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Investigation of Modulus of Elasticity and Surface Electrical Resistivity in High Performance Concrete(HPC) Using Natural Zeolite

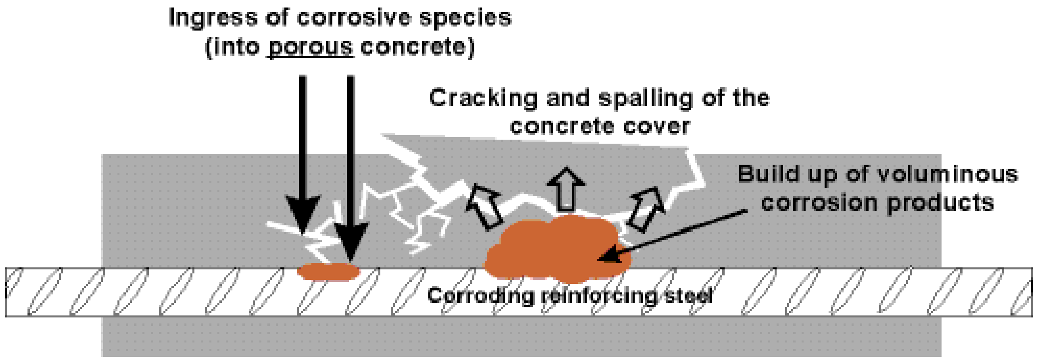
NCUR 2017

Introduction

- Corrosion is the biggest problem in the concrete structures and billions of dollars are used for the maintenance cost.
- It has become very important to develop High Performance Concrete (HPC) due to weathering problems in nation’s concrete infrastructure namely bridges and pavements.
- HPC generally increases the durability against the chloride induced corrosion along with long term compressive and tensile strength.
- Therefore, a natural pozzolanic cementitious material known as natural zeolite is being used for enhancing the performance of HPC.
- Natural zeolite, a crystalline hydrated alumino-silicate processed (volcanic ash) mineral and its highly effective pozzolan due to natural occurrence of aluminum silicate.

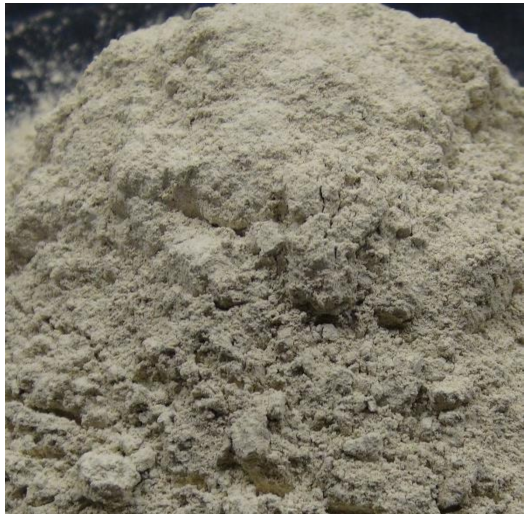
Objectives

- Identifying proper binary and ternary based HPC mixtures design with variation of feasible water to cementitious material ratio and different aggregate sizes.
- Surface electrical resistivity (SR) and modulus of elasticity testing is performed under the durability investigation against the chloride induced corrosion in concrete structures.
- Modulus of elasticity is related to stiffness and strength of concrete and it widely used in design of reinforcement concrete structures
- This SR data provides indirect indication to corrosion rate in reinforced concrete structures.



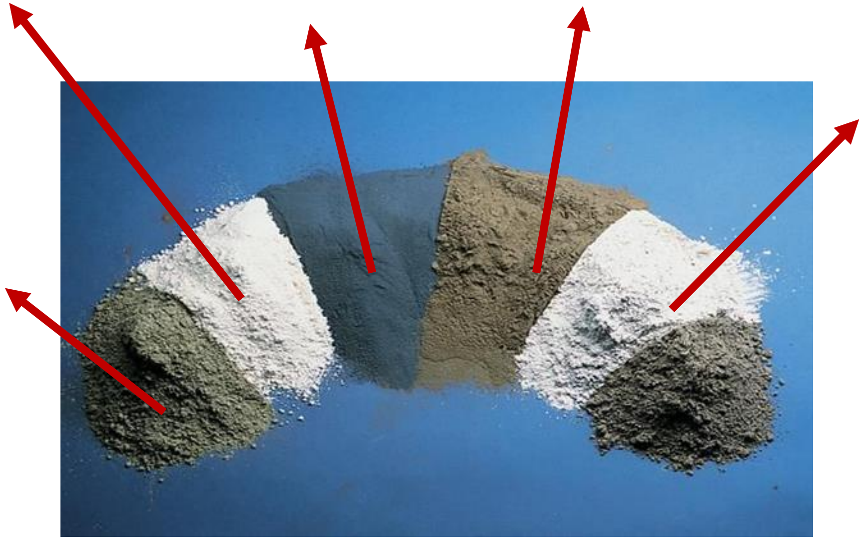
Materials

- Zeolite: major cementitious material being investigated
- Type II-V Cement (TII-V), since Type I Cement is prohibited in California due to sulfate attack problem
- Other Supplementary Cementitious Materials (SCMs):
  - Ground granulated blast furnace slag of grade 120 (G120S)
  - Class C Fly Ash (C)
  - Class F Fly Ash (F)
  - Silica Fume (SF)
  - Metakaolin (M)
  - Pumice (P)
- Chemical Admixtures
  - Glenium 3030 water reducer (ASTM C494 Specification)
  - MBVR Air Entrainer (ASTM C494 Specification)



Resources:
http://www.kmizeolite.com/contact.html

Concrete Mixtures



Ordinary Portland Cement (OPC)

+

Zeolite (**10%, 15%, 20%, 25%, 30%** replacement by mass)

=

Binary based concrete mixtures

Concrete Mixtures

Ordinary Portland Cement (OPC)

+

Zeolite (**15% and 20%** replacement by mass)

+

Supplementary Cementitious materials (SCM)

= Ternary based concrete mixtures

- Water to cementitious material ratios (W/C) were kept at either 0.44 or 0.4
- Coarse aggregates of 1/2" or 3/4" were used in the mixtures
- Zeolite was replaced with cement with varying percentage level of 10, 15, 20, 25, and 30 % by mass.

