  - 7,000-12,000 psi
  - 48-83 MPa
- Pour depth
  - 38.1mm - 127mm (1.5" to +5")
- Non-critical & static equipment
- General civil construction
- Anchor bolt cables or rods without high tensile loads
- Elevated temperature environments
- Filler material
- Can be pumped with recommendations from suppliers
- ASTM 1107 and/or CRD C621

# Epoxy Grouts Are Not The Same

	ASTM C1339 Flow Box Time	ASTM D2471 Peak Exotherm Temp F	ASTM C579 Method B, Load Rate II Compressive Strength	
			3 Day	7 Day
Brand A	59	105.2	14,106	15,629
Brand B	28	100.5	12,795	14,485
Brand C	10.2	116.6	13,456	14,029
Brand D	89	99.8	13,245	14,200
Brand E	9.7	114.6	12,767	13,423

## PIP STS03601 Epoxy Grout Specification

### 5.1.1

Epoxy grout for equipment or machine baseplates shall meet the following physical properties (see API 610 Appendix L):

**5.1.1.1** Minimum compressive strength (ASTM C579): 12,000 psi (80 MPa) at 7 days

# ASTM C1339 Flow Box Test

FLOW Box Video



# Epoxy Grouts

Should be mixed  
according to  
manufacturers  
directions

Each type will  
have different  
yields &  
aggregate bags

# Field Modified Pumpable or Pourable Grouts

Typically, deep pour technology with reduced aggregates

## Altered physical attributes

- Accelerated exothermic reaction
- Shortened pot life
- Decreased compressive strength +/- 10% (per bag)
- Lowered compressive modulus of elasticity
- Higher Coefficient of Linear Thermal Expansion (COLTE) effects

Yield is compensated with resin system

- Hidden costs
- 1 bag = 20% to 25% of the unit, yield, or volume

## For Example:

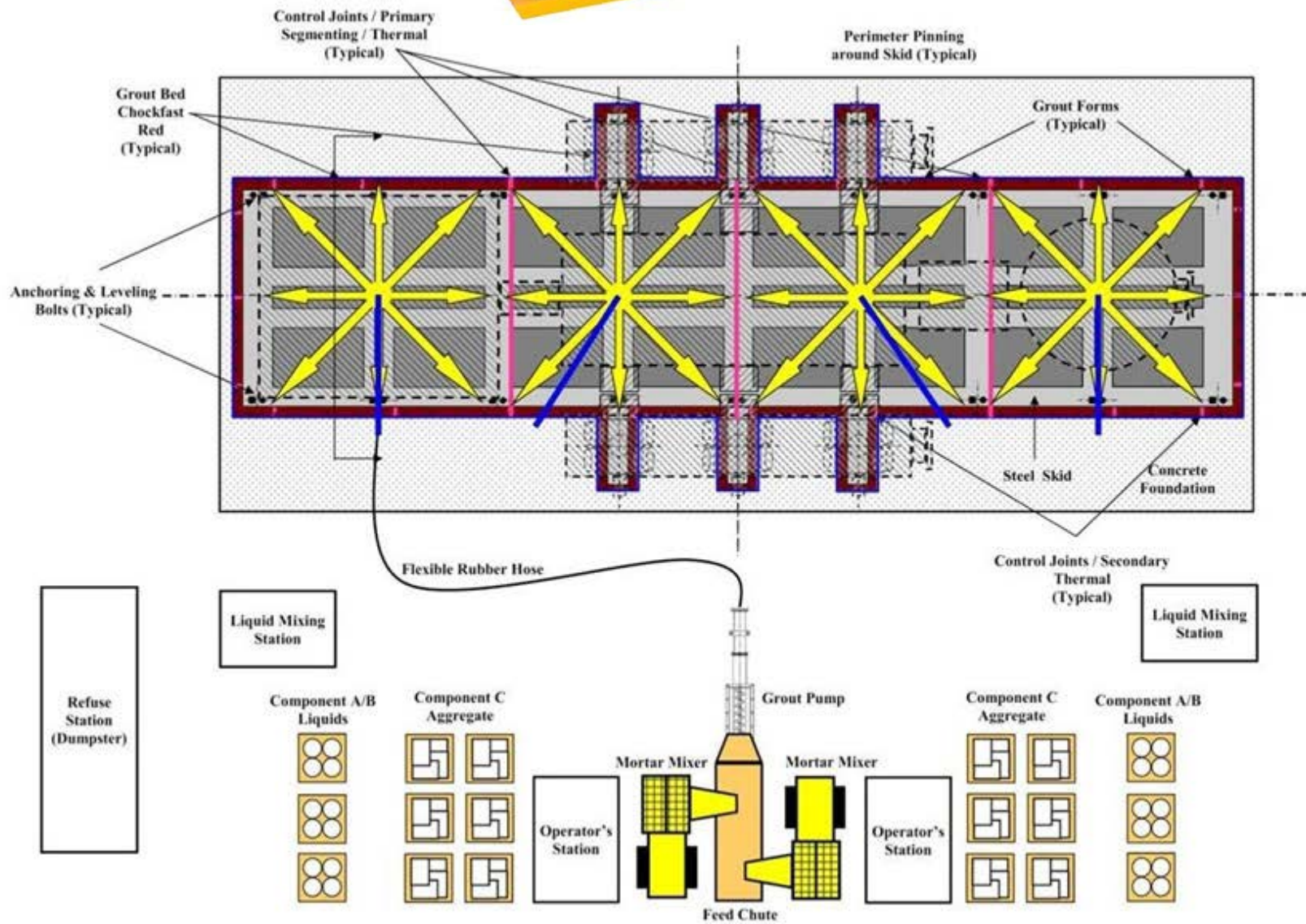
- Project Requirement: 250 standard units of epoxy grout
- \$2,203.82 AED per unit (\$600 USD)
- \$550,954.50 AED Total estimated material cost (\$150,000 USD)
  - + 55 extra cans of resin
  - + \$121,209.99 AED material costs (\$33,000 USD)
- \$672,164.49 Total final material costs (\$183,000)

# Value Engineered or Designed Pumpable Grouts

- Highly fluid three-component epoxy grout
- No reduction or manipulation of aggregate required
- Formulated to maximize installation
- Enhanced constructability
- Schedule flexibility
- Can be poured traditionally
- High effective bearing area (EBA) over 95%
- Advantageous efficiency
- Multiple stories
- Long distances
- Better ergonomics
- Develops safer practices

