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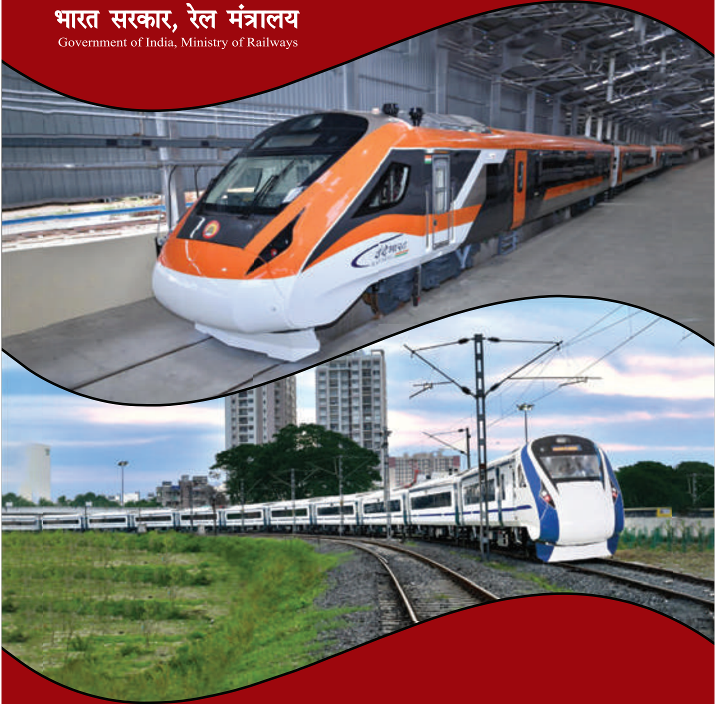
भारत सरकार, रेल मंत्रालय
Government of India, Ministry of Railways



INDIAN RAILWAY TECHNICAL BULLETIN
MARCH - 2024

VOLUME-LXXX NUMBER-388

INDIAN RAILWAY TECHNICAL BULLETIN

Volume : LXXX Number : 388

March 2024

Indian Railway Technical Bulletin published quarterly by the Executive Director/Administration, Research Designs and Standards Organisation, is not an official publication. Neither the Government of India nor the Railway Board and Research Designs and Standards Organisation are responsible for the opinion or statements made therein.

The Annual Subscription Charges of IRTB published by RDSO (w.e.f. : August 2011) is as follows :

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Yearly subscription (four issues)	Rs. 400/- (excluding postal charges which is at present Rs. 40/- per copy)
Single copy (subscription of one issue)	Rs. 100/- (excluding postal charges which is at present Rs. 40/- per copy)
Foreign	
Yearly subscription (four issues)	Rs. 1000/- (excluding postal charges which is at present Rs. 90/- per copy)
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Yearly subscription (four issues)	Rs. 240/- (excluding postal charges which is at present Rs. 40/- per copy)
Single copy (subscription of one issue)	Rs. 60/- (excluding postal charges which is at present Rs. 40/- per copy)

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Edited and published by:
Executive Director/Administration,
Research Designs and Standards Organisation,
Ministry of Railways,
Manak Nagar, Lucknow-226011
RDSO Website: http://www.rdso.indianrailways.gov.in, Email: publicationrdso@gmail.com

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Criteria of De-Stressing of Long Welded Rails (LWR) Based on Stress Free Temperature

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Abstract : On Indian Railways, various maintenance operations and extreme weather patrolling in LWR are carried out subject to rail temperature variation from de-stressing temperature. However, no technique is used at present for the measurement of stress free temperature of LWR and the follow up action afterwards. De-stressing temperature and Stress-Free temperature (SFT) are almost equal at the time of de-stressing of LWR. However, various improper maintenance activities, longitudinal movement of the sleepers in the ballast or of the rails relative to the sleepers, may alter the original stress-free temperature. Therefore, actual stress levels may be different than those anticipated and LWR may behave differently during maintenance. It is desirable to maintain the desired stress free temperature in LWR.

On Indian Railways, destressing of LWR during maintenance is carried out empirically based on the observation of behaviour of LWR or due to some special track maintenance activities or after unusual occurrences and there is no objective criteria for carrying out the de-stressing at present. However, modern technologies are available world over that can be adopted for measurement of stress free temperature of LWR and for rationalizing the maintenance practices of LWR.

Several methods and technologies have been evolved world over for measurement of stress-free temperature based on the different working principles with different success levels. Out of these, two non-destructive technologies/ methodologies, which are also commercially available, are found to be promising for use over Indian Railways. Measurement of stress free temperature (SFT) may be a parameter for analyzing the behavior of LWR and deciding the various maintenance activities accordingly. To rationalize the criteria of de-stressing and other maintenance activities of LWR, measurement of SFT by using modern non-destructive equipment/technology being used worldwide need to be adopted. Variation of measured SFT beyond a limit from original SFT/de-stressing temperature may be the criteria for carrying out de-stressing of LWR.

This paper covers the international practices being followed for maintenance decision based on SFT measurement and accordingly, use of modern technology for measurement of SFT and protocol for de-stressing of LWR based upon the SFT values has been proposed for Indian Railways. Similarly, Extreme weather patrolling i.e. hot weather patrolling and cold weather patrolling may be introduced based upon the temperature variation w.r.t. stress free temperature of LWR.

सारांश : भारतीय रेलवे मे एलडब्ल्यूआर के विभिन्न मरम्मत कार्य और एक्सट्रीम वेदर पेट्रोलिंग कार्य, रेल तापमान की डी–स्ट्रेसिंग तापमान से भिन्नता के अनुसार की जाती है। हालाँकि, वर्तमान में एलडब्ल्यूआर के स्ट्रेस फ्री टेम्परेचर (एसएफटी) को मापने और उसके बाद की प्रक्रिया के लिए किसी तकनीक का उपयोग नहीं किया जाता है। एलडब्ल्यूआर के डी–स्ट्रेसिंग के समय डी–स्ट्रेसिंग तापमान और स्ट्रेस फ्री टेम्परेचर (एसएफटी) लगभग बराबर होते हैं। हालाँकि, विभिन्न अनुचित रखरखाव गतिविधियाँ, बैलास्ट में स्लीपरों की लम्बवत गति या स्लीपरों के सापेक्ष रेलों की लम्बवत गति, मूल स्ट्रेस फ्री टेम्परेचर को बदल सकती है। इसलिए, वास्तविक स्ट्रेस का स्तर प्रत्याशित से भिन्न हो सकता है और एल.डब्ल्यू.आर. रखरखाव के दौरान अलग व्यवहार कर सकता है। अतः एल.डब्ल्यू.आर. में वांछित स्ट्रेस फ्री टेम्परेचर बनाए रखना वांछनीय है।

भारतीय रेलवे में रखरखाव के दौरान एलडब्ल्यूआर की डी–स्ट्रेसिंग, एलडब्ल्यूआर के व्यवहार के अवलोकन के आधार पर या कुछ विशेष ट्रैक रखरखाव गतिविधियों के कारण या असामान्य घटनाओं के बाद किया जाता है और वर्तमान में डी–स्ट्रेसिंग करने के लिए कोई वस्तुनिष्ठ मानदंड नहीं है। हालाँकि, दुनिया भर में आधुनिक टेक्नोलॉजी उपलब्ध हैं जिन्हें एलडब्ल्यूआर के स्ट्रेस फ्री टेम्परेचर (एसएफटी) को मापने और एलडब्ल्यूआर के रखरखाव कार्य प्रणाली को तर्कसंगत बनाने के लिए अपनाया जा सकता है। इनमें से दो नॉन–डिस्ट्रक्टिव टेक्नोलॉजी व्यावसायिक रूप से उपयोग के लिए भी उपलब्ध हैं। भारतीय रेलवे में स्ट्रेस फ्री टेम्परेचर (एसएफटी) का मापन, एलडब्ल्यूआर के व्यवहार का विश्लेषण करने और उसके अनुसार विभिन्न रखरखाव गतिविधियों को तय करने के लिए एक पैरामीटर हो सकता है। एलडब्ल्यूआर की डी–स्ट्रेसिंग और अन्य रखरखाव गतिविधियों के मानदंडों को तर्कसंगत बनाने के लिए दुनिया भर में उपयोग किए जा रहे आधुनिक नॉन–डिस्ट्रक्टिव उपकरण/टेक्नोलॉजी का उपयोग करके एसएफटी मापन को अपनाने की आवश्यकता है। मूल एसएफटी/डी–स्ट्रेसिंग तापमान से एक सीमा से अधिक मापे गए एसएफटी में परिवर्तन एलडब्ल्यूआर को डी–स्ट्रेसिंग करने का मानदंड हो सकता है।

यह पेपर एसएफटी मापन के आधार पर रखरखाव के निर्णय के लिए अपनाई जाने वाली अंतरराष्ट्रीय प्रथाओं को शामिल करता है और तदनुसार, एसएफटी के मापन के लिए आधुनिक तकनीक का उपयोग और एसएफटी के वैल्यू के आधार पर एलडब्ल्यूआर की डी–स्ट्रेसिंग करने के लिए प्रोटोकॉल भारतीय रेलवे के लिए प्रस्तावित किया गया है। इसी प्रकार, एलडब्ल्यूआर के स्ट्रेस फ्री टेम्परेचर के सापेक्ष तापमान भिन्नता के आधार पर एक्सट्रीम वेदर पेट्रोलिंग यानी हॉट वेदर पेट्रोलिंग और कोल्ड वेदर पेट्रोलिंग को शुरू किया जा सकता है।

1. Introduction:

On Indian Railways, various maintenance operations and extreme weather patrolling in LWR track are done subject to rail temperature variation from de-stressing temperature. However, no technique is used at present for the measurement of stress free temperature of LWR and follow up action afterwards. De-stressing temperature and Stress Free temperature (SFT) are almost equal at the time of de-stressing of LWR. However, various improper maintenance activities, longitudinal movement of the sleepers in the ballast or of the rails relative to the sleepers, may alter the original stress free temperature. Therefore, actual stress levels may be different than those anticipated and LWR may behave erratically during maintenance. It is desirable to maintain the desired stress free temperature in LWR for its satisfactory behavior.

On Indian Railways, destressing of LWR during maintenance is carried out empirically based on the observation of behaviour of LWR or due to some special track maintenance activities or after unusual occurrences and there is no objective criteria for carrying out the de-stressing at present. However, modern technologies are available world over that can be adopted for measurement of stress free temperature of LWR which can be utilized in rationalizing the maintenance practices of LWR.

It would be more rational to measure stress free temperature of LWR with use of modern technologies and upgrade the maintenance operations like de-stressing of LWR and introduction of hot weather/cold weather patrolling etc accordingly. By measuring SFT of LWR, decision to carryout de-stressing operation may be taken on need basis. Also, de-stressing of LWR is required to be done more accurately to ascertain the satisfactory behavior of LWR. After de-stressing operation, its accuracy may be checked by measurement of actual stress free temperature.

2. Extant Provisions of IRPWM-2020 for de-stressing during maintenance [1]:

"Para 347 De-stressing during Maintenance' stipulates as under:

(1) Abnormal behavior of LWR/CWR can be inferred by observing one or more of the following:

(a) When the gap observed at SEJ

(i) Differs beyond limits specified in Annexure- 3/9.

(ii) Exceeds the maximum designed gap of SEJ

(iii) When tip of tongue rail/corner of Stock Rail crosses the reference line

(b) In case of excessive creep of more than 20 mm in the central portion of LWR is noticed.

(2) In such cases as in **Sub Para (1) above,** LWR/CWR shall be inspected by ADEN for

(a) deficiency of ballast,

(b) poor compaction / consolidation of ballast,

(c) deficiency of fittings,

(d) poor toe load of ERC

(e) formation trouble if any,

(f) whether procedures as per **Para 349** were followed during permanent repairs after earlier rail fracture(s),

(g) the possibility of defective thermometers being used by the staff.

After the above inspection, the deficiency shall be made good at the earliest by suitable corrective action, to improve the track resistance. Thereafter, the SEJ/LWR shall be kept under close observation by active monitoring by the JE/SSE/P.Way. If LWR/CWR still behaves abnormally, a decision shall be taken by ADEN for de-stressing of LWR/CWR.

(3) After special maintenance operations mentioned in **Para 346**, de-stressing shall be undertaken.

Para 346 Special Track Maintenance-

Special track maintenance in LWR includes following operations:-

(a) Through fittings renewal

(b) Deep screening/mechanised cleaning of ballast

(c) Lowering/Lifting of track

(d) Major realignment of curves

(e) Sleeper renewal other than casual renewals

(f) Rehabilitation of bridges and formation causing disturbance to track

(4) After restoration of track following an unusual occurrence mentioned in Para 348 de-stressing shall be undertaken.

Para 348 Unusual Occurrences: List of unusual occurrences are under:

(a) Rail fractures or replacement of defective rail/ glued joint.

(b) Damage to SEJ.

(c) Buckling or tendency towards buckling.

(d) Factors causing disturbance to LWR/CWR such as accidents, breaches etc.

(5) If number of locations where repairs by way of replacement of rail/weld have been done, exceed three per km, de-stressing of affected portion of LWR/CWR shall be done."

3. Stress Free Temperature (SFT) of LWR and its Measurement:

3.1 De-stressing temperature is the average rail temperature during the period of fastening the rails to the sleepers after de-stressing of LWR. Stress free temperature (SFT) is the temperature of rail in LWR at which the rail is free of thermal stresses.

Various maintenance operations and extreme weather patrolling in LWR are carried out subject to rail temperature variation from de-stressing temperature. De-stressing temperature and stress free temperature are almost equal at the time of de-stressing of LWR. However, due to various improper maintenance activities, longitudinal movement of the sleepers in the ballast / rails relative to the sleepers may alter the original stress free temperature.

By measuring stress free temperature of LWR at any time, suitable maintenance decision like de-stressing of LWR and introduction of hot weather / cold weather patrolling may be taken. SFT measurement will enable the field officials to know the actual stress condition in the LWR and accordingly maintenance decision will become need based and more rational.

3.2 Methodologies/Technologies for measurement of Stress Free Temperature (SFT):

Several methods and technologies have been evolved world over for the measurement of stress-free temperature with different success levels and they are not free of shortcomings. Some of these technologies exist as commercial products, while others are at a research and development phase. Existing methods and technologies for measurement of stress-free temperature along with basic principles and shortcomings are tabulated as under:

Technologies for Measurement of Stress Free Temperature (SFT) or Rail Neutral Temperature (RNT) [2]

SN	Method	Basic Principles	Shortcomings
1.	Rail Cutting	Cut rail to release thermal deformations for direct measurement of rail deformations.	Time consuming, Destructive, Disruptive to train operations
2.	Rail Lifting	Impose vertical force to unclipped rail until reaching a pre-determined distance. Vertical stiffness correlated to axial force to estimate Rail Neutral Temperature (RNT).	Time Consuming, Semi-destructive, Disruptive to train operations
3.	Hole-drilling	Material removal from a hole drilled into the rail web along the rail neutral axis relieves the stress that can be computed utilizing deformation measurement techniques.	Semi-destructive, Disruptive to train operations, Sensitive to hole sources of error, Sensitive to surface strain, Potential plastic deformations caused by drilling procedure.
4.	Deformation measurements	Uses strain gauge or extensometer data to measure rail thermal elongation to compute stress.	Contacting, Instrumentation installation, Roles on changing dimension, Needs stress-free reference measurement
5.	Ultrasonic Waves	Changes in ultrasonic wave characteristics (e.g. speed, polarization, non-linearity of guided waves) propagating in the medium are correlated to the stress state in rail.	Contacting, Needs stress-free reference measurement, Sensitive to material structure/defects, Sensitive to rail surface quality, Potentially high instrumentation demands.
6.	X-Ray	Distance between two atomic planes in a crystal is measured and related to material stresses. Change in interplanar spacing is indicative of axial stress development.	Measures a small surface volumes, Needs stress-free reference measurement, Distance data of the atomic planes, Requires clean surface, High instrumentation demands
7.	Magnetic	Electromagnetic and acoustic response signals (Barkhausen noise) produce a magnetic field. The permeability in the magnetic field is correlated to the longitudinal stress.	Time consuming calibration, Reference material measurement, Eliminate local surface perturbations, High Instrumentation demands.
8.	Vibro-elastics	Exciting the rail to obtain vibration mode characteristics that change with axial force.	High instrumentation demands, High instrumentation accuracy needs stress-free reference measurements, Advanced FE calculations
9.	Piezoelectric	The Piezoelectric excites the rail to obtain an EMI response signal from the rail that indicates deformation.	Contacting, Instrumentation installation, High instrumentation demands Exists in experimental stages.

3.3 Out of above, two non-destructive technologies/ methodologies, which are also commercially available, are found to be promising for use over Indian Railways. These technologies are as under:

(a) Vertical Rail Stiffness Equipment (VERSE) based on the rail lifting Principle

(b) Rail Scan Technique based on Barkhausen Noise (Magnetic) Principle

3.3.1 VERSE (Vertical Rail Stiffness Equipment):

(i) Measuring Principle:

In this method, rail is lifted at center and required force to lift the rail is measured, which depends on the stresses in the rail. This method needs opening of fittings/fastenings of about 30m length of track for measurement of SFT. The system is based on the principle that the vertical force required to lift a rail varies with the axial force contained within. VERSE is a combined mechanical/software system which produces initial results at site from a hand held computer. The limitation of the equipment is that the temperature during measurement should be less than SFT. This technology requires traffic block for a period of 20-30 minutes. A typical VERSE system with its components is shown in figure below:

Fig.- VERSE setup on track for measurement of SFT

(ii) Measurement Procedure:

a) Taking a measurement requires around 30m of track to be unclipped which is normally done by two persons whilst another one sets up the VERSE frame which sits on the sleeper and straddles the rail.

b) At points 10m each side of the centre point, the rail is lifted onto a rail support spacer. This leaves a 20m length of rail suspended freely.

c) VERSE equipment is positioned over the central point, and the rail is jacked steadily to a load of 10 KN and monitored by a load transducer. Displacement is simultaneously monitored for each increment of load to another transducer attached to the rail.

d) Vertical displacement in rail due to vertical load depends on the stresses contained within the rail.

e) The output from both transducers is sent to a hand held computer.

f) The software menu prompts the user to enter certain site specific data such as rail temperature, rail profile and actual rail height.

g) The software then calculates the SFT directly. VERSE equipment is self-calibrating for each lift and the software is able to check the validity of each measurement. Time on site is between 20 to 30 minutes per measurement.

