IN SEARCH OF AN OPTIMUM TRACK STRUCTURE: INDISPENSABILITY OF BALLAST ECONOMIC FOR SUITABLE AND SUSTAINABLE DEVELOPMENT

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ABSTRACT

The discussable pretext came under hypothecation when higher version of locomotive series needs to orient in the existing track grid pattern of Bangladesh Railway (BR). As such average contribution (%) of each load bearing permanent way element in regard of elastic behavior need to check critically as the track itself with its elasto-plastic properties cannot be expressed by an exact analysis because of the inhomogeneous behavior of the ballast bed, the protective layer of the formation and the subsoil. The superstructure thus includes all non-granular components of the railway track, while the substructure includes the granular components. Primarily mechanical model of railway tracks has been selected. The ballasted track structure dynamic responses vary largely on individual component properties. From the concluded remarks one could claim the finality in regard of maintaining track configuration and regular maintenance of existing track grid & track geometry by fostering the shortage of ballast cushion which may ensure the economic track where the higher initial quality can be translated into a longer service life due to suitable maintenance. Initial quality of an optimum track is often hindered due to speed restriction indication which is not new to Bangladesh Railway. This imposition of speed restriction is against the committed fable of BR.

Keywords: *Hypothecation, permanent way, inhomogeneous behavior, railway track, ballast cushion.*

1. INTRODUCTION

In order to make the decision-making procedures in regard of incorporate & introduce higher axle loaded locomotive & rolling stock in Railway Transport System sometimes calls for high technical and economical requirements as embodied by the quest for higher train velocities, larger transport capacity, lower energy consumption during transport, greater traveler comfort, better safety levels and lower maintenance costs.

The discussable pretext came under hypothecation when higher version of locomotive series needs to orient in the existing track grid pattern of Bangladesh Railway. As such average contribution (%) of each load bearing permanent way element in regard of elastic behavior need to check critically as the track itself with its elasto-plastic properties cannot be expressed by an exact analysis because of the inhomogeneous behavior of the ballast bed, the protective layer of the formation and the subsoil. Empiric parameters and connections found out by repeated trial experiments are used for this purpose where the track components are categorized into two groups. The first group is designated as the superstructure, consisting of the rails, the fastening system and the sleepers, where as the substructure, consisting of the ballast layer, a possible sub-ballast layer and the sub-grade (Figure 1).

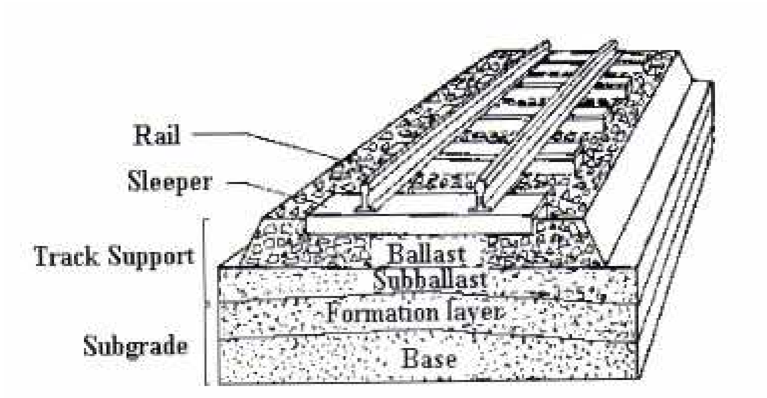

Figure 1: Railway ballasted track components

The superstructure thus includes all non-granular components of the railway track, while the substructure includes the granular components. To offer resistance to axle loads higher than 11.96T (existing), maintaining sufficient resiliency, strength and energy absorption are of prime, premium and supreme structural demand along with upgrading higher rail section with larger weight (90 lb). Ever increasing axle loads and pressing demand of higher train speed can be sustained at some extent by thorough maintaining the floating track support (Figure). The study of this paper has revealed the phenomenon of those propositions analytically.

