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Compatibility Of Ballastless Track For Railway System

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Abstract

In a Railway Project, track is the most important component of the project. Decision taken on railway track selection will decide the future of the full project. Ballastless track is the most reliable option for any high-speed railway project, but simultaneously it is difficult to select the type of ballastless track suitable for the project. The paper explains the guidelines for selection of ballastless track not only in terms provenness but also the suitability of different ballastless track structure with change in bridge structure through analysis of Midas model.

Type of bridges considered in the study is 37m Box girder with two types of track i.e. Precasted slab track and Plinth type cast-in-situ track structure and 54m steel and concrete composite girder with Precasted slab track and Plinth type cast-in-situ track structure. 60 E1 section of rails are considered for the study.

INTRODUCTION

From the last 20 years, India is focusing on planning and construction of transport infrastructure in the country which includes Roads (both Urban and Rural), Highways, Expressways, Metros, Waterways, Railways of various types etc. In which railways has one of the major proportion and success of railway depends on the type of track laid in that system. Railways in India changed a lot in "concept" from railways in which all type of trains run on the same tracks i.e. Passenger trains, Express trains, Freight trains etc. to systems dedicated to freight trains (DFCCIL), system for local passenger i.e. Metros, system for High speed i.e. High Speed Railways, etc.

Track is the most important component of a Railway project, which includes not only technical importance but also it includes safety of passengers and the people residing nearby. There is no redundancy of track in a railway system, success of the railway project depends on the type of track laid and its design & quality of installation of track eg: Metros can able to operate safely for 18 to 20 hours daily, just because its track structure permits to do so without any failure and it also means that hardly anytime is left for the maintenance of track that too in night whereas in conventional system traffic frequency is quite less in comparison to the Metros but the load on the track is multiple times the Metro system. Therefore, it is very important to decide what type of track to be used for that particular infrastructure, which is broadly divided into Ballasted track (conventional track used in Indian railways) and Ballastless Track (used in Metro projects). It is also demand of the hour to increase the speed of Railways i.e. track to be designed for high speeds, due to which new railway projects are being implemented such as Regional Rapid Transit System (RRTS) with an operating speeds of 200Kmph connecting important nodes of Metros to nodes in sub-urban towns. Also, High Speed Railways with an operating speed of 300- 350 Kmph, connecting various metro cities.

Track is a structure which is dependent on the structure below the track such as earth embankments, composite slabs, Steel gireders, I girders, PSC girders, Tunnels etc. . So, it is important to study track structure alongwith the super-structure of the girder, to study the track slab performance and suitability with the bridge super structure. The paper will discuss the Ballastless track structure (Precast slab type and Cast-in-situ plinth type) and to find out the suitability of track structure with the various types of structure below the track, by developing a model in Midas software.

a. Load Transfer on Track

The track on a railway system, also known as the Permanent way, is the structure consisting of:

- Rails
- Fastening System
- Track Structure system
    - Precasted Slabs/Cast-in-situ concrete (or Sleepers and Ballast)
    - Concrete between viaduct and Precasted slab (or underlying subgrade)

The basic purpose of the track structure is to transfer load of the trains to the formation. In ballasted track or conventional tracks, the transfer of loads from trains to rails, rails to sleepers, then sleepers to ballast and finally ballast to formation. The basic principle of transfer of load is to reduce stresses which is maximum at rail & wheel level in the order of 300 MPa to minimum at formation in the order of 5MPa. In track it is very difficult to calculate the exact loads in dynamic condition therefore the static loads are used with dynamic factor.

To understand the basics of Ballastless Track a comparison between ballasted and ballastless tracks is very important to identify when and where the ballastless track systems perform better. The intention of this study is to understand how to decide which track is suitable for particular project and the comparison is preliminary and not conclusive.

b. Ballasted Track Vs Ballastless Track

	Ballasted Track Structure	**Ballastless Track Structure**
PARTS OF TRACK	➢ Rails ➢ Track Fastening ➢ Rail Support such as Sleepers ➢ Ballast	➢ Rails ➢ Rails Fastening ➢ Rail Seat • Sleepers Discretely supported, concrete blocks or slabs. • Supported Continuously as in case of Embedded track ➢ Hydraulic Bound Layer (HBL) in case of Rheda type track/ Concrete/ Concrete Asphalt Layer in case of Shinkansen type track
SUPPORTING STRUCTURE	➢ Support layer or Frost Protection Layer ➢ Compacted Earthwork in embankment or track in cutting.	➢ Support layer or Frost Protection Layer ➢ Compacted Earthwork in embankment or track in cutting. ➢ Bridges

1.1 Table

PROJECT BACKGROUND

a. Objective

The objective of the study is to track slabs alongwith the super-structure of the girder to establish the performance and suitability of track slab with the bridge super structure. This will help to decide the type of ballastless track to be used in combination with the type of super structure.

b. Selection of Type of Track

The steps include track functional and technical requirements of the project. Functional requirements are such as type of project and alignment of the track which will be passing through various locations

a. Within city eg: Metros are being constructed in the city area and most of the cities where Metros are being constructed are highly populated.
b. Connecting Different part of the country for passenger traffic through conventional railways, High speed railways
c. Connecting nearby cities of major metro cities eg: RRTS system which is designed in such a way so that it can connect city centres, hence passing through cities and also along national highways and open areas
d. Connecting various part of the country for freight Traffic such as DFFCC project alignment of such is kept in open areas

Life cycle cost of the track which is another one of the most important feature of a track structure in India being a cost sensitive country, installation and maintenance ease of track etc.

