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Q82 AGEING AND REHABILITATION OF CONCRETE AND MASONRY DAMS AND APPURTENANT WORKS

AN OVERVIEW OF AGEING AND ITS MANAGEMENT IN CONCRETE DAMS

Introduction:

Concrete has been used in dams of varying designs which have evolved over the years, ranging from early masonry and gravity dams, through 20th century designs using multiple arches and buttresses, arch dams, concrete faced rock filled dams (CFRD), to the currently popular roller compacted concrete (RCC). In addition, concrete has been used in various appurtenant works including spillways, intake towers and channels, outlet works, fish passage facilities and navigation works.

Most of these structures must perform over extended periods and be available to function safely under demanding conditions such as seasonal temperature extremes, floods and earthquakes, to name a few. The need to deal with "ageing" of the concrete in the structures is clearly increasing as many of them enter "middle age", being over 40 or more years old.

Question 82 at the 21st Congress therefore addresses the following issues:

1) Types, causes and detection of ageing.
2) Analysis of ageing process and its consequences on dam safety.
3) Rehabilitation work, particularly using modern methods and materials.
4) Prevention measures (physical and organizational) to mitigate ageing process.

The Question excludes the damages covered by routine maintenance, not affecting dam safety.

Types, causes and detection of ageing:

A long service life is often considered synonymous with durability. It is customary to define durability of Portland Cement concrete with reference to the environmental conditions (ACI Committee 201) and its ability to resist weathering action, chemical attack, abrasion, or other form of deterioration in terms of retaining its ability to retain its original form, quality and serviceability.

Water is usually available and is generally involved in the forms of deterioration of concrete in dams and the rate of deterioration is often related to the degree of permeability. Physical effects that adversely affect the durability of concrete include: surface wear; cracking due to salt; and exposure to temperature extremes such as fire or frost. Deleterious chemical effects include: leaching of cement paste by acidic solutions; sulfate attack, alkali-aggregate reactions (AAR); and corrosion of embedded steel.

Analysis of ageing process and its consequences on dam safety:

In most cases of deterioration the specific causative process can be identified by inspection by concrete materials experts, frequently using petrographers, augmented by field and laboratory testing. The role of non-destructive testing techniques such as ultra-sonic testing and their analysis and presentation using tomography methods is a developing field and can help develop an "internal" view of the structural condition.

The effects of these processes on structural integrity and dam safety can sometimes be obvious and in other cases such as AAR, detailed modeling, sometimes using special purpose finite element analyses, is necessary to identify the mechanisms and forecast potential effects such as cracking and deformation in the future.

One key aspect is the long term susceptibility to corrosion and performance of high strength anchors. These are increasingly used to improve stability of structures where construction joints are deteriorating or where criteria have escalated. Corrosion of reinforcing steel is clearly a major problem although is often more of a maintenance issue and not always related to dam safety.

Understanding the predominant processes at work can provide a basis to plan an appropriate structural management program. In some such cases the process may have a finite lifetime while in others it will continue indefinitely. When the process is seen to be continuing indefinitely, the approach needs to be one of long-term maintenance rather than a one-time fix and long-term budget provisions made accordingly. Economic analyses of remedial measures options should thus be done on a "life cycle" basis.

Rehabilitation work, particularly using modern methods and materials:

Many methods of treating surface deterioration have been developed including: chemical treatment of the upstream face; upstream concrete type coating using epoxy, gunite or shotcrete; sealant materials to provide a waterproof membrane; geo-membranes attached to the face; downstream drainage layers covered with gunite or shotcrete and reinforced and anchored to the downstream face, grouting or other internal treatment; and RCC buttresses on the downstream face.

Remedies for more invasive forms of deterioration such as alkali-aggregate reactions or other swelling or internal mechanisms tend to be more structural in nature since no "cure" is available once the structure is constructed. Some solutions have involved anchoring to improve shear strength on lift joints or as an attempt to restrain the structure against the cause. Others involved stress relief by slot cutting or other structural modifications.

Prevention measures (physical and organizational) to mitigate ageing process:

No material is inherently durable. As a result if interactions with its environment, the microstructure and consequently, the properties of materials change with time. A material may be assumed to have reached its end of service life when its properties under given conditions have deteriorated to such an extent that that the continuing use of the structure is unsafe or uneconomical.

In addition to having to deal with the physical and chemical processes of deterioration, the determination of acceptability of the condition of such structures is often made more difficult by changing criteria such as escalation in design floods (PMF's) and earthquakes (MCE's) due to improved knowledge and society's evolving demands for public safety. The economic value of the water supply, energy generation or flood control facilities containing these structures is frequently substantial and thus life extension and rehabilitation of existing concrete dams and appurtenant works is an important activity. It is vital that the industry understands the processes of ageing, how to assess its extent and what measures can be taken to cost effectively extend the life of these facilities.

There is little doubt that in constructing new concrete dams, careful selection of materials, supplemented by sufficiently comprehensive testing, appropriate mix design and good quality control will go a long way to ensuring longevity. The effective life of concrete dams can, in almost all cases, be extended indefinitely with proper design and construction, appropriate operation and good maintenance, and with rehabilitation of deficiencies when required. The most pervasive agent of deterioration is water, and thus measures to limit access of water to the concrete, both externally and internally should be the primary objective in most cases. In addition to techniques such as grouting and sealing to reduce leakage and leaching, although superficial, regular “housekeeping” and cleaning of exposed faces which minimizes plant growth and accumulation of deleterious deposits, can play a significant beneficial role plus adding value through pride of ownership.

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