3.3.2 Rail Scan Technique based on Barkhausen Noise (Magnetic) Principle:

(i) Measuring Principle: Rail Scan technique, based on the principle of Barkhausen - noise measurement has been developed for the non-destructive determination of neutral temperature of LWR tracks. By magnetizing ferromagnetic (magnetizable) materials, high frequency electromagnetic and acoustic response signals arise, and this is called as Barkhausen Noise. Its magnitude depends on the structure of material and its stress state. Correlation between the magnitude of the noise and the stress state of the examined material is established by means of calibration measurements.

Before measurement of SFT of a particular LWR, calibration is required. Measurements of Barkhausen noise are taken for different longitudinal stresses and used to plot a calibration curve of the Barkhausen noise as a function of longitudinal stress. After the calibration, device is ready for the non-destructive measurements of SFT in LWR tracks.

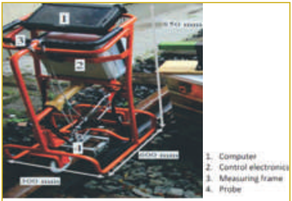

Fig. Rail Scan device for Measurement of SFT

(ii) Measurement Procedure:

Rail scan device consists of a trolley pushable on track manually, a central instrument unit mounted on the trolley, the measuring head, industrial computer and battery. The device can be moved easily on the rail by one person. Measuring head consists of two clamping claws which can be pressed on the rail head against a spring. Measuring heads are replaceable suitably based on the type of rail section. For the calculation of Neutral temperature of LWR, measurement must be executed twice for both cold and warm rail. The difference in rail temperature should be minimum 7 degree C.

In one cycle, measurement of 50 cross-sections is taken which covers approximate 300m length. One cycle of measurement takes approx. 30 minutes.

4. International Practices for De-stressing of LWR based on the Stress Free Temperature (SFT):

4.1 Provisions of UIC 720 R[3]:

UIC Code UIC 720 R ‘Laying and Maintenance of CWR Track’ stipulates that during permanent repair of rail fracture and track buckling or distortion, de-stressing of LWR should be done to maintain the desired stress free temperature.

Further, as per UIC code, buckling safety evaluation is done by determining the allowable rail temperature (T_{all}) as under:

$$T_{all} > (T_{max} - T_n)$$

Where, T_{max} is maximum rail temperature and

T_n is neutral temperature or stress-free temperature, which is not the installation or fastening temperature (t_f), but the actual value in the service life of CWR which is usually different due to changes induced by rail/track kinematics and maintenance actions. In the absence of non-destructive techniques to determine T_n, a ‘safety factor’ is usually established to account for stress free temperature variation as under:

$$T_n = T_f - SFTN$$

Where, T_f is installation temperature and SFTN is Stress Free Temperature variation safety factor. For UIC Track, the recommended values for SFTN are in the range of 5 - 10^{0}C.

From above, it may be inferred that, variation of stress free temperature from desired stress free temperature may be kept in the range of 5-10^{0}C from safety criterion stipulated in the UIC 720R.

4.2 Provisions of U.S. Department of Transportation (Federal Railroad Administration, USA) FRA[4]:

The safe range of Rail temperature is defined as [DRNT +/- 20°F (i.e. DRNT ±11.11^{0}C)], where DRNT is Desired Rail Neutral Temperature. If the rail temperature is found above or below this range, de-stressing is required to be done.

4.3 Provisions of Australian Rail Track Corporation (ARTC):

4.3.1 ETM-06-10 document of ARTC describes the procedure for stressing CWR with a tensor when rail temperature is below design Stress Free Temperature (SFT). The current design SFT for ARTC is 38^{0}C. [5]

a) Para 6 of this document specifies the SFT requirement at sites that require removal of rail/weld defects or require short rail installation. It mentions that at such sites, it is recommended to establish the SFT status of the track either from historical records, from any indication that SFT may be incorrect or establish using the Rail frame or Verse as being within the range (38^{0}C ± 5^{0}C) prior to commencement of work.

It also mentions that it is recommended that the SFT of the adjacent sections of track be established using the Rail frame or Verse and correcting stressing works undertaken until achieving an SFT within the range (38^{0}C ± 5^{0}C).

b) Para 7 of this document describes the monitoring requirements, controls and corrective action necessary to ensure that all stressing activities comply with ARTC standards. Rail stressing sites and short rail installation sites shall be inspected using an improved method of measurement.

Verse and Rail frame measuring techniques are the ARTC approved methods of measuring the SFT of long welded rail. In future, other methods may become accepted and listed in type approval for measurement of SFT.

It mentions that the acceptance limits for correct stressing are the design SFT ± 5^{0}C (or 33^{0}C to 43^{0}C). Measured SFT outside these limits shall be referred to the person responsible for asset management of the area.

4.3.2 ETM-06-08 document of ARTC specifies and describes the requirements for managing track stability. It specifies requirements for inspection and assessment of stability of concrete sleeper welded track, managing track stability during high temperatures and preventing, investigating track buckles etc. [6]

Para 6 of this document stipulates about Stress Free Temperature (SFT) measurement. This para specifies location of measurement, status of schedule, frequency of measurement, Assessment and Actions in regard to SFT. The location of SFT measurement include locations following stressing, locations near bunching points, locations with lateral instability or creep, broken rail, rail weld defects, short rail installation, random selection of locations and other locations. This para does not clearly mention response to SFT measurement at such specific locations. Though, this para specifies response to SFT measurement at all other locations as follows:

Measured SFT	RESPONSE
SFT 28^{0}C – 24^{0}C (average of both rails)	Increase monitoring or Stress, with priority having regard to other contributing factors.
SFT 23^{0}C or less (average of both rails)	Stress, with priority having regard to other contributing factors. Treat as special location until rectified.
SFT 48^{0}C or more (on either rail)	Stress

It means that if measured SFT at other locations is beyond design SFT ± 10^{0}C, stressing works is to be done.

As mentioned in para 4.3.1 above, ETM-06-10 clearly mentions that SFT should be within design SFT ± 5^{0}C (or 33^{0}C to 43^{0}C) at sites that require removal of rail/ weld defects, short rail installation and after stressing work. These locations are same as specific locations mentioned in para 6 of ETM-06-08 and therefore, response to measured SFT at specific locations of ETM-06-08 should be in line with ETM-06-10 i.e. stressing works is to be done, if measured SFT is beyond SFT ± 5^{0}C. At other locations, the table above shall be applicable.

4.3.3 From above, it may be inferred that de-stressing of LWR shall be required if measured SFT is beyond the range of SFT ± 5^0 C.

5. Proposed Criteria of de-stressing based upon the SFT measurement on IR:

With the recent development in continuation of LWR on earlier restricted locations such as sharp curves & steep gradients, through turnouts and over bridges, length of LWR track is going to increase. Behavior of such long welded rails may not be assessed accurately merely through monitoring the gap at SEJs at either end only.

Measurement of stress free temperature (SFT) may be a parameter for analyzing the behavior of LWR and deciding the various maintenance activities. To make the criteria of de-stressing and other maintenance activities need based, measurement of SFT by using non-destructive proven equipment/technology being used worldwide need to be adopted. Variation of measured SFT beyond a limit from original SFT/de-stressing temperature may be the criteria for carrying out de-stressing of LWR.

5.1 Limit of variation of SFT: A limit of variation from original SFT is required to be decided for Indian Railways that may be followed for carrying out de-stressing operation of LWR based on SFT. Such provisions of various countries as discussed in Para 4 above are summarized as under:

5.1.1 EN provision: Variation of stress free temperature from desired stress free temperature may be kept in the range of 5-10^{0}C from safety criterion stipulated in the UIC 720R.

5.1.2 Federal Railroad Administration, USA: Safe range of Rail temperature is defined as [DRNT +/- 20°F (i.e. DRNT ± 11.11^{0}C)], where DRNT is Desired Rail Neutral Temperature. If the rail temperature is found above or below this range, de-stressing is required to be done.

5.1.3 ARTC provision: SFT of track be established using the Rail frame or Verse and correcting stressing works undertaken until achieving an SFT within the range (38^{0}C + 5^{0}C).

Indian Railways system at present does not have experience of maintaining track stability based on measurement of SFT of LWR. Therefore, to begin with, considering the provisions of various countries, the limit of variation of measured SFT from original SFT/de-stressing temperature for IR may be kept as +/- 5 degree C for all locations. After gaining experience with time, the accepted variation limit may be reviewed.

5.2 Proposed Protocol for De-stressing of LWR:

5.2.1 De-stressing of LWR based on the measurement of Stress Free Temperature (SFT) may be done as under:

(i) SFT to be measured by any proven approved non-destructive technique.

(ii) SFT of each LWR to be measured before start of summer once in a year.

(iii) Measurement of SFT to be taken at centre of LWR and at every km of a LWR in non-breathing length.

(iv) On curves shaper than 440 m radius and/or on gradient steeper than 1 in 100, SFT necessarily be measured, if not covered in the regular measurement at every Km of LWR mentioned above.

(v) In addition, SFT also to be measured under following conditions:

(a) Abnormal behavior of LWR as specified in para 347 (1) of IRPWM, June-2020

(b) LWR affected by unusual occurrences specified in Para 348 (a) & (b) of IRPWM, June-2020

(c) If number of locations where repairs by way of replacement of rail/weld have been done, exceed three per Km

(d) One out of ten locations or part thereof selected at random from all de-stressing work site locations (including the locations as detailed in Para 346 & 348 of IRPWM-2020) in the jurisdiction of a SSE/P.Way (Incharge) for ascertaining the correctness of design de-stressing temperature of LWR. One location here shall represent the length of LWR de-stressed (say 1 km) at a time.

If measured SFT of a randomly selected location of LWR is beyond +/- 5 degree Centigrade w.r.t. original de-stressing temperature as mentioned in Para (vi) (b) below, two more locations (one preferably adjacent and one at random) out of 10 locations shall be selected for measurement of SFT. If value of SFT of any of these two selected LWRs is beyond prescribed limit, SFT of all other de-stressing work site locations shall be measured.

(vi) Based on the measured value of SFT of LWR, action to be taken as under:

(a) If measured SFT of a particular location of LWR is within +/- 5 degree C w.r.t. original de-stressing temperature, de-stressing of subjected stretch is not required.

(b) If measured SFT of a particular location of LWR is beyond +/- 5 degree C w.r.t. original de-stressing temperature, de-stressing of affected portion subject to minimum 500m on either side of measuring point shall be done.

5.2.2 After special maintenance operations mentioned in Para 346 and after unusual occurrences mentioned in Para 348 (c) & (d) of IRPWM, June-2020, de-stressing to be undertaken invariably.

6. Proposed criteria for Introduction of Hot and Cold Weather Patrolling based on the SFT measurement:

Para 1005 of IRPWM stipulates regarding Hot and Cold Weather patrolling. Keeping other stipulations same, the Hot and Cold Weather patrolling may be introduced based on the temperature variation w.r.t. measured value of SFT of LWR instead of de-stressing temperature (td) as mentioned in para 1005 of IRPWM - June 2020. Therefore, revised provisions regarding Introduction of Hot and Cold Weather Patrolling (related to de-stressing temperature) may be as follows:

6.1 Hot Weather Patrolling to be introduced when the rail temperature rises above:

(a) SFT+25^{0}C on PSC sleeper track with sleeper density 1540 nos. per Km and above.

(b) SFT+20^{0}C on PSC sleeper track with sleeper density less than 1540 nos. per Km.

6.2 Cold weather Patrolling should compulsorily be started when rail temperature goes below SFT-30^{0}C.

7. Way Forward:

At present Indian Railway system does not have experience of maintaining track stability based on the SFT measurements. It is therefore proposed that criteria of de-stressing and extreme weather patrolling of LWR based on stress free temperature may be implemented on provisional basis in the first phase. Based on the results and experience gained, it may further be implemented on regular basis and further necessary amendment in IRPWM may also be done accordingly.

8. Conclusion:

De-stressing temperature and Stress-Free temperature (SFT) are almost equal at the time of de-stressing of LWR. However, the original stress-free temperature may alter with time. To ensure satisfactory behavior of LWR, it is desirable to know the actual stress levels in LWR and to maintain the desired stress free temperature in LWR. SFT may be measured by using any proven non-destructive technology. VERSE & RSDS are two such promising equipments which are commercially available and may be used.

At present, there is no objective criteria in Indian Railways Permanent Way Manual (IRPWM) to carry out de-stressing based on change in stress free temperature. It would be more rational to carryout de-stressing of LWR based on the SFT measurement. Criteria for destressing and Protocol for de-stressing based on the SFT measurement has been proposed. The behavior of LWR may be assessed on few LWRs initially for further decision on regular adoption.

Hot weather patrolling and cold weather patrolling may also be introduced at temperature variations with respect to the actual measured stress free temperature.

9. References:

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[3] UIC Code 720 R ‘Laying and Maintenance of CWR Track’, 2nd edition, March 2005.

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[5] Document No. ETM-06-10 ‘Managing Track Stability’ issued by Australian Rail Track Corporation (ARTC)

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Advancing Railway Infrastructure: Ballastless Track with Pandrol Booted Block System on USBRL Project

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Abstract : This paper brief into the adoption of Ballastless track with a primary focus on the Pandrol Booted Block system of Ballastless track, which is laid for 67.45 Km (56%) among the three BLT system adopted in Katra- Banihal section of USBRL Project. The 111 Km stretch of Katra to Banihal section of USBRL Project is culmination of tunnels and bridges and only 7 Km is on open space which is mostly in yards. As a result of such challenging location, the Katra- Banihal stretch of the project integrates the cutting-edge technology of Ballastless track (BLT) system to ensure seamless, maintenance free and efficient railway operations. By adopting the Pandrol booted block sysytem, the USBRL project aims to eliminate the need for frequent maintenance activities associated with traditional ballast-based tracks. This shift towards maintenance-free operations translates into improved reliability, and enhanced passenger satisfaction.

सारांश : यह पेपर बैलास्टलेस ट्रैक के पेंड्रोल बूटेड ब्लॉक सिस्टम पर प्राथमिक फोकस के साथ बैलास्टलेस ट्रैक को अपनाने के बारे में संक्षेप में बताता है, जो यूएसबीआरएल परियोजना के कटरा–बनिहाल खंड में अपनाई गई तीन बीएलटी प्रणालियों में से 67.45 किलोमीटर (56%) के लिए बिछाया गया है। यूएसबीआरएल परियोजना के कटरा से बनिहाल खंड का 111 किमी लंबा हिस्सा सुरंगों और पुलों की परिणति है और केवल 7 किमी खुली जगह पर है जो ज्यादातर यार्ड में है। ऐसे चुनौतीपूर्ण स्थान के परिणामस्वरूप, परियोजना का कटरा–बनिहाल खंड निर्बाध, रखरखाव मुक्त और कुशल रेलवे संचालन सुनिश्चित करने के लिए बैलास्टलेस ट्रैक (बीएलटी) प्रणाली की अत्याधुनिक तकनीक को एकीकृत करता है। पेंड्रोल बूटेड ब्लॉक सिस्टम को अपनाकर, यूएसबीआरएल परियोजना का लक्ष्य पारंपरिक गिट्टी–आधारित ट्रैक से जुड़ी लगातार रखरखाव गतिविधियों की आवश्यकता को समाप्त करना है। रखरखाव–मुक्त संचालन की दिशा में यह बदलाव बेहतर विश्वसनीयता और बढ़ी हुई यात्री संतुष्टि में तब्दील होता है।

1. Introduction

The USBRL project, spanning 272 Km represents a significant milestone in modern railway infrastructure. Out of 272 Km of USBRL Project, 161 Km has already been commissioned. The intervening 111 Km stretch of Katra-Banihal section traverses through rugged and mountainous terrain with complex geology, particularly associated with the young Himalayan. The alignment of the project is a culmination of tunnels and bridges, with 97 Km (89%) in tunnels, 7 Km on bridges and only 7 Km on embankment/cutting. Due to challenging location, the Katra- Banihal stretch integrates cutting-edge technology of Ballastless track (BLT) system on the entire stretch including yards from Katra- to Banihal. This implementation ensure seamless, smooth comfort riding, high speed potential and much lesser requirements of maintenance efforts during operation and efficient railway operations.

The Katra- Banihal section of the USBRL Project has adopted three different BLT systems.

i. Slab track system with DELKOR fastening.
ii. Twin booted system with Pandrol fastening.
iii. RHEDA 2000 Sleeper with vossloh-300 fastening system.

This technical paper covers the various technical details regarding design, supply, laying of Pandrol booted block system of BLT, which has been provided for about 67.45 Km (i.e. KRCL- 24.90 Km & IRCON- 42.35 Km) for Katra-Banihal section of USBRL Project. M/s Rahee Infratech has been appointed as the EPC contractor, M/s Pandrol Iberica has been appointed as the system provider to execute the project. M/s Korean Railroad Technical corporation is commissioned by the EPC contractor to carryout the analysis and design of ballastless track.

2. Brief about Pandrol Twin Booted Block System:

The Pandrol booted block is a slab track system for railways developed by PANDROL, comprises of twin concrete block bearing on resilient block pads (Crumb rubber pad) housed in rubber boots (with an asymmetric channel) encased in track concrete. The rails are secured fastened to the concrete blocks using the Pandrol fastening system.

In this BLT system, rail seat blocks are replaced as needed thorughout the service life. This system combines the advantages of ballastless track by way of providing a strong, durable and minimal maintenance track and also advantages of ballasted track by facilitating quick restoration and feasibility of substantial adjustments in the eventuality of derailment, among other scenarios.

The concrete block housed in rubber boot with Crumb rubber Pad, ensures an appropriate level of resilience, reassures high protection against noise & vibrations and excellent electrical insulation features.

