Combined Strengthening and Cathodic Protection for Reinforced Concrete

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Cathodic Protection & Carbon Fiber Strengthening

- Cathodic Protection (CP) and Carbon Fiber Strengthening have each revolutionised the durability and performance of reinforced concrete structures.
- From time to time, both have been present on elements of the same structure, raising concerns of interaction and possible interference.
- Or economics dictate either/ or to be used when both are needed on a structure

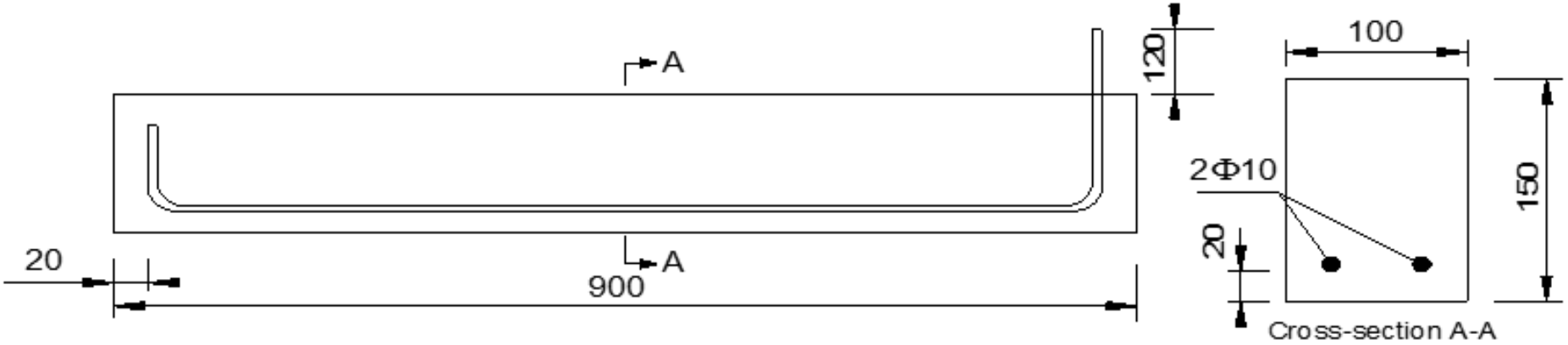
Carbon Fiber as an Impressed Current CP Anode

- Whilst carbon fiber is capable of conducting an electrical current, this does not necessarily make it a good candidate as an Impressed Anode for CP.
- CF systems as applied to concrete rely on an adhesive, usually epoxy, to bond it to the substrate.
- Epoxies, unless highly modified, are not generally good electrical conductors.

CF/CP Laboratory Trials

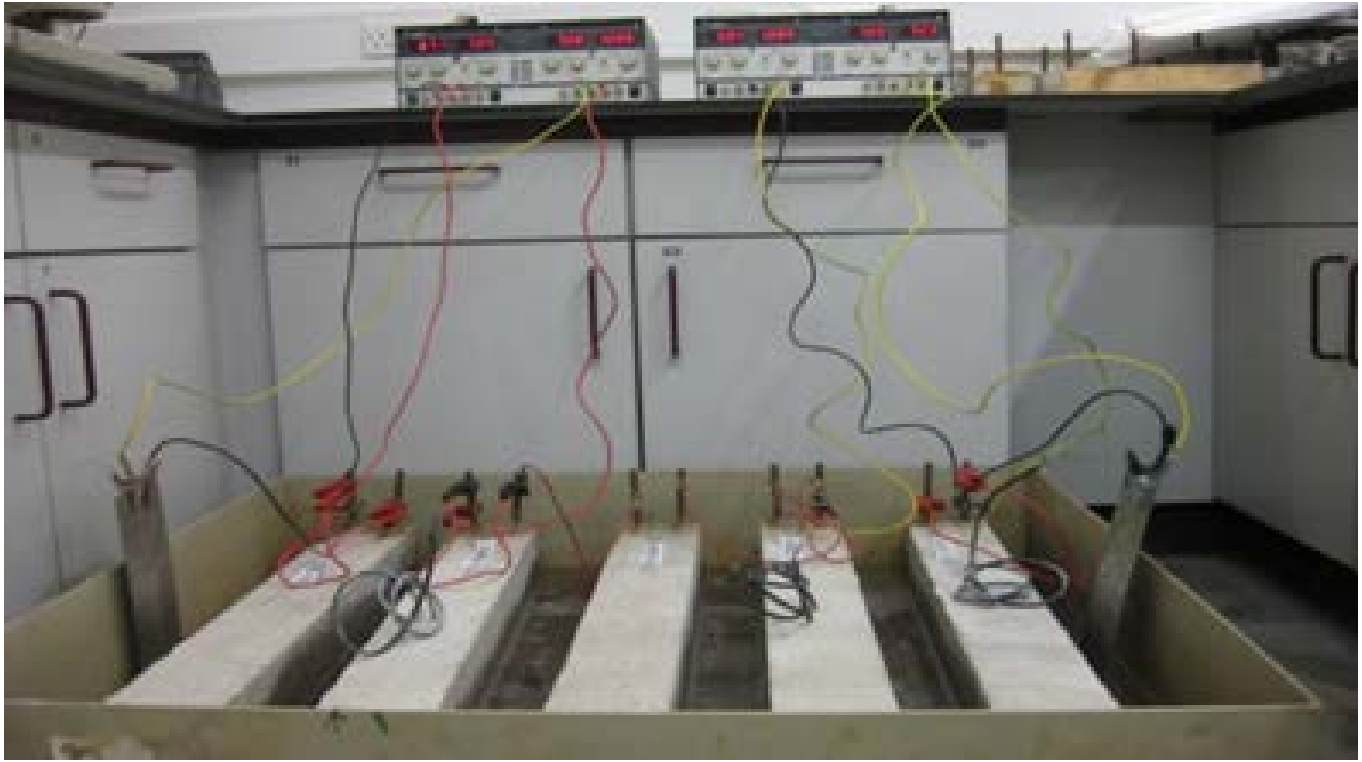
- Initial trials were carried out using conventional CF fabric and epoxy adhesive on specially design beams.
- The beams allowed the steel reinforcement to be pre-corroded anodically using an external cathode.
- After that, they were reinforced with epoxy bonded CF fabric.
- The CF was used to pass a current to cathodically protect the pre-corroded steel.

