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Influence of stiffening ballasted track bed overlying a masonry arch bridge using a polyurethane polymer material

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HIGHLIGHTS

- A finite element analysis of a masonry arch railway bridge has been conducted to study the stabilizing effects on the bridge using polyurethane polymer reinforcement of part of the ballast.
- This work provides a technique for the stabilization of masonry bridges using polyurethanes in order to address specific problems associated with the bridge structure.
- The finite element analysis has shown that by installing the polymer material actually reduces the displacement in the bridge, these studies are still on-going.

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ABSTRACT

A finite element analysis of a masonry arch railway bridge has been conducted to study the stabilizing effects on the bridge using polyurethane polymer reinforcement of part of the ballast. Ballast is a highly non-linear granular material and its behaviour is influenced by the formation and subgrade structure. The track support and its deterioration with time is dependent on a number of parameters. Arch structures were designed for lower vehicle loads than they are currently subjected to so this work is focused on finding an innovative way of extending the scope of a proven ballast strengthening technique (XiTRACK) to encompass arch bridges, allowing a better distribution of the loads from the trains and hence to reduce the pressure on the arch. This work will provide a technique for the stabilization of masonry bridges using polyurethanes in order to address specific problems associated with the bridge structure. This involves numerical modelling of the ballast structure, the arch fill and the response of an arch barrel to achieve the optimum use of the material. The work is still under development as the current analysis uses a linear elastic model of the bridge, due to calibration of the data readings taking from the actual bridge, however further work using non linear plasticity is underway.

1. Introduction

Previous work on the finite element analysis of masonry bridges includes a two dimensional simulation for the evaluation of the load carrying capacity. This simulation took into account the strengthening effects due to arch fill interaction as observed in experimental tests. The upper bounds on the collapse load and the corresponding mechanics were obtained using a finite element application of kinematic theorems of limit analysis [4]. [3] used a simplified discrete-crack finite element modelling approach to model the performance of an unreinforced brick and block work masonry wall subjected to out of plane impacts. The approach involved the use of linear elastic solid elements for the masonry blocks with a specially formulated contact interface model for the masonry joints. [5] performed finite element analysis of longitudinal and transverse load effects on the masonry arch.

Experimental and field studies on the effects of applying polyurethane polymer GeoComposites for reinforcement of railway tracks by has been reported by [10,11]. Maintaining track geometry in ballasted tracks is a critical issue for the safety and operational performance of the railway system. The *in-situ* three dimensional polyurethane ballast reinforcement technique has been proven through controlled laboratory tests using a 200 ton capacity cyclic compression machine. The experimental tests are used to demonstrate the performance of the GeoComposite for applications such as railway tunnels and station platforms where clearance issues are critical [10]. Laboratory testing was also performed on the settlement behaviour of full scale tests of

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unreinforced and polymer reinforced railway track using the GRAFT I (Geopavement and Railway Accelerated Fatigue Testing) facility [7]. The measured settlement profile for each track specimen was monitored up to a maximum of 500,000 load cycles at different load levels and formation conditions. The results are compared to settlement models and good agreement is found allowing the settlement profile of any unreinforced clay subgrade in GRAFT I to be established at any load level. The polymer treated track was observed to significantly reduce permanent track settlement, effectively giving slab-track like performance [7].

This preliminary study investigates the effect of polyurethane GeoComposites performance on the stiffness of the track and the stress level on the arch fill using a linear elastic model. In this work a 3-dimensional finite element analysis has been performed to analyse the effect of various polymer rafts in order to reduce the stress on the arch bridge structure. The polymer raft (hereby called XiSPAN for masonry bridges) will be modelled underneath the rail as shown in Fig. 2.

The XiSPAN addresses fundamental requirements by providing a means of restoring the function of an arch bridge while avoiding the need for the removal of the track. Fig. 1a illustrates the polymer geo-composites being used to create a structure within the ballast. In this case the track is not removed while work is carried out, while Fig. 1b shows the complete removal of the track to apply the polymer before replacing the track [10,11].

Whiley Hill bridge (Ref. DAE1–13 – Fig. 3) is located in county Durham UK. The bridge consists of a single span and carries the Darlington to Shildon railway line. Recent deflection pole monitoring has identified that the bridge deflects unacceptably under freight loading which has been recently introduced along the line. The bridge was elected for a trial using the XiSPAN polymer and ballast GeoComposite. XiSPAN uses polymers poured onto clean ballast to create a stiff near surface layer. Such layers have been found to have beneficial effects on the capacity and performance of masonry arch bridges [6].

2. Modelling

The geometry of the exposed underside of the bridge was surveyed using a laser sweep. The maximum span of the arch barrel was approximately 3.3 m and the rise varied from 1.6 to 1.7 m. The distance between the North and South abutments decreased from 3.3 m to 3.25 m at the base of the abutments and the height of the abutments was about 2 m.

Following the extrusion drawing of the bridge, the next stage was to include the railway track and sleepers as shown in Fig. 4. The dimension of sleepers was as follows: 250 mm width by 2.6 m length, with a spacing of 650 mm between sleepers. The

Fig. 1a. Polymer application with the rails in place.

Fig. 1b. Polymer application with the rails removed.

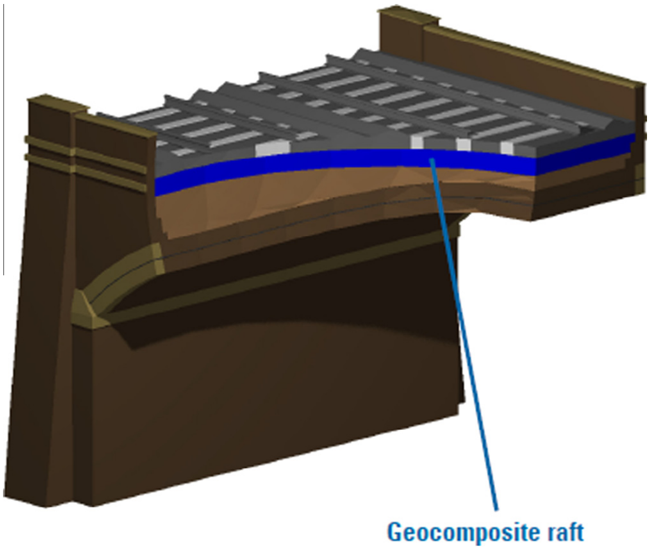

Fig. 2. Masonry arch bridge with XiSPAN raft ([2]).

Fig. 3. Whiley Hill bridge.

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