Characteristics of Concrete Linked to Ballistic Resistance
Design of Testing Materials

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Agenda

- INTRODUCTION
- OBJECTIVES
- METHODOLOGIES
- RESULTS
- CONCLUSIONS
- REFERENCES
- ACKNOWLEDGEMENTS

Introduction

Main Project Mission:

- Attempt to isolate the effects of cementitious matrix strength and fiber reinforcement on the ballistic resistance of concrete, using ERDC's Cor-Tuf UHPC as a basis.

Ductal

Cor-Tuf

Normal Concrete

HSC

UHPC

Introduction

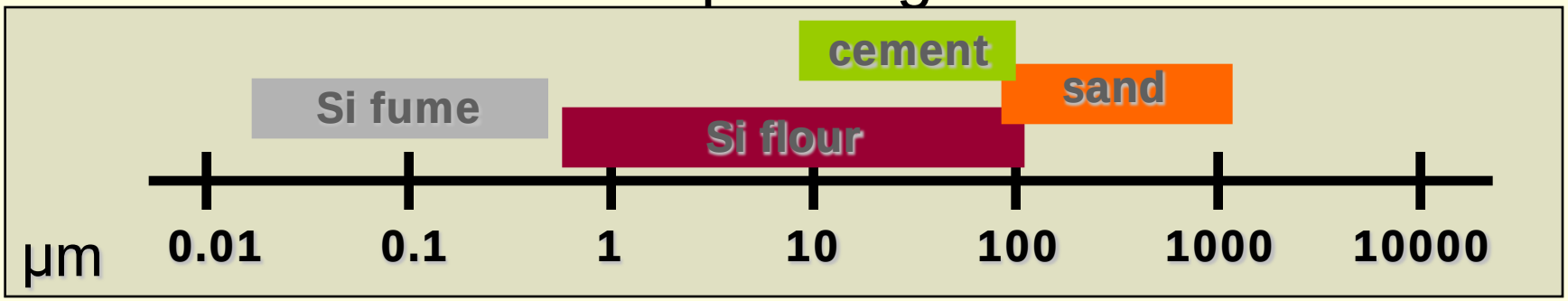
Ultra High Performance Concrete (UHPC):

- Compressive strength greater than 150 MPa (21.7 ksi)
- Internal fiber reinforcement
- High binder content with special aggregates
- Very low water/cement ratio and high-range water-reducing admixtures

Introduction

Corps of Engineers' **Cor-Tuf** UHPC:

