Structural Investigation of Hong Kong's ageing public rental buildings

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Summary

The Hong Kong Housing Authority (HKHA) maintains a stock of over 1000 reinforced concrete domestic buildings of 7 to over 40-stories, providing homes to about 680,000 families. HKHA launched in 2005 a comprehensive structural investigation programme to look into the structural conditions of the older buildings and to establish what needs be done to better sustain them. This paper describes the investigation methodology adopted and some of the findings of the investigation of the first batch of about 80 buildings. The significance of chloride contamination in relatively porous concrete and of moisture in the concrete of these old buildings and the sources of contamination, in particular sea water used for toilet flushing, are discussed.

Keywords: structural investigation, concrete, maintenance, corrosion, chloride contamination, moisture content, steel area loss, defect symptoms, hidden corrosion.

1. Background

The Hong Kong Housing Authority (HKHA) maintains a stock of over 1000 reinforced concrete domestic buildings of 7 to over 40-stories, providing homes to about 680,000 families. HKHA launched in 2005 a comprehensive structural investigation programme to look into the structural conditions of the older buildings and to establish what needs be done to better sustain them.

Hong Kong's climate is sub-tropical, warm and humid. Effect of acid rain, coastal environment and use of sea water for flushing in the toilets also increase the risk of chloride contamination of the buildings. The inherent problems of earlier design, which include lower concrete strength and smaller concrete cover to reinforcement as well as lack of waterproofing system, poor floor screed and pipes piercing through the floor, also made the builidngs more vulnerable to ingress of water and contaminants into the concrete.

2. Methodology for the investigation

A tailor-made five-stage methodology has been developed for the work with due consideration to the specific conditions of HKHA's building stock. It includes information search, visual inspection, testing, structural assessment and development of repair solutions. A representative sampling approach has been used and is further supported by adopting method of grouping and categorisation of elements of similar properties or deterioration performance. The concrete strength and steel reinforcement area loss are statistically assessed and are represented by characteristic values at 95% confidence level.

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3. Findings and discussions

3.1 Environmental loads

Five stations at different locations were set up to measure the deposition rates of airborne chloride ions. Airborne-chlorine ions deposition rates were also measured inside a typical toilet. It can be seen that the airborne chloride ion levels close to the coast is much higher than those of a distance from the coast. The aerosol effect of toilet flushing with sea water could produce an internal environment in the toilet similar to the environment very near the coast, in terms of level of air-borne chloride ions. Collection flasks were also used to collect rainwater for tests for pH values. Results are still being collected at the time of submission of this paper. The first set of data collected have pH values between 4.2 and 4.3.

3.2 Built in factors

To study the corrosion activities inside the concrete but without any visual defect, test data for locations without visual defects in toilet ceiling were used. It can be seen that there is a significant chance that what appears to be a sound structural member may have the embedded reinforcement corroded to an advanced stage. Such phenomena of "hidden corrosion" is well recognised of chloride-induced corrosion in porous concrete. With a higher chloride level, there is a significant higher level of 'hiddeness' of the steel bar corrosion.

The steel reinforcement corrosion was found more pronounced in the wet areas of the buildings including the toilet and external cantilever corridors. A non-destructive method using moisture meter was therefore adopted to assess the moisture content in the concrete. It can be seen that the wetness of the toilet ceilings is very variable between buildings of different estates of basically similar toilet layout design. That phenomena can be attributable at least in part to the high dependence on site workmanship of 'wet-trades' within small confined space and weakness of the design of the toilet against ingress of water. It is very likely that the water often contains chloride from leaking toilets and drains as well as from aerosols of toilet flushings, as the chloride ion levels of toilet's slabs were found to be consistently higher than those of other structural elements.

3.3 Post-completion factors

The investigation provides broad evidence to suggest that the repairs would not be effective if they were not carried out to tackle the root cause. Small patch concrete repairs in chloride contaminated concrete might induce 'patch - accelerated corrosion' of steel embedded in the contaminated concrete adjacent to the repaired patch. Laying an extra screed on the top of the original porous sand-cement screed at the toilet might create an 'aquaduct' to spread the water and a 'sponge' soaked with water which slowly seeps into the concrete slab below.

The investigation reveals that older buildings tend to have more corrosion problems, but it is far from being the norm. The ones which require the most effort to sustain were found not the oldest. Some buildings were found to require repair work which is rather substantial, costly and disruptive. Earlier investigation might have reduced the life-time cost and nuisance of the repairs.

4. Conclusion

Based on the above discussions, the following conclusions can be drawn -

(a) Building deterioration is a complex issue requiring in-depth study. Full understanding of various factors including environmental factors affecting the deterioration is important.

(b) Chloride contamination of toilets with sea water WC flushing with toilet-cum-bathroom design, contributes significantly to the deterioration of these toilets.

(c) Phenomenon of hidden corrosion is evident from the investigation findings. This calls for further research and greater attention.

(d) Early investigation and maintenance is a preferred strategy to arrest the deterioration of the buildings.