BEHAVIOUR OF THE ALUMINIUM BASE GRID STRUCTURE IN RELATION TO THE SUBGRADE REACTION COEFFICIENT

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ABSTRACT

The aim of the paper, as of the previous research continuity, is to show the effects of the subgrade reaction coefficient modelling on the aluminium base grid structure and foundations. That kind of structure is more frequently used for the objects built on the faraway locations because of the small self-weight and small surrounding ground impact. Both factors direct influence on the investment. Commonly, the shallow concrete foundation system is supporting the aluminium grid construction, which is used as a base for the structure above. The above structure is modelled as load, while the soil is modelled through the subgrade reaction coefficient. The aluminium grid construction itself could occur in two extreme variations known as the rigid and soft grid. The test example deals with both forms and analyses their structural responses. The main influence on the structural response has contact with the underlying structure. For the subgrade reaction coefficient modelling the Se_Calc software is used.

Keywords: *Aluminium grid structures; subgrade reaction coefficient; Se_Calc*

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1. INTRODUCTION

There are two reasons why this kind of structures are investigated. The first reason is that a surrounding ground impact lies in the area of the shallow foundation and the rest of the grid structure is on the columns above the ground. The height of the column will define the distance between the grid, the soil and the foundation. The second reason is the actual problem with climate change when this kind of structure gives local people and authority more flexibility in the cases of possible unpredicted flooding.

Since the work on the foundation requires less time than in the case of commonly used constructions, it is possible to have the situations of founding on the soil with different characteristics. But, in this paper, we assume that the soil has the same characteristics. The problem occurs when we want to model the soil trough subgrade reaction coefficient, the value necessary for the Winkler spring model of soil. For this purpose, we used the software SE_Calc [1] that gives the different values of subgrade reaction coefficient given by different authors [2].

After defining the subgrade reaction coefficients, different values by different authors, it is interesting to watch the answer to these phenomena on the simple aluminium grid structure. In this case, the grid represents the rigid base structure for the main upper structure which is for now out of our domain of interest and its influence will be represented only as load.

Since this paper represents the continuity of research on the topic [3], [4], of the subgrade reaction coefficient influence on the behaviour of the structures and foundation systems, we are here dealing with aluminium grid structures based on the concrete foundations. As in most engineering cases, the shallow foundations are also used here. First of all [3], [4], [5] the Winkler springs' modelling has to be used for the connection model between soil and foundation. In other words, it is necessary to find out the numerical value of the subgrade reaction. That value will be given to the software, in this case, Tower 3D Model Builder [6] as numerical input for Winkler's spring rigidity. In its essence, that value represents the relationship between stress under the foundation and its deflection [7], [8]. For its determination, we used the software SE_Calc [1], [2]. After the calculations, we monitored the behaviour of the aluminium grid structure.

2. SUBGRADE REACTION COEFFICIENT

Software SE_Calc was developed for determination the subgrade reaction coefficients value for the square shallow foundation by different authors' equations [3], [4], [5]. The software is closely explained in the references [9], [10], [11].

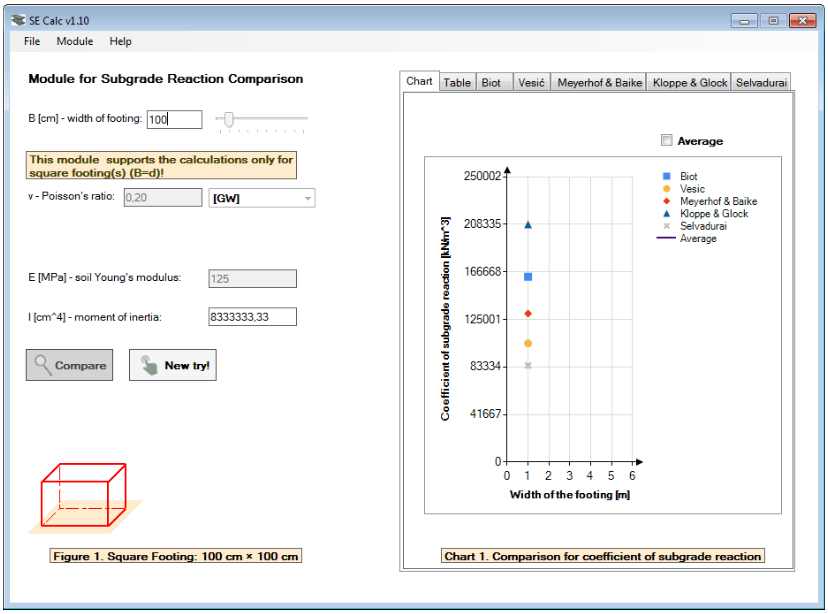

Fig. 1. Graphically interpretation of the subgrade reaction coefficient

It was tested on examples from the literature [2] and was upgraded in the last version with the options of the mean value calculation. That value represents the average of the subgrade reaction coefficients for all authors considered by software.