Concrete Mixing and Curing Method

Mixing of Concrete (Left)

Curing of Concrete Samples (Right)

Experimental Method

- Cylinders of 4" diameter and 8" length were poured with concrete according to ASTM C192 specification.
- The cylinders were used for testing modulus of elasticity at 28 days and surface electrical resistivity at 7, 28, 56 and 91days.
- Concrete cylinders are cured in saturated lime water tank.
- 4- point Wenner Probe device is used as Non Destructive Testing for surface electrical resistivity.
- For modulus of elasticity compressometer is used as Destructive Testing.

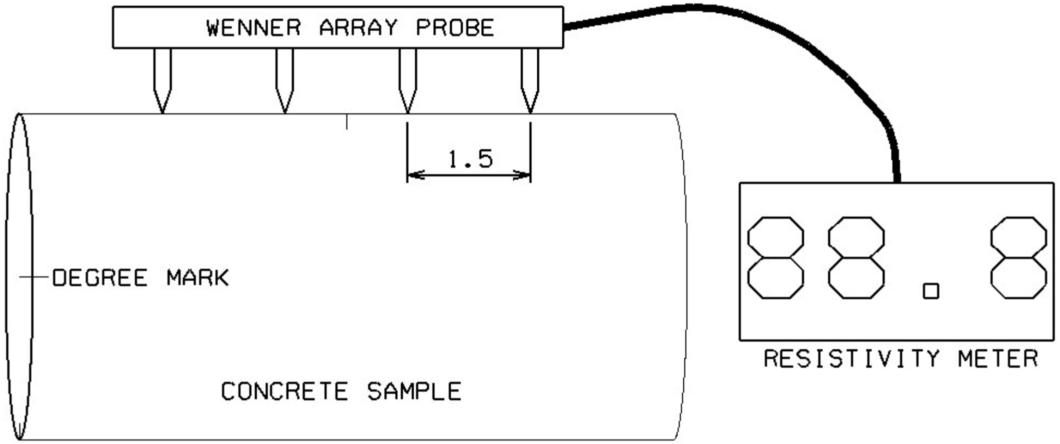
Surface Electrical Resistivity

- 3 Concrete cylinders are tested using 4- point Wenner Probe testing at 7, 28, 56 and 91 days.

Chloride Ion Permeability	Surface Resistivity Test kΩ−cm
High	< 12
Moderate	12 – 21
Low	21 – 37
Very Low	37 – 254
Negligible	> 254

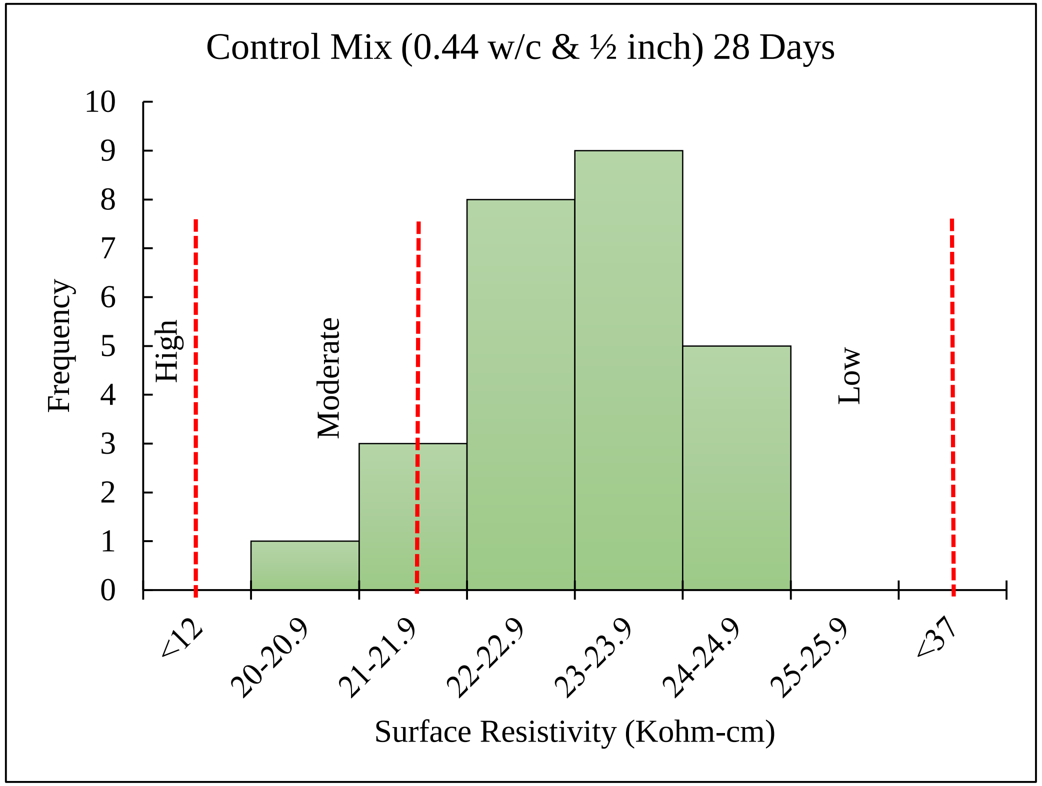
Surface Resistivity - Permeability From FDOT

FIGURE 1



Resource : Florida Method of Test For Concrete Resistivity as an Electrical Indicator of its Permeability Designation: FM 5-578

