Determination of Settlement for Beam on Elastic Foundation by ETABS Software

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Abstract

In this study a numerical examples and solutions has been obtained by using three system of beam resting on elastic foundation (BOEF) which was adopted previously by three different engineering software. The first part of this paper was related to verify the model of (BOEF) by using ETABS2015 by make a comparison with previous results by determination the maximum settlements at the mid of span which show a good agreement between ETABS2015 and other results, where the total differences was vary from 2.13 % to 3.27%. . The second part of this study was highlighted on the settlement of BOEF with different parametric study (beam thickness, soil subgrade reaction(K_S) and the load location), case (1) was selected for this goal. In this paper it is found that the differential settlement along the beam are decrease as increasing in the beam stiffness in addition to possibility to obtain uplift (positive settlement) for some type of changing in the load location specially for higher thick beam . It was noticed that the settlement are increased significantly as reducing in the (K_S). Finally this study show a different form of deflection by combination two of parametric study.

Keyword: Soil subgrade reaction, beam , elastic foundation, settlement, ETABS

1-Introduction

one of the simplest methods to representing strip or companied footings for analyzing the forces and settlement under these footings is by considering a beam resting on elastic foundation which it is well known as Beam on Elastic Foundation (BOEF) .Where the reaction forces of the soil under the beam are proportional to the settlement of the beam at each point along the footing. That is to say foundation resting on individual spring has own identical ,independent , linearly and closely spaced for each to other with knowing value of spring stiffness to produce a modulus of subgrade reaction which also known as the soil stiffness or soil reaction in force divided by cubic distance (kips/in^3 ,kN/m^3, ..etc.) K_s in the vertical direction (z). Which it is considered as the intensity of the reaction force on foundation pressure. The bed of springs is used to determine the deformation, shear and moments in different type of foundations which become the bases of structural design. Also the springs use to represent the interaction between the soil and the foundation which producing by Winkler [1] and developed later by Heteyni [2] and Kerr [3] ,thus this model some time called a Winkler foundation , Beam on elastic foundation analysis or Winkler method

Where the K_S is the soil subgrade reaction and can be obtained by using the plate-load test data

$$K_s=q/\delta \quad (1)$$

q is the load in force per area , δ is the settlement

Vesic'[4] suggested another formula to find out the value of the K_S by using the stress-strain modulus as shown in the equation.

$$K_S'=0.65(E_SB^4/E_FI_F)^{1/12}x(E_S/1-u^2) \quad (2)$$

B, I_F and E_F are the foundation properties, width, moment of inertial and modulus of elasticity respectively. Bowles [5] stated that 'Since the twelfth root of any value multiplied by 0.65 will be close to 1, for all practical purposes the Vesic's equation reduces to'

$$K_S'= (E_S/1-u^2) \quad (3)$$

Where the E_S and u are the modulus of elasticity and Poisson's ratio for soil respectively. Finally the soil subgrade reaction K_S can be expressed as following equation .

$$K_S= K_S'/B \quad (4)$$

Where much software is formulated to analysis such as these problems like the aforementioned engineering program which used in this study to make the comparison by considering the absolute percentage.

$$R\% = \frac{W1-W0}{W0}x\% \quad (5)$$

R % is the percentage of absolute of deference of two values

W_0 is the value of displacement of the independent

W_1 is the value of displacement of the ETABS model

2-ETABS modeling

In previous studies many engineering software has been used , Ronald JANCO [6] used the ANSSYS to model and analysis a beam on elastic

foundation . Yun-gang Zhan [7] use the ABAQUS in modeling beam on elastic foundation using plate element in finite method. Determination of settlement in this study was done by using commercial software ETABS2015 [8] which is a finite element tool to use for analyzes the beams subjected to concentrated load. Representing the elastic continuum is difficult method due to the complexity nature of soil; Winkler model is the principle of the analysis of foundation used in the soft was by substituting of soil subgrade reaction (K_s) to compute the settlement under the beam on elastic foundation.

