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CHENAB BRIDGE

PART II.

FABRICATION AND ASSEMBLY

CASE STUDY ON CHENAB BRIDGE ARCH BASE PLATES AND BEARINGS: METAL-TO-METAL GROUT SYSTEM

Anuraag Srivastava, Manager – Technology
DIAMANT Triumph Metallplastic Pvt Ltd, India

Carsten Kunde, Managing Partner
DIAMANT Polymer GmbH, Germany

INTRODUCTION

Steel-to-steel connections are widely prevalent in bridge construction. Traditionally, all steel bridges have specifications that require 100% contact for complete designed load transfer.

Ensuring such 100% contact between the mating surfaces has been a challenge faced by design and fabrication engineers worldwide.

Achieving it may be one of the most difficult and expensive processes in larger and more complex steel constructions.

Improper or non-100% contact severely affects the ability to transfer design loads and leads to a shorter life of the structure and its components such as bearings.

Advancements in materials science allow for a range of new metal grouting systems that are assisting engineers and steel fabricators around the world in solving this issue with minimum effort.

In recent years, a lot of progress has been made in materials science. New polymeric metals have been developed that allow for a 100% gap compensation through non-traditional methods.

These new-generation materials use very high-strength fillers in a matrix that boasts of low creep, nearly zero shrinkage and the ability to withstand high cyclic loads.

They do not have functional impact or degradation from environmental factors such as salt water, UV Light, heat and rain.

Another very useful characteristic of these materials is the ability to use these directly on-site without the use of advanced machinery / special tools.

In India, one of the fastest growing bridge construction markets, a number of steel bridges are under various stages of construction - the goal being speed and quality as the country upgrades its infrastructure.

In this case study we present the usage of one such new-generation material which was used on the arch base plates and in bearing top-girder bottom interfaces of the Chenab Bridge project in India.

DIAMANT MM1018 is a special formulation that can withstand 160N/mm^2 compression stress and has been proven to withstand environmental degradation with no impact on performance.

The material is suitable for use in gaps as small as 0.1mm and has been tested for performance up to 140mm height by the German Institute of Construction Technology (DiBT) along with cyclic fatigue to withstand heavy rail traffic.

PROBLEM DESCRIPTION

The Chenab Bridge is the highest Railway arch bridge in the world at a height of 359m from the bed level and a 469m main arch span.

The bridge was designed as a two-ribbed arch with steel trusses made of concrete-filled steel box segments.

The bridge is located in an area that is exposed to temperature changes between -10°C and +40°C and moisture making corrosion protection among key requirements.

The concrete arch base foundations support the entire arch. The steel arch is seated upon 8 arch base plates, 4 on each side of the river Chenab, see Figure 1.

The arch base plate is embedded in the concrete pillars. Each base plate has an area of approx. 6.3m^2.

The arch base plates are mated with the arch base segments and stressed using Dywidag bars that pass into the concrete pillars, see Figure 2.

The arch base segments are steel box segments that are field fabricated and are prone to minor deflections due to manufacturing limitations.

A non-full contact connection can therefore lead to the selective transfer of loads. This may compromise the level of structural safety and hence is a critical requirement.

Figure 1: Arch base mounted on the arch base plate

Gap creation

The arch base segment is a box structure with stiffeners. During the extensive welding process, steel is prone to heat-related distortions.

Even when conforming with existing fabrication standards, an acceptable warp at fabrication will yield a very high distortion on structures of this size and complexity.

In the case of the base segments, due to the extensive use of stiffeners over a large surface area, a 100% flat surface was not possible to achieve.

The arch base plates embedded in the concrete are placed at an angle in all 3 planes of the bridge's 3-dimensional 'X-Y-Z' geometry.

This posed a further challenge to meet the 100% load transfer and matched mating face requirement.

Figure 2: Arch base plate with Dywidag bars

Traditional methods of gap compensation

A number of techniques have been used traditionally to overcome these situations with each having a limitation for a project of this nature and scale.