Technical requirements include :

a. Design Speed of the Railway system.
b. Location of installation of track such as bridges/At grade/Tunnel. Further type of Bridge/tunnel.
c. Availability of design know how for that particular track.
d. Availability of suitable fastening system for that particular type of track.
e. Availabilty of space for the installation of track.
f. Type of trains run on the track.
g. Local conditions of the region.

c. Types of Ballastless Track Systems

i. **Bi-Block Sleeper track:** These are one of the most proven ballastless track system used for high speed railways. It consist of two concrete bi-block connected through steel lattice truss. Blocks are embedded in monolithic concrete. Vibration attenuation in this system is through fastening system only therefore for higher vibration attenuation Mass Spring System (MSS) is required. The advantages of the system is low maintenance during its life cycle as only replaceable components are rail pads of fastening system. The main disadvantage being difficult to replace in case of emergency. Example of such system is Rheda 2000, Zublin etc.

ii. **Booted Block System:** These type of systems consist of concrete blocks covered with rubber boots and resilient block pad below the block in the rubber boot. This is Top Down technology of Ballastless track installation. These concrete blocks are hanged to the rails and then plain cement concrete will be poured all around. Fastening system along with resilient block pad provides dual elasticity. Rubber boot separates system with surrounding concrete and the resilient pad below the concrete block reduces vibration. These types of systems are easy to replace in case of requirement. Sonneville system, Stanton system are common examples of booted system.

iii. **Elastically Supported Precasted Slab Track:** In these systems Precast slabs are laid over the Cement Asphalt Mortar (CAM) or elastomeric layer (Rubber layer) and non-shrink grout. Shear Pockets are provided for lateral and longitudinal resistance to keep the slabs in its position during train movements or temperature related deformations. The most important benefit of these system is that they can be replaced easily in case of derailments or any other exigency. Example of such system is Slab Track Austria and Shinkansen.

iv. **Plinth Type Ballastless Track:** The system is Cast-in-Situ type ballastless track system which is constructed in Top-Down method i.e. Fastening are hanged on rails and concreting is done then below the fastening system.

d. Basic Design of Ballastless Track

For designing the ballastless track the following loads are generally considered:

Permanent Loads

Self-weight

Creep: Creep is not considered for calculating the track slabs because of its short length.

Shrinkage: Shrinkage is not considered for calculating the track slabs because of its short length.

Variable vertical loads

Load Model 71 according to EN 1991-2 is adopted. It describes the static effect of vertical loading due to normal rail traffic.

Load factors :Load classification factor Load Model is based on an axle load. Other axle loads may be accounted for by introducing a “Load classification factor” α.

Dynamic Factor: Dynamic factor: Φ is to be adopted from EN 16432-1.

Eccentricity: According to EN 1991-2, 6.3.5 the effect of lateral displacement of vertical loads shall be considered by taking the ratio of wheel loads on all axles as up to 1.25:1.00 on any track.

Uplifting forces at deck end joints:Due to rotations and displacements of the bridge decks, uplifting forces occur in the first rail support points next to the bridge joints.

Variable horizontal loads

Nosing force :Nosing forces act normally to the track axis in horizontal direction.

Centrifugal forces: Centrifugal forces are applied outwards in horizontal direction at a height above the running surface.

Wind: Wind load can be calculated IRS: BR-2008 and IS: 875 (part 3).

Traction and braking: In EN 1991-2, indications are given for traction and braking forces. They act at the top of the rails in the longitudinal direction of the track. The characteristic values of traction and braking forces can be taken as 20 % of each axle load, the forces are not distributed over a given length.

Thermal actions

a. Uniform temperature component

The uniform temperature loads are based on the Design of viaducts/bridges which refers to IRC: 6-2017 (see [9]). The shade air temperature extremes for the region of design as per fig. 15, resp. fig. 16 of IRC.

Minimum and maximum effective bridge temperatures are specified by clause 215.2 of IRC: 6-2017.

b. Vertical temperature difference component

The effect of vertical temperature differences is considered by using an equivalent linear temperature difference component with $\Delta TM,heat$ and $\Delta TM,cool$.according to EN 1991-1-5.

c. Horizontal temperature difference component

Due to the short length of the track slab, no horizontal temperature difference component is considered for the track slab design.

d. Horizontal loads due to thermal expansion of the rails in curved sections

Forces arising from track-bridge interaction

In case there are continuous rails between the bridge structure and an embankment (i.e. if there are no expansion devices), the bridge and the track jointly resist the longitudinal actions. Exceptional loads

Exceptional loads : considering track imperfections & train wheel imperfections are covered by increasing the total axle loads by 10 %.

Accidental and seismic load cases

a. Derailment load
b. Seismic load

METHODOLOGY

To achieve the objective of the study, various models are developed, with 2 tracks on same girder with 4.5m Track center, gauge of the track is taken as Standard Gauge i.e. 1435mm and rail section is taken as UIC 60. The method of preparing each model is as under:

a. In 1st case the Box Type concrete girder of span 37m with Precasted slab track is considered. For easy understanding the Box girder is modelled as line model and the track slabs as plate model, connected elastically with each other, which is the case of precasted track slab with elastic material below the track slab. The general size of the track slab is length is 3.98m and width is 2.4m and there is two derailment containment guard of height 200mm.
b. In 2nd case the track slab is Rigidly connected with the above Box Type concrete girder mentioned in case 1.
c. In 3rd case the Box Type concrete girder of span 37m with Cast-in-situ Plinth type Track slab is considered. As in the case 1 and case 2 the Box girder is modelled as line model and the Plinth slabs as two plate models, connected rigidly with Box girder. The general size of the track slab is length is 3.98m and width of each Plinth is 0.9m and there is derailment containment guards with height 200mm.
d. In 4th case the Steel composite girder of span 54m with Precasted slab track is considered. The Steel girder is modelled as grillage model and track slab is modelled as plate model, connected elastically with each other. The size of the track slab is same as of case 1.
e. In 5th case the track slab is Rigidly connected with the girder mentioned in case 4.
f. In 6th case the same steel composite girder as mentioned in case 4 with Cast-in-situ plinth type Track slab is considered. As in the case 4 and case 5 the Steel composite girder is modelled as grillage model and the Plinth slabs as two plate models, connected rigidly with girder. The general size of the plinth track slab is length is 3.98m and width is 0.9m and there is derailment containment guards with height 200mm.

