UK-China Science Bridge
Remote Monitoring of Corrosion Activity of Concrete at Hangzhou Bay Bridge

Introduction
- Concrete structures in marine environments experience deterioration caused by reinforcement corrosion due to external salts, freeze-thaw, repeated wetting and drying cycles, abrasion due to wave impacts and biological attack.
- In general, corrosion of reinforcement caused due to carbonation, chloride ingress and leaching account for more than 50% of the reported cases in concrete structures.
- The environmental factors that influence the deterioration mechanisms are moisture, temperature, wind, carbon dioxide and salts from the sea water.
- It is essential to continuously monitor the performance of concrete structures right from the construction phase to the end of service life of the structure.

Exposure Site
- Hangzhou Bay Bridge is one of the longest trans-oceanic bridge in the world; Length 35.6 km
- Aggressive environment with tidal variations up to 9m height and waves travel at 30 kmph
- The exposure site located underneath the service centre and hotel built at the mid-length of the bridge
- Three different types of concrete C30, C40 and HPC exposed at four different levels viz., Atmosphere zone, Splash zone, Tidal zone and Submerged zone

Sensor Technique and Monitoring System
- The integrated sensor probe consists of three different sensors viz. 2-pin electrical resistance sensor array, temperature sensor and corrosion sensor.
- The electrical resistivity or conductivity measured at different depths in the cover zone of concrete can be related to early age properties of concrete such as rate of hydration, setting characteristics, microstructure formation and long-term changes in transport properties of concrete in the cover zone.
- The temperature sensors placed in four different depths helps in monitoring the thermal gradients in concrete.
- The surrounding environmental data monitored using weather station in combination with the electrical resistivity, temperature and corrosion measurements help in predicting the remaining service life of the concrete structure.
- The monitoring control system installed at Hangzhou bay bridge can be remotely operated from QUB, Belfast.
- The corrosion activity data and weather conditions at the bridge are automatically transmitted to a central PC at QUB through cloud computing.

Results and Conclusions
- The electrical resistivity changes monitored for C30, C40 and HPC concrete shows three different phases associated to the setting characteristics of concrete and pore structure formation in the concrete.
- The prolonged increase in electrical resistivity observed for HPC concrete clearly shows the influence of slow pozzolanic reaction by the mineral admixtures viz. Flyash and GGBS in the concrete mix.
- The spatial distribution of electrical resistivity was able to monitor the influence of curing, which resulted in lower resistivity values at the 10 mm depth in comparison to resistivity at 80 mm depth.

Concrete exposed to marine environment (atmosphere zone)
- The electrical resistivity changes at 10mm depth from the surface for C30, C40 and HPC concrete increases with time and fluctuates in response to the diurnal variations in external temperature and moisture conditions.

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