Reservoir Repair and Upgrade: Still the same issues?

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SYNOPSIS. Data has been collated on remedial and upgrade works on over 200 dams and nearly 400 separate remedial works activities worldwide. An assessment of the works shows that the most common works required are stabilisation works, works to outlets and then grouting / cut-off works. Of the driving forces behind the works 65% come from reactive forces, i.e forces internal to the project such as deterioration and 35% from pro-active forces such as legislation. A comparison of the reactive forces shows that the breakdown of causes in this data set is essentially the same as that produced by ICOLD in 1983.

INTRODUCTION

Research was undertaken to:

- Assess and understand the activities that are undertaken on dams and hydropower facilities to maintain the structures in good condition.
- Determine what techniques are commonly used.
- Understand the reasons why the activities were undertaken.
- Assess what patterns and trends emerged.

The original research activities, gathered on papers published between 1995and 2004 were spilt into regular and "one-off" activities with a concentration on "one-off" activities. This paper only considers the causes for the "one-off" activities and does not discuss the techniques employed. Following completion of the assessment the data was compared with a study undertaken by ICOLD, published in 1983 and a comparison of the results of the two assessments was made.

DATA SET VARIABILITY

Data on over 200 dam/hydropower sites and approximately 400 cases of remedial works were recorded. All different types of dam were represented: Ages ranged from recently constructed structures through to dams dating back over 1000 years. Heights ranged from a few meters to over 150m with

Ensuring reservoir safety into the future. Thomas Telford, London, 2008

the majority of dams less than 40m high. Lengths ranged from less than 100m to over 10km. All regions of the world were represented with the majority of the dams in the dataset located in Western Europe and North America.

ACTIVITES UNDERTAKEN

The activities undertaken on the structures included: stabilization, reconstruction or abandonment, sealing works, membrane works, grouting or cut-off works, works to the reservoir (e.g. raising its level), outlet works (e.g. spillways, low level outlets, M&E works), monitoring activities and crest works. The distribution of the types of works is shown on Figure 1. Each of these areas of activities was further subdivided and the types of works assessed. Data on the subdivision of the activities are not provided due to space constraints but it is the intention to publish this data in the future.

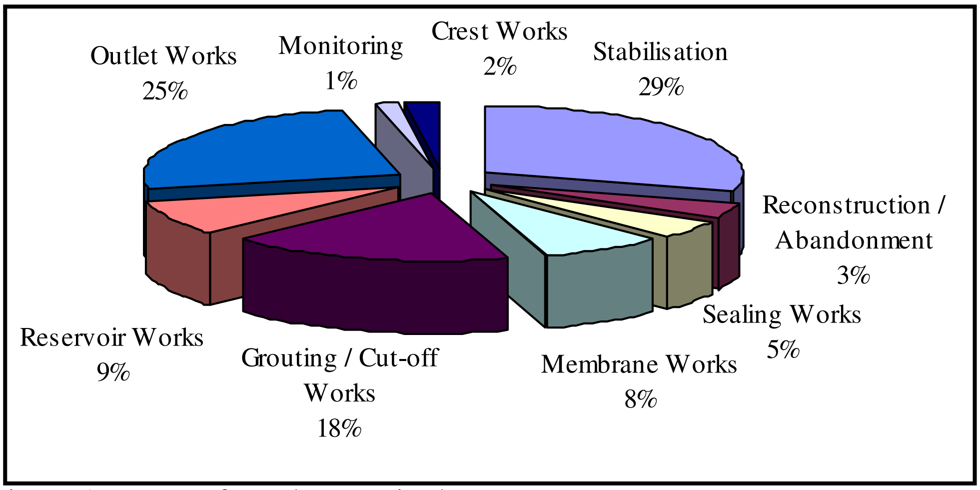

Figure 1: Types of Works Required

DRIVING FORCES

The activities identified were grouped in terms of the driving forces behind the activities. The driving forces were split into “Pro-active” and ”Re-active” data sets i.e. those that are performed as a result of external requirements and those that are required to fix something. As can be seen from Figure 2 the majority of the works are Reactive.