The analysis done in these models are only for live loads of trains only applied on one track at a time. The loads are applied on the rails above 214mm from track slab top. The 17t train load is considered for the study.

PRESENTATION/IMPLEMENTATION

Case 1: Box Girder with Precasted track slab with elastic material below the track slab

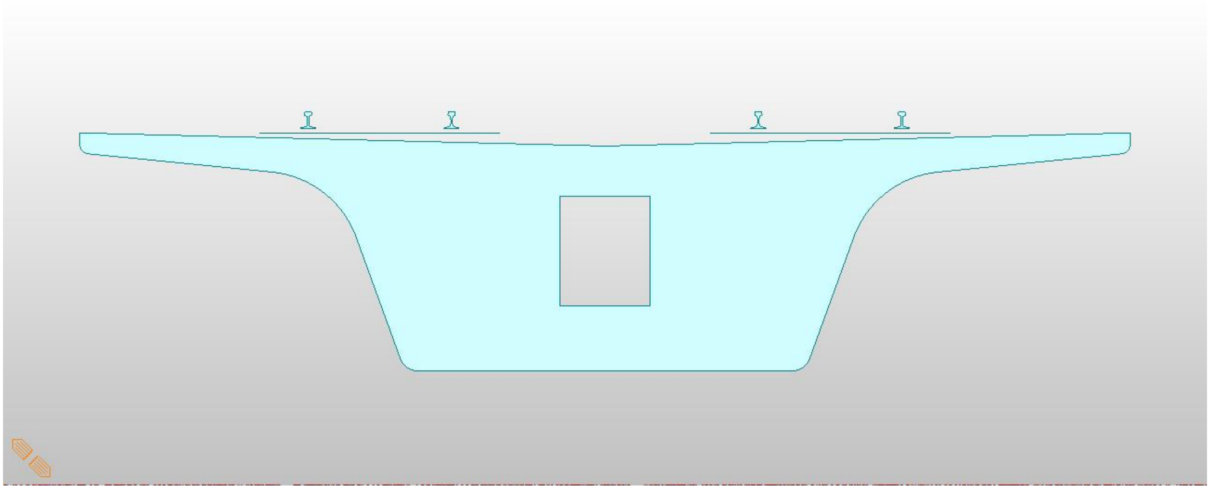

Figure 1a Box Girder with Slab track

