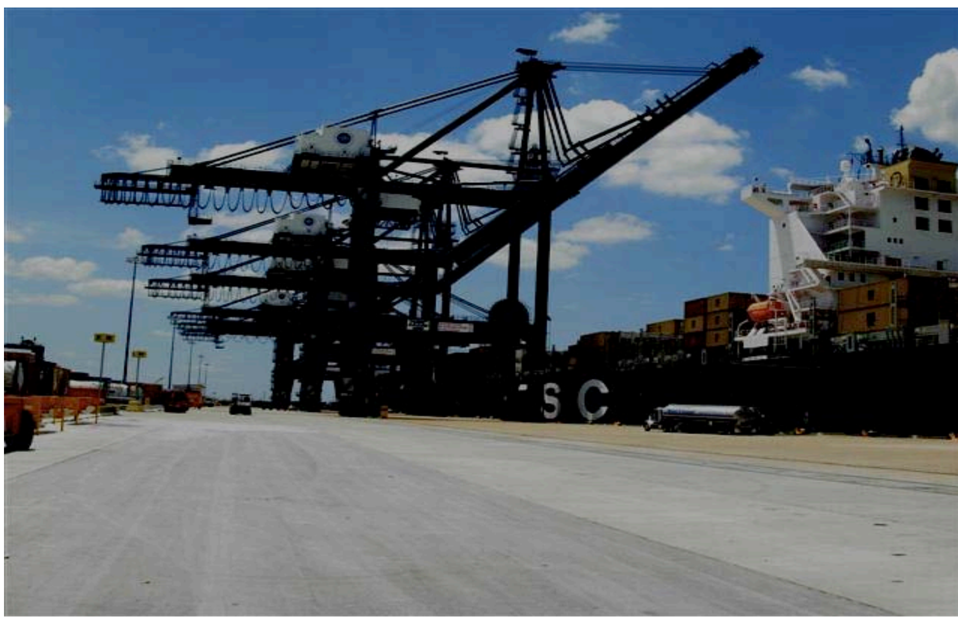
Roller Compacted Concrete Pavement

Matthew W. Singel, PE

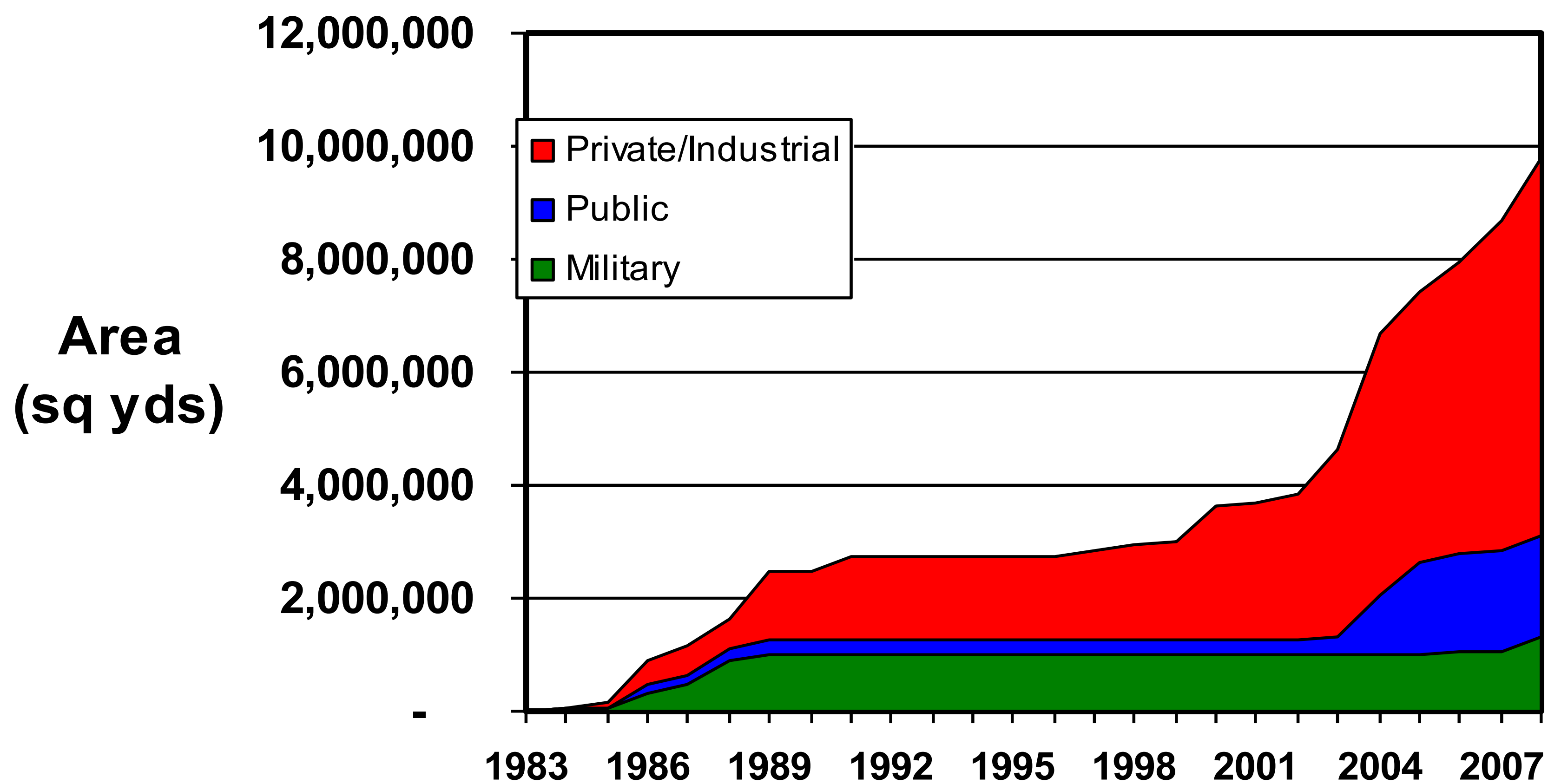



What Is RCC?

- RCC is
  - No Slump
