Innovative monitoring to answer difficult questions

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Summary

The first author came to monitoring after a long period as an experimental researcher. In 2000 he moved into consulting and came across many situations where expensive monitoring had been installed without proper thought about what could be measured and how it would impact on decision-making processes. This paper presents some examples of poor measurement that could not provide useful insight. It then presents some examples of monitoring used to answer difficult questions about structural behaviour. We conclude that monitoring can be invaluable in diagnosis of structural faults, and that it need not be expensive to be effective. It is crucial however that the specifiers first ask the question, "Is it a fair test?" We find that monitoring typically needs to be carried out over extended periods, but that measurements must also be sufficiently frequent to make it possible to track all types of movement, not just the movement of immediate interest. Any movements measured must be properly investigated, not simply dismissed as errors. Finally, we present a case in which an a-priori belief in an invalid explanation of observed behaviour was so strongly held that clear results from simple monitoring, backed up by intrusive investigation, failed to overcome it.

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1. Introduction

In primary school science classes, the question most firmly driven home is:

"Is it a fair test?"

Engineers, at least in the UK, are not good at asking that question. We provide a few motivating examples without identifying details.

The crack in Figure 1 is a metre or so from the edge of a bridge. If it widens at all it will do so through wearing away of the material not through moving apart of the sides. This high-grade installation will show nothing useful. Measuring out of plane movement would be better but only if it could be done fast enough to pick up the range of live load movements. Often very high cost measuring is done without proper consideration of the frequency of measurement required. If axles cross a bridge in 1 second a frequency of at least 10Hz is required to be sure of finding the limits of movement.

One error that is particularly common is the assumption that stress can be measured. Strain may be a surrogate for stress but only changes in strain can be measured and often only very locally. An attempt to understand the stress patterns in an old riveted plate girder must take into account the nature of the girder and of the loads (Figure 2). Thus a welded strain gauge of 50mm gauge length attached to one plate of a built up riveted flange is likely to show predominantly local effects. If the rivets are at 100mm centres, a gauge length of 500mm might be more appropriate and some form of framing system might be needed to ensure that the strain is effectively averaged over the width.

In another case, accelerometers were used to measure x,y and z displacements on 5 piers of a masonry railway viaduct (Figure 3). Measurement "events" were triggered by movement and ran

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