3-Numerical examples for beams on elastic foundation

3-1 Verification

3-1-1 Case (1):

An example for beam on elastic foundation obtained from LARSA4D [9] which used the example of Heteyni [2] (independent value of settlement). Both of these results will be used to compare with those results which obtained by using the ETABS 2015 where the aforementioned example has the following data:-

1-Beam of thickness (1 inch) with (3 inches) wide and (30 inches) long. Modules of elasticity of material E= 30,000 Ksi

2-Cross section will yield moment of inertia equal to (0.25 in^4) and area of (3 in^2)

3- The soil subgrade reaction is equal to (5000 lb/in^3)

4- Beam subjected to concentrated load in the middle of span with (P= 8 kip) as shown in the Figure (1) .

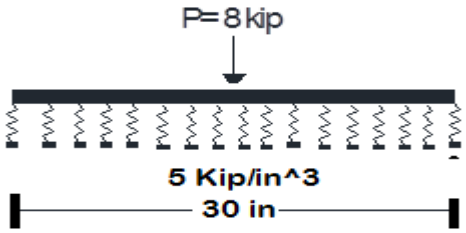

Figure (1): Beam on elastic foundation ,after [9]

Beam showing in the Figure (1) can be modeling for ETABS as shown in the Figure (2)

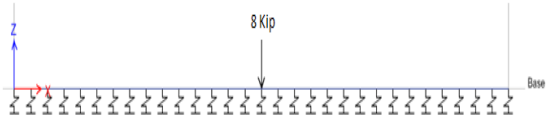

Figure (2): Modeling shape for beam of case (1)

3-1-2 Case (2):

An example for beam on elastic foundation obtained from ELPLA [10] which used the example of Rombach [11] (independent value of settlement) these result of both aforementioned reference will be used to compared with those result which obtained by using the commercial software of ETABS 2015 where the aforementioned example has the following data:-

1- Strip footing of thickness (d =0.6m) and length (L=5m) to be consider

2- The analysis was carried out for (1 m) width

3- The cross section of the beam yield a moment of inertia I_{yy} equal to (0.018m^4)

4- The soil subgrade reaction is equal to (50,000 kN/m^3)

5-The beam subjected to wall load of (P=1000 kN/m) at the center, Figure (3)

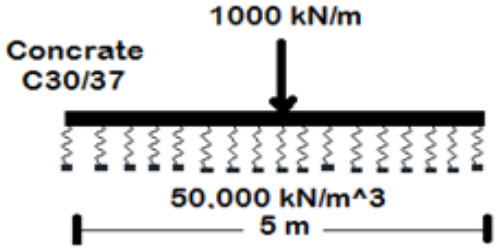

Figure (3): Beam on elastic foundation, after [10]

Beam showed in Fig. (3) can be modeling for ETABS as shown in the Fig.(4)

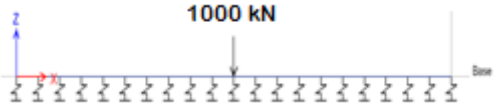

Figure (4): Modeling shape for beam of case (2)

3-1-3 Case (3):

An example for beam on elastic foundation obtained from software verification for SAP 2000 [12] which used the example of Timoshenko [13] (independent value of settlement) both of these result will be used to compared with those result which obtained by using the commercial software of ETABS 2015 where the aforementioned example has the following data:-

1-Simply supported beam of width of (b =36 in) and depth of (d =36 in) and length (L=15 ft) to be consider

2-The cross section of the beam yield a moment of inertia I_{yy} equal to (139968 in^4)

3-The modulus of elasticity of beam is equal to (4000 ksi)

4-Soil subgrade reaction equal to (800 kip/ft^3)

5- Beam subjected to concentrated load in the middle of span with P= 500 kip as shown in the figure below:-

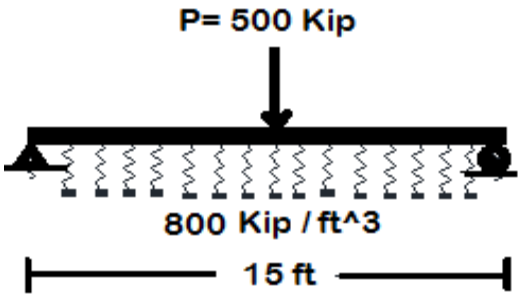

Figure (5): Simply supported beam on elastic foundation, after [12]

Beam showing in the Figure (5) can be modeling for ETABS as shown in the Figure(6)

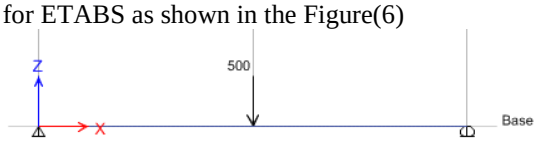

Figure (6): Modeling shape for beam of case (3)

3-2 Results and discussions

After modeling of the previous three cases by using ETABS2015 with same properties and boundary conditions a deform shape can be obtain for each example as showing in the following Figures .