  - No reinforcing steel
  - No finishing
  - Consolidated with vibratory rollers
- *Concrete pavement placed in a different way!*

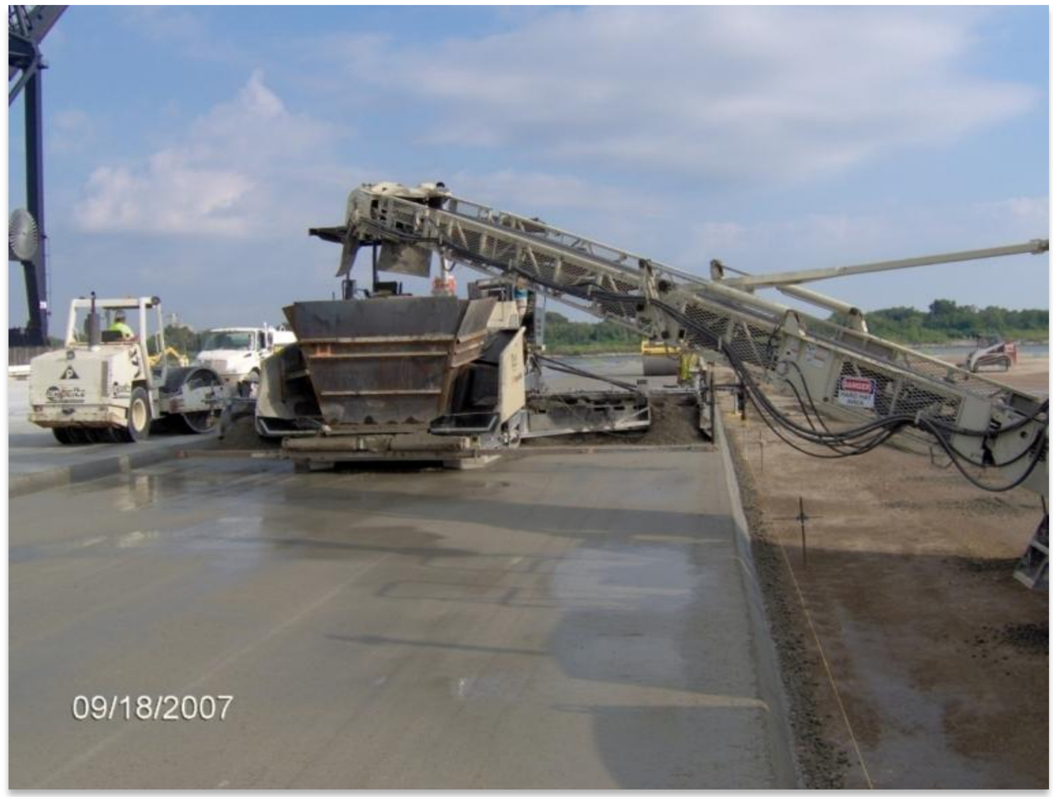
Which Sample is RCC ?