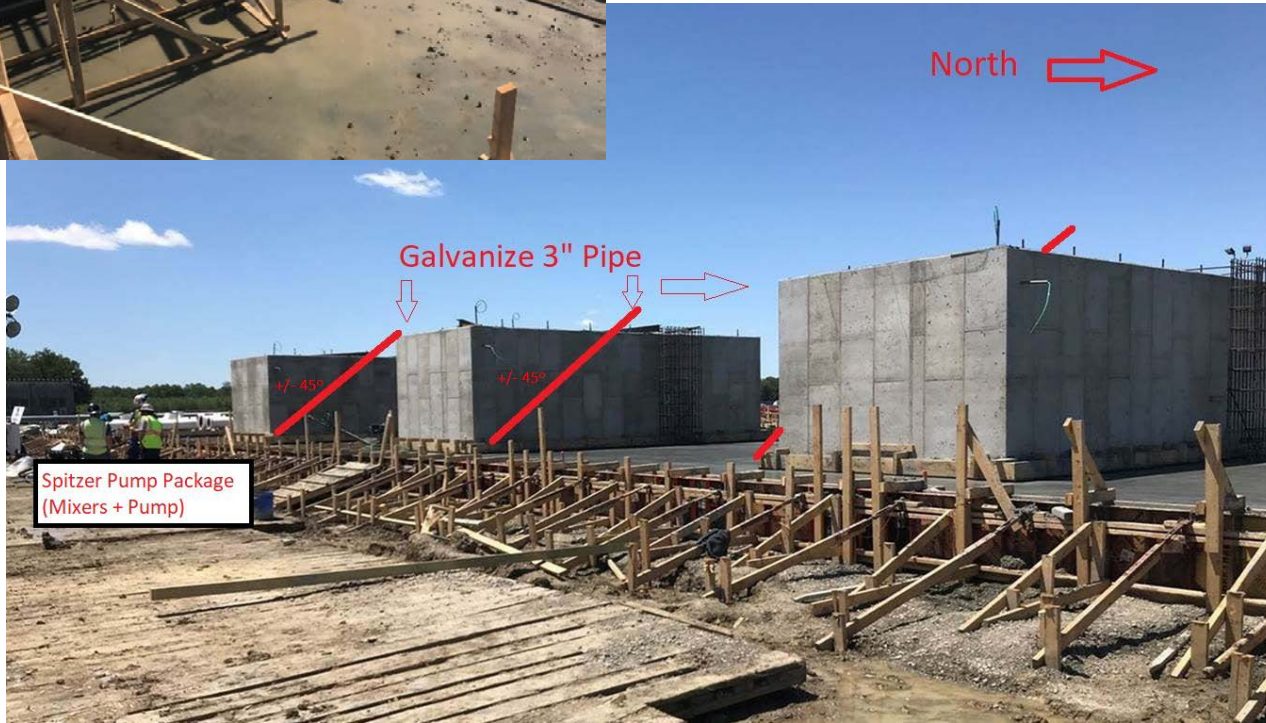
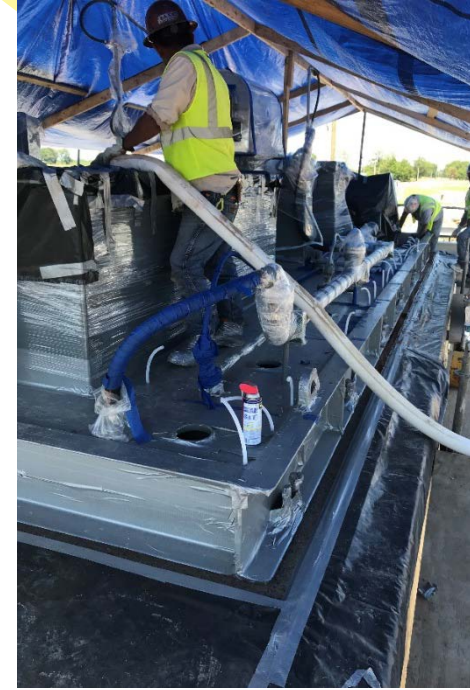
## Typical attributes

- Compressive Strength
  - +14,000 psi (97 MPa)
- Compressive Modulus
  - +1.6 x 10<sup>5</sup> psi (11 MPa)
- Tensile Strength
  - +2,300 psi (16 MPa)
- Coefficient of Linear Thermal Expansion (COTE)
  - 16 to 19.1 x 10<sup>-6</sup> in/in/°F
  - 20.1 to 34.4 x 10<sup>-6</sup> mm/mm/°C
- Bond-Steel
  - +2,050 psi (14.1 MPa)
- Bond-Concrete
  - +1,550 psi (10.7 MPa) or Concrete failure