Test Beam Design

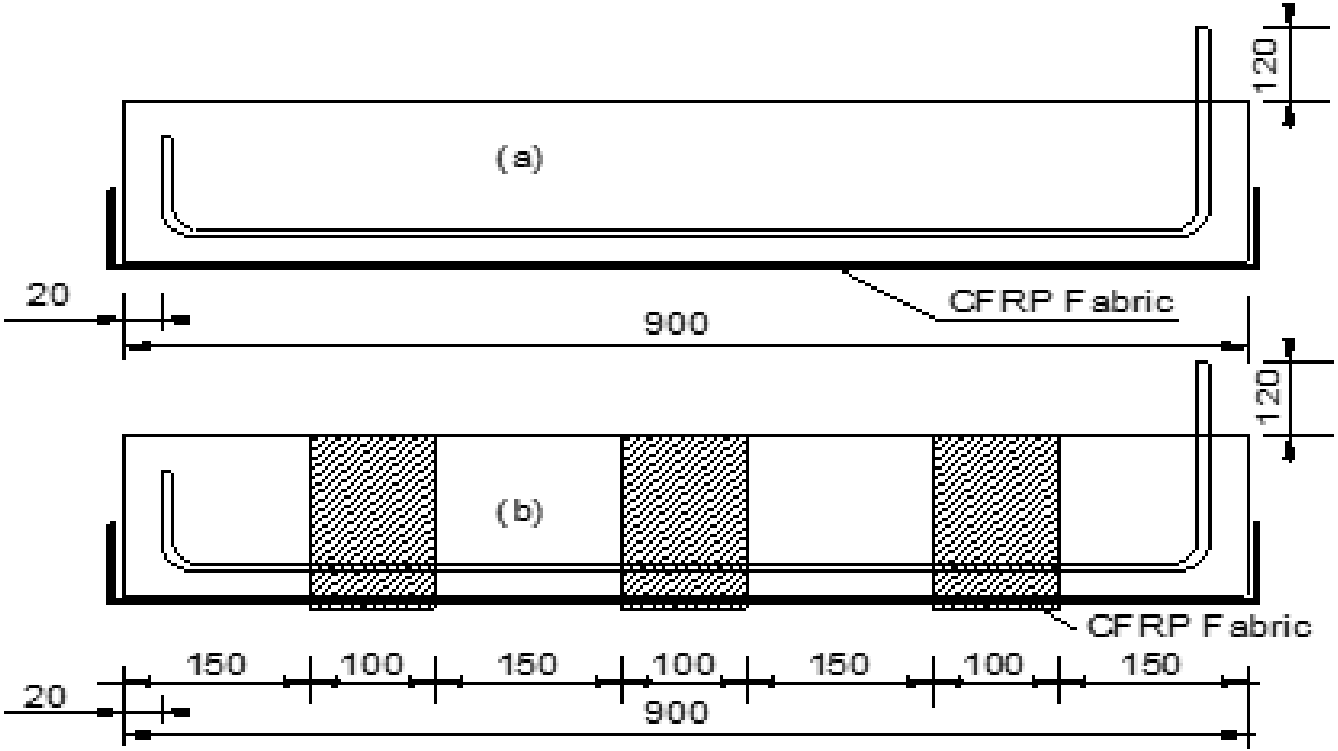


(All dimensions in mm)