RCC Pavement Usage in the U.S.A.



RCC Speed of Construction

- ✓ No reinforcement
- ✓ No forms
- ✓ No hand finishing



Binder Selection

- Typically
  - Cement
  - Cement and flyash
- Binder content
  - 12% to 16% of aggregate weight.
- For finish
  - no less than 500 lbs per cubic yard.

Typical Mixture Design

- 450 – 550 lbs/CY Cementitious Material.
- 3400 –3700 lbs/CY Well Graded Aggregate.
- 20 – 30 gallons/CY Water.
- W/C Ratio usually between 0.3 – 0.45.
- Water amount usually dictated by Moisture/ Density Relationship.

Structural Characteristics

- Compressive Strengths
  - 4000 – 9000 psi @ 28 days.
- Flexural Strengths
  - 450 – 1100 psi.
- Strengths might be achieved with lower cement factors but surface requires fines.

Surface Texture

Highly dependent on aggregate gradation and binder content.

Surface Texture

RCC TESTING

- Laboratory Mix Design
- Test Section
- Q/C Testing during Construction

TEST METHODS

Method	Mix Design	Test Section	Production
Aggregate Gradation, SG and Abs.	yes	yes	yes
Moisture Content	yes	yes	yes
Temperature	yes	yes	yes
Consistency-Modified Vebe Test	not often	not often	not often
Modified Proctor Compaction Test	yes	yes	yes
Compressive Strength of Cylinders	yes	**yes**	**yes**
Compressive Strength of Cores	no	**yes**	only if needed[1]
Flexural Strength of Beams	No	**yes**	only if needed[1]
Density by Nuclear Gauge	no	**yes**	**yes**

[1] These tests may be performed if test results of molded cylinders are below specified st

WHY TEST SECTIONS

- Demonstration of equipment and procedures for mixing, handling and placing
- Establishment of compaction procedures
- Evaluation/fine tuning of mixture
- Training for Q/C and construction personnel
- Development of Q/C correlation factors

SAMPLING AND TESTING AT TIME OF PLACEMENT OF TEST SECTION

- Density and moisture content using nuclear gauge
  - Single probe
- Dry back moisture content
- Molded RCC specimens
  - Molded cylinders with vibratory hammer (ASTM C 1435)
  - Molded beams with vibratory hammer (use Army Corp Method….ASTM not currently available)

STRENGTH TESTING PROGRAM TO DEVELOP CORRELATION FACTORS

Test Location	A		B	
Age, days	7	28	7	28
No. of molded cylinders	3	3	3	3
No. of drilled cores	3	3	3	3
No. of sawed beams	3	3	3	3

COMPRESSIVE STRENGTH OF MOLDED CYLINDERS (ASTM C 1435)

(Three Layers)

COMPRESSIVE STRENGTH OF MOLDED CYLINDERS (ASTM C 1435)

(Five Layers)

DRILLED CORES

FLEXURAL STRENGTH OF BEAMS
(ASTM C 78)

