International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-11, September 2019

Optimal Design and Spacing of Mono-Block Prestressed Concrete Sleeper under Vertical load

Mohamed Y Mohsen, Hany I Ahmed, Hany S Riad, Amr A Abdel Rahman

Abstract**: *The present paper proposes scientific and practical methodology to solve the following problems: the value of dynamic impact factor, sleeper spacing, Wheel load distribution along successive sleepers, stress beneath the sleeper and stress reduction within the railway successive layers. The proposed methodology aims to determine the following items: the suitable sleeper spacing for a given rail type, the wheel load distribution along successive sleepers, the moment within mono-block pre-stressed concrete sleeper (B70), the crushing strength between (sleeper and ballast surface) and finally the suitable effective ballast depth. A feasibility study to calculate the total cost of 1Km of either a single track or a double track per year, as well as selecting railway track elements economically & technically according to the external loads and mechanical characteristics.***

Keywords: Effective ballast depth and Railway construction feasibility study, pre-stressed concrete sleeper (B70), sleeper spacing, vertical dynamic Load.

I. INTRODUCTION

The railway track is subjected to loads that are vertical, transversal and longitudinal which are generated by the rolling stock running on the track apart from the forces that are exerted due to earthquake. Vertical Loads considered as a part of all lateral and longitudinal forces acting on the track, either directly or indirectly [1]. They are playing a very important role in the design, construction, operation and the maintenance of the track, their vertical strain determine the rail type selection, the sleepers' material, spacing, fastenings, dimensioning of the elastic pads and ballast depth [2]. The vertical loads are exerted on the rail rolling surface and are transferred to the subgrade through the track components. During their transfer, the surface area increases, while the developing stresses decrease [3, 4].

II. WHAT IS THE DYNAMIC IMPACT FACTOR β?

The design of track components is usually conducted with the help of static analysis. The question arises, however, what is the dynamic impact factor β by which the static load should be multiplied in order to take into account in the static analysis the dynamic effects [5]. "(1)" according to Schramm (β) had been used.

Manuscript published on 30 September 2019.
*****Correspondence Author(s)

Mohamed Youssef Mohsen, Civil Engineering department, Beni-Suef University, Beni-Suef, Egypt. Email: myoussef209@gmail.com
Hany Ibrahim Ahmed, Civil Engineering department, Beni-Suef University, Beni-Suef, Egypt. Email: Hany281@yahoo.com
Hany Sobhy Riad, Civil Engineering department, Ain Shams University, Cairo, Egypt. Email: HanySobhyR@yahoo.com
Amr Ali Abdel Rahman, Civil Engineering department, Ain Shams University, Cairo, Egypt.

$$\beta = 1 + C\,[(4.5S^2/10^5) - (1.5S^3/10^7)] \qquad (1)$$

Where:
S: Train speed (Km/hr)
C: Correction factor depending on track element

III. CONCRETE SLEEPERS SPACING AND DESIGN

The present study deals with the prestressed monoblock concrete sleeper, the same procedure can be applied for reinforced twin block.

A. Sleeper Spacing

If the sleeper spacing is small, track maintenance will be more difficult, while the closer the sleepers are spaced, the better the load distribution and the smaller stresses developed. A compromise should therefore be found between the above two requirements. Sleeper spacing has an optimum value for standard gauge tracks is 0.60 m, which can be reduced to 0.55 m in cases of subgrade inadequacy and small radius of curvature with maximum tolerances ± 0.02m [6]. In railways with higher values of axle load (e.g., the USA), sleeper spacing may be reduced to 0.50 m. On lightweight railways, sleeper spacing may be increased, but rail fatigue must be carefully considered [7]. The present paper proposes a methodology to overcome the above mentioned problem, this methodology based on scientific and practical knowledge and applicable through the following steps:

Step 1: Applying "(2)" of Johan's formulas to calculate the maximum bending moment M

$$M = P_w\, L_s\, \alpha\, \beta \qquad (2)$$

Where:
P_w: wheel load taken 12.5 ton
L_s: sleeper spacing
$\alpha = 0.057 + (x_1+x_2)/2400$ = factor taking into consideration the effect of x_1 & x_2 which are the distances in cm from the front and rear wheels to the wheel in between respectively, for x_1 and x2 more than or equal to 280 cm, therefore $\alpha = 0.29$

Step 2: Assuming maximum permissible rail stress (f) = 2000 Kg/cm² for $S \le 60$, equal to 1750 Kg/cm² for $60 < S < 100$ and equal to1500 Kg/cm² for $S \ge 100$ Kph.

Step 3: "(3)" for Calculating the suitable sleeper spacing for a given rail type.

$$L_s = 1.25 \times (Z \times f) / (P_w\, \alpha\, \beta) \qquad (3)$$

Where:
Z: Rail section modulus.

Figure (1) summarize the suitable sleeper spacing for a given rail type under a wheel load of 12.5 ton.