Pre-Corroding Reinforcement



CF/Epoxy Application



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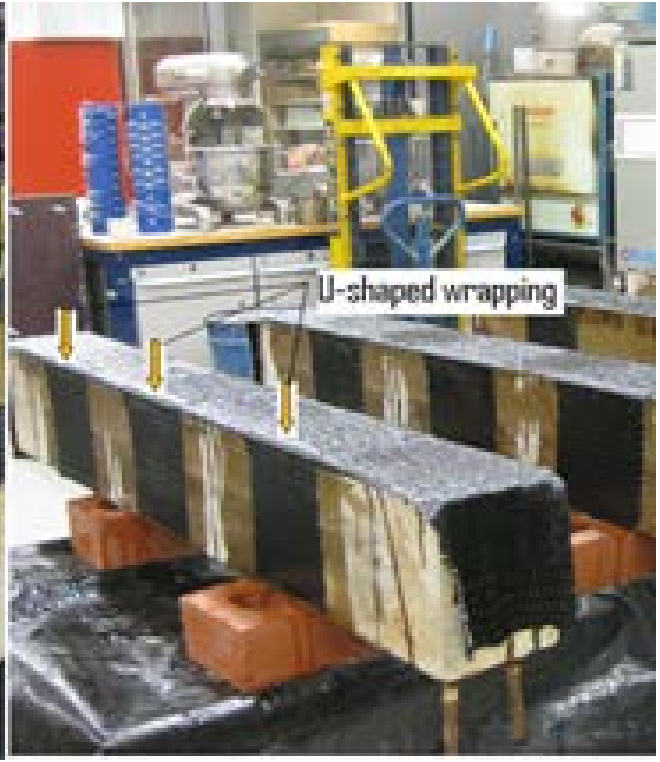
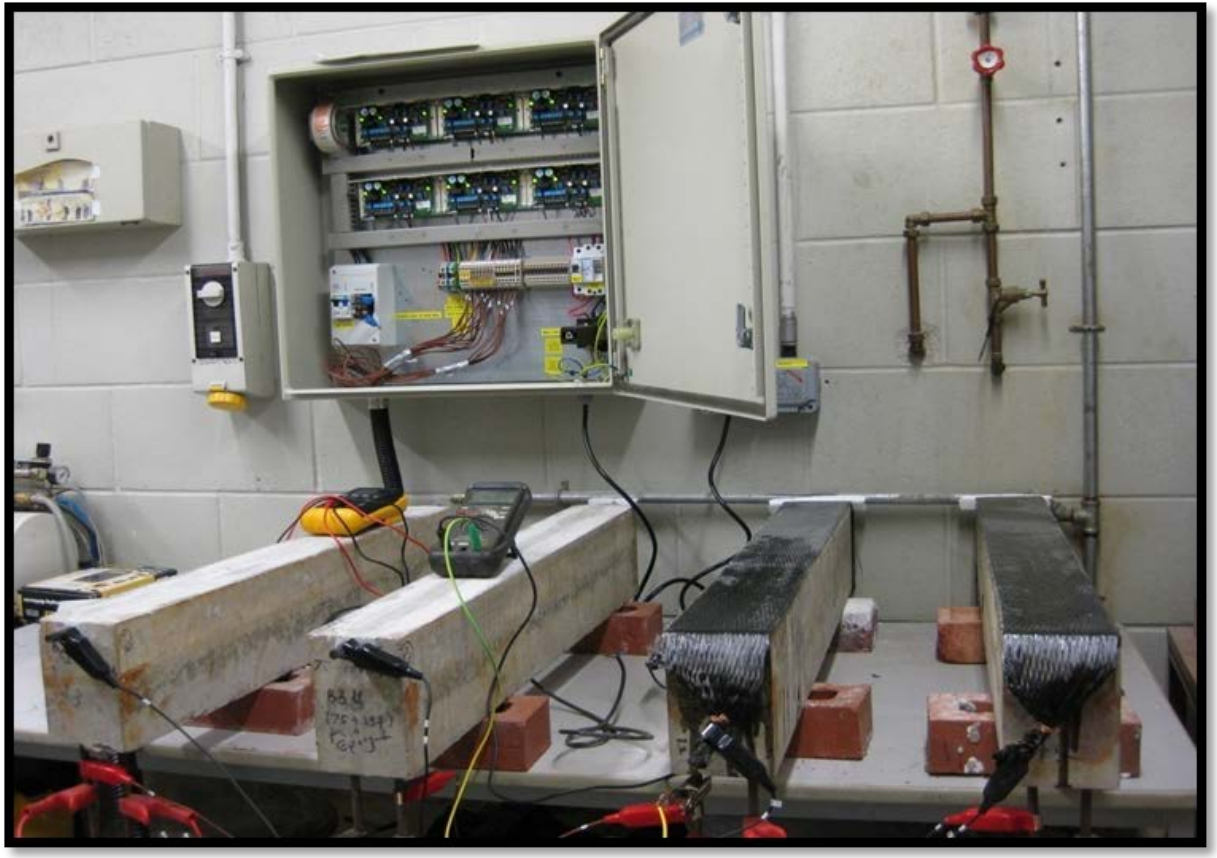
CF/Epoxy Application