FLEXURAL STRENGTH OF BEAMS
(ASTM C 78)

SUMMARY OF TEST RESULTS FROM THREE TEST SECTIONS

Test Section	Pavement Design Thickness (in.)	Test Location	Age (days)	Comp. Str. of Cyl. (psi)	Comp. Str. of Cores (psi)	Flexural Str. of Sawed Beams (psi)	Correlation Factor Cylinders, C_{cy}[1]	Correlation Factor Cores, C_{co}[1]
1	9	A	8	5190	2590	390	5.4	7.7
		B	8	4010	2510	420	6.6	8.4
			31	5310	2880	450	6.2	8.4
2	9	A	9	4690	3210	675	9.9	11.9
			28	4520	3680	710	10.6	11.7
		B	9	4520	2550	610	9.1	12.2
			28	4400	2740	660	8.9	12.6
3	7	A	9	6760	5990	750	9.1	9.7
			28	9550	6700	925	9.5	11.3
		B	9	6290	5090	670	8.4	9.4
			28	7750	6000	780	8.9	10.1

[1] Ccy and Cco are based on ACI's empirical formula $R= C(f_c)^{0.5}$

Note: Highlighted values represent minima and maxima of data ranges

Test Section

- Highly desirable, especially for larger projects
- Contractor develops rolling requirements with actual equipment and approved mix
- Assures contractor's ability to
  - Place and compact RCC to appropriate density
  - Construct fresh, cold, and (if required) horizontal joints
  - Demonstrates surface quality and smoothness
  - Cores and/or beams can be cut for strength correlation

Subgrade/Subbase Preparation

- **Must be stiff to allow full compaction of RCC**
- **Stable subgrade and subbase** (if specified)
- **Must be smooth and at specified grades**
- **Block off fixtures**
- **Set up stringlines** (if necessary)
- **Moisten subbase prior to RCC placement**

Basic Construction Sequence

- Produce RCC material
- Transport by dump trucks
- Place with an asphalt paver
- Compact by steel drum (and sometimes) pneumatic-tired rollers
- Cure with water or curing compound

Production

Continuous Pug Mill

- High-volume applications
- 250 to 1,000 tons/hr
- Mobilize for large projects (25,000 sy+)

Central Concrete Batch Plant

- Highly accurate proportioning
- Local availability (larger metropolitan areas)
- Output for average size projects

  (< 5 acres)

Dry Concrete Batch Plant

- **Highest local availability**
- **2-step process**
  - **Feed into transit mixers**
  - **Discharge into dumps**
- **Reduced production** (unless admixtures used)
- **Most Flexible - Allows producer to service other customers between batches of RCC**

Continuous Mix Pug Mill

- High-volume applications
- Excellent mixing efficiency for dry materials
- 250 to 1000+ tons/hr
- Mobile, erected on site
- Higher mobilization costs