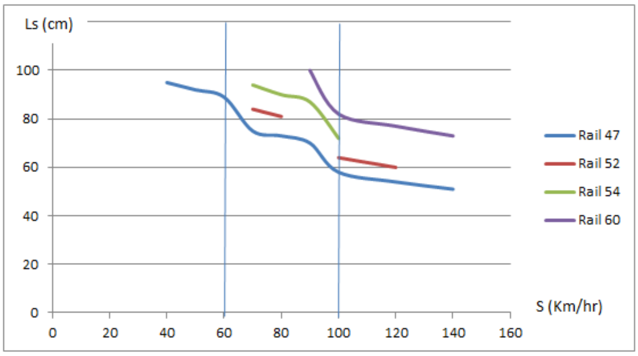


Fig.1. Suitable sleeper spacing for a given rail type under a wheel load with12.5t

From figure (1), it's clear that Sleeper spacing increases with decreasing the speed and rail ENR47 (Egyptian National Railways) gives a sleeper spacing smaller than other rail types also, the smaller rail used the smaller sleeper spacing developed. Rail ENR47 can be used for any speed while Rail UIC 60 used for speed more than 90 Kph and Rail 54 is used for speed between 70 to 100 Kph as well as rail 52 is recommended to be used for speeds (70 to 80 Kph) and (100-120 Kph). Rail ENR47 only is used for Speeds less than 60 Kph while for speeds (60-100 Kph) all rail types are used and for speeds greater than 100 Kph all rail could be used except rail 54 and finally by applying a feasibility study the lowest construction cost could be applied for speeds (60 to 140 Kph).

B. Sleeper Design

- Distribution of wheel load along successive sleepers:

The sleeper below the direct wheel load is assumed to support 50% while the neighboring sleepers support 25% for each side. Recently, wheel load distribution along successive sleepers is found according to stress measurements and finite element analysis applications as shown in figure (2), [8].

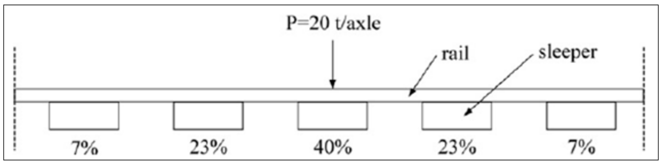


Fig.2. Wheel load distribution along successive

- Stresses developing beneath the sleeper

Analysis of the effects occurring at the sleeper-ballast interface is especially complex; it belongs to the unilateral contact problems of mechanics and at present no analytical results can be obtained [9, 10]. The present research assumes the most practical distribution of sleeper ballast contact stress as shown in figure (3).

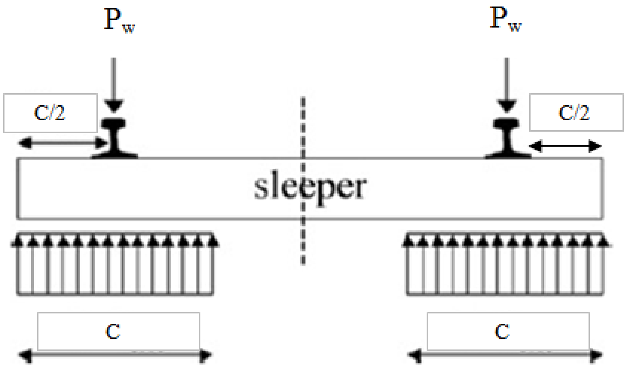


Fig.3. Simplified sleeper model

Stresses between ballast and sleeper are considered uniform over a length 2C below each rail However, the last assumption is not accurate [9, 10]. Methodology is proposed to determine the wheel load distribution along successive sleepers:

Step 1: Applying "(4)" of Zimmermann formula.

$$\xi = n\sqrt[4]{\frac{@bc\,L_s^3}{2EI}} \tag{4}$$

Where:

ζ: Sleeper spacing according to Zimmermann formula

@: Sleeper reaction coefficient

b: Sleeper width

C: Length of the uniform stresses between ballast and sleeper

E: Young's Modulus and

I: Rail inertia.

Step 2: Using the deflection curve proposed by Zimmermann. Figure 5 gives a relation between relative sleeper distances (ζ) versus relative deflection (y).

Step 3: Determining wheel load distribution along successive sleepers for @=25 kg/cm/cm, b= 25 cm, C= 110 cm and L_s = 60 cm, when using Rail ENR 47, ENR 52, ENR 54, or UIC60 which have 1670, 2090, 2297 and 3055 cm^4 Inertia respectively. So, the load distribution on 5 successive sleepers shown in figure (4) can be calculated from "(5)"

$$P_z = P_w / (y_o + 2(y_1) + 2(y_2) \tag{5}$$

Where:

y_o = Sleeper deflection beneath wheel load = 1

y_1 = Sleeper deflection at first neighboring sleeper

y_2 = Sleeper deflection at second neighboring sleeper

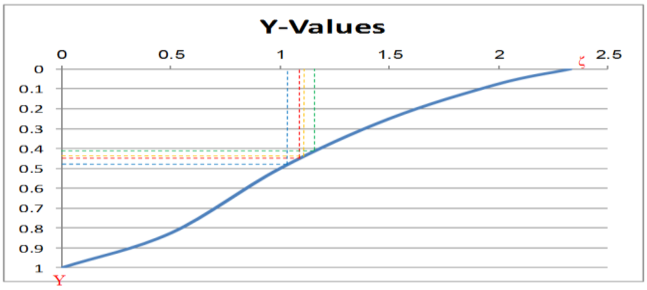


Fig.4. Zimmermann distribution of relative sleeper deflection y versus sleeper spacing according to Zimmermann formula

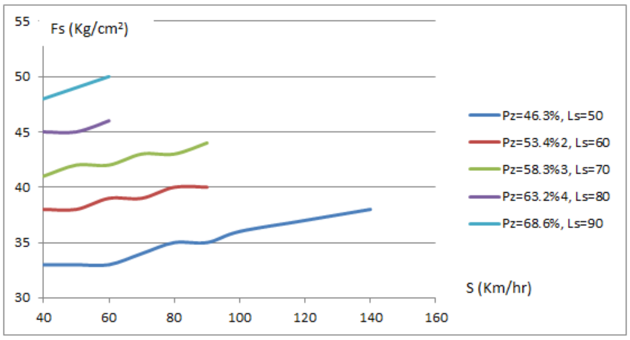


Fig.5. Sleeper share P_z when the wheel is applying directly over this sleeper for rail type ENR47, ENR52, ENR54, and UIC 60 respectively

Figure 5 summarizes the sleeper share P_z for the wheel load P_w when the wheel is applying directly over this sleeper when rail type is ENR47, ENR52, ENR54, and UIC60 respectively under the following conditions @=25, b=25cm, c=90cm and sleeper length =240 cm.

