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Defects in Cast-in-situ Ballastless track

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Abstract - *It is a well-known fact that ballastless tracks have proved to be effective alternative to the tracks with ballasts and hence they have been adopted in India a decade ago. The conventional ballastless track are cast-in-situ types, in which the pre-cast concrete sleeper are embedded in the Cast-in-situ concrete slab thereafter rails and fastener are provided. The present work focus on the various type of defects found in Cast-in-situ ballastless tracks along with their and countermeasures. Causes of defects is analyzed, according to corresponding quantitative equation, affective technical measures of concrete are put forward. The best alternative for conventional ballastless tracks i.e. "Pre-stressed bi-block sleeper ballastless track" has also been proposed.*

Key Words: Ballastless track, concrete, crack, Deterioration, Reduction of crack, Pre-stressed bi-block sleeper,

1. INTRODUCTION

Cast-in-situ Ballastless track is a track in which ballast is particularly replaced by cement-base materials (concrete). It is a known fact that steel is the main construction material used in railways, but with the introduction of ballastless technology, the application of concrete in the railway has increased largely. Moreover, the failure of cast-in-situ ballastless track (especially crack and deterioration of concrete) has been observed at the many places in India. Cast-in-situ ballastless tracks (slab track) are not adopted for high speeds and long distances. Hence, in India generally cast-in-situ slab track is placed at different places (i.e. platform of railway station), because at platform train speed, vibration generation is much more less instead of when train is in motion. Cast-in-situ ballastless track fails owing to the Non-linear and irreversible behavior of the materials, the tracks tend to float in longitudinal and lateral directions over time and concrete failure.

The present work focuses on the cause of these concrete defects in the Cast-in-situ ballastless tracks and the corresponding remedial measures. It's an observed fact that Cast-in-situ ballastless track construction offers an effective alternative to the conventional methods due to the enormous reduction of maintenance work and the long service life with constant serviceability conditions, furthermore the application of higher cant and cant deficiency allow the reduction of the minimum values like radii for curves or the increase of speed for lines equipped with ballastless track. Non-linear and irreversible behavior of the materials in concrete has become study focus; there is a little research done for this type of behavior of concrete materials against structural style of ballastless track.

1.1 Structure of Cast-in-situ BLT:

Cast-in-situ ballastless track in which precast concrete sleeper is fixed in position on the base slab reinforcement and further concrete mix is poured into the arrangement and hence the structure becomes monolithic. Once the concrete becomes hard enough, fasteners of rails are fixed on the embedded precast sleepers. As shown in fig.1, the rail and fastener is directly embedded with concrete base slab (without the provision of sleepers), and fig.2 shows the cast-in-situ ballastless track in which rail and its fastener are fixed with pre-cast sleeper which is initially embedded in concrete slab.

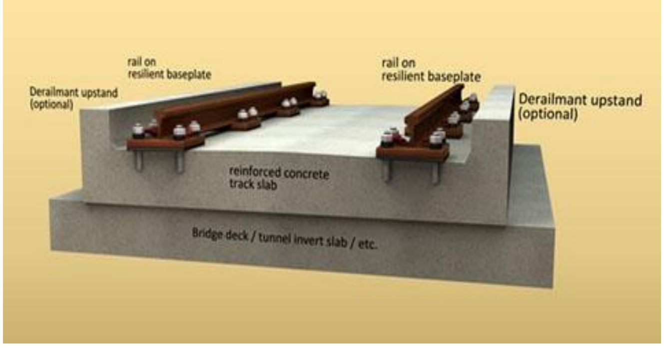

Fig.1 Ballastless track (rail and fattener embedded in base slab)

Rail traffic is reaching out towards new horizon on ballastless track systems. The arguments are indeed convincing: long life cycles, top speed, ride comfort, and great load-carrying capability. Modification of this technology ensures safety and stability at speeds as high as 300 kmph. Practically ballastless track systems ensure its serviceability at a very low maintenance costs over many years.

Fig.2 Cast-in-situ Ballastless track

2. Concrete defects in Cast-in-situ BLT:

There are two main components in cast-in-situ ballastless tracks i.e. (i) track slab with sleeper and (ii) rail fitted with fastener.

2.1 Defects in track slab with sleeper

Main defect which have been observed in cast-in-situ ballastless track is deterioration of concrete of track slab. The service life of concrete structures is reduced drastically because of the deterioration of concrete. Deterioration of concrete takes place due to many reasons such as poor quality materials, degradation due to environmental effects, design and constructional errors or an adverse combination of these factors.

Fig.3 Deterioration of Cast-in-situ BLT

Track slab is a kind of cast-in-situ concrete with precast concrete sleeper structure. The R.C.C sleeper forms a monolithic structure with the concrete bed that encloses it. Design principle of track slab is 'no crack design', but some cracks are observed in the track slab due to load action, environmental factor like temperature and creep of concrete.

Longitudinal crack which is induced by the non homogeneous stress easily appear in the range of fastener. There are many cracks is in the inner side of frame track slab, and some cracks run through the total depth of track slab. Some cracks were developed due to Non-linear and irreversible behavior of concrete material. Sometimes cracks are also caused by freezing and thawing of saturated concrete, or corrosion of reinforcing steel. However cracks from these sources may not appear for years.