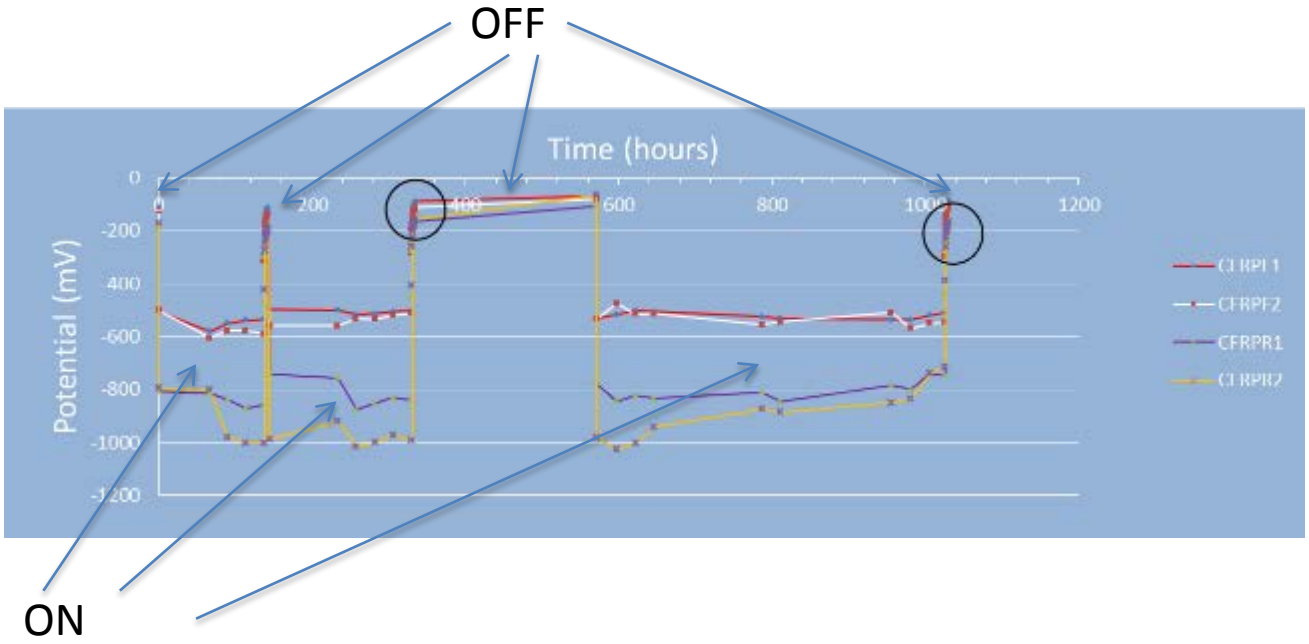
Applying CP Current



CF as an Impressed Current CP Anode

- In order to identify possible sensitivities to acid generation or other side effects of employing as an anode, the CF was driven at a higher than usual current.
- CP of the steel was easily achieved and after a period of operation the beams were tested in three point loading.
- The results were encouraging, showing a significant degree of strengthening despite running the CF anode hard.

CP Energization & Control Data

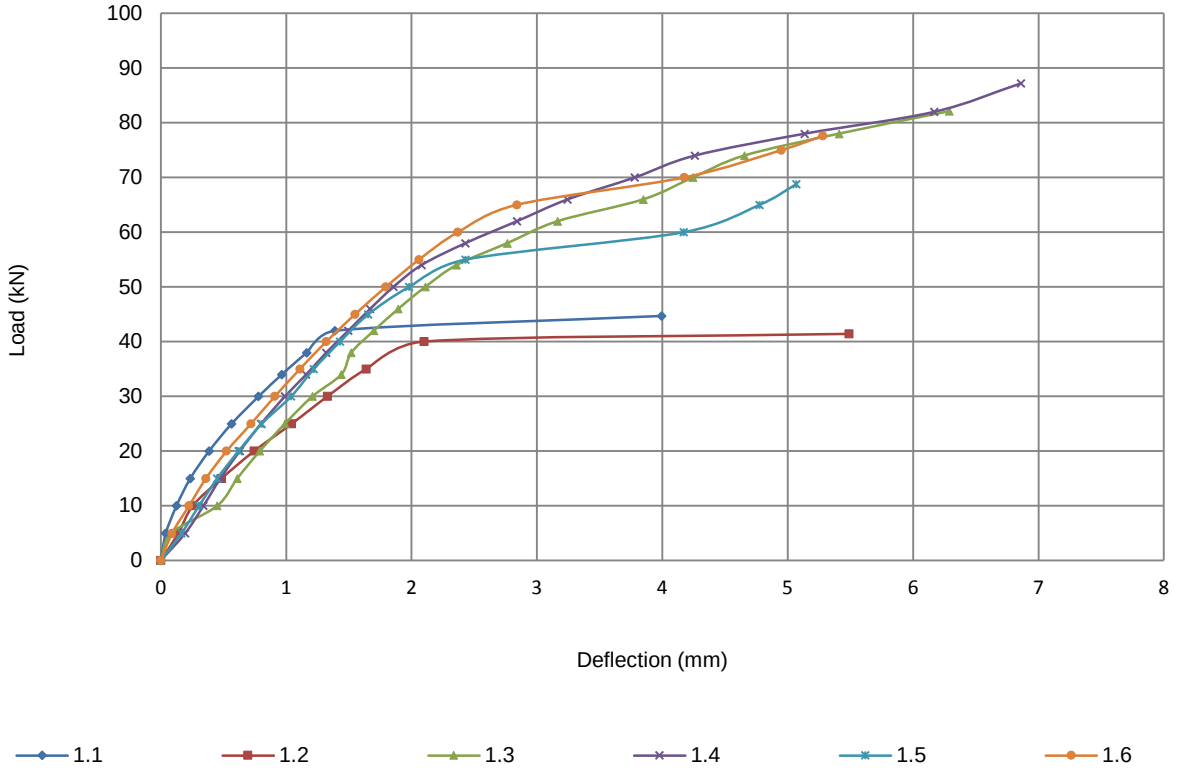


CF Fabric Load/Deflection Type (a)