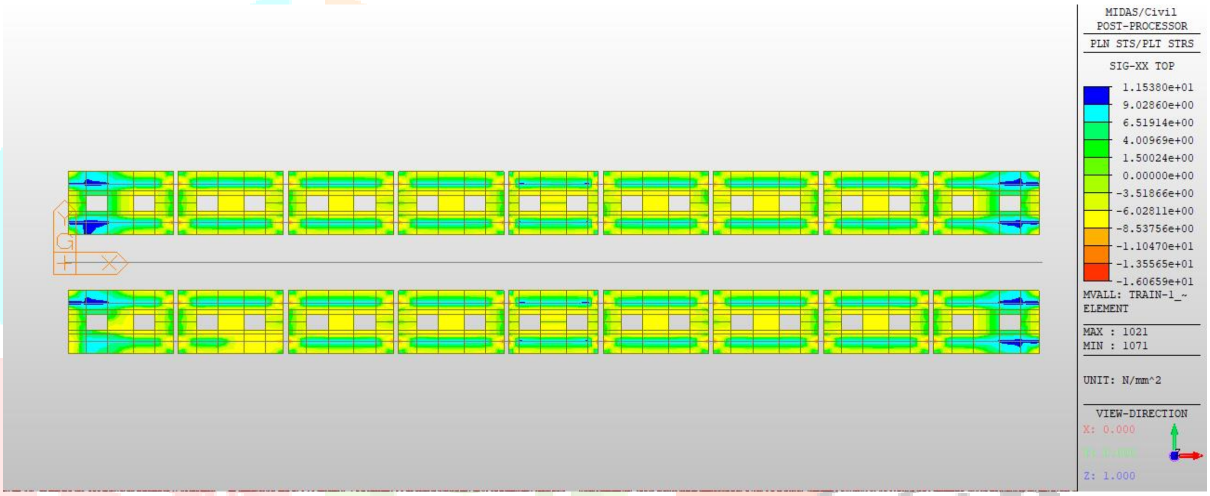

Figure 1b Longitudinal Stresses

Figure 1c Transverse Stresses

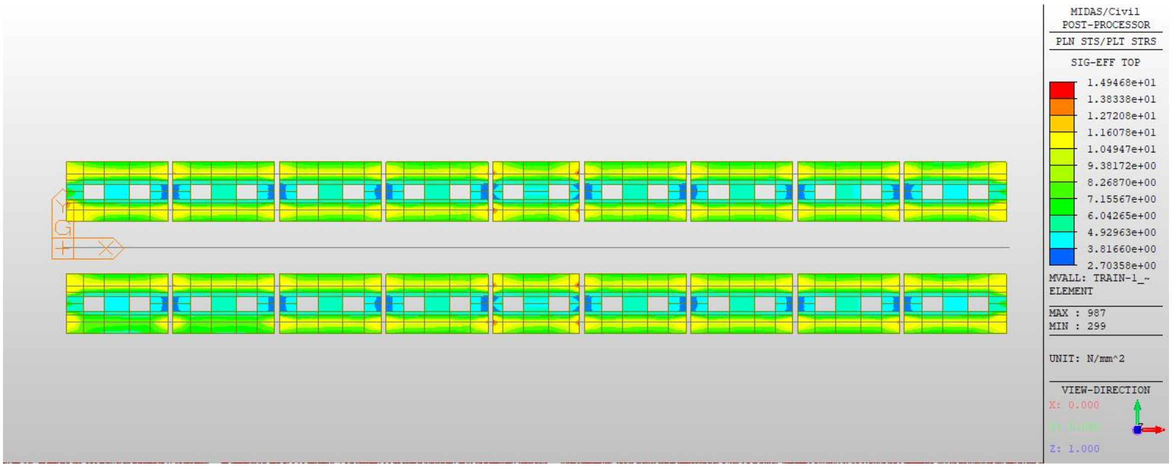

Figure 1d Effective Stresses

Case 2: Box Girder with Rigidly Connected Precasted track slab

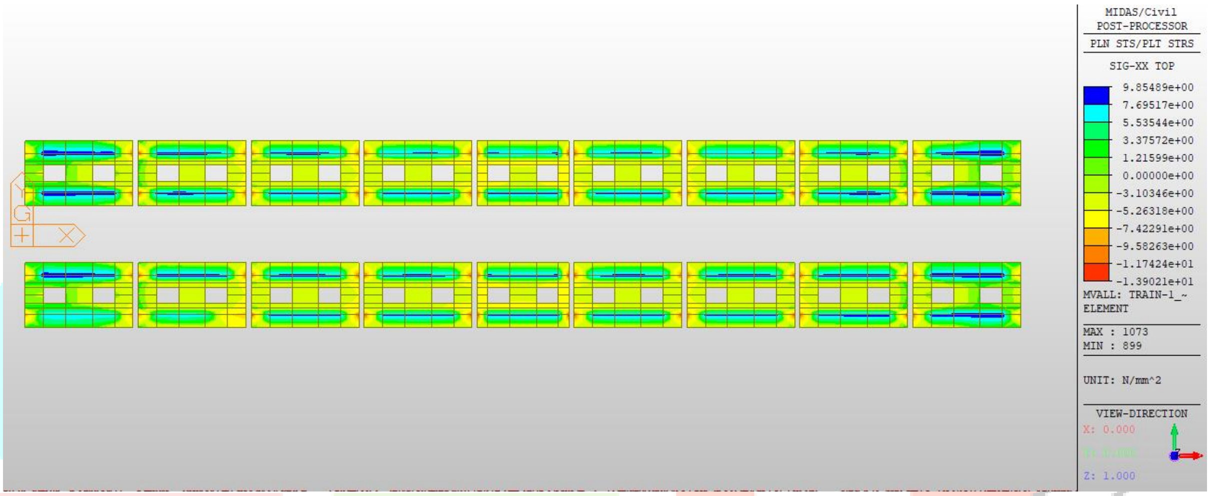

Figure 2a Longitudinal Stress

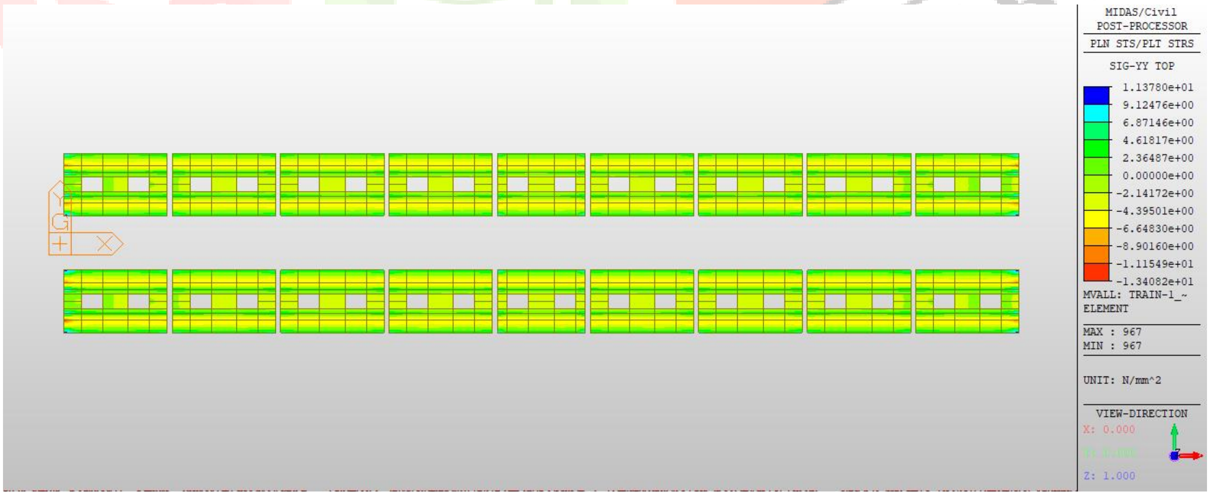

Figure 2b Transverse Stress