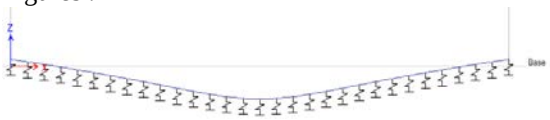

Figure (7): Deformed shape of beam in case (1)

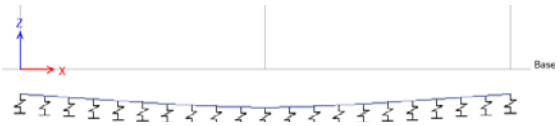

Figure (8): Deformed shape of beam in case (2)

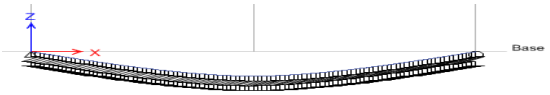

Figure (9): Deformed shape of beam in case (3)

A results of settlement in the middle of span according to the independent reference of Heteyni[2] , Rombach[11] and Timoshenko[13] in addition to engineering program of LARSA4D[9] , ELPLA[10] , SAP2000[12] and ETABS for the cases of 1, 2 and 3 respectively are tabulated in the Tables of 1,2 and 3 which showing the absolute difference ratio of 2.27%,2.13% and 3.27% respectively

Table (1): Settlement value for case (1) in the mid of span

Point	Displacement (in)			
	Heteyni	LARSA4D	ETABS	R%
Mid. span	0.04348	0.043478	0.042493	2.27

Table (2): Settlement value for case (2) in the mid of span

Point	Displacement (in)			
	Rombach 2000	ELPLA	ETABS	R%
Middle of span	0.47	0.46	0.48	2.13

Table (3): Settlement value for case (3) in the mid of span

Point	Displacement (in)			
	Timoshenko	SAP2000	ETABS	R%
Middle of span	0.08933	0.08933	0.08614	3.27

It can be noted that there is a minor differences in the results between the ETABS 2015 results and the independent values (Heteyni, Rombach 2000 and Timoshenko) it is may be come due to some differences in the input data but still consider as acceptable tolerance (less than 5%).

4- Parametric study

After verifying the modeling of beam on elastic foundation by using ETABS 2015 [8] where all result is agree well with other software. In this part of this study a three aspects of beam thickness, soil subgrade reaction(k_s) and load location to figure out the effect of each aforementioned aspect on the settlement of beam by adopting example (1) .

In this section the study will discuss the impact of some parametric study on the settlement of beam on elastic foundation where the parametric study is consist of the following items:-

a- Effect of beam thickness

A thickness of 0.5, 1, 2, 3, 4 and 5 inches for the beam of case (1) are adopted to investigate the settlement under concentrated load with the same specification where the value of aforementioned thickness was only changing in each program of ETABS2015 running.

b- Effect of the location of concentrated load

It is will be done by changing the location of load of 8 kips from node (x=0) to the midpoint of beam as mentioned before where the distance of (x=15) inches at each interval of 3 inches as appear in Figure (10) below

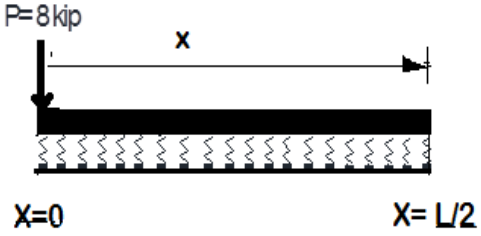

Figure (10): Individualized beam of 30 inches

To figure out the how can the location of load effect on the settlement of beam on elastic foundation

c- Effect subgrade reaction (K_s)

To determine the impact of soil subgrade reaction on the settlement of beam on elastic foundation subjected to concentrated load with the same specification of materials and other circumstances of case (1), a different value of subgrade reaction of $3x10^3$, $4x10^3$, $5x10^3$, $6x10^3$ and $7x10^3$ lb/in^3 will be used to find out the effect of soil subgrade reaction on the settlement of beam resting on elastic foundation.

