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Road and Rail Infrastructure V

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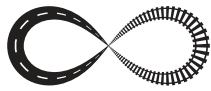
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POSSIBILITY FOR RUNNING FREIGHT TRAINS AT SPEED 80 KM/H ON EXISTING SAUDI RAILWAYS FREIGHT LINE

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Abstract

The aim of the study is to improve and upgrade the current operational speed from 60 km/h to 80 km/h on existing freight line of Saudi Railways Organization (SRO) network with upgraded infrastructure and higher axle load, the existing freight line currently running with a speed of 60 km/h with an axle load 225 kN, rail type UIC 54 Continuous Welded Rails (CWR), Pre Stressed Concrete (PSC) sleepers, the reason to increase the speed from 60 km/h to 80 km/h is because of the demands of freight transportation (containers transportation from eastern region to the central region), in order to enhance the speed a solution was proposed by the SRO management to conduct a study for increasing the speed to meet the upcoming higher volume of freight containers transportation within a limited time period, same time to increase the axle load to bear double containers freight traffic. Monitoring of the existing railway track was done by Engineering Survey team, operational speed was recorded in different locations with higher and lower gradient points, data of axle pressure was accorded from rolling stock department to establish a new proposal for increasing speed and axle load. The proposed solution will effect on the existing freight line, it will requires to upgrade the existing track infrastructure (rails, sleepers, ballast profile, curves, culverts and bridges etc.), it will also effect on the cost of current budget as a result of upgradation and maintenance of existing railway track, it will ultimately an economic benefit from the increasing freight transportation of SRO.

Keywords: railway, speed, safety, freight line

1 Introduction

The network of railways in the kingdom is extended with a total length of 1,412 kilometers, and it links two regions, Eastern Region and Central Region, where 40 % of the population is located as well as 50 % of the economic activity is going on. The SRO trains carry annually more than 1.3 million passengers and 350 thousands containers, which means more than 80 % of the containers directed to Central Region through Dammam Port in Eastern Region and two million tons of ordinary movable goods which need about 500 thousands trucks to be shipped on the road, [1]. The number of passengers and cargo is expected to grow after operating the existing expansion projects and those are being planned, as the number of traded containers on the land bridge project (see fig. 1) expected to be on the year of 2020 more than 700 thousands typical containers which mean a total of 8 million tons of cargo, [1]. As per Integrated Railways Modernization Plan (2015-2020), SRO would be handling approximately 9 million tons of freight traffic, to meet this ambitious growth rate of over 6 % in freight traffic, it has been planned to run higher axle load wagons at an increased speed of 80 km/h. [1] Further emphasis has been given on development of improved rail-port in

Dammam Eastern Region of Kingdom of Saudi Arabia (KSA) connectivity and dedicated freight corridor towards Central Region. The running of 80 km/h freight train will be primarily started on high density golden quadrilateral and its diagonals connecting the three metropolitan cities Dammam, Hufuf and Riyadh. The scope of this research is limited to the implication of increasing the speed of freight train to 80 km/h, [8].



Figure 1 Land Bridge Project (Dammam, Riyadh, Jeddah)

2 World Scenario

In various advanced countries like America, Australia, Japan etc., the freight train are already running at 100-200 km/h. In these countries the freight trains runs on a dedicated freight lines, also in SRO there are dedicated lines for freight line no. 2 and for passage line no. 1 & 3, but some time rail infrastructure has to carry both goods and passenger traffic, [6].

3 Implications of increasing speed of freight train to 80 km/h

The implications of increasing the speed will effect on dynamic increase, rail stresses, sleepers, ballast, formation, track geometry, wheel flat, bad welds, culvers and track maintenance costs.

3.1 Effect of dynamic increase

In SRO, the value of dynamic increase is adopted on the basis of results reported in yearly report published in 2015, in the yearly report tests for speed effect were conducted between Hufuf – Riyadh section of railway Al route Dammam to Riyadh. The track consisted of 52 UIC rails with standard fish plated section on CST-9 sleepers and the vehicles selected were diesel electric loco (GMC4, GMC6, Bogie Coach (all coiled IRS) Bogie wagon (BOS MK-1, BCX MK 11 etc.) 4 wheelers (OH/CR) based on the data collected during the trial, envelope curves have been drawn for the following two categories [4]:

- Locomotive;
- Bogie wagons.

The value of dynamic increase for locos and wagons is calculated from these enveloping graphs. These values suffers inadequacies on following two accounts.

- The vehicles have changed and their suspension is materially different from the once provided on stock used for freight doubling line.
- Presently the track consists of mainly UIC 54 kg rail laid on PSC sleepers against 90R on CST-9 sleepers used in freight doubling line. This is expected to cause a change in track response.