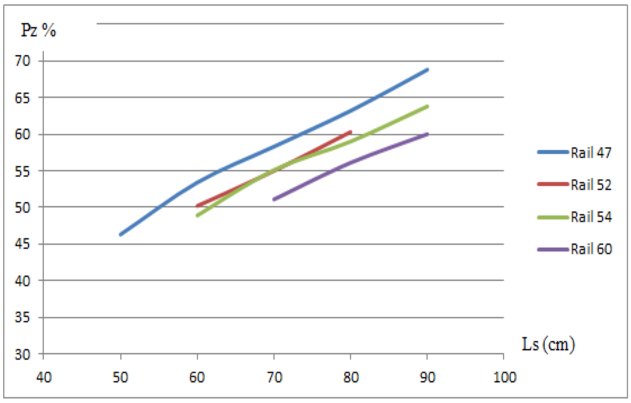


Fig. 6-a. Moment of B70 sleeper and the corresponding maximum stress using rail ENR47

From figure (5), the sleeper share under direct wheel load ranging from 46.3% to 68.8%. Also, the maximum sleeper share developed when using rail ENR 47 while the minimum sleeper shares when using Rail UIC 60 where ENR 52 and ENR 54 are most likely each other. Table (1) Summarizes the percentage share of wheel load (P_w) along successive sleepers according to Zimmermann formula for sleeper spacing 60 cm.

Table (1) Load distribution along successive sleepers according to Zimmermann formula for Rail ENR47, ENR 52, ENR 54 and UIC 60

Rail type	ENR47	ENR52	ENR54	UIC60
Sleeper just under load	55.50%	52.70%	51.50%	47.90%
First successive	22.25%	22.78%	22.91%	23.15%
Second successive	0%	0.87%	1.33%	2.89%

Source: authors.

- Sleeper stress (F) : Applying “(6), (7)”

$$M_{sleeper} = P_z \times \beta_{sleeper} (L_{sleeper} - G - W_{r1} - W_{r3})/8 \quad (6)$$

$$F = (M_{sleeper} / Z_{sleeper}) \quad (7)$$

Where:
$M_{sleeper}$: Maximum bending moment under the rail center line
P_z: sleeper share for the wheel load P_w
$\beta_{sleeper}$: Shramm's formula at C = 0.4
$L_{sleeper}$: Sleeper length
G: Standard gauge =1435mm
W_{r1}, W_{r3}: Rail head width, Rail foot width respectively.
$Z_{sleeper}$: sleeper section modulus.

Figures (6a-6d) shows moment ($M_{sleeper}$) within mono-block pre-stressed concrete sleeper (B70) and the corresponding maximum stress (F), for wheel load = 12.5 ton, $Z_{sleeper}$ = 1755.513 cm^3, @=25, b=25 cm, c=90 cm, L_s=60cm and sleeper length = 240 cm.

From figure (6-a), sleeper spacing of 50 cm is valid for speeds from 40 to 140 Kph corresponding to sleeper stress from 33 to 38 Kg/cm2 respectively. Sleeper spacing of 60 & 70 cm are valid to speeds from 40 to 90 Kph corresponding to sleeper stresses from (38 to 40 Kg/cm^2) and (41 to 44 Kg/cm^2) respectively. Also, Sleeper spacing of 80 & 90 cm are valid for speeds less than 60 Kph corresponding to sleeper stresses more than 45 Kg/cm^2.

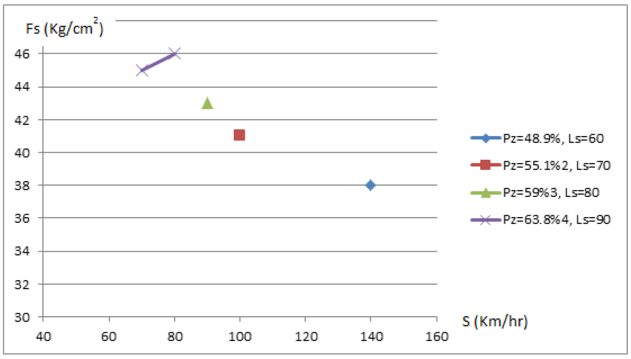
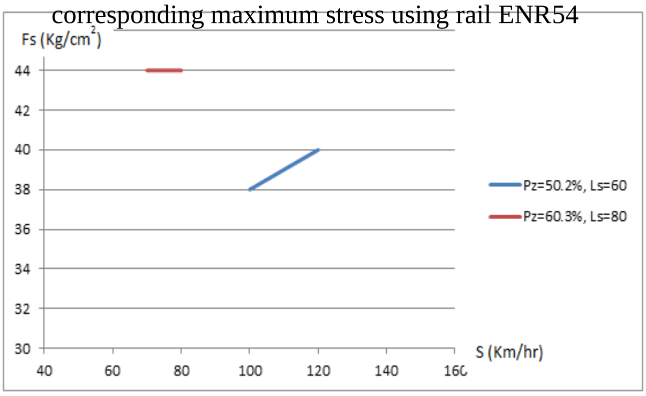