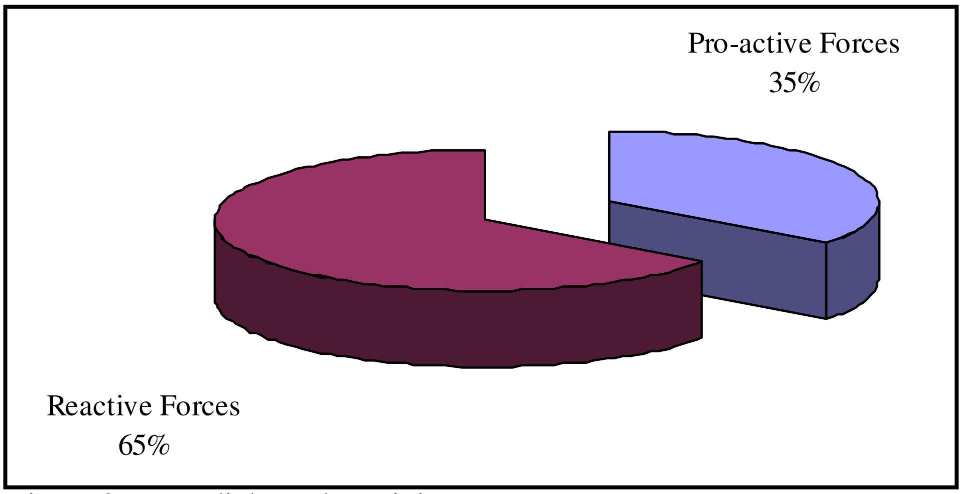

Figure 2: Remedial Works Driving Forces

Reactive Forces

Of the reactive forces, the data set demonstrates that the most common driving force behind the works is impermeability (leakage), closely followed by human influences (issues resulting from design, construction or operation errors). Together these make up over half of the causes for remedial works. Natural events include damage from floods, seismic events etc. Age related forces include age (elements reaching the end of their lifetime), siltation, corrosion and spillway erosion. Ground condition forces include settlement, abutment deterioration and landslides. Concrete expansion is self explanatory and includes alkali aggregate reaction. The break down of the Reactive Forces are shown in Figure 3.

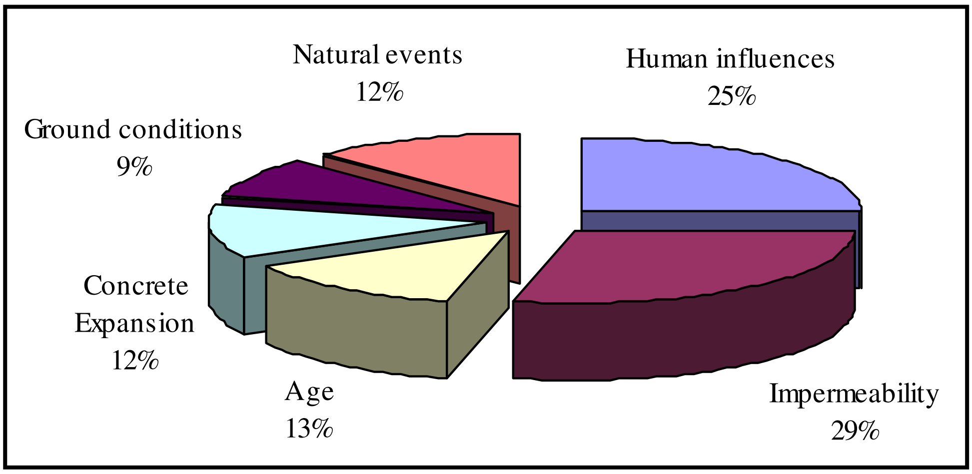

Figure 3: Reactive Forces

<u>Pro-active Changes</u>
The Pro-active changes were split into two sections, Legislational and Operational/Functional Changes and the split is shown on Figure 4.

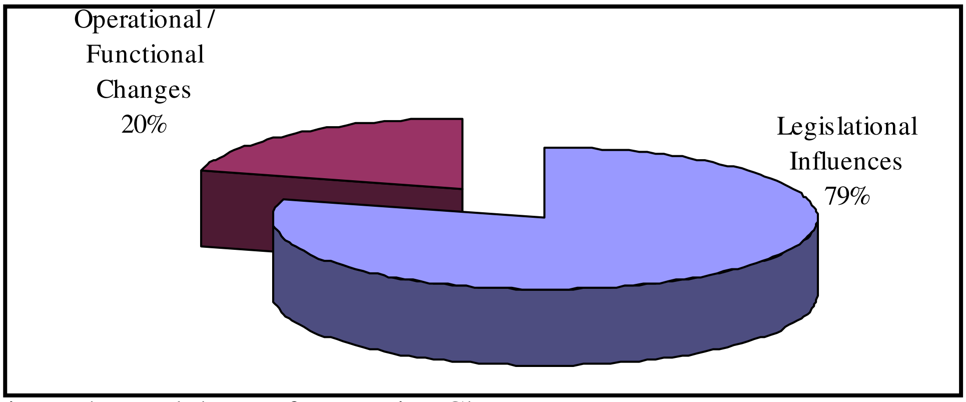

Figure 4: Breakdown of Pro-active Changes

Legislational Influences
Figure 5 shows a comparison between the different legislational influences. The data set includes all types and ages dams. With the exception of Old Aswan Dam, Egypt none of the dams is from Africa or South America, and only a few are located outside North America and Europe. This reflects the different levels of the development of dam safety legislation and guidance regulations worldwide. Of the influences New Flood relates to the revision of the design flood, crest details relates to the requirements for protection or freeboard, Stability relates to requirements for safety factors, and Instrumentation to requirements for instrumentation.