2. METHODOLOGY:

Primarily mechanical model of railway tracks has been selected where elements of tracks are classified according to their properties as follows:

- Components with mass and inertia properties, rail and sleepers;
- Components with elastic properties, rail pads; and
- Components with mass, inertia and elastic properties; ballast.

The ballasted track structure dynamic responses vary largely on individual component properties, the contract relationship between components, the physical body of the components, and the dynamic load actions. Rail and sleepers with mass and inertia properties tend to keep the track stable under static longitudinal buckling forces. Rail pads and ballast with elastic properties soften energy transfer and dampen the dynamic force frequency, resulting in a lower and less harmful load action.

However, with the analysis it is found that in a well-ballasted track structure, the rail pad does not damp vibration of the sleeper and plays insignificant role in softening transient load action. In contrast, the greater is the rail pad damping constant, the more effectively are dynamic forces transmitted to the sleepers. It was also found that if the ballast damping is much greater than 2000 lb/y, which is typical of well-compacted ballast and railway track dynamic behavior is affected little by rail pad damping.

In response to the above a repeated review has been conducted which include a more specific definition of the loading environment and examination of: the relationships between the major wheel and vehicle parameters; the attenuation effects of schematic representation for the calculation of the optimum ballast bed thickness.

It would be impractical and costly to accumulate a comprehensive set of measurements of track forces under the varied mix of traffic and track in Bangladesh. Consequently, these force studies would be best undertaken by sophisticated track analysis model. The model includes the following:

a) Determination of Tractive effort (from T.E. curve) of the locomotive wheels.
b) Gear Effect.
c) Determination of Speed Effect.
d) Calculation of Total Loads at different speeds.
e) Analysis for stress in Rails.
f) Analysis for stress on formation.
g) Frequency spectrum of wheel loading.

Based on the above hypothecation, repeated analysis has been formulated on trial & error basis and recorded the results as described in the next Para(s).

3. RESULTS/SUMMARY OF THE FINDINGS

3.1 Comparative Stage Calculation

Axle Load of Locomotive vs Different Track Parameters

3.2 Track Particulars & Locomotive Parameters (Existing Position)

- Axle Load – 11.96 T
- Speed – 80 Kmph
- Rail – 75A
- Sleeper density – N+5
- Ballast Cushion – 4″

Sl. No	Stress Criterion	Calculated Value	Safe/Permissible Limit	Result	Remarks
1	Analysis for Stress in Rail (T/in^2)	9.168	14.00	Safe	-
2	Track Depressions and intensity of pressure on Formation (T/ft^2)	2.27	2.3	Safe	

3.3 Track Particulars & Locomotive Parameters (Stage - 01)

- Axle Load – 15.00 T
- Speed – 80 Kmph
- Rail – 75A
- Sleeper density – N+5
- Ballast Cushion – 4 ″

Sl. No	Stress Criterion	Calculated Value	Safe/Permissible Limit	Result	Remarks
1	Analysis for Stress in Rail (T/in^2)	12.214	14.00	Safe	-
2	Track Depressions and intensity of pressure on Formation (T/ft^2)	2.60	2.3	Not Safe	Sleeper density/Cushion or combination of both need to upgrade

3.4 Track Particulars & Locomotive Parameters (Stage - 02)

- Axle Load – 15.00 T
- Speed – 80 Kmph
- Rail – 75A
- Sleeper density – N+5
- Ballast Cushion – 6 ″

Sl. No	Stress Criterion	Calculated Value	Safe/Permissible Limit	Result	Remarks
1	Analysis for Stress in Rail (T/in^2)	12.214	14.00	Safe	-
2	Track Depressions and intensity of pressure on Formation (T/ft^2)	1.85	2.3	Safe	

3.5 Track Particulars & Locomotive Parameters (Stage - 03)

- Axle Load – 15.00 T
- Speed – 80 Kmph
- Rail – 75A
- Sleeper density – N+6
- Ballast Cushion – 4 ″