Fig. 6-b. Moment of B70 sleeper and the corresponding maximum stress using rail ENR52

Fig. 6-c. Moment of B70 sleeper and the corresponding maximum stress using rail ENR54



From Fig. (6-b), Sleeper spacing of 60 cm are valid for speeds from 100-120 Kph corresponding to sleeper stresses from (38 to 40) Kg/cm^2 and Sleeper spacing of 80 cm are valid for speeds 70-80 Kph corresponding to sleeper stresses 44 Kg/cm^2.

From Fig. (6-c), Sleeper spacing of 60, 70 and 80 cm are valid for speed 140, 100 and 90 Kph corresponding to sleeper stresses 38, 41 and 43 Kg/cm^2 respectively and Sleeper spacing of 90 cm are valid for speeds 70-80 Kph corresponding to sleeper stresses 45-46 Kg/cm^2.

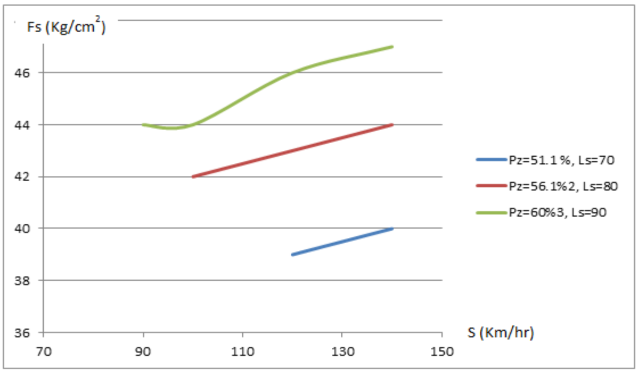


Fig. 6-d. Moment of B70 sleeper and the corresponding maximum stress using rail UIC60

From Fig. (6-d), Sleeper spacing of 70 cm are valid for speeds 120-140 Kph corresponding to sleeper stresses 39-40 Kg/cm^2. Sleeper spacing of 80 cm are valid for speeds 100-140 Kph corresponding to sleeper stresses 42-44 Kg/cm^2. Sleeper spacing of 90 cm are valid for speeds 90-140 Kph corresponding to sleeper stresses 44-45 Kg/cm^2, while Rail UIC 60 is not appropriate for sleeper spacing less than 70 cm.

IV. BALLAST SECTION DESIGN

A wheel load of 10 tons has a wheel rail contact stress = 7700 kp/cm^2 which transmitted to the rail base plate to be 20 kp/cm^2. When the stress transmitted to the sleeper track bed contact the stress becomes 2kp/cm^2, then finally the stresses are reduced to be 0.4 kp/cm^2 on track bed subgrade contact as shown in figure 7.

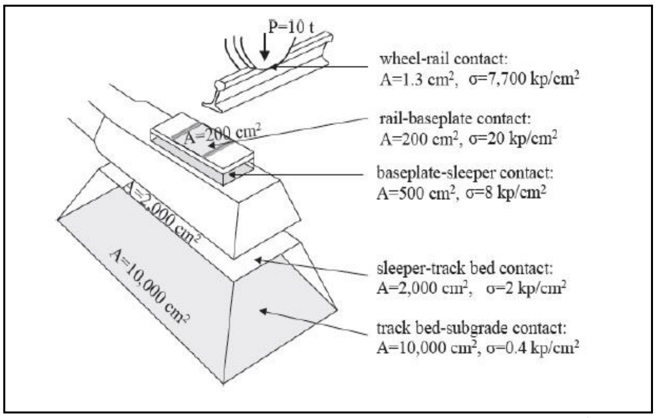


Fig. 7. Stress reduction due to successive layers of railway track

$$P\,(III) = \frac{1.5\,Pz\,\beta\,Soil}{(3C+b)\,hb\,Tan\,\omega}$$

From figure (7), it is deduced that Stresses are reduced by 19250 times between the point where the wheel load is applied and the sub grade [11]. "(8), (9)" represent contact pressure between sleeper and ballast $P_{(I)}$ and the contact pressure between ballast and subgrade $P_{(III)}$.

$$P\,(I) = \frac{Pz\,\beta\,ballast}{(C \times b)} \quad \leq \quad \text{Ballast crushing strength} \qquad (8)$$

$$P\,(III) = \frac{1.5\,Pz\,\beta\,Soil}{(3C+b)\,hb\,Tan\,\omega} \quad \leq \quad \text{Subgrade bearing capacity} \qquad (9)$$

C=*L*-*A*= 90cm, *L*: sleeper length, *A*: distance between centerlines of the track rails
b= sleeper width =25 cm, **ω**= angle of repose =45° for good ballast & 33° for bad one.

Table (2a-2d) Summarizes the crushing strength between sleeper and ballast surface for wheel load = 12.5 t for the following rail types ENR47, ENR52, ENR 54 and UIC 60.