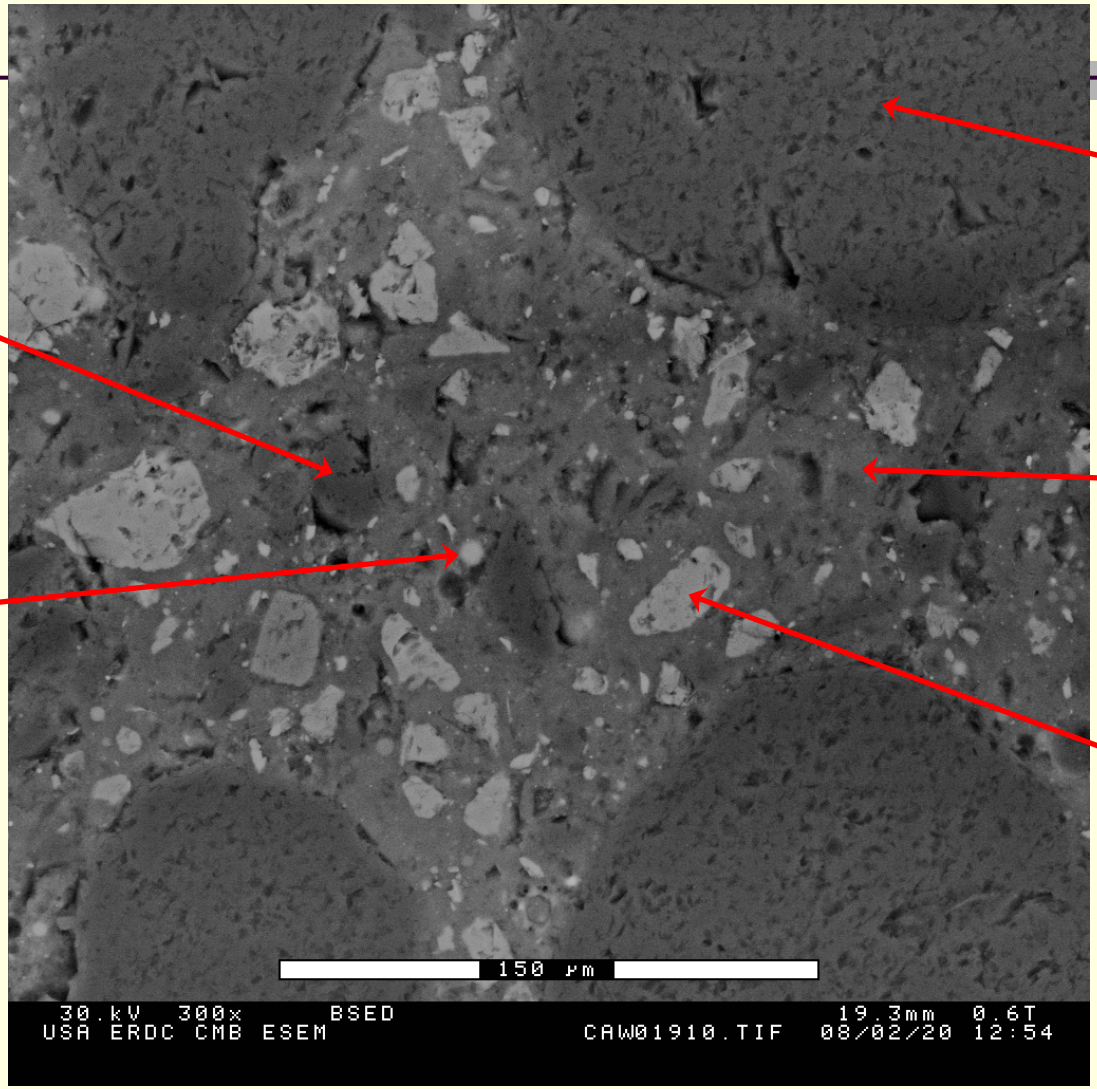
- No coarse aggregate
- Dense Particle packing



- Superplasticizer
- Low w/c ratio (0.22)
- Ambient cure up to 20,000 psi
- Heat cure up to 30,000 psi

Cement	Sand	Silica Flour	Silica Fume	Superplasticizer	Water	Fibers
31.6	30.6	8.8	12.3	0.4	6.6	9.8

Scanning Electron Micrograph of Cor-Tuf



Sand

Silica Flour

CSH Paste

Silica Fume

Unhydrated Cement Grain

Objectives

- Create a set of cementitious materials having nearly the same mineralogy and paste morphology as the UHPC CorTuf, while ranging in unconfined compressive strength from 5 to 30 ksi.
- Develop a curing process for Cor-Tuf UHPC and the new materials that will decrease the curing time, while acquiring the same material properties.
- Fabricate thin panels with different strengths and with fibers in order to test their ballistic performance.

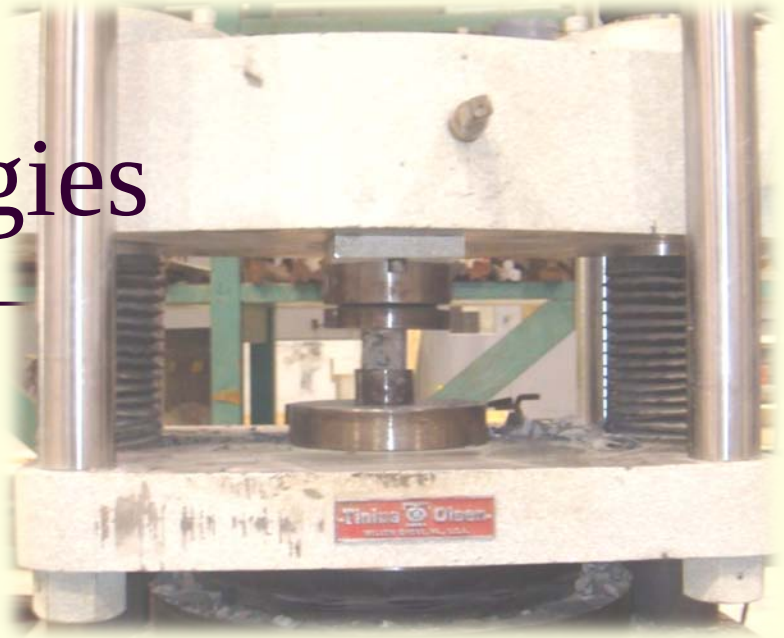
Methodologies

Experiment Setup:

