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INVESTIGATING THE CHARACTERISTICS OF APPROACH SLAB ADJACENT TO RAILWAY CULVERTS USING A 3D FINITE ELEMENT MODEL

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ABSTRACT: Sudden changing in the track vertical stiffness along the railway track increases the dynamic loads in this place. Culverts and bridges are one of the places that railway track stiffness changes suddenly. Sudden and uneven changing of vertical stiffness between the culverts and tracks increases dynamic load, asymmetric deformations, failure of the track components and maintenance costs. One of the methods to solve the above problems is to build an approach slab in the adjacency of culverts and bridges. In the present study, the behavior of railway track adjacent to culverts with approach slab has been evaluated according to different supporting conditions (weak and rigid subgrades). For this purpose, a 3D finite element model of railway track and culvert with approach slab is built, and then different sensitivities on the geometric dimensions of approach slab (including thickness, length and slope) are analyzed. Results show that the most appropriate railway track behavior in different subgrades occurs with the construction an approach slab with the length of 4m, the thickness of 30cm and the slope of 2.5%. Finally, based on static analysis, a proper slab in the adjacency of culverts decreases rail and ballast vertical displacement about 18% and 24% respectively and based on dynamic analysis, dynamic stress in the subgrade layer, dynamic vertical displacement of the rail and the ballast and vertical acceleration of the rail decrease 48%, 23% ,22% and 25% respectively. Also the performance of slab in the weak subgrade is better than to the rigid subgrade.

KEYWORDS: Transition zone, Approach slab, Railway ballasted tracks, Culvert, Finite element modeling

1 INTRODUCTION

There are usually many technical structures along the railway tracks such as bridges and culverts. Track vertical stiffness changes suddenly where the track passes of the structures; that these locations are called transition zones. Sudden changing in track stiffness in these locations can lead to the asymmetric deformations, railway roughness, components damaging of track system and as a result the maintenance costs increased [1-2]. Studies show that track stiffness changing along the track is one of the main sources of railway track geometric damages. In Netherlands, 40 % of maintenance costs are related to maintenance of the standard track geometric conditions and the maintenance costs of transition zones are 2 to 4 times higher than other parts of the track [3]. According to Sasaoka and Davies (2005) [4], annually, about 200 million dollars is spent on the maintenance of transition zone in America railway tracks [4]. Also in Europe, annually 85 million euros is spent for the maintenance of transition zones [5].

One of the methods for the gradual transition of track stiffness and solving railway track problems in the transition zone is to build an approach slab around the culvert structure and the bridge [6]. Also Coelho, Michael and Hicks (2015) [7] determinate after field studies and numerical modeling that hanging sleepers (the free distance between sleeper floor and ballast layer) are the main reason for the weak performance of approach slab in the transition zone adjacent to culverts. The computational results of Lei and Zhang (2009) [8] and Callege et al. (2015) [9] show that stiffness transition pattern of track has a significant effect on the dynamic behavior of track and train, and the track smooth stiffness distribution can significantly decrease the interaction forces of wheel, railway and vertical velocity of railway. In the construction of Tehran-Isfahan high speed railway in Iran is proposed that a proper transition zone with a length of 20m in the vicinity of bridge and culvert be used by improving backfill [10]. David and Li (2006) [11] stated that if the ballast settlement was limited, the approach slab is appropriate for stiffness transition, because there is no hanging sleepers conditions which is the main cause for weak track behavior. also the concrete approach slab that is placed between ballast and sub-ballast layers has many advantages to increase the amount of track subgrade module and decrease the railway displacement [11]. Shahraki, Warnakulasooriya and Witt (2015) [12], investigated the dynamic behavior of the different types of the transition zone (installing auxiliary rails, gradually increasing the length of the sleepers and enhancing the substructure) under the train moving loads by a FE model. Coelho, Michael and Hicks (2015) [7], in order to achieve the proper perspective on the dynamic behavior of the transition zone, have had field controlled and monitored the culvert transition zone with concrete approach slab and introduced the information about the dynamic behavior of the transition zone under the passing of trains. Also researcher evaluated the short-term and long-term behavior of culvert transition zone with a concrete approach slab around with field study. In other comprehensive research has evaluated a culvert transition zone in Netherlands, including culvert structure, the approach slab, embankment and the adjacent ballast track. Results show that the hanging sleeper is the main cause for the weak performance of approach slab in the culvert transition zone.

A review of technical literature related to the transition zone adjacent to culverts show that the effects of approach slab geometric parameters such as length, thickness and slope have not been examined separately on the behavior of railway track at the transition zone adjacent to culverts. Therefore, in this study the issue is investigated assuming the appropriate supporting conditions for sleepers and there are not hanging sleepers in finite element modeling. In this regard, is examined the appropriate dimensions for approach slab which caused the proper behavior of transition zone.

2 MODELING

In order to evaluate the approach slab behavior at the railway transition zones, the numerical modeling is performed at culverts by using the finite element software of ABAQUS. Hence, the ballasted track super structure components (including rail, fastening, sleeper and ballast), culvert structure, approach slab, subgrade and soil layers have been modeled as 8-node elements. The mechanical properties of components that used in modeling are shown in table (1) according to Coelho (2010) [13] and Feng (2011) [14].

Table 1. Mechanical properties of components used in modeling

Model components	**Modulus of elasticity (MPa)**	**Poisson's ratio**	**Density (kg/m^3)**	**Model components**	**Modulus of elasticity (MPa)**	**Poisson's ratio**	**Density (kg/m^3)**
Rail	220000	0.3	7850	**Sand layer 2**	113	0.3	1900
Sleeper	15000	0.1	2510				
Steel Base plate	100000	0.3	4850	**Sand layer 1** (Weak subgrade)	20	0.3	1900
Ballast	200	0.2	1800				
Organic soil layer	8.3	0.5	1700	**Sand layer 1** (Rigid subgrade)	100	0.3	1900
Sand layer 3	143	0.3	1900	**Culvert structure**	35000	0.15	2500

Length and width of model are 20 m and 9 m respectively. Cross section of rail is UIC60 and dimension sleeper is 0.2 m in 0.15m and its length is 2.6 m. Span length and heights of concrete culvert are 2 m in 2 m. The elastic behavior is one of the main assumptions in the present model. It is well known that in general the soil behaves non–linearly however, for small strain levels, such are expected to occur during the passage of a train, and elasticity is a good approximation of the real behavior [15]. The maximum element size is chosen to be 0.40 m which is in agreement with the limit of ten elements per wavelength, as defined in Muir Wood (2004) [16]. Interface elements are used to simulate the contact between surfaces with tie constraint and boundary conditions in bottom of model is fixed.

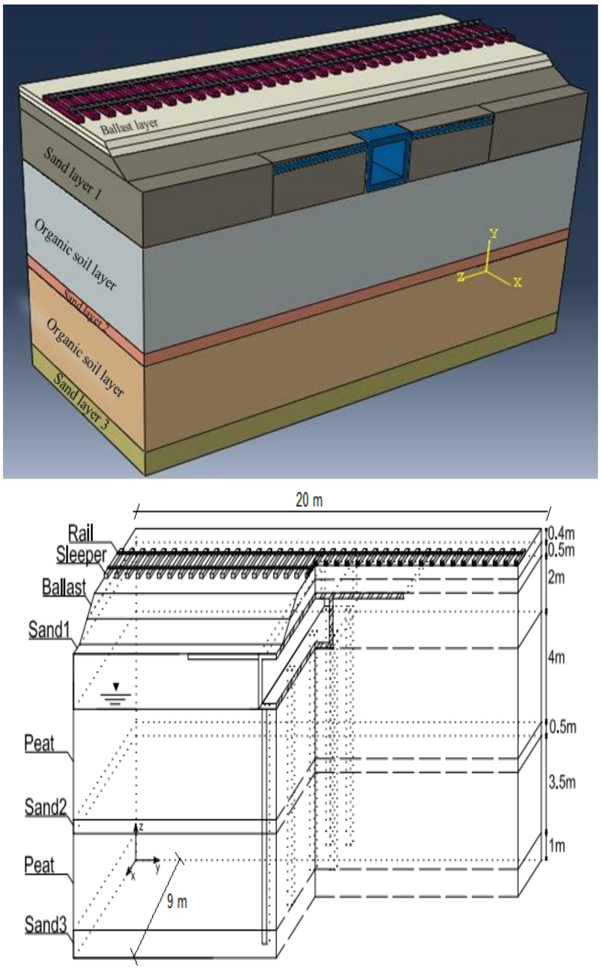

Figure 1. 3D finite element model of the transition zone adjacent to culvert along with the approach slab

Figure (1) shows the 3D finite element model that is built of the railway track adjacent to culvert along with the concrete approach slab. In figure (2), is shown the position of locations where their responses used for sensitivity analysis of various parameters. Measurement data are obtained in pointes p31, p6, p7, p23, p8, p24, p10, p9 and p30 in the level of rail, middle of the ballast and on the subgrade. The train loading is modeled with one moving axle with constant magnitude 18 ton that its speed is about 300 Km/h for high speed railway. Modeling of loading is shows in Figure (3).