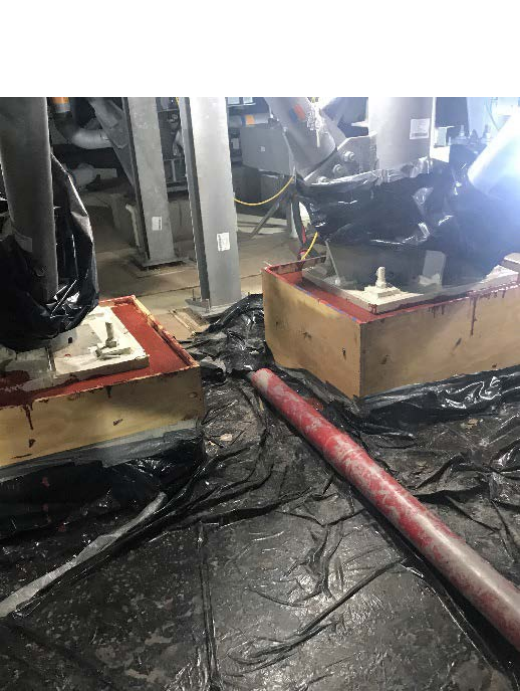


# Value Engineered or Designed Pumpable Grouts



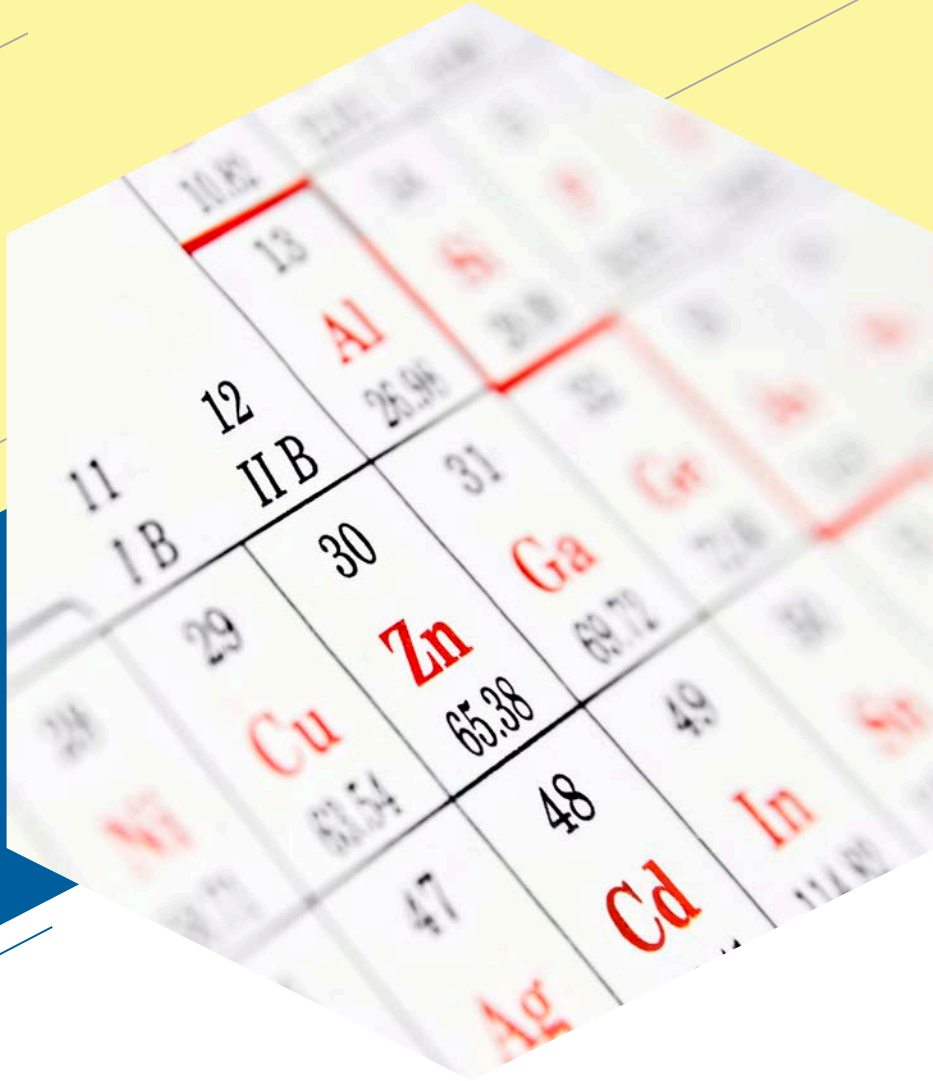


# Value Engineered or Designed Pumpable Grouts



# Extended Aggregate Systems

- Amplified yield
    - 20% to 25% per bag
  - Add  $\frac{3}{8}$ " rounded pea gravel (washed & kiln dried) or 1 extra bag of unit
  - Increased Modulus of Elasticity
    - ASTM C 579
  - Improved coefficient of linear thermal expansion (COTE)
    - Closer to steel & concrete
  - Enhanced compressive PSI strength
  - Good bondability
  - Pour depth flexibility
    - 101.6mm to 1,219.2mm (4" to 48")
  - Gentle exothermic cure
    - 24 hours
  - Better economy
- Uses**
- Foundation Block
  - Deep baseplates or skids
  - Quick turnaround
  - When you can't wait on concrete cure



# Technical Aspects of Grouting



# Equipment Foundations – API 686

- Soil-supported reinforced concrete foundations
  - Elevated machinery may be directly supported by structural steel with adequate stiffness & strength
  - Thickness is normally  $\frac{1}{5}$  the least plan dimension & less than  $\frac{1}{10}$  the largest plan dimension
  - Grout representative should be consulted to determine the maximum & minimum thickness of grout
- Follow ACI 318 Building Code Requirements for Reinforced Concrete
- Block foundations have a minimum mass of:
  - 3x the mass of centrifugal and rotary screw machinery
  - 5x-10x the mass for reciprocating equipment
- Width of foundation should be at least 1.5x the vertical distance from the base to the machine centerline
- Consider protective epoxy coatings or corrosion prevention concrete additives to avoid foundation and internal rebar deterioration
- 27.58 MPa compressive strength in 28 days (4,000 psi)
- High early concrete can be used to strip forms and place equipment sooner
  - BSA specialized concrete solutions to pour epoxy grout in 3 days vs. 28 days

# Compressive Strength

- Measure of the ability of a material to resist breaking under crush loading
- Maximum load applied before failure divided by the cross-section area
- Typical units are in lb/in<sup>2</sup> or MPa (N/mm<sup>2</sup>)
- Epoxy Grout is not Concrete

## Process Industry Practices (PIP) STS03601

- Minimum 82.74 MPa @ 7 days (12,000 psi)
- ASTM C579 Method B Modified





# Compressive Strength

- 2" (50 mm) cube specimens
- Molds to be brass or stainless steel
- The molds should have interior surfaces that are flat within 0.002" (0.50 mm)
- Mold height and width of each mold cavity must be within 50.8mm +/- 1.59mm
- Interior Sides of mold must be within 90° +/- 0.5°
- If not smooth, sand ground, or machine
- Do not cap the specimen with capping materials
- Load rate for cube 0.2 to 0.25 in/min
- In lieu of waiting 28 days, the specimen can be artificially increased by heating

