BIM and geosynthetics

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ABSTRACT: What is BIM? What are the benefit and the advantages? How BIM can be used within the geosynthetics industry? How geosynthetics can be incorporated with BIM? This paper will describe the use of BIM (Building Information Modelling) within the geosynthetics industry and how the design with geosynthetics could create an optimized solution, reducing the safety risks and improve the whole-life asset management of the project. The paper will describe the use of BIM in the design of a soil reinforcement ramp approaching an existing Victorian age bridge abutment with a complex geometry. The results presented in this paper extend also the experience and the development of BIM within the geosynthetic industry including some reference and examples.

Keywords: BIM; sustainable; information; modelling;

1 INTRODUCTION

1.1 *Definition of BIM*

“Building Information Modelling (BIM) is an intelligent 3D model-based process that equips architecture, engineering, and construction professionals with the insight and tools to more efficiently plan, design, construct, and manage buildings and infrastructure” (Autodesk).

BIM is a feature for managing the information produced during a construction project, in a common format, from the earliest feasibility stage through design, construction, operation and finally demolition. This toll allows the best and most efficient use of that information. A BIM model could incorporate graphic, physical, commercial, environmental and installation data.

The use of BIM can increase efficiency and reduce errors. The designs are built in three dimensions before work proceeds on site; the attributes of all the elements composing the object (e.g. building or infrastructure) can be found in the model; and a spatial interaction or ‘clashes’ can be identified and resolved during early stages in the model rather than on site when is too late to make a change.

1.2 *Key elements*

Some key element needs to be defined in a BIM model:

- Labelling and naming documents help in tracking and finding data throughout the life of the asset and allow all those professional working on the project follow the same procedures and approach. The process is well described in BS 1192, which is already used for numbering drawings on many projects.
- Filing, storing and manipulation information. On many projects, this involves the use of a 3D model and representation of the object which could be a building or a bridge structure for example.
- Sharing and exchanging information about the defined object including its construction, operation, performance and maintenance. Traditionally, this has involved exchanging drawings, technical specification and manuals, in paper or electronic format and this may continue.

The difference is that when BIM is used, the information will be generated from the BIM, rather than by preparing the documents separately.

2 MAIN BENEFIT

BIM is closely associated with the sustainability of construction and has evolved in a market where costs are increasingly being scrutinized.

In order to maximize the benefits of using BIM within a project, it is necessary that there is consistency in how teams collaborate, consistency in how tasks are approached and consistency in how information is shared. Collaboration between the all parties should start (ideally) at the very first bid strategy meeting when it will be agreed with all project partners that a common cross-discipline BIM delivery methodology is adopted.

Using a central BIM models, cross collaboration could be enhanced and the designs could be reviewed and updated more efficiently prior to design team meetings. From these updates, all design changes to individual disciplines could be shared with the rest of the team to ensure all disciplines are working to the latest information. This is especially important when the civil team for example identify different levels across the site; using BIM software a new model could be simultaneously created and the whole design team are then all working to the correct levels. In addition to collaborative design reviews a shared model could used to perform clash detection studies, which enable a rapid ongoing resolution of clashes avoiding costly abortive work being incurred if discovered down program.

The example shown below in this paper will highlight the most important benefit of using BIM such as faster project delivery, clear appreciation of costs and carbon emission, enhance operational safety and minimizing wastage of material and resources.

3 HANNEYS CROSSING BRIDGE

BIM has minimized the potential number of errors carried through the design and construction of these soil reinforced ramps within the reconstruction and raising of a Victorian over-bridge on the Great Western Main Line to accommodate overhead power lines.

The Great Western Main Line [GWML] is one of the oldest and busiest in the railway lines in the United Kingdom, linking London with the Midlands, the south west and west and most of South Wales. Engineered by Isambard Kingdom Brunel, it was originally founded in 1833 and ran its first trains in 1838.

Now, with freight and passenger traffic continuing to grow rapidly, the line is undergoing an £2.8bn process of upgrade and electrification. According to the train operators, these improvements to infrastructure will allow the introduction of faster cleaner and greener rolling stock which will provide a 20% increase in passenger capacity.

The “Hanneys Bridge” carries an un-sealed public byway across the railway line, providing north-south access to a sewerage works from the village of Grove (Oxfordshire), immediately south of the line. Built in the 1870’s, the bridge required partial demolition and reconstruction to create sufficient overhead line equipment [OLE] clearance. However, none of this expansion and improvement seems to come without its share of challenges to overcome. Not least of which is the re-engineering of many of the original overbridges, some dating back more than 150 years.