Surface Electrical Resistivity



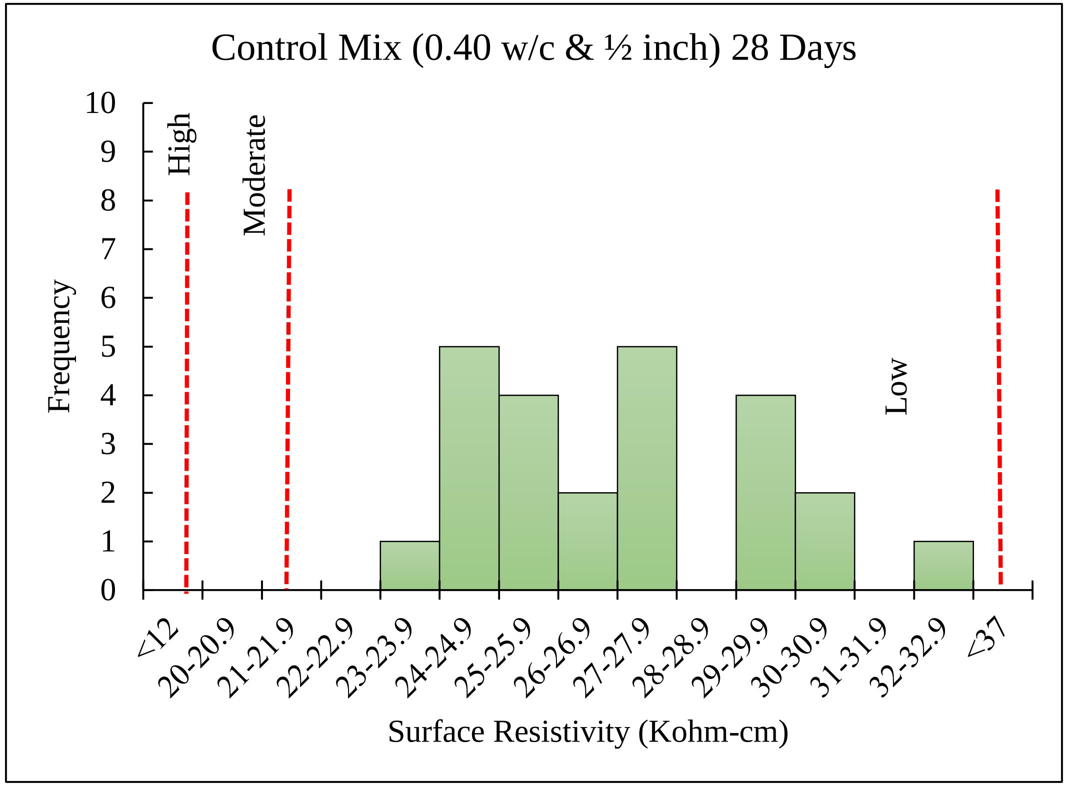


Figure 1: Comparison of surface electrical resistivity of Ordinary Portland Cement (OPC) to 0.44 with 0.40 w/c for ½" aggregate size