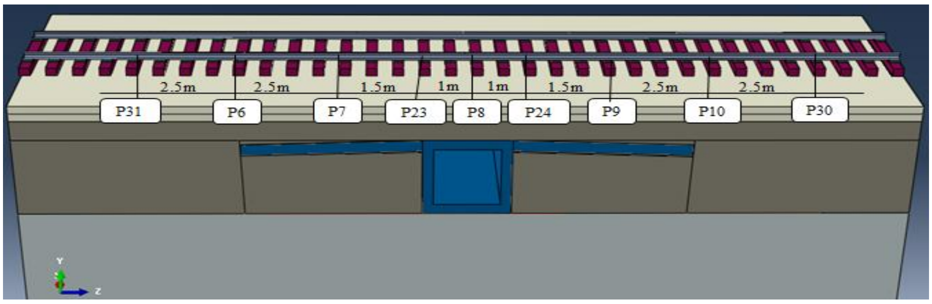

Figure 2. Position of measurement data in 3D finite element model

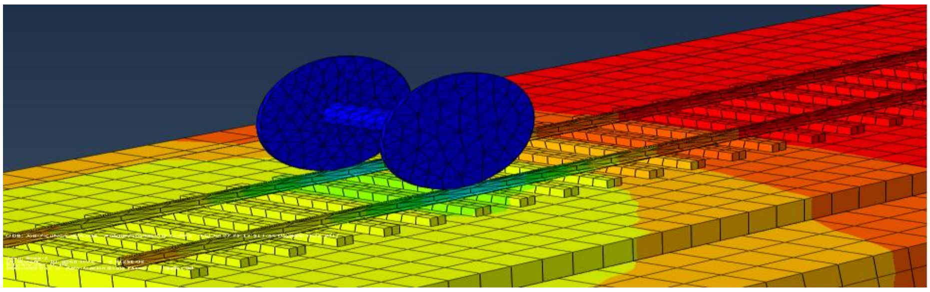

Figure 3. Modeling of loading with one moving axle

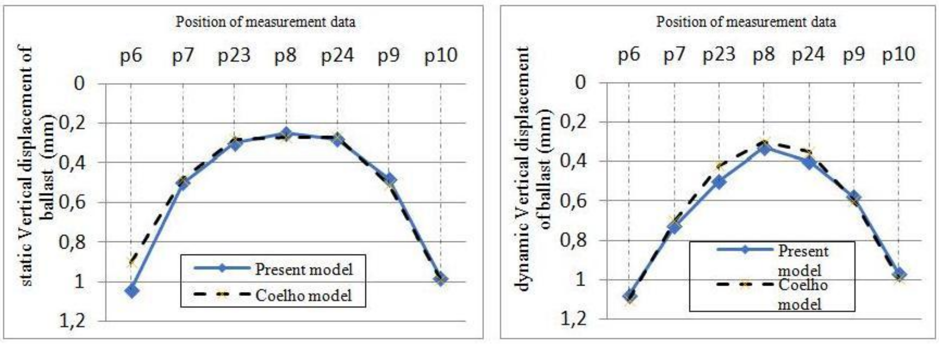

Figure 4. Comparison of the static and dynamic ballast displacement along the track between the reference model [13] and modeling of the present study

For the model validation, the results of Coelho studies have been shown [13]. Figure (4) shows the amount of static and dynamic vertical displacement of the ballast along the track for the reference model [13] and the research model that is used in this study. As observed in this figure, the results of static and dynamic vertical displacement of the ballast for modeling of the present study and the reference model of Coelho were very similar and the difference is less than 2.3% and 5.7% respectively.

3 INTERPRETATION OF MODELING RESULTS

In this section, the results of sensitivity analysis performed on the finite element models that have been described. In this regard, the modeling results are compared in both states of with approach slab and without approach slab and the effect of approach slab geometric parameters such as length, thickness, and slope are evaluated on the railway track behavior at the transition zone adjacent to the culverts for weak and rigid subgrade. In the following charts and Figures, state without the approach slab is shown whit "H = 0 cm" or "no transition" chart.

3.1 Evaluating the effect of approach slab thickness on the railway track behavior at culverts transition zone

The concrete approach slab can be constructed with constant thickness and downward slope or be constructed with variable thickness. In this study, the approach slab is considered with constant thickness but with downward slope. In order to evaluate the effect thickness of approach slab, static vertical displacement of the rail, static vertical displacement of the ballast, dynamic vertical displacement of the rail, dynamic vertical displacement of the ballast, dynamic stress in the subgrade layer and vertical dynamic acceleration of the rail are presented in Figures (5,6,7,8,9,10) respectively and the effect of approach slab thickness on the railway track behavior are evaluated for rigid subgrades with modulus of elasticity 100 MPa and in Figures (11,12,13,14,15,16) the above mentioned criteria are presented for weak subgrades with modulus of elasticity 20 MPa. In the following charts, the effect of approach slab with different thicknesses (with dimensions of 10 cm, 20 cm, 30 cm and 40 cm) are compared to the culvert without the approach slab ("H = 0" cm or "no transition").

Additionally, the summary of evaluation results of approach slab effect with different thickness for rigid and weak subgrades, based on the desired criteria are shown in the tables (2 and 3), respectively. The tables show the values of appropriate performance and the desired effect of approach slab on the railway track behavior in culverts relative to the state which there is no approach slab adjacent to culvert.

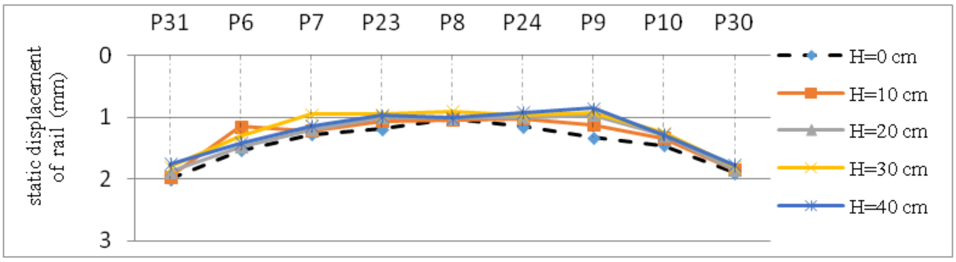

Figure 5. Static vertical displacement of the rail in rigid subgrades (E=100 MPa)

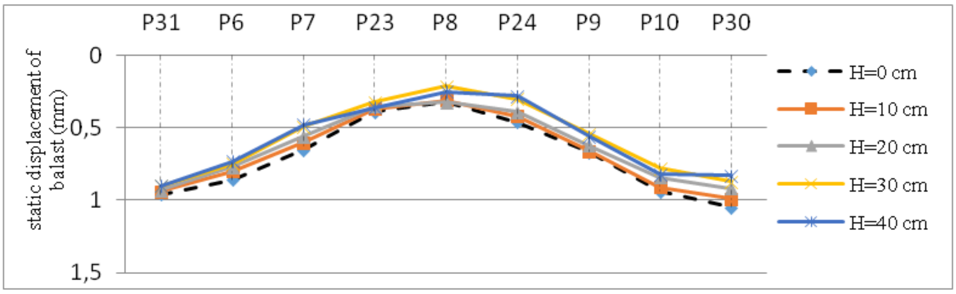

Figure 6. Static vertical displacement of the ballast in rigid subgrades (E=100 MPa)