- Variables:
  - Compressive Strenght
    - ✓ 5 ksi
    - ✓ 17.5 ksi
    - ✓ 30 ksi
  - Reinforcement

- ✓ NF
- ✓ F1 Dramix ZP305
- ✓ F2 Baumbach

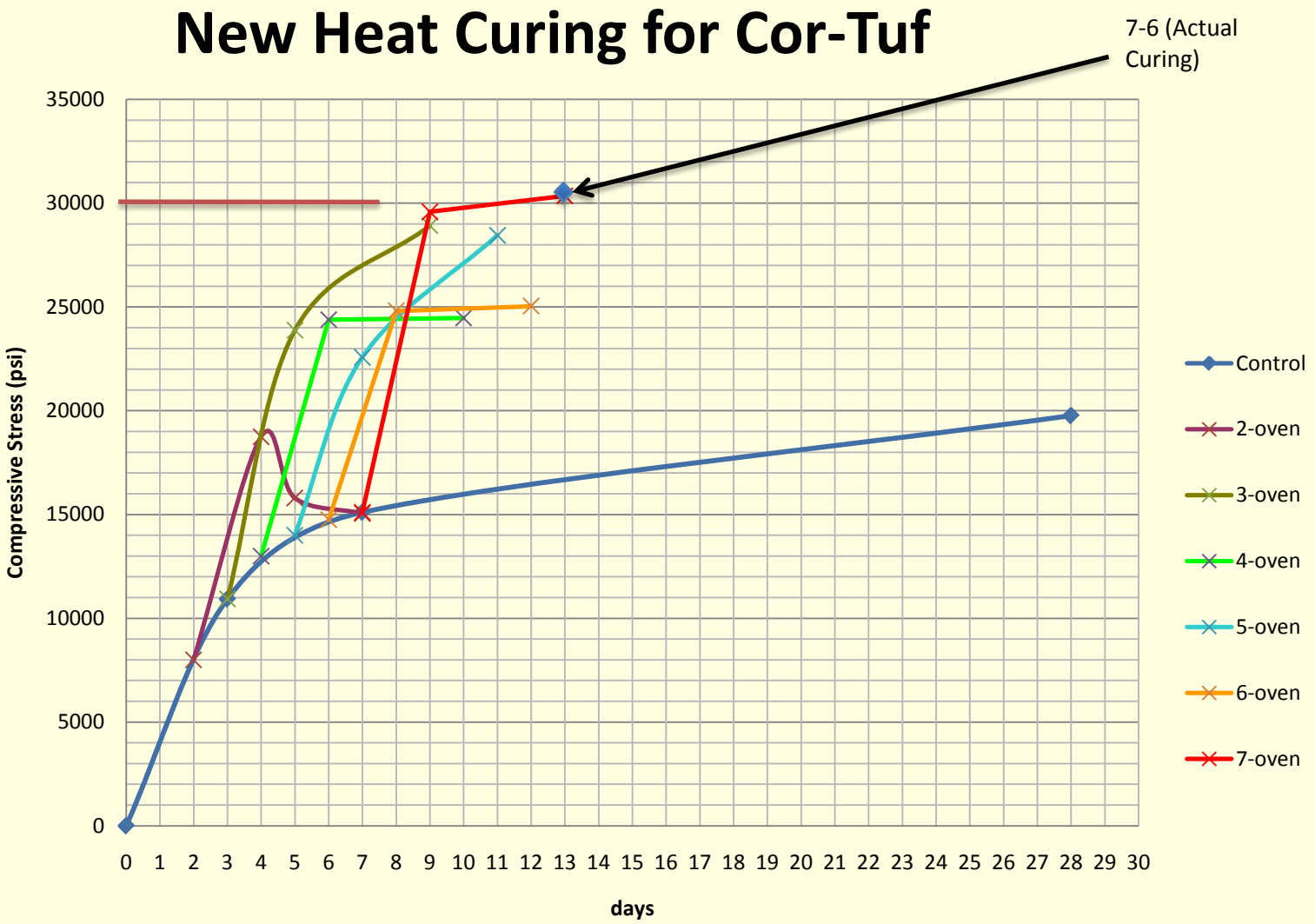
Methodologies



- Mixes were done varying:
  - ✓ w/c ratio
  - ✓ binder and aggegate content
  - ✓ curing process
- Specimens were collected and tested at:
  - ✓ 3 days
  - ✓ 7 days
  - ✓ 28 days
  - ✓ heat time
- Cor-Tuf mixes were tested at:
  - ✓ 2-2
  - ✓ 2-5
  - ✓ 3-2
  - ✓ 3-6
  - ✓ 4-2
  - ✓ 5-2
  - ✓ 5-6
  - ✓ 6-2
  - ✓ 6-6
  - ✓ 5-6
  - ✓ 6-2
  - ✓ 6-6
  - ✓ 7-2
  - ✓ 7-6

