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Study on Deviations and Settlements of Rails and Its Maintenance in Broad Gauge Railway Track

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ABSTRACT
The deviation of Rail track is a problem that had happened on Rail road systems. This resulting in the noise, vibrations, fuel consumption and taking more time. Since small changes in the aligned track will result significant change in the total cost of travel. For this, there are manual methods however it is more complex one and needs more manpower. So now a days instrumental and machinery utilization becomes more faster and cost effective to settle various issues on railway track.The aim of this paper is to identify the location with oms, direction and amount of deviation occurred on the Railway track. The Methodology of this study involves collection of reduced level's for 40km and deviations and settlements which are observed through the selected track and then these Horizontal deviations and vertical settlements are further analysed to calculate Track Geometry Index (TGI) with the help of Analytical approach called track degradation Concept. The basic tests on soil and a few descriptions about the Embankment soil and Ballast is investigated and are compared with the Recommended specifications of Indian Railway.TGI value obtained is 51.6 which comes under second condition that is need for basic maintenance as specifed by Indian railways
KEYWORDS: Track ; Deviation ; Rail ; Geometry Index and Alignment.

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I. INTRODUCTION

Railway track is one of the main railway facilities and the basis for train operations. Safe, stable, and uninterrupted train operations primarily depend on continuous track regularity [19]. Rail traffic accidents due to derailments are nowadays become a common problem and lead problematic to Indian railways. Railway track plays a base element in railway system and is greatly and directly influences on safety and cost efficiency. Investigations have been carried out for the identification of problems and are associated with track degradation process, which causes a low level of safety, which causes traffic accidents have become a social-economical problem. Indian Railway always improves the condition of the track for its good operating, but the problems in a single kilometer of the track will result in the lakhs to be repaired. Hence the total (LCC) Life cycle cost will be in crores [15]. In present study, as the load goes on increasing and the design is old, but no improvements done in last five years for beneath layers of embankment and the changes in seasonal effects and shows impact on embankment stability, which results in causing deviations. However, due to changing temperatures and the resulting unstable mechanical properties of layers, considerable difficulties have been encountered.
Track degradation from Geometrical aspect is considered for analysis and adopted. This study deals with geometrical perspective of track degradation; twist deviation parameter is very much defined for tracks and its effects [1]. The roles of several parameters that influences railway track deterioration most, are examined and with a view to make railway track maintenance more effective and cost efficient [8]. TQI is a new parameter to get more information about track geometry and the track maintenance standard can be judged [9].
The present area considered for study purpose is East Coast Railway and surveyed for Vertical settlements and horizontal deviations. This paper tends to analyze the deviations of rails, and compares standards between field measurements and Design standards.

II. PROBLEM DESCRIPTION

The deviations of Rails in a Railway track are an issues which are common in all Railways, that results in the vibrations, noise, fuel consumption and time taken. Since the small change in the alignment will result in

significant change in the total cost of travel. The problems in the 1km piece of the studied track is badly out of alignment, cross-level across the rails having rotted ties, consecutive ties where missed with spikes and having loose fish plates.

III. STUDY AREA

The Vizianagaram – Bobbili Line is a Railway line is the part of the East Coast Railway of Indian Railways. It has a total distance of 50km from which the First 40km section has been taken for the study purpose. The area covered by this line (including branch lines) is rich in mineral resources, Coalfields, TPC power stations and Thermal and NTPC Power stations, NALCO, Vedanta Aluminium Limited and plant at Hirakud at another side of orissa. All the goods trains from these stations with heavy loads are expected to passes through this Line towards Visakhapatnam off south India. On at another side, the Vishakhapatnam Port started in 1933 carries its locomotives trains through this line towards Orissa. As this stretch carried a load of 6-10GMT/year but now it was increased to about 29GMT/year. Hence deviations and settlements are there from Vizianagaram to Bobbili site. These deviations and settlements are surveyed with the Total station and calculated its magnitude in 'mm'.