Sl. No	Stress Criterion	Calculated Value	Safe/Permissible Limit	Result	Remarks
1	Analysis for Stress in Rail (T/in^2)	12.214	14.00	Safe	Cushion need to increase at 6″
2	Track Depressions and intensity of pressure on Formation (T/ft^2)	2.420	2.3	Not Safe	

3.6 Track Particulars & Locomotive Parameters (Stage - 04)

- Axle Load – 15.00 T
- Speed – 80 Kmph
- Rail – 75A
- Sleeper density – N+6
- Ballast Cushion – 6 ″

Sl. No	Stress Criterion	Calculated Value	Safe/Permissible Limit	Result	Remarks
1	Analysis for Stress in Rail (T/in^2)	12.214	14.00	Safe	More satisfactory
2	Track Depressions and intensity of pressure on Formation (T/ft^2)	1.721	2.3	Safe	

3.7 Track Particulars & Locomotive Parameters (Stage - 05)

- Axle Load – 18.00 T
- Speed – 80 Kmph
- Rail – 75A
- Sleeper density – N+5
- Ballast Cushion – 4″

Sl. No	Stress Criterion	Calculated Value	Safe/Permissible Limit	Result	Remarks
1	Analysis for Stress in Rail (T/in^2)	15.22	14.00	Not Safe	Rail, Sleeper density/Cushion or combination of all need to upgrade
2	Track Depressions and intensity of pressure on Formation (T/ft^2)	2.934	2.3	Not Safe	

3.8 Track Particulars & Locomotive Parameters (Stage - 06)

- Axle Load – 18.00 T
- Speed – 80 Kmph
- Rail – 75A
- Sleeper density – N+5
- Ballast Cushion – 6″

Sl. No	Stress Criterion	Calculated Value	Safe/Permissible Limit	Result	Remarks
1	Analysis for Stress in Rail (T/in^2)	15.22	14.00	Not Safe	Higher grade of Rail need to introduce
2	Track Depressions and intensity of pressure on Formation (T/ft^2)	2.08	2.3	Safe	

3.9 Track Particulars & Locomotive Parameters (Stage - 07)

- Axle Load – 18.00 T
- Speed – 80 Kmph
- Rail – 75A
- Sleeper density – N+6
- Ballast Cushion – 6″

Sl. No	Stress Criterion	Calculated Value	Safe/Permissible Limit	Result	Remarks
1	Analysis for Stress in Rail (T/in^2)	15.22	14.00	Not Safe	Still Higher grade of Rail need to introduce
2	Track Depressions and intensity of pressure on Formation (T/ft^2)	1.936	2.3	More Safe	

3.10 Track Particulars & Locomotive Parameters *(Stage - 08)*

- Axle Load – 18.00 T
- Speed – 80 Kmph
- Rail – 90A
- Sleeper density – N+6
- Ballast Cushion – 6″

Sl. No	Stress Criterion	Calculated Value	Safe/Permissible Limit	Result	Remarks
1	Analysis for Stress in Rail (T/in^2)	11.16	14.00	Safe	satisfactory
2	Track Depressions and intensity of pressure on Formation (T/ft^2)	1.936	2.3	Safe	

3.11 Track Particulars & Locomotive Parameters (Stage - 09)

- Axle Load – 18.00 T
- Speed – 90 Kmph
- Rail – 90A
- Sleeper density – N+6
- Ballast Cushion – 6″

Sl. No	Stress Criterion	Calculated Value	Safe/Permissible Limit	Result	Remarks
1	Analysis for Stress in Rail (T/in^2)	11.60	14.00	Safe	satisfactory
2	Track Depressions and intensity of pressure on Formation (T/ft^2)	1.98	2.3	Safe	

3.12 Track Particulars & Locomotive Parameters *(Stage - 10)*

- Axle Load – 18.00 T
- Speed – 100 Kmph
- Rail – 90A
- Sleeper density – N+6
- Ballast Cushion – 6 ″

Sl. No	Stress Criterion	Calculated Value	Safe/Permissible Limit	Result	Remarks
1	Analysis for Stress in Rail (T/in^2)	12.20	14.00	Safe	satisfactory
2	Track Depressions and intensity of pressure on Formation (T/ft^2)	2.03	2.3	Safe	

4. CONCLUDING REMARKS

- Locomotives of 15T Axle Load can be introduced at maximum 80 Kmph with 75A Rail, N+5 Sleeper densities with the provision of maintaining 6″ Ballast Cushion

- Locomotives of 15T Axle Load cannot be introduced at maximum 80 Kmph with 75A Rail, N+6 Sleeper densities with the provision of maintaining 4″Ballast Cushion.