Table (2a) Crushing strength between sleeper and ballast surface for wheel load 12.5 ton for rail ENR47

P_z (ton)	*Speed* (Km/hr)	β	*P(I)* Kg/cm²
	P_z = 46.3% P_w		
5.788	100	1.060	2.7
	120	1.077	2.7
	140	1.094	2.8
	40	1.012	2.6
	50	1.018	2.6
	60	1.025	2.6
	70	1.033	2.7
	80	1.042	2.7
	90	1.051	2.7
	P_z = 53.4% P_w		
6.675	40	1.012	3.00
	50	1.018	3.00
	60	1.025	3.00
	70	1.033	3.1
	80	1.042	3.1
	90	1.051	3.1
	P_z = 58.3% P_w		
7.287	40	1.012	3.3
	50	1.018	3.3
	60	1.025	3.3
	70	1.033	3.3
	80	1.042	3.4
	90	1.051	3.4
	P_z = 63.2 % P_w		
7.900	40	1.012	3.6
	50	1.018	3.6
	60	1.025	3.6
	P_z = 68.6 % P_w		
8.575	40	1.012	3.9
	50	1.018	3.9
	60	1.025	3.9

Source: Author

Retrieval Number: K21170981119/19©BEIESP
DOI: 10.35940/ijitee.K2117.0981119
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Table (2b) Crushing strength between sleeper and ballast surface for wheel load 12.5 ton for rail ENR52

P_z (ton)	*Speed* (Km/hr)	β	*P(I)* Kg/cm²
P_z = 50.20 % P_w			
6.275	100	1.060	3.00
	120	1.077	3.00
P_z = 60.30 % P_w			
7.537	70	1.033	3.50
	80	1.042	3.50

Source: Author

Table (2c) Crushing strength between sleeper and ballast surface for wheel load 12.5 ton for rail ENR54

Pz (ton)	*Speed* (Km/hr)	β	*P(I)* Kg/cm²
P_z = 48.90 % P_w			
6.112	140	1.094	3.00
P_z = 55.10 % P_w			
6.887	100	1.060	3.2
P_z = 59.00 % P_w			
7.375	90	1.051	3.4
P_z = 63.80 % P_w			
7.975	70	1.033	3.7
	80	1.042	3.7

Source: Author

Table (2d) Crushing strength between sleeper and ballast surface for wheel load 12.5 ton for rail UIC60

P_z (ton)	*Speed* (Km/hr)	β	*P(I)* Kg/cm²
P_z = 51.10% P_w			
`6.38	120	1.077	3.10
	140	1.094	3.10
P_z = 56.10% P_w			
7.012	100	1.060	3.30
	120	1.077	3.40
	140	1.094	3.40
P_z = 60.00 % P_w			
7.50	100	1.060	3.50
	120	1.077	3.60
	140	1.094	3.60
	90	1.051	3.50

Source: Author

- check of sub grade bearing capacity

Figures (8a-8d) represents the suitable effective ballast depth (h_b) for a bearing capacity of 1.50 kg/cm^2 under a wheel load = 12.5 ton for the following rail types ENR47, ENR52, ENR54 and UIC60 by applying "(10), (11)".

Where: $h_{b\ min} \le h_b \le h_{b\ max}$

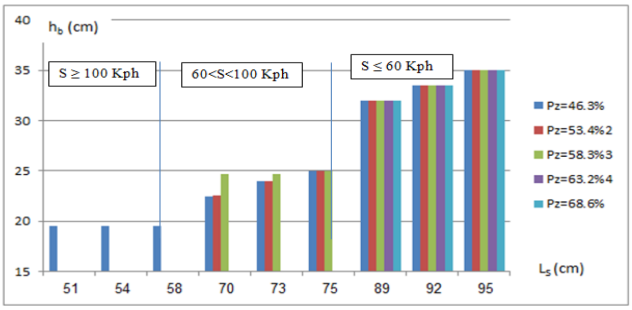


Fig. 8-a. Effective ballast depth (h_b) using rail ENR47

$$h_{b\ min} = (L_s - b)/2\ tan\boldsymbol{\omega} \quad (10)$$

$$h_{b\ max} = L_s /2\ tan\boldsymbol{\omega}$$
(11)

From figure (8-a), when the maximum speed is lower than 60 Kph, the sleeper spacing is greater than 90 cm and the effective ballast depth varying from 32-35 cm regardless sleeper share (46.3% - 68.6%) however, when the speed is between 60-90 Kph, the sleeper spacing is between 70-75 cm and the effective ballast depth varying from 24-25 cm regardless sleeper share (46.3% - 58.3%), but When the speed is between 100-140 Kph the sleeper spacing is between 51-58 cm and the effective ballast depth is 19 cm with sleeper share 46.3%.

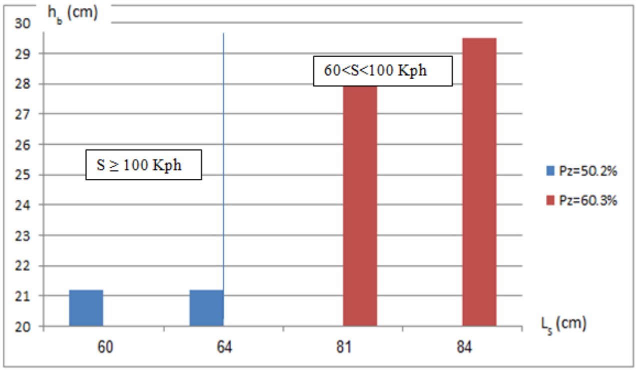


Fig. 8-b. Effective ballast depth (h_b) using rail ENR52

From figure (8-b), rail ENR52 is not valid for speed ≤ 60 Kph. Also, when the maximum speed is 70 or 80 Kph, the sleeper spacing is 84 cm and 81cm while the effective ballast depth 29.5and 28 cm respectively with sleeper share (60.3 %),

as well as when the maximum speed is 100 or 120 Kph, the sleeper spacing is 64 cm and 60 cm respectively and the effective ballast depth 21.2 cm with sleeper share (50.2 %).