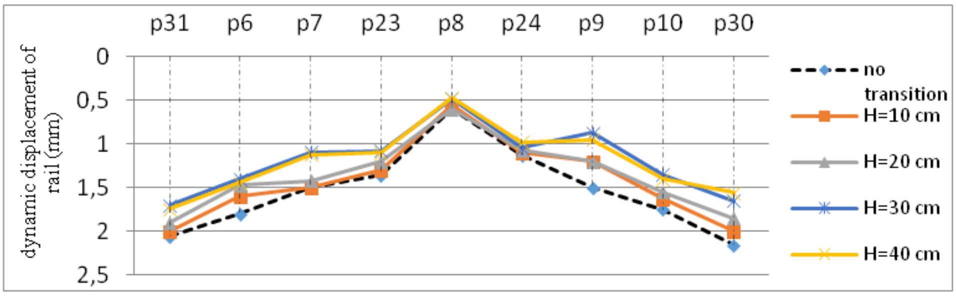

Figure 7. Dynamic vertical displacement of the rail in rigid subgrades (E=100 MPa)

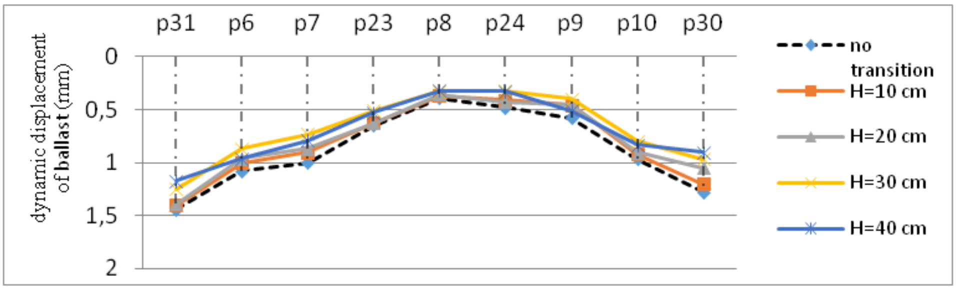

Figure 8. Dynamic vertical displacement of the ballast in rigid subgrades (E=100 MPa)

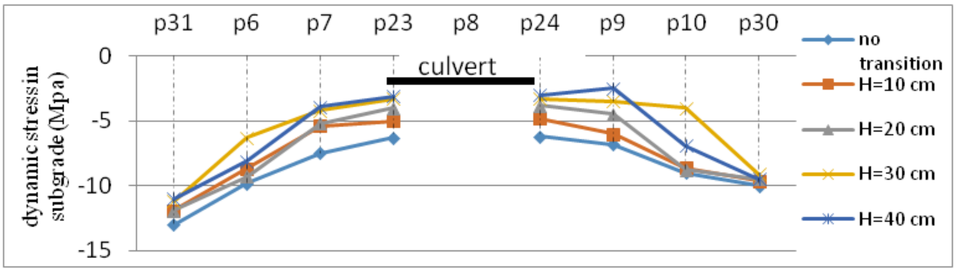

Figure 9. Dynamic normal stress in the subgrade layer in rigid subgrades (E=100 MPa)

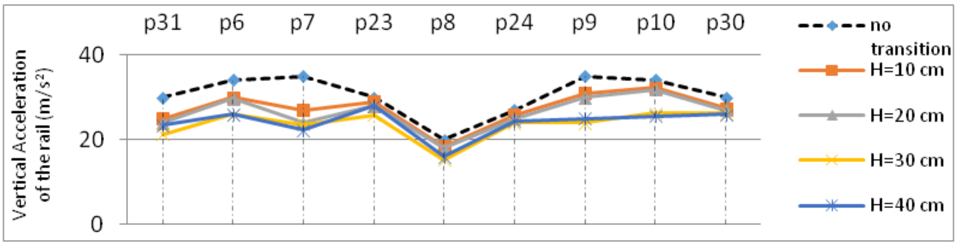

Figure 10. Vertical acceleration of the rail in rigid subgrades (E=100 MPa)

Thickness approach slab is very important in order to have a proper and gradual transition of stiffness between ballasted track and technical structures along the railway tracks such as bridges and culverts. The proper thickness of the approach slab depends on thickness of the slab culvert and quality of ballasted track which indicates difference of stiffness.

According to results of above Figures and Table (2), the railway track behavior in the rigid subgrade (100 MPa modulus of elasticity) has been improved, when had an approach slab with a thickness of 30 cm and based on parameters of static displacement of rail, vertical static displacement of ballast, vertical dynamic displacement of rail, vertical dynamic displacement of ballast, dynamic stress in the subgrade layer and vertical acceleration of the rail; 16.53 %, 20.48 %, 22.68 % , 22.52%, 37.6% and 22.16 % respectively relative to the state without the approach slab. In fact track modulus has increased with addition of approach slab with a thickness of 30 cm and it has the best result due to the absorption of stress by slab especially in the location under the approach slab. But high track modulus is not always good for railway track behavior in culvert transition zone; Results show that efficiency of approach slab with a thickness more than 30 cm in the railway track behavior is the same as 30 cm. And the performance of approach slab with a thickness less than 20 cm is unsatisfactory.

Table 2. Evaluating effect of approach slab with different thicknesses in the rigid subgrades

Thickness of approach slab	Evaluating effect of approach slab based on criteria (%)					
	Static Vertical rail displacement	Static Vertical ballast displacement	Dynamic Vertical rail displacement	Dynamic Vertical ballast displacement	Dynamic Normal Stress in subgrade	Reduced Acceleration of Rail
H=10 cm	8.64	4.97	6.9	8.34	13.8	10.22
H=20 cm	9.85	9.24	10.48	10.71	20.10	13.18
H=30 cm	16.53	20.48	22.68	22.52	37.6	22.16
H=40 cm	13.93	18.48	22.16	19.45	34.3	20.49

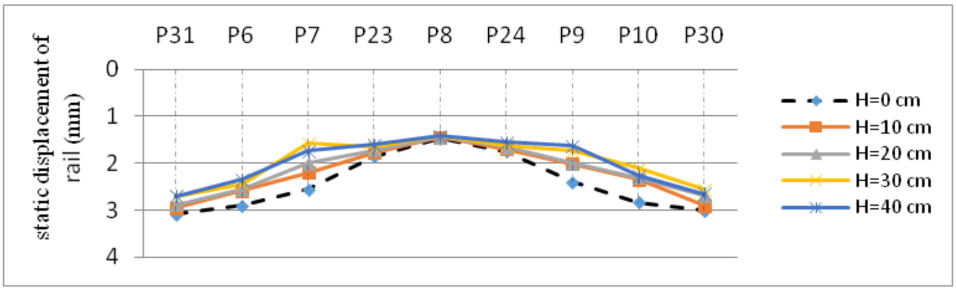

Figure 11. Static vertical displacement of the rail in weak subgrades (E=20 MPa)

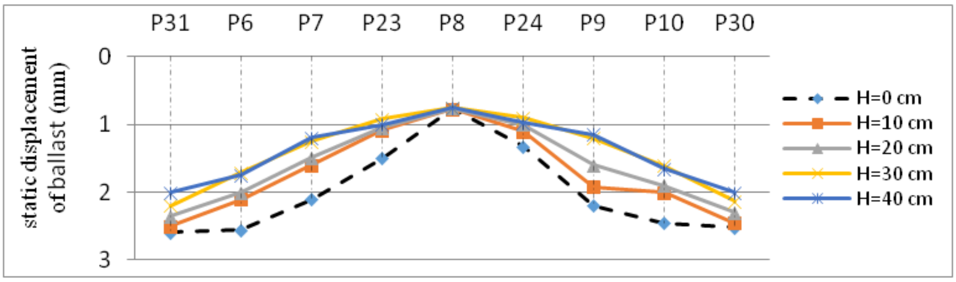

Figure 12. Static vertical displacement of the ballast in weak subgrades (E=20 MPa)