IV. METHODOLOGY

In this paper, the method to evaluate the track conditions such as deviations and settlements have been analyzed by track degradation concept. Settlements due to shrinkage of embankment and loads, which effect in sudden increment or decrement. Soil sample tests are conducted for the site condition where maximum deviation is occurred to access type and behaviour of soil and checked the limits as per Indian railway standards. The problematic zone is identified by oscillation measuring device (OMS) [14]. Condition of the railway track is accessed by track geometry index (TGI), which is based on the different geometry parameters such as Unevenness (UI), Twist (TI), Alignment (AI), Gauge (GI) over a stretch of 200 m. Based on TGI, the level of maintenance of track is assessed as per Indian railway standards [4].

TGI is evaluated by the below equation (developed by Indian Railways) :

$$\text{TGI} = 2UI + TI + 6AI + GI/10$$

Where,
UI = Unevenness
TI = Twist
AI = Alignment
GI = Gauge

V. CALCULATION OF DEVIATIONS AND SETTLEMENTS

The survey work gives the results on the behavior of the track geometry, which shows the track substructure resembling the failure condition in terms of shrinkage [13]. These deviations are calculated by importing the Total Station data into Autocad software.

In this study, a new parameter called deviation is defined, which is the difference of the actual alignment and the existing alignment on the different basis. The measurement limits have been calculated based on the twist measurement from Vizianagaram to Bobbili railway line sections, which are part of the East coast railway network. From the twist, twist deviation have been accessed for different speed and to geometry of the track shown in Table 1.

5.1 Horizontal deviations, Vertical settlements and OMS

Horizontal deviations will occur due to lateral replacement of Rail cum sleeper from its original position. So there will be partial amount of deviations can be occured. Among all the survey done for finding levels and alignment of the study track stretch, the maximum deviations are observed in the chainages 435, 440, 441, 445.

This following chainage graph shows the deviation in left and right direction from its center line for a single kilometer show as an example in below figure.1.

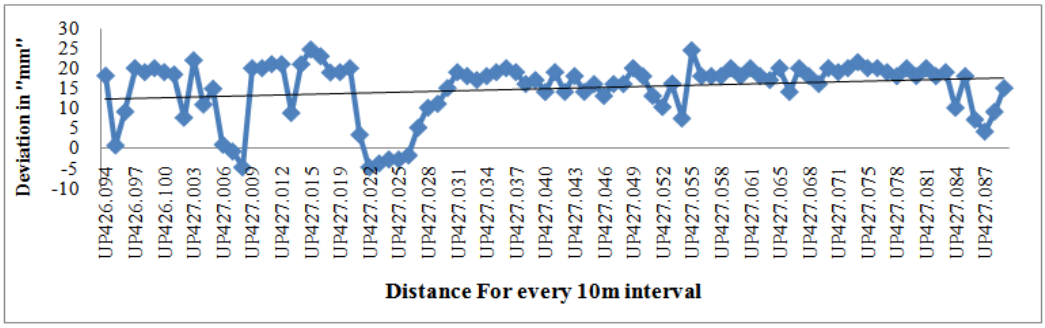

Fig. 1. Graph shows the twist deviation for a single kilometre length of track in a chainage at 426.

Following graph shows the average standard deviations occurred in the selected length of the track and is further calculated for mean deviation as shown in figure2.

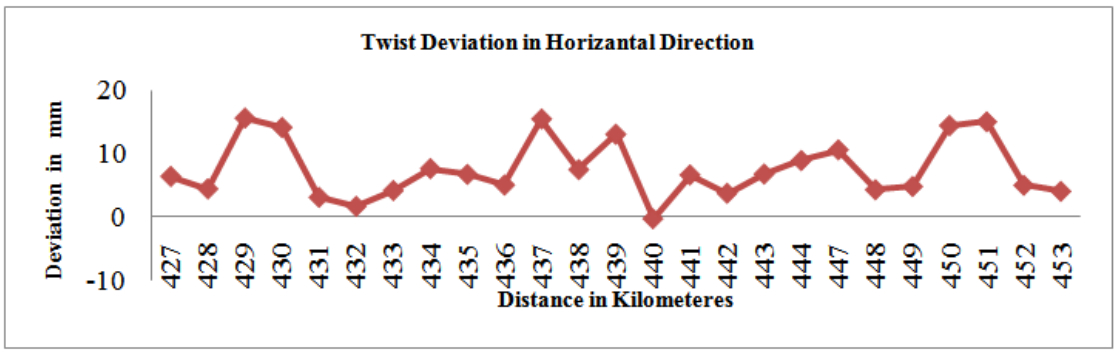

Fig. 2. The Graph shows the twist deviation for all length of track as whole a single Km chainages from 427 to 453.