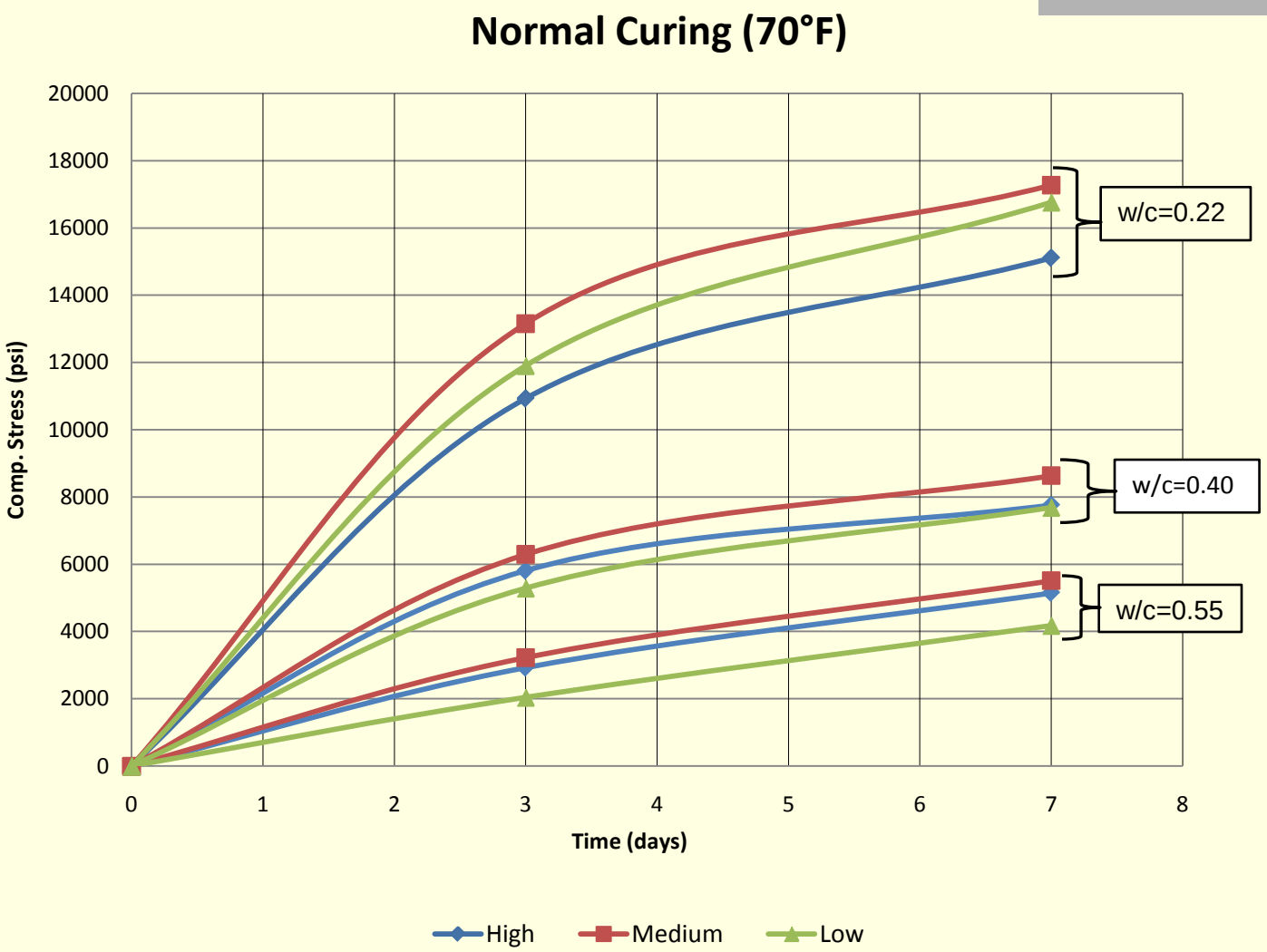
	Cementitious Material (%)	Cement Content (%)	Aggregate (%)
High	53	38	47
Medium	47	36	53
Low	40	33	60

