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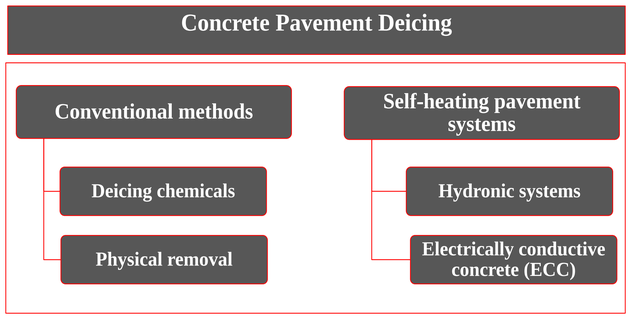
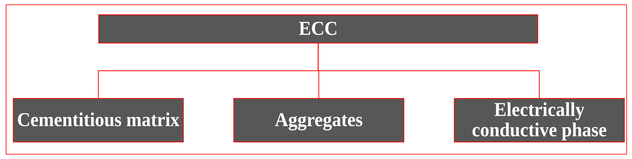
Mix Design Development of Electrically Conductive Concrete (ECC)

Deicing of Concrete Pavements



General Constituents of ECC

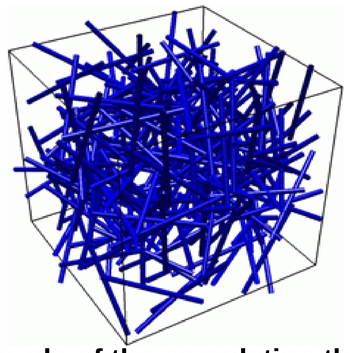


What is the Conductive Phase?

Conductive fibers and/or granular materials which could be substituted for part of aggregate in concrete

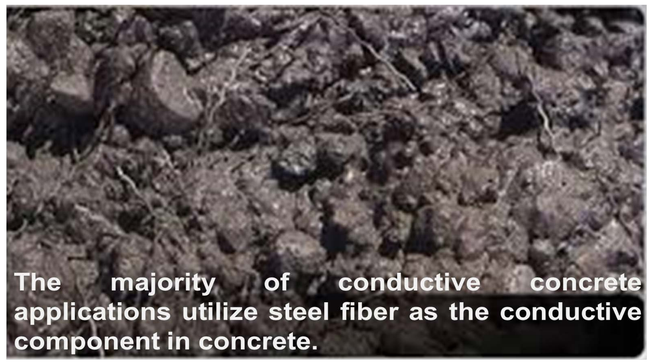
Basic Mechanism

The volume of conductive materials in the concrete matrix should exceed a certain value called "*PERCOLATION THRESHOLD*"



At upper levels of the percolation threshold, conductive materials, being in contact with each other, build up a conductivity network inside concrete

Problem: Use of Steel Fiber in ECC



- **Use of steel fiber can create durability, aesthetic and safety concerns**
- **Use of steel fiber should is avoided in critical transportation infrastructure applications**

Alternative Solution

Carbon based conductive materials including carbon fibers (CF) and carbon powders (CP) are an alternative to steel products in ECC mix design

Objectives

- **To develop a reliable ECC mix design for critical transportation infrastructure system trough successful and safe application of carbon products**

- **Requirements of optimum ECC mix design**
  - ✓ **Electrical conductivity**
  - ✓ **Strength and workability**
  - ✓ **Durability**
  - ✓ **Economical efficiency**
  - ✓ **Safety requirements**

Detailed Research Approach

- **Investigate the most suitable conductive materials (fibrillar and granular materials) through mortar tests**
- **Determine percolation threshold through mortar tests using conductive materials selected in the previous stage**
- **Develop a preliminary ECC mix design based on mortar test evaluations**
- **Investigate the validity of the mortar test determining percolation threshold for concrete cases**
- **Determine the final conductive materials volume fraction in ECC**
- **Adjust the ECC mix design to provide the desirable workability and strength performances**
- **Make 4×4 ft. ECC slab with electrodes and test its deicing performance**
- **Perform ECC slab durability evaluation mainly focusing on freezing-thawing resistance and abrasion resistance with other standardized test evaluations**

Conductive Mortar Test Evaluations

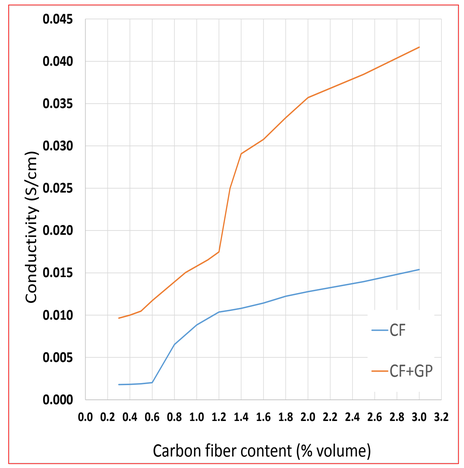
Carbon fibers considerably reduce concrete workability → Higher conductivity should be achieved by lower Carbon Fiber content

- **Significant improvement of conductivity can be achieved by**
  - **Increasing CF contents**
  - **Using the combination of CF and CP rather than CF only**
- **Use of the combination of CF and CP is more reliable and cot effective solution as considering other requirements**

Semi-spherical Carbon Particles have lower impact on workability

Carbon Particles contribute to the formation of network in lower fiber contents

The optimum mix can be achieved by using combinations of Carbon fiber and semi-spherical Carbon particles



Conductivity variations with carbon based conductive material contents: CF only and CF with 15 % of CP

Key Findings

- **0.6 to 1% of carbon fiber (CF) with 10 to 15% of carbon powder (CP) provide desirable conductivity performance**
- **As considering strength and workability, 0.8% of CF with 10% of CP is proposed**

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