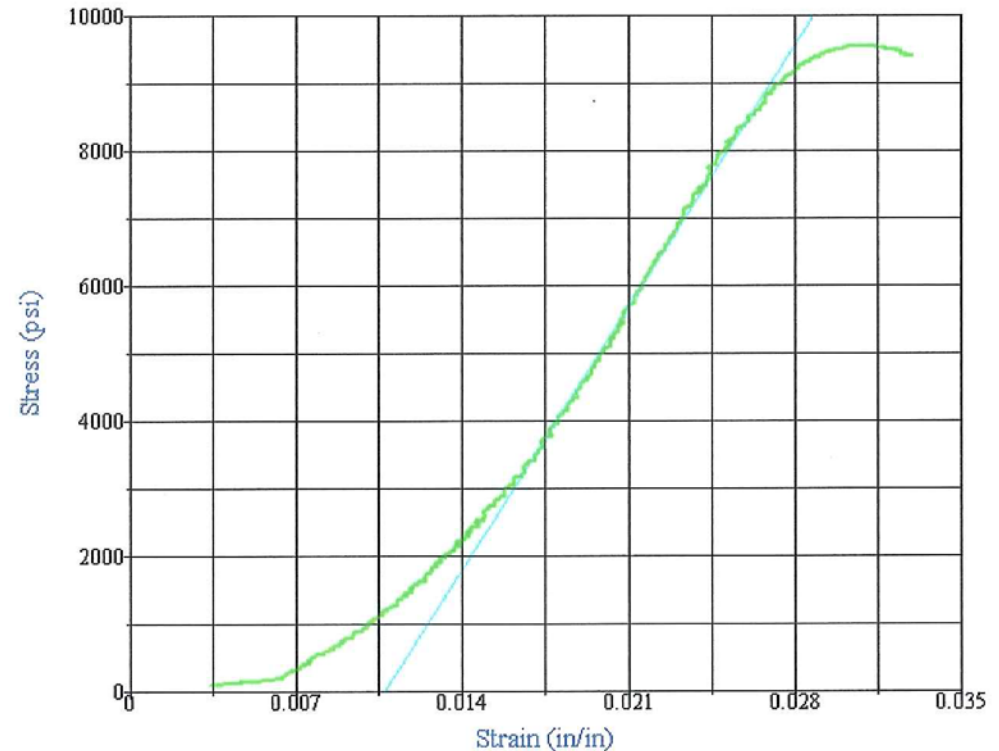


# Compressive Modulus of Elasticity

- Stiffness of a material
- Relationship of the amount of deformation that occurs when a load is applied to a material
  - A stiff material needs more force to deform compared to a soft material
- Used to predict the amount of movement when torquing anchor bolts

*Deflection =*

$$\frac{(\text{Height of Grout} * \text{Applied Compressive Load})}{(\text{Compressive Modulus of Elasticity} * \text{Contact Area})}$$



# Coefficient of Linear Thermal Expansion

## **FasTrac CE815**

$16 \times 10^{-6}/^{\circ}\text{F}$  at  $32^{\circ}\text{F}$  to  $140^{\circ}\text{F}$

## **FasTrac CE815 Super Flow**

$16 \times 10^{-6}/^{\circ}\text{F}$  at  $32^{\circ}\text{F}$  to  $140^{\circ}\text{F}$

## **FasTrac CE820 Chock**

$17 \times 10^{-6}/^{\circ}\text{F}$  at  $32^{\circ}\text{F}$  to  $140^{\circ}\text{F}$

*A similar coefficient of linear thermal expansion between grout and the mounting surface can help prevent issues in the field and allow the equipment system to act more monolithically.*

ASTM C531

# Coefficient of Linear Thermal Expansion

General Recommendations for Spacing of Expansion Joints

General Operating Environment	Expected Temperature Cycling	Joint Spacing (ft)	Joint Spacing (m)
Indoors / Climate Controlled	Low	6-7 ft.	1.8-2 m
Non-Climate Controlled Environment	Medium	5-6 ft.	1.5-1.8 m
Outdoors	High	3-5 ft.	0.9-1.5 m
Crane Rails	Medium	6-10 ft.	1.8-3.1 m

# Adhesion or Bond Strength

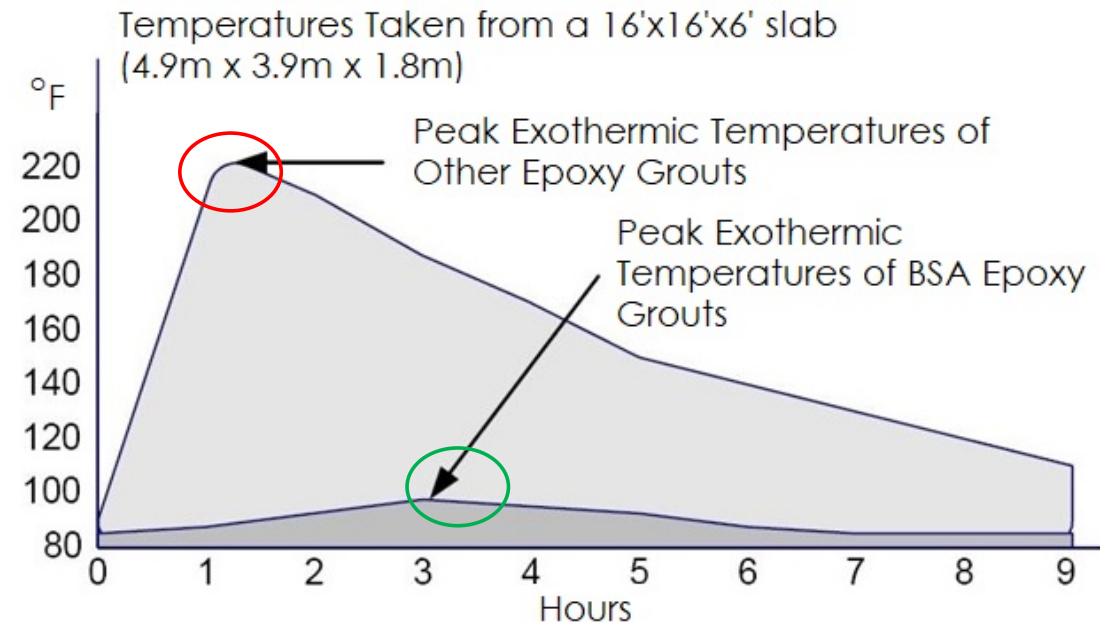
- The ability of a material to bond to a substrate
- Often depends on the tensile strength of the substrate
- Applicable Testing Standards based on material
- PIP STS03061 Minimum Bond – Epoxy Grout to Concrete = 2000 psi (14 MPa)

Material	Test	Psi	MPa
	C882 Slant Shear	3,500	24.1
	C1583 Tensile	Concrete Failure	