Though the value of dynamic increase has been adopted as per the values given in freight doubling line but it is recommended that these values must be revised based on present rolling stock and latest track structures, [5].

3.2 Rail stresses

In SRO, rail stresses are calculated by theory of “Beam on Elastic Foundation” (BOEF) treating rail to be continuous beam supported closely spaced elastic supports. The calculation takes into consideration the factors like effect of adjacent wheel, speed effects, [6]. The bending stress in rail for axle load of 225 kN & 325 kN for BOXN double deck container wagon for 54 kg & 60 kg rails have been calculated for 60 km & 80 km and shown in following table, [8].

Table 1 Calculation of rail stresses

No.	Rail Section	Axle Load	Maximum Rail Stress at different speeds [kg/mm ²]	
1	54 kg	22.5 ton	60 km	80 km
			21.26	22.64
		22.5 ton	23.52	25.20
2	60 kg	32.5 ton	20.41	21.41
<i>Permissible Stresses</i>		<i>72 UTS</i>	<i>90 UTS</i>	
		<i>19.25 (CWR)</i>	<i>22.25 (CWR)</i>	

3.3 Effect on sleepers

The primary function of a sleeper is to transmit the load of rolling stock to the formation through ballast, while maintaining the gauge, cross-levels and alignment. On SRO the sleeper has been standardized to 60 kg PSC mono block sleeper. Rational design of sleeper is difficult as the load on rail seat, which govern the design of a sleeper, is dependent on a number of factors like dynamic wheel load, sleeper spacing, and condition of track expressed as track modulus and bending stiffness of rail. The design of sleeper has therefore been evolved on the basis of simplified loadings and extensive field trails on the sleepers so designed. The present design of 210 kg PSC mono block sleeper has been evolved for current axle load of 225 kN, [6]. To understand the implications of increase in speed on sleeper, it is necessary to know the load transferred at rail seat by the axle load, which is given by the following expression:

$$W = Q_s (U/64EI)^{0.25} \quad (1)$$

Where: *W* – load at rail seat of the sleeper; *Q* – static wheel load; *S* – spacing of sleepers; *U* – track modulus; *E* – modulus of elasticity of rail section; *I* – moment of inertia of rail section.

The static wheel load worked out is increased by 150 % to account for dynamic wheel load for the axle load of tones, the value of static wheel load at rail seat for 60 kg rail section with a spacing of 60 cm, with a track modulus of 75 kg/cm for first 4 ton and 300 kg/cm for the remaining, works out to 5.232 tones, which is no different from the design static load of 6 tones. Hence the new design of 220 kg PSC mono block sleepers will suffice for the increase in speed to 80 km/h with an axle load of 325 kN, [6, 8].

3.4 Effect on ballast

The support beneath the rails is a critical factor for effective transfer of loads, as per a classic text in railroad engineering, writes:

- The track structure truly is a system. The quality of one component affects overall performance, as well as the life expectancies of other components. Simply increasing the weight of rail, which creates greater stiffness or bending resistance, will not necessarily compensate for other poor components (e.g., sleepers or ballast), [3].
- The function of ballast is to transfer and distribute the load from sleepers to larger area of formation, to provide elasticity and resilience to track for riding comfort, to provide effective drainage, to provide necessary longitudinal and lateral resistance to track and to provide means for maintenance of alignment and unevenness. Increased speed will require increased depth of ballast cushion, [3].

Table 2 Load of axle on ballast

No.	axle load/GMT	Depth of ballast (cm)	Depth of sub-ballast (cm)
1.	For 225 kN		
	Up to 15	20	15
	15-35	25	15
	More than 35	25	25
2.	For axle load 325 kN		
	Up to 15	30	30
	15-35	30	60
	More than 35	30	70

3.5 Effect on formation

The formations on the core routes of SRO were constructed many decades ago, without any consideration to the soil strength and its geo-technical requirements. Due to phenomenal increase in axle loads, traffic and speeds during the recent years, large lengths of formations have started showing signs of distress and instability and their lengths are likely to increase with increase in speed, [4]. Even with present axle load and speed over 60 km is identified as weak formation and as much as 40 km is under speed restriction on this account. With increase in effective axle load with speed more length will cross threshold limit and get added to the list. The formation treatment should be planned in phase manner to remove the speed restriction so implementation of unrestricted speed of 80 km/h for freight traffic can be achieved, [8].