Surface Electrical Resistivity

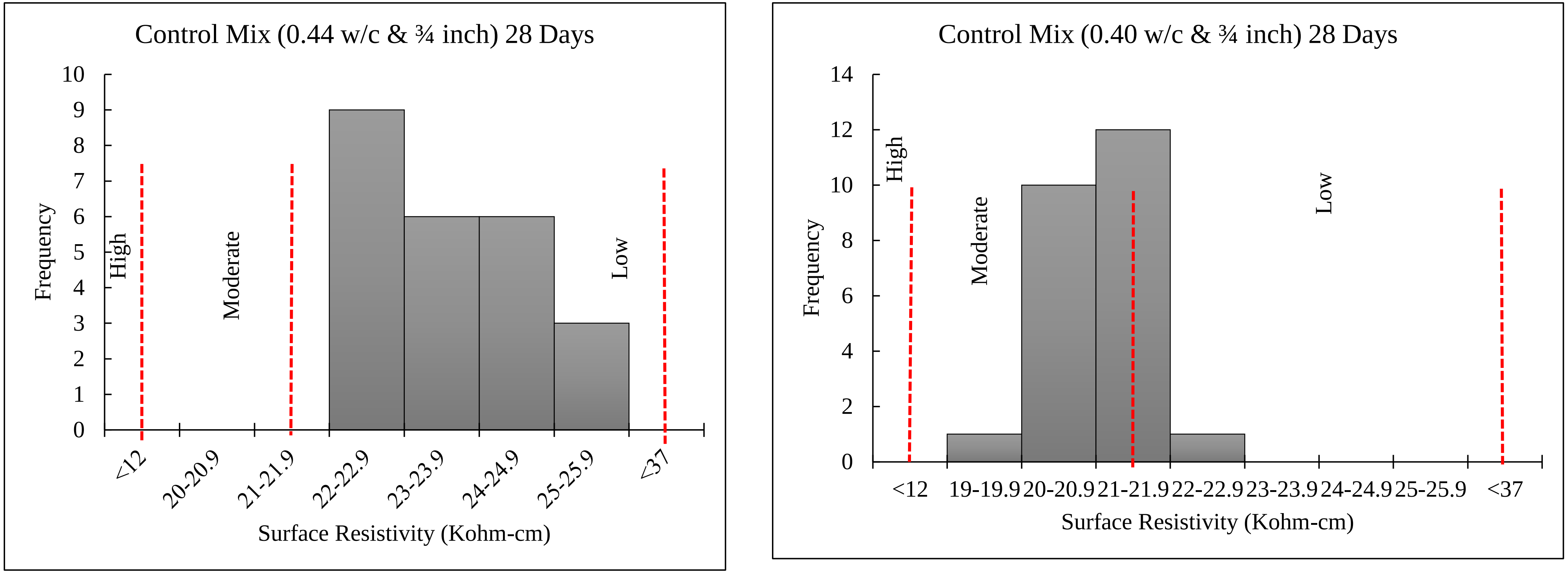
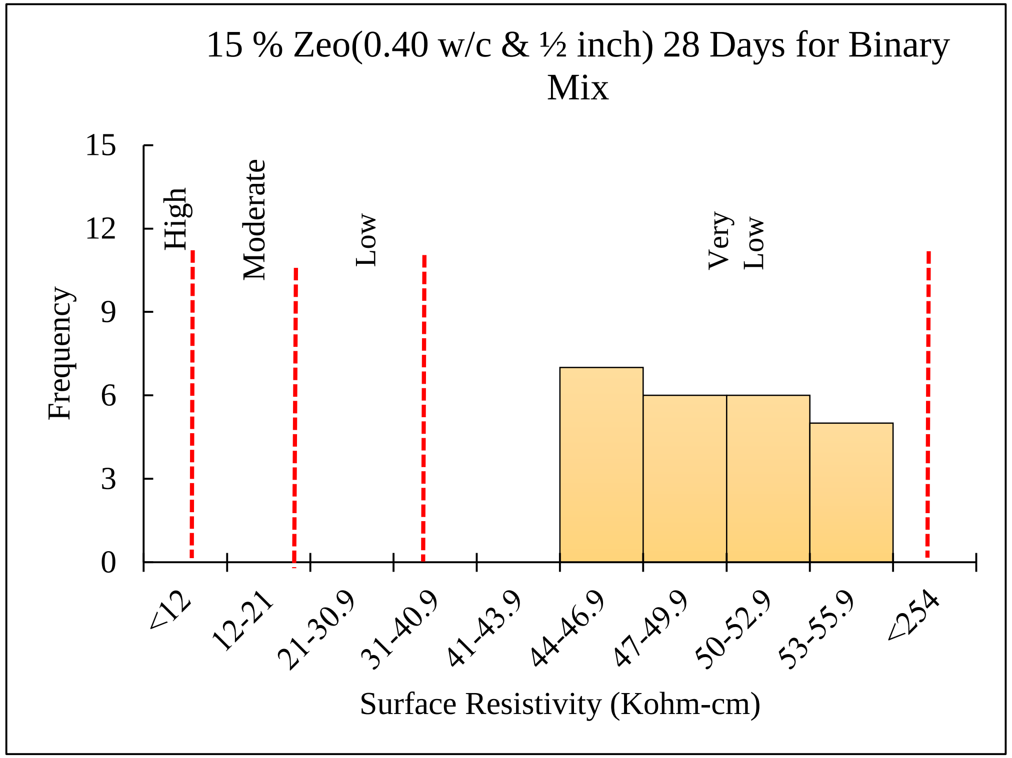
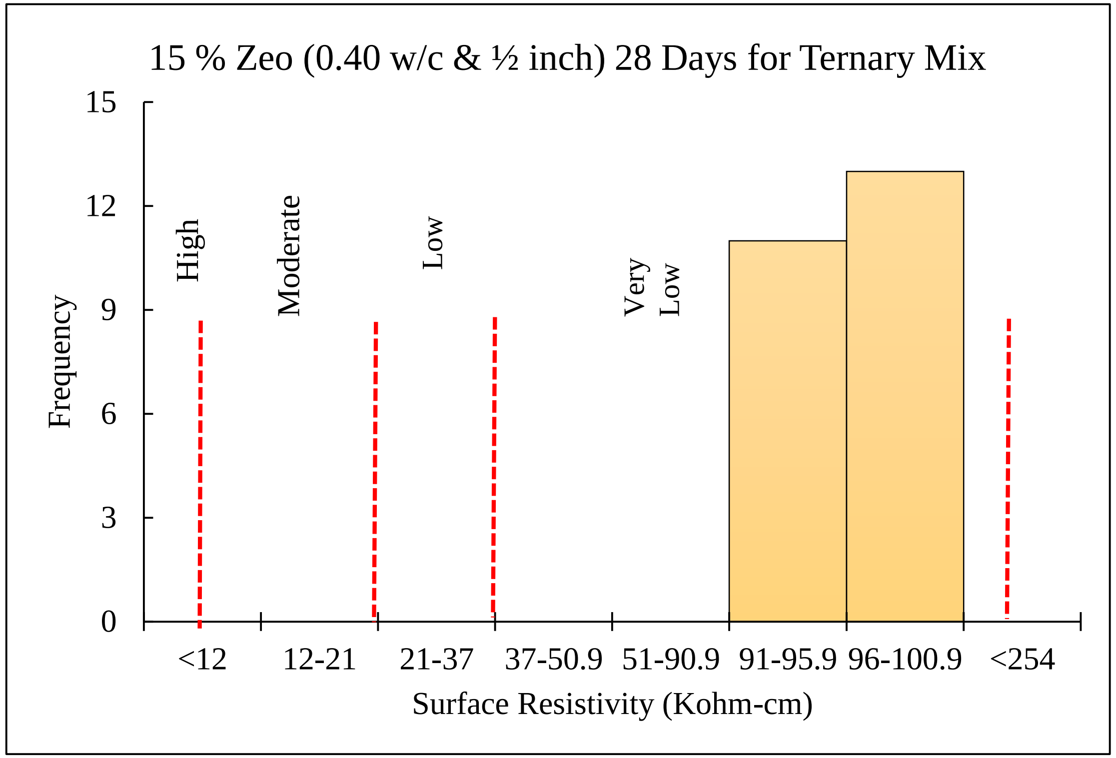


Figure 2: Comparison of surface electrical resistivity of Ordinary Portland Cement (OPC) to 0.44 with 0.40 w/c for ¾ ” aggregate size