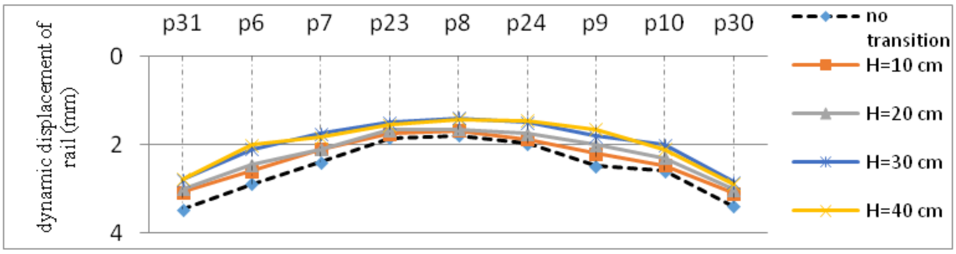

Figure 13. Dynamic vertical displacement of the rail in weak subgrades (E=20 MPa)

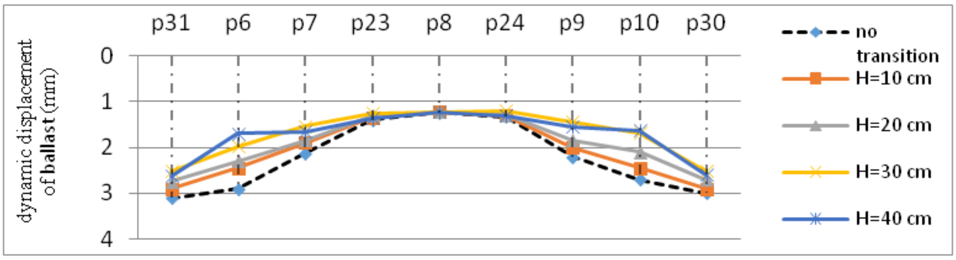

Figure 14. Dynamic vertical displacement of the ballast in weak subgrades (E=20 MPa)

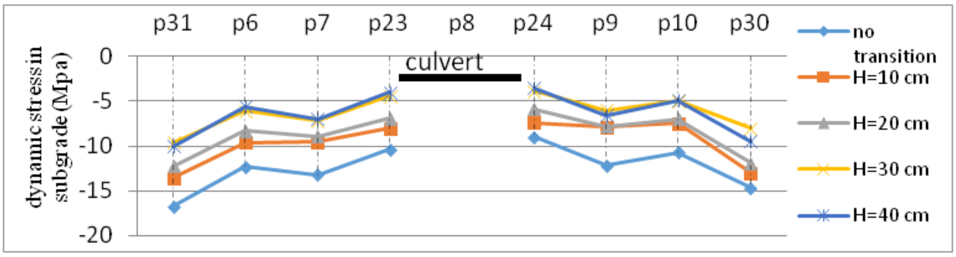

Figure 15. Dynamic normal stress in the subgrade layer weak subgrades (E=20 MPa)

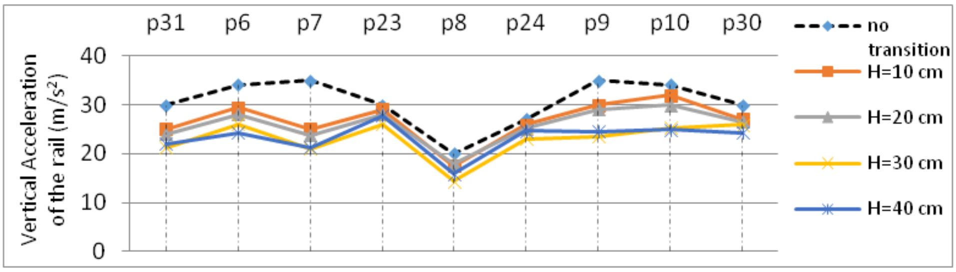

Figure 16. Vertical acceleration of the rail in rigid subgrades (E=20 MPa)

Table 3. Evaluating effect of approach slab with different thicknesses in the weak subgrade

Thickness of approach slab	**Evaluating effect of approach slab based on criteria (%)**					
	Static Vertical rail displacement	**Static Vertical ballast displacement**	**Dynamic Vertical rail displacement**	**Dynamic Vertical ballast displacement**	**Dynamic Normal Stress in subgrade**	**Reduced Acceleration of Rail**
H=10 cm	8.35	13.72	8.32	6.87	23.3	12.13
H=20 cm	11.04	19.32	12.54	11.8	31.2	14.86
H=30 cm	17.43	28.53	22.96	20.93	50.30	24.64
H=40 cm	17.33	28.9	22..82	18.75	49.90	23.08

According to the above charts, Figures and the results of Table (3), it is observed that for weak subgrades (20 MPa modulus of elasticity) the performance of the approach slab with a thickness of 30 cm is better, than other thicknesses of approach slabs. Similarly, the railway track behavior is decreased about 17.43 % and 28.53 % based on the two parameters of vertical static displacement of rail and ballast respectively. Also based on the dynamic analysis, vertical dynamic displacement of rail and ballast, dynamic normal stress in subgrade and vertical acceleration of the rail are decreased 22.96 %, 20.93 %, 50.3 % and 24.64%, relative to when it didn't have approach slab. Furthermore it is observed that the effect of approach slab in weak subgrades is more than in rigid subgrades because approach slab in weak subgrades increases the track modulus and also prepares a subgrade with better conditions. According to Figures (5) and (6), static displacement of the rail and the ballast layer at point P31 for the charts "H=0" are 1.94 mm and 0.95 mm respectively. These values are shown in Figure (17) in the displacement contours of the Abaqus software output.

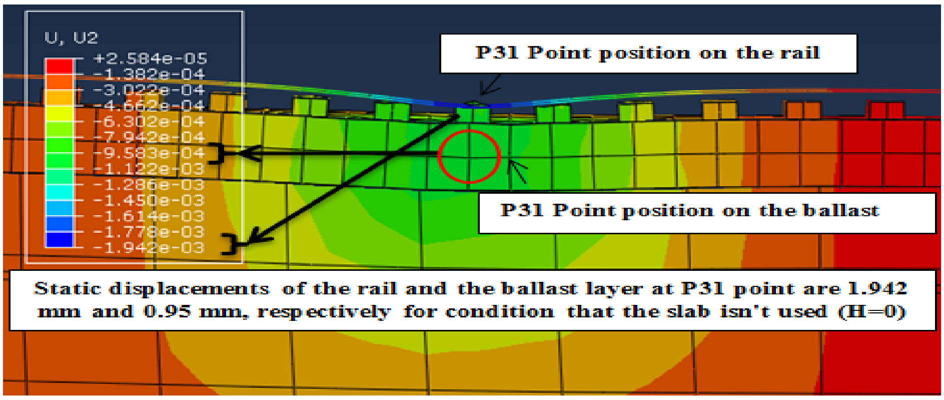

Figure 17. Displacement contours of the Abaqus software output for the chart no transition

3.2 Evaluating the effect of approach slab length on the railway track behavior at culverts transition zone

Another important parameter of approach slab is its length around different structures that is important for gradual and moderate transition of stiffness. The length of approach slab adjacent to the culverts often constructed in the range of 3 to 6 m. In this study, the approach slabs are investigated with lengths of 3, 4, 5 and 6 meters. In order to evaluate the effect of approach slab length, static vertical displacement of the rail, static vertical displacement of the ballast, dynamic vertical displacement of the rail, dynamic vertical displacement of the ballast, dynamic stress in the subgrade layer and vertical acceleration of the rail are presented in Figures (18,19,20,21,22,23) respectively and Table (4) for rigid subgrades, and is presented in the Figures (24,25,26,27,28,29) and Table (5), for weak subgrades respectively**.**

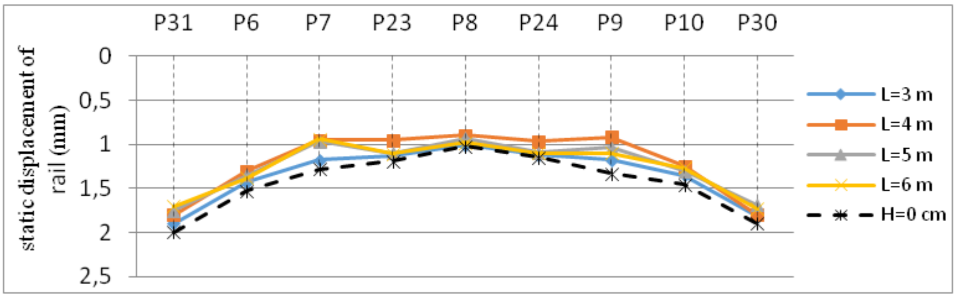

Figure 18. Static vertical displacement of the rail in rigid subgrades (E=100 MPa)