Continuous Pug Mill

Mixing Chamber

Transporting & Placing

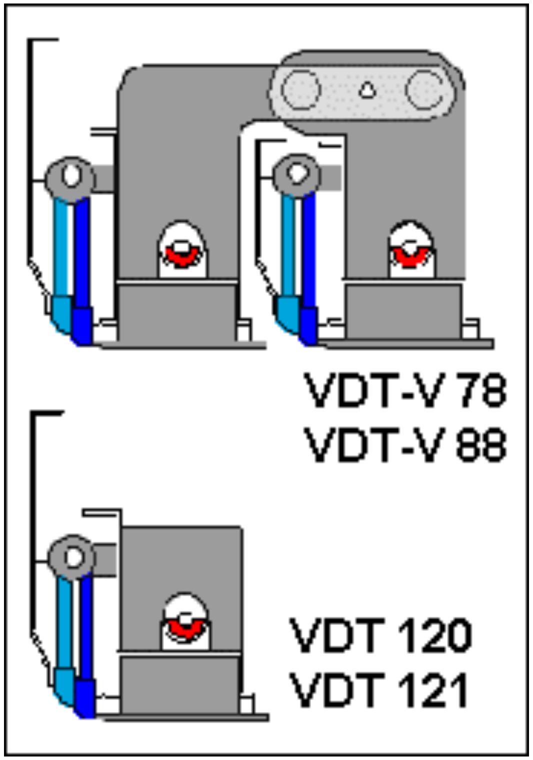
Placing

- Layer Thickness
  - 4 in. Minimum Thickness.
  - 9 – 10 in. Maximum Thickness in a single lift.
- Timing Sequence
  - **Adjacent lanes placed within 60 minutes for “fresh joint”**
  - **Multiple lifts placed within 60 minutes for “fresh joint”**
  - Note: times can be increased with admixtures, positive weather conditions, etc.
- Production should match paver capacity
  - Continuous forward motion for best smoothness

Placing Equipment

- **High density pavers**
  - **Vibrating screed**
  - **Dual tamping bars**
  - **High initial density, 90-95%**
  - **Reduces subsequent compaction**
  - **High-volume placement (1,000 to 4,000 cubic yards per shift)**

High Density Screed



Screed uses Dual Tamping Bars and Vibrators to Achieve initial density.

Wide Paving Widths

Paving widths up to 35 feet at 9 inches thick

Paving Train

Paving Train

Compaction-Final Density

- Final density is critical for strength and durability
- Compacted to 98% Modified Proctor
- Rubber-tire roller
- DD 130 steel wheel
- Rubber coated steel drum roller

Concrete Curing Compound

- White-pigmented concrete curing compounds
- Apply at 1 to 1 ½ times the normal application rate for conventional concrete pavement.

Moisture/Density Relationship

- Develop Proctor Density using proposed mixture design.
- Evaluate moisture-density and density-strength relationships in the test section.
- Most slabs require 98% compaction throughout the slab to achieve proper flexural strength.

Nuclear Gauge - ASTM C1040
[Direct Transmission]

Strength Testing

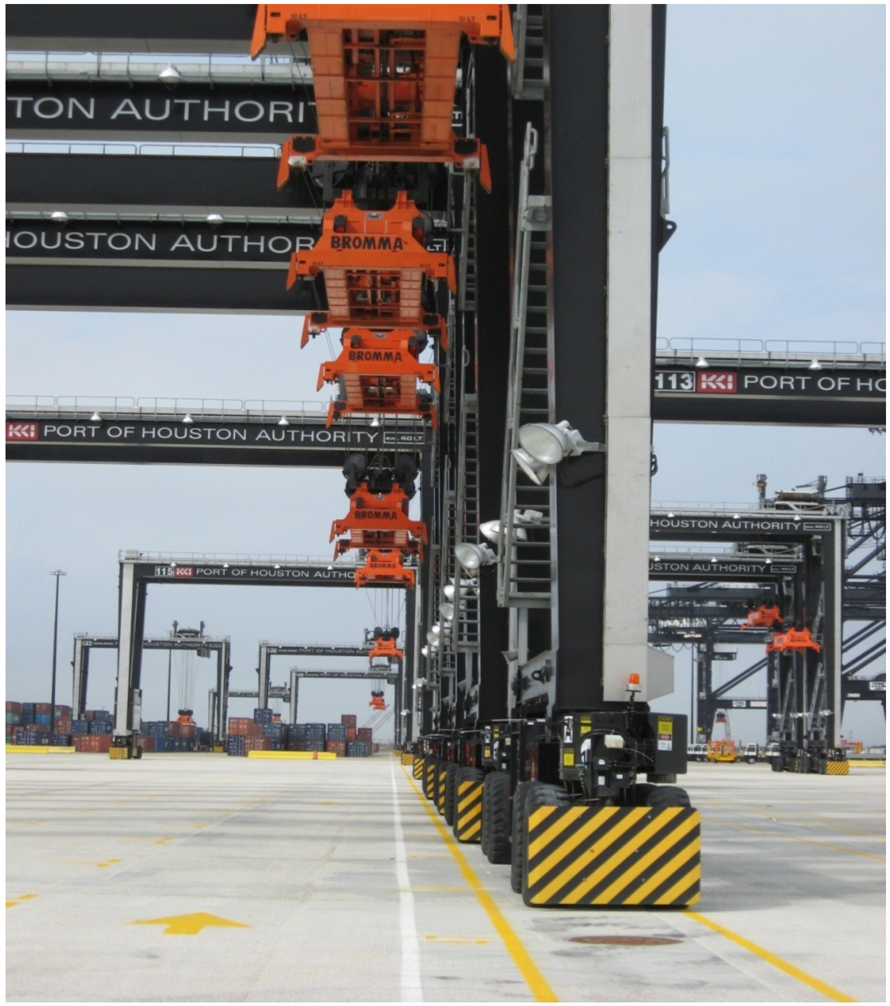
- Fabricating Cylinders
- With Vibrating Hammer
- ASTM C1435