This track system is in use in various rail networks globally for more than 30 years and is well proven in similar conditions. The two major system providers of booted block system world over are Pandrol and Soneville. The fastening system have been used for trains with speeds of up to the order of 250 kmph and axle loads up to 25 tons.

3. Different components of Pandrol Booted Block system:

The Pandrol booted block system of BLT system consists of following components:

1) Concrete Blocks-Twin individual blocks with individual motions.
2) Resilient Block Pad- absorbs vibrations and distributes load.
3) Rubber Boot- isolates the concrete blocks from the slab.
4) Fastening System- Pandrol fastening system
5) Monolithic Concrete Slab.
6) Derailing Block

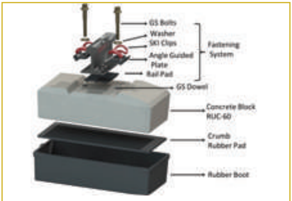

Fig- 1 : Typical Sketch: Twin booted block system of BLT in Tunnels

3.1 Concrete booted block (RUC60):

These prefabricated concrete blocks were cast in the sleeper plant established at site in Reasi. The dimensions of precast concrete booted block are 660mm x 290mm(LxB) at Bottom, 676mm x 306mm(LxB) at top, with a height of 185mm at gauge face and 209mm at other side. The grade of concrete used for booted block is M-45. Total 2.27 lakhs number of booted block were required for the project and the factory had a capacity of producing 900 blocks/day with two casting machines manufactured from Netherland.

The following steps are involved in the construction of RUC 60 Concrete block:-

i. Transferring the concrete (M45) from batching plant to inside the yard (EOT area) through mechanical hoist.
ii. Concrete transportation to casting machine hopper through EOT crane.
iii. Feeding concrete into the casting machine hopper.
iv. After cleaning the machine mould, install the reusable frame and lock with machine locking key. After demoulding oil and install the dowels and maintain its position through machine vacuum.
v. After installing the steel armour cage, pouring the concrete in the mould while maintaining bottom vibration.
vi. Place the top vibrating table on the mould, and applying vibration on the top, allowing concrete to compact properly.
vii. After lifting top vibration plate and finishing the concrete top face, place the pallet on top of frame and lock with locking clamp.

viii. Tilt and overturn the machine mould, unlock the clamp and place the pallet on casting bed thus demoulding the block top.

ix. After initial setting of concrete, apply curing compound on the exposed top area of concrete block.

x. Shifting of blocks while still in steel frame/ reusable edge placed over steel pallet from casting bay to demoulding area with forklift.

xi. Demoulding the reusable frame from concrete block.

xii. Examining and finishing the block, and outing the block in rubber boot with rubber pad.

xiii. Sealing the rubber boot with adhesive tape.

xiv. Place the booted block assembly on the steel frame pallet to make a lot.

xv. Cover the block lot with polythene cover and shifting to stacking area.

xvi. Booted block stack in the stacking area.

xvii. Quality check of Concrete blocks:

Quality control of booted block includes compressive strength testing of 28 days and bending strength testing. The blocks for testing should be no less than 28 days from the date of manufacturing. For bend test, one block is tested upright, another in reverse position. The load value to obtain is:

- Upright block of 20 Ton
- Reverse block 12 Ton.

The bend load test must be reached gradually and regularly, with an increase not exceeding one ton per second and once the maximum value is obtained, it must be kept constant for three minutes. Once the block is unloaded, any cracks appearing on the sides of the superstructure of the block should close. A closed crack is one that is barely visible to the eye and never larger than 0.05 mm. If the test result of both blocks is successful, the corresponding batch is considered valid.

3.2 Rubber boot: The boot is made of rubber to impart an appropriate level of elasticity and excellent electrical insulation features. This rubber boot envelopes the concrete block, effectively isolating it from the concrete slab, thereby providing additional elasticity along with the elastic pad. The rubber boot is manufactured by Pandrol, Spain and is 6mm thick and features an asymmetric channels. The dimensions of the rubber boot are 660x290 mm (LxB) at the bottom and 670x300 mm (LxB) at top, with a thickness of 12mm.

Fig- 2 : Rubber Boot with asymmetric channels for removable Block

3.3 Crumb rubber pad : An elastic pad is positioned between the concrete block and rubber boot, playing a crucial role of providing resilience and determining the stiffness of the system. This component is the key element in absorbing vibration and contributes to the system's capacity for vibration attenuation. The dimensions of the Crum rubber pad K30 are 655 x 282 mm (LxB) with a thickness of 12mm and it is manufactured by Pandrol (SRS) imported from Belgium.

Fig- 3 : Crumb Rubber Pad K30

3.4 Fastening System: The fasteners are used to securely fasten the rail, offering resistance against vertical, lateral and longitudinal movement. These fasteners are provided at every Rail seat of twin booted blocks at spacing of 600 mm centre to centre.

Fig- 4 : Fastening Assembly on Booted Block

The various components of fastening system used in Booted block system is as under:

i) GS threaded Dowel assembly.
ii) GS Bolt & Flat washer.
iii) Elastic Clip SKL-1.
iv) Angle guided plate.
v) Rail pad.

Details of the components of fastening is as under:

3.4.1 GS Threaded Dowel assembly: This assembly is incorporated during the casting of the concrete block and consists of a thermoplastic GS threaded dowel and GS Metallic Coil. The GS threaded dowel is made of Thermoplastic (Polyamide reinforced with fiberglass 30%) and is manufactured by Bearplast, Italy. The dimension of the GS Dowel is 23mm internal diameter, 29mm outer diameter and a length of 130mm. In Compression test, applying a compression force F1 = 75 kN should not result in displacement of screw exceeding 1 mm. The residual deformation should be less than or equal to 0.3 mm. Further, the application of compression force F2 = 90 kN, the dowel should not have any cracks or exfoliation visible when magnified 6x.

The metallic coil is made of special steel with 6 spires and is manufactured by Bearplast, Italy. The dimension of the metallic Coil is 72mm long and is placed over the dowel for bounding with concrete.

Fig-5: GS threaded Dowel with Metallic Coil

3.4.2 GS Bolt & Washer: The GS Bolt serves as a threaded fastener used to secure the SKL1 Elastic Rail Fastener within the track concrete layer facilitated by the Dowel embedded in the booted block concrete.

The material used for GS bolt, type E-7 is steel quality 5.6 according to standard ISO 898-1. The bolt is manufactured at Kaypee, Ludhiana, India. The GS Bolt is forged from a single piece of material without welding, ensuring its robustness to with stand high magnitude loads. The screw spike is hot dipped galvanized with a minimum coating thickness of 50 micron. The spike has a shank length of 159±5 mm and shank dia. of 23mm for strengthening the fastener with the track concrete layer. The GS Bolt exibits tensile strength greater than 500 N/mm^2, hardness value in range of 155-220 HV5 and elongation % greater than 20%. The production limit of its elements, includes carbon content 0.55%(max.), Sulphur 0.06%(max) and phosphorus 0.05%(max). The Bending test is performed with the shank folded in its threaded part, without blows, on a mandrel with a diameter equal to 4D, at an angle of 90 degrees, the test must not produce, visible to the naked eye, cracks, breaks or other defects.

The Flat washer used with the bolt is manufactured in Ludhiana, India as per technical specification of ISO 896-3. The material used is steel 100 HV class defined in ISO 898-3 and is hot dip galvanized according to standard ISO 10684 of IS) 1461. The Flat Washer has an internal diameter of 24mm & outer diameter of 50mm, a thickness of 4mm and weight 47.6 gram. Mechanical properties should have Vickers hardness, HV of min. 100 and max. 200.

Fig- 6 : GS Bolt, Type E-7, Hot Dip Galvanised

3.4.3 Elastic Clip: The main function of rail clip is to securely fasten the rails to the exact gauge and provide a continuous toe load on the rail under static and dynamic conditions. For each booted block, two elastic clip (SKL-1) is used, which is red painted and are manufactured at Pandrol, Spain.

The Raw material for the rail clip is obtained from hot rolled rounds of the steel, complying with steel 38Si7. The micrographic examination of structure must be martensitic, with medium-sized regular grain, free of ferrite, and should not exhibit total decarburization. In the case of partial decarburization, the limit depth of the decarburized zone should not exceed 0.25 mm.

The diameter of the round used in the rail clip manufacturing is 13 mm, with a tolerance of + 0.2 mm, and a maximum permissible ovalization of 0.32 mm. It weights 0.481 kg and its chemical composition corresponds to 38Si7 steel. The production limit for its elements includes a carbon content in the range of 0.37 to 0.44%, silicon in the range of 1.5 to 1.9%, Manganese in range of 0.6 to 0.8%, sulphur 0.030%(max) and phosphorus 0.04%(max). All these properties make the fastener quite good for resisting the high dynamic train loads.

The Fatique test of elastic clip should survive up to 5 million cycles at a test frequency of 15-18 Hz with a vibratory force of amplitude 1.4mm.

To ensure proper toe load of rail clip on Rail, the fastener is tightened during installation by applying a 250Nm Torque wing torque wrench.

Fig- 7 : Elastic Clip- SKL-1

3.4.4 Angle Guided Plate: This component is positioned beneath the elastic clip and two angle guided plate are used for each booted block. The angle guided plate weights 0.107kg per plate and are made of Polyamide 66 reinforced with 35% Glass Fibre. These angle guided plates manufactured at Carbonaire, Chennai, India.

The dimensions of the angle guide plate are 110x77.2 mm (LxB) with a 27mm dia hole of for screw bolt. The density is 1.4± 0.03 g/cm3 and electrical resistance of assembly after watering must exceed 5 KΩ. Resistance under lateral load is tested by applying compression stress of 85KN under the test condition and the parts must not show signs of cracking or deterioration.

Fatique resistance under lateral load is tested by application of 100,000 load cycles square wave cycles with a variation of the compression force between a Max load of 45 KN and a Min of 5KN at the frequency of 5 HZ. Post test, the parts must not show signs of cracking and deterioration. Angle guided plate A2 are available with 0mm, +3mm & -3mm.

Fig-8 : Angle guided plate A2

3.4.5 Rail pad:

The component which is placed between sleeper and rail is PAS 60 (engraving) seat plate and is 6mm thick. These pad are made of EVA (Ethelene Vinyl Acetate) and manufactured at Carbonaire Chennai, India.

The dimensions of the Rail Pad PAS60 are 165 x

Fig- 9 : Rail Pad- PAS 60 Seat Plate

148 mm (LxB) with a thickness of 6mm. The production limit of its elements includes carbon content in the range of 1 to 1.5%, density of 0.92 to 0.96 g/cm3 and Melt flow index of max. 5.2g. The hardness should comply with 32 to 47(ShoreD) and stiffness should be greater than 500 KN/mm when measured between 20 and 95 KN. The electrical resistance should have min10^8 Ohm-cm(transv).

3.5 Track Slab:

The top layer of track system is called 'Track Concrete Layer" which comprises a twin booted block system embedded in the cast-in—situ M35 concrete layer with reinforcement for crack control. The characteristic strength of TCL concrete at 28 days shall not be less than 35MPa. The Track Concrete Layer is cast over the 1st stage M20 concrete layer of concrete. The spacing of the fasteners/booted block shall be 600mm to ensure that the permissible bending stress in the rails are not exceeded stipulated values. The maximum permissible cant as per IRPWM is 165mm. In canted track, the outer rail is lifted upward to achieve the required cant with respect to inner rail. The Figure 10 and Figure 11 shows typical track structure with booted block for straight and canted alignment respectively.

The railway track passes through tunnels, bridges and on formation. The details of BLT parameters for same is as under:

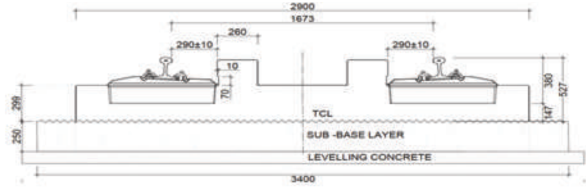

Fig- 10 : Cross section of TCL at 0 Cant.

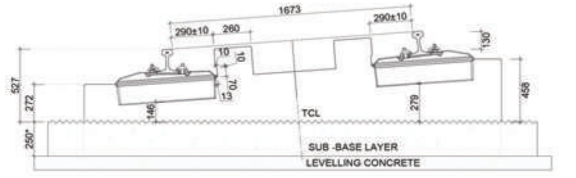

Fig- 11 : Cross section of TCL on canted track.

3.5.1 Tunnel: The initial phase involves laying a variable thickness of First stage concrete of M20 on tunnel invert. Subsequently, Top concrete layer of M35 grade reinforced concrete is directly laid over this Fist stage concrete. The Track concrete layer (TCL) beneath the Booted block has a minimum depth of 147mm and a width of 2900mm. A crack joint is provided at every 6m c/c on the top of the Track concrete layer of 2mm wide and 60mm deep. The TCL slab are spaced at a minimum length of 64.2m, center to center separated by 25mm Gap between them. The typical track cross-section for the tunnel has been shown in fig. 12.

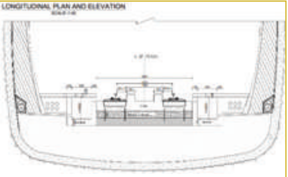

Fig- 12 : Cross section of TCL in tunnel.

3.5.2 Bridges: The deck slab concrete of the bridge serves as the First stage concrete layer and shear connector reinforcement for TCL has been pre-provided within the deck slab. Directly over the deck slab concrete, the Track concrete layer (TCL) is laid and securely connected through shear connectors. Each track slab on the bridge has a length of 6.0m and a 100mm slab gap is provided at every 6m interval. Each slab segment is casted in a single pour. The minimum length of track slab is adjusted to accommodate a minimum three fastening system, ensuring a length not less than 1.0 m.

Fig- 13 : Cross section of TCL on Bridges.

3.5.3 Embankment : The formation and top surface must undergo through compacted in according with GE G-14. After completion of blanketing layer, the EV2 value shall be verified on-site and should confirm the design assumption of 120 MPa. A levelling course of PCC is provided over the blanketing layer. A sub-base consists of an RCC layer with a thickness of 250mm and over it Track concrete layer (M-35) is cast. The sub-base is securely connected with TCL using shear connector. The minimum length of slab center to center is 12m separated by 25mm slab gap. In case longer slabs are casted, crack joints is provided at every 12m center to center on the top of the track concrete of 2mm wide and 60mm deep. A typical sketch of cross section of BLT on emabnkment is shown in figure-15.

3.5.4 Transition Zone of BLT:

When the train moves from higher stiffness zone to a lower stiffness zone (or vice versa), the wheels may suffer an abrupt change of rail deflection causing discomfort to passengers. The transition arrangement serves as a transitional system between two track-forms of varying stiffness. The transition arrangement provides a smooth movement of the train, minimizing the impact of discontinuities that exist along the track. An abrupt change in the vertical stiffness of the track system causes the wheel to experience an abrupt change in elevation. This is due to sudden differential track deflection.

The geotechnical performance of the embankment has been adopted with appropriate EV2 value of 120 MPa. It must be aimed to gradually decrease the stiffness from one track form to another and adopt a suitable method such that the rail deflection shall be in a range of 1 mm to 2 mm.

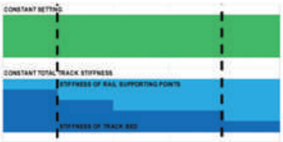

Fig- 14 : Typical setting of transition zone showing change of Rail support stiffness and change of track-bed stiffness.

a) **Transition from Ballasted track to Ballastless on embankment:** The transition shall be designed between the ballasted track and Ballastless track both supported on the embankment such that the total deflection is less than 2mm. This is achieved by gradually reducing the RCC layer thickness under the BLT to provide a smooth change in deflection from Ballastless track to Ballasted track.

The transition from BLT on embankment to ballasted track shall be provided as shown in figure-16. No change of thickness is envisaged, however RC trough under ballasted track shall be provided as per RDSO guidelines. The length of transition maybe further optimised based on permissible speed and site conditions. The grade of concrete of RCC (bound base) approach slab shall be M30.

b) **Transition from Ballastless track in tunnel to Ballastless track on embankment:** The transition shall be designed between the BLT on Embankment to BLT in Tunnel such that the total deflection is less than 2mm. This is typically achieved by providing a RCC approach slab (with inverted step) gradually reducing the thickness under the BLT on embankment to provide a smooth change in deflection from BLT in Tunnel to BLT on embankment as shown in figure-17. The approach slab shall be provided with a thickness varying from 600mm for 7.5m, 400mm for 7.5m and 250mm for 7.5m. The total length of the transition shall be 22.5m. Minimum reinforcement is envisaged as no major stresses shall be applicable. The grade of concrete of RCC (bound base) approach slab shall be M30.

c) **Transition from Ballastless track on embankment to Ballastless track on bridge:** The transition shall be designed between the BLT on Bridge to BLT on Embankment such that the total deflection is less than 2 mm.

This is typically achieved by providing a RCC approach slab (with inverted step) gradually increasing the thickness under the BLT on embankment to provide a smooth change in deflection from BLT on embankment to BLT on Bridge as shown in figure-18.

The approach slab shall be provided with a thickness varying from 350 mm for 11.25 m and 250 mm for 11.25 m. The total length of the transition shall be 22.5 m. Minimum reinforcement is envisaged as no major stresses shall be applicable. The grade of concrete of RCC (bound base) approach slab shall be M30

3.6 Derailment Protection:

Derailment protections are provided to mitigate the impact damage that may occur in the event of train derailment. The derailment protection is a cast in situ reinforced concrete over the TCL. The derailing guard is made discontinuous at every 6m c/c with 50mm gap and 100mm gap at slab gap, this will also function as cross drain. For maintenance purpose (removal and laying of booting blocks) minimum of 280 mm is required. As per SOD, the maximum clearance permitted is 300 mm (250 ± 50) mm. Thus, the clearance of 290 ± 10 mm is provided.

Derailing guard has been designed such that incase of derailment:

(i) The wheels of derailed vehicle under crash load, moving at maximum speed are retained in the tunnel.

(ii) Damage to track and supporting structures is minimum.