Fig.4 Deterioration of Cast-in-situ BLT

2.2 Defects in rail fitted with fastener:

Concrete crack were lie in the range of fastener, and in base slab on which rail joint fitted with fastener rested on it also. Base slab concrete below rail joint is completely deteriorated. Some cracks are also developed in this area. In fastener, pendrol clip are loosened often due to vibration of joint and Nut-bolt of fish plate is also loosened, when load action is more. At some places concrete crust is peel off in the range of fastener. Concrete crack were also developed due to water accumulation in base slab of ballastless track.

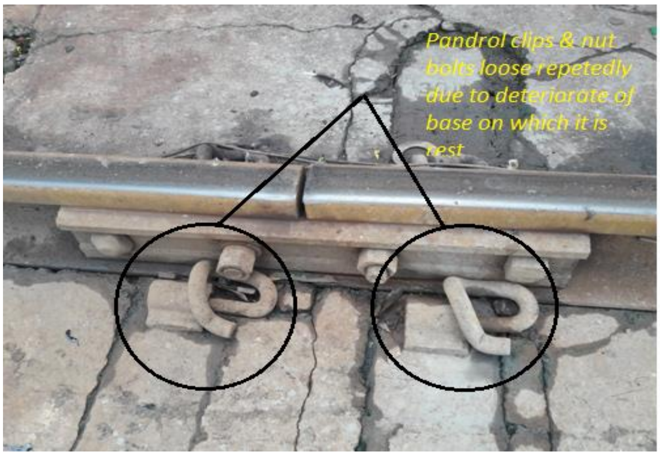

Fig.7 Repeatedly loosened fastener due to the deterioration of base on which it is rested upon.

3.0 Damage due to concrete defects in Cast-in-situ Ballastless track:

There are two main hazards in cast-in-situ BLT, one is reduced durability of track structure and safety of train travel; other is deterioration of track slab by corrosion action owing to the water accumulation, chemical attack, & temperature effect. Depending on the severity of the attack, the consequences of alkali–aggregate reaction are; (1) degradation of appearance (2) deterioration in strength (3) decrease in durability.

Cracks in the track slab will become entryway of the corrosion substances, Under the CL^- or Co_2 environment. The steel in the slab will be corroded and the resulting expansion will aggravate the cracking of the concrete, sequentially reducing the durability of the concrete structure. Under movable load, concrete of track slab is easy to disintegrate and the sleeper rap, which affect the safety of the train. Some cracks lie in the range of fastener; leading to the loosening of the fasteners, thus affect track stability. In addition, there may be potential incipient fault of travel.

Fig.5 Cracks in frame of track slab

For Cast-in-situ BLT structure, concrete cracks not only harms the concrete, but also harms the conterminal part. Cracks in base slab is pathway to the water, immersing the water for a long time, the superstructure accelerates falling in, at the same time increase sedimentation value of base, thus affect the stability of base and reduce the durability and bearing capacity of base. Moreover, the cracks in base concrete aggravate corrosion of its steel.

Fig.6 cracks in base slab of ballastless track

4.0 Defects Cause for Cast-in-situ BLT:

Following are the various causes of defects shown in the Cast-in-situ ballastless track.

4.1 Causes of Deterioration of concrete:

Deterioration of track slab is frequently caused by combination of various adverse factors. The main responsible cause is alkali aggregate reaction in concrete and temperature effect. Alkaline pore solutions in the concrete react in moist conditions with certain types of aggregate to form an expansive gel, resulting in the internal disruption of the concrete. The reaction is slow and its effects only become noticeable after several years of service. It can result from physical damage, chemical attack, structure movement and from material degradation on exposure to severe environmental conditions. Saline water is also cause for deterioration of concrete, whereas area affected by salty water or salty land.

The chemical cause of concrete deterioration includes carbonation; sulphate attack and steel corrosion. Other factors contributing to concrete degradation include high structural stress, thermal stress, and shrinkage, poor quality of materials and workmanship and poor maintenance.

Fig.8 Oil and chemical attack on concrete

4.2 Causes of crack due to Temperature effect:

Temperature crack is a kind of crack caused by temperature changing in the concrete structure or non uniform temperature distribution. The temperature changing and non-uniform temperature distribution may be divided into interior and exterior temperature difference. The former difference is caused by heat of hydration delivered by hydration action of cementitious material, and the latter is caused by environmental temperature changes the ballastless structure positioned in. The surface cracks in the temperature crack usually appear during the time of construction. The deep and penetrating one often happens two to three months even more after concrete casting. At the same time the width of the crack changes with the season, and the crack is wide in the winter and narrow in the summer.