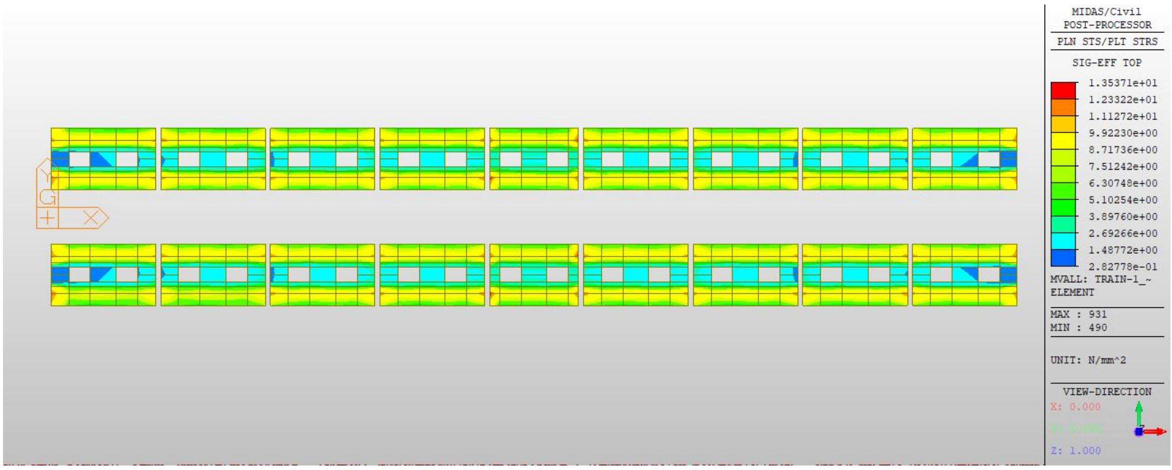

Figure 2c Effective Stress

Case 3: Box Girder with Rigidly connected Plinth Track

Figure 3a Longitudinal Stress

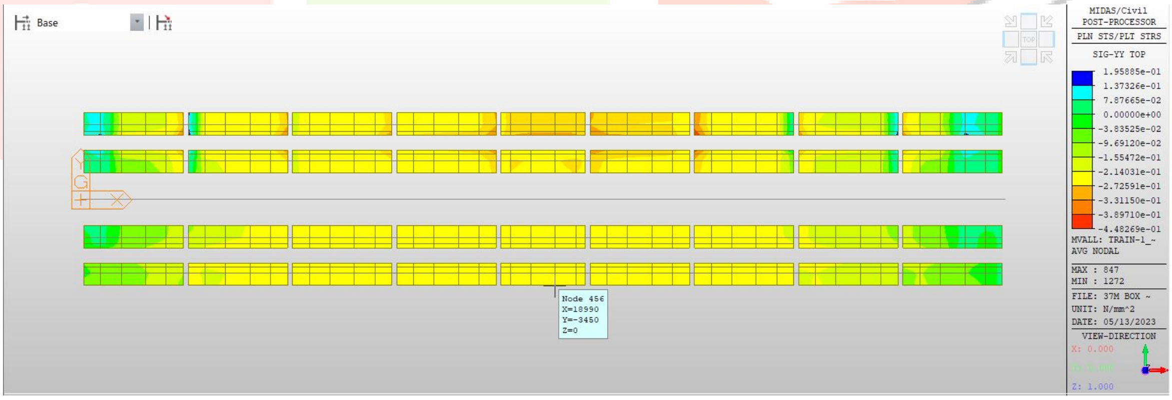

Figure 3b Transverse Stress

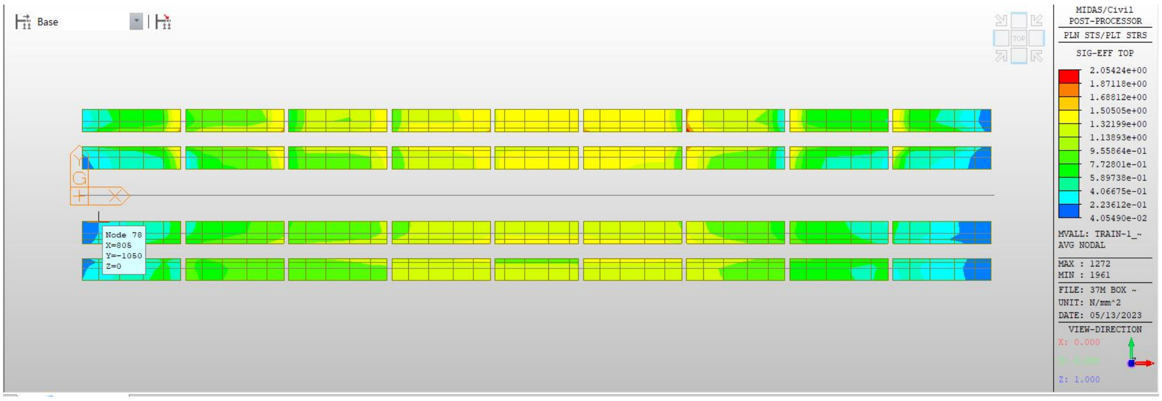

Figure 3c Effective Stress

Case 4: Steel Composite Girder with Precasted track slab with elastic material below the track slab