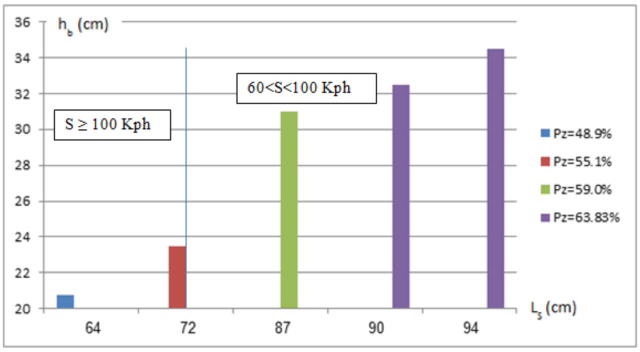


Fig. 8-c. Effective ballast depth (h_b) using rail ENR54

From figure (8-c), rail ENR54 is not valid for speed ≤ 60 Kph. When the speed is 70 or 80 Kph, the sleeper spacing is 94 cm and 91 cm while the effective ballast depth 34.5 and 32.5cm respectively with sleeper share 63.8 %. When the speed is 90 Kph, the sleeper spacing is 87cm and the effective ballast depth is 31cm with sleeper share 59%. At speed 100 Kph, the sleeper spacing is 72 cm and the effective ballast depth 23.3cm with sleeper share 55.1%, while at 140 Kph, the sleeper spacing is 64 cm and the effective ballast depth 20.7 cm with sleeper share 48.9%.

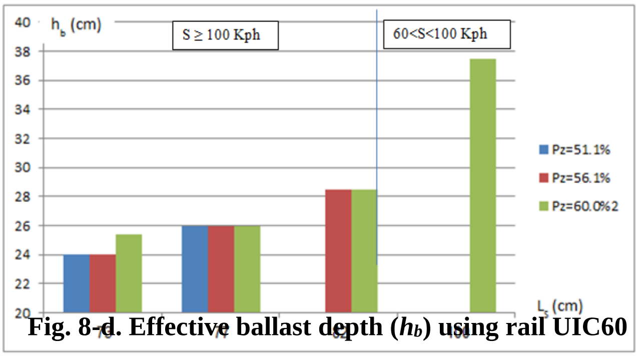


Fig. 8-d. Effective ballast depth (h_b) using rail UIC60

From figure (8-d), rail UIC60 is not valid for speed ≤ 90 Kph. When the speed is 90 Kph, the sleeper spacing is 100 cm and the effective ballast depth 37.5 cm and with sleeper share 60 %. At speed 100 or 120 or 140 Kph, the sleeper spacing is 82, 77 and 73 cm, while the effective ballast depth is 28.5, 26 and 24 cm respectively with sleeper share 56.1 or 60 %. When the sleeper share is 51.1% for speeds 120 and 140 Kph, the sleeper spacing is 77 and 73 cm while the effective ballast depth is 26 and 24 cm respectively.

V. FEASIBILITY STUDY TO DESIGN 1 KILOMETER OF TRACK

Figure (9) shows a cross section recommended by ENR for single track.

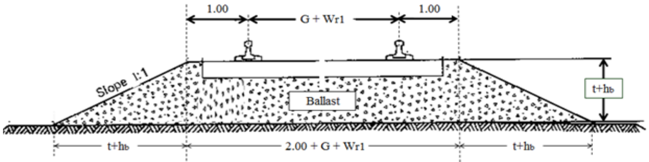


Fig. 9. Cross section for single track

Calculating rail age applying "(12), (13), (14), (15)", then rail ENR47 age can be calculated, Where sleeper age ranging from (40 to 50 years) depending on the following conditions: (vibrations, temperature, ground water, humidity and exhausts ….etc.) taken 45 years as an average while ballast age is ranging from (50 to 60 years) taken 55 years as an average [12].

Rail cost = ((2000 (m/Km) × W_r (kg/m') × Rail price (L.E/Kg))/ Rail age (year) (12)
Where: Rail age = $\Delta h_r/\Delta h_t$ (year) (13)
W_r: weight of 1 meter of the new rail.
Δh_r: the total wear within rail age (mm)
Δh_t: the average rail head wear rate (mm/year)

Applying the following empirical equation to obtain Δh_r:

$$Z_1 = (M/F) = Z_{new} - (\Delta h_r/30)\ (W+0.53(h_r+\Delta h_r)) \qquad (14)$$

Z_1: Rail modulus when the wear factor equals to 1
Z_{new}: modulus of new rail
h_r: Rail height

Applying the following empirical equation to obtain Δh_t:

$$\Delta h_t = C_1 - (t/C_2) \qquad (15)$$

Where C_1 & C_2 are two constants measured in the field depending on train speeds, traffic, axle load and horizontal curve if exists.
Sleeper cost = (1000m / sleeper spacing in m) × (price of one sleeper)
Ballast cost = volume of ballast × price of 1m³ ballast = ((2.00 + G + $Wr1$ + t + h_b) × (t + h_b) ×1000 × price of 1m³ ballast)
Track cost (L.E / Km / year): Total cost of 1Km of single track per year = (rail cost/rail age) + (sleeper cost/sleeper age) + (ballast cost/ballast age)
Similarly for double track, figure (10) shows a cross section recommended by ENR for single track.