Port of Houston Authority Pavement Requirements

- ✓ Heavy Duty Pavements
- ✓ Durability
- ✓ Low Maintenance
- ✓ Level Surface
- ✓ Speed of construction
- ✓ Low Cost

Bayport Phase 1 Container Yard

Heavy Duty Pavement



Heavy Loading from Rubber Tire Gantry (RTG)

Heavy Duty Pavement

Point Loads from Container Corner Castings

Heavy Duty Pavement

Loaded Containers (Max. 5 High)

Containers & Equipment

PACECO 16-WHEEL

Rubber Tired Gantry (RTG) Cranes

Containers & Equipment

THDC 955
-courtesy the Taylor Group

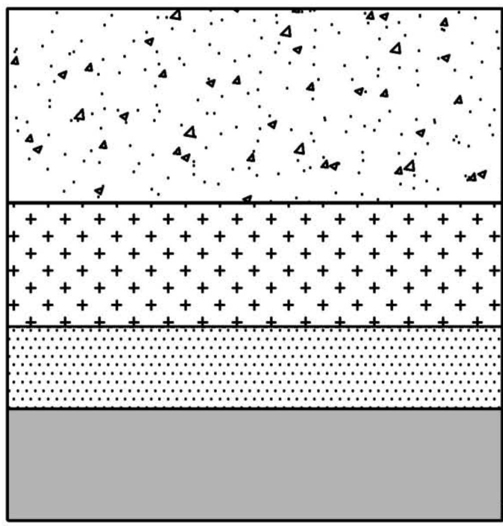
-courtesy the Taylor Group

"Top Pick" Lifts

Subgrade Design

Both Lime (5%) & Cement (5%) Stabilization

RCC Pavement Section Components



18” RCC Surface

12” CTB w/ Recycled concrete

4” Drainage Layer

8” Stabilized Subgrade

[redacted]