# Peak Exothermic Reaction

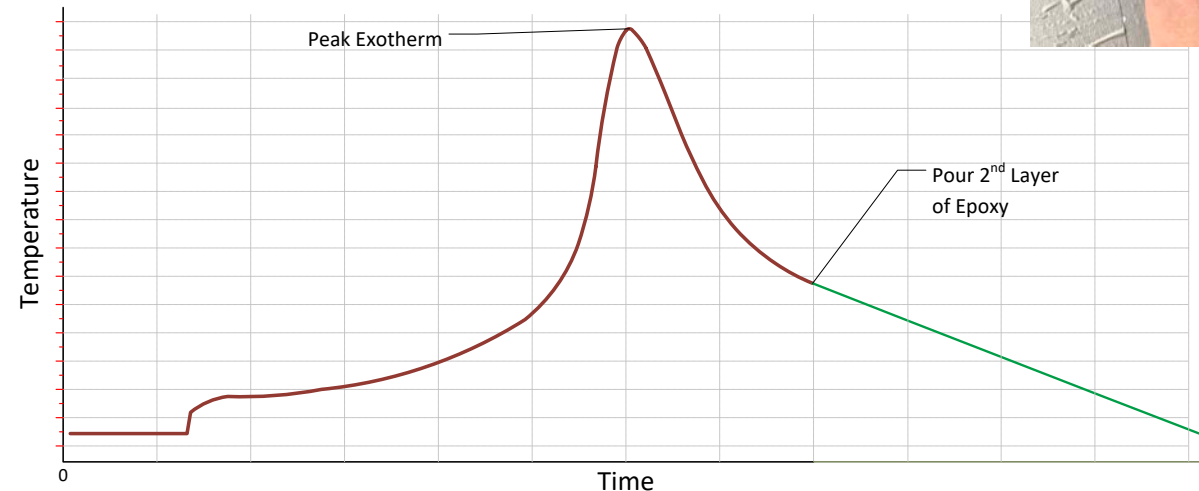
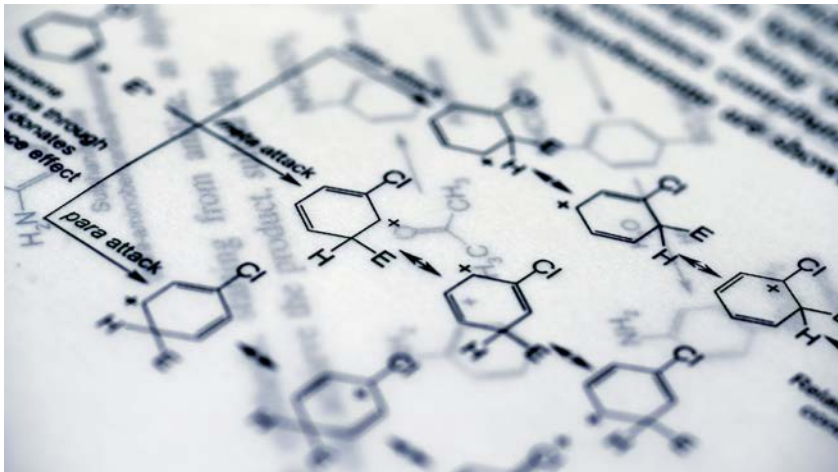
- Maximum internal temperature reached during the exothermic cycle
- Most effected by the amount of material in a location and initial temperature of material
- Higher values can lead to overexpansion and over contraction, which could lead to formation of voids and loss of surface contact
- Applicable Standards
  - Epoxy Grouts ASTM D 2471
  - Epoxy Chocks ASTM D 2471





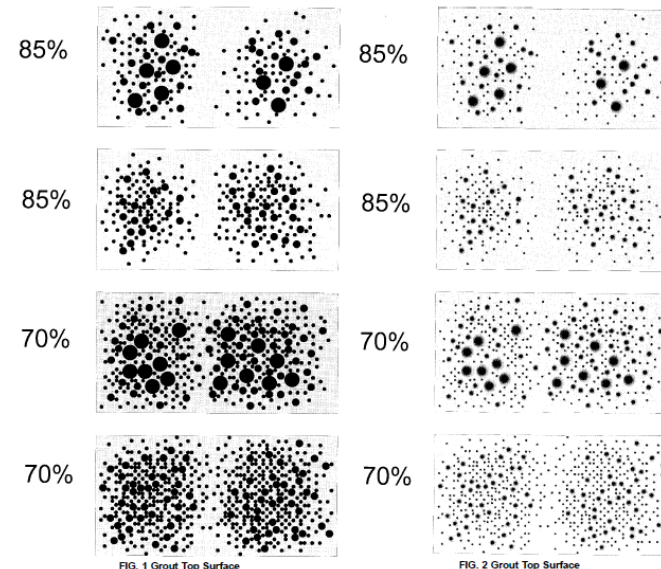
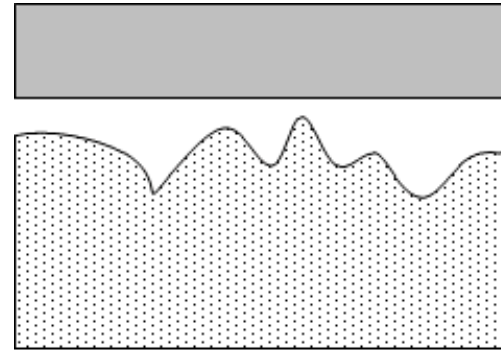
# Pouring Layers of Epoxy Grout

- Ideal time is to pour when previous layer has completed exothermic cycle and still warm, +/- 24 hours
- If more than 24 hours is exceeded:
  - Amine blush (waxy appearance) may form on surface, limiting bond creation across layers
  - Roughen surface with 40 grit sandpaper & clean
- No loss in compressive strength
- Adhesion across layers is greater than tensile strength



# Effective Bearing Area

- Concrete surface & steel baseplates have irregular surfaces
- Material is needed to fill irregularities and provide full support to base of machinery
- Percentage of surface-to-surface direct contact
- Factors that can affect EBA
  - High Exothermic Temperatures
  - Entrapped Air
  - Overpour Height
  - Size and Shape of Aggregate
  - Coefficient of Linear Thermal Expansion
  - Pot Life
  - Manipulation of yield (aggregate dose)





# Grouting Practices & Techniques

# Grouting Practices & Tips

- Pre-condition Grout
  - 48 hours
  - 65°F-95°F | 16°C-35°C
- New concrete foundations must be cured (ASTM D4263)
- No oil, grease, water, soil, debris, or etc. on foundation
- Keep dry
- Chip concrete surface
  - Exposed 50% broken aggregate
  - Pneumaticmoil/chisel bit
  - Could be ¾" to 1" peaks and valley difference (19mm-25mm)
- Bedplate
  - Clean, bright metal
  - White metal / sandblast
  - Smooth sharp edges
  - Primer
- Re-Check depth
- Analyze vent holes
- Confirm bolting designs
- Leak free form work
  - 3 coats paste wax
  - 45° chamfer edge
- Expansion joints
  - Styrofoam, neoprene, etc.
  - ½" to 2" thick (13mm-51mm)
- Review constructability