Vertical settlements are occurred due to the shrinkage of Embankment and loads, which affect sudden increment or decrement in its profiles in the length of the track. The following figure shows the vertical profile of a rail in its longitudinal direction at chainage of 428. Settlements occurred at chainage 441, 442 and the vertical elevations at chainage 428 only show as an example in this paper in figure.3. and there is a need for proper compaction of side slopes. Shrinkage of embankments is accessed based on soils tests conducted in the particular zone and their remarks are tabulated in table 2. The following table shows the laboratory tests conducted and the results obtained for the selected chainage.

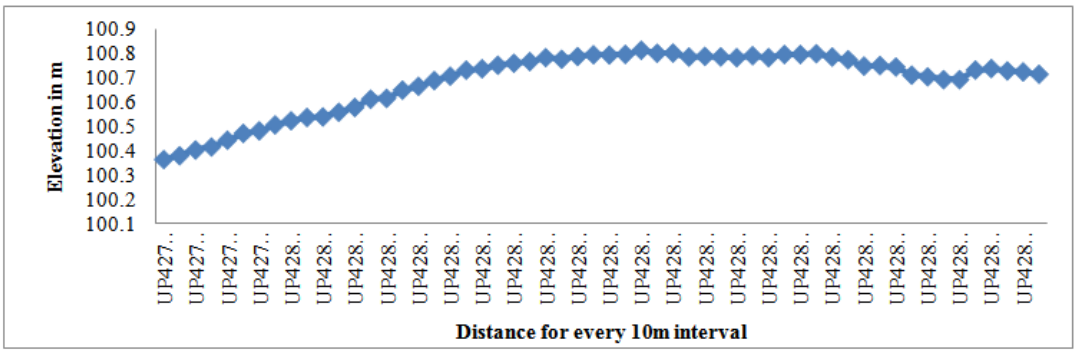

Fig. 3. Vertical Elevations in Chainage 428

Settlements due to loads is accessed by OMS(Oscillation measuring device) at the chainages where there is sudden increment or decrement in speed of train occurs. The following table 1 shows the location, chainage speed and acceleration recorded in a travel while surveying from Vizianagaram to Bobbili section.

Table. 1 Vertical and Lateral Acceleration observed through OMS

SECTION:VBL- VZM	**OMS RUN NO :592**
LINE : DN	**DATE OF RUN: 06 Feb-15**
KM FROM: 427 to 464	**TH. LIMIT >= 0.15**

Kilometer	Distance(m)	ACCELERATION VALUE		
		Vert. Accn.(g)	Lat. Accn.(g)	Speed (Km/h)
427	993.1	0.16		104.23
432	496.7	0.15		108.56
432	558.8	0.16		108.56
432	861.2	0.16		108.56
432	868.2	0.19		108.56
432	875.1	0.17		108.56
432	908.6	0.16		108.56
432	908.6		0.15	108.56
432	920.1		0.18	108.56
432	980.7	0.17		108.56
433	110.4	0.16		110.97
433	844.1	0.16		110.97
433	854.9	0.16		110.97
433	996.1	0.18		110.97
434	200.5		0.17	99.12
434	364.9	0.16		99.12

As the observed OMS report is too lenghtly in original format, the report was compressed as shown above. The problem zone was identified by the deviated values and oscillation measuring device. There are maximum deviations which are up to about 30mm maximum and chainages observed are 441, 442, 435 etc., but at a place of Ch: 441/2, a sudden increment in the profile of the vertical gradient has occurred and leading to Rail wheel burns.

Table. 2 comparison of Soil Test results with Indian Railway recommendations.