1.1+1.2 – controls – no CP no CF

1.3+1.4 – CF applied; no CP

1.5+1.6 – CF+CP applied

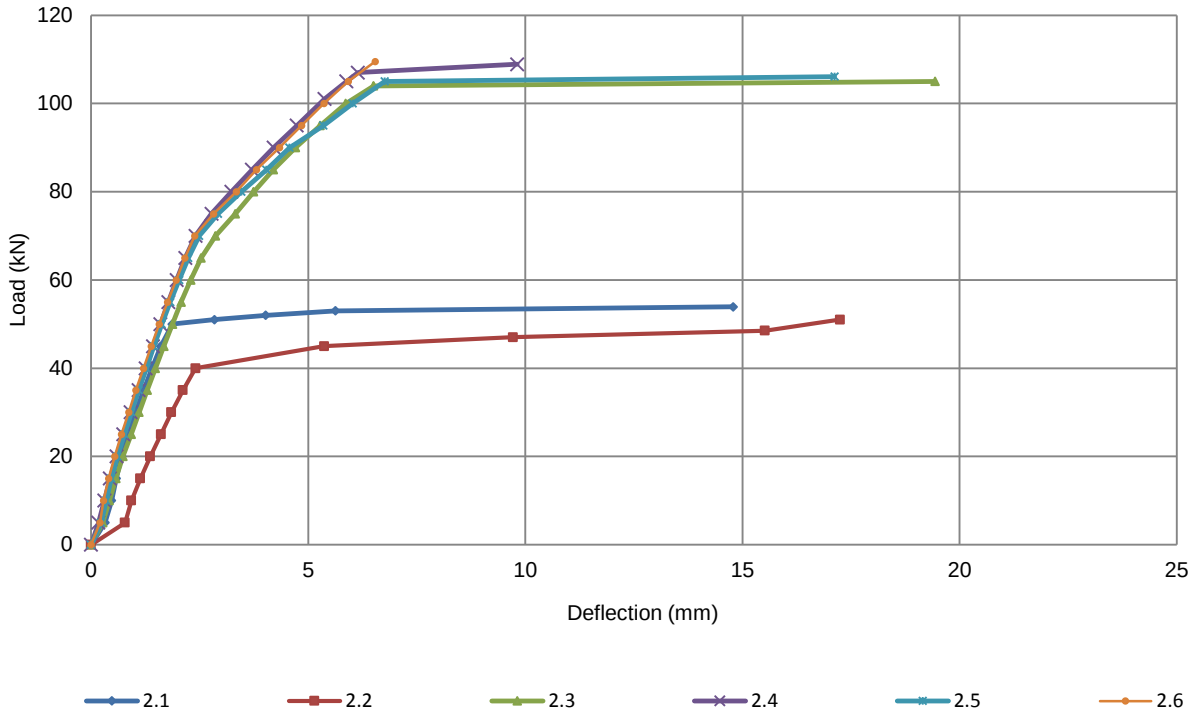


CF Fabric Load/Deflection Type (b)

