POLICY BRIEF

July 2016
The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

Ensuring the safety of South Africa's large dams

A recently completed Water Research Commission (WRC) project has investigated the optimal use of ambient vibration monitoring for tracking the behaviour of arch dams.

Background

Dam safety is concerned with ensuring that the structural integrity of a dam is maintained throughout it service life. This requires a sound understanding of the loading environment, structural behaviour, material deterioration mechanisms and structural performance of a dam at any given time.

The most common approaches for dam safety evaluation are visual inspections, instrumented monitoring and finite element modelling.

This WRC project integrated continuous ambient vibration monitoring (AVM) and static monitoring of a concrete arch dam, the latter using the Westergaard method. By developing relationships between the dam's response (natural frequencies and dam wall deformations) and the operating loading (reservoir level, temperature) the onset of anomalous behaviour can be detected and the future response of a dam can be predicted.

Methodology

Roode Elsberg Dam, a double curvature arch dam located in the Western Cape, was used as a case study in the investigations.

Numerical investigations using the Westergaard method and the fluid structure interaction were carried out in the finite element analysis package, ABAQUS, and the results of the investigations were compared to field measurements.

Roode Elsburg Dam.

Multiple regression analysis was used to investigate the relationship between the loading and response of the dam.

Main findings

Investigations revealed that natural frequencies of arch dams are not very sensitive to reservoir orientation. A comparison of the results of hydrodynamic analysis of the dam shows that the natural frequencies obtained using the Westergaard method are about 23% lower than the natural frequencies obtained using the fluid structure interaction approach.

Natural frequencies obtained using the Westergaard method are about 20% lower than measured natural frequencies, while the results of the fluid structure interaction approach are within 3% of measured natural frequencies.

Furthermore, the study showed that the dynamic behaviour

of arch dams is strongly dependent on the reservoir level. The natural frequencies of the dam decreased with the water level. The dam's dynamic behaviour is also influenced, albeit weakly, by seasonal temperature variation.

Seasonal variation of deformations, on the other hand, are strongly dependent on temperature variation. In addition, the reservoir level also influences deformation of the dam, especially as the dam fills rapidly.

This is an important observation, which has only been possible through continuous monitoring of both static deformations and natural frequencies of the dam.

Conclusions

The study concluded that the Westegaard method overestimates the added mass for dynamic analysis of arch dams under operating conditions. This makes the method unsuitable in its current form for dynamic analysis of arch dams under ambient conditions.

The study confirmed that dynamic monitoring should form part of a dam safety evaluation strategy as it provides information that improves understanding of structural behaviour of dams. The information obtained from dynamic monitoring is critical for finite element model updating.

Recommendations

It is recommended that ambient vibration monitoring should form part of dam surveillance systems. This will enable robust detection of anomalous behaviour of arch dams by minimising false alarms. Ambient vibration monitoring also provides key information for developing realistic finite element models of arch dams.

It is clear that seasonal temperature variations contribute significantly to the deformation behaviour of arch dams. Furthermore, temperature has a strong influence on aggregate-alkali reactions, which leads to swelling and deterioration of concrete.

Long-term temperature shifts due to climate change would thus have an impact on the structural performance of dams. It is recommended to investigate the impacts of climate change on the structural performance of concrete arch dams in South Africa.

Further reading:

To order the reports, *Finite element model validation and long-term monitoring of concrete arch dams using vibration monitoring* (**Report No. 2244/1/16**), contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.