Design and Development of Ballastless Track with Indigenous Fastening System

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Synopsis

Use of ballastless track, popularly known as Slab Track, may be inevitable in locations like tunnel, viaduct, station areas, busy corridors such as suburban transit system, where intermediate intervention for maintenance cannot be economically afforded. A large number of ballastless track (BLT) forms have been designed and tried all over the world to have a BLT form which is durable, economical and can be used for most civil structures without many changes. A large number of ballastless track forms have been developed and tried on Indian Railways as well and quest to have an economical, durable and functional design suitable to local conditions continues. A similar attempt was made in the year 2004-05 on Central Railways by conceiving a design with fundamental concept of using reinforced cement concrete (RCC) beam and slab arrangement, building-in two levels of resilience, one below the rail as in conventional ballasted tracks, and another above the RCC beam, in order to replenish the missing resilience of ballast. Two trial lengths were constructed on Central Railway- first at Pune Railway Station in 2006 and another on Mumbai CST Railway Station in the year 2007. Both the lengths have stood test of time for last 9-10 years verifying the concept, also needing

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some improvement. This paper brings out the basic concept, observations made on the performance of trial length and further improvement of the concept to have a long lasting and economical solution of BLT form for Indian Railways. Both the authors, working in different capacities on Indian Railways, have been associated with the development from the inception of formulating concept, first design & it's trial on Central Railway and design modifications, and laying of trial length undertaken recently.

Introduction :

An economical and long lasting design of ballastless track (BLT) has been a long quest on Indian Railways for the inevitable need of such track form in number of locations e.g. tunnels, viaducts, heavy suburban sections, platform lines, etc. Further, high density suburban areas do need a track form which is able to attenuate noise and vibrations as well, the concern for which is growing by day on account of public consciousness and environmental considerations. BLT offers options of pre-design of desired level of resilience which not only results into a track most suitable for given operating conditions but also in achieving desired levels of noise and vibrations.

Indian Railways (IR) so far has constructed BLT mostly in the form of washable aprons on platform lines, on Kolkota Metro and in few cases, in tunnels. A number of designs used on platform lines so far have provided only limited success. BLT constructed based of propriety designs obtained from advance railway systems are not only expensive but also have posed problems due to poor availability of fastenings and design alteration alternatives which may be required on account of changing civil structure and operating conditions. This underlined the need of developing a design which not only caters to operating conditions of IR, but uses indigenous components for their easy and economical availability.

1. Concept Design of Components

The design was conceived using basics of civil engineering. Years of observations of various ballastless track designs tried and used on Indian Railways were suggestive that it is difficult to obtain a long lasting design which integrates a pre-stressed concrete (PSC) member with reinforced concrete construction done in-situ. Therefore, it was planned to have only reinforced cement concrete (RCC) as the basic load bearing member, giving up the obvious attraction of using tested and proven design of PSC sleeper (tie) of Indian Railways. Use of plain cement concrete was also considered due to implicit economy and ease of construction, however, was dropped due to bending stresses getting developed due to track rolling, particularly during acceleration and de-acceleration. This decided the design of the base for BLT.

The design of suitable fastening system to be used with BLT emerged from the need of replenishing the missing resilience available from ballast available in conventional ballasted track. The top resilience provided by the rail pad by 6 mm thick Grooved Rubber Sole plate for Indian Railway Standard for Pre-Stressed Concrete (PSC) sleepers on ballasted deck was retained. This pad by design is stiff enough to prevent excessive rail vibrations and yet contribute towards achieving the target equivalent stiffness for the track form as a whole.

The missing resilience of ballast was replaced with additional resilience level designed in the form of 10 mm thick softer pad placed above the RCC beam, just under the rail seat, the two pads separated with a steel bearing plate. The design of steel plate was so conceived that it is able to provide the required rail cant of 1 in 20 in the track assembled form. The rail securing arrangement on the steel plate with the IR design of Elastic Rail Clip (ERC-tension clamps) was developed with number of trials, initially with welding additional curved plate over the flat having space to accommodate central leg of ERC in driven position. The design was improved further by welding a shoulder on a canted steel plate using steel flats/squares.

Due to typical passenger coach design on Indian Railways discharging human excreta on tracks, the fastening system is subjected to heavy corrosive forces. The canted bearing plate was therefore hot dipped galvanized for first trial stretch put at Pune station of Central Railway. However, non-galvanized canted bearing plates were used on Mumbai trial length to have comparative performance and to explore possibility of economizing on galvanizing effort.

An alternative design was conceived to have an SGCI (Spheroidal Graphite Cast Iron) flat plate which was easy to cast and creating 1:20 cant in the body of precast concrete beam itself. The prototypes were developed and tested and were found to be almost one third of the cast with the first alternative of going for a steel canted bearing plate.

As the designed conceived for the BLT used all the components which had either been developed indigenously or were already under prolonged use on Indian Railways, this design was named as Ballastless Track with indigenous Fastening System (BLT-IFS).