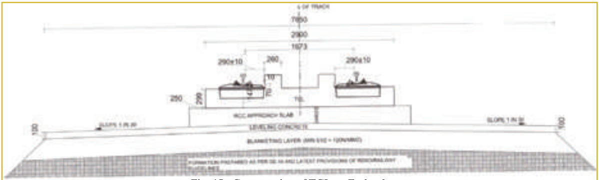

Fig- 15 : Cross section of TCL on Embankment

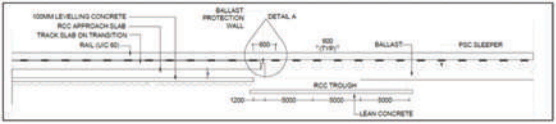

Fig- 16 : Transition detail from BLT on embankment to Ballasted track on embankment.

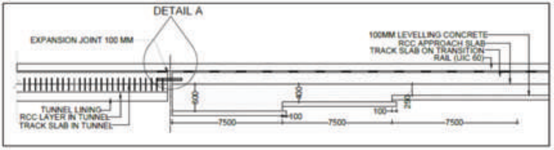

Fig- 17 : Transition detail from BLT in Tunnel to BLT in embankment.

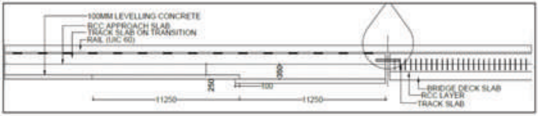

Fig- 18 : Transition detail from BLT in embankment to BLT in bridge.

d) Method of construction and installation of track slab and turnout in Ballast-less track system:

A strict configuration of all the bed layers, together with the adequate height of the slab in relation to the blocks is indispensable when building this type of track superstructure. The inability to correcting the alignment and levelling implies the need for adhering to millimetric tolerances during assembly. These factors underscore the significance of the assembly and acceptance of a track set within a concrete slab.

The construction principle used in these systems, is known as "Top/Down" approach. This involves securing Rails, sleepers with fittings etc. at the designed level, alignment and parameters using specially designed arrangements and supports. Following this, in situ concrete is poured between the supporting structure and the Botted block of grade M-35.

4.1 The following stages are involved in Track slab installation:

a. Survey work:

i. Joint Survey with Civil agency surveyor for verification of Control Points (Fig.11).
ii. Distribution of error if any.
iii. Survey of as build tunnels for cross section at interval of every 5m in case of curves and 10m in straight alignment. Total 14 points are taken at one cross section of tunnel.

Fig.-19: Survey work in tunnel

iv. Re-designing of alignment if any deviation.
v. Checking of S.O.D./infringement with dynamic gauge.
vi. After clearance from dynamic Gauge, work out of rail level.
vii. Submission of Level sheet and plinth for approval of Client.

b. Activities before Casting of track slab:

i. Approval of LWR Plan.
ii. FB Welding of rail of required length.
iii. Pulling of Rail panel at required location.
iv. After completion welding of rails in one tunnel pairing of rail panel.

v. Marking of Centerline based on as built Drawing and best fit alignment.

vi. Levelling course, which will be PCC or RCC as per design.

Fig.-20: Levelling course- PCC in tunnel

vii. Ensuring the drainage system as per drawing.

Fig.-20: Side drain work in tunnel

c. Activities for laying of Top concrete Layer:

i. Center line marking over the leveling surface at every 5m interval in case of curves and 10m interval for straight portion.

Fig.-21: Center line marking

ii. Pulling of rail/ rail panels and placing in position.

iii. Lifting of rail/rail panels with Jacks and supported on wooden blocks.

Fig.-22: Lifting of Rail and supporting on wooden block

iv. Fixing of rail on Gauge support Frame (GSF) at every 1.8m c/c, as shown in Fig.23.

Fig.-23: Rail fixed over GSF

v. Fixing of Booted blocks with Track Fastenings on suspended Rails at required spacing of 600mm c/c.

Fig.-24: Fixing of Booted Block on Rail

vi. Anchoring of GSF with the help of turnbuckle/ Push pull from Side wall, drain wall bracket or Brackets.

vii. Placing of reinforcement as per drawing and binding.

Fig. 25: Reinforcement work completed & tunbuckle anchored from tunnel side

viii. Rail Cant 1 in 20 is also checked with Gauge and ensured. Adjustment for any correction is made with GSF.

Fig. 26: Rail Cant checking and correction

ix. Fixing of alignment with the help of centerline already marked. Reference Rail is taken as inner Rail on curves or Right hand Rail for straight. Center gauge(Half gauge) is used to correct the alignment of Rail with centerline marked. Adjustment for any correction is made with GSF turnbuckle.

Fig. 27: Alignment with Center Gauge

x. Rail Level is checked with digital level for reference rail. Adjustment for any correction is made with GSF spindle Screw.

Fig. 28: Rail level checking with digital level

xi. Vertical clearance in Tunnel is checked with digital laser distance meter.

Fig. 28: Rail level checking with digital level

xii. Versine of curve track is checked with 10m chord length 5m interval and for straight track versine is checked with 20m chord, 5m interval. Adjustment for any correction is made with GSF turnbuckle.

xiii. Once level and alignment of reference rail is corrected, the other Rail cross level and alignment is corrected with Gauge cum Level.

Fig. 29: Rail cum gauge for correction of other Rail

xiv. Fixing of shuttering to the true dimension. Filling putty in the gap of shuttering if any.

Fig.-30: Fixing of shuttering

xv. Final correction of track Parameters.

xvi. Cleaning the surface by blower and secure the fitting by covering with polyethylene.

Fig. 31: Covering Block with polythene

xvii. Offer for checking and inspection of client representative and approval for Concreting. Pre-pour checklist are ensured.

xviii. Placement of Concrete pump at appropriate and convenient place. Laying & Linking of Concrete pipe line.

Fig. 32: Concrete Pump in tunnel

xix. Order for concrete of approved Mix Design from batching plant.

xx. Arrangement of sufficient number of vibrators & one standby with needle well in advance.

xxi. Pouring of concrete and ensure proper compaction.

Fig. 33: Concreting work

xxii. Finishing Top surface as per Drawings.

Fig. 34: Finish surface

xxiii.Reopen and remove the GSF Fittings (12 hour to 24 hours).

xxiv.Next day casting of derailment guard shall be done.

Fig. 34: Derailing Guard Casting .

xxv. Any surface needs attention shall be attended.

Fig. 35: Completed TCL in tunnel

In the above sequence, the casting cycle will rotate.

d. Activities after Completion of Casting of track slab:

i. Rail painting
ii. Rear works
iii. Parameters to check adjustment..
iv. Fixing of fittings after removal of plugs.
v. Fixing of Rail over the fastening.
vi. Correction of parameter of track.
vii. De-stressing of Rail Panels at required temperature.
viii. AT Welding of de-stressed panel.
ix. Checking of Final Parameter & welding tolerance from Client's representative.

5. Design criteria and other technical considerations:

5.1. Design criteria:

Railway board vide letter no: 2016/39/CE-III/BR/BLT dated 06.02.2018, circulated technical eligibility criteria and special conditions of contract for design and construction of ballastless track on viaduct/ tunnels o Indian Railways. As per the document the operating regime on Indian Railways has been mentioned as follows:

a. Axle load and speed:

Traffic type	Axle load	Speed
Goods	25 T	100 kmph (Proposed)
Passenger	22 T	160 kmph (Existing)

b. Electric traction (Minimum): 25KV AC.
c. Track circuits: AFTC/DC.
d. Gauge: Broad Gauge, (Nominal 1673 mm).
e. Ambient temperature: (-)5º to 50 ºC.
f. Rail temperature: (-)15º to 76 ºC.
g. Humidity: 100%

Based on the above document, PSUs (IRCON and KRCL) has awarded BLT works to different agencies. As per Technical specifications of tender document, the agency has considered the following parameters for designing of track slab and fastening system.

i. To resist the 25 T axle load (speed 100 kmph) & 22 T axle load (speed 160 kmph).
ii. Provision of a level base for uniform transmission of rail forces.
iii. To have geometrical accuracy and enable installation of track to the tolerances laid down.
iv. To ensure adequate drainage and facilitate easy cleaning of apron.
v. Resistance against weathering.
vi. The spacing of fasteners shall be at 600mm so that permissible bending stress in rails are not exceeded.
vii. Provision of RCC derailment guard at lateral distance of 250±20mm from running edge of rail.

5.2. Codes and standards:

The track slab and other fastening system has been designed by referring various national and international standards. Following Railway, Indian and international codes/standards were referred for designing the BLT system.

5.2.1. Indian Railway standards:

i. IRS Concrete Bridge Code: 2014 (Including Correction Slip No. 3 dated 20.01.2015), Code of practice for Plain, Reinforced & Pre-stressed Concrete for General Bridge construction.
ii. IRS Bridge Rules : 2014 (Incorporating

Correction Slip No. 46), Rules specifying the loads for Design of Super structure and Sub structure of Bridges and for assessment of the strength of existing Bridges.

iii. IRS Seismic Code: 2017, Code for Earthquake resistant Design of railway Bridges.

iv. IRS T-12-2009 (Including CS 4 dated 04.03.2019), Indian Railway Specification for Flat bottom Rails.

v. IR Schedule of Dimensions 1676 mm Gauge (BG): 2004 including CS 27 dated 17.07.2019.

vi. Manual of Instructions on Long welded Rails: 2005, (Including Correction Slip No. 16 dated 20.01.2014).

5.2.2. Indian standards:

i. IS-456: 2000, Code of practice for plain and reinforced concrete.

ii. IS-2502: 1963, Code of Practice for Bending and Fixing of Bars for Concrete Reinforcement.

iii. IS-1786: 2008, High strength deformed steel bars and wires for concrete reinforcement specification.

iv. IS-875 Part 3: 2015, Code of practice for design wind loads.

v. IRC:6-2017, Standard Specification and Code of Practice for Road Bridges, Section: II Loads and Load combinations.

5.2.3. International standards:

i. BS-5400 Part 2: 2006, Steel concrete and composite bridges.

ii. ACI 358.1R-92, Analysis and design of Reinforced and Pre-stressed-concrete guide way structures.

iii. BS-EN 16432-2:2017, Railway applications – Ballastless track systems.

iv. EN 1992-1-1:2004 Design of concrete structures- General Rules.

v. EN 1992-2:2005 Design of concrete structures- Design and detailing rules.

vi. EN 1991-1-5:2003 Actions on structures- Thermal Actions.

5.3 Track tolerances:

The track tolerances over Ballast-less track when installed and during service under floating conditions according to as per Technical Specifications of tender document shall be as shown below in table-1.

Parameter	Installation	Service
Gauge (with reference to 1673 mm, measured below 14 mm rail top) for straight track and for curve up to the radius of 350 m.	±1 mm	±3 mm
Cross Level on straight and curved track	±1 mm	±3 mm
Variation in versine on curved track (20 m chord with half overlapping)	±3 mm	±6 mm
Vertical alignment over a 3.6 m chord	±1 mm	±6 mm
Lateral alignment over a 7.2 m chord on straight track	±1 mm	±3 mm
Twist on 3.6 m base	±1 mm	±5 mm

For Straight including curves of 400 m radius the gauge shall be up to 3 mm tight i.e. up to 1673 mm and for Curves less than 400 m radius up to 5 mm slack i.e. up to 1681 mm.

5.4. Design service life:

The BLT system has been designed to cater for the following service life:

a. Removable RUC60 Block with GS Dowel- Should not be required to be replaced during service life of 30 year.

b. GS Bolt- Should not be required to be replaced during service life of 30 year.

c. Fastener components (Elastic Clip, Rail Pad, Angle guide plate, Flat Washer, Crum rubber Pad, Rubber boot with asymmetric channels): 300 GMT or 15 years whichever is less.

5.5. Design methodology, modelling analysis and software used:

For detailed design, the calculations has been carried out by the designer with respect to the requirements of Ultimate Limit State and Serviceability limit state as per IRS Concrete Bridge Code: 2014. Detailed calculations has been carried out to analyze the effect of each load combination on the track slab and the vertical up-stand of track slab i.e. derailment guards shall be designed for horizontal force due to derailment of train.

The designer has modelled, the track slab in STAAD Pro Advanced program as plate elements. The concrete Slab was assigned as an elastic plate supported on spring foundation with spring constants equivalent to the actual/ allowable deflection. Loads on the track slab has been applied at most critical wheel location which will be identified by moving load analysis. Various load cases have been used to conduct a static load analysis on the track slab.

Summary of the critical moments in FEA has been taken for the top and bottom faces in the transverse and longitudinal direction for both sagging and hogging condition. The same was used to design the reinforcement, checking the stresses and crack width.

Manual program in excel sheet was used by the designer for reinforcement design, stress check and checking of crack width and AutoCAD was used for production of typical drawings.

Detailed design report including finite element analysis results, calculations details, check for stress and crack width and reinforcement details with all structural and GFC drawings has been submitted by the designer and approved by concerned authority of PSUs before execution of work.

6. Test Specification & Standards

Approval tests on Assembly Booted Block System (Big, UIC 60) for USBRL Slab track according to EN 13481-5:2012+A1:2017 Category "C". The tests have been carried out at the LADICIM (Laboratorio De La Division De Ciencia E Ingenieria De Los Materiales) University of Cantabria, Spain.

6.1 Test specimen

For the investigations three booted concrete blocks equipped with the SKL-1 fastening system for UIC-60 were supplied to LADICIM. The concrete slab simulators block support of the booted block, for the tests were manufactured at LADICIM as shown in figure below.

Fig.-36: Manufacturing the simulator Slab

The approval tests performed on the booted concrete block equipped with PANDROL Brand Rail Assembly, type SKL-1 for UIC-60 were carried out according to the CEN Standard EN 13146 series, "Railway applications track Test methods for fastening systems. The fastening system was set by the client to category C whose boundary conditions includes Maximum construction axle loads < 260 kN and Minimum track curve radius 150 m. The torque applied to fix the rail corresponds to a gap of 0.5 mm between the clip and the grooved area of the angled plate, following the manufacturer's instructions.

6.2 Tests performed

Following tests were performed in sequence on the prepared test specimen:

6.2.1. Determination of clamping force according to EN 13146-7:2019:

The clamping force, exerted by the fastening system, is crucial for effectively transmitting the load to the sleeper. Maintaining a certain minimal value of the clamping force is imperative. The objective of the test is to measure the vertical force necessary to separate the Rail from the surface on which it is supported.

The test premium was carried out in according with the standard procedure of chapter 7 of EN 13146-7. The sleeper was fixed to the base of the test equipment to carry out the test, taking the sleeper as he fixed reference. The test setup is shown in the figure-37. A vertical load is applied to the rail in a servosis 150 KN Press, centred on the fasting axis. The rail displacement with respect to the sleeper is measured using four DG 5.0 Solartron sensors placed in the area where the railway supposed on the rail pad, two on each side.

The displacement sensors are set at zero at the beginning of the test an increasing tensile force with the rate of 10 KN/min is applied to the rail section until the force required to separate the rail from the slipper and manually remove the rail pad is reached.

The assembly is then unloaded and the load at zero rail displacement P, is recorded, which is reduced to approximate 0.9 P. Then the load is increased at the rate of 10 KN/min until a load of 1.1P is reached in order to replace the rail pad.

The load recorded at the zero rail displacement position at the last unloading branch, P_0

considered to be the clamping force of the spring element acting on the rail is obtained from the load displacement diagram. The operation was repeated twice on the same test assembly. The characteristic clamping force per rail, P_0 is the mean of the 3 value of training the test.

The test setup is presented in figure 37.

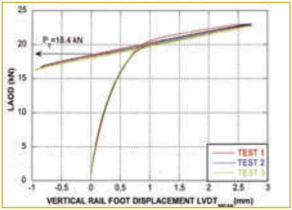

Fig.-37: - Clamping force Test rig arrangement

This procedure was repeated two times to get an average clamping force P_0. This test was conducted before and after repeated load test and result obtained as under:

Clamping force variation obtained is presented in table below.

Clamping force (KN)		
Value Before repeated loading test	Value After repeated loading test	Variation
18.4 ± 0.3	14.9 ± 0.2	-19.0± 0.2%

6.2.2. Determination of longitudinal rail restraint according to EN 13146-1:2019 before repeated loading.

When addressing factors such as creep, relaxation, temperature effects, pull apart of broken rail and braking forces, it is useful to know the relation between the longitudinal load on the fastening and the displacement in the longitudinal direction. The determination of the maximum load especially holds particular significance. The longitudinal rail restraint was conducted in according to EN 13146-1 before the repeated load test.

According to EN 13146-1 a longitudinal tensile force is applied (V= 0.2 KN/s) in the rail until the rail starts slipping versus the concrete block. During the test the displacements and the respective loads are recorded.

The test setup is presented in figure 38

Fig.-38: Longitudinal Rail resistance arrangement

This procedure is retried four times to use the last three load displacement curves for evaluation.

The Longitudinal rail restraint was determined before and after repeated test load and variation obtained is presented in table below.

Longitudinal Rail restraint (KN)		
Value Before repeated loading test	Value After repeated loading test	Variation
9.7 ± 0.2	9.3 ± 0.2	-4.1± 0.1%

6.2.3. Determination of the vertical stiffness according to EN 13146-9 before repeated loading: -

The static and dynamic stiffness is determined on the fully assembled specimen according to chapters 7.1 and 7.2 of EN 13146-9. The test setup is presented in figure 39.

Fig.-39: Test rig for the determination of the vertical stiffness of the system

To determine the static vertical load of the complete fastening the test assembly, supported horizontally. The mounted rail is loaded and unloaded three times in a quasi-static way (category C due to table 2 of EN 13481-5: under load F_{SA1} = 1 KN; upper load F_{SAmax} = 64kN). Three loading and unloading ramps at loading rate of 2 KN/s is evaluated by means of the deformations at F_{SA1} =1KN and F_{SA2} =(0.8* F_{SAmax} = 51.2 KN).

Finally, the vertical stiffness k is determined by K_{SA}.

$$KSA = \frac{F_{SA2} - F_{SA1}}{d_{51.2} - d_1} = \frac{50.2}{d}$$

The static, vertical stiffness K_{SA} is 32.8 ±1.0 KN/mm before the repeated load test.