2.1+2.2 – controls – no CP no CF

2.3+2.4 – CF applied; no CP

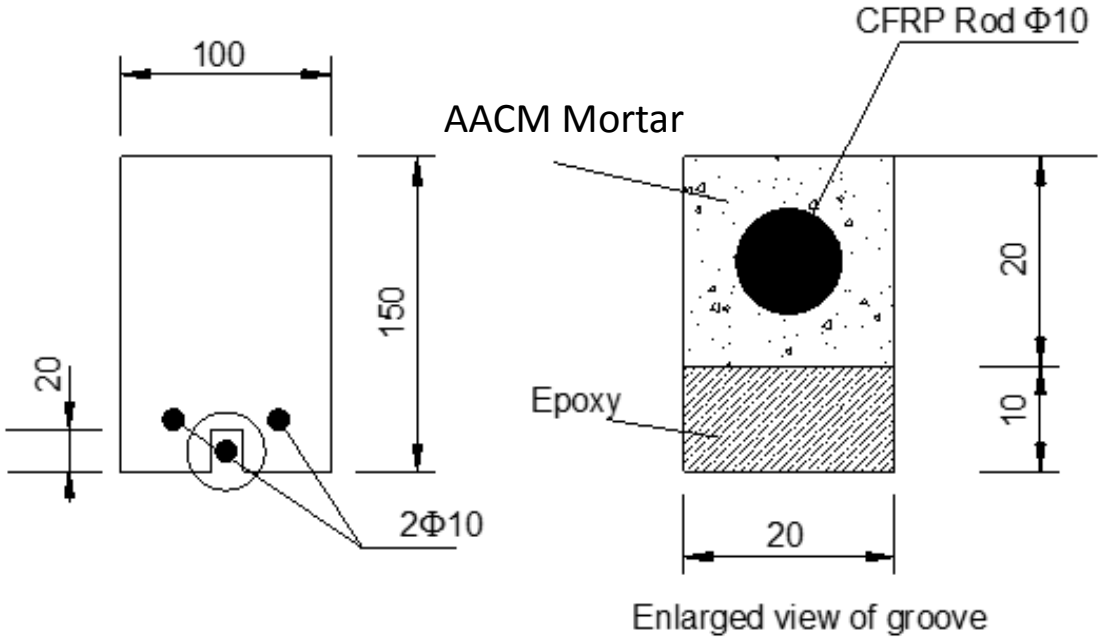
2.5+2.6 – CF+CP applied



Enhancing Performance with AACM

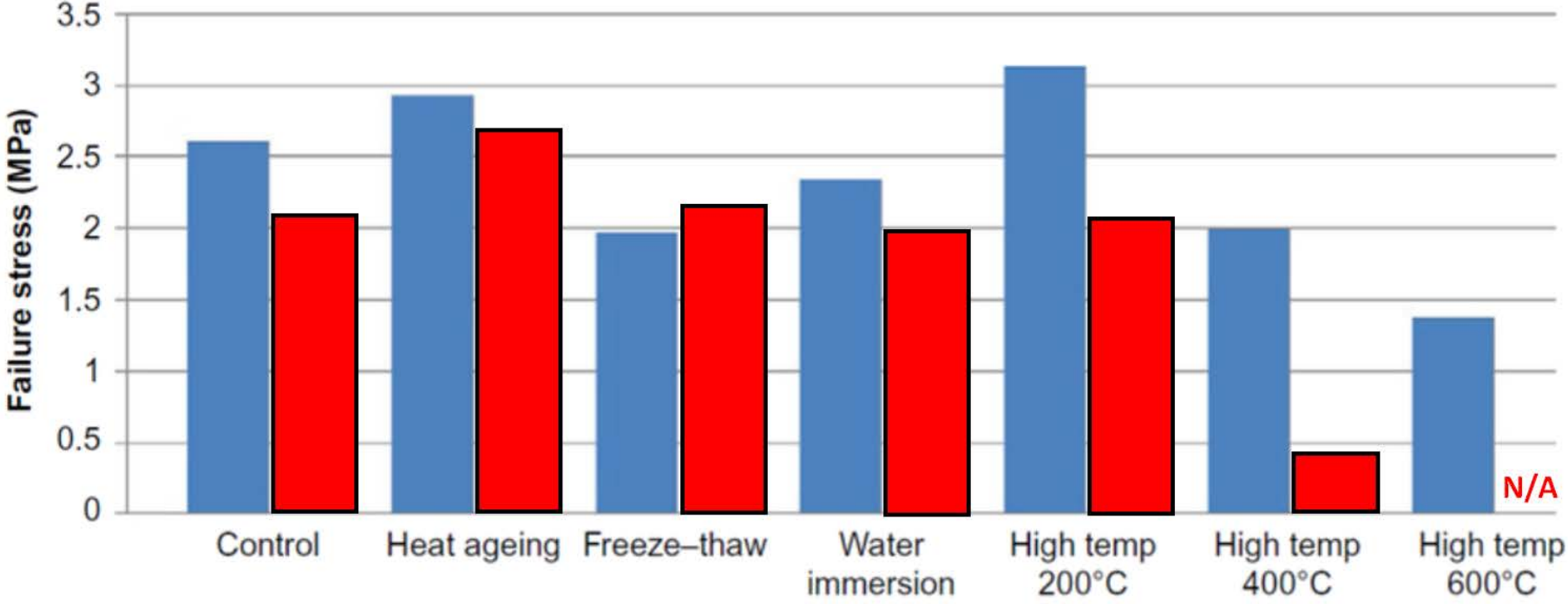
- Despite the relative success, the poor electrical properties of the epoxy adhesive was the long term limiting factor to the effectiveness of the CP.
- An alternative approach, avoiding the use of epoxy, was therefore investigated.
- This used CF rods imbedded in grooves using a modified AACM-based mortar, offering good adhesion, improved acid resistance plus resistance to high temperatures.

