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Deterioration of concrete in a hydroelectric concrete gravity dam and its characterisation

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Abstract

A hydroelectric concrete gravity dam in the Snowy Hydro network had shown signs of concrete distress in the form of cracking in some sections of the dam wall, and vertical movements in the wall, measured in routine surveys on the crest of the dam wall. Concrete elements of the associated power station had also shown some degree of distress in the form of cracking. Alkali-aggregate reaction (AAR) was considered among other mechanisms as a likely cause of cracking.

In order to investigate the main causes of cracking of the various elements of the power station and the dam wall, core samples ranging in length from 0.3 m to 10 m were extracted and investigated for the presence of AAR, its extent, likelihood of continuing reaction, residual expansion potential, and effect on the strength of concrete.

Results of the investigation showed that mild AAR was present in some sections of the wall of the power station but not in the floor, where drying shrinkage could have caused the cracking. Mild AAR was also present in sections of the dam wall with minor visible cracking, but it was stronger and more widespread in the badly cracked area. It was suggested that the walls of power station could be treated by appropriate surface coating to mitigate the progress of AAR, and the badly cracked portion of the dam wall be anchored to stabilise the vertical movement. Other portions of the dam wall did not appear to need treatment.

Keywords: Concrete dam; AAR; Residual alkali; Residual expansion; Strength

1. Introduction

The dam and power station investigated are a part of the Snowy Mountain Hydro-Electric System and are under the control of Snowy Hydro Ltd. Routine measurements of movements in the dam wall had revealed that some sections of the dam had shown as much as 13 mm movement over the 13 years of measurement between 1988 and 2001, i.e. 1 mm/year. Fig. 1A shows a general view of the dam wall observed from downstream, and graphical presentation of the movements measured on various locations on the crest. Regularly spaced surveillance points had been located on the crest and deformation markers (DM), suitable for the measurement of vertical movement, installed on the crest. Fig. 1B shows the total vertical movement at each DM location on the crest, over the measurement period, and Fig. 1C illustrates the change in the vertical movement over the same period for each measurement site. Note that the DM positions in Fig. 1B correspond to the same locations on the crest shown in Fig. 1A, i.e. locations of DM5–DM8 correspond to the spillway location. In order to maintain a high level of operational efficiency, in February 2002 Snowy Hydro Ltd. commissioned a review of this facility including the power generation components and the concrete structures. A preliminary inspection was first carried out on the power station and dam wall by the authors to ascertain their long-term durability. As a result, alkali-aggregate reaction (AAR) was suspected as the cause of deterioration of the concrete in the power station. Stronger evidence of AAR was observed on the dam wall, which were similar to previously reported cases of AAR in Australian dams [1–4].

AAR expansion and cracking can adversely affect the properties and performance of concrete structures, the extent of which would depend on the reactivity of aggregate, extent of