Surface Electrical Resistivity

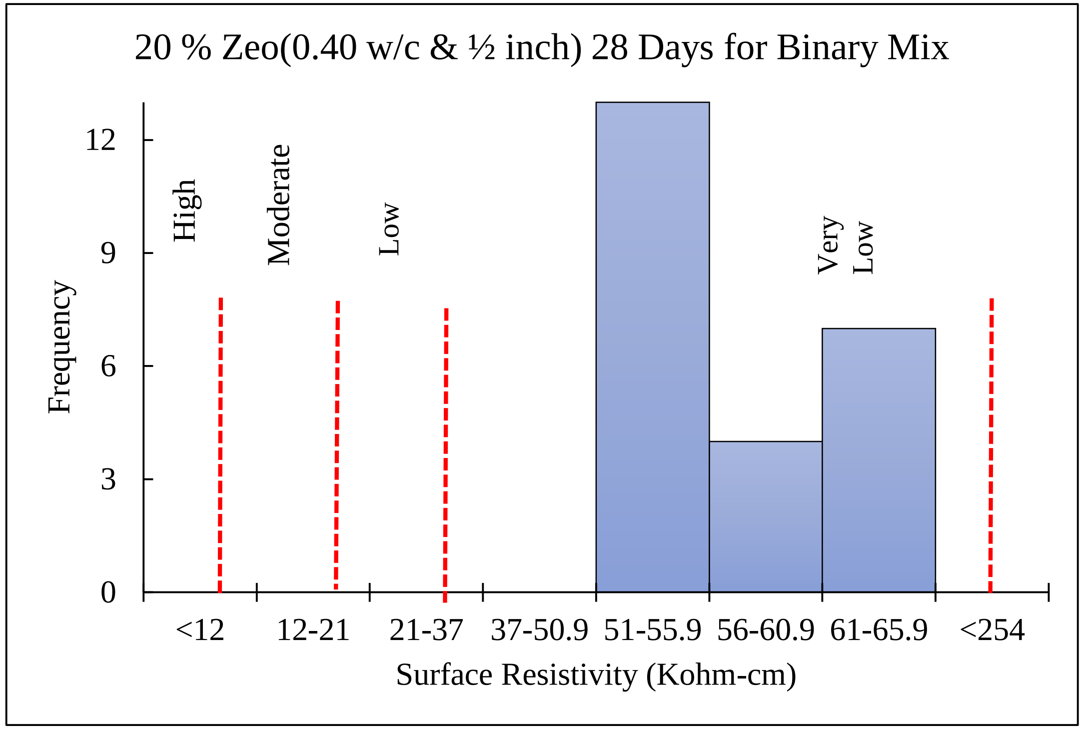


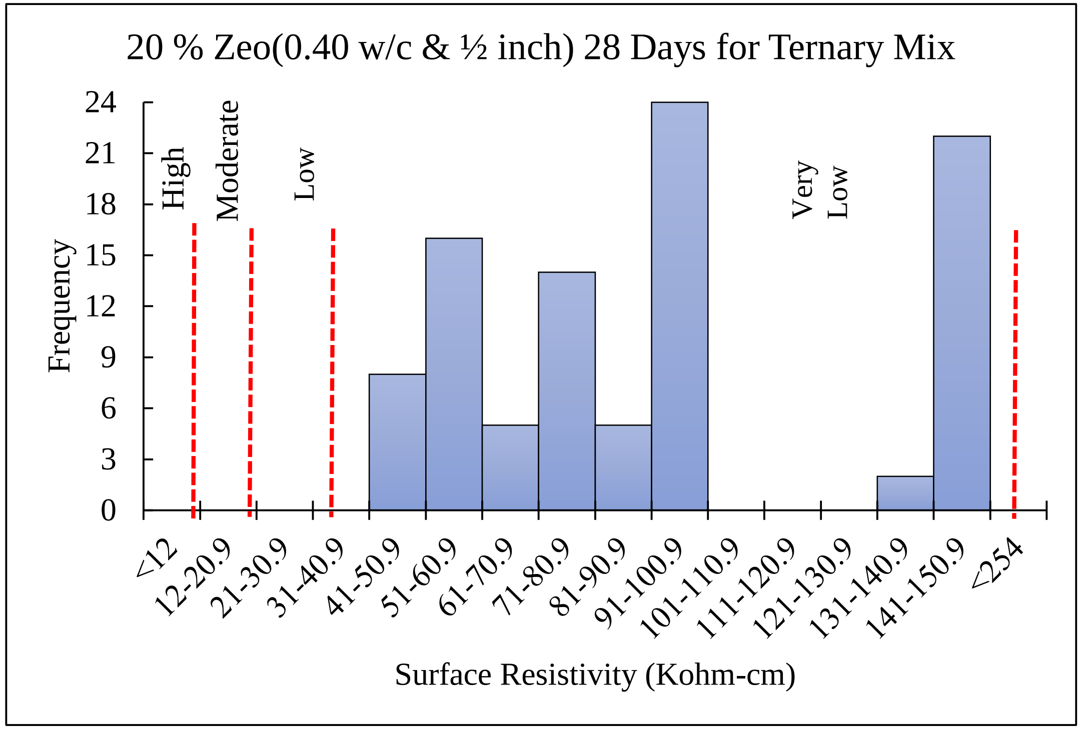


Mix Design
75TII-V/**15Z**/**10SF**

Figure 3: Comparison of surface electrical resistivity of binary to ternary mixture

Surface Electrical Resistivity





Mix Designs:
60TII-V/**20Z**/20F
70TII-V/**20Z**/10M
55TII-V/**20Z**/25C
55TII-V/**20Z**/25P

Figure 4: Comparison of surface electrical resistivity of binary to ternary mixture