3.6 Effect of track geometry

Dynamic effects of 225 kN axle loads have been reported in technical studies for different speeds, track quality and radius of curves. The track quality was expressed in terms of standard deviation of vertical profile and alignment. Track with standard deviation σ less than 1

mm was considered to be very good that with 1-2 mm good and more than 2 mm moderate. The important results of the above studies are [5]:

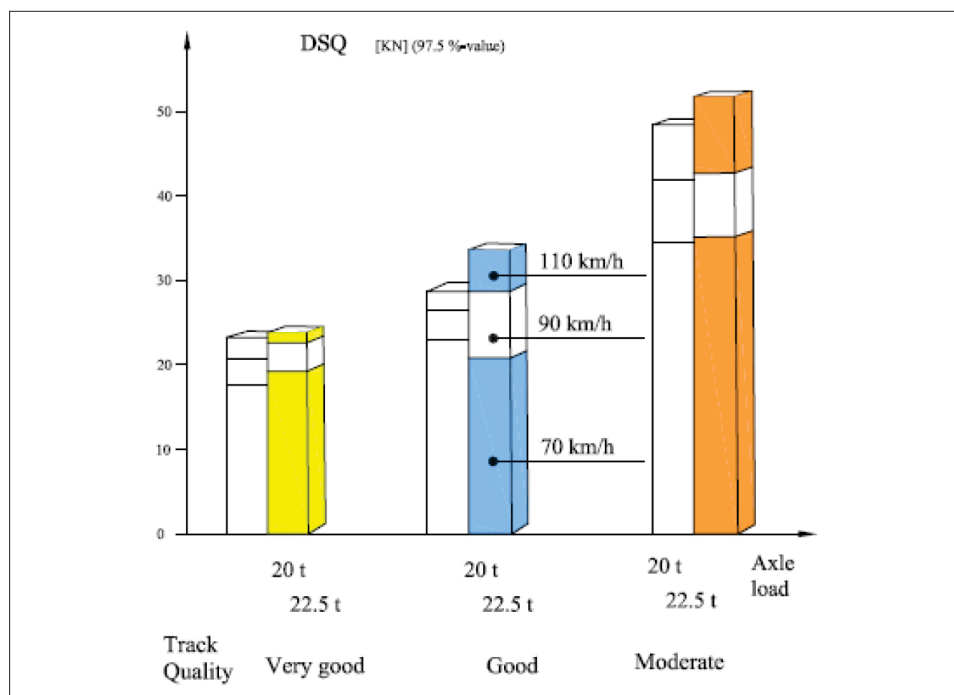


Figure 2 Dynamic component of wheel load, axle load, speed and track quality

- The dynamic wheel force increases with the increase in speed and a poorly maintained track will have most pronounced effect, where increase in the wheel force can be up to 22 % of axle loads for speed ranging between 60 to 80 km/h.
- The lateral rail-wheel force increases with increase in curves and deterioration of quality of maintenance.
- Stability of track depends upon the total lateral track load especially that part which is present over a length of at least 2 m. This lateral load referred to as ΣY_{2m} increases with increase in curves.