Results

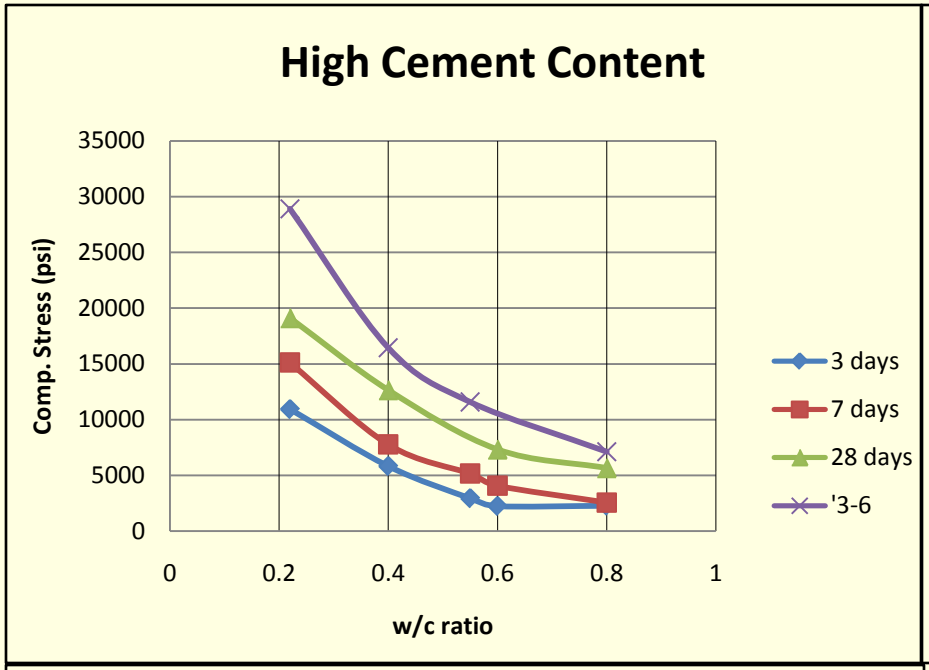


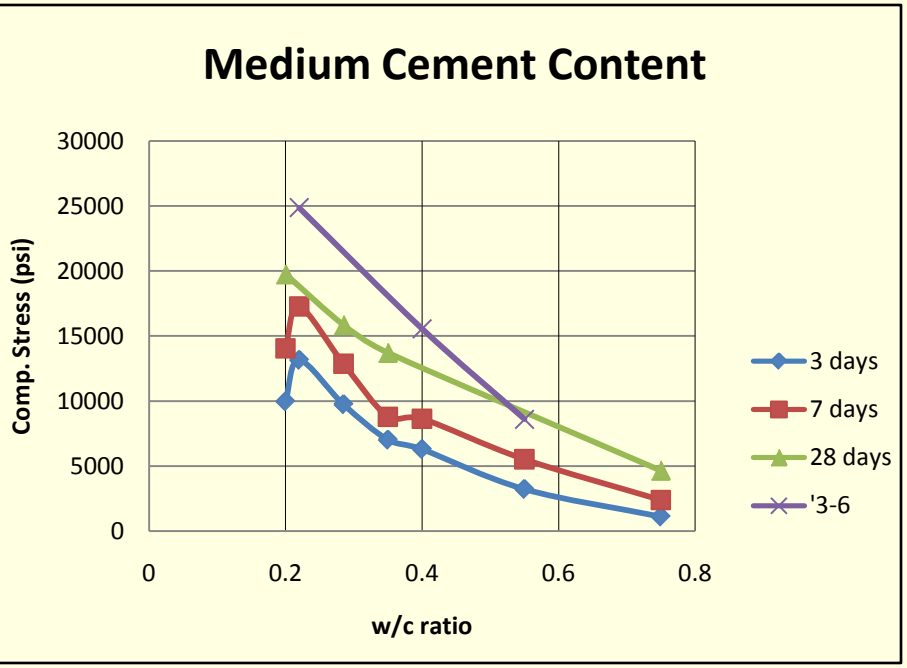
w/c	cement	3	7	28	2-2	2-5	3-2	3-6	4-2	4-6	5-2	5-6	6-2	6-6	7-2	7-6
0.22	H	10930	15108	19767	18749	15058	23881	28917	24390	24472	22571	28448	24814	25039	29581	30347