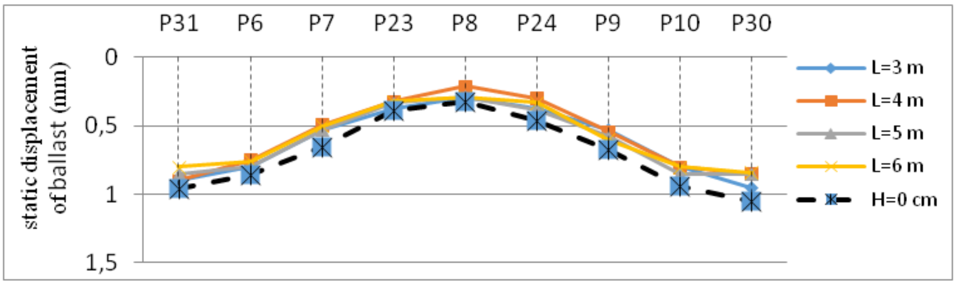

Figure 19. Static vertical displacement of the ballast in rigid subgrades (E=100 MPa)

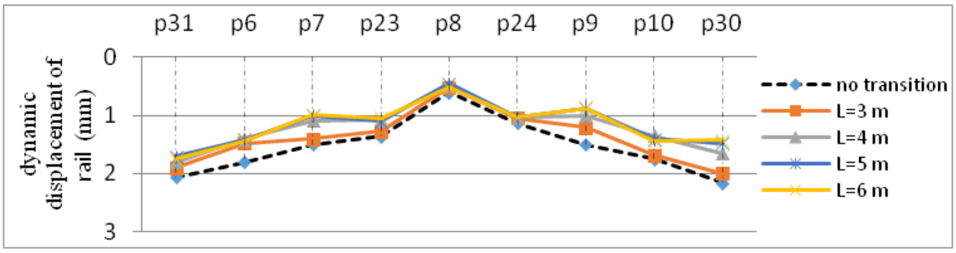

Figure 20. Dynamic vertical displacement of the rail in rigid subgrades (E=100 MPa)

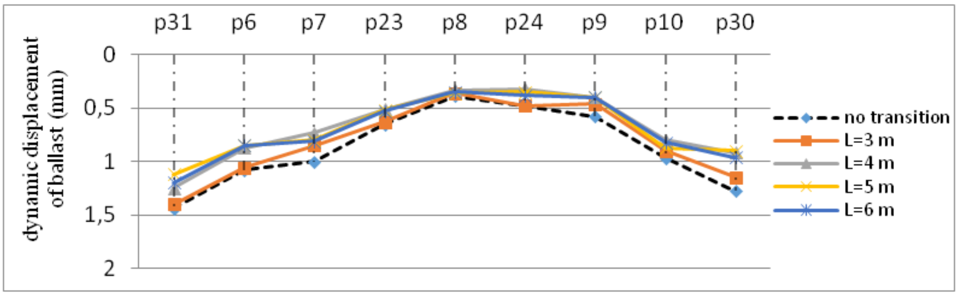

Figure 21. Dynamic vertical displacement of the ballast in rigid subgrades (E=100 MPa)

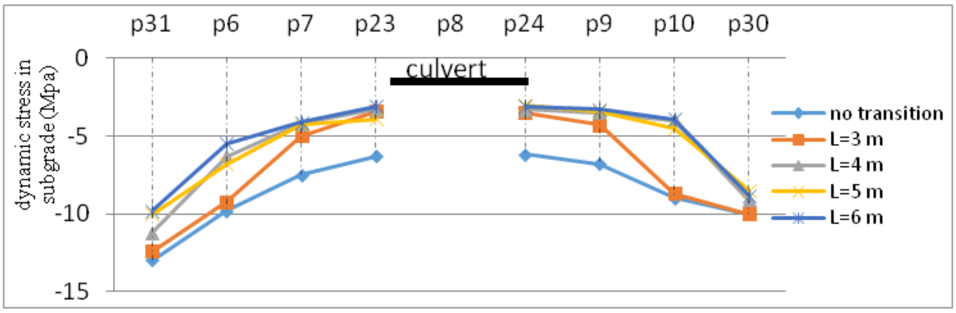

Figure 22. Dynamic normal stress in the subgrade layer in rigid subgrades (E=100 MPa)

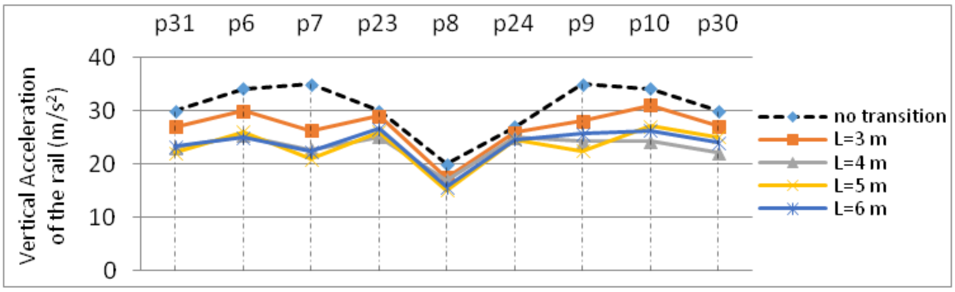

Figure 23. Vertical acceleration of the rail in rigid subgrades (E=100 MPa)

Table 4. Evaluating effect of approach slab with different lengths in the rigid subgrades

Thickness of approach slab	**Evaluating effect of approach slab based on criteria (%)**					
	Static Vertical rail displacement	**Static Vertical ballast displacement**	**Dynamic Vertical rail displacement**	**Dynamic Vertical ballast displacement**	**Dynamic Normal Stress in subgrade**	**Reduced Acceleration of Rail**
L=3 m	5.67	12.34	9.86	7.61	21.7	11.71
L=4 m	16.53	20.46	21.18	22.95	37.6	23.15
L=5 m	12.66	13.46	24	21.04	37.55	23.25
L=6 m	11.73	16.92	22.8	19.78	40.2	21.83

The appropriate length of approach slab adjacent to the culverts is related to various parameters for example difference track stiffness in transition zone, train velocity, requisiteness of decrease dynamic loading, technical condition and etc. We need an approach slab with more length whatever difference track stiffness to be high in transition zone. In the above Figures and Table (4), the results of sensitivity analysis on the approach slabs with various lengths is shown in the rigid subgrade. The results indicate that the approach slab with a length 4 m has more favorable performance according to the study parameters. On this basis, parameters of static displacement of the rail, vertical static displacement of the ballast, dynamic vertical displacement of the rail, dynamic vertical displacement of the ballast, dynamic stress in the subgrade layer and vertical acceleration of the rail is decreased 16.53 %, 20.46 %, 21.18 %, 22.95 %, 37.6 % and 23.15% respectively, relative to when didn't have approach slab. Results show that efficiency of approach slab with a length more than 4 m in the railway track behavior is the same as 4 m and the performance of approach slab with a length less than 3 m is undesirable. In fact minimum 4 m length for slab creates transition of stiffness gradually between ballasted track and culvert. The length of concrete slabs has a great effect on reducing the vertical acceleration of the rails. And an approach slabs with length less than 3 m have been observed, that have few effect on different parameters. Figures (18) and (20) show that presence of concrete slab reduces the relative displacement between culvert and ballasted track and also stiffness and displacement is transferred gradually.