Modified Test Beam Design

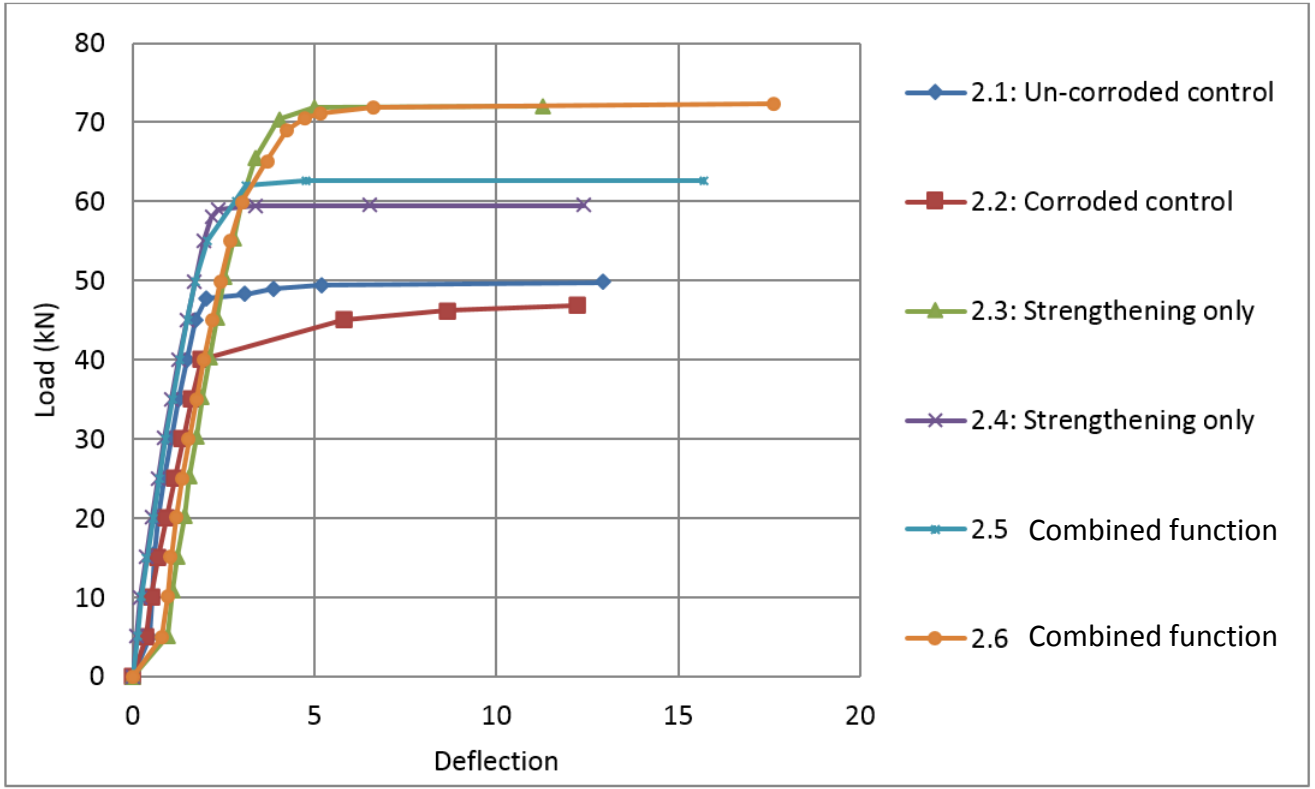


(All dimensions in mm)

Shear Bond Strength
AACM (blue) & Epoxy (red)



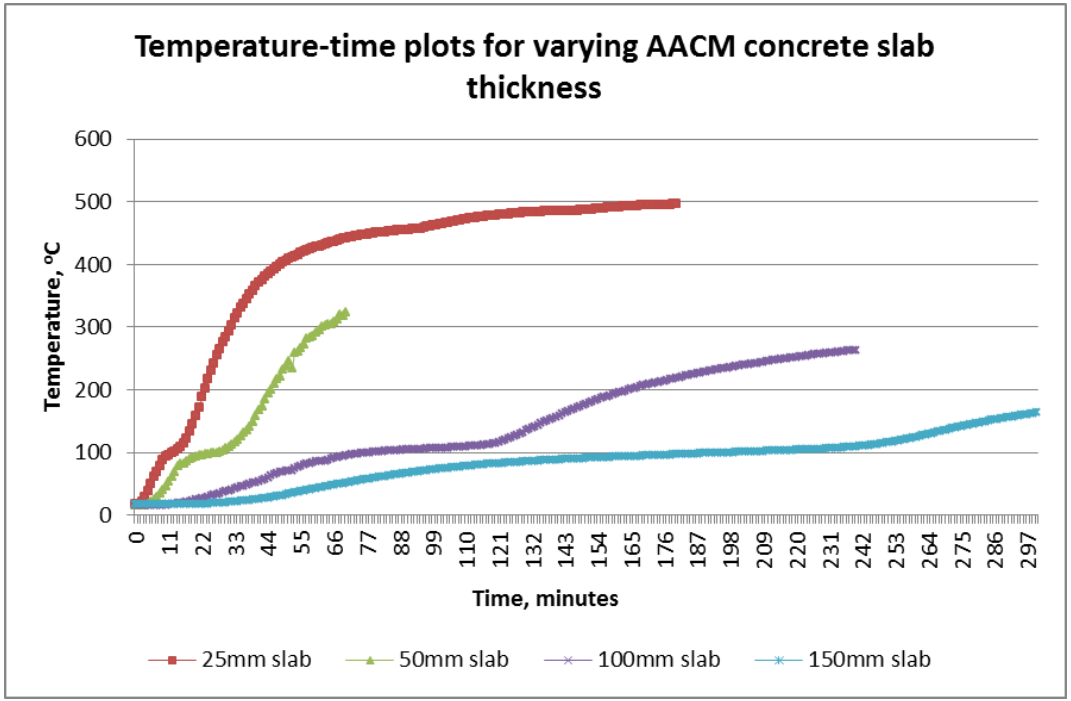
CF Rod with AACM Mortar & Epoxy Over-Layer Load/Deflection