In addition to combination of effect of beam thickness with the rest of parametric study separately

4-1 Results and discussion

4-1-1 Effect of beam thickness

By increasing the beam thickness from 0.5 to 5 inches as mentioned previously it can observe that there is a reducing in both of settlement at the mid of span and the differential settlement along the beam where the load at mid span as shown in the Table no.1 in appendix A .For more clearance all results in the aforementioned appendix will be used create a chart showing the changing in the value of settlement due to increasing in the beam thickness. It is also can be notice that the deflected shape of beam transform from curvature to be Simi line as increasing in beam thickness as shown in Figure (11) below :-

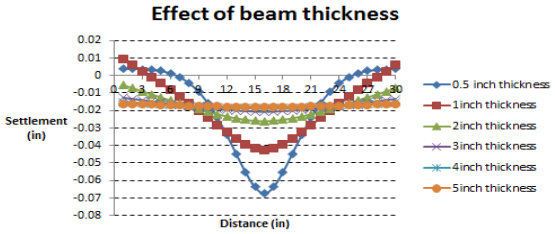

Figure (11): Effect of beam thickness

4-1-2 Effect of location of concentrated load

As the load are moving from the edge to the midpoint of beam (0.6 inch thick) a different values of settlement at each node can be seen as shown in Table no.2 in appendix A . All result mentioned in table no.2 are used to create a chart showing the changing in the value of settlement in nodes for each for each changing in the load location along the beam as shown in the Figure (12)

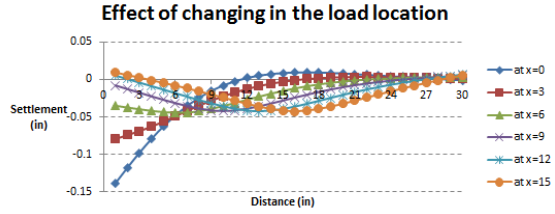

Figure (12): Effect of the load location

The Figure above exhibit two kind of deflection (positive and negative) which they are keeping in changing according to load location . Both effects of the load location and beam thickness are toke in the consideration by using ETABS for modeling abeam with different load location and different value of thickness which can be summarized in the following Figures :

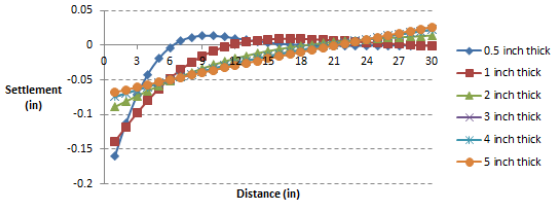

Figure (13): Different values of thickness for load at x=0

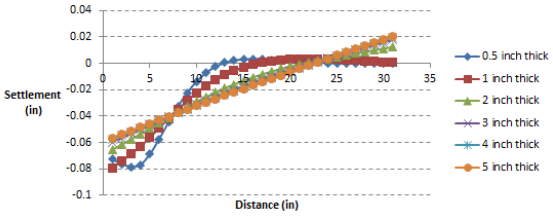

Figure (14): Different values of thickness for load at x=3 in

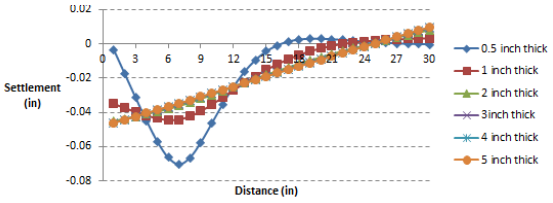

Figure (15): Different values of thickness for load at x=6 in

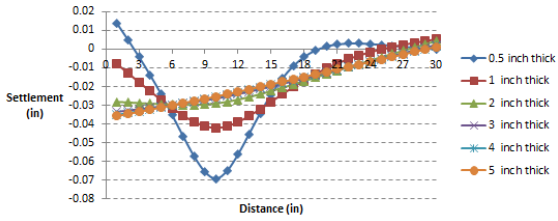

Figure (16): Different values of thickness for load at x=9 in

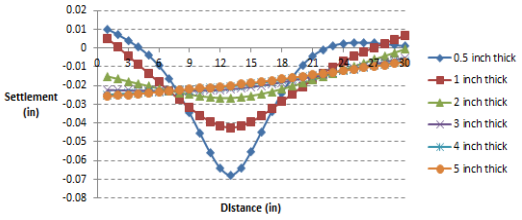

Figure (17): Different values of thickness for load at x=12 in

And finally for different values of thickness for load allocated at the center of the span which is

similar to Figure (11) as shown below in Figure (18)