- **Machining:** This requires the use of large specialized milling machines that have to be placed at the site of installation to machine the plates in the final resting position. This is a very expensive and time-consuming process when used on completely horizontal connections. In the case of inclined connections, this would be a major challenge since both faces would need machining after studying final alignments.
- **Steel shims:** This method makes use of custom steel plates prepared based on the gaps observed, however with no certainty of full contact. Most gaps have a varying profile which limits the use of these plates. The use of embedded Dywidag bars also complicates the installation of custom shims.
- **Lead sheets:** These are used since they take the shape of metal plates but they can fail at higher loads and have very poor creep properties.

Creep

By definition (sometimes called cold flow) creep is the tendency of a solid material to move slowly or deform permanently under the influence of mechanical stresses.

It can occur as a result of long-term exposure to high levels of stress that are still below the yield strength of the material.

This is an important factor when using products and materials to fill gaps, especially for preloaded connections as creep may lead to a loss in tension force which in turn reduces the load capacity of the construction.

COMPENSATION OF GAPS USING DIAMANT METAL-TO-METAL GROUTING

Material Description

DIAMANT MM1018 is a 2-component metal reactive resin system based on epoxy resins with high-filled proportions of diverse, mainly metallic powders.

The product is available in a few different versions based on application requirements.

The fluid and paste versions have been tested and acknowledged by the German Institute of Construction Technology since January 2013 for the holohedral, 100% force-fit gap compensation with respect to filling unevenness and roughness between metal elements in face plates, bridge bearings, railroads and steel elements as per general Approval Z3.822042/1/.

A number of other tests have been carried out by authorities across the world proving all the parameters required for its suitability for the case of the gap compensation at the arch base.

The material has seen use across other projects in India and has proven its use in very aggressive operating environments.

Usage on the Chenab Bridge

Engineers at the Bridge contractor upon intense discussions with the bridge designers and DIAMANT engineers decided upon the use of the liquid grade of the material.

A decision was taken to place the arch base on the base plates in their final position and then proceed with pressure grouting, see Figure 3.

One of the concerns with such a project is always to prove to the client that the grouting is providing 100% fill and the resultant transfer of full load at cure.

Figure 3: Injection of MM1018 between the arch base plate and first arch segment

Figure 4: Steel elements that are not evenly supported lead to uneven application of force and pose a problem for corrosion protection

Figure 5: Typical gap situation observed in bearing installation

The material is designed to self-cure naturally without the use of accessory agents or machinery.

Concerns related to the post-life (operational life of the compound after mixing) of the compound being sufficient to grout such a large area were also addressed by way of the application methodology.

BRIDGE BEARINGS

Traditionally, in this interface construction companies have used shaped wedges and cement and cement epoxy grouts.

While these are good when used with concrete interfaces they have shown to severely fall short in steel connections and also the stresses transmitted through the metal segments.

These have led to crushed or shattered grouting and in turn expensive bearing loss and replacements.

The success of the metal-to-metal grouting at the arch base helped the installation of the bridge bearings interfacing with the bottom of the girder.

An approach similar to arch-based grouting was followed to solve the issue of gaps due to the bridge camber and bearing top plate.

As steel fabricators learn and implement new possibilities using the advanced metal grouting material, new possibilities are available to them to ensure even the smallest of gaps are reliably filled.

Figure 6: Bearing installation with gap between upper bearing plate and bridge girder

Figure 7: MM1018 application between upper bearing plate and bridge girder to ensure 100% connection of the bearing to the bridge

FUTURE TRENDS AND SUMMARY

Gap compensation between steel elements is a challenge across all constructions. With advanced materials and technologies that are under continuous development, the possibilities available to engineers are huge.

The MM1018 system and method have seen increasing acceptance globally and are the new way of the future. The Chenab arch bridge project proved the utility and effectiveness of the MM1018 system.

While the gap was closed to a 100% force fit, the material also exhibits permanent corrosion protection on account of its formulation.

This protects and improves the longevity of the connection with respect to the elements.

In recent years with an increasing focus on reliability and reduced construction timelines, materials such as Diamant MM1018 and their variants shall see an increasing demand across the globe.

In India, as the Indian Railway upgrades its infrastructure, with major constructions in process, the metal-to-metal grouting system provides its engineers, fabricators and end users an economically viable, fast, proven, globally approved, reliable and high-quality solution.

The use of a liquid shim is seeing increasing use across bridge bearing applications, flange connections in process plants, marine applications and more recently in quickly refurbishing older structural connections.

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