For specifying the test loads and positions according to table 3 of EN 13481-5, the vertical dynamic stiffness of the systems has to be

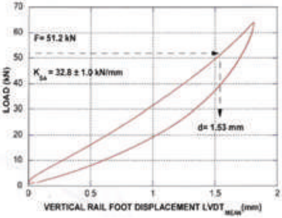

Fig.-40: Vertical Static stiffness test before repeated loading test

determined. To this, the specimen was loaded with a sinusoidal force of 5 Hz. The under load F_{LFA1} was 1 KN, the upper load $F_{LFA2} = 0.8 \cdot F_{LFAmax}$ = 51.2 KN (F_{LFAmax} = 64.0 KN). The dynamic stiffness at low frequency of 5HZ for 1000 cycles were evaluated based on the deformations at F_{LFA1} and F_{LFA2}.

The dynamic stiffness K_{LFA} is 46.1 ± 1.4 KN/mm before the repeated load test as shown in Fig- .

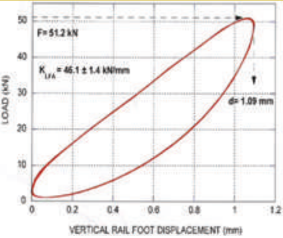

Fig.-41: Dynamic stiffness test at low frequency test (5 Hz)

The vertical stiffness variation obtained before and after repeated load testing is presented in table below:

Vertical Static Stiffness (KN/mm)		
Value Before repeated loading test	Value After repeated loading test	Variation
32.8 ± 1.0	31.8 ± 1.0	-3.0± 0.1%

6.2.4. Repeated load test according to EN 13146-4: -

The laboratory test to assess the effect of repeated loading is the means of assessing the potential long-term performance of the fastening in the track. The cyclic repeated loading is meant as a simulation of the repeated loading of passing trains.

The test setup is presented in figure 42.

Fig.-42: Test rig for the repeated load test

The test parameters were taken from standard EN 13481-5 as those corresponding to a rail fastening assembly for a category "C" slab with the dynamic stiffness being between 50-75 KN/mm, which is as follows:

- Compressive cyclical sinusoidal load
- $F_{MIN.}$ = 5kN
- $F_{MAX.}$ = 60 kN (According to EN 13481-5, category C and K_{LFA} < 50kN/mm)
- α = 33°
- (x) = 25 mm
- 3x 10^6 cycles at 4 Hz

During this test the maximum temperature of any component shall not exceed 50°C so in order to control the temperature evolution a ventilation fan and a laser thermometer was used. Figures 43 to 46 show the displacements of the rail foot, the rail head and the booted block with respect to the slab simulator block. The applied load is represented versus all of the displacements measured at the beginning (1,000 first cycles) and at the final of the test (3-10° cycles). The LVDTs were set to zero at minimum load (5kN) before commencing the test, and the first measurement was after 1,000 cycles.

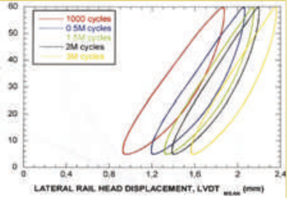

Fig. -43: Lateral Rail head displacement during repeated loading test

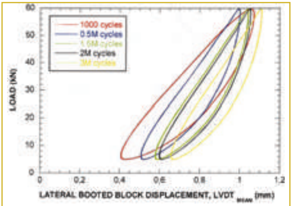

Fig. -44: Lateral Booted block displacement during repeated loading test

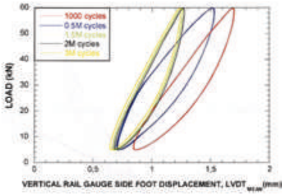

Fig.-45: Vertical Rail gauge side foot displacement during repeated loading test

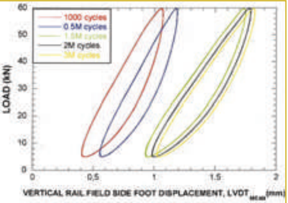

Fig. -46: Vertical Outer rail foot displacement during repeated loading test

The relative displacements recorded during the repeated loading test between 1000 cycle and $3x10^6$ cycle are tabulated below:

CYCLES	$F_{applied}$	Measurements (mm)*			
		Rail head	Booted block	Gauge side Rail foot	Field side Rail foot
First cycles (10^3 cycles)	F_{MN}	0.95 ±0.03	0.41 ±0.01	0.84 ±0.03	0.41 ±0.01
	F_{MAX}	1.87 ±0.05	1.07 ±0.03	1.70 ±0.03	1.07 ±0.03
Final cycle ($3\text{-}10^6$ cycles)	F_{MN}	1.57 ±0.05	0.66 ±0.02	0.64 ±0.02	1.03 ±0.01
	F_{MAX}	2.36 ±0.07	1.11 ±0.03	1.24 ±0.04	1.82 ±0.05
Variation	F_{MN}	0.62 ±0.02	0.25 ±0.01	0.20 ±0.01	0.62 ±0.02
	F_{MAX}	0.49 ±0.01	0.04 ±0.01	0.46 ±0.01	0.75 ±0.03

The figure-47 shows the temperature values recorded on each component, with their corresponding colour code during the repeated loading test. All the fastening elements kept their temperature below 50° C as established by the standard.

6.2.5. Inspection of the rail fastening system after the repeated load test: -

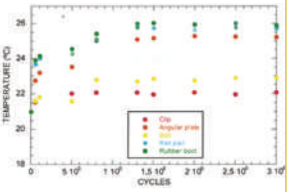

Fig. -47: Vertical Outer rail foot displacement during repeated loading test

After the test sequence, the fastening system was disassembled and a visually inspection of all components was carried out. The components of the rail fastening system showed negligible wear after 3 million load cycles.

In general view, there was not any fracture, please note that the edges of the rail pad were cutoff to enable the removal of the pad during the clamping force test.

Pictures of the rail fastenings after repeated load test are shown in Figure 48 to 50 below:

Fig. -48: Fastening components after all mechanical test

Fig. -49: Fastening components after all mechanical test

Fig. -50: concrete Block after all mechanical test

6.2.6. Determination of electrical resistance according to EN 131465:2017 on a concrete block assembly (V2): -

The electrical resistance is determined according to EN 13146-5:2012 (incorporating corrigendum May 2017).

The test was carried out under cover and protected from rain and draughts in a ventilated place within the range of temperature (15-30)°C. The dry slab track was supported on two electrically insulating blocks, not less than 50 mm thick.
The test setup is presented in figure 51.

Fig.-51: Electrical resistance test arrangement

The electrical supply is alternating current supply of (30 ± 3) V RMS and (50 ± 15) Hz. The water spray equipment was put over the sleeper and it sprayed at a rate of (7± 1)l/min for each nozzle for 2 min. The voltage, current and electrical resistance during spraying were recorded with a mustimeters and for 10 minutes after stopping the watering. The test was repeated twice more, leaving not less than 120 h between consecutive tests. The conductivity of the water obtained was 46.2mS/m and this value should exceed 5 kΩ. The mean electrical resistance measures was 37.2 kΩ.

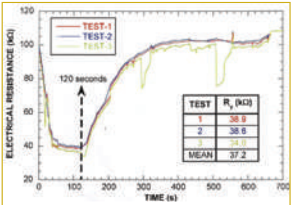

Fig.-52: Electrical resistance test

6.2.7 Effect of severe environmental conditions according to EN 13146-6 on a half concrete block (V3): -

The assembly was tested insisde the spray fog salt cabinet for 300 hours. The fog salt dissolution was prepared according to EN ISO 9227. Finally , the fastening was dismantled and reassembled without failure of any component.
The Figure 53 shows the state of the assembly components during and after the test. -


Fig.-53: Effect of severe environmental condition test-I

6.2.8 Vertical load test for Cast-in fastening components according to EN 13146-10:2017:

The test was performed according to EN 13146-10:2017 on only one sample. The test consisted in applying an increasing tensile load P to the cast-in component at a rate of 50 KN/min until a specified load, which was held for 3 minutes before unloading. The standard EN 13146-10:2017 established that if the load hasn't been specified the designer, then this load shall be 60KN when there are two cast-in components per rail seat, 40 KN when there are three and 30 KN if there are four or more cast-in components.
The figure 54, shows the test arrangements.
The result is summarised in figure 55. The insert held the 60 KN for the full 3 minutes without

Fig.-54: Vertical load test arrangement

any visible failure. The test was stopped at 94KN so as not to exceed the load cell capacity without removing the insert.

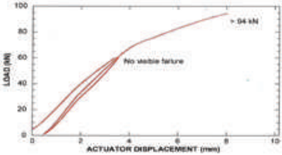

Fig.-55: Vertical load test

7. Maintenance of Pandrol booted block system:

The booted sleeper system offers considerable advantages for simplicity of construction and maintenance. All Components are easily accessible to maintenance teams and can be easily inspected and maintained with standard track tools. Due to ergonomic design of booted block, it wights only 97Kg and is light enough to be handled by one person. The concrete blocks can be replaced, if needed and both concrete blocks are independent. The procedure for which is simple and it required fastening of 15m Rail on either side needs to opened. The rail is then lifted with Jack and concrete block to be replaced can be removed and new block can be placed.

During maintenance inspection, the components of BLT are inspected for any broken or missing part, cracked or other defect, deformation or wear. Further for GS bolt, inspection is carried out to check the tightening of the bolt is between the nominal values (220±20Nm) during installation. One time installed, if bolts are lower than 160Nm re-tighten to nominal value and check the area.

During maintenance following corrections can be done:

7.1 Gauge & Lateral Correction: There are two different ways of doing Gauge/Lateral correction

a) It is possible to regulate the gauge/lateral position of the rail without modifying the position of the block. This can be be achieved by exchanging angle guided plate. With angle guided plate gauge upto 10 mm be adjusted as shown in below table.

TABLE OF COMBINATION OF THE ANGULAR GUIDED PLATE A2				
GAUGE	OUT	IN	IN	OUT
0	A2/0	A2/0	A2/0	A2/0
+2.5	A2/ -2.5	A2/+2.5	A2/0	A2/0
+5	A2/ -2.5	A2/+2.5	A2/+2.5	A2/ -2.5
+7.5	A2/ -5	A2/+5	A2/+2.5	A2/ -2.5
+10	A2/ -5	A2/+5	A2/+5	A2/ -5

b) Additionally, If gauge or lateral correction is not able to adjust with exchanging angle guide, then correction can be done by removing the concrete block. After removing the concrete block, the concrete pocket is broken with equipment like jackhammer to required correct position, thereafter, the concrete block is placed in corrected alignment and remaining space of concrete block is grouted with quick setting cementitious grout.

7.2 Vertical Alignment Correction: There are two different ways of doing vertical correction.

a) It is possible to regulate the height of the rail without modifying the position of the block. For that height adjustment plates (upto 10mm) between concrete block and Rail pad are used (metallic or plastic depending upon the thickness).

Fig.-56: Height adjustment plates

b) Additionally, It is possible to regulate the height of rail by adding Shims (upto 12mm) between the concrete block and the Pad. However, it requires removal of concrete block.

Overall, this system of BLT is more convenient for maintenance, wherein the whole sleepers can be exchanged as both twin block are independent. The new sleeper can be slotted in with the rail fasteners already pre-assembled. In case of derailment this is advantageous and should reduce the time to reopen the track; there are no reinforced concrete plinths to be permanently damaged.

8. Conclusions: -

The integration of the Pandrol Booted block System in the USBRL project signifies a significant leap forward in railway infrastructure development. By adopting the Ballastless track technology (BLT) of Pandrol Booted block system and leveraging the maintenance-free advantages, USBRL project is poised to revolutionize railway operations. The unique feature of Pandrol booted block system lies in the replaceable maintenance aspect for individual for any faults or damages in individual concrete booted blocks, which can be isolated and addressed promptly and ensuring rapid repairs and minimizing the need for extensive repairs or replacement of the entire track section. This replaceable feature not only accelerates maintenance activities but also reduces costs and ensures uninterrupted services for commuters. Ultimately, the Pandrol Booted Block system paves the way for a reliable, cost-effective, and maintenance-free railway network on the 111 km stretch of the USBRL project.

❖❖❖

Power Quality – Phenomena, Monitoring, Measuring & Corrective Measures

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Abstract : Power quality analysis evaluates electrical parameters like voltage, current, and waveform distortion to detect issues such as fluctuations and harmonics. By monitoring these factors, it ensures reliable and efficient operation of electrical systems, mitigating risks and preventing damage in various equipment. This article provides information on various power quality parameters, brief information on causes, effects and mitigation techniques. It also contains the measuring devices and location of power quality for monitoring.

सारांश : विद्युत गुणवत्ता के विश्लेषण का वोल्टेज, करंट और वेवफॉर्म डिस्टोर्शन जैसे पैरामीटर का मूल्यांकन करके फ़्लक्चुएशन और हार्मोनिक्स जैसी समस्याओं का पता लगाने के लिए किया जाता है। इन कारकों की सतत निगरानी द्वारा विद्युत प्रणालियों की विश्वसनीयता एवं उनका कुशल संचालन सुनिश्चित किया जाता है, जो जोखिमों को तो कम करता ही है तथा इसके साथ उपकरणों में होने वाली क्षति व अन्य खराबियों को भी रोकता है। यह आलेख विभिन्न विद्युत गुणवत्ता पैरामीटर, कारणों, प्रभावों और शमन तकनीकों पर संक्षिप्त जानकारी प्रदान करता है। इस आलेख मे बिजली की गुणवत्ता पर निगरानी के लिए प्रयोग किए जाने वाले उपकरण और उनको स्थापित करने के स्थान के बारे मे बताया गया है।

1. Introduction

Power quality is a term that describes a set of parameters of electric power and the load's ability to function properly with that electric power.

The quality of electric power delivered is characterized by two factors namely- “continuity” of supply and the “quality” of voltage.

A few years back, the main concern of consumers of electricity was reliability of supply. It is however not only simple supply reliability that consumers want today, but they also want an ideal AC line supply, that is, a pure sine wave of fundamental frequency and, in addition, a rated peak voltage value. Unfortunately, the actual AC line supply that we receive from utility differs from this ideal.

There is no such thing as perfect power quality in the real world. Power quality can only be improved to the best possible extent by the parameters of PQ that are harmonics, transients, sudden switching operations, voltage fluctuations, frequency variations etc.

2. Importance of Power Quality

The quality and continuity of the electric power supplied is very important for the efficient functioning of the end user equipment. Most of the commercial and industrial loads demand high quality uninterrupted power. Thus maintaining the qualitative power is of utmost important.

The quality of the power is affected if there is any deviation in the voltage and frequency values at which the power is being supplied. This affects the performance and lifetime of the end user equipment. Whereas, the continuity of the power supplied is affected by the faults, which occur in the power system.

3 Demerits of Low PQ

The Low power quality creates many problems which occur in transmission system and distribution system. These problems are also responsible in deteriorating the consumer appliances.

One PQ parameter has effects different than effect of other parameters such as Low power factor parameter causes more resistive power loss due to increase in current, higher temperature rise, insulation deterioration, penalty by utility, use of higher rated equipment, increased cost of installations etc. while harmonics parameter causes quality causes line losses by increasing the current in neutral & use of increased size of cables, sensitive load/ equipment performance etc, where Sag & under voltage parameter causes functioning of sensitive load, Swell & transient parameter causes degradation or dielectric failure of electrical equipment etc and many other PQ parameter effects the electrical appliances.

There are a number of ways in which electric power can be of poor quality these are non-linear load, improper wiring, incorrect earthing, and unbalanced loads are just a few examples of conditions that can produce electrical noise through an electrical system and compromise power quality.

In order to enhance the behaviour of the power system, these all problems should be eliminated.

4. Ideal Power Conditions

It is important that power feeding electrical loads is "clean," meaning voltage and current waveforms are relatively in phase, free of distortion, and balanced between each other. Low quality power can increase utility bills and cause damage to critical power equipment, resulting in higher Maintenance/ production costs and greater chance of downtime.

An "ideal" three-phase power system has the following characteristics:

- The current is in phase with the voltage for each phase. Power Factor = 1.
- The phase voltage and currents are exactly 120 degrees apart and equal to each other. No unbalance.
- The voltage and current sine waves are not distorted or interrupted in any way.
- The source impedance is zero, so that events at the load do not affect the source voltage.

The actual frequency is equal to the nominal frequency.

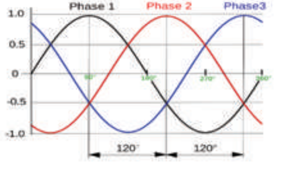


Figure 1 : Waveform Representation of an Ideal 3-Phase System

No power system is "ideal" in the real world, but understanding these characteristics can help identify non-ideal power characteristics of real systems. There is some acceptable range of deviation from "ideal" for each applications, which can be defined as "acceptable power.

5. Various Power Quality Related Phenomena

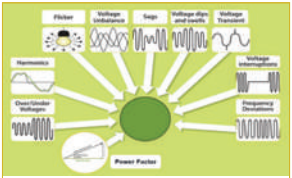


Figure 2 : Various PQ related phenomena

6. Power Interruptions

The simplest type of power quality problem occurs when power delivered to an electrical load goes away, this is called a "power interruption." The different types of power interruptions are classified according to their duration.

- **Momentary interruption**

  A momentary interruption is a complete loss of voltage on one or more phase conductors for a time period between 0.5 cycles and 3 seconds.

- **Temporary interruption**

  A temporary interruption is a complete loss of voltage on one or more phase conductors for a time period between 3 seconds and 1 minute.

- **Sustained interruption**

  A sustained interruption is a complete loss of voltage on one or more phase conductors for more than 1 minute.

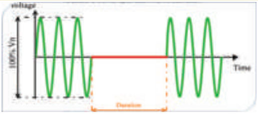


Figure 3 : Example of a Power Interruption

7. Under Voltage, Sag, Over Voltage, Swell and Transient

The second simplest type occurs when voltage at the load drops below a minimum rated voltage or climbs above a maximum rated voltage for some period of time. Depending on how long these conditions last, they may be referred to as under voltage or overvoltage and sags or swells.

