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Cement & Concrete Composites 22 (2000) iii–iv

Cement & Concrete Composites

Editorial

It is now slowly dawning on us that whilst the engineering and technological face of the world has dramatically changed our way of life in the last four to five decades, we have landed ourselves in a major international crisis – the damage and destruction of our infrastructure systems all over the world. The continual erosion and deterioration of the basic amenities of life to large sections of the population in every part of the universe should begin to cause worry and concern, and make us wonder why all these are happening when we have made several advances in our understanding of the microstructure and micromechanics of materials of construction. In other words, do we have a Durability Crisis in addition to the Infrastructure Crisis that is challenging the concrete industry?

Most of us have been taught to believe – or is it sometimes planted on us? – that concrete is a material of enduring quality that needs no maintenance, and that it is a medium that will not deteriorate. And in addition, there is our perceived assumption that somehow the impermeability of concrete and protection of the embedded steel against aggressive agents will be automatically and adequately provided for by the cover thickness and the presumed quality of concrete. Our experience shows that neither can be achieved as a normal and natural consequence of the process of concrete construction.

There is no doubt that long experience and a good understanding of its material properties tell us that concrete can be a reliable and durable construction material even when it is exposed to moderately aggressive environments provided it is formulated correctly, and care and control are exercised at every stage of its production and fabrication, and this is followed by well-planned regular inspection and maintenance schemes. Side by side with this knowledge is also the experience that when exposed to salt-laden and other aggressive environments, there is an unacceptably high risk of premature corrosion deterioration of concrete structures, even when specific building code requirements of durability in terms of concrete cover and concrete quality are achieved in practice.

A lot of research during the last four decades explains why this apparently contradictory situation exists. One of the puzzling and intriguing characteristics of concrete is its double-faced nature. Whilst being intrinsically protective to steel, it is also the same material that controls the ingress of water, air, oxygen, chlorides, sulphates and other deleterious agents that damage concrete and lead to the progressive destabilization of the steel. And modern portland cements are the real culprits in that changes in the mineralogy of the manufactured cement have enabled engineers to achieve structural design strengths with lower cement contents and higher water–cement ratios. The same changes in chemical composition have at the same time produced adverse effects on the amount and rate of evolution of the heat of hydration. These two contradictory effects have combined to produce concretes' that are not totally resistant to penetration by aggressive ions and concrete material and structural degradation have become common in many parts of the world.

Three major factors – cracking, depth and quality of cover to steel, and the overall quality of the structural concrete – control the transport mechanism of aggressive agents into concrete, and determine the electrochemical stability of the embedded steel. There is one other factor – one that is beyond our control – that has a predominant influence on the rate and intensity of deterioration, i.e., the micro- and macro-environment of the structure to which it is exposed during its life. The effects of the time-dependent, combined interaction of loading, and adverse climatic environmental and geomorphological exposure conditions are cumulative, concomitant and synergistic, a complex combination of many individual mechanisms, the exact role, effect and contribution of each of which to the totality of damage cannot be realistically assessed but the ultimate result is an unknown factor affecting the microstructure leading to increased permeability and decreased durability.

The fact that this trend of premature deterioration of concrete, and sometimes failure, is just not confined to one part of the world, gives credibility to a feeling that we do not fully understand the behaviour of materials, and in situ structural performance in the real world exposure conditions. There is overwhelming evidence that this lack of durability of concrete and civil engineering constructions in general is a matter of major concern all over the world. To give some typical examples, the current total construction industry expenditure in the UK is about £56 billion – 50% of this is currently spent on repair and rehabilitation. The cost of corrosion to the UK economy is estimated at £15 billion per year, whereas in Europe, damage repair every year is estimated to cost £1.4 billion ECU. In the US, the 1998

0958-9465/00/$ - see front matter
PII: S0958-9465(00)00013-5

ASCE Report on America's Infrastructure estimated a five-year total investment need of US$ 1.3 trillion, just to put back the roads, bridges, dams, drinking water and other infrastructure systems to good serviceable life. The average state of America's infrastructure was rated as Grade D – Poor!

Do we still need to be convinced that we face, in addition to an Infrastructure Crisis, a Durability Crisis? Do we really have a durability problem with concrete construction? Need we worry? Are we happy with the education and training we provide to all those who subsequently become involved in the construction industry? Should we have concerns for the natural and man-made environments, deeply felt all over the world and crossing traditional disciplines and national boundaries?