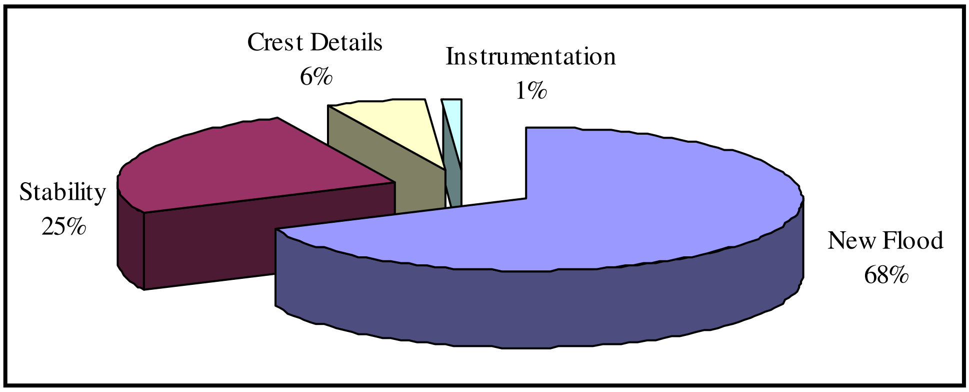

Figure 5 :Legislative Sub-Categories

Operational/Function Changes

The operational/Function Changes are shown in Figure 6. Most of the dams in the data set were constructed for water supply, with a few hydropower structures included. No flood dams or recreational structures are included. This is unsurprising given the nature of the dam functions and the economic return from raising or other operational changes. Or put another way there is insufficient income generated from a flood or a recreational structure to finance operational changes.

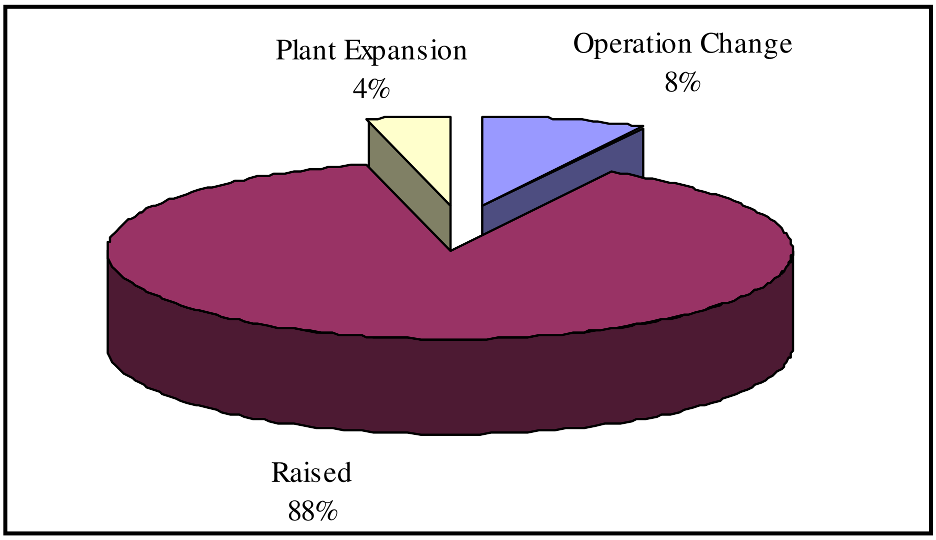

Figure 6: Operational/Functional Changes

Of the operational/function changes raising of the structures (resulting in increased reservoir volume) constitutes the vast majority. Operational changes such as to water supply occurred on a few structures and the expansion of the plant on even fewer. A considerable number of the dams were constructed in the period following the Second World War. This relates to the large number of dams built at this time and present in the data set, rather than to any other.