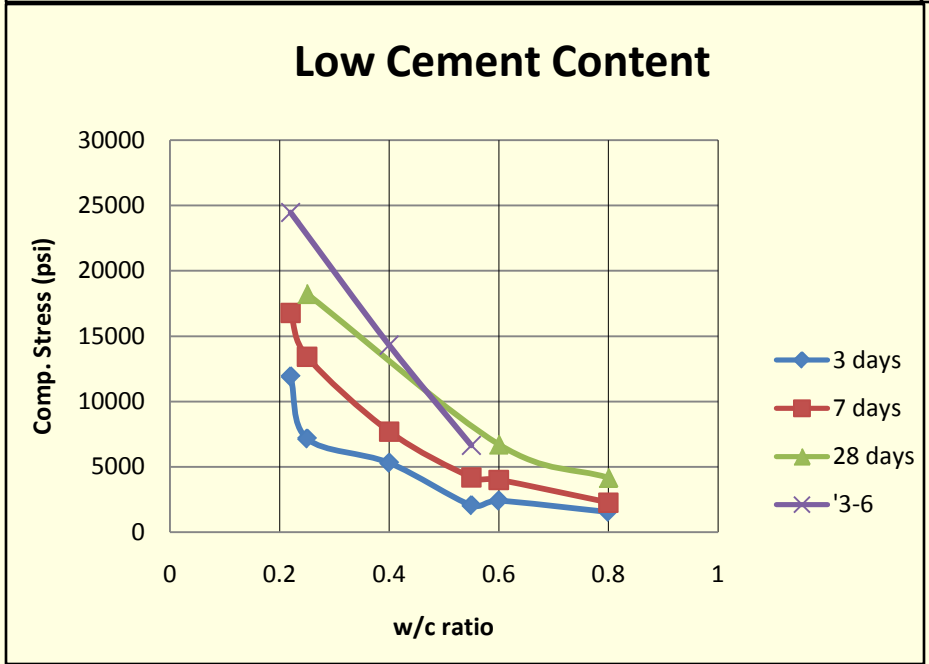
Results


Normal Curing (70°F)
Comp. Stress (psi)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
1
2
3
4
5
6
7
8
Time (days)
w/c=0.22
w/c=0.40
w/c=0.55
High
Medium
Low

Results


High Cement Content
Comp. Stress (psi)
35000
30000
25000
20000
15000
10000
5000
0
0
0.2
0.4
0.6
0.8
1
w/c ratio
3 days
7 days
28 days
'3-6


Medium Cement Content
Comp. Stress (psi)
30000
25000
20000
15000
10000
5000
0
0
0.2
0.4
0.6
0.8
w/c ratio
3 days
7 days
28 days
'3-6


Low Cement Content
Comp. Stress (psi)
30000
25000
20000
15000
10000
5000
0
0
0.2
0.4
0.6
0.8
1
w/c ratio
3 days
7 days
28 days
'3-6


173-09
CTN

Results

- New Cor-Tuf Curing Process:
  - ✓7-2
  - ✓3-6
- Panels:

✓5ksi:
- High Cement
- 0.8 w/c ratio
- 7-2 curing

✓17.5ksi:
- High Cement
- 0.38 w/c ratio
- 3-6 curing

✓30ksi:
- High Cement
- 0.22 w/c ratio
- 7-2 curing

Conclusions

- When the w/c ratio decreases, the compressive strength increases.
- For normal curing the medium cement gives the highest compressive strength.
- For heat curing Cor-Tuf is by far the highest compressive strength.
- Curing can be accelerated by heating the specimens. Also a much higher strength can be achieved.

References

- ASTM Standard C109, 2008, *Standard Test Method for Compressive Strength of Hydraulic Cement Mortars (Using 2-in. or [50-mm] Cube Specimens)*, ASTM International, West Conshohocken, PA.

- ASTM Standard C305, 2006, *Standard Practice for Mechanical Mixing of Hydraulic Cement Pastes and Mortars of Plastic Consistency*, ASTM International, West Conshohocken, PA.

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Questions?

U.S. Army Engineer R&D Center
Geotechnical and Structures Laboratory

Concrete and Materials Branch