2. Method of Construction:

Though conceived as in-situ RCC construction, different methods of construction were used for Pune and Mumbai trial lengths for the sake of experience as method of proper construction of a slab track plays a very significant role in overall quality of track, durability and a long service life.

2.1 Pune Station:

The existing platform track on busy platform number-6, after brining it in final line and level as proposed to be on BLT, was transferred on temporarily supports so that minimum track possession time was used during construction.

The platform line was excavated to required level and provided with sub-base of compacted stone ballast layer and plain cement concrete to have the desired bearing capacity and also to act as levelling and sealing course. After required curing, the reinforcement steel for the main beam and slab portions was placed. Special jigs were developed which held the inserts (shoulders) to be casted in-situ for securing the canted bearing plate. These jigs were developed in-house and manufactured by bridge workshop of central railway located at Manmad and were so designed that they could be rested over the running rail and held the 4 inserts to be casted in-situ with the help of nuts and bolts which could release the inserts without any shaking/disturbance after getting casted in the concrete.

After placement of reinforcement steel, required shuttering, ready mix concrete of M40 grade was used for concreting under line block. The track was transferred to new construction after 21 days of curing of RCC under another line block.

Fig.1: Cast in situ BLT-Ifs at Pune Stn

Fig.2: Rail Seat condition after 7 yrs service

2.2 Mumbai Station:

This trial length was done on newly constructed platform line no. 18. A special reference frame for ensuring line and level of the track was developed and fabricated by the bridge workshop as there was no need to go for cumbersome arrangement of supporting a running track as done for first trial stretch at Pune station.

The canted bearing plates used were not galvanized to have experience of their efficacy if the cost of galvanizing could be saved. The drainage channels provided were in the form of trough rather than well-formed U-shaped channels as done at Pune station to help avoiding use of shuttering and form work for speedy and more economical construction. The rest of the construction method was more or less same as used for casting trial length on Pune station.

3. Trial Observations:

3.1 Pune Station:

Structural Integrity of RCC portion: No structural issues have been observed until the last inspection done in March, 2013. The status is same even on date as verified from local p-way maintenance personnel. The RCC portion is crack free showing no disintegrated features anywhere in the whole mass. No noticeable wear on rail seat portion has been observed.

Health of Inserts (Shoulders): 6 out of 32 inserts casted in-situ have got loosened showing need of improvement in the method of construction of rail seat despite satisfactory performance in-general.

Fastening System: Due to loosening of inserts, the corresponding tension clamps (ERC) have also lost the clamping force else there are no specific issues with the tension clamps. Recent observations show that a number of ERCs have got broken which require replacement.

Both the rail and sleeper-beam pads have performed satisfactorily without any need for change in last 9 years. Some insulated liners have been changed due to breakage which is considered to be routine maintenance activity.

There are no track circuiting failures reported as per the feedback obtained from maintenance personnel indicating satisfactory performance of electrical resistance built in the basic design. A typical rail seat condition at the end of 7 years is shown in fig. 2.

3.2 Mumbai CST Station:

Structural Integrity of RCC portion: No structural issues have been observed until the date of inspection in May, 2016. The RCC portion is crack free showing no disintegration anywhere in the whole mass. Due to typical construction method used for this trial, some rail seat concrete got settled during the process of initial construction, indicating need for improvement in the method of construction particularly in rail seat area.

Health of Inserts (Shoulders): The health and grip of shoulder in general has been found to be satisfactory after prolonged use.

Canted Bearing Plate: There is severe to heavy corrosion noticed on bearing plates more pronounced on the gauge side of track, obviously on the account of typical coach designs of IR which lets toilets discharge into the track. This emphasized need of galvanizing of bearing plates or use of corrosion resistance material e.g. Cast Iron, etc.

Fastening System: The tension clamps and rail pads had in-general been functioning satisfactorily except on some rail seats where there is apparent seizure of ERCs on account of heavy corrosion. The beam pads had warped/crushed at few locations, particularly on those locations where concrete in rail seat area got settled. This indicated that the improvement in construction method particularly of rail seat area should address this problem.

There had been no track circuiting issues as per the feedback given by maintenance personnel indicating satisfactory performance of electrical resistance built in the basic design.