7.1 Under-voltage

An under-voltage occurs when the rms voltage drops below 90% of the nominal rms voltage and stays at that level for more than one minute. The term "brownout" often refers to an intentional or unintentional drop in voltage in an electrical power supply system.

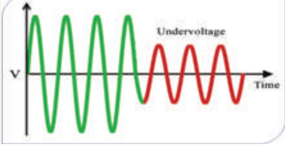


Figure 4 : Waveform of under-voltage supply

7.2 Sag

Sags occur when the rms voltage decreases between 10% and 90% for a duration of a half-cycle to one minute. In a 50Hz power system, a complete sine wave lasts approximately 20 milliseconds, a half cycle is approximately 10 milliseconds.

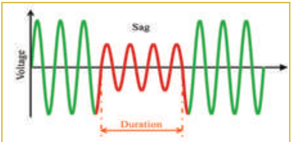


Figure 5 : Sags occur on the power system

7.3 Overvoltage

An overvoltage is an event where the rms voltage rises above 110% of the nominal rms voltage and stays there for more than one minute.

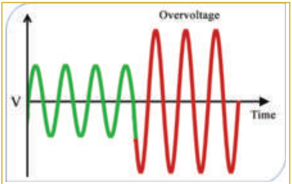


Figure 6 : Waveform of overvoltage supply

7.4 Swells

Swells are defined as an increase in the rms voltage to over 110% for a duration of a half-cycle to one minute.

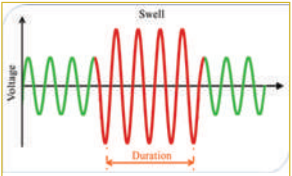


Figure 7 : Swells occur on the power system

Reductions in voltage and sags usually occur when the rms current to the load increases significantly. There are following categories of sags and swells, depending on their duration:

- Instantaneous: 0.5 cycles to 30 cycles
- Momentary: 30 cycles to 3 seconds
- Temporary: 3 seconds to 1 minute
- Sustained Undervoltage or Overvoltage: more than 1 minute

7.5 Transient

Transients occur when spikes are superimposed on a voltage or current sine wave, ranging in amplitude from just a few volts to several thousand volts. Lightning and utility switching typically cause high energy impulsive transients of short duration, while electronic devices, VFDs and switching inductive loads typically cause low energy transients continuously.

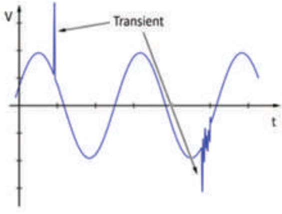


Figure 8 : Waveform of Supply Voltage having Transient

8. Power Factor

Power factor is a way to characterize how much electrical power goes toward producing useful work such as light, heating, or machinery. Low power factor means a large amount of energy is being lost in the system in the form of wasted heat, which generally equates to higher energy bills and equipment degradation.

Motors, solenoids and pumps typically have impedances that are combinations of resistance and inductive reactance, which vary with the mechanical load on the machine. Capacitors have impedances that are combinations of a typically small resistance and larger capacitive reactance component.

When reactance is present in an AC system, the

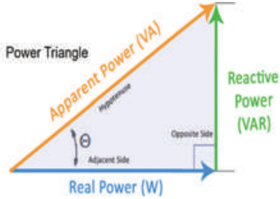


Figure 9 : Representation of Three types of power - real, reactive, and apparent

voltage and current sine waves will shift out of phase from each other. Voltage leads current with inductive reactance and Current leads voltage with capacitive reactance, the two cancel each other out.

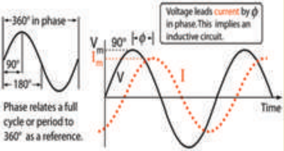


Figure 10 : Voltage and Current sine waves in an AC Reactive Circuit

Low power factor tends to occur in industrial facilities that contain a large number of motors or other inductive loads. Utility companies typically charge large industrial and commercial customers a penalty for low power factor.

9. Harmonics

Harmonics are a form of waveform distortion that occurs in circuits containing semiconductor based electronics such as LED lighting, switching power supplies, electronic ballasts, computers, robotics, test equipment, etc. These "non-linear" loads impose higher frequency sine waves on the system, which result in more power lost in the form of wasted heat.

The excess heat produced by harmonics can have detrimental effects on a power system.

Transformers are especially susceptible to damage caused by harmonics due to stray "eddy currents" which circulate in the iron core and produce excess heat.

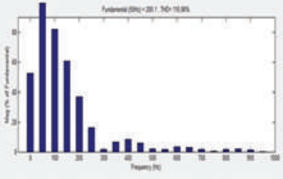


Figure 11: FFT Waveform Spectrum of Power Supply Contains Harmonics

Harmonics are identified by their frequency in multiples of the "fundamental" or main frequency (50Hz in the India). For example, the third harmonic in a 50 Hz system would be 150 Hz (50×3 = 150) and the 5th harmonic would be 250 Hz (50 x 5 = 250).

The magnitude of each harmonic frequency can be measured using power quality meters and are generally displayed in the form of a harmonic spectrum. Total harmonic distortion (THD) and total demand distortion (TDD) are sometimes used with power quality meters to simplify harmonic distortion as a single measurement rather than an entire spectrum.

9.1 Sources of Harmonics

Main sources are Non-Linear Loads given as under

Electronic Switching Power Converters

- Computers, Uninterruptible power supplies (UPS), Solid-state rectifiers
- Electronic process control equipment, PLC's, etc
- Electronic lighting ballasts, including light dimmer
- Reduced voltage motor controllers

Power Converters

- Three-phase power converters
- VFD

Arcing Devices

- Discharge lighting, e.g. Fluorescent, Sodium and Mercury vapour
- Arc furnaces, Welding equipment, Electrical traction system Ferromagnetic Devices
- Transformers operating near saturation level
- Magnetic ballasts (Saturated Iron core)
- Induction heating equipment, Chokes, Motors

Appliances

- TV sets, air conditioners, washing machines, microwave ovens, Fax machines, photocopiers, printers.

9.2 Effects of Harmonics

- Affect operation of sensitive equipment like control and monitoring devices
- Distortion of telephone signals
- Harmonics cause additional losses (Joule effect) in conductors and equipment
- Derating of power sources (generators, transformers and UPSs) leading to over-sizing
- Oversizing of conductors on account of the flow of harmonic currents due to skin effect
- Reduced service life of equipment, and
- Nuisance tripping of breakers and installation shutdown
- Higher neutral current

10 Phase/ Voltage Unbalance

Unbalance occurs in three-phase power systems when single-phase loads (lighting, office equipment, etc.) do not draw the same amount of current on each phase. An ideal condition occurs when the loads are balanced, meaning that the voltage and current phases are exactly 120 degrees apart from each other, although the currents might not be in-phase with the voltages.

A balanced three-phase 4-wire system will have zero current on the neutral wire. The amount of current on the neutral wire in an unbalanced system will increase as the unbalance increases.

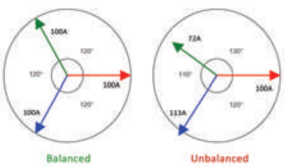
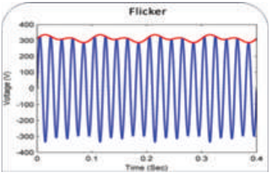


Figure 12: Phasor Showing the Balance and Unbalance of current in 3-ph power system

Motors being driven by unbalanced voltage will introduce a "negative sequence voltage" having a rotation opposite to that occurring with balanced voltages. This negative sequence voltage produces in the air gap a flux rotating against the rotation of the rotor, tending to produce high currents. The locked-rotor torque and breakdown torque are decreased when the voltage is unbalanced. If the voltage unbalance should be extremely severe, the torque might not be adequate for the application. The full-load speed is reduced slightly when the motor operates at unbalanced voltages.

11. Flicker (Voltage Fluctuation)

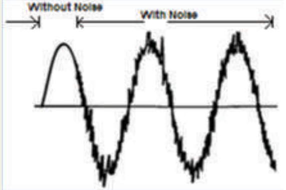
Repetitive voltage reductions in lighting circuits can be detected by the human eye, a phenomena known as "flicker." The term flicker refers to a very specific problem related to human perception of light produced by incandescent light bulbs, not necessarily general voltage fluctuations.



12 Noise, Notching, DC offset, Interharmonics

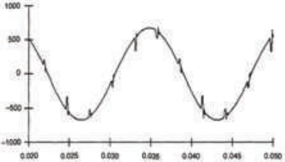
12.1 Noise

Noise refers to unwanted, high frequency oscillations that are super imposed on an alternating voltage or current sine wave. This phenomenon is usually intensified by improper grounding and is capable of disrupting electronic devices such as computers and programmable controllers.



12.2 Notching

Notching is a periodic voltage disturbance caused by the normal operation of power electronic devices when current is commutated from one phase to another. During this period, there is a momentary short circuit between two phases, pulling the voltage as close to zero as permitted by system impedances.



a. Notching waveform per phase

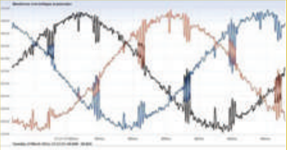


Figure 12: Voltage notching caused by a three-phase converter

b. Three Phase Notching waveform

12.2.1 The presence of a DC voltage or current in an AC power system is termed DC offset

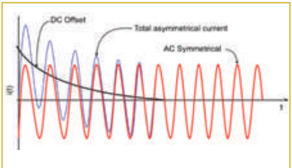


Figure13: DC offset in Power supply at the time of switching or short circuit

The magnitude of the DC component is determined by the initial condition the instant before switching takes place. When no energy is stored in the inductor when switching takes place i(0−)=0, there will be no DC offset. If the current is at a positive maximum i(0−)=Ipeak, there will be maximum DC offset and so on.

The DC component is basically a 1st order exponential response of the form $Ioe^{(-t/T)}$ with a decay rate determined by the circuit time constant. For an inductive circuit excited by a sinusoidal source (AC) source, the time constant is given by T=L/R, where, L is the circuit inductance and R is the circuit resistance.

12.2.2 Inter-harmonics

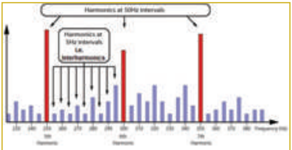


Figure14: DFT output of Inter-harmonics in 50 Hz supply

13. PQ Monitoring

Table 1: Suggested Monitoring Locations

(Ref: Clause 3.2.4.2 of Section 20.2 of NEC: 2023)

S.N	Equipment concern	Recommended Monitoring Location
1.	Specific piece of equipment exhibits problems related to power quality	At the equipment connection to the facility's electrical system (that is, circuit breaker)
2.	All equipment connected to distribution system within a facility exhibits problems to power quality	At the branch connection to the facility's electrical system (that is, motor control centre)
3.	Entire facility exhibits problem related to power quality	Secondary of the transformer serving the facility (*see* note)
NOTE:	Electric service provider may monitor the primary of same t ransformer.	

14 PQ Measuring Devices & Techniques

14.1 Some of the PQ Measuring Devices

14.1.1 Multimeters

It is very necessary to check the voltage, current levels within a facility. Overloading of circuits, under voltage, overvoltage problems and unbalances between circuits can be detected in this manner. For the measurements, a simple multimeter is required and do checks for voltages and currents as under:

- Phase-to-Earth voltages
- Phase-to-Neutral voltages
- Neutral-to-Earth voltages
- Phase-to-Phase voltages (three-phase system)
- Phase Currents
- Neutral Current

14.1.2 Disturbance Analyzer

Disturbance analysers and disturbance monitors form a category of instruments that have been developed specifically for power quality measurements. They typically can measure a wide variety of system disturbances from very short duration transient voltages to long-duration outages or under voltages. Thresholds can be set and the instruments left unattended to record disturbances over a period of time. The information is most commonly recorded on a paper tape, but many devices have attachments so that it can be recorded on disk as well.

14.1.3 Harmonic Analyzer

Harmonic analyzers specialize in measuring harmonic distortion in electrical systems. They provide detailed information about the amplitude and frequency of harmonics present in the waveform.

14.1.4 Flicker Meter

Over the years, many different methods for measuring flicker have been developed. These methods range from using very simple rms meters with flicker curves to elaborate flicker meters that use exactly tuned filters and statistical analysis to evaluate the level of voltage flicker.

14.1.5 Oscilloscope

Oscilloscopes can be used to provide a visual representation of voltages and currents when supplied with appropriate probes. Digital oscilloscopes can store voltage and current waveforms. Further, some digital scopes allow the direct calculation of peak, average, rms, and other values.

14.1.6 Power Quality Analyzer

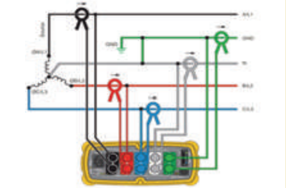
Power quality analysers are the most commonly used tools to observe real-time readings and collect data at high speeds for downloading to computers for analysis, opposed to a power recorder or "data logger" which is mainly used for simple voltage and current measurements.

14.1.7 Measurement of PQ by Power Quality Analyzer

Power quality analysers are the most commonly & effective and easy device to take real-time readings and collect data. This data can be later transferred to computers for analysis.

A cycle is the time that the waveform takes to travel from the zero line up to its positive peak, back down to its negative peak, and then back to zero. Power quality meters can be extremely high speed devices designed to capture events down to the sub-cycle level.

In an ideal 50Hz system, one cycle takes 20 milliseconds, or 0.02 seconds. This is called the period of the wave, and is represented by the letter T. Frequency is equal to the inverse of the period, f = 1/0.02 = 50Hz.



The type of meter to be used will depend on the data to be captured. For example, a simple ampere load evaluation or utility bill audit would require a far less sophisticated meter than trying to pinpoint the cause of a nuisance trip or other power interruption.

The most important factor to consider when performing power quality analysis is safety. Often times meters are applied live with equipment in service which can be an extremely dangerous task so it should be performed by qualified personnel while observing all appropriate safety precautions.

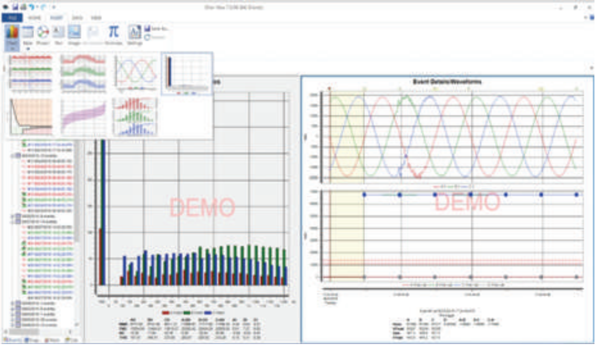
14.1.8 Power Quality Reports

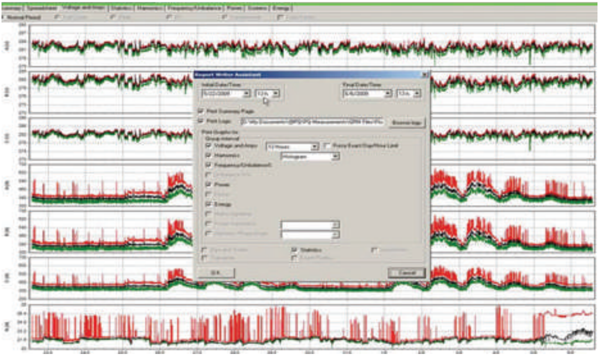
A power quality meter can plot the voltage and current waveforms as functions of time, this is called an oscillogram. Data can be extracted from the power quality recorder and analysed to determine the overall condition of the power system using various time plots and tables.

The actual data analysis is usually performed by an electrical engineer, who will generate a report that provides a summary of the various power conditions, a list of events that occurred during the analysis, and any corrective action or recommendations that should be considered.

Power Quality Meters are capable of calculating a large number of power measurements at extremely high speeds. These measurements may include minimum, average, and maximum values for parameters such as:

- Current and voltage RMS
- Phase relationship between waveforms
- Power factor and frequency
- Active power (kW), reactive power (kVAr), apparent power (kVA)
- Active energy (kWh), reactive energy (kVArh) and apparent energy (kVAh)
- Harmonic spectrum, THD, TDD





14.2 Corrective Measures of Major PQ Problems

Most Common PQ Countermeasures and Mitigation.

Table 2: Most Common PQ Countermeasures and Mitigation Solutions

Ref: Table 7 of Clause 3.3 of Section -20.2 of NEC-2023

PQ Phenomena	Specific PQ issue	Typical Causes	Suggested Counter Measures
Transients	Impulsive	Lightning strike, transformer energization, capacitor switching	Reduce the magnitude and incidence of switching transients. Reduce the lightning surges entering the customer facility, Install surge/ lightning arrestors and/or isolation transformers.
	Oscillatory	Line or Capacitor or load switching	
Short duration voltage variation	Sag and swell	Ferro resonant transformers, single line - to-ground faults	Reduce the incidence rate, amount of variation or the duration of RMS variations; Install dynamic voltage restorers, constant voltage transformers, PWM, Autotransformers
	Interruption	Temporary (self-clearing) faults	
Long duration voltage variation	Under voltage	Switching on loads, capacitor de-energization	Reducing the load changes, reducing the source impedance, or decoupling the load from lighting circuits.
	Over voltage	Switching off loads, capacitor energization	
	Sustained interruptions	Faults	Limit the incidence rate and duration of sustained interruption

Voltage Imbalance	-	Single phase loads, Single phasing condition	Improve voltage regulation and load balancing
Waveform distortion	Harmonics	Adjustable speed drives and other non-linear loads	Use active or passive filters to reduce harmonic voltage distortion, neutral upsizing, transformer based solutions
	Notching	Power electronic converters	Observe proper routing of conductors, Retrofit drives that incorporate Silicon Controlled Rectifiers (SCRs) and diodes
	DC Offset	Geo-magnetic disturbance, half wave rectification	Use d.c link chokes
Voltage Flicker	-	Arc furnace, arc lamps	Dynamic compensation (Static VAR Compensator)
PF		Inductive Load, Capacitive load	Use Capacitors, Inductors for Compensation

Conclusion:

In conclusion, power quality analysis is essential for maintaining the reliability and efficiency of electrical systems. By identifying and addressing issues such as voltage fluctuations and harmonics, it helps to prevent damages and ensures optimal performance in diverse environments, safeguarding equipment and enhancing operational integrity

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Amrit Bharat Express

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Abstract : Worldwide three Phase System are being utilized for passenger services. It is observed that highway transportation is preferred for medium and short distance travel for the countries with vast land and relatively medium population (e.g. USA), for the countries with medium land and relatively less population (e.g. Germany, France and other European countries), the railway transportation system with higher acceleration and relatively more frequent start-stop train sets is being operated. For countries with vast land and large population (e.g. India, China), Railways has been enhancing passenger capacity which is being catered in two ways. First in the suburban area; distributed power trains like EMU/MEMU/ DEMU/Metro are being used and for the long journey, single headed trains are being operated for passenger services. However, in the present time under Mission Raftar and Atmanirbhar Bharat concept of train set, Vande Bharat (Distributed Power) and Amrit Bharat (Push Pull compliant locomotives) has been deployed in the field.