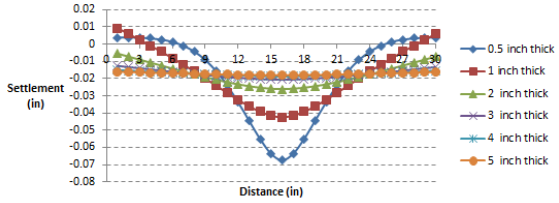

Figure (18): Different values of thickness for load at x=15 in

From above Figures it can be noted that increasing the beam thickness are working to reduce both of the settlement and the differential settlement and as mentioned above . While the changing in the load location are working to change the shape of deflection and the location of both positive and negative settlement

4-1-3 Effect of soil subgrade reaction (K_s)

Settlement at each node along the beam of case (1) by using a different values of soil subgrade reaction are tabulated in Appendix A Table (3) where the values of settlement along the beam are used to create a chart as shown in the figure (19) which exhibit obvious increasing in the settlement at the midpoint of beam as the soil subgrade reaction are decrease .

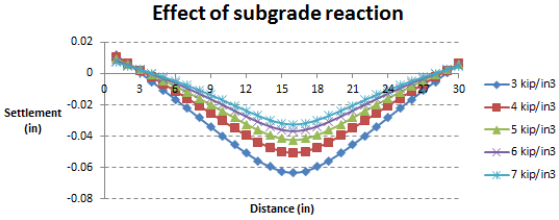

Figure (19): Effect of the soil subgrade reaction

Similarly to the previous part of this study a lot of charts are obtain by combination the effect of subgrade reaction and different values of thickness as showing below:

By reviewing the charts it is clearly to notice that all figures give the same shape of deflection but in different values of settlement depending on values of both soil subgrade reaction and the beam thickness for the same location of concentrated load (at the midpoint of beam)

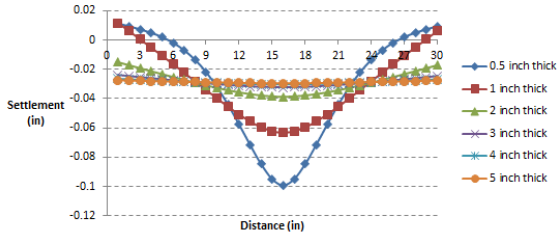

Figure (20): Effect of different value of thickness for beam resting on soil subgrade reaction of 3 ksi/in

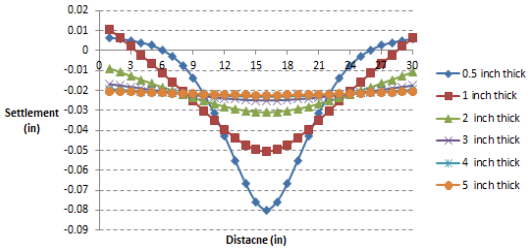

Figure (21): Effect of different value of thickness for beam resting on soil subgrade reaction of 4 ksi/in

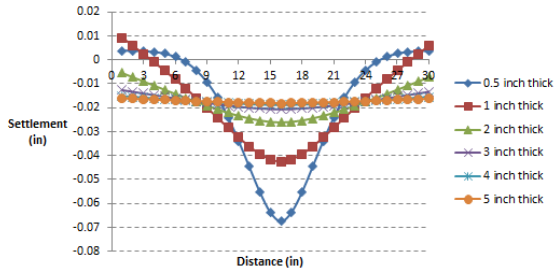

Figure (22): Effect of different value of thickness for beam resting on soil subgrade reaction of 5 ksi/in