The increase in elevation of the bridge deck from 4.00m to 5.25m from top of rail head to soffit, meant that the approach ramps at each side of the structure also had to be raised to meet the new bridge deck level. To achieve Eurocode compliant design criteria and accommodate the required 40 ton vehicular loadings, the old ramps had to be cut down and completely replaced with new structures.

The ground investigation identified predominantly soft surrounding soils, highlighting the need for major reconstruction. On the plus-side, the surveys revealed that the original Victorian brick abutments to the bridge were still in excellent condition and would only require stabilisation and relatively minor reinforcement to increase their height and bearing width to accommodate the new raised deck.

As the line had to remain operational throughout the reconstruction, the original bridge deck was removed and replaced over the Christmas period 2015. Two new cill beams were installed on the raised and deepened abutments and the new deck was craned into position.

The solution proposed by the main engineer consultant required the complete removal of the original ramps and the construction of a pair of replacement ramp structures. As there was no land-take, the design was to be undertaken within the footprint of the existing embankments. A number of options were considered but a reinforced soil solution with 70 degrees facing was adopted, over a geogrid reinforced, basal reinforcement platform.

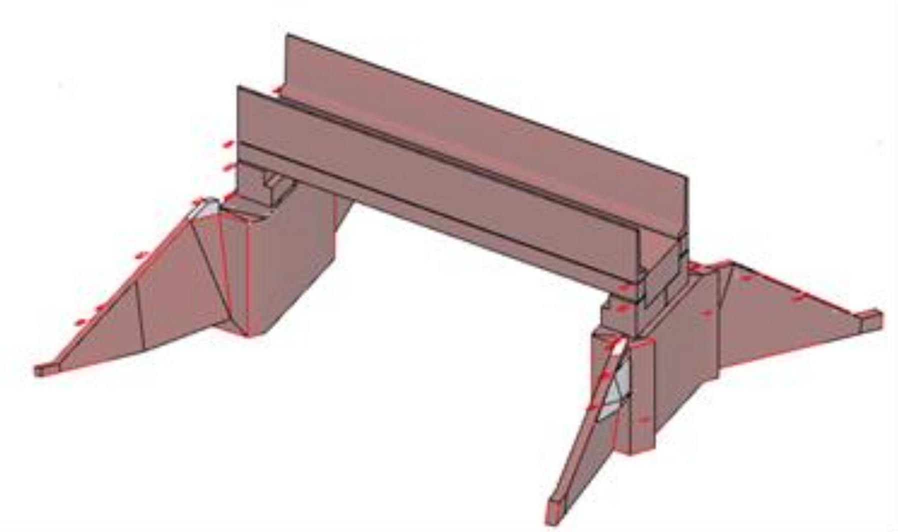

Figure 1. BIM model of the new narrow bridge deck and Victorian bridge bricks abutment.

The stability of those ramps constructed on soft soil such as at Hanneys Crossing is governed mostly by the shear resistance of the foundation and is an issue of bearing capacity.
According to BS 8006:2010, reinforcement is placed at foundation level to prevent shear failure both in the embankment fill and in the foundation soil. Beneath the exiting ramps to a depth of up to 400mm an uni-axial high strength stiff reinforcement layer was then introduced to improve embankment stability.

Figure 2. High strength uni-axial geogrid acting as basal reinforcement placed underneath the soil reinforced ramps

This reinforcement provided the additional strength needed to achieve the equilibrium state, increasing the safety factor against catastrophic failure. With the stiff, geosynthetics reinforcement at the base of the embankment, the resulting stress condition are “vertical and inward” rather than “vertical and outward,” as would be the case for an unreinforced embankment.

Stability analysis carried out using Mac.St.A.R.S 4.0 [Stability Analysis of Reinforced Soil and Walls] and MacBars [Software for basal reinforcement], indicated that the use of bonded geogrids made of straps comprising a core of high tenacity polyester tendons encased in a durable sheath of low density polyethylene [LLDPE] would provide sufficient support for the embankment to ensure that stability is enhanced to an acceptable factor of safety.

The new reinforced soil approach ramps were constructed using a factory fitted double twist mesh system combined with biaxial-array geosynthetic straps that were introduced within the embankment to provide stability to the structure. The system was designed to produce a steeply sloping vegetated face which will quickly blend in with the surrounding rural landscape.

The soil reinforcement ramps forms then an embankment between approximately 10.0m and 14.0m wide. The embankment has a maximum height of 6m.