- Locomotives of 15T Axle Load can be introduced at maximum 100 Kmph with 75A Rail, N+6 Sleeper densities with the provision of maintaining 6 Inch Ballast Cushion.

- Locomotives of 18T Axle Load can be introduced at maximum 100 Kmph with 90A Rail, N+6 Sleeper densities with the provision of maintaining 6 Inch Ballast Cushion.

From the above remarks one could claim the finality in regard of maintaining track configuration and regular maintenance of existing track grid & track geometry by fostering the shortage of ballast cushion which may ensure the economic track where the higher initial quality can be translated into a longer service life due to suitable maintenance. Initial quality of an optimum track is often hindered due to speed restriction indication which is not new to Bangladesh Railway. This imposition of speed restriction is against the committed fable of BR which may better illustrate by the following bar chart:

Table 1: Length according to sectional speed with restrictions

Sectional speed with restrictions	Length (Km)
6 - 11	70.84
11 - 15	269.13
16 – 20	237.76
21 - 25	114.62
26 - 30	133.26
31 - 35	62.35
36 - 40	168.56
41 - 45	66.00
46 - 50	116.05
51 - 55	0.0
61 - 65	0.0
71 - 75	438.85
76 - 80	909.68
91 - 95	46.65

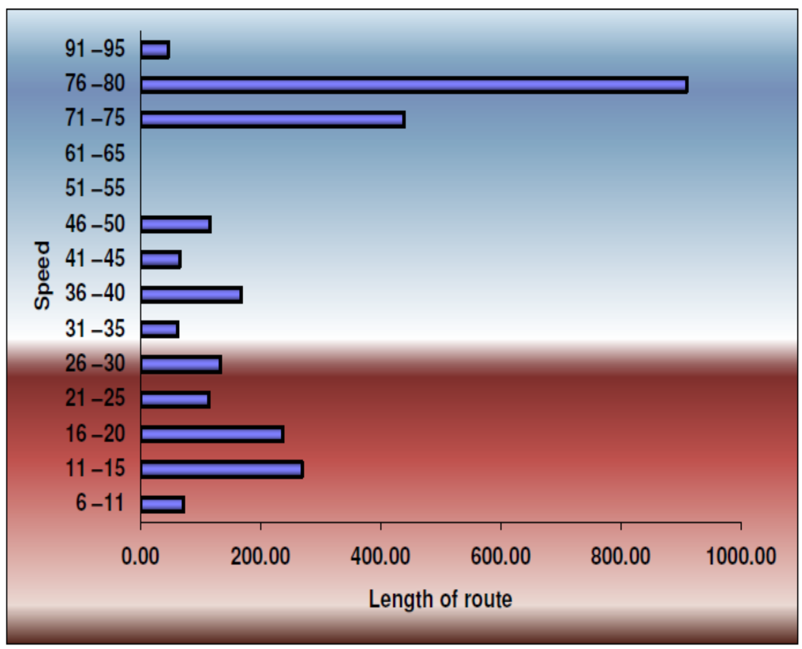

Figure 2: Speed vs. Length of route

[Source: Maximum permissible speed is 75 kmph for MG section & 100 kmph for BG section at BR Network]
[Source: World Bank's Railway Database]

The above context is quite unusual for a competent railway network like BR which has the glorious history of development, setting & seal of almost 154 years when recorded rail network was found at 03 countries in Asia, at 03 countries in Europe & at solitary country in America continent.

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