# Concrete Surface Prep



## Chip Surface

- Removal of top laitance
- Typically  $\frac{3}{4}$ " to 2" (19mm-51mm)
- Reveal 50% broken aggregate
- Pneumatic moil or chisel bit
- No jackhammers
- Bushing or scarifying the surface is not the same as chipping

## Clean Other Surrounding Contact Surfaces

## Smooth Sharp Edges

- 90° Angles Produce Cracking

# Skid or Base Surface Prep



## Best Preparation

- White Metal Sandblast
- Solvent Wash

## If not installed immediately

- Complexed zinc primer
- Applied at 3 mills or less to clean steel
- Scuff sand bottom or mounting surfaces
- Cleaned and degreased

Because zinc is more reactive than steel it corrodes first (sacrificially), before the steel. It is this mechanism that slows or prevents steel corrosion.

- Organic Zinc
- Inorganic Zinc
- Complexed Zinc
- Epoxy Zinc Primers





# Grouting Primers

## Inorganic Zinc & Paint

- Most commonly available
- Preferred for better corrosion protection
- Not recommended in structural systems
  - Low internal tensile strength
  - Higher risk of failure with base & grout
- Made using grout metallic zinc powder with inorganic polymeric liquid

## Complexed Zinc

- High quality
  - 2-Component
  - Polyamide epoxy containing complexed phosphate
- Zinc & phosphate combined at the molecular level
- Non-metallic compound with anticorrosion attributes
- Promotes adhesion of grout to steel
- Compatible to epoxy

# Analyze Vent Holes





# Analyze Vent Holes



## Verify Vent Holes

- ½" Diameter (13 mm)
- On 18" centers (457 mm)
- Look for structure elements that would block flow
- Potential air entrapment zones
- More is better

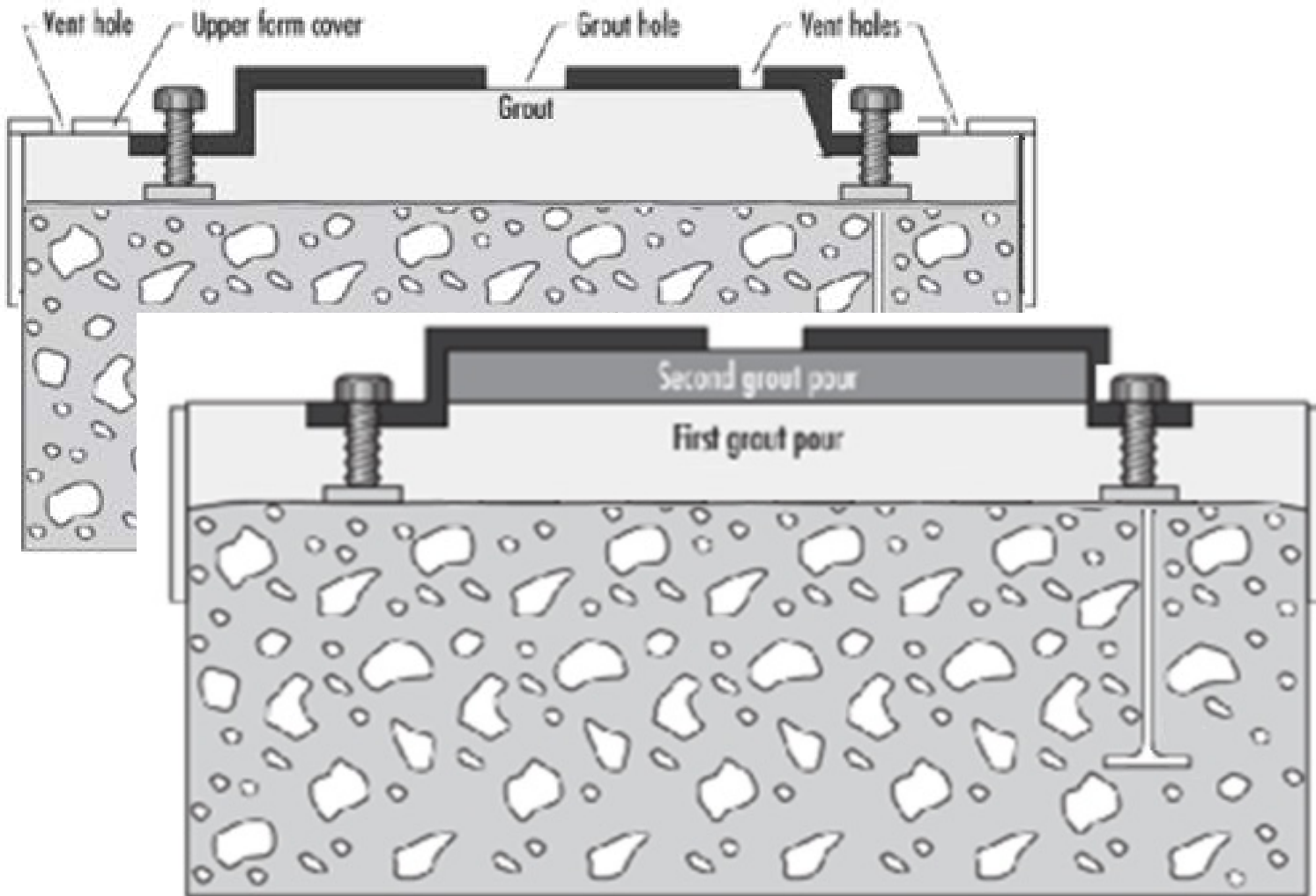
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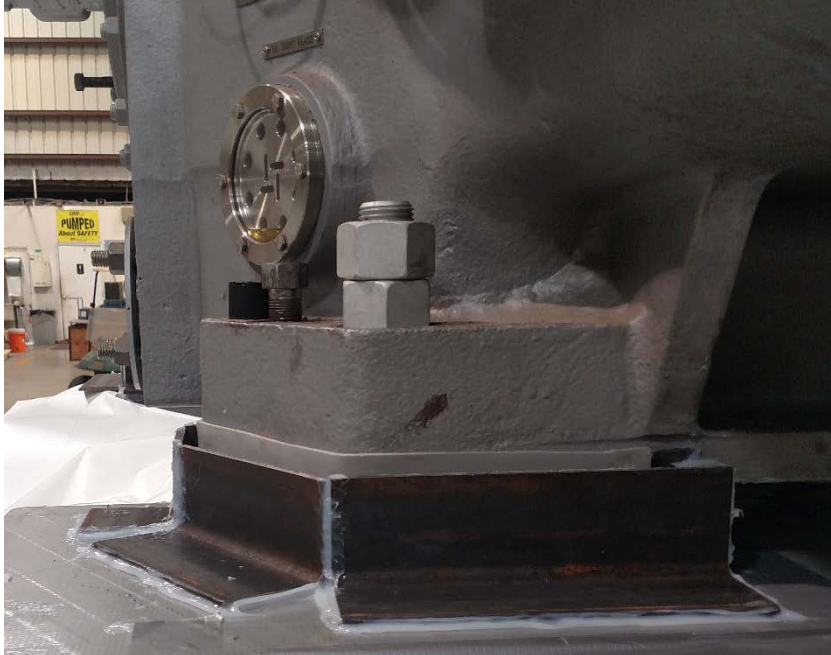
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# Leak Free Formwork