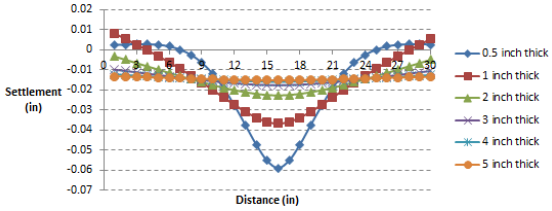

Figure (23): Effect of different value of thickness for beam resting on soil subgrade reaction of 6 ksi/in

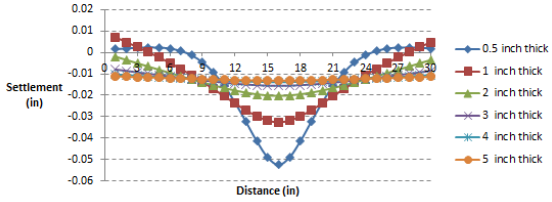

Figure (24): Effect of different value of thickness for beam resting on soil subgrade reaction of 7 ksi/in

5-Conclusion

In spite of the commercial software of ETABS2015 are specialized for analysis and design of the super-structure frame but through the study we show that the modeling of Beam On Elastic Foundation (BOEF) could be implemented by ETABS2015 with accurate results by obtaining a good agreement with the other engineering software. In connection with parametric study we can notice the following conclusions

a- Regarding the effect of beam thickness, it can be noted that both of the settlement and differential settlement was reduce as the beam thickness is increase where the deflected shape will become semi-line and the reduction in the settlement and the differential settlement along

the beam are from 37.04% to 73.17% and from 78.09% to 11.24% respectively .

b- The change in load location gives a different shape of settlement in addition to different sign of settlement (positive and negative)

c- By using a different values of subgrade reaction which can be consider as indicator of the soil stiffness , the value of settlement was decrease as the soil subgrade reaction was increase , with approximately of keeping on the shape of settlement as curve due to location of load in the mid of foundation span.

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ايجاد مقدار الهطول تحت عتبات المستندة على اساس مرن بواسطة برنامج ايتاب 2015

ابراهيم سليم حربة عدي صاحب برهان الربيعي

جامعة النهرين - كلية الهندسة - قسم الهندسة المدنية

الخلاصة :-

تم التطرق في هذه الدراسة الى نوع من انواع الاساسات والمستخدمة بشكل واسع في عملية تنفيذ المباني والمستندة الى اساس مرن والخاصة بنظرية Beam On Elastic Foundation (BOEF) او تسمى في بعض الاحيان نظرية Winkler نسبة الى العالم الذي قام بتمثيل التربة وذلك باستخدام محموعة من النوابض ذات مقاومة معلومة والتي تستند عليها الاسس مثل الاسس الشريطية او الاساس المركب companied and strip footings والمتعرضة الى احمال منقولة من المقاطع اللانشائية الخاصة بالمنشأ مثل الاعمدة اوالجدران الحاملة للاوزان حيث تم استخدام البرنامج الهندسي ETABS2015في عملية تمثيل وتحليل ثلاث انظمة من ال (BOEF) والتي تم الاستفادة منها سابقا في بعض البرامج الهندسية الاخرى حيث تم ايجاد قيم الهطول في منتصف الSpan لغرض المقارنة والتحقق verification وكانت النتائج جيدة جدا حيث كان نسبة الاختلاف تتراوح مابين 3.27% و3.12% . ولغرض معرفة تصرف مثل هذه المقاطع الانشائية تم استخدام المثال الاول لغرض اجراء بعض التغيرات وذلك باعتماد بعض حالة او اكثر من ال parametric study والتي كانت تضم سمك العتبة ,مقدار رد فعل التربة بالاضافة الى تغيير موقع الحمل . ومن اهم ما لوحظ في ذلك الفصل هو امكانية حصول الهطول الموجب uplift في بعض الحالات نتيجة لتغيير موقع الحمل وكذلك نقصان في درجة التحدب والحصول على هطول منتظم كلما زاد نسبة الجساءة الخاصة بالعتبة مع ملاحظة ان تغيير مقدار رد فعل التربة لايؤثر على شكل الهطول بقدرما يؤثر على مقدار الهطول حيث يتناسبان بشكل عكسي فكلما زادت قوة تحمل التربة قل مقدار الهطول .