COMPARISON WITH THE ICOLD ASSESSMENT

A comparison between this data set and the ICOLD data set from 1983 is shown in Figure 7. This shows that despite the passage of time the proportions of the causes for remedial works as a result of reactive forces have essentially not changed. The one exception, where the new data set varies significantly from the ICOLD data set, is concrete expansion. The difference in this instance is probably a question of time with more occurrences having been identified over the past few years.

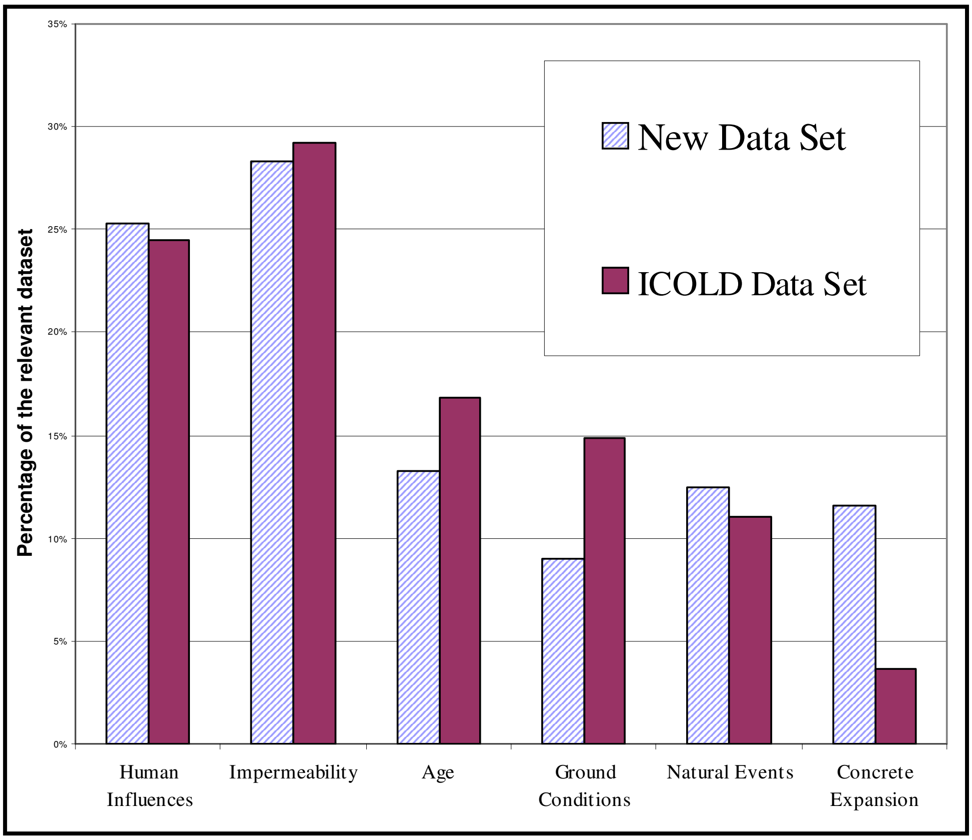

Figure 7: Comparison of ICOLD and New Data set for Reactive Forces – Grouped at the top level

The immediate logical conclusion to the general matching of the proportions of the reactive forces between the new and ICOLD data sets is that, despite publication of data, owners, designers and contractors are not eliminating problems that are known to be likely to occur. However, this is harsh as without comparative data sets of dams that have not required remedial works it is impossible to note whether the occurrence of these problems has reduced in the dams built since the publication of the ICOLD data set in 1983.

TRENDS

It has been difficult to establish specific trends from the data set. Ideally an evaluation of a controlled data set (e.g. all the dams in a region of country) would be required to properly assess trends, but this could not be accomplished. However, despite these shortcomings, a major trend that can reasonably be concluded from the works is the increase in the amount of works resulting from Pro-active Forces and in particular legislation. The other trend that can be concluded from the research is that the base causes for remedial works, as a proportion of the remedial works performed has not changed between the study performed by ICOLD in 1983 and this study.

SUMMARY & CONCLUSIONS

A dataset of reservoir activities, including remedial and upgrade works, has been collated and analysed. This data set shows the wide range of activities that have been performed on a wide variety of different structures. Of these activities the big three activities are stabilisation works, outlet works (including spillways and low level outlets) and works to improve the impermeability (reduce the leakage) of the structure. The data set also shows that the majority of works performed are "Reactive" i.e. required to fix something. However, "Pro-active" influences are still a significant proportion of the works required. Comparison of the data set with the ICOLD study shows that there is little change on the pattern of works between the two studies.

REFERENCES

Dodd, A.O., (2003) *Reservoir Remedial Works and Maintenance Activities,* Master Of Philosophy, City University School Of Engineering and Mathematical Sciences.