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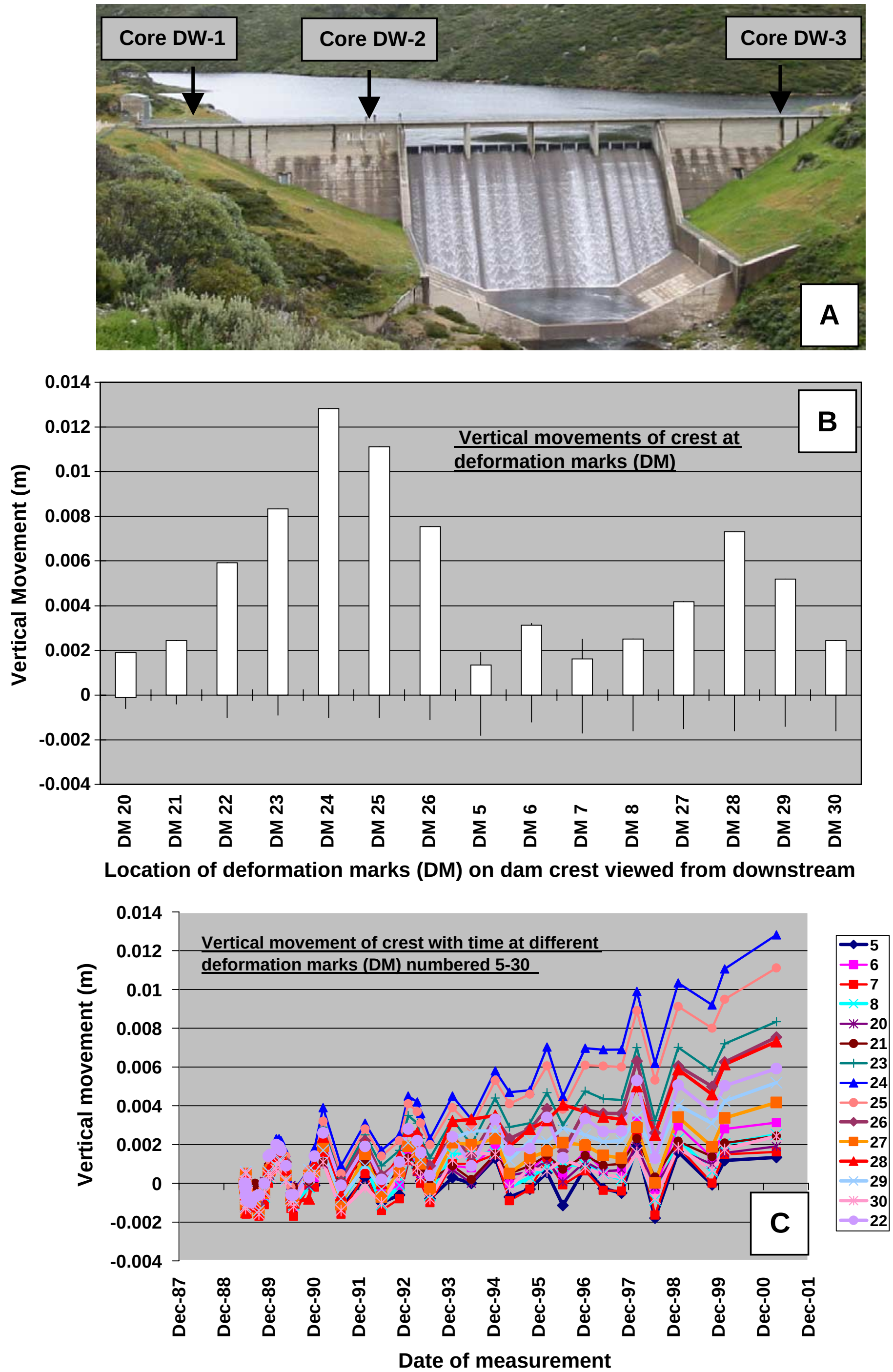

Fig. 1. General view of the dam from downstream (A), vertical movement of crest at different positions on the crest (B), and trend of expansion at each location with time (C).

reaction, type of element affected (mass concrete, reinforced, prestressed, etc.) and exposure conditions. The pattern of AAR cracking also depends on the type of element, being random (map-cracking) in plain and lightly reinforced concrete and directional in prestressed concrete. It is well known that steel reinforcement and applied stress have restraining effects on AAR expansion; the effects increasing with increased levels of reinforcement and applied stress [5]. At low levels of steel reinforcement, the AAR expansion could result in yielding failure of mild steel [6]. The compressive and tensile strength and elastic modulus of AAR-affected concrete were found to have been reduced by 60%, 50% and 30%, respectively, as a result of AAR, although the load bearing behaviour of the elements was not affected [6]. Other investigations have also provided evidence that most strength properties of AAR-affected concrete deteriorate compared to those of un-affected concrete [7–10].

Deterioration in the mechanical properties of concrete had caused serious problems in the Australian dams [1–4] which have all needed multi-million dollar rehabilitation. All these