1

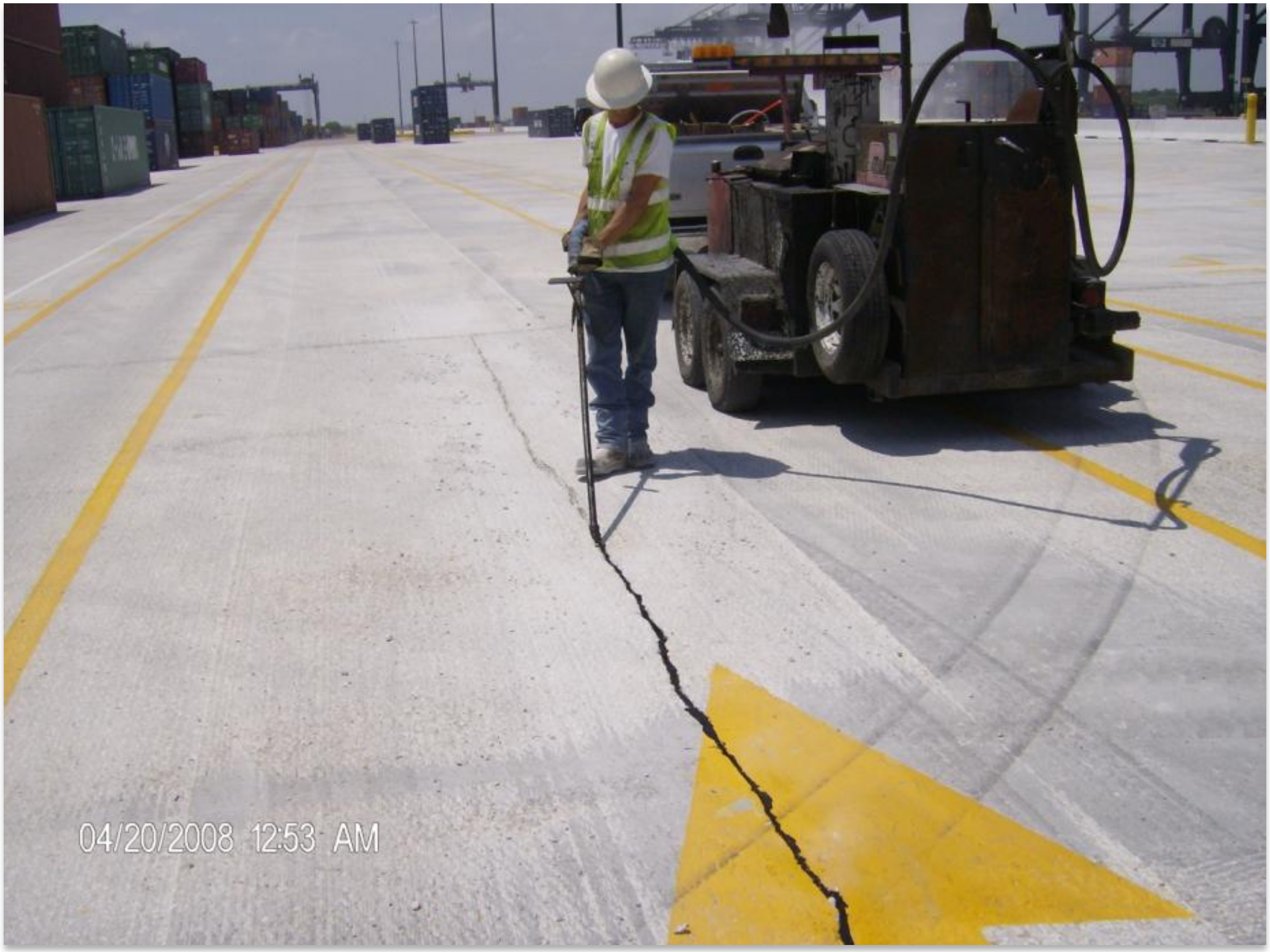
SCALE: NTS

FOR LOCATION SEE SHT. C–231 THRU C–239

GROUNDED CONTAINER STORAGE

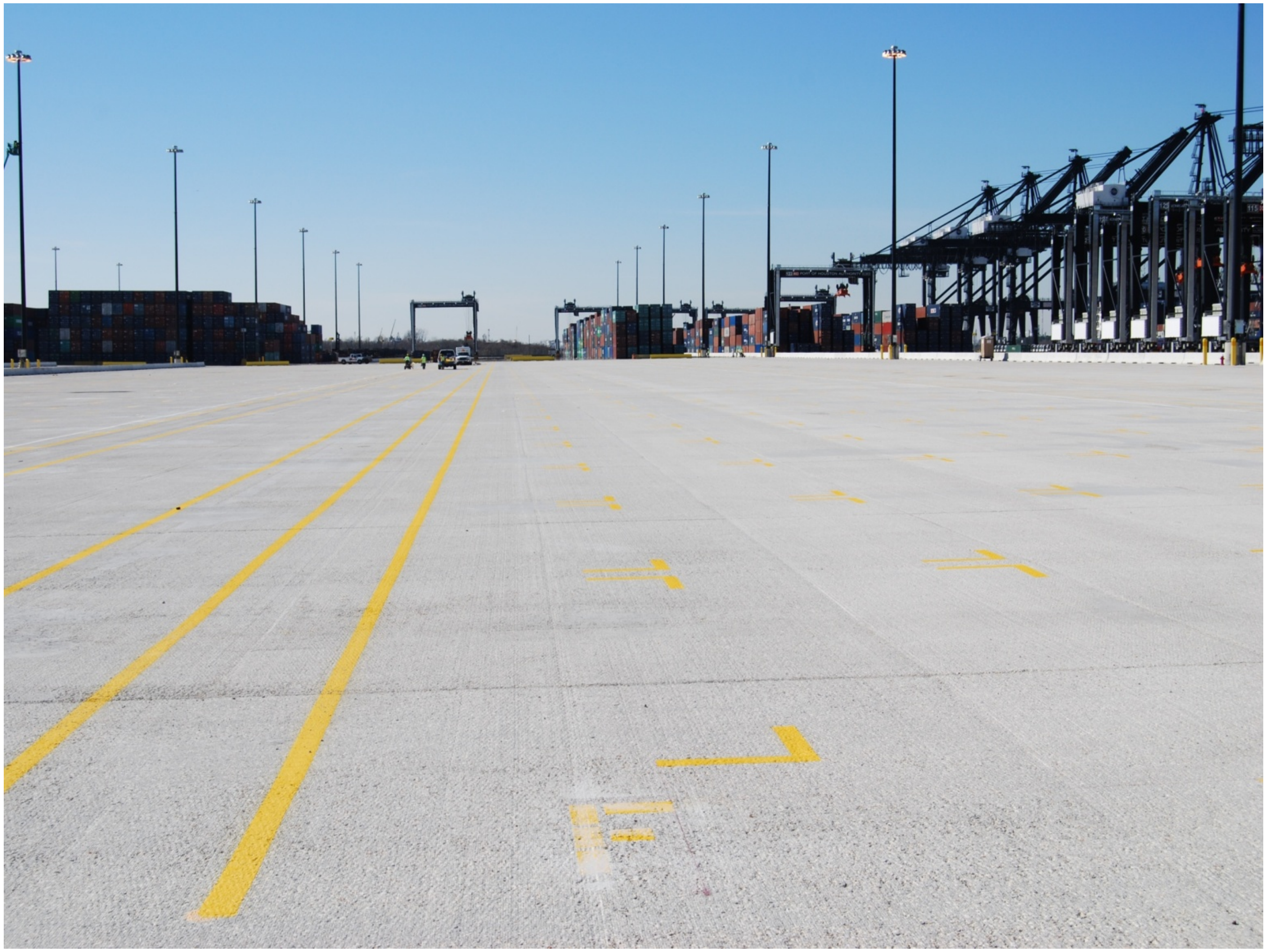

AGGREGATE
HIGHWAY DIVISION
WE CAN DRILL IT
WE CAN PULL IT
1203

Low Maintenance



Cracking

Level Surface



Surface After Grinding

Time Comparisons

50 Acre Container Yard using conventional methods of concrete placement

17 Month Project

VS.

50 Acre Container Yard using Roller Compacted Concrete

11 Month Project

Cost Comparisons

Example:

50 Acre Paved Container Yard Project Comparisons

18" Reinforced Concrete Paving - $80.00 SY

14" Reinforced Concrete Paving – $68.00 SY

VS.

18" RCC Concrete Paving - $50.00 SY

14" RCC Concrete Paving - $40.00 SY

POH Bayport Terminal
Houston, Texas

45 Acres in 2007

POHA Bayport Terminal Phase I Section I

- Project Let 2006
- Project built 2007
- 50 Acres of RCC Pavement
- Anticipated construction time savings: 4 months
- Exceeded time estimated time savings by over a month

Central Freight
Austin, Texas

10 Acres in 1987

Border Station Brownsville, Texas

15 Acres in 1998-99

Port Staging Site
Corpus Christi, Texas

2 Acres in 1993

POH Bayport Terminal Houston, Texas

45 Acres in 2007

Cement Council of Texas

Thank You!

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Which Sample is RCC ?