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Editorial

In the previous Editorial, it was argued that the current structural design philosophy of designing concrete structures for Ultimate Limit State and Checking for Serviceability Limit State is no longer valid or relevant to the construction industry of the 21st century. Indeed, with our present knowledge and understanding of the mechanics and mechanisms of reinforced concrete deterioration processes, Design for Serviceability Limit State—i.e. Designing for Durability and Structural Integrity—is far more critical and of paramount importance, if we are to ensure that our stock of structures are able to deliver the durable service life for which they are designed. But designing for the Serviceability Limit State needs a clearer and thorough understanding of the performance of materials and structures in their real life exposure conditions. And experience tells us that this is not a simplistic process, as the progress of damage involves many interactive and inter-dependent parameters, several of which are beyond the control of engineers, and indeed, not anticipated or fully appreciated at the design stage. So the fundamental question is this—can engineers rise to this challenge and be able to design structures which will give durable performance for the period of service life for which they are designed?

There is—and can only be—one answer to this challenge, and it is best illustrated by Alkali Aggregate Reactivity (AAR). We now know that if we are able to develop techniques that are meaningful and effective to identify, evaluate and rehabilitate concrete structures that are affected and damaged by AAR, then we need to adopt an integrated material and structural design strategy—a Holistic approach—to tackle the problem of AAR. Traditionally, we believe that for AAR to occur and cause damage, three essential conditions need to be satisfied. However, experience now tells us that this concept ignores a vital component of AAR in the field, namely, the exposure conditions in which the structure has to breathe and carry loads safely and strongly. In a real structure, AAR and related expansion and damage will continue as long as the above three conditions are met. The reactive mineral phase, and the source and amount of alkali already present in the concrete structure cannot obviously be changed or controlled. So the critical factor that will control the progress of AAR and related deterioration in a real structure has to be the availability of moisture, from whatever source it might be.

Both field and laboratory test data emphasize the crucial role and function of exposure conditions in the phenomenon of AAR. The two pieces of vital information which are critical to the whole process of structural assessment and rectification of AAR—affected structures—namely, the rate of expansion of the concrete in the structure in its service environment, and the residual ultimate total expansion potential of the concrete in the structure—are highly dependent on the environment and exposure mode i.e. water availability and temperature. The choice of the test methodology to evaluate the effects of these influences is also thus very critical if we are able to be to prolong the service life of the deteriorating structure.

Many laboratory tests and field studies show that in almost all concrete mixes used in practice, there is nearly always enough residual mixing water to initiate AAR. However, invariably in all cases, the availability on internal residual mixing water is not sufficient to create ongoing damage, widening of cracks and loss of engineering properties. External sources of moisture are thus required to continue and accelerate the deterioration process. There is now enough field evidence to confirm that seasonal exposure and climatic variations enable most concrete structures to maintain internal relative humidities sufficiently high to sustain expansive alkali—aggregate reactivity. Thus most of the concrete in highways and dams in desert areas, and bridge decks and columns in dry climates can maintain sufficient internal dampness to sustain expansive reactions on and off. Similarly massive concrete members indoors in controlled environments can also retain adequate humidity for a long time. Equally, moderately elevated temperatures can also be effective in drying concrete sufficiently to substantially reduce or even stop the reaction for some period of time. Thus, for many structures it is the external environment that is the primary cause of

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continuing and damaging expansive reactivity. So protection from external environment, and control of ingress of water and water-borne contamination is the first line of defence in the rectification process of any concrete element suspected of AAR.

Protective coatings can thus offer a very positive and reliable solution for the long-term durability of concrete structures from the surrounding environment and ongoing AAR. However, experience world-wide on the use of such coatings, sealants, penetrants, impregnants and membranes has not always been favourable, partly because of the high variability of coatings of similar generic types in their diffusion characteristics and resistance to external aggressive agents, and partly because of their lack of long-term durability. But, above all, it is our lack of understanding of the basic engineering properties required for protective coatings to perform effectively and efficiently in realistic environments that has led to the present state of affairs of suspicion, mistrust, unreliability and short-term durability.

It is in situations such as this—indeed in all engineering situations—that we need to adopt a HOLISTIC approach—an integrated material and structural design strategy which will enable us to develop materials that can carry out their intended functions effectively, reliably and for a clearly defined specific design life. Similar to the gross inadequacies and limitations of current building design code specifications in their lack of ability to ensure durable service life of concrete structures exposed to aggressive salt-laden environments, there are no adequate specifications for surface coatings. Those that exist cater only for short term performance, and do not take into account the engineering and microstructural characteristics required to enable coatings to resist and retain their protective qualities when exposed continually to aggressive salt-laden environments.

So what is the Holistic Challenge confronting engineers and material scientists formulating protective coatings? What should be the chemistry of the coating? And how do we evaluate the qualities of the coating in real aggressive exposure conditions? It is obvious that we can never realistically simulate field conditions in the laboratory, and therefore ultimately, the only reliable tests are those where the coatings are exposed to real environments, although laboratory tests can be extremely valuable and provide guidance in formulating the chemistry of the coating. Experience and extensive research show that it is this type of Holistic approach which will alone enable us to develop protective coatings with guaranteed service life of the order of 15–20 years.