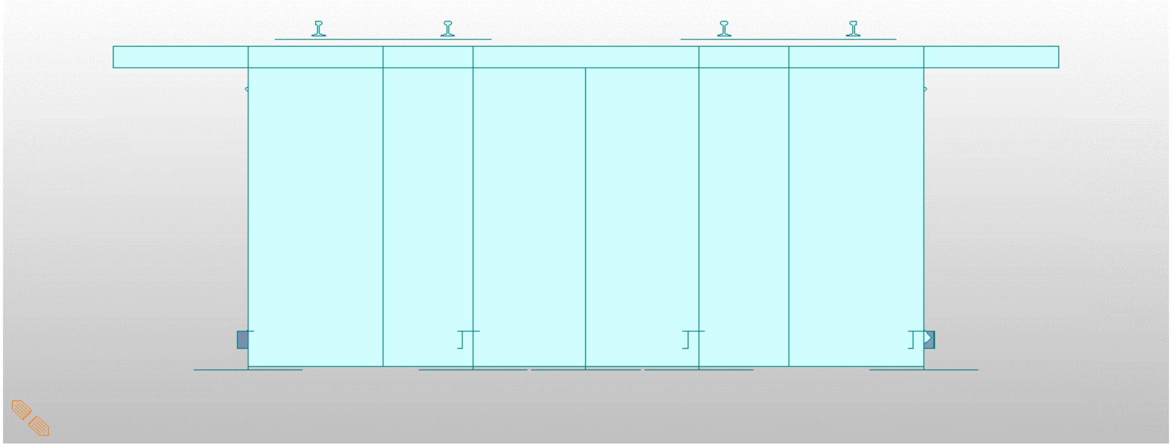

Figure 4a Cross Section of Steel Composite Girder with Precasted Slab track

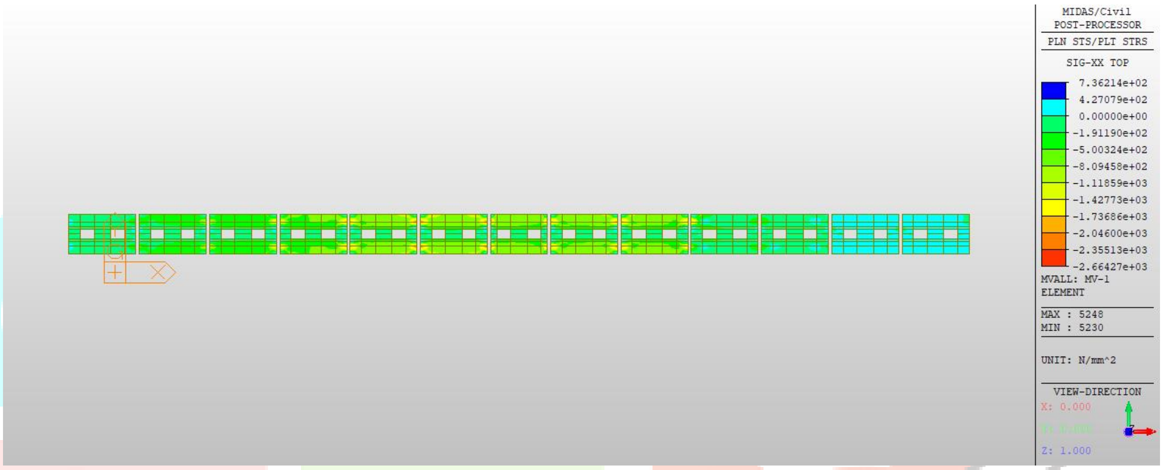

Figure 4b Longitudinal Stress

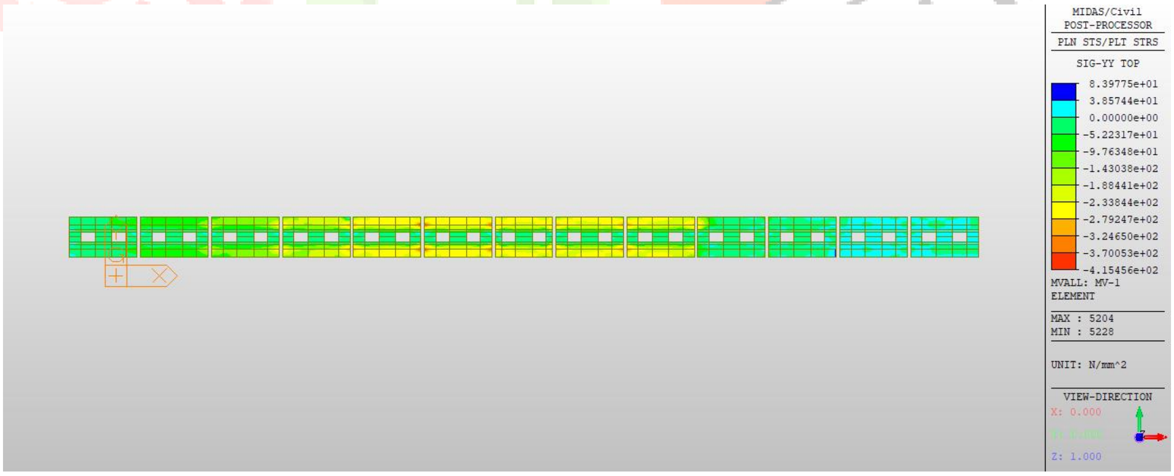

Figure 4c Transverse Stress

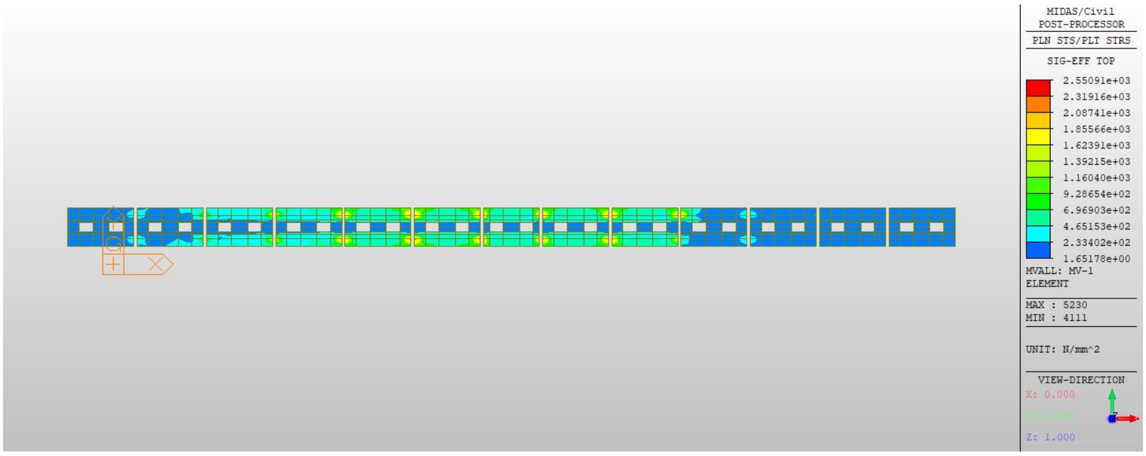

Figure 4d Effective Stress

Case 5: Steel Composite Girder Rigidly Connected Precasted track slab

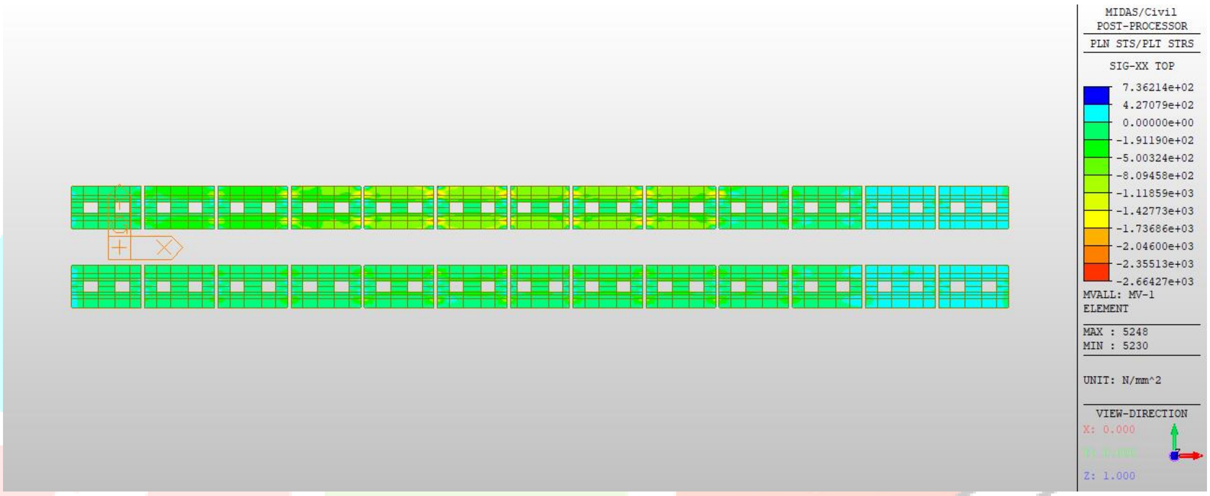

Figure 5a Longitudinal Stress

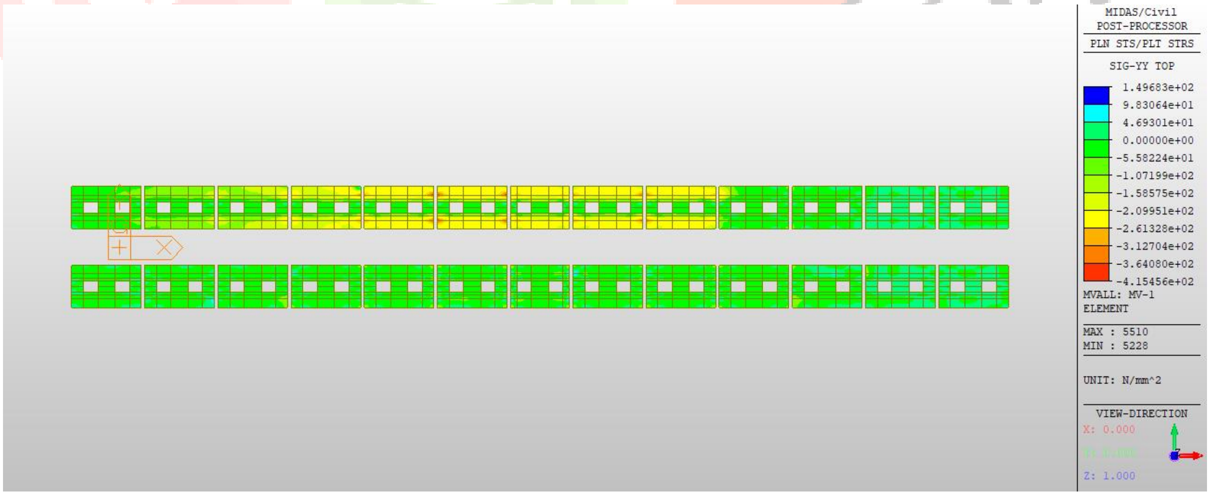

Figure 5b Transverse Stress

