Concrete problems today are multifactorial -

Root Causes – by Hamid Khan

Regular and planned asset maintenance is vital for reinforced concrete structures. Such maintenance shall not be a 'cosmetic repair' rather a proper root cause analysis must be carried out to identify and understand the actual source of the problem. Though material selection is an important step in asset maintenance and refurbishment projects but only after the root cause has been addressed. Conducting proper root cause analysis in restoration and refurbishment projects would prevent one from falling into a vicious cycle of 'repairing the repair'. A study conducted by Jingmond and Agren (2015) has highlighted the importance to look at the root causes of the defects in concrete from the organisational perspective as well, instead of the operational level only.

Defect or problem in an existing reinforced concrete structure is multifactorial; it often stems from obscure reasons. Like the cause of a common headache is often attributed to a pathological cause leading to expensive and often needless investigations and treatments, whereas, the actual cause is a stress-triggered tension headache. Similarly, stomach infections are common during monsoons in some countries, which are due to the 100 year old corroded sewage pipes leaking into the parallel running municipal water pipes. Point to ponder here is that whether treating the gastro patient with medicines or changing water filter would make the situation better without addressing the root cause of the problem or not?

Corrosion of the steel generates iron oxides and hydroxides, resulting in the increase of volume 5 to 10 times of its original size. This increase in volume causes expansive forces to accumulate within the concrete around reinforcement and results in concrete spalling. Cracks provide easy access to oxygen, moisture, chlorides and other corrosive agents - the conditions suitable for electrochemical corrosion process. Bridge girders often exhibit unexpected end cracking upon pre-stress release, a concern for bridge asset owners. These cracks propagate into the bottom flange of the girder where strands are located and can increase in width with increased traffic loads. Leakages from bridge expansion joint penetrating the bottom flange cracks could easily trigger severe corrosion currents. In this case expansion joints leakage must be arrested prior to the crack and concrete repair activity.

Concrete Cracks provide easy access to corrosive agents

A common and predominant form of cracking at an early age on new concrete bridge decks is known as *transverse cracking* which appear along the length of span over transverse reinforcement. These cracks accelerate corrosion rates, reduce the service life of the asset and increase maintenance costs. Multiple factors such as materials and concrete mix design, ambient temperature changes, humidity, bridge design characteristics and construction practices that contribute to volume change and/or to degree of restraint of concrete mass result in cracking. Transverse cracking cannot be attributed to all the above factors. It is important to identify the major contributing factor(s) to address the root cause of cracking.


Linear Transverse cracks on new bridge deck due to plastic shrinkage- Surface grinding to open the face of the crack and sealing with epoxy resin

A crude approach while examining the corrosion induced damage in bridge structures, particularly in the marine environment, is to assume the presence of chlorides as the main cause of failure. Chlorides might be the reason of corrosion but not the actual cause of the bridge defect. The root cause of failure of the bridge structure cannot be attributed to corrosion. There are many factors involved that could lead to corrosion and ultimately lead to failure of the bridge, such as, cracks in bridge girder web and flange, poor bridge drainage system, failed bridge deck waterproofing membrane, inappropriate bridge joints, void in the prestressed or post tensioned cable ducts due to excessive grout bleed. Other factors at macro level are related to design, material, environment and construction practices. It is important to address the main contributing factor(s) of the defects in bridge structures affected by corrosion.


Cathodic protection to bridge piers affected by cracks, corrosion and spalled concrete, using embedded galvanic anode units 'Galvashield XPT' (left) and distributed galvanic anode system 'Galvanode DAS' (right)

It is quite common to observe local white patch of efflorescence which appears like a chalky powder at ground floors due to rising or penetrating horizontal dampness inside institutional buildings, hotels and residential apartment buildings. This phenomenon occurs due to number of factors. For example, one of the factors is the absence or damage of proper damp proof course due to which the moisture from the below ground or landscape planters outside hotel rooms seep through the external walls and result in dampness white patches along the perimeter of the internal wall. Treating the damp patch from inside could only solve the problem temporarily but it would recur unless the damp proof course is repaired.

Concrete repairs conducted without considering the actual source are 'cosmetic repairs' and last only for few months. For instance, repairing the spalled concrete of a balcony with quick-fix patch method, even applying the best quality repair mortar, would not solve the problem unless the root cause has been identified and addressed. It could be attributed to more than one cause such as leakage due to failure of waterproofing membrane, an AC drain pipe leak, faulty concealed pipe joints or the combination of these factors. Corrosion of reinforcement that has caused spalling of balcony is not the root cause here.

Balconies concrete corrosion and spalling due to multiple factors

Roof leakages in the buildings result in seepage to the flats below. This causes discomfort to the occupants and frequent disputes between the landlord and the tenant in regard to the liability to repair. The failure of roof waterproofing is often attributed to the poor workmanship. Based on this notion, the roof refurbishments are carried out but the leakages appear again after some period of time. A research conducted by Leung and Cui (2005), on roof construction defects have highlighted that the root cause of failure of the roof waterproofing membrane stems from the roof parapet wall cracks. It further concluded that the design and choice of material for roof parapet wall is critical to avoid the waterproofing membrane failures on the roof slab. Other reasons of roof leakages could be wrong termination details of the waterproofing membrane at up-stands and drains, improper selection of the waterproofing system and poor roof joint detailing.

Soffits severely corroded due to roof leakages of a residential building

Falling of the external tiles from the building facades can cause damage to assets and pose a potential safety hazard to pedestrians. The number of casualties and injuries caused by the failures of external wall finishes is a serious concern to the authorities in many countries. Ho, Lo and Yiu (2005), in their research highlighted various factors that could lead to external tile failures such as thermal and moisture effect that induce movement of tiles, inferior quality adhesive, poor workmanship, improper joints, weathering, vibration and substrate properties. The failure could be due to a single factor or it could be an effect of a combination of the above factors. It is vital to recognise and address the major contributing factor of the de-bonding and falling of tiles.

Finding the real cause of a concrete problem rather than merely dealing with its symptoms is the key to success for a durable repair and refurbishment job. Aspirin quick-fix approach in handling concrete defects would only provide temporary cosmetic solution. The aim is to create an awareness among the civil contractors and engineers that to solve the concrete defects effectively they need to drill down through the symptoms to reach to the actual root cause. Re-examining, re-designing, re-assessing, re-selecting, re-applying and lots of *'re-s'*, can easily be avoided by examining and fixing the *root cause* of the concrete defect to ensure the same problems are not recurring.

About the Author: *Hamid Khan working presently* as *Brand Manager – Concrete Durability at Parchem (DuluxGroup), Australasia, holds a bachelor degree in Civil Engineering discipline. He also holds Masters in Business Administration and Masters in Strategic Marketing (with Distinctions) from the University of Wollongong. Hamid is certified in Concrete Technology and Construction, by City & Guilds of London Institute (UK) and is a qualified expert in Concrete repair & refurbishment with 18 years of experience in the industry. He was associated with Fosroc International in Dubai for 14 years taking up roles of Regional Specification Manager and Marketing Manager Strategy-Gulf States. Hamid's experience comes from the Gulf, Middle East, Europe, East Asia and Central Asia.*