# Formwork

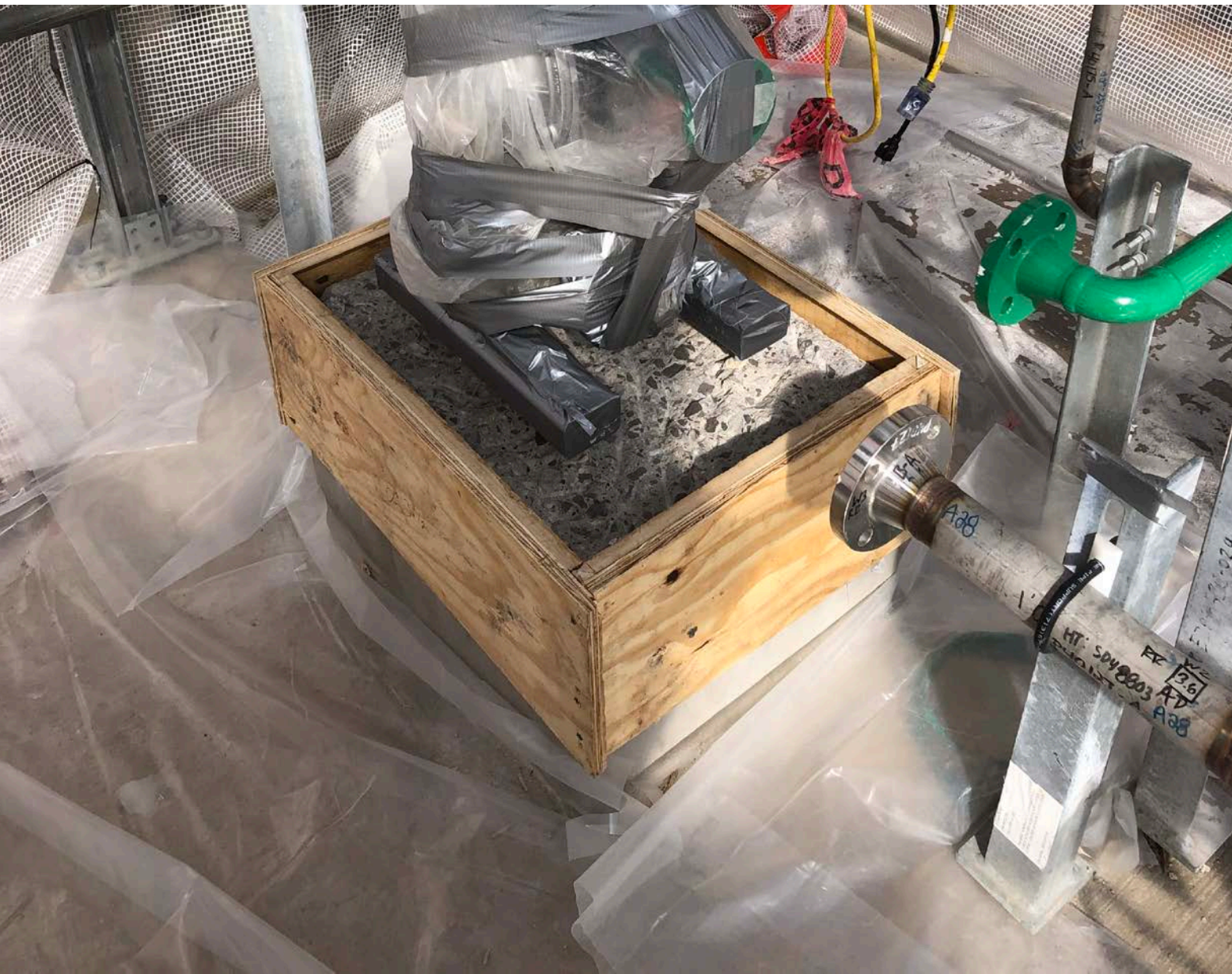


- Use headboxes
- Leak free & watertight
- 3 coats of wax
- Metal dam for chocks
- 45° chamfer edge
- No power nailing
  - Can cause concrete fractures





# Formwork



- Use headboxes
- Leak free & watertight
- 3 coats of wax
- Metal dam for chocks
- 45° chamfer edge
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  - Can cause concrete fractures

# Grouting Practices & Tips

- Adequate grout supply
- Pre-Condition working environment
  - 12 hours
- Head boxes ready
- All Bolts wrapped
  - Weather stripping + duct tape
  - Prevent grout bonding
- Proper damming
- Removal of shims/jacks
- Alignment confirmed
- Proper mixing equipment
  - Mortar Mixer
- Arrangement of proper clean up procedure
- Mix products according to manufacturer or distributor recommendations
- Seal joints
  - Expansion joint compound or polysulfide joint sealant
- Post-Condition working environment
  - 48 hours
  - Transition gradually
- Final inspection





# Grouting Practices & Tips



# Grouting Practices & Tips





# Grouting Practices & Tips





# Precondition of Grout & Environment





# Precondition of Grout & Environment

- Pre-Condition working environment and all grouting components
  - 12 hours
  - The aggregates represent 80% of your yield, climatize appropriately