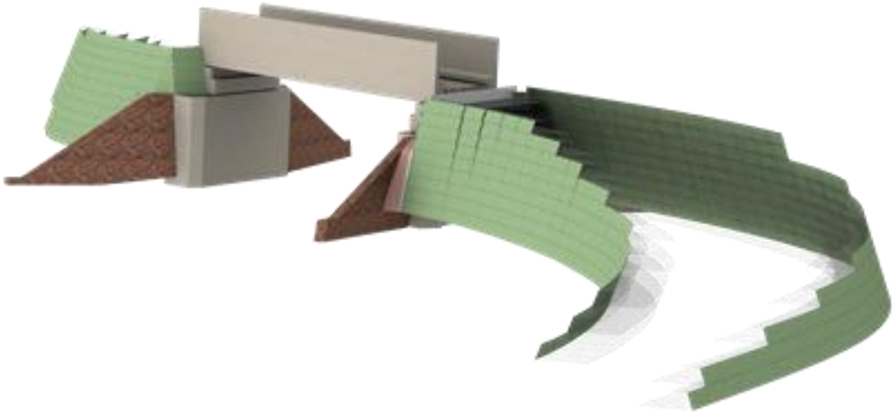

Figure 3. Representation of the soil reinforcement approaching ramps

The geometry at the interface with the bridge abutments and the new ramp structure was highly complex, requiring significant use of 3D modelling to determine the configuration of the various reinforced soil elements used. This geometrical complexity arose from the re-use of the existing abutments and installation of a narrower bridge deck.

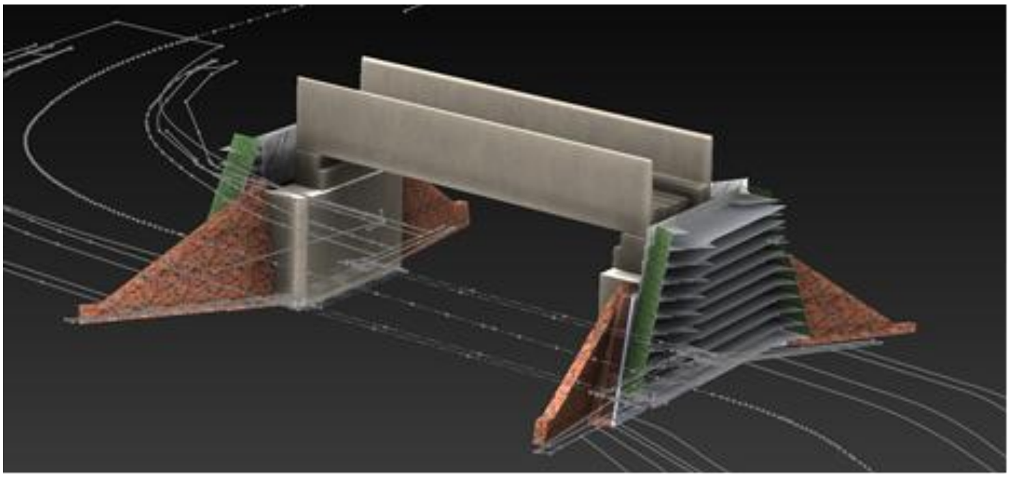

Figure 4. 3D-model showing of the link between the existing structure and the new designed geosynthetic solution

Throughout BIM, this complex construction detail was resolved before the project started on site. The model was used to check the design integrity and eliminating errors using a clash detection.

Clash detection eliminated also the need for wasteful rework on site and enabled a more efficient material management (e.g. with an exact material bill of quantities that avoided to over-order construction material). BIM allows also to reduce the safety risk from design and installation point of view: the critical detail was reviewed and managed by all the parties involved and they worked on the project.

To overcome this complex interface geometry, the double twist soil reinforced system was adapted so it could be used to form a 85 degrees slope rather than the more usual 70 degree.

To allow for this and to avoid compaction works taking place over the railway, the soil reinforcement at the interface were backfilled with lean-mix concrete. This allowed for the tops of the abutments, which were exposed due to the installation of a narrower bridge deck, to be utilized in the design and allowed for an aesthetically pleasing brickwork cladding to be specified.

With an increase in elevation of road level at the bridge of some 2.0m, it was necessary to similarly increase the level of the approach embankments while maintaining an adequate factor of safety of the abutments. This issue was addressed by constructing an almost vertical reinforced soil wall immediately behind the abutments, so that the forces exerted by the new structure onto the abutments were sufficiently low.

