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The behaviour of railway level crossings: Insights through field monitoring

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ABSTRACT

The development of reliable methods for measuring deflections as trains pass has enabled valuable insights into railway track behaviour to be gained. This is especially useful for problem areas such as transitions from normal ground onto hard substructures and complex track geometries such as switches and crossings.

To date, much of the research on transition zone behaviour has focussed on transitions associated with underbridges and other substructures. Switches and crossings have received some attention and level crossings generally very little. This paper describes and discusses the behaviour of a transition onto a level crossing in the south of England, UK. Measurements are presented from both trackside and on-train instruments. It is found that at this crossing, maintenance constraints have resulted in a group of unsupported or hanging sleepers on the approach to the crossing; and that this fault is not effectively rectified by tamping. Comparisons are also made between the way the fault shows up in measurements from trains of the loaded track profile and data from trackside measurements.

Introduction

Transition zones occur at changes of track form and/or sub-base properties, and are characterised by a change in the effective track support stiffness seen by a train. Often, the track will transition onto a substructure or a different track form that is less susceptible to, or incapable of, settlement – for example, an underbridge or a concrete slab track. This sudden increase in support stiffness or resilient modulus gives rise to additional dynamic forces associated with a change in the vertical position of the wheel which, over a number of loading cycles, can lead to the development of differential permanent settlements, increased loads and an accelerated rate of track geometry deterioration. Similarly, a sudden decrease in the support stiffness gives rise to additional impact loads as wheels drop to accommodate the increased deflection caused by train passage. This recursive link between resilient modulus/subgrade strength, dynamic load, and settlement/geometry deterioration are well known; see, for example, the discussion by Li and Davis (2005) and finite element analyses by Banimahd et al. (2012).

A further concern is the ability to maintain the transition by conventional means. If the transition does not include a minimum continuous depth of ballast (usually at least 200 mm) beneath the sleepers leading up to and over the changed track form, mechanized methods of track maintenance, such as tamping, are difficult to use right up to and over the change in track form. This could result in a group of sleepers that are never mechanically maintained

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becoming unsupported or hanging, reducing further the apparent support stiffness seen by the train and accelerating the rate of geometry deterioration. Even when a continuous minimum depth of ballast is provided, problems with hanging sleepers can arise if the feature being crossed is short and very stiff, as demonstrated by Coelho et al. (2011) for a piled reinforced concrete culvert passing underneath a railway in the Netherlands.

Most investigations into transition zone behaviour in the literature have been focused on the (perhaps more obvious) problems of transitions onto bridges or over culverts (e.g. Coelho et al., 2011; Tutumluer et al., 2012; Paixao et al., 2013). A problem deserving just as much attention is that of transitions onto and off level crossings. Although level crossings do not experience as great a change in support structure stiffness as may be expected for structures such as bridges, there are particular difficulties in maintaining them so that the transition could be thought of as both due to changes in track structure (associated with providing a road surface) and discontinuities in maintenance practice. Moreover, there is a historical stock of level crossings (over 6500 in the UK) for which the construction form is not generally consistent and in some cases unknown.

The visible parts of the track at a level crossing are the rails and the concrete panels that form the road surface. Maintenance at such locations is problematic. In the UK, the relevant standard NR/L3/TRK/4041 (Network Rail, 2012) states that "*level crossings are a fixed point in the profile of the track. The track shall not be lifted or re-canted through level crossings when track tamping is undertaken*". Therefore, tampers are not permitted to lift the track near level crossings. This is significant because best practice tamping involves a design overlift of some tens of millimetres. This is needed to account for the fact that tamping disturbs the micromechanical structure of the ballast, so that when it is first reloaded newly tamped track will undergo large settlements as demonstrated in laboratory tests by Aingaran (2014). While the track may not be lifted through a level crossing it should still be possible to remove the crossing panels to tamp through and re-align the track.

However, there remain further significant practical difficulties to re-aligning the track. These include the limited scope to slew the track laterally without moving the crossing edge beams (with the consequent need for remedial works at the road surface interface) and also that tamping through crossings requires a road closure from the local authority which may have a lead time of 8–12 weeks. As a result, the level crossing panels are sometimes not removed and tamping operations are gradually ramped down over a distance of up to 20 m on either side of the crossing, leaving any geometry faults in place. Where tampers cannot be or are not deployed, handheld vibrating (Kango-type) hammers can be used to re-compact the ballast around and beneath individual sleepers but may not provide the same consistency of geometry realignment. Additionally, services and drainage running along the road may pass through specially constructed conduits or culverts beneath the track (as is the case for the level crossing studied here).

Thus the deviations from standard maintenance practice necessary at level crossings effectively create transition zones between conventionally-maintained ballasted track, and track that is partly stiffened by the presence of the concrete panels and tarmac roadway. Practical difficulties can also result in level crossings being left unmaintained for longer periods.

There are several ways in which the careful design of transitions onto hard structures such as bridges can prevent differential settlement, ensure that the support stiffness does not change abruptly, and mitigate the particular localised mechanisms of track degradation. If successful, these transitions should involve the same or less maintenance cost as regular track, and there is much current research into their effectiveness (e.g. Paixao et al., 2013; Li and Davis, 2005; Coelho et al., 2011; Tutumluer et al., 2012). In contrast, there are no recognised transition designs for approaches to level crossings.

The potential problems caused by the lack of an effective transition design and ongoing maintenance restrictions at level crossings could be ameliorated by alternative designs and/or maintenance practices. One possible measure could be use of self levelling sleepers, that automatically increase in height to mitigate the effects of differential settlement (Muramoto et al., 2013). Such systems are not currently approved for use on the UK rail network, but their use could be justified if there were confidence that the additional initial costs would be more than offset by a reduction in future maintenance costs.

This paper aims to:

- characterise the behaviour of the approach to a typical level crossing and
- assess the factors affecting the performance of the crossing over time,

with reference to:

- trackside measurements of sleeper deflections during train passage, made using geophones and remote video monitoring and
- on-train measurements made from the track recording car and using an inertial measurement system mounted on a bogie of an in-service train.

The difficulties of obtaining spatial consistency between trackside and on-train measurement data are also discussed

Study site

As part of a programme of on-going monitoring at problem sites in the UK (Track 21, 2014), the National Infrastructure Laboratory at the University of Southampton has been investigating track performance on the approach to a level crossing near a station in southern England, UK. The purpose of the investigation was initially to evaluate the before and after performance of a level crossing where a renewal was due to take place. However in the event, the renewal was only carried out on one side of the level