Surface Electrical Resistivity

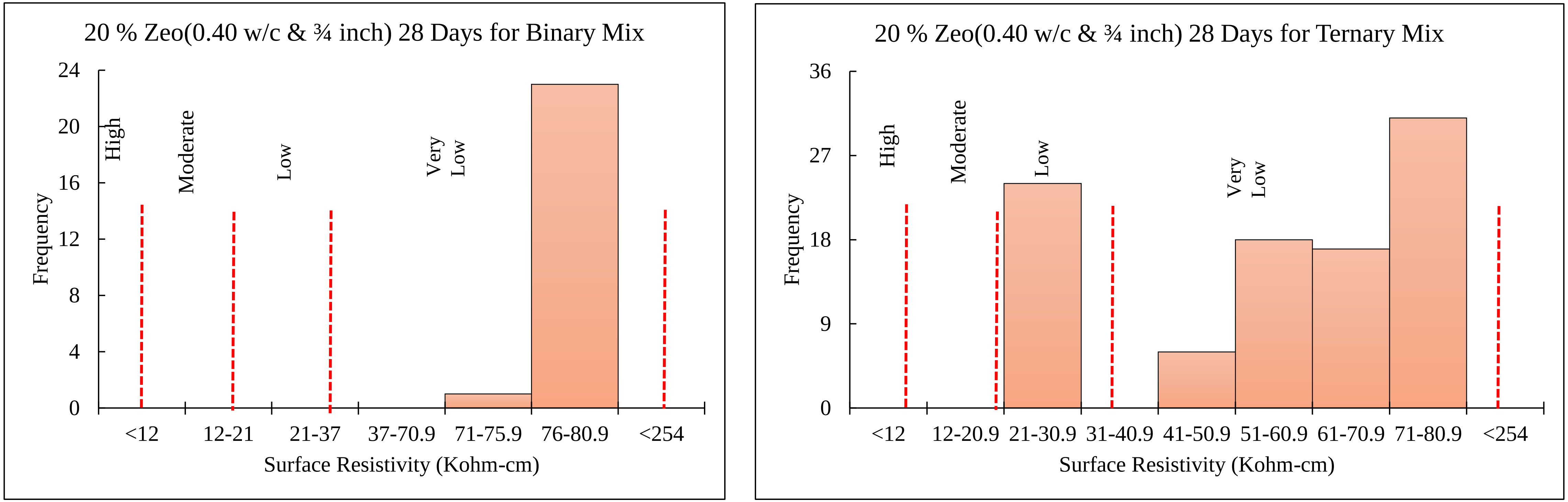


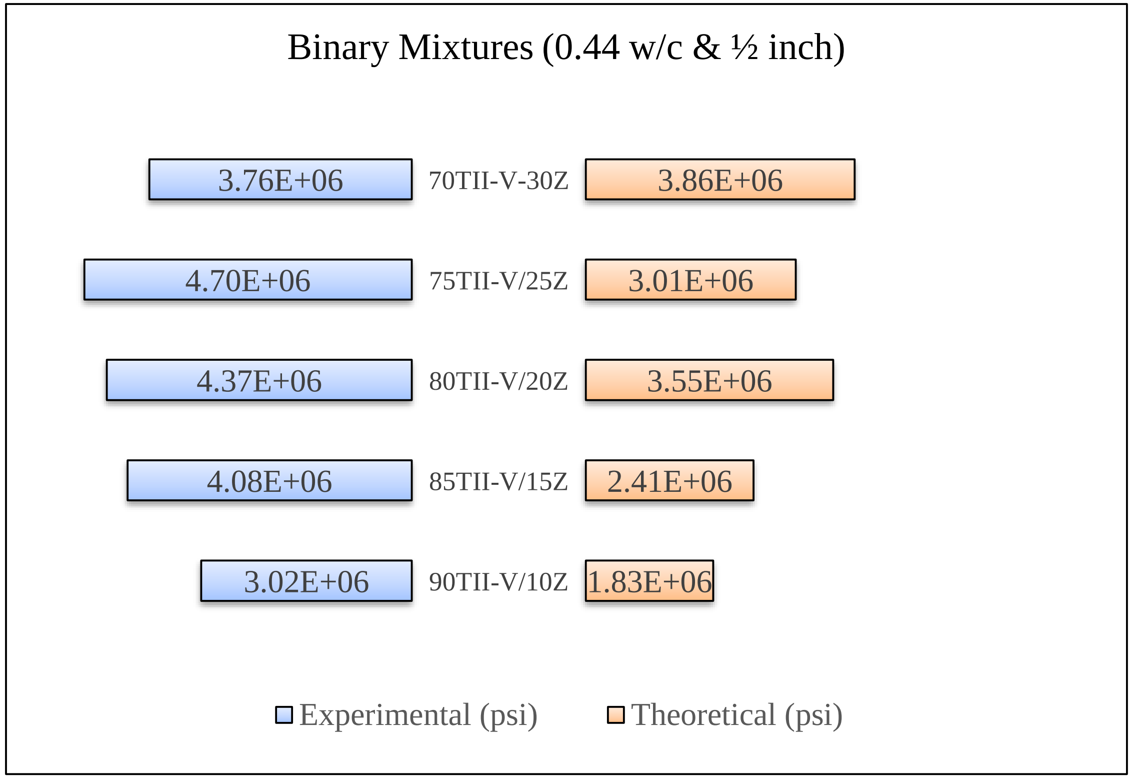
Figure 5: Comparison of surface electrical resistivity of binary to ternary mixture

Mix Designs:
60TII-V/**20Z**/20F
70TII-V/**20Z**/10M
55TII-V/**20Z**/25C
55TII-V/**20Z**/25P

Modulus of Elasticity

- Modulus of Elasticity is tested at 28 days and average for 2 cylinders is taken into account.
- Measuring Modulus of Elasticity (E) is obtained:
  - Theoretically : using this equation, $E = 57{,}000\sqrt{f_c^{`}}$
  - Graphically : based on slope of strain and stress curve within an elastic deformation region
  - Experimentally : using compressometer equipment