4.1 Concrete crack caused by drying shrinkage and plastic shrinkage:

The common cause of cracking in concrete is shrinkage due to drying. This type of shrinkage is caused by loss of moisture from the cement paste constituents which can shrink by as much as 1% per unit length. The evaporation of water in the concrete paste will produce dry shrinkage which is a non reversible process. Unfortunately, aggregates provide internal restraint that reduces the magnitude of this volume change about 0.05%. Upon wetting, concrete tends to expand. It is the combination of shrinkage and restraint, which is usually provided by another part of the structure or by the subgrade that causes tensile stresses to develop. Cracks may propagate at much lower stresses than are required to cause crack initiation. When the concrete dry shrinkage deformation strength is bigger than stretching resistance of concrete resisting external, the crack will happen in the concrete. The formula of the dry shrinkage deformation is as follows:

$$\varepsilon_s = \varepsilon_{cs}\left[1 - \frac{Va^{1/3}}{1+\frac{Ec}{Ea}\left(Va^{-\frac{2}{3}}-1\right)}\right] \text{ .... (1)}$$

ε_s = dry shrinkage deformation of concrete
ε_{cs} = dry shrinkage of cement hardened stone
Va = volume content of aggregate
Ea, Ec = elastic modulus of aggregate and Hardened cement stone

Plastic shrinkage cracks are caused by a rapid loss of water from the surface of concrete before it has set. The critical condition exists when the rate of evaporation of surface moisture exceeds the rate at which rising bleed water can replace it. Water receding below the concrete surface forms meniscus between the fine particles of cement and aggregate causing a tensile force to develop in the surface layers. If the concrete surface has started to set and has developed sufficient tensile strength to resist the tensile forces, cracks do not form. If the surface dries very rapidly, the concrete may still be plastic, and cracks do not develop at that time; but plastic cracks will surely form as soon as the concrete stiffens a little more. Synthetic fiber reinforcement incorporated in the concrete mixture can help resist the tension when concrete is very weak. Conditions that cause high evaporation rates from the concrete surface, and thereby increase the possibility of plastic shrinkage cracking, include: (1) Wind velocity in excess of 5 mph (2) Low relative humidity (3) High ambient and/or concrete temperatures.

5.0 Remedial Measures for Defects in Cast-in-situ Ballastless track:

5.1 For Deterioration and temperature crack:

Deterioration defects in concrete are caused mainly by the alkali aggregate reaction and temperature effect. Remedies for alkali aggregate reaction are that (1) Use only non-reactive aggregates (not always available). (2) Use only low alkali cements (the only available cements may be high in alkalis). (3) Use appropriate extenders (experimentation is needed to optimize effectiveness). (4) Prevent continued wetting of the concrete (often unfeasible in practice).

Reducing the temperature difference of uniform and non-uniform. Temperature destroying stress and uniform temperature difference and non-uniform one presents positive relation. The bigger the temperature difference is, the bigger is the stress caused. Caused by hydraulic heat, non-uniform temperature difference reduced is to reduce hydraulic heat of cement by adding mineral admixture, which may improve work performance and durability of concrete.

5.2 For reducing drying shrinkage and Plastic shrinkage:

- Use of maximum practical amount of aggregate in the mix.
- Adopt the lowest water-to-cement ratio
- Use of properly spaced contraction joints and proper steel detailing
- Use of shrinkage compensating cement
- Use of proper subgrade preparation, including uniform support and proper sub-base material at adequate moisture content
- Minimize the mix water content by maximizing the size and amount of coarse aggregate and use low –shrinkage cement
- Use of spray-applied aids or plastic sheets preventing rapid loss of surface moisture and hence avoiding plastic-shrinkage cracks.
- Reinforce curing; it needs not only in time curing but also sufficient curing, which means the time of curing must be long enough. Reinforcing curing can guarantee the strength development of the concrete. Moreover sufficient curing may also put off the time of dry shrinkage and release the degree of the dry shrinkage. The action on both sides makes the dry shrinkage happen after the concrete and the hardened cement stone have enough resistivity, so that the dry shrinkage crack of concrete may be efficiently reduced.
- The more the elastic modulus ratio of aggregate and hardened cement stone, the smaller the dry shrinkage deformation of the concrete. Therefore, choose the hard texture and high elastic modulus ratio of aggregate as possible as we can.
- Furthermore, the effective method to reduce the elastic modulus of cement stone is to add prime mineral admixtures; especially the prime fly ash.
- The solution of reducing the plastic crack is to choose proper component of cement or cementatious material, and control the time interval between initial set and final set. Before initial set, concrete in shape of flowing can't crack, but when it has lost flowing power the crack will be caused because of not enough strength to resist its shrinkage stress.

6.0 Alternatives of Cast-in-Situ Ballastless track:

Now a day's High speed railway is the future of whole railway system. There are best alternatives of Cast-in-situ ballastless track are Pre-stressed concrete bi-block sleeper ballastless track system. The basic system structure, however, always consists of modified bi-block sleepers which are securely and reliably embedded in a monolithic concrete slab. Highly elastic rail fastenings are essential to achieve the vertical rail deflection required for load distribution and for smooth train travel. The concrete track-supporting layer is the major load-distributing element of the system. Since it is cast-in-place, it can be individually adapted to any substructure type and condition. For embankments, it is designed as a continuous slab with free crack formation.

Fig. 9 Pre-stressed concrete Bi-block sleeper ballastless track system

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