Track cost (L.E/Km) analysis in Tables (3), (4), and (5).

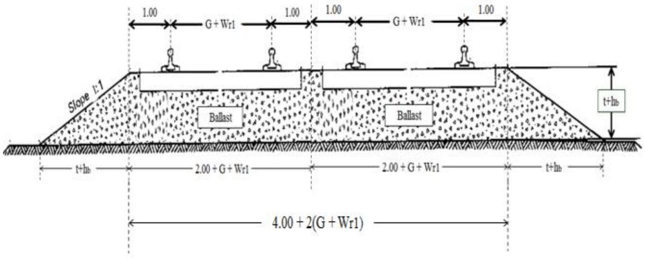
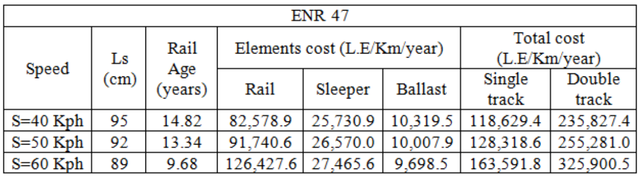


Fig. 10. Cross section for double track

Rail cost = **(**(4000 (m/Km) × W_r (kg/m') × Rail price (L.E/Kg)**)** / Rail age (year)
Sleeper cost = (2000m / sleeper spacing in m) × (price of one sleeper)/ sleeper age
Ballast cost = volume of ballast × price of 1m³ ballast
= **(**($4.00 + 2(G + Wr_1) + t + h_b$) × ($t + h_b$) ×1000 × price of 1m³ ballast**)**/ballast age

S= 100 Kph							
Rail type	Ls (cm)	Rail Age (years)	Elements cost (L.E/Km/year)			Total cost (L.E/Km/year)	
			Rail	Sleeper	Ballast	Single track	Double track
ENR 47	58	19.84	61,684	42,145	7,217	111,047	221,338
ENR 52	64	16.63	81,126	38,194	7,528	126,849	252,882
ENR 54	72	15.64	89,769	33,950	7,995	131,715	264,352
UIC 60	82	16.36	96,006	29,810	8,995	134,811	268,503

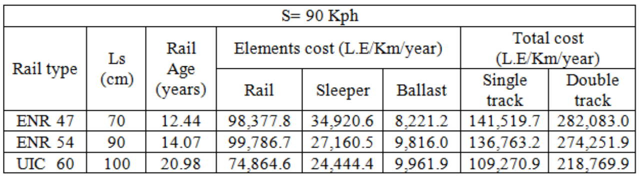
Table (3) summarizes the total cost for single and double track when using ENR47 for speeds 40, 50 and 60 Kph



ENR 47							
Speed	Ls (cm)	Rail Age (years)	Elements cost (L.E/Km/year)			Total cost (L.E/Km/year)	
			Rail	Sleeper	Ballast	Single track	Double track
S=40 Kph	95	14.82	82,578.9	25,730.9	10,319.5	118,629.4	235,827.4
S=50 Kph	92	13.34	91,740.6	26,570.0	10,007.9	128,318.6	255,281.0
S=60 Kph	89	9.68	126,427.6	27,465.6	9,698.5	163,591.8	325,900.5

Table (4) summarizes the total cost for single and double track when using ENR47, ENR54, and UIC60 for speeds 90 Kph

Source: Author



S= 90 Kph							
Rail type	Ls (cm)	Rail Age (years)	Elements cost (L.E/Km/year)			Total cost (L.E/Km/year)	
			Rail	Sleeper	Ballast	Single track	Double track
ENR 47	70	12.44	98,377.8	34,920.6	8,221.2	141,519.7	282,083.0
ENR 54	90	14.07	99,786.7	27,160.5	9,816.0	136,763.2	274,251.9
UIC 60	100	20.98	74,864.6	24,444.4	9,961.9	109,270.9	218,769.9

Table (5) summarizes the total cost for single and double track when using ENR 47, ENR 52, ENR 54, and UIC 60 for speeds 100 Kph

VI. CONCLUSION AND RECOMMENDATIONS

Note: the unit cost for rail is assumed 13 L.E/kg, while for sleeper 1100L.E /piece and for ballast 247.5 L.E/m^3. The following conclusions are recommended for single and double track when using ENR 47 for speeds 40, 50 and 60 Kph: For low speed (40-60) Kph, ENR 47 is the preferable type.

- As the speed increases the following results developed (sleeper spacing decreases - rail age decreases - rail and sleeper cost increase but the ballast cost decrease - total cost of the track construction increase).
- The total track cost for the double track is approximately twice that of the single. Any fluctuations in the track elements cost leads to the change of the total cost, then the lowest cost alternative could be changed.
- Rail cost : Sleeper cost : Ballast cost are 10:2.6:1 respectively.

The following conclusions are recommended for single and double track when using ENR 47, ENR 54, and UIC 60 for speed 90 Kph.

- Using heavier rail type gives the following results (larger sleeper spacing developed, that means sleeper cost reduction - ballast cost increase - longer life time acquired - total cost of the track construction decrease).
- ENR 47 and ENR 54 costs are nearly equal, while for UIC60 cost is decreased due its long life time.
- Rail cost : Sleeper cost : Ballast cost are 9.75:3:1 respectively.