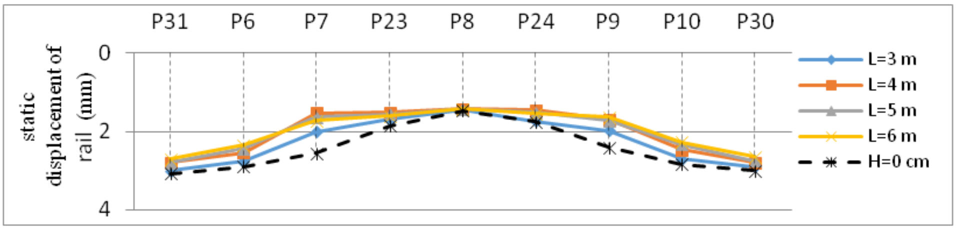

Figure 24. Static vertical displacement of the rail in weak subgrades (E=20 MPa)

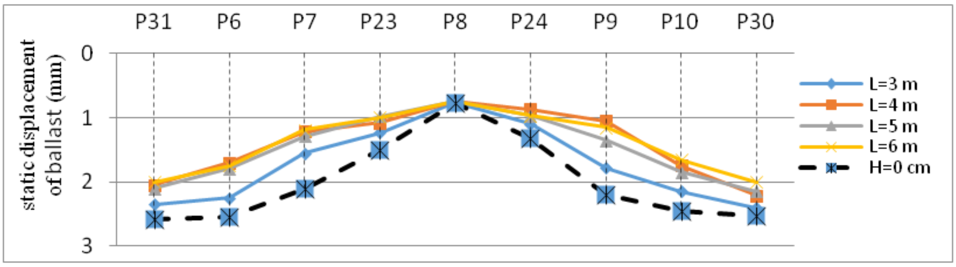

Figure 25. Static vertical displacement of the ballast in weak subgrades (E=20 MPa)

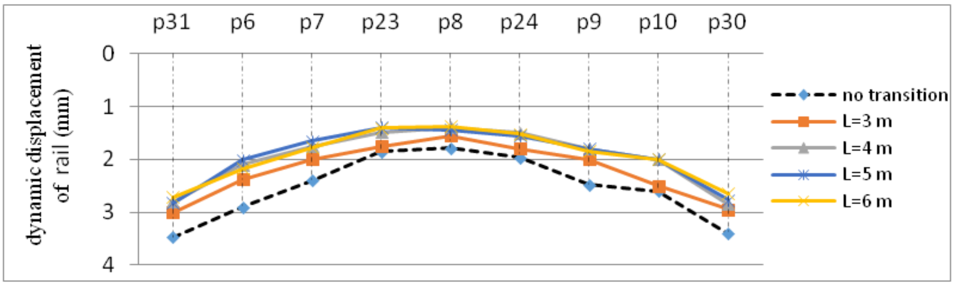

Figure 26. Dynamic vertical displacement of the rail in weak subgrades (E=20 MPa)

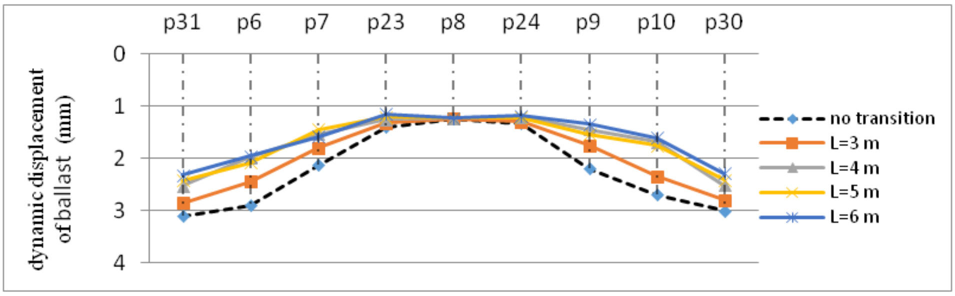

Figure 27. Dynamic vertical displacement of the ballast in weak subgrades (E=20 MPa)

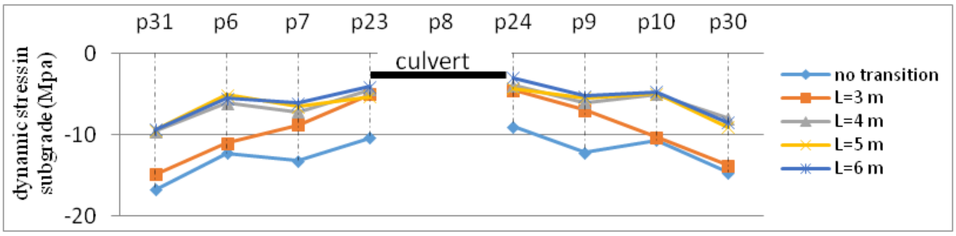

Figure 28. Dynamic normal stress in the subgrade layer in weak subgrades (E=20 MPa)

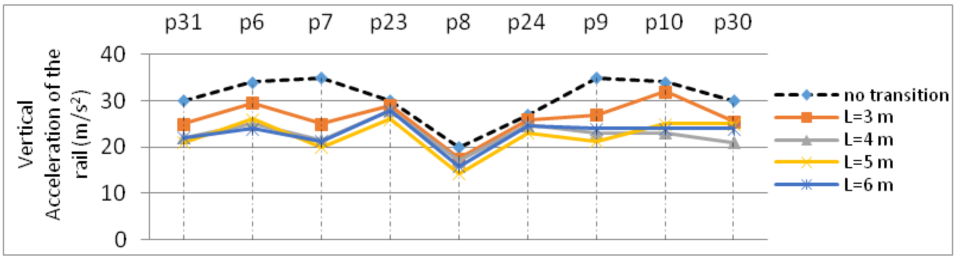

Figure 29. Vertical acceleration of the rail in rigid subgrades (E=20 MPa)

Table 5. Evaluating effect of approach slab with different lengths in the weak subgrades

Thickness of approach slab	Evaluating effect of approach slab based on criteria (%)					
	Static Vertical rail displacement	Static Vertical ballast displacement	Dynamic Vertical rail displacement	Dynamic Vertical ballast displacement	Dynamic Normal Stress in subgrade	Reduced Acceleration of Rail
L=3 m	7.28	13.26	12.45	9.78	26.2	13.64
L=4 m	16.53	28.21	22.86	20.93	50.3	25.31
L=5 m	16.45	25.43	23.91	21.33	50.2	26.19
L=6 m	17.33	28.99	23.78	24.16	54.5	23.74

According to the results of Figure (24-29) and Table (5) in weak subgrades the performance of the approach slab with length a 4 m is better than other lengths. The railway track behavior decreased based on the parameters of static displacement of the rail, static displacement of the ballast, dynamic vertical displacement of the rail, dynamic vertical displacement of the ballast, dynamic stress in the subgrade layer and vertical acceleration of the rail, about 16.53%, 28.21%, 22.86%, 20.93 %, 50.3 % and 25.31 % respectively relative to when it didn't have approach slab. Slab with length a more than 4m have relatively high impacts on the reduction of dynamic stress in subgrade. According to Figure (28) and Table (5), is shown that approach slab has a favorable effect on the reduction of normal stress in the subgrade layer because this slab causes the forces to be dampening.

3.3 Evaluating the effect of approach slab slope on the railway track behavior at culverts transition zone

For gradual and moderate transition of the railway track stiffness, usually the approach slab built with variable thickness or constant thickness with downward slope. In this part, the effect of approach slab with 4 m length and 30 cm thickness with the slopes of 0, 1.5, 2.5, 3.5, 5 and 10 percent is examined relative to when it didn't have approach slab. Similar to previous sections, the evaluations have been performed based on the parameters. Results presented in Figures (30 to 41) and Tables (6 and 7), for rigid and weak subgrades. Construction a slab with a proper slop to downward from culvert to ballasted track is effective to gradual stiffness transition and better result is earned in limitation of slope.