S.No	Description	Recommended by Indian Railways	Existing on site	Remarks
1	For BG topwidth double line	10.82m	9.15m	Less (Erosion)
2	Bank offset	90cm	75cm	Less (remoulded)
3	Side slope	2:1	2.2:1	Slips in bank slopes
4	Extra wide bank	50cm	0	Not provided
5	LL (Liquid limit)	Shouldn't be >35	8%	Satisfied
6	Ip (plasticity index)	<10		
7	Cu(Coefficient of uniformity)	>4 to 7	5.71	
8	Cc(coefficient of curvature)	1 to 3	0.8	graded gravel
9	Gradation test- Single Blanket Layer over Embankment Fill	Cu > 4 ,1 < Cc < 3, Fine Particles (size smaller than 75 microns) less than 50%	Same	Well graded gravel or sandy gravel with little or no fines GW
10	MDD	90%		
11	Fines agg <75µ	Not more than 5%	2%	Good
12	CBR	3 to 8	9.2	Good

As per the soil tests there is 50cm erosion in the embankment, and soil classified as a well graded gravel, and it is examined that 1m extra wide on the top of Embankment is not provided. Ballast quality and condition in the study stretch are as mentioned in the table 3.

Table. 3. Comparison of IR Recommendations and site condition for Ballast before and after study

S.No	Description	Recommended by Indian Railways	Existing on site	Remarks
1	Size of the ballast	50mm	30 to 50mm	Crushed due to loads
2	Size and Gradation:			
	Size of the sieve:			
	65mm	5% Max	0%	10% reduction in contracted rates if retention on a 40 -mm square mesh Sieve is between 65% and 70%.
	40mm	40% to 60%	68.5%	
	20mm	Should not be less than 98%	95%	
3	Depth of the Ballast cushion (d) = $\frac{Sleeper\ \ spacing\ -width\ of\ the\ sleeper}{2}$	15 – 20 cm	19.8	Less (Sleeper tends to settled to about 4cm)
4	'd' under Fish plates	30 cm	21.5 cm	Less (crushed and shrinkage to 28% but limit is only 8%)
5	Aggregate Abrasion	30% Max	36% on test	Less (More dust Evaluation during traffic passage)

6	Aggregate Impact	20% Max	28% on test	Less (Leads to reduction in thickness of Ballast Layer)
7	Water absorption	1%	4% on test	Moisture retains and leads to less life

VI. CALCULATION OF TRACK GEOMETRICAL INDEX

1.1. Issues with Twist Deviation Parameter

The Twist is occured only in straight line and curve with theoretically constant cant, if there is an asymmetrical longitudinal fault of the track. There is a twist already built in for the sections with cant transitions, therefore if there is a longitudinal fault in this section it is larger, than in other sections of the track. In this case, the basic twist of the cant transition and the twist caused by the longitudinal fault are added together [1].

The twist deviation was calculated according to the below-mentioned formula. This is the difference between the averaged twist and the twist in the given point.

$$S_{ei} = S_a - S_i,$$

Where:
S_i : twist (mm);
$S_{a:}$ averaged twist in the averaging length (mm);
S*ei*: twist deviation.
Using twist deviation in order to solve the deviation problems is not new among railway professionals are using a similar parameter according to their standards. The main idea of the method is that the twist values are averaged over a given length and this value will be the new baseline [14]. The difference between this baseline and the twist values provide the new local geometry parameter called twist deviation. The research of this article was based on this method.

6.2. *Track Geometry Index*

Indian Railways has developed a formula to represent the quality of track called TGI. This model is based on the standard deviation of different geometry parameters over a stretch of 200m segment. TGI is calculated for each segment and the average value of such segments in every km gives the general TGI value. With respect to the effect of each geometry parameter on the ride quality, TGI has given different value for various geometry parameters as shown in the following formula [5]:

$$\mathrm{TGI} = 2UI + TI + 6AI + GI/10$$

The TGI is an SD based index evolved by Indian Railway. TGI takes into account the index for different geometry parameters, assessing the track condition with respect to a range defined at one end by "best-maintained track" and at the other by 'track needing urgent maintenance'. The index for individual parameters e.g., the gauge is worked out as follows [6].

$$\mathrm{GI} = 100 * e^{\frac{SDm - SDN}{SDu - SDN}} / \mathrm{n}$$

Where,
SD*m* =SD of measured parameter;
SD_N = SD value of newly laid track; and
SD*U* =SD values for a track needing urgent maintenance.
SD*m* (Standard deviation of measured Parameter) values is observed from field survey by total station and the average value is evaluated for every kilometer. SD_N 7values for a newly laid track and SD*U* a track needing urgent maintenance are tabulated below as per railway standards.