Appendix (A)

Table (A- 1)

Beam thickness (in)	0.5	1	2	3	4	5
Node no.						
1	0.003932	0.009309	-0.005482	-0.01264	-0.015094	-0.01607
2	0.003849	0.005923	-0.007235	-0.013327	-0.015409	-0.016236
3	0.003696	0.00252	-0.008989	-0.014015	-0.015725	-0.016404
4	0.003349	-0.000932	-0.01074	-0.014702	-0.016041	-0.016573
5	0.002626	-0.004469	-0.012483	-0.015385	-0.016356	-0.016741
6	0.00129	-0.008125	-0.01421	-0.016061	-0.016668	-0.016909

7	-0.000935	-0.011925	-0.015911	-0.016725	-0.016975	-0.017074
8	-0.004347	-0.015877	-0.017571	-0.017369	-0.017274	-0.017235
9	-0.009223	-0.019969	-0.019172	-0.017987	-0.01756	-0.01739
10	-0.015771	-0.024152	-0.02069	-0.018569	-0.017831	-0.017538
11	-0.024048	-0.02834	-0.022099	-0.019106	-0.018082	-0.017675
12	-0.033855	-0.032399	-0.023364	-0.019586	-0.018307	-0.0178
13	-0.044605	-0.036137	-0.024449	-0.019997	-0.018501	-0.017908
14	-0.05517	-0.039297	-0.025308	-0.020322	-0.018658	-0.017998
15	-0.063707	-0.041552	-0.025892	-0.020548	-0.01877	-0.018064
16	-0.067494	-0.042493	-0.026143	-0.020655	-0.01883	-0.018105
17	-0.063707	-0.041552	-0.025892	-0.020548	-0.01877	-0.018064
18	-0.05517	-0.039297	-0.025308	-0.020322	-0.018658	-0.017998
19	-0.044605	-0.036137	-0.024449	-0.019997	-0.018501	-0.017908
20	-0.033855	-0.032399	-0.023364	-0.019586	-0.018307	-0.0178
21	-0.024048	-0.02834	-0.022099	-0.019106	-0.018082	-0.017675
22	-0.015771	-0.024152	-0.02069	-0.018569	-0.017831	-0.017538
23	-0.009223	-0.019969	-0.019172	-0.017987	-0.01756	-0.01739
24	-0.004347	-0.015877	-0.017571	-0.017369	-0.017274	-0.017235
25	-0.000935	-0.011925	-0.015911	-0.016725	-0.016975	-0.017074
26	0.00129	-0.008125	-0.01421	-0.016061	-0.016668	-0.016909
27	0.002626	-0.004469	-0.012483	-0.015385	-0.016356	-0.016741
28	0.003349	-0.000932	-0.01074	-0.014702	-0.016041	-0.016573
29	0.003696	0.00252	-0.008989	-0.014015	-0.015725	-0.016404
30	0.003849	0.005923	-0.007235	-0.013327	-0.015409	-0.016236
31	0.003932	0.009309	-0.005482	-0.01264	-0.015094	-0.01607

Table (A- 2)