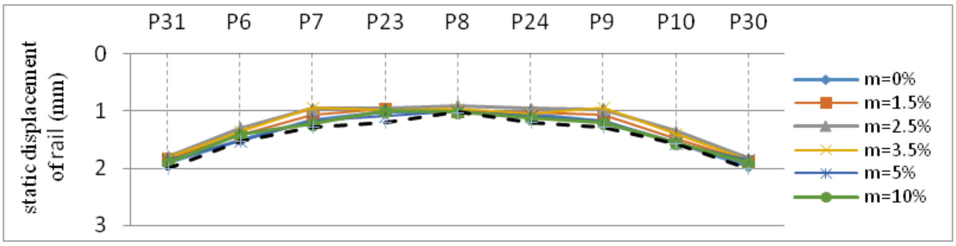

Figure 30. Static vertical displacement of the rail in rigid subgrades (E=100 MPa)

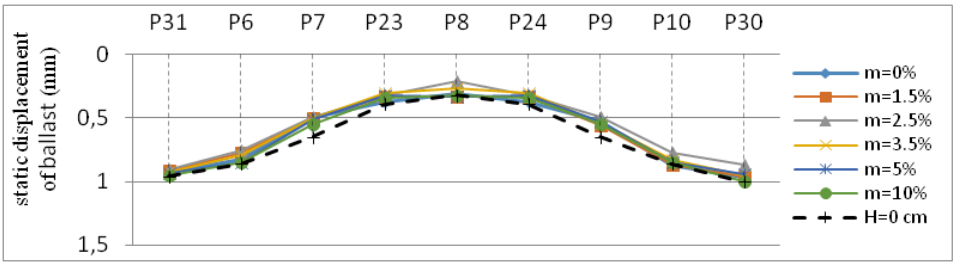

Figure 31. Static vertical displacement of the ballast in rigid subgrades (E=100 MPa)

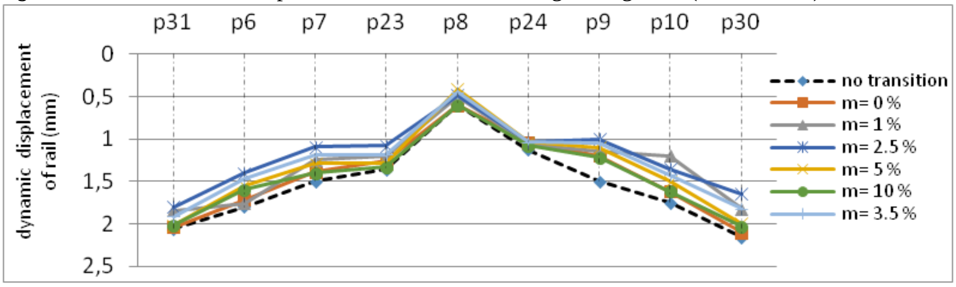

Figure 32. Dynamic vertical displacement of the rail in rigid subgrades (E=100 MPa)

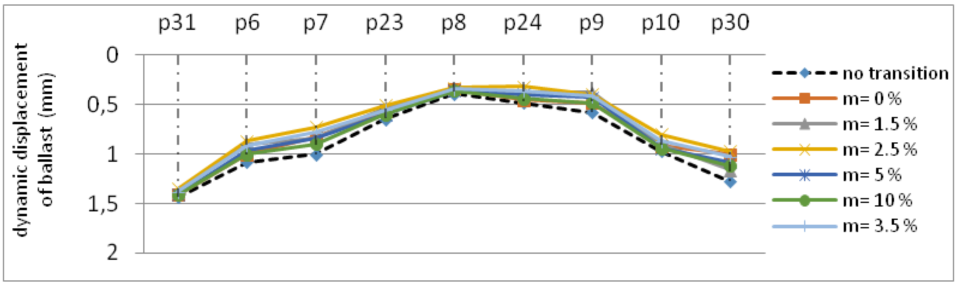

Figure 33. Dynamic vertical displacement of the ballast in rigid subgrades (E=100 MPa)

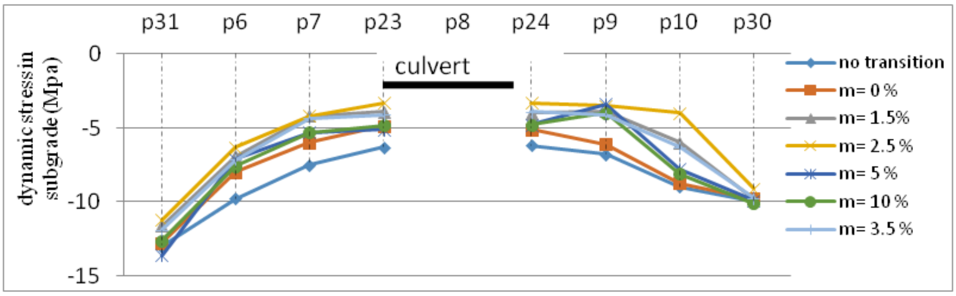

Figure 34. Dynamic normal stress in the subgrade layer in rigid subgrades (E=100 MPa)

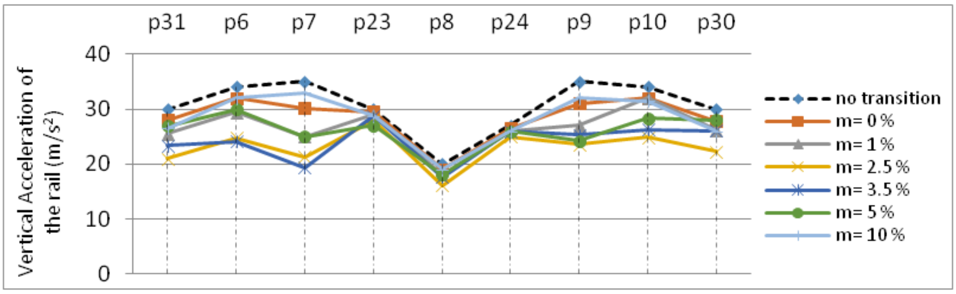

Figure 35. Vertical acceleration of the rail in rigid subgrades (E=100 MPa)

Table 6. Evaluating effect of approach slab with different slopes in the rigid subgrades

Thickness of approach slab	Evaluating effect of approach slab based on criteria (%)					
	Static Vertical rail displacement	Static Vertical ballast displacement	Dynamic Vertical rail displacement	Dynamic Vertical ballast displacement	Dynamic Normal Stress in subgrade	Reduced Acceleration of Rail
M= 0 %	5.9	7.34	6.48	11.06	11.9	6.68
M= 1.5 %	10.75	9.23	14.97	15.5	29.5	12.87
M= 2.5 %	16.64	18.0	21.17	21.75	37.5	23.91
M= 3.5 %	14.46	13.62	16.0	16.75	27.7	19.98
M= 5 %	5.9	9.54	13.67	11.76	19.8	14.35
M= 10 %	5.64	6.64	6.5	8.45	18.8	7.31

According to the Figures and Table (6), the approach slab with 2.5% slope, has the greatest effect on the railway track behavior on rigid subgrade. Existence of approach slab with the length a 4 m , the thickness a 30 cm and with the slopes of 2.5%, decreased static displacement of rail, static displacement of the ballast, dynamic vertical displacement of the rail, dynamic vertical displacement of the ballast, dynamic stress in the subgrade layer and vertical acceleration of the rail 16.64 %, 18 %, 21.17 %, 21.75 %, 37.5 % and 23.91% respectively.

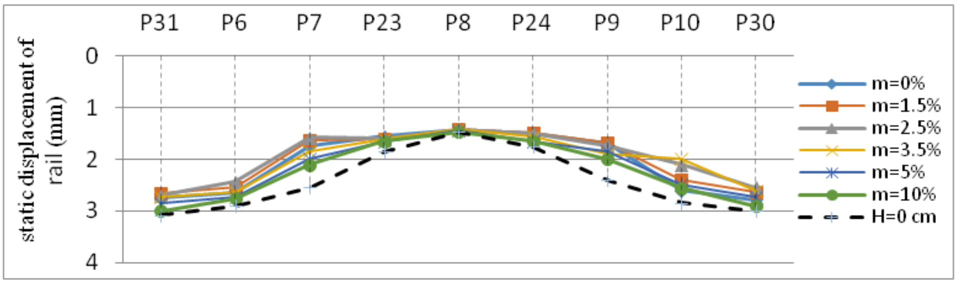

Figure 36. Static vertical displacement of rail in weak subgrades (E=20 MPa)