The following conclusions are recommended for single and double track when using ENR47, ENR52, ENR54, and UIC 60 for speed 100 Kph.

- The heavier rail type used, the larger sleeper spacing developed.
- There is no effect of the rail type on the rail age except for rail ENR 47 because it has inertia more than the required.
- Rail cost : Sleeper cost : Ballast cost are 10.35:4.5:1 respectively.
- Using heavy rail increases the rail and ballast cost, while the sleeper cost decrease.
- The total cost increases when using heavier rail.

REFERENCES

1. American Railway Engineering Association, “Concrete Ties,” 1982.
2. Gallego I., “Vertical Track Stiffness as a New Parameter Involved in Designing High-Speed Railway Infrastructure,” ASCE, Journ. of Transp. Eng., Vol. 137, No 12, 2011.
3. Esveld, C., “Modern railway track second edition,” Zaltbommel, MRT-Productions, 2001.
4. Lichtberger, B., “Track compendium: Formation, permanent way, maintenance, economics,” Eurailpress, 2005.
5. Profillidis, V. “Railway Management and Engineering,” Section of Transportation, Democritus Thrace University, Greece, Vol. 2, 2014.
6. Buekette J., “Concrete Sleepers,” Track Course, RIA, London, 1983.
7. European Standard, “Prestressed Monoblock Concrete Sleepers,” European Committee for Standardization, Brussels, 1994.
8. Profillidis, V., “Applications of Finite Element Analysis in the Rational Design of Track Bed Structures,” Computers and Structures, Vol. 22, No 3, 1986.
9. Liolios A., Profillidis V. et al., “A Nonconvex Numerical Approach to the Dynamic Soil-Pipeline Interaction Induced by High-Speed Railway Traffic,” International Conference: Nonsmooth/Nonconvex Mechanics with Application in Engineering, Thessaloni, 2002.
10. Panagiotopoulos P., “Hemivariational Inequalities: Applications in Mechanics and Engineering,” Springer, Berlin, 1993.
11. Prud’homme A., “La Voie,” RGCF, Paris, 1970.
12. UIC, “Factors affecting Track Maintenance Costs and their Relative Importance,” Paris, 1992.

AUTHORS PROFILE

Mohamed Youssef Mohsen Youssef
Assistant Lecturer at faculty of Engineering Beni-Suef University, Egypt
Address: 1 Ehab Ezzat Street Nasr City, Cairo, Egypt.
Email: myoussef209@gmail.com
mohamedyousif@eng.bsu.edu.eg
Place of birth: Suez, Egypt Date of birth: April 28, 1984 Languages: Arabic and English Educational Qualifications: PhD Candidate in Railway Engineering, Dept. of Public Works, Ain Shams University. Thesis title “Investigation on the manufacturing, installing and maintenance management of prestressed monoblock concrete sleeper in Egypt railway network", Aug. 2015.

M.Sc. in Civil Engineering, Faculty of Engineering, Ain Shams University, Egypt, February 2013.

Thesis Title: “Optimal Utilization of Cairo Regional underground Railway lines”.

B.Sc. in Civil Engineering, Department of Civil Engineering, Faculty of Engineering, Higher Technological Institute, Egypt, August 2006.

Hany Ibrahim Ahmed
Email: hany281@yahoo.com
Address: 2143 Zahra Nasr City, Cairo, Egypt
H.I. Ahmed is an associate professor of Strength and Properties of Materials, Civil Engineering Department, Faculty of engineering, Beni-Suef University. Ph.D. from Cairo University in 2014. Research interests include Durability and Microstructure Concrete, Mass Transport Properties of Concrete, Nanotechnology, Fibrous Concrete, Software Engineering, and Artificial Intelligence.

M.Sc. in Civil Engineering, Structural engineering department, Shoubra Faculty of Engineering, Benha University, Egypt, 2009.

B.Sc. in Civil Engineering, Structural engineering department, Shoubra Faculty of Engineering, Benha University, Egypt, 2002.

Manager of materials laboratory, faculty of Engineering, Beni-Suef University. Certified project manager, IPMA level C

HANY SOBHY RIAD, Nationality : Egyptian, Specialization : Railway and Transportation Planning, Position : railway expert, Actual Profession: Professor of Railway Engineering at Faculty of Engineering – Ain Shams University – Cairo – Egypt, Year of birth : 4 March 1948 , Address: 5 Staff members of Ain Shams University Apartments – Demerdash – Abbasia – Cairo – Egypt E-mail Address: hanysobhyr@yahoo.com

Mobile Phone: +2 01117557275
Telephone: +2 26823976
KEY QUALIFICATION

- Experience of railway track design and maintenance for lines , station signals and turnouts.
- Experience of rail way economy and management
- Experience of traffic data collection and analysis of transport system.

Dr. Amr Ali Abdel Rahman, Chairman of the Structural Engineering Department and Professor of Concrete Structures, Ain Shams University, Cairo, Egypt. He is a member in the following Egyptian Codes; Design and Construction of Concrete Structures, Design and application of Fiber Reinforced Polymers in Construction (Vice President), and Planning, Design and Construction of Bridges and Highways. He is also a member in the Arab Code for Design of Bridges, Supreme committee for Engineering Consultants and General Secretary of the Egyptian Society of Engineers/Civil.
He is a Consultant Engineer, who participated in the design of several projects in the Middle East and Canada. He has more than 30 years of experience working in the field of design of conventional and prestressed Concrete Structures and strengthening using Fiber Reinforced Polymers.