The location of load	x=0	x=3	x=6	x=9	x=12	x=15
Node no.						
1	-0.13825	-0.07941	-0.03506	-0.00796	0.005188	0.009309
2	-0.11764	-0.0742	-0.03743	-0.01282	0.000546	0.005923
3	-0.09785	-0.06885	-0.03973	-0.01766	-0.00411	0.00252
4	-0.07941	-0.06304	-0.04183	-0.02245	-0.00878	-0.00093
5	-0.06269	-0.05625	-0.04349	-0.02711	-0.01348	-0.00447
6	-0.04788	-0.04905	-0.04441	-0.03152	-0.0182	-0.00813
7	-0.03506	-0.04183	-0.0442	-0.03549	-0.02289	-0.01193
8	-0.0242	-0.03487	-0.04229	-0.0388	-0.02747	-0.01588
9	-0.01522	-0.02836	-0.03925	-0.04114	-0.03182	-0.01997
10	-0.00796	-0.02245	-0.03549	-0.04211	-0.03577	-0.02415
11	-0.00227	-0.0172	-0.03135	-0.04118	-0.03907	-0.02834
12	0.002052	-0.01265	-0.02708	-0.03892	-0.04142	-0.0324
13	0.005188	-0.00878	-0.02289	-0.03577	-0.04241	-0.03614
14	0.007329	-0.00558	-0.0189	-0.03208	-0.04149	-0.0393
15	0.008648	-0.00298	-0.01523	-0.02814	-0.03926	-0.04155
16	0.009309	-0.00093	-0.01193	-0.02415	-0.03614	-0.04249
17	0.009454	0.000626	-0.00902	-0.02028	-0.03246	-0.04155
18	0.009208	0.001763	-0.00652	-0.01664	-0.02851	-0.0393
19	0.008678	0.002544	-0.00441	-0.0133	-0.02449	-0.03614
20	0.007952	0.003031	-0.00267	-0.0103	-0.02056	-0.0324
21	0.007099	0.00328	-0.00125	-0.00764	-0.01681	-0.02834
22	0.006175	0.003341	-0.00013	-0.00533	-0.0133	-0.02415
23	0.005219	0.003259	0.000746	-0.00333	-0.01007	-0.01997
24	0.004259	0.003069	0.001415	-0.00161	-0.00711	-0.01588
25	0.003312	0.002804	0.001919	-0.00013	-0.00441	-0.01193
26	0.002388	0.002486	0.002296	0.001161	-0.00193	-0.00813
27	0.001489	0.002135	0.002581	0.002304	0.000374	-0.00447
28	0.000612	0.001764	0.002804	0.003341	0.002544	-0.00093

29	-0.00025	0.001383	0.002988	0.004313	0.004626	0.00252
30	-0.0011	0.000998	0.003153	0.00525	0.00666	0.005923
31	-0.00195	0.000612	0.003312	0.006175	0.008678	0.009309

Table (A- 3)

Subgrade reaction value	3 kip/in^3	4 kip/in^3	5 kip/in^3	6 kip/in^3	7 kip/in^3
Node no.					
1	0.011643	0.010603	0.009309	0.008126	0.007113
2	0.006082	0.00634	0.005923	0.005369	0.004826
3	0.000508	0.002061	0.00252	0.002594	0.002521
4	-0.005102	-0.002262	-0.000932	-0.000232	0.000164
5	-0.010769	-0.00666	-0.004469	-0.00315	-0.002288
6	-0.01651	-0.01116	-0.008125	-0.006196	-0.004875
7	-0.022328	-0.015778	-0.011925	-0.009402	-0.007632
8	-0.028207	-0.020514	-0.015877	-0.012785	-0.010581
9	-0.034104	-0.025341	-0.019969	-0.016338	-0.013722
10	-0.03994	-0.030201	-0.024152	-0.020023	-0.017026
11	-0.045599	-0.034992	-0.02834	-0.023766	-0.020424
12	-0.050915	-0.039567	-0.032399	-0.027441	-0.023801
13	-0.055666	-0.043722	-0.036137	-0.030867	-0.026984
14	-0.05957	-0.04719	-0.039297	-0.033798	-0.029735
15	-0.06228	-0.049633	-0.041552	-0.035911	-0.031737
16	-0.063374	-0.050637	-0.042493	-0.036805	-0.032593
17	-0.06228	-0.049633	-0.041552	-0.035911	-0.031737
18	-0.05957	-0.04719	-0.039297	-0.033798	-0.029735
19	-0.055666	-0.043722	-0.036137	-0.030867	-0.026984
20	-0.050915	-0.039567	-0.032399	-0.027441	-0.023801
21	-0.045599	-0.034992	-0.02834	-0.023766	-0.020424
22	-0.03994	-0.030201	-0.024152	-0.020023	-0.017026
23	-0.034104	-0.025341	-0.019969	-0.016338	-0.013722
24	-0.028207	-0.020514	-0.015877	-0.012785	-0.010581
25	-0.022328	-0.015778	-0.011925	-0.009402	-0.007632
26	-0.01651	-0.01116	-0.008125	-0.006196	-0.004875
27	-0.010769	-0.00666	-0.004469	-0.00315	-0.002288
28	-0.005102	-0.002262	-0.000932	-0.000232	0.000164
29	0.000508	0.002061	0.00252	0.002594	0.002521
30	0.006082	0.00634	0.005923	0.005369	0.004826
31	0.011643	0.010603	0.009309	0.008126	0.007113