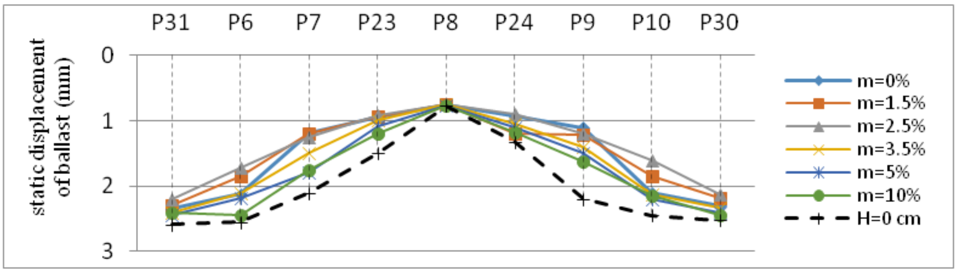

Figure 37. Static vertical displacement of ballast in weak subgrades (E=20 MPa)

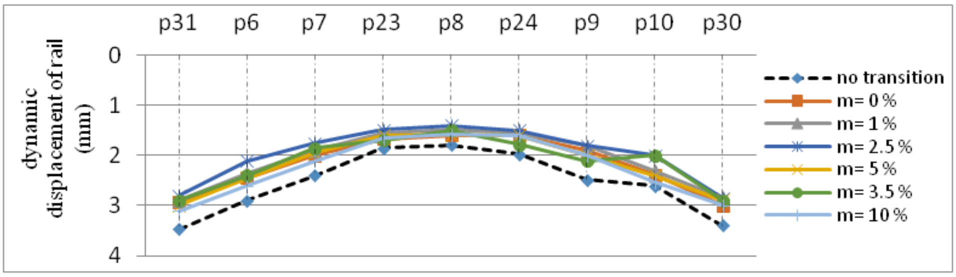

Figure 38. Dynamic vertical displacement of rail in weak subgrades (E=20 MPa)

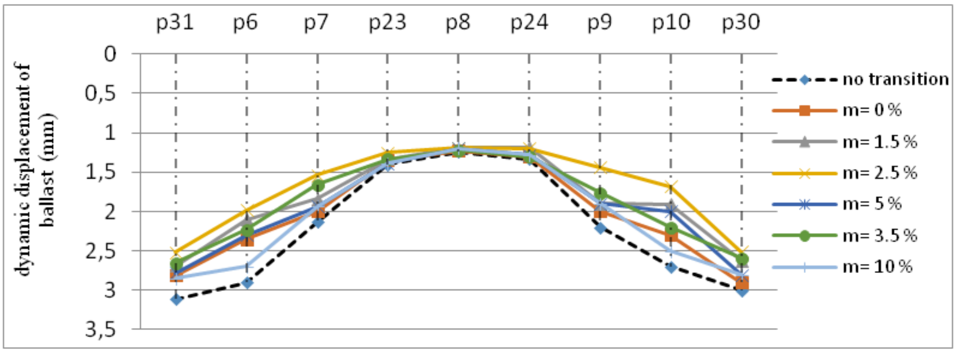

Figure 39. Dynamic vertical displacement of ballast in weak subgrades (E=20 MPa)

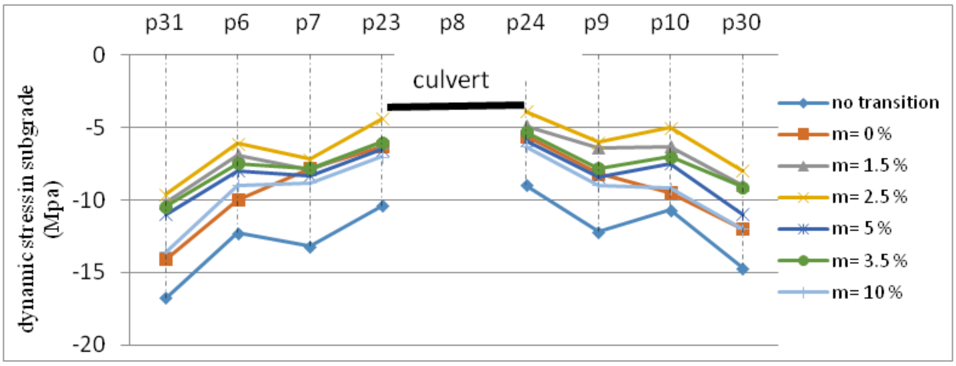

Figure 40. Dynamic normal stress in the subgrade layer in weak subgrades (E=20 MPa)

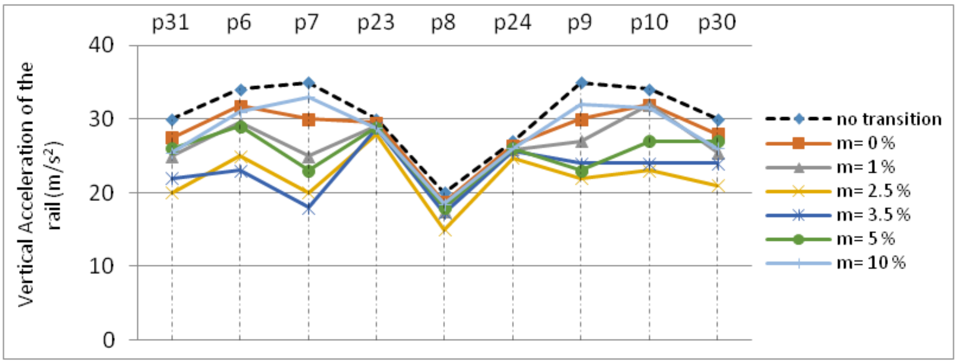

Figure 41. Vertical acceleration of the rail in rigid subgrades (E=20 MPa)

Table 7. Evaluating effect of approach slab with different slopes in the weak subgrades

Thickness of approach slab	Evaluating effect of approach slab based on criteria (%)					
	Static Vertical rail displacement	Static Vertical ballast displacement	Dynamic Vertical rail displacement	Dynamic Vertical ballast displacement	Dynamic Normal Stress in subgrade	Reduced Acceleration of Rail
M= 0 %	14.48	23.43	14.49	7.62	26.9	7.38
M= 1.5 %	16.81	23.67	18.49	14.5	42.3	13.62
M= 2.5 %	18.55	28.54	22.86	21.27	50.3	26.95
M= 3.5 %	10.79	18.64	16.02	13.45	38.7	23.5
M= 5 %	15.49	14.07	14.93	10.46	33.1	16.11
M= 10 %	7.95	11.31	12.13	6.62	25.1	8.3

Results of above Figures and Table (7) show that, in the weak subgrades, the slab with 2.5% slope has the greatest effect on the railway track behavior rather than other slopes at the culverts transition zone. The railway track behavior with 2.5% slope in the weak subgrades is decreased based on the parameters of static displacement of the rail, static displacement of the ballast, dynamic vertical displacement of the rail, dynamic vertical displacement of the ballast, dynamic stress in the subgrade layer and vertical acceleration of the rail 18.55%, 28.54%, 22.86, 21.27%, 50.3% and 26.95% respectively.

4 CONCLUSION

One of the methods that used as the railway track transition zone is implementation of the approach slab in the vicinity of the culverts. In this article, the effect of geometric parameters of the approach slab such length, thickness and slope on the railway track behavior are evaluated at the transition zone adjacent to the culverts with 3D finite element modeling. Additionally, usually the subgrade conditions are different at the culverts, because in this study the behavior of approach slab has been evaluated with various subgrade conditions (weak and rigid). The results of modeling show that the approach slab improve the railway track behavior at the transition zone but increasing thickness and length of approach slab always doesn’t improve railway track behavior. After separate sensitivity analysis on the thickness, length and slope of approach slab, and analysis of the results is found that the most appropriate behavior of the railway track at different subgrades occurs with construction of approach slab with 4 m length and 30 cm thickness and 2.5% (downward) slope and it is claimed that the railway track will have better performance with the existence of this approach slab in culvert transition zone. Finally based on static analysis, a proper slab in the adjacency of culverts decreases rail and ballast vertical displacement about 18% and 24% respectively and based on dynamic analysis, dynamic stress in the subgrade layer, dynamic vertical displacement of the rail and the ballast and vertical acceleration of the rail decrease 48%, 23% , 22% and 25% respectively. Also the performance of slab in the weak subgrade is better than to the rigid subgrade.

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