Modulus of Elasticity



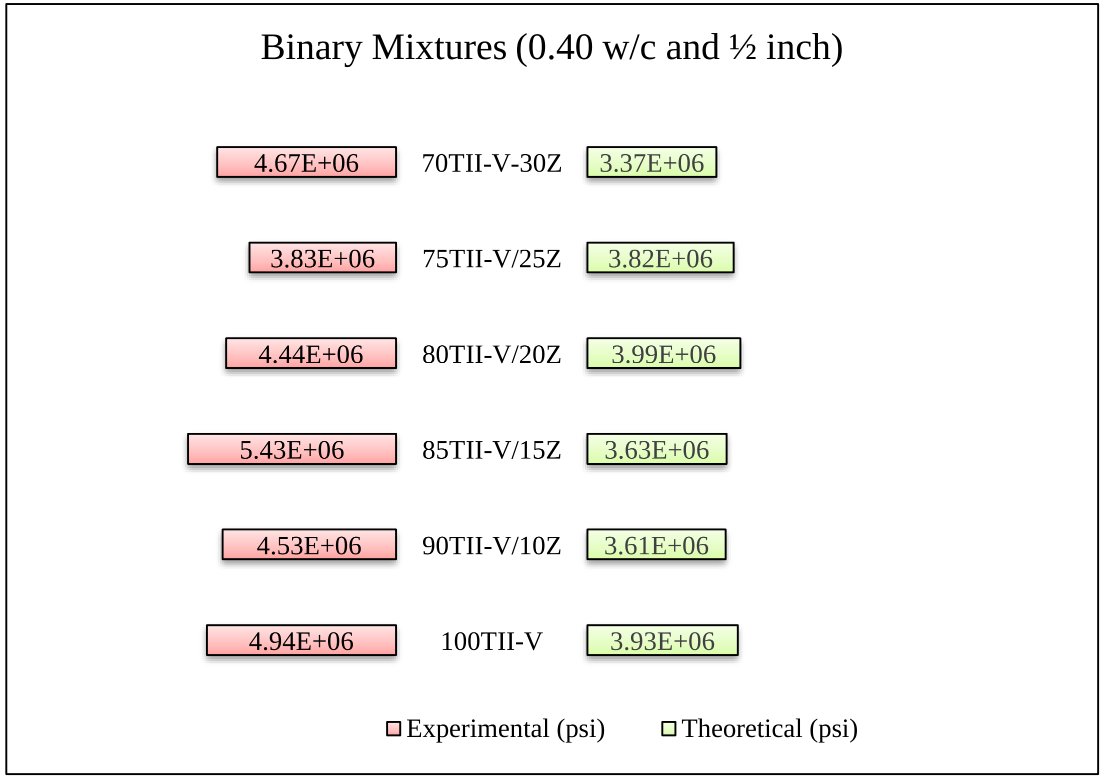
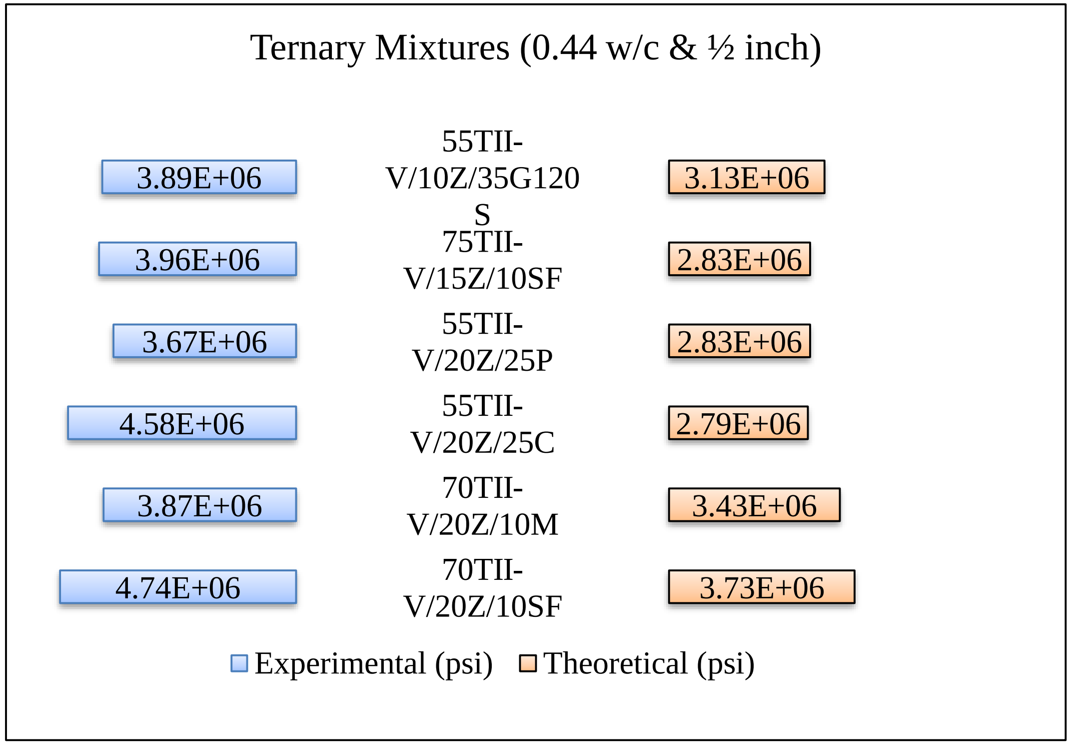


Figure 6: Comparison of experimental to theoretical modulus of elasticity for binary mixtures

NOTE: Data for control mix for 0.44 w/c and ½” is still in progress

Modulus of Elasticity



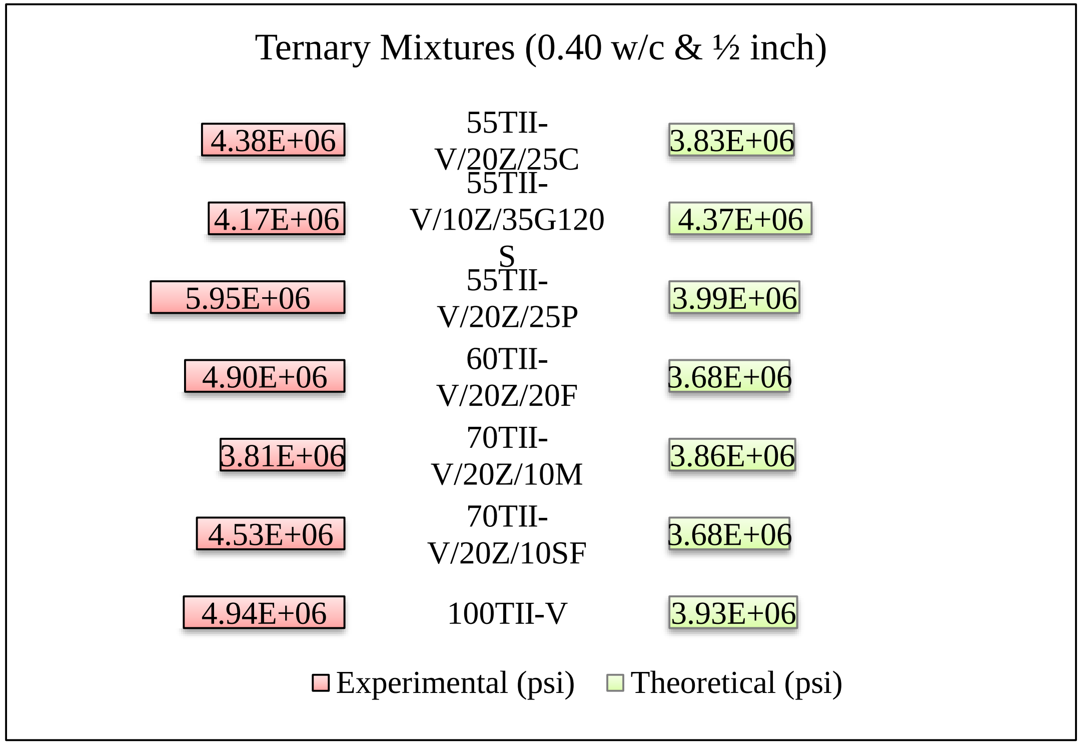
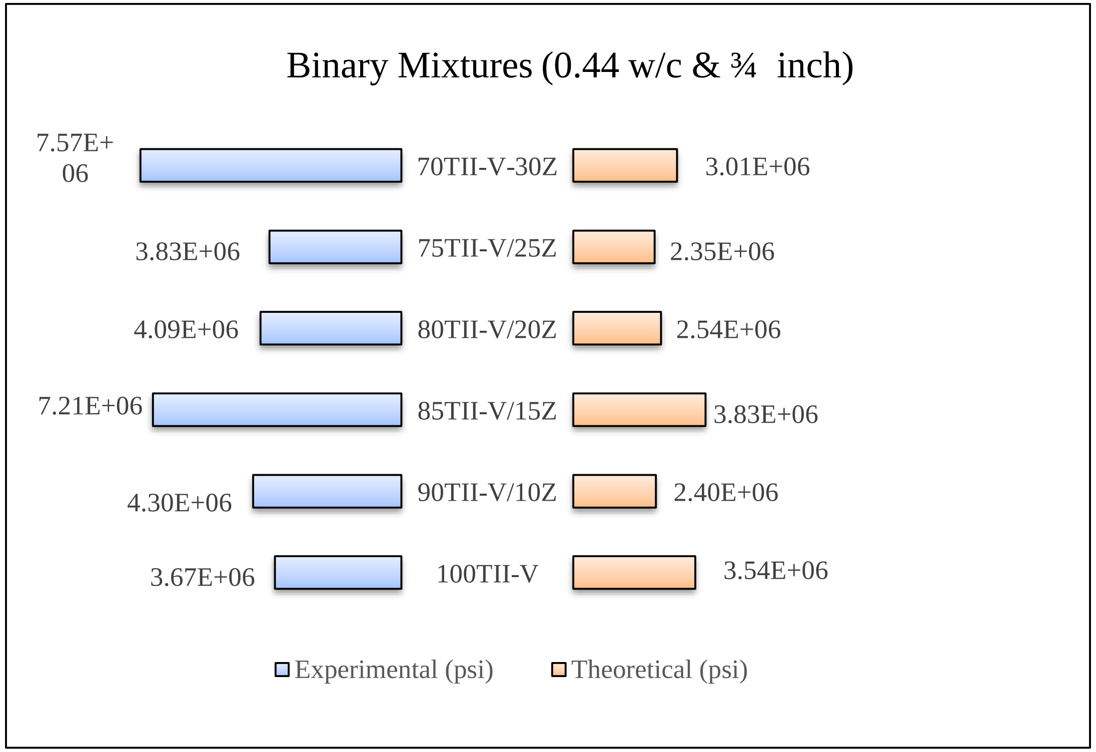