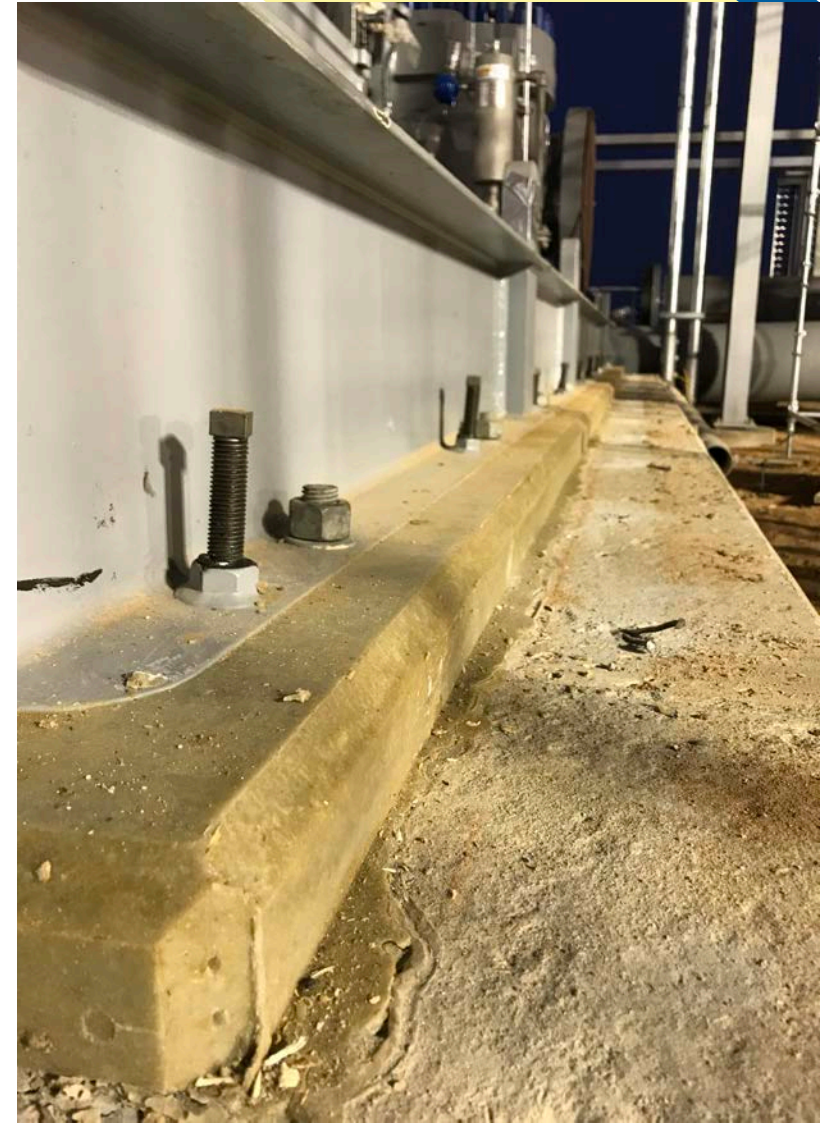
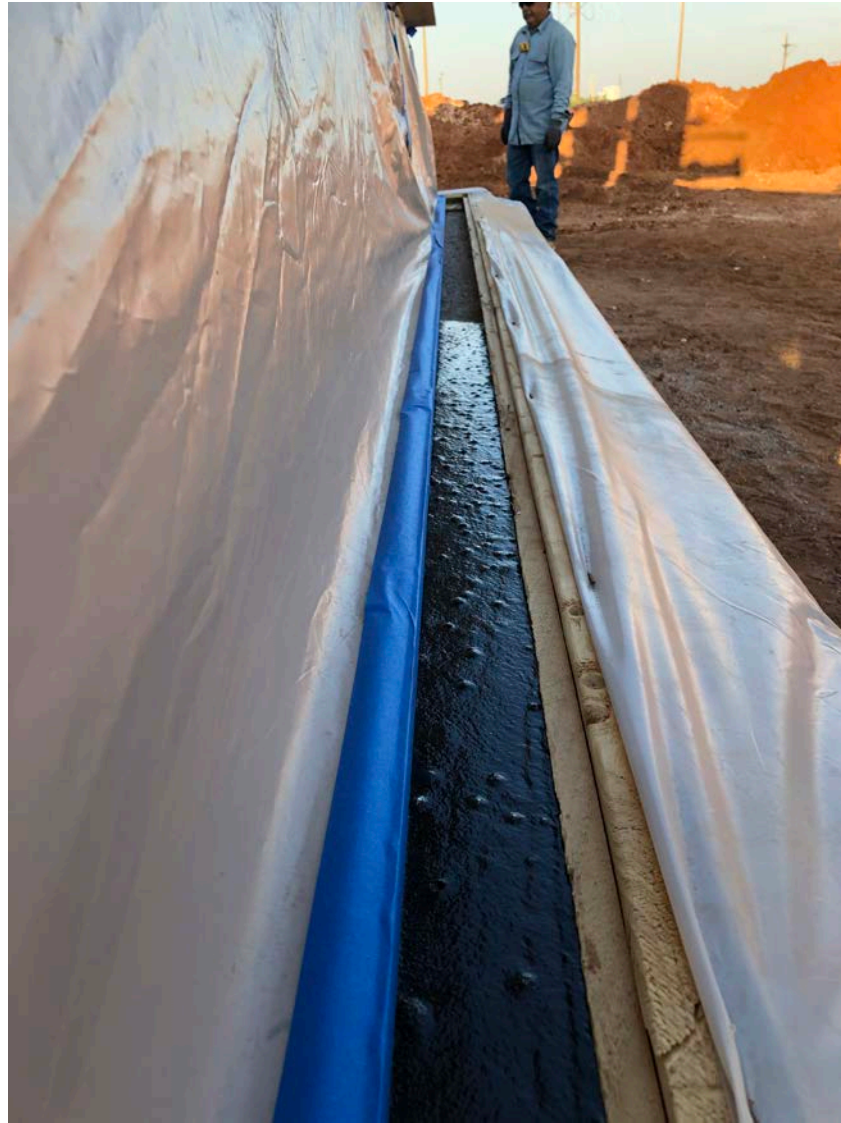
# Precondition of Grout & Environment



- Pre-Condition working environment and all grouting components
  - 12 hours
  - The aggregates represent 80% of your yield, climatize appropriately
  - Tents / Enclosures
  - Heating Blankets
  - Wind blocks
  - Heaters



# Grouting Practices & Tips





# Grouting Practices & Tips



# Grouting Practices & Tips





# Grouting Practices & Tips







## References

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