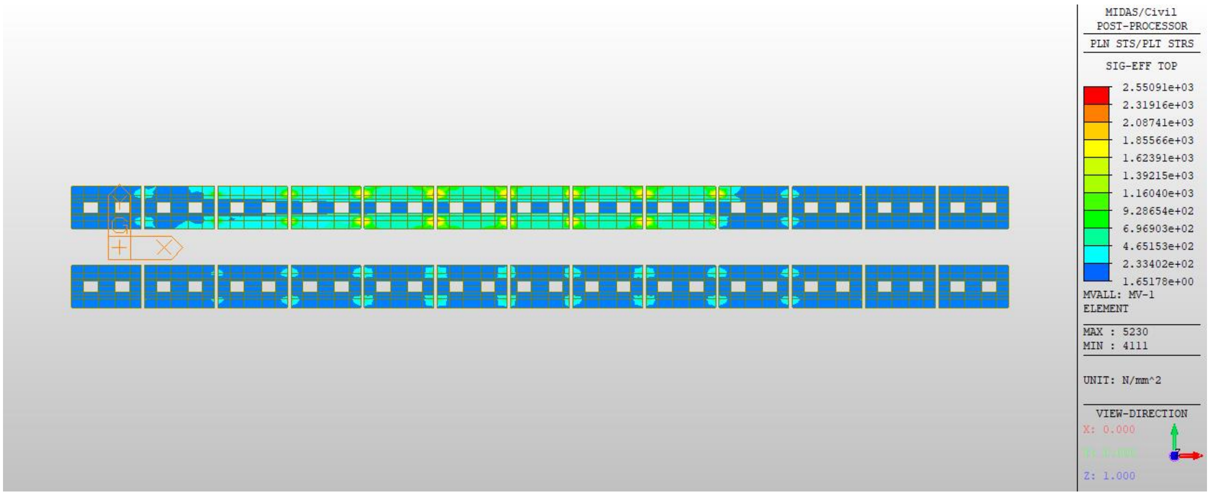

Figure 5c Effective Stress

Case 5: Steel Composite Girder Rigidly Connected Precasted track slab

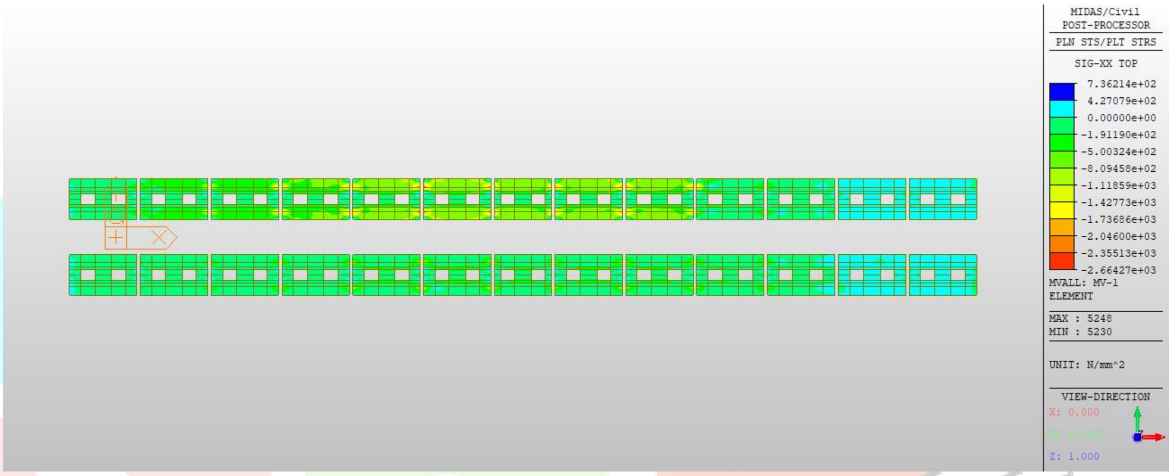

Figure 6a Longitudinal Stress

Figure 6b Transverse Stress

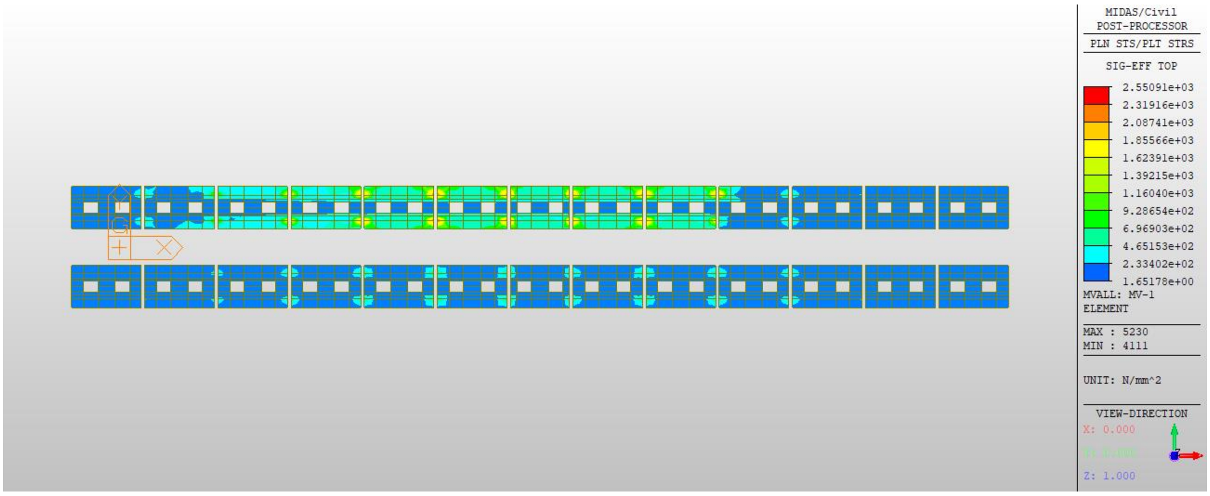

Figure 6c Effective Stress

Results

After comparing following points were observed :

1. Track on Box Girders: While comparing different Ballastless Track on Box girder, the stresses in the Preacasted track slabs connected rigidly have 15-20% less stresses than slabs with rubber pad below it. Whereas the Plinth type of slab track have least stresses.

2. Track on Steel Composite Girder: Stresses in Precasted Slab Track which is rigidly connected with Steel Composite Girder and Plinth Type Track are in line with each other whereas the Precasted slab Track with rubber below the track slabs have 35-40% less stress than rigidly connected ballastless tracks.

3. Overall stresses in Ballastless track on Box girder is much less than the Track on steel composite girder.

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