Modified AACM Mortar

- The modified AACM mortar has proven to have many desirable properties.
- In addition to acting as an electrically conductive inorganic adhesive for CF applications, it can be used alone as an anode material.
- The inherent durability of the AACM matrix makes it resistant to a wide range of chemical environments and elevated temperatures.
- It is manufactured from mainly recycled industrial by-products so is low carbon for LEED considerations

Fire Resistance



- Tested to European code EN1363-1 for 1”, 2”, 4” and 6” precast slabs
- Material resists at least to 1200°C for 5 hours (limit of test)
- Heat transference depends of thickness
- Only 140°C transferred through 6” slab

Example Use of AACM Anode Mortar:

The Commerce Bank, Kansas City

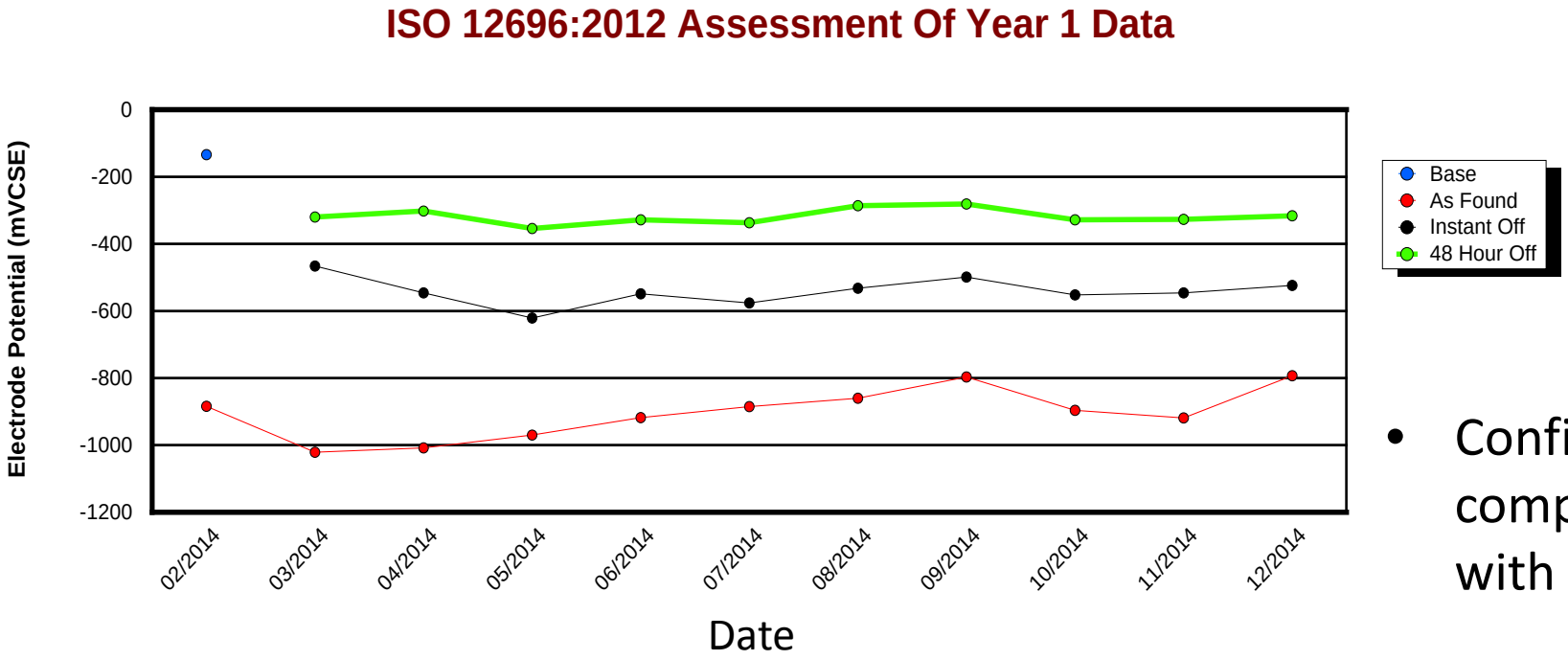
ICRI Award of Sustainability 2015

Modified AACM mortar – as a CP repointing anode

(installed at -5^{o}C)

Delivering CP from bed joints to protect structural steelframe

Summary CP Performance Data



- Confirms compliance with ISO

The Present and the Future for AACMs

- Repair mortars
- Anode mortars
- Precast concrete
- Cast-in place concrete
- Sprayed concrete

New & existing structures with built-in corrosion control, environmental, chemical and fire resistance & structural strengthening for low carbon sustainable whole life management of structures.

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