$$\Sigma Y_{2m} < 0.85 (10 + Q/3) \tag{2}$$

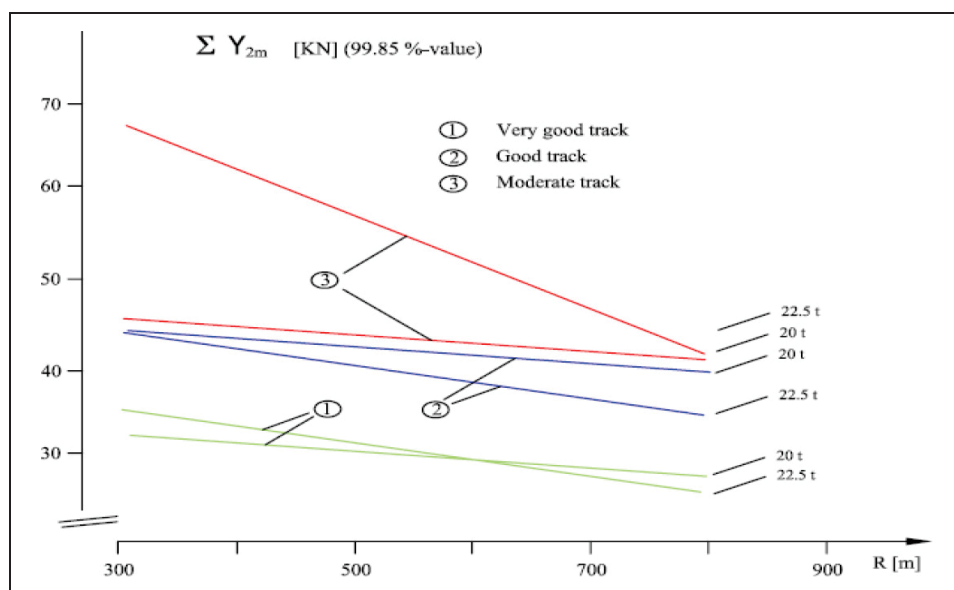


Figure 3 Dynamic Lateral load in curves

From the figure 3 it can be observed that the lateral force ΣY_{2m} increases with increase in curves and deterioration of quality of track maintenance. Though it is not possible to apply the above studies directly to SRO conditions because of difference in rolling stock and track, but it gives a fair insight into the disturbances in geometry caused due to the lateral forces on sharp curves. From the figure 3 it can be seen that the limiting value is likely to be reached for curves sharper than 450 m radius. [5] Thus the curves in general and with radius sharper than 450 m in particular will require a greater care of track geometry with increase in speed.

3.7 Effect of wheel flats

The largest loads applied to the track from vehicles are those which arise from irregularities on wheel such as wheel flat. The reports of the tests carried out on flat tires measuring the effects of speed, size, sleeper type and axle loads. The results reveal;



Figure 4 Effects of speed and higher axle loads

The relationship between the flat size and force is almost linear. The increase in dynamic wheel force is more for concrete sleepers than for wooden sleepers. Studies have also revealed that movement of wheels with flats can generate dynamic forces, as high as six times the normal static load, in extreme situations. The Dynamic forces increase with increase in speed and axle loads. On SRO, the effect of rail/wheel defects and vehicle suspension, on static wheel load, is represented by a speed factor which can assume a maximum value of 1.75 for locomotives and 1.65 for wagons. Such occasional high loads may result in higher rail stresses reducing the fatigue life of rails and causing fracture of rail/welds in extreme cases. The problem assumes alarming proportions in case of thermite welds (which have the impact strength of 7-10 % of parent rail) in CWR territories, during winter season, when the full tensile stresses are present in rail section, [8].

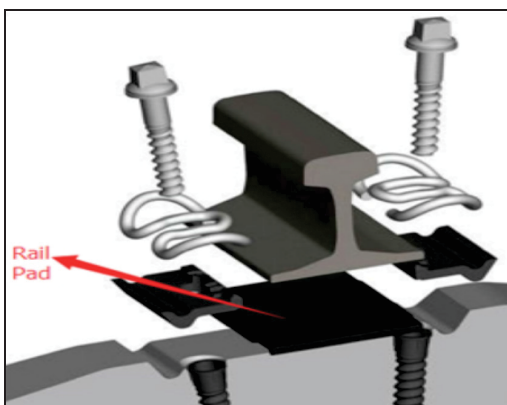


Figure 5 Rail pads for reducing impacts loads

According to UIC leaflet, flats on wheel with diameter of 1000-630 mm should be restricted to a length of 60 mm and a depth of 0.9-1.4 mm, on SRO, the permitted sizes of wheel flats are 50 mm for locomotives and coaching stock and 60 mm for goods stock, [8]. So far as the permitted size of wheel flats are concerned, it is sincerity of detection and errored detachments of wagons with flats, another possible solution could be use of flexible rubber pads, which has potential of reducing the impact loads, [5].

3.8 Effect of bad welds

Even relatively small vertical deviation in weld geometry can cause huge dynamic forces on passage of a wheel. Misalignments are especially responsible for this, in order to confine these dynamic load geometrical deviation in welds should be limited to a few tens of a millimeter. [3] An example of load distribution as a function of time during passage over a poor weld, the behavior is small like sharp peak of some millisecond i.e. force which only has a local influence on wheel/rail contact stress much broader which penetrates the whole construction as effect of bad weld showing Fig. 6, [7].



Figure 6 Effects of bad welds

3.9 Effect on culverts

During the inspection after the 80 km/h speed test which was conducted between Huf-Riyadh section of SRO network Dammam-Riyadh, It was observed the effects of increasing speed with existing axle load on culverts it starts to appear cracks and settlement in foundation was noticed see Fig. 8, [5]. Other factors which may affects as:

- Atmospheric conditions such as extremely high or low temperatures and air-pollution may cause abnormal expansion, contraction and distortion of steel girders, freezing of moisture in voids or gaps leading to cracks, corrosion of reinforcement, softening of mortar, deterioration of masonry and spilling off of concrete, etc.
- Flow of water over the designed discharge with high velocity may scour and undermine the bridge foundations. Debris transported by flowing water may block the waterways.
- Impact loads, vibrations, scour and ground water movements may cause settlement of foundation and longitudinal or lateral displacements or cracks in the structure.
- Loads exceeding the designed values and excessive earth pressures may lead to the failure of the bridge structure.
- Lack of adequate cushions over the culverts may result in their getting crushed.
- Faulty materials and workmanship may cause cracks or other faults in the concrete structure, [6].