Figure 7: Comparison of experimental to theoretical modulus of elasticity for ternary mixtures

NOTE: Data for control mix for 0.44 w/c and ½" is still in progress

Modulus of Elasticity



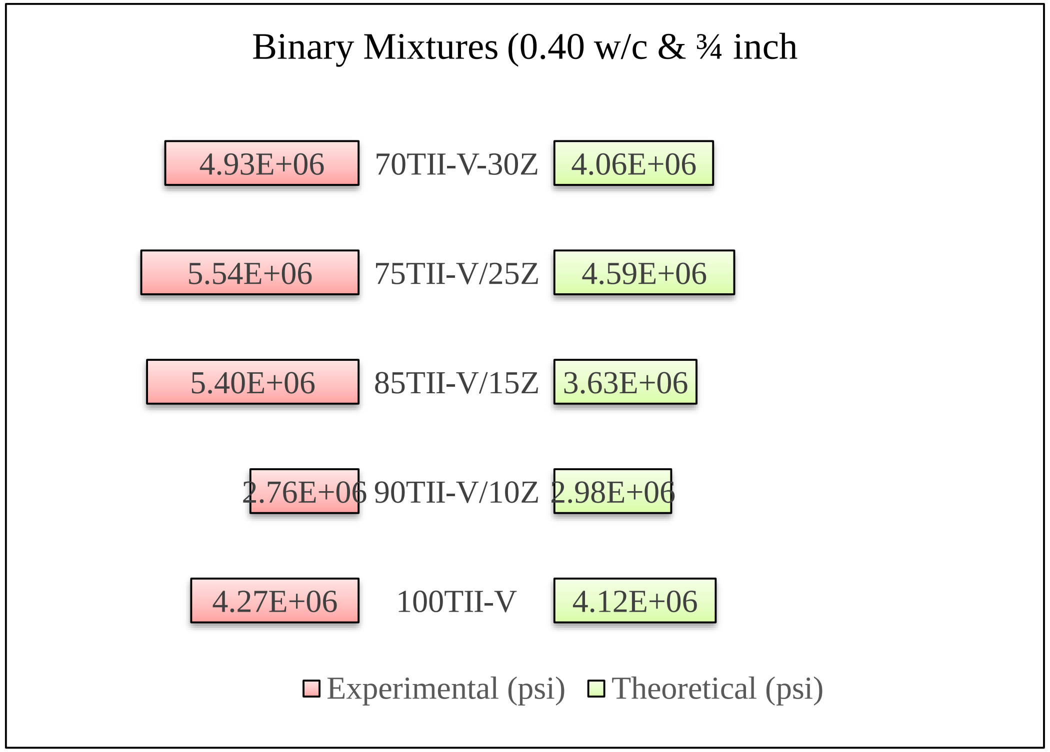


Figure 8: Comparison of experimental to theoretical modulus of elasticity for binary mixtures

Conclusions

- Zeolite based concrete mixtures with water to total cementitious material ratio (W/C) at 0.4 and ¾ ” aggregates provide promising results in terms of development of high surface electrical resistivity and modules of elasticity .
- Results for modulus of elasticity for theoretical and experimental are within 10 to 20 % of error of margin and this is acceptable.
- Based on the analysis, it can be concluded that zeolite is very sensitive to W/C ratios and size of the aggregates.
- In summary, zeolite based concrete mixtures achieved low corrosion rate and will increase the service life due to chloride induced corrosion.

Acknowledgment

- I am grateful to my professor Dr. Pratanu Ghosh for giving me a chance to do research under his guidance. I also want to thank following people for supporting our research sponsoring required materials.
- Ken Sears (Fly Ash)
- Paul Heis, BASF (Silica fume and Chemical admixtures like MBVR and Glenium 3030)
- Gary Kirk (Calportland Cement for Type II-V)

Questions?