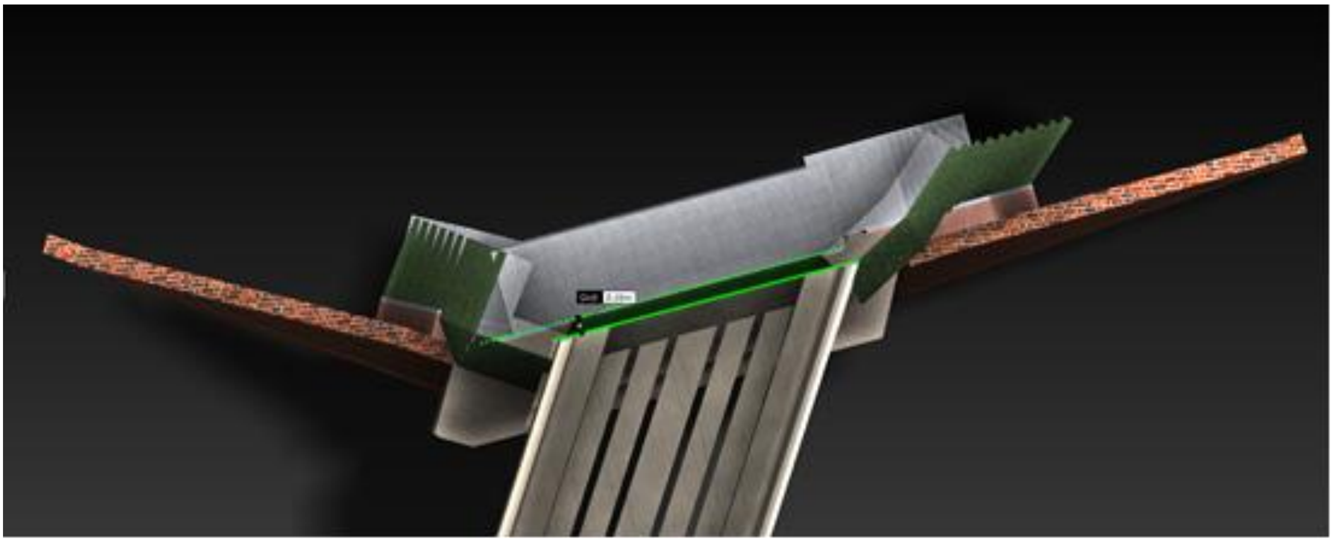

Figure 5. A detailed 3D-survey of the existing Victoria bridge abutments identify also the minimum distance of this vertical reinforced soil wall. This survey was included in the BIM model.

With consideration of long-term strain development within the geogrids, a detailed construction methodology was developed to minimize post-construction strains in the reinforced soil structures and minimize stresses transferred to the abutments.

By combining reinforced soil walls, slopes and basal reinforcement, a highly adaptable and elegant design solution can be developed. The reinforced soil elements can be combined seamlessly to overcome the many challenges faced on a project such as Hanneys Crossing.

Reconstruction of the Hanneys Bridge approach ramps began in late March 2016 and finished around June 2016. Throughout the works, the GWML remained open to traffic. The close working relationship between the design, supply and construction partners ensured an efficient, timely and on-budget conclusion to the works. In this project, the use of BIM made possible to reveal the impacts of different design, delivery and operational decision, including costs and other resources. Enabling development of more efficient, more cost-effective and sustainable solutions against agreed parameters.

Figure 6. General view of the project some months after construction

4 CONCLUSION

BIM is a coordinated process supported by the available computer technology that adds value by developing, managing and sharing the characteristics of an asset throughout its design life or its lifecycle.

The project shown in this paper has been a great example of how BIM can be used to deliver against challenging technical, construction and commercial requirements.

It’s important that the geosynthetics industry is able to work in partnership with the construction industry and customers to develop this innovative approach.

By successfully integrating their own manufacturing technologies with BIM data to supply products and solutions for a sustainable built environment, geosynthetics manufactures could bring benefits to the broader construction sector from linking design, project and manufacturing information.

REFERENCE

BS 1192-4:2014 - Collaborative production of information

PAS 1192-2:2013 – Specification for information management for the capital/delivery phase of construction project using building information modelling

PAS 1192-3:2014 - Specification for information management for the capital/delivery phase of construction project using building information modelling

NBS – National BIM Report 2016 (United Kingdom)

ICE – Institution of Civil Engineers UKBS 6031, 2009, Code of practice for earthworks. British Standard Institution, UK

BS 8006-1 (2010). Code of practise for strengthened/reinforced soils and other fills. British Standards Institution, UK