Figure 7 Effects of increasing speed and higher axle load on existing culverts of fright line

3.10 Increase in track maintenance costs

The increase in the speed with higher axle loads will effect on the cost of current maintenance as well as the upgradation of the existing infrastructure, in this way SRO established a track infrastructure technical committee in collaboration with Al-Mobty Company for contracting track maintenance management, the initial report states that it will be an increment up to 20 % in existing cost of track maintenance that will be around 38.6 million Saudi Riyals, [8]. The committee developed method for quantitative calculations as per following expressions;

$$E = K T^\alpha P^\beta V^\gamma \quad (3)$$

Where:

- E – deterioration since renewal or last maintenance operation;
- T – Tonnage;
- P – total axle load (static + dynamic);
- V – speed;
- K, α , β , γ – constants, depends on track geometry deterioration, rail surface defect & culverts.

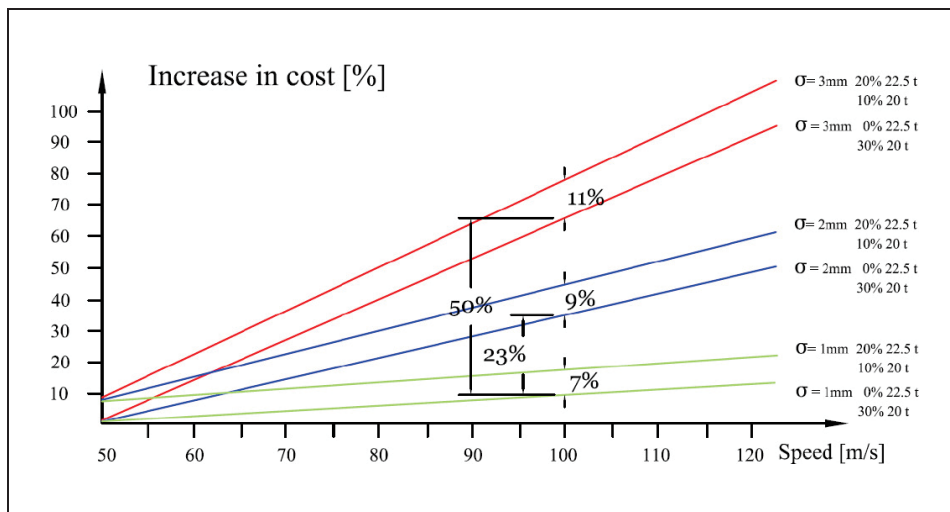


Figure 8 Increase in maintenance cost in relation with track quality, axle load and speed

4 Conclusion

Following are the conclusions on the requirement of track structure for operation of 325 kN axle load wagon is as under:

- Rail: 60 kg (60 E1);
- Sleeper: PSC (in special cases ST sleepers with elastic fastening);
- Sleeper Density: 1660 Nos.
 - a) As a maintenance strategy it may be necessary to destress CWR twice, once before winter and again before summer especially in Siding No. 5 to Siding Harad the behavior should be critically watched.
 - b) Increased ballast cushion as stipulated in SRO letters to Al-Mobty.
 - c) The treatment for bad formation should be planned route wise, in phase manner, to remove the speed restriction so that, implementation of unrestricted speed of 80 km/h for freight traffic can be achieved.
 - d) Track is to be maintained to high standard by reducing the track tolerances by using mechanized method of maintenance, reduce the overall maintenance cost as the maintenance cost increases with speed and with deterioration in track quality.
 - e) Preventive Rail Grinding at predetermined intervals will not increase safety but also it will be as cost effective solution for prolonging the life of rails.
 - f) Curves in general and sharper than 750 m radius in particular will require better maintenance of track geometry, as the lateral forces on curved track increases with increase in axle load and increase in speeds hence they have to be inspected more frequently.
 - g) Wheel flats are to be given a serious consideration in terms of detection, enrooted detachments, SRO needs to ensure that the wheels are going for profiling and wheel length.
 - h) Bridges are to be maintained to be fit to at least SRO high speed manual standard.
 - i) Culverts approaches where the track stiffness changes abruptly, will require special monitoring due abrupt changes in vertical dynamics of heavy wheels. Bridge approaches on either side up to 50 m should be maintained critically.

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