Table. 4. Standard deviation (SD) values [7] (Sadeghi & Asgarinejad, 2008)

Parameters	Length Chord	SD for newly laid track	SD values for urgent maintenance mm	
			SD for maintenance with Max. speed >= 105 km/h	SD for maintenance with Max. speed = 105 km/h
Unevenness	9.60	2.50	6.2	7.2
Twist	3.60	1.75	3.8	4.2
Gauge	1	1	3.6	3.6
Alignment	7.2	1.50	3.0	3.0

Table. 5. Calculation of Track Geometric Index

Track: VZM TO VBL		**Track Geometry Index**			
YEAR: 2015 Data					
Chainage	**Mean(Sa)**	**SD(Si)**	**Sei = Sa - Si**	**e**	**GI**
427	12.39	6.03	6.360	8.067187	806.7187
428	10.65	6.25	4.400	8.981096	898.1096
429	18.72	3.13	15.59	1.960444	196.0444
430	19.80	5.71	14.09	6.901283	690.1283
431	8.90	5.84	3.060	7.353100	735.3100
432	7.54	5.91	1.630	7.608517	760.8517
433	9.83	5.70	4.130	6.867700	686.7700
434	13.5	5.90	7.600	7.571493	
435	10.10	3.41	6.690	2.247360	224.7360
436	9.7	4.7	5	4.21658	421.658
437	19.28	3.83	15.45	2.758354	275.8354
438	11.04	3.6	7.44	2.465609	246.5609
439	18.53	5.5	13.03	6.229327	622.9327
440	1.23	1.56	-0.33	0.911482	91.14825
441	10.86	4.26	6.6	3.402091	340.2091
442	8.8	5.1	3.7	5.125081	512.5081
443	10.9	4.16	6.74	3.240118	324.0118
444	14.3	5.43	8.87	6.020209	602.0209
447	11.8	1.24	10.56	0.779751	77.97511
448	8.8	4.54	4.26	3.899996	389.9996
449	9.7	4.93	4.77	4.717219	471.7219
450	19.3	4.9	14.4	4.64869	464.869
451	20.6	5.613	14.987	6.58234	658.234
452	10.08	5.12	4.96	5.175327	517.5327
453	7.7	3.7	4	2.588865	258.8865
		4.64252	-4.64252	4.812769	481.2769
Obtained Value	**TI = 4.64**	GI = 481			
Considered values	**UI = 6.2**	**AI = 3.0**			

Therefore,

$$\text{TGI} = 2UI + TI + 6AI + GI/10$$

$$\text{TGI} = 2UI + TI + 6AI + GI/\text{n}$$

= 2(6.2) + 4.64 + 6(3.0) + 481 /10

= 51.6.

From the site work, the obtained TGI value is 51.6 but as per Indian Railway Specified the values is tabulated below [9].

Table. 6. TGI Classification for Maintenance

S. No	TGI Value (Track Geometry Index)	Maintenance is requirement
1	TGI > 80	No maintenance required
2	50 < TGI < 80	Need basic maintenance
3	36 < TGI < 50	Planned Maintenance
4	TGI< 36	Urgent Maintenance

As per above the table.6, the Value obtained 51.6 falls in the second condition within the limit of 50 < TGI < 80. So there is a need for basic maintenance of track from Vizianagaram to Bobbili section.

VII. CONCLUSION

In this study, deviation is estimated, which is the difference of the actual alignment. The measurement limits have been calculated based on the twist measurement of several vizianagaram to bobbili railway line sections, which are part of the East coast railway network. Direction and amount of deviations occurred are recorded upto about 30mm Maximum and 5mm minimum. Twist deviations exceeding limits in each chainage is compared with Limits specified by IR and chainages such as 426, 431, 435 and 441 are recorded as maximum. Embankment top width had losses to about 750mm. Among all the survey accomplished for the calculation of levels and alignment, the maximum deviations observed in the chainages are 435, 440, 441 and 445. All the problems associated with the track such as deviations and settlements have been solved based on parameters and the obtained values are TI = 4.64, GI = 481, UI = 6.2, AI = 3.0. Based on the estimated Value of TGI which is 51, falls in the second condition within the limit of 50 < TGI < 80, there is a need for basic maintenance of track from Vizianagaram to Bobbili section.

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