The drainage channels in the form of troughs needed further slope improvement to avoid any kind of water logging if the BLT is to be used for platforms as washable aprons. It is significant to note that despite water logging at a couple of locations, there were no signs of distress or disintegration in RCC r

Fig3: BLT-IFS at CSTM

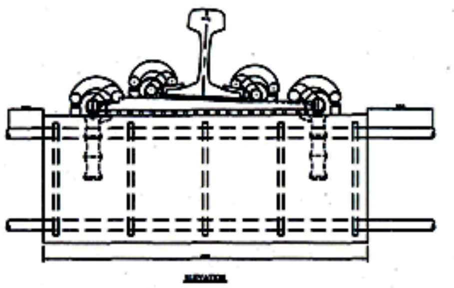

Fig.4: Single RCC Block Concept

4. Design Modifications

The field trial observations are the best judge for the efficacy of any design conceived at drawing board level. Observations made above for over 7 years for the two trial lengths provided considerable insight in conceiving the modifications needed for improving the deficiencies in the design conceived initially. The major change needed was in the method of construction of rail seat area, this being the most significant part of track in ensuring efficacy of functioning of fastening system and ensuring gauge, level and line

The experience gained from the two trials were suggestive that the rail seat area casted in field cannot be 100% reliable and a couple of bad rail seats in track are enough to mar the track, needing imposition of speed restriction, the option of repair of BLT being an expensive preposition. The basic engineering sense and years of railroad maintenance experience suggested to go for casting of rail seat in controlled conditions e.g. in a workshop or a mechanized plant.

The first alternative was developed in the form of having a partly casted RCC block with reinforcing bars protruding out to act as dowels to integrate with in-situ concreting (Fig. 4). The single RCC block could be used for both the rail seats, providing considerable ease in handling due to its smaller size. The idea had to be dropped due to additional amount of steel needed for developing lap lengths increasing overall cost of construction. The idea also expected more quality control on the field staff in the joining of two blocks to achieve correct track gauge, line and level and entailed higher labour and supervision cost for the same reason.

It was decided to carve out the whole of RCC beam from the total RCC layout of the basic BLT-IFS design, having it partly casted in concrete sleeper plants as large numbers of these plants have been developed by Indian Railways across the length and breadths of the country, therefore, ensuring both quality and availability of the product. The rest of the design was more or less kept same as conceived in 2004-05 with suitable modifications in the construction sequence which needs jigs and fixtures to hold the partly pre-cast rail seat beam (PCRSB), the whole BLT mass to be casted through second-pour concrete in-situ.

5. Prototype Development & Testing:

The concept was converted into a prototype produced using the facilities available in one of the concrete sleeper plants using M55 grade concrete. After required curing of the sample PCRSB, the fastening assembly was installed and tested successfully for various parameters e.g. general fitment; clamping force; gauge; level; electrical resistance; etc. A separate test was done for checking pull out strength of inserts (shoulder) and the insert did not come out for a pulling force of 6 ton, a standard used for construction of PSC main line sleepers as well. The testing therefore prima-facie proved the modifications done addressing the major of issue of rail seat quality observed in the performance of trial lengths.

Fig.5: 1st Prototype (Flat Top)

Fig. 6: 2nd Prototype (Canted Top)

It was experienced while developing first prototype with the use of canted base plate of steel, that over-all cost of the design would be much higher than the similar designs available through trade. This was on account of fabrication involved in building cant in the steel bearing plate and subsequent need for going for galvanising for corrosion prevention. Further, flat PCRSB top would need shuttering during concreting in the field to carve out well-defined drainage channels between the beams.

This necessitated evolving a low cast design of bearing plate. A flat bearing plate casted with SGCI (Spheroidal Graphite Cast Iron) emerged as obvious choice due to it's lower cast and ease of manufacturing. The design of PCRSB was also modified in such a manner that required rail cant of 1:20 is built in the sleeper beam itself obviating the need for the same in the base plate. This design also provided option of obviating the need of shuttering during second pour in-situ concreting of whole BLT mass, therefore further economising the design. The design is currently proposed for speeds upto 110 kmph for passenger trains and 25 t for freight stock. The design has been so conceived that it has enough flexibility to make it fit upto 200 kmph with minimum alterations.

The use of BLT-IFS has since been cleared by Indian Railway Board for field trial for 110 kmph to begin with. A trial length of 100 m has been laid recently on Bhopal-Vidisha 3rd line and section awaiting opening and performance evaluation of BLT-IFS.

6. Conclusion:

An economical and long lasting design of ballastless track (BLT) has been a long felt need on Indian Railways for the inevitable requirement of such track form in number of locations e.g. tunnels, viaducts, heavy suburban sections, platform lines, etc.

A design was therefore conceived using basics of civil engineering incorporating years of observations of various ballastless track form designs tried and used on Indian Railways. The experience suggested to go for either Cement Concrete base or RCC base, as earlier tried PSC ties acting as base did not meet with the desired expectations. The design also incorporated use of indigenous fastening system under use on IR for a long time successfully for the reasons of economy and field ease.

Two trial lengths were constructed in the year 2006 and 2007 at Pune and Mumbai stations respectively and based on the observations made during the trial, necessary design modifications have been carried out in 2013 at RDSO. The modified design in the form of partly pre-cast rail seat beam (PCRSB) uses a SGCI flat bearing plate over 1:20 canted rail seat built in the sleeper-beam itself. The prototype of the PCRSB was manufactured and tested successfully.

The design has since been cleared for trial on Indian Railways and first trial length of 100 m laid on Bhopal-Vidisha section recently and is likely to address the long felt need of an economical, durable and suitable form of Ballastless Track.

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