सारांश : दुनिया भर में यात्री सेवाओं के लिए तीन चरण प्रणाली का उपयोग किया जा रहा है। यह देखा गया है कि विशाल भूमि और अपेक्षाकृत मध्यम आबादी वाले देशों (जैसे संयुक्त राज्य अमेरिका) के लिए मध्यम और छोटी दूरी की यात्रा के लिए राजमार्ग परिवहन को प्राथमिकता दी जाती है, मध्यम भूमि और अपेक्षाकृत कम आबादी वाले देशों (जैसे जर्मनी, फ्रांस और अन्य यूरोपीय देशों) के लिए राजमार्ग परिवहन को प्राथमिकता दी जाती है। उच्च त्वरण और अपेक्षाकृत अधिक लगातार स्टार्ट–स्टॉप ट्रेन सेट वाली रेलवे परिवहन प्रणाली संचालित की जा रही है। विशाल भूमि और बड़ी आबादी वाले देशों (जैसे भारत, चीन) के लिए, रेलवे यात्री क्षमता बढ़ा रहा है जिसे दो तरीकों से पूरा किया जा रहा है। उपनगरीय क्षेत्र में प्रथम ईएमयू/ एमईएमयू/ डीईएमयू/ मेट्रो जैसी वितरित पावर ट्रेनों का उपयोग किया जा रहा है और लंबी यात्रा के लिए यात्री सेवाओं के लिए सिंगल हेडेड ट्रेनों का संचालन किया जा रहा है। हालाँकि, वर्तमान समय में मिशन रफ्तार और ट्रेन सेट की आत्मनिर्भर भारत अवधारणा के तहत, वंदे भारत (वितरित बिजली) और अमृत भारत (पुश पुल अनुरूप लोकोमोटिव) को क्षेत्र में तैनात किया गया है।

WAP-5 Push Pull Compliant Amrit Bharat Train

CLW has manufactured locomotives for Amrit Bharat Express which is a modified version of existing WAP-5 HOG compliant locomotives. It has rake with 22 LHB Non AC passenger coaches with two locomotives at each end. The First pair of locomotives was dispatched from CLW on 19.10.2023 and integrated with rakes at ICF.

Brief features of Amrit Bharat train are as follows:-

- Push Pull operation through WTB and repeaters which enhances acceleration and power reserves.
- Reduces coupler forces and leads to safer operation.
- The complete rake can negotiate gradients without a banker and no turn out time is required for reversal.
- One end of the locomotive is aerodynamic with a 45 degree angle and the other end connecting to coaches is flattened. Thus reducing the energy consumption due to air drag.
- Single Look out glass complying with UIC 651 and EN 15152 for better visibility.
- Composite Converter for HOG operation. No requirement of Diesel Power Car.
- Kavach (SIL-4 category) is provided.
- Aesthetically improved FRP based Driver desk.
- Motorized electrically operated wiper assembly.
- 360 degree rotational driver seats.
- LED based Signal Exchange Lamp.
- Twin beam LED Head light and lighting system for better visibility.
- Real-Time Train Information System (RTIS).
- Crew voice and video recording system (CVVRS)

Technical details of Amrit Bharat are as follows:

Description	Wap-5 Push Pull Aerodynamic
Total H.P.	6000 X 2
Wheel Arrangement	Bo-Bo
Max. Tractive effort at start	258 KN X2
Total weight of loco	78 T ±1% each
Axle loads (Max.)	19.5 T ±2%
Length over buffers	18250 mm each
Total width of loco	3130 mm
Maximum permissible speed	160 kmph.

Detailed features of Amrit Bharat Train

CLW has manufactured WAP-5 HOG compliant locomotive pairs with one cab side having aerodynamic appearance and the other cab with flat design. Now it is known as the Amrit Bharat train set. This locomotive is equipped with composite converter, modified driver desk, modified wiper assembly, modified windshield and window glass, RTIS, CVVRS, KAVACH and this locomotive runs in LHB rake train formation (LWS/LWSCN) in Push-Pull mode with 03 nos. repeaters fitted in equidistant rakes for WTB communication. The software and hardware configuration of the arrangement has been made in such a way that HOG converters from both (i.e. front and rear) locomotives can be utilized for feeding the complete train, dispensing the need of the power cars. To achieve the aerodynamic profile, the alignment of cab AC projection on the roof of the cab front has been rotated 90°. There is no major change in the machine room layout except relocation of the fire-extinguisher system to accommodate KAVACH equipment.

Unique features of Amrit Bharat train set are as follows:-

1. **Cab:** Modified locomotive has aerodynamic shaped Cab-1 with modified driver desk and Cab-2 side has flat end with provision for shunting of locomotive.
2. **Cab Inside:** Modified WAP-5 locomotive pair is equipped with state-of-art special cab items like prefabricated driver desk and driver seat. These special items are having following advantages vis-à-vis the existing one:

   (a) Customized FRP based driver desk: Since Amrit Bharat train-set with aerodynamic cab side end has a single wind shield, FRP based driver desk, similar to use in Vande Bharat, has been fitted in the locomotive for better ergonomic look. Customized FRP based new driver desk houses speedometer display on the desk-top along with existing equipment like throttle, reverser, brake handles, BL key, meters, switches, lamps etc. This driver desk has additional provision for TCAS display. Locomotive has additional features like water bottle holder, writing pad, etc. which provide an ambience for better driving of the locomotive. In addition to this it has additional features with fixed locations for adapting the HMIs (Human Man Interface) of Propulsion System, KAVACH and CVVRS which provides a seamless view of operation and maintenance. Memotel is integrated in the middle of the driver desk, thus giving a good view to both Loco Pilot and Asst. Loco Pilot at the same time. It also allows adoption of a single window (wind shield).

(b) Driver Seat: During running of locomotives in different terrains, extreme operating conditions, temperatures, noise etc. make loco-drivers feel fatigue and exhausted. One of the most probable reasons for fatigue is seat comfort, as wrong sitting posture, especially for longer duration, can lead to discomfort to crew and health disorders such as pain in back, neck and shoulder. Seat cushion is one element between the seat and driver that reduces the vibration and enhances the seating comfort. New driver seat, similar to use in Vande Bharat, is designed to be adjustable and comfortable with 360˚ rotational freedom. These aspects improve driver's performance leading to less human errors and thus reducing possibility of accidents.

(c) Cab Furnishing: The cab furnishing furnishing has an effect on comfort, safety and the efficiency of loco pilots. Moreover, the cab furnishing should be noise resistant & heat resistant for comfort & smooth operation of the train by crews. Noise and heat absorbent FRP furnishings have been used in WAP-5 of Amrit Bharat Train to make the cab inside comfortable and noise free.

3. **Cab Front:** Amrit Bharat Train is equipped with electrically operated wiper assembly with washer tank, flasher light, signal exchange lamp and modified windshield and window glasses. These special items are having following advantages vis-à-vis the existing one:

(a) Electrically operated wiper assembly with washer tank: Electrically operated wiper assembly with motor has been introduced in Amrit Bharat Train which is a state-of-art system. The arm length of the Wiper assembly has been increased to suit the large windscreen. Hence, proven wiper assembly of Vande Bharat has been adopted in the modified WAP-5 of Amrit Bharat Train.

(b) Flasher light and signal exchange lamp: Flasher light and signal exchange lamp, similar to as used in Vande Bharat, has been fitted in Amrit Bharat as the front angle has been adopted similar to Vande Bharat.

(c) Windshield and window glasses: In order to modify existing WAP-5 cab design to aerodynamic look similar to Vande Bharat, modifications in windshield and window glasses were imperative. This modification has been done to achieve an aerodynamic profile. The front inclination of modified cab has been kept as 45˚ against 70˚of the existing one. The two part window shield has been modified to a single wind shield and the Memotel on the middle pillar has been relocated to the driver desk.

4. **Colour Scheme:** The colour scheme for Amrit Bharat has been developed in consultation with ICF, similar to the one being adopted for Vande Bharat Train. Same colour scheme has been followed for the rake as well as for the end locomotive.

Commercial operation of Amrit Bharat train:-

02 pairs of Amrit Bharat train were flagged off by the Honourable Prime Minister of India on 30th December 2023. 1st pair was inaugurated physically at Ayodhya Dham Junction and the 2nd pair was inaugurated simultaneously through video conferencing. The first commercial service commenced on 1 January 2024 from Darbhanga Junction (DBG) to Anand Vihar Terminal (ANVT).

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Study on Artificial Intelligence and its Future Potential with Emerging Applications in Indian Railways

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Abstract : The Indian Railways is one of the largest national railway system in the world. It is one of the most preferred system of transportation of people and goods. Due to higher demand for mobility and growth in India's population over past several decades, it has a mammoth of tasks to perform. These could be train operations, scheduling, track maintenance, ticketing, signaling, catering services, rolling stock, etc. With the advent of digitalization all over the world, new ways to operate must be looked into.

The scope of this paper is to find out the possible applications of Artificial intelligence by Indian Railways covering a broad range of AI fields and various domains in infrastructure maintenance, safety and security of passengers, operational efficiency, punctuality, revenue management and passenger services etc.

सारांश : भारतीय रेलवे दुनिया की सबसे बड़ी राष्ट्रीय रेलवे प्रणालियों में से एक है। यह लोगों और वस्तुओं के परिवहन की सबसे पसंदीदा प्रणालियों में से एक है। पिछले कई दशकों में भारत की आबादी में गतिशीलता और वृद्धि की उच्च मांग के कारण, इसके पास करने के लिए बहुत सारे कार्य हैं। ये ट्रेन संचालन, समय निर्धारण, ट्रैक रखरखाव, टिकटिंग, सिग्नलिंग, खानपान सेवाएं, रोलिंग स्टॉक आदि हो सकते हैं। दुनिया भर में डिजिटलीकरण के आगमन के साथ, संचालन के नए तरीकों पर विचार किया जाना चाहिए। इस पेपर का दायरा भारतीय रेलवे द्वारा आर्टिफिशियल इंटेलिजेंस के संभावित अनुप्रयोगों का पता लगाना है, जिसमें एआई क्षेत्रों की एक विस्तृत श्रृंखला और बुनियादी ढांचे के रखरखाव, यात्रियों की सुरक्षा, परिचालन दक्षता, समय की पाबंदी, राजस्व प्रबंधन और यात्री सेवाओं आदि में विभिन्न डोमेन शामिल हैं।

Introduction

Indian Railways under the aegis of the Ministry of Railways, Government of India, constitutes the backbone of the nation's transportation infrastructure Spanning over 70,000 kilometers of tracks and orchestrating a network of more than 20,000 passenger trains, it ranks as the fourth-largest railway system globally as of April 2019. Over the past 150 years, Indian Railways has remained an indispensable lifeline for countless individuals, offering inclusivity across diverse demographics.

In a world evolving with air travel and expressways, Indian Railways maintains its enduring significance as the primary mode of mass transit for both people and goods. However, as passenger and cargo volumes surge, optimizing operations and bolstering safety and security have become pressing concerns. The complexity of managing an extensive railway network, encompassing intricate schedules, multifaceted routes, and the coexistence of passengers and freight traffic, presents formidable challenges.

Indian Railways embarks on a comprehensive modernization endeavor, involving complete electrification, high speed track construction, and the creation of tunnels, bridges, and infrastructure. Protecting this extensive and forthcoming infrastructure from operational and security hazards is imperative. With tens of thousands of kilometers of tracks and daily train movements, achieving this consistently and efficiently through human effort alone is unfeasible. This is where advanced technologies and artificial intelligence (AI) come into play as catalysts for transformation.

AI integration across operations, emphasizing safety, security, preventive maintenance, efficiency, punctuality, and ticketing, has become imperative. As Indian Railways propels towards a digitalized, cashless future, AI emerges as a pivotal enabler. It promises an array of services, ranging from managing train operations and facilitating ticket bookings to maintaining systems and overseeing railway assets. In the ever-evolving landscape of rail operations, AI and machine learning are no longer optional but essential. Indian Railways stands at the precipice of a transformative journey, where AI will be instrumental in overcoming the escalating complexities of the rail industry.

Future Potential and Emerging Applications of Artificial Intelligence

1) Intelligent escalator passenger safety management:

Escalators are essential and indispensable parts of subways and train stations, shopping malls, underground passages and other objects of public infrastructure. Their length can reach 140 m, and the height of the rise can be 70 m. During the operation of escalators, some events can occur that threaten the health and life of passengers. Specifically, it can be a fall into the escalator tunnel, pinching of body parts of small children and animals, equipment malfunction: brakes, electricians, grounding, etc. These events can be caused by sharp stops and breakdowns of escalators and by abnormal behavior (children, sick and drunk people, etc.) passengers on escalators can stand in an unstable manner, not hold on the handrails, push each other, stumble and fall on the sharp edges of the steps. Escalators can be overloaded, thus creating dangerous situations. All this can result in serious injuries and even death. Dozens of people die every year in such accidents, and injuries are counted in thousands

The novelty of the AI based approach lies in the advanced complex processing of information from three types of sources (video, audio, sensors) using machine learning methods and recurrent neural networks with controlled elements.

The use of such solutions for intelligent processing of signals from sensors in the interests of ensuring the safety of passengers on escalators makes it possible to expand the possibilities of both recognition and prediction of threatening events.

The process of intelligent passenger safety control on escalators is shown in Fig 1.

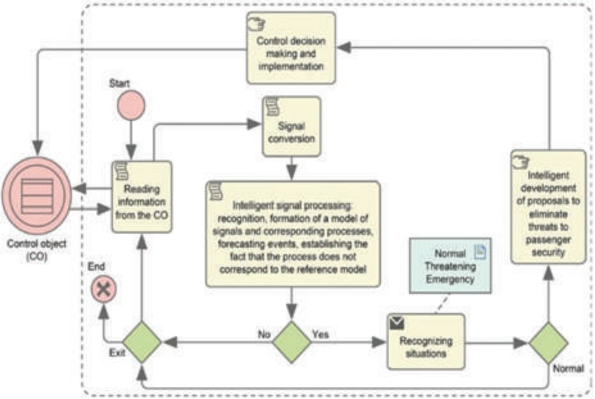

Fig. 1

2) Detecting infrastructure and safety hazards in the railway using Artificial Intelligence:

AI can be used to monitor railway infrastructure for potential hazards. This information can be used to take preventive measures and reduce the risk of accidents. AI can also be used to identify safety hazards that are not visible to the human eye. For example, AI could be used to detect cracks in railway tracks that are not visible to the human eye.

The advisory roles in train positioning, acceleration, safe braking, and interlocking can eliminate the need for direct control of the driver.

With the help of sensors, lasers, and cameras, any obstacle on the path can be detected. This helps in taking the split-second decisions bringing AI-assisted tram to an abrupt stop.

An architecture for AI-based Train Operation Control.

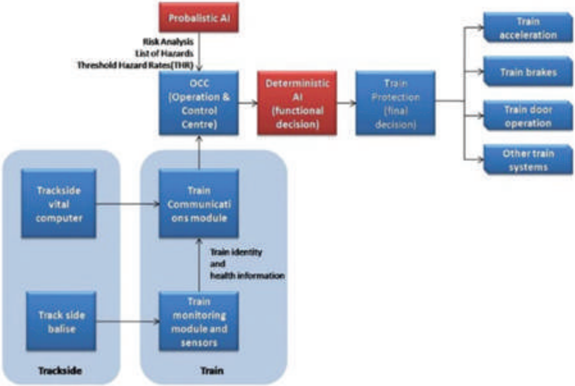

Fig. 2

3) Train Scheduling:

Traffic management is another area where AI can be applied in railway signaling. AI algorithms can optimize train schedules and routing to reduce waiting times, improve punctuality, and increase capacity. AI can also monitor and control the speed and acceleration of trains, leading to energy savings and reduced wear and tear on equipment.

All signaling rules assume that tracks at stations are occupied by at most one train at a time. This can be ensured by algorithms, simulation models, graphs, heuristics and control systems with the required degree of Artificial Intelligence in Indian Railways.

The information which can be obtained from AI shall include:

(i) Time duration from the first event to the last event,

(ii) The total or average running time of trains,

(iii) The priority-weighted running time of trains,

(iv) Robustness of the timetable to deviations, and combinations thereof.

A typical Scheduling Algorithm using Artificial Intelligence

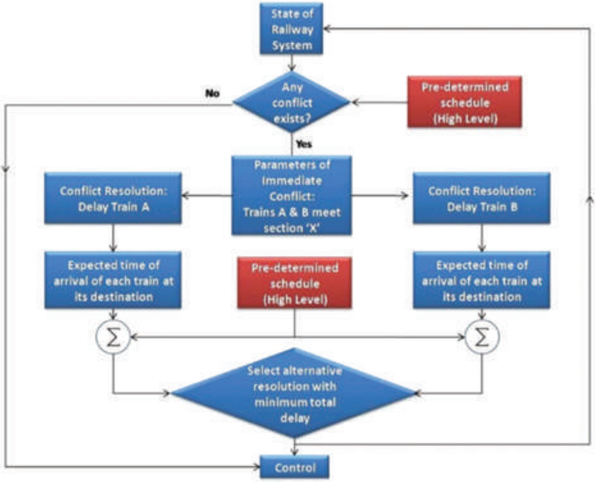

Fig. 3

4) Asset Management:

The fool proof working of the signaling system is important for safe train operations. Railways completely depend on the health of its signaling assets along with real-time information. Most of the delays happen due to the failure of signals. So far, Indian systems follow a manual maintenance system and find-and-fix methods. But the adoption of Artificial Intelligence in Indian Railways can help predict failures by remote condition monitoring of the system well in advance.

This can be possible by embedding smart sensors on critical rail components and take necessary preventive actions. Inputs shall be collected on fixed intervals and sent to a central location (such as operations control center or OCC). As a result, any problems in the signaling system would be detected on a real-time basis.

5) Delay Prediction and Reduction:

One major role of Artificial Intelligence in Indian Railways can be the prediction of train delays. This is an important consideration for the highly limited nature of railway networks. Currently, there is no mechanism in IR to take corrective actions for the delay in train timings. Such delays are caused due to train priorities, downstream conflicts with other trains, freight loads, and irregular stopping times. A human cannot process all of these factors simultaneously, or come up with an optimal solution for the network as a whole.

Accurate delay predictions due to the incorporation of Artificial Intelligence in Indian Railways would help dispatchers (controllers) in downstream portions of the network. It would also improve the passenger experience by providing early updates regarding their journeys. A system to predict delay time would learn from past train delay data, predict how long each delay will be, and use a cloud-based service to deliver updates.

6) Data Management:

Cloud-based AI technology aids in storing and managing the vast amount of data generated by the rail industry. This ensures cost savings, steady accessibility, and integration with other software for informed decision making.

7) Tunnel Security:

Tunnels play a critical role in taking the railways through the mountainous terrain, and if not secured properly, they can also be a security risk. That's where AI surveillance helps in identifying if there are any people in the tunnel, their exact location and the movement of train etc. For instance, the system can keep a track of the train's speed and direction of movement inside the tunnels, and report if the train moves over/below the prescribed speeds or comes to a stoppage inside the tunnels. It can also identify if there is a theft or object removal which could potentially jeopardize safety of train movements in the area under surveillance. If there is smoke or fire, video cameras can identify the incident and alert security personnel to prevent the fire from spreading out of control.

In today's dynamic world, having the capability to real-time monitor and respond to security risks and threats is critical. With billions of rupees and large number of lives to protect, AI-driven video analytics and CCTV systems are going to be key in ensuring safety and sustainability of operations for the railways in the years ahead.

8) Inventory Management:

Keeping records of maintenance of rail equipment manual not only consumes a lot of time but there could also be chances of human error. AI can automate maintenance alerts, improving inventory management, and ensuring safe travel by preventing accidents. Digitized records would be more efficient as well.

9) Punctuality:

Currently, railway networks do not use automated algorithms for functions like time duration from the first event to the last event, total or average running or priority-weighted time of trains, robustness of the timetable to deviations, and combinations thereof to ensure that either a track section between two stations is occupied by at most one train at a time (in absolute block signaling), or every piece of track between two signals is occupied by at most one train at a time (in automatic block signaling).

Use of algorithms, simulation models, graphs, and control systems with the required degree of AI in Indian Railways approach will generate high-level and microscopic timetables and schedules of train movement. It will help in listing the tracks to be occupied, time required for switching tracks, requirements for signaling and evaluating parameters of immediate conflict, thereby enabling instance scheduling decisions. Use of AI will help controlling the speed profiles of trains. It will help detect obstacles on the tracks and help predict train delays caused due to train priorities, downstream conflicts with other trains, freight loads, and irregular stopping times and reduce such instances. It is impossible for human beings to process all factors leading to train delays or coming up with an optimal solution for the railway network. The program operates in three stages: 'sense,' which collects train network data; 'analyze,' which assesses potential outcomes; and 'respond,' which assigns track resources to trains according to physical capabilities and safety standards.

10) Weather-Induced Maintenance Alerts:

Harnessing the power of AI in railways, predictive maintenance goes beyond traditional methods, offering weather-induced maintenance alerts that significantly benefit the railroad industry. By integrating weather forecasts with maintenance systems, railway operators can anticipate potential weather-related wear on tracks and infrastructure.

For instance, when adverse weather conditions like heavy rain or extreme heat are predicted, AI algorithms can analyze how these conditions might impact the tracks and other components. Maintenance crews are then alerted to conduct timely inspections and repairs, preventing potential safety hazards and service disruptions.

With weather-induced maintenance alerts, railways can proactively address weather-related challenges, ensuring the continuous and safe operation of trains.

Conclusion:

Every field in India has started used various technologies to improve their efficiency. AI holds enormous potential for Indian Railways, both in current applications and future possibilities. From improving safety and efficiency to enhancing passenger experience and environmental sustainability, AI is poised to revolutionize the railway sector, making it more advanced and passenger-friendly. Continuous innovation and investment in AI technologies will be essential for realizing these benefits and transforming Indian Railways into a world-class transportation system.

However, it is essential to acknowledge that the full-scale adoption of AI based train systems will take time, possibly spanning decades. In summary, the integration of artificial intelligence (AI) and emerging technologies in the Indian railway industry represents a transformative opportunity with immense potential.

With proper investments, upgrades and a skilled workforce, the railway system can evolve into a more efficient, safer, and passenger-friendly mode of transportation. The future of Indian railways is undoubtedly intertwined with the evolution of AI and emerging technologies, promising a brighter and more technologically advanced era for rail travel in the country.

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Energizing Sustainability: The Expansive Role of Energy Managers and Auditors in Indian Railways and Beyond

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Abstract : **This article delves into the burgeoning opportunities for energy managers and auditors in Indian Railways. It highlights the significance of the National Certification Examination in equipping professionals with the necessary skills for managing resources effectively and conducting comprehensive energy audits. Emphasizing key areas such as energy efficiency mandates, renewable energy integration, regulatory compliance, and green building practices, the article underscores the pivotal role of these professionals in driving sustainability amidst India's relentless pursuit of energy security and sustainable development.**

सारांश : यह लेख भारतीय रेलवे में ऊर्जा प्रबंधकों और लेखा परीक्षकों के लिए बढ़ते अवसरों पर प्रकाश डालता है। यह संसाधनों को प्रभावी ढंग से प्रबंधित करने और व्यापक ऊर्जा ऑडिट आयोजित करने के लिए पेशेवरों को आवश्यक कौशल से लैस करने में राष्ट्रीय प्रमाणन परीक्षा के महत्व पर प्रकाश डालता है। ऊर्जा दक्षता जनादेश, नवीकरणीय ऊर्जा एकीकरण, विनियामक अनुपालन और हरित भवन प्रथाओं जैसे प्रमुख क्षेत्रों पर जोर देते हुए, लेख भारत की ऊर्जा सुरक्षा और सतत विकास की निरंतर खोज के बीच स्थिरता को चलाने में इन पेशेवरों की महत्वपूर्ण भूमिका को रेखांकित करता है।

Introduction :

The pursuit of sustainability in India's energy landscape is marked by the crucial role played by energy managers and auditors. In this article, we delve into the multifaceted scope of their responsibilities within Indian Railways and explore the promising avenues for their expertise in other industries post-retirement.

The National Certification Examination for Energy Managers and Energy Auditors is a professional certification program administered by the Bureau of Energy Efficiency (BEE) in India. This examination is conducted in accordance with the provisions of the Energy Conservation Act, 2001, and its subsequent amendments.

The purpose of this certification is to ensure that energy managers and auditors possess the necessary knowledge and skills to effectively manage energy resources and conduct comprehensive energy audits. Energy managers are responsible for implementing energy management programs within organizations to optimize energy usage and reduce costs, while energy auditors assess energy consumption patterns and identify opportunities for improvement.

Candidates preparing for this examination typically study various aspects of energy management, including energy conservation techniques, energy efficiency measures, renewable energy technologies, energy auditing methodologies, and relevant legislation and regulations.

Successfully passing this certification exam demonstrates competency in energy management and auditing practices, enhancing professional credibility and opening up career opportunities in the field of energy management and sustainability.

The Role of Energy Managers and Auditors in Indian Railways : Indian Railways stands as a colossal infrastructure network, vital for the nation's economic and social development. Within this expansive domain, energy managers and auditors hold significant responsibility in ensuring the efficient utilization of resources and the implementation of sustainable practices.

- **Energy Efficiency Mandates in Indian Railways:** The Indian government, through initiatives like Perform, Achieve, and Trade (PAT), has mandated energy efficiency measures across various sectors, including railways. Energy managers are tasked with implementing these measures, driving energy savings, and reducing operational costs.

- **Integration of Renewable Energy Sources:** The emphasis on renewable energy integration within Indian Railways presents a significant opportunity for energy auditors. Assessing the feasibility and efficiency of renewable energy projects becomes paramount in this context, aligning with the nation's renewable energy goals.
- **Regulatory Compliance and Green Building Practices:** Compliance with energy conservation norms and the adoption of green building practices are essential aspects of sustainability within Indian Railways. Energy auditors play a critical role in ensuring adherence to these norms, fostering a culture of environmental responsibility.
- **Technology Adoption and Future Prospects:** The adoption of smart technologies, IoT, and data analytics is poised to revolutionize energy management within Indian Railways. Energy managers and auditors equipped with expertise in these areas are well-positioned to drive efficiency gains and operational excellence.

The Future Scope of Energy Managers and Auditors Post-Retirement

Beyond their roles within Indian Railways, energy managers and auditors possess a wealth of experience and expertise that can be leveraged in diverse industries post-retirement. Let's explore the promising avenues for their contributions:

1. **Industry Compliances on Energy Efficiency Mandates, Renewable Energy Integration**

   The Indian government has been actively promoting energy efficiency initiatives through programs like Perform, Achieve, and Trade (PAT) under the Bureau of Energy Efficiency (BEE). Regulatory mandates and policies are likely to continue, creating a demand for professionals who can implement and manage energy efficiency measures. The emphasis on renewable energy sources is increasing, and energy managers play a crucial role in integrating renewable energy technologies into existing systems. There are growing opportunities for auditors to assess the feasibility and efficiency of renewable energy projects. Many industries are now required to undergo energy audits and comply with energy conservation norms as part of environmental and sustainability regulations. Energy auditors are essential in ensuring that industries adhere to these compliance requirements. Sector specific applications:

   - In the manufacturing sector, energy managers and auditors can drive energy efficiency improvements, optimize industrial processes, and implement sustainable practices. Their expertise is instrumental in reducing energy costs and enhancing competitiveness.
   - Energy managers and auditors play a crucial role in optimizing energy consumption in healthcare facilities, ensuring uninterrupted power supply for critical medical equipment, and implementing renewable energy solutions to enhance resilience.
   - Within the hospitality industry, energy managers and auditors contribute to reducing energy consumption in hotels, resorts, and restaurants through efficient lighting, HVAC systems, and water heating solutions, thereby enhancing operational efficiency and guest satisfaction.
   - Government institutions can benefit from the expertise of energy managers and auditors in implementing energy conservation measures, conducting energy audits, and promoting sustainability initiatives across departments and agencies.

2. **Cost Savings and Sustainability :** Organizations are recognizing the economic benefits of energy efficiency, including reduced operational costs and improved sustainability credentials. Energy managers are integral to implementing strategies that not only save costs but also contribute to corporate social responsibility and environmental goals.

3. **Green Building Practices:** With an increasing focus on sustainable construction and green building practices, energy managers and auditors are needed to optimize energy consumption in buildings. Certification programs such as Leadership in Energy and

Environmental Design (LEED) drive the demand for professionals in this area.

4. **Emerging Technologies:** The adoption of smart technologies, IoT (Internet of Things), and data analytics in energy management is creating new opportunities for professionals to optimize energy consumption through advanced systems and predictive analytics.

5. **Consultancy Services and Entrepreneurship:** Many retired energy managers and auditors choose to venture into consultancy services or entrepreneurship, offering specialized energy management solutions to various industries. Their experience and insights are invaluable in guiding organizations towards energy efficiency and sustainability.

6. **International Best Practices:** As companies increasingly align with international standards and best practices, the demand for professionals with expertise in energy management and auditing is likely to rise.

The role of energy managers and auditors extends far beyond Indian Railways, encompassing diverse sectors where their expertise is indispensable for driving sustainability and efficiency. Post-retirement, their wealth of experience and knowledge continue to fuel positive change, shaping a greener, more sustainable future for industries across India. The ongoing commitment to energy efficiency, coupled with the adoption of renewable energy and emerging technologies, is expected to create a sustained demand for professionals in this field.

Source:

1. https://beeindia.gov.in/en
2. https://www.aipnpc.org/
3. https://energy.gov/

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Techniques to Maximize Solar Generation from Grid Tide Rooftop Solar Plants Provided at Wayside Railway Stations

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Abstract : The Government of India set an ambitious target for the Indian Railway to become net zero/Carbon Neutral by 2030. To achieve this commendable target, Rooftop Solar (RTS) plants installed at all stations. But at the wayside stations even during day time, availability of DISCOM supply is less, so in order to maximise solar energy generation, single phase 5KWp RTS plants have been provided with an auto changeover switch between DISCOM and AT Supply.

सारांश : भारत सरकार ने 2030 तक भारतीय रेलवे को नेट ज़ीरो/कार्बन न्यूट्रल बनाने का महत्वाकांक्षी लक्ष्य रखा है। इस सराहनीय लक्ष्य को प्राप्त करने के लिए, सभी स्टेशनों पर रूफटॉप सोलर (आरटीएस) संयंत्र स्थापित किए गये है। लेकिन छोटे (way side) स्टेशनों पर दिन के समय भी, डिस्कॉम आपूर्ति की उपलब्धता कम होती है, इसलिए सौर ऊर्जा उत्पादन को अधिकतम करने के लिए, सिंगल फेज़ 5 KWp रूफटॉप सोलर (आरटीएस) संयंत्रों को डिस्कॉम और एटी आपूर्ति के बीच एक ऑटो चेंजओवर स्विच द्वारा जोड़ा गया है।

Introduction :

Due to less load requirement way side stations cannot have RTS plant of more than 15 KWp. Station having 3 phase DISCOM connection can use this drawing for 3 nos RTS plants of single phase (one on each phase).

Working :

This modification will ensure use of full solar generation in load or if in excess, it can back feed to DISCOM through net metering. In absence of DISCOM supply this arrangement will feed generated solar power to 25 KV OHE through AT & CLS panel. This way whole day solar power generation can be utilized with maximum financial benefit in monthly energy bill of DISCOM. Single phase Auto change over switch should be of 30/30A capacity.

This arrangement can also be utilized for single phase DISCOM connection.

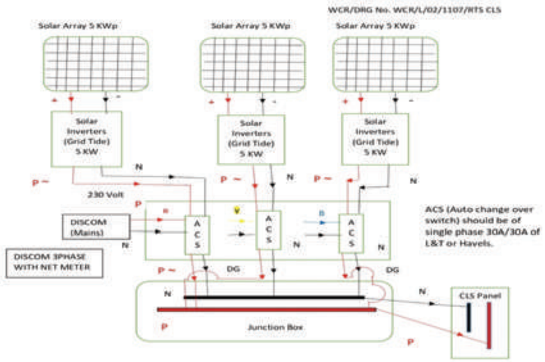
Fig. 1

Implemented : This innovation has been implemented at Morak and Salpura station of Kota division of WCR.

Advantages:

1. Ensures full Solar generation even in case of DISCOM supply failure/breakdown.
2. Reduces Monthly energy bill of small stations by consuming solar generated power locally.

Drawing :



SCHEMATIC DIAGRAM FOR SINGLE PHASE, 5 KWP RTS PLANT, 3 NOS, CONNECTION WITH AUTO CHANGE OVER SWITCHES (ACS).

FOR WAY SIDE STATIONS HAVING RTS PLANT CAPACITY UP TO 15 KWp & 3 PHASE DISCON CONNECTION AVAILABLE.

Conclusion : AT way side railway stations, DISCOM supply are not reliable i.e. available for less duration and frequent power cuts are there. Due failure of local power supply, RTS plant generation also stops, to overcome this problem of no generation, above system is very effective and can be adopted in Indian Railways for way side stations RTS plants.

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Instructions for the guidance for contribution to the Indian Railway Technical Bulletin published by RDSO

Articles are invited from the serving and retired Railway personnel of the Zonal Railways, Railway Institutes and Production Units for publication in Indian Railway Technical Bulletin (IRTB) on:

(i) Technical articles relevant to railway working.

(ii) Reference to Railway-relevant good articles from reputed magazines.

(iii) Short notes on handy gadgets or practical hints on care, maintenance and operation of equipment used in railway working.

About the article:

- Article should normally not exceed 3000 words. Article should begin with a synopsis, both in English & Hindi not exceeding 100 words. Reference should be quoted numerically in a bibliography at the end. Standard or well recognized notations should be used. Personal reference and lengthy quotations should be avoided.

  In case of reference to articles (item ii above), whereabouts of the article (name of magazine, publication month, article's name, author's name), and 2-3 lines about what the article is about and how it is so good - should be sent.

- Author's full name, designation and photograph should be sent.
- The authors should certify that the articles sent for publication in the Indian Railway Technical Bulletin have not been sent elsewhere for publication.
- The entire content (article, photograph, certification etc.) should be sent in hard copy to Executive Director / Administration, Research Designs and Standards Organisation, Manak Nagar, Lucknow-226011 as well as in soft copy (editable e.g. .doc as well as non-editable, e.g. .pdf formats) to e-mail: publicationrdso@gmail.com, aliordso@gmail.com.

Articles from officials of RDSO should be routed through, and approved by, the concerned Executive Director. In case of articles from outside RDSO, they should be duly forwarded by department head (SA Grade and above). Retired Railway personnel may send their article directly.

Decision of Executive Director /Administration regarding selection of article for publication in IRTB shall be final.

Comments and criticism in the form of 'Letters to the Editor' on articles which have appeared in earlier issues of the bulletin are welcome. Suggestions about improving the IRTB are also welcome.

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भारत सरकार, रेल मंत्रालय

Government of India Ministry of Railways

INDIAN RAILWAY TECHNICAL BULLETIN

Printed at : Prakash Packagers, Lucknow