In this paper, we used the values from Table 1 (given below). The average value will be the starting point for tracking the behaviour of the aluminium grid structure. Thus, the subgrade reaction coefficients for a base dimension of the square 100 × 100 × 60 cm foundation are shown in Table 1 and represented in Fig. 1.

Table 1. Numerical value of the subgrade reaction coefficient

Author	Value of the subgrade reaction coefficient	Deviation from the average value
	kN/m^3	%
Vesic	162490.76	+17.79
Biot	104107.95	-24.53
Meyerhof & Baike	130208.33	-5.62
Kloppe & Glock	208333.33	+51.02
Selvadurai	84635.42	-38.65
Average	137955.16	0.00

3. ALUMINIUM GRID

3.1. Generally about aluminium alloys in structures

Pure aluminium is weak, with a tensile strength ranging from about 90 to 140 N/mm^2 depending on the temper. It is employed for electrical conductors and domestic products, but for serious structural use, it has to be strengthened by alloying. The strongest alloys have a tensile strength of over 500 N/mm^2.

The choice of a suitable aluminium alloy for use in load-bearing structures is determined by a combination of these factors: strength, durability, corrosion resistance, physical properties, weldability, shape-ability, and availability of the required alloy and special shapes on the market [12], [13], [14], [15], [16], [17], [18].

Aluminium structures are classified into three durability groups A, B and C (A the most durable). For structures used in 6xxx heat-treatable alloy, EN AW-6082, EN AW-6061, EN AW-6005A, EN AW-6106, EN AW-6063 and EN AW-6060 alloys are suitable. These alloys belong to the durability class B. From the 7xxx alloy series, the EN AW-7020 alloy is suitable for general structural applications and has a durability grade C. The AW-6082 alloy is one of the most commonly used alloys suitable for heat treatment and is often the main structural alloy for welded and un-welded applications. It is a high strength alloy and is available in the form of full and hollow extruded profiles, tubes, plates. It is increasingly used in parts exposed to the marine environment.

The alloy EN AW-6061 is also a widely used alloy suitable for heat treatment for welded and non-welded applications, in various profile shapes. Both alloys are commonly used in fully heat-treated condition as EN AW-6082-T6 and EN AW-6061-T6. The choice of these alloys is justified from a structural point of view. However, care must be taken in heat-affected zones for welding joints. Another good characteristic of aluminium is corrosion resistant. In short, it could be stated that corrosion is a natural process as nature attempts to return metals to their original, stable, oxidised state. The degree and severity of corrosion is a function of both the material and its operating environment. Aluminium has a very high affinity with oxygen [19]. Only Beryllium has a higher affinity. When a new aluminium surface is exposed in the presence of air (or an oxidising agent), it very rapidly acquires a thin, compact self-healing film of aluminium oxide (about 0,5μ in the air). In non-stagnant water, thicker films (of hydrated-oxide) are produced. This film is relatively chemically inert. It is on the inactivity of the surface film that the good corrosion resistance of aluminium depends.

3.2. Physical properties

In the testing example, the alloy EN AW-6082-T6 will be used. The basic physical properties of aluminium and aluminium alloys are shown in Table 2.

Table 2. Basic physical properties of aluminium and steel

Physical properties	Aluminium	Steel
	EN AW-6082-T6	*S235*
Melting point	660°C	1500°C
Density at 20°C	2700 kg/m^3	7850 kg/m^3
Thermal elongation	$23 \cdot 10^{-6}$°C^{-1}	$12 \cdot 10^{-6}$°C^{-1}
Specific heat	920 J/kg°C	490 J/kg°C
Thermal conductivity	240 W/m°C	240 W/m°C
Modulus of elasticity	70 000 MPa	210 000 MPa
Shear modulus	27 000 MPa	81 000 MPa
Poisson's coefficient	0.3	0.3

4. TESTING EXAMPLE

4.1. Generally about aluminium alloys in structures

The grid structures [20] are a special type of the structures, which by its static way of behaviour, belong to the spatial beam structures. They occur when the beam carrier system is set in two directions and interconnected like in Fig. 2. Type of the connection determines the way of the static response of the grid. If the beams from one direction are placed in the way that they only lie on those from the other direction then we are talking about soft grid structure, because only forces without moments are transmitted between the beams. The other opposite case is the complete rigid connection between the beams from one direction to the one from the other direction. All six components of general forces are transmitted, so the rigid grid is statically functioning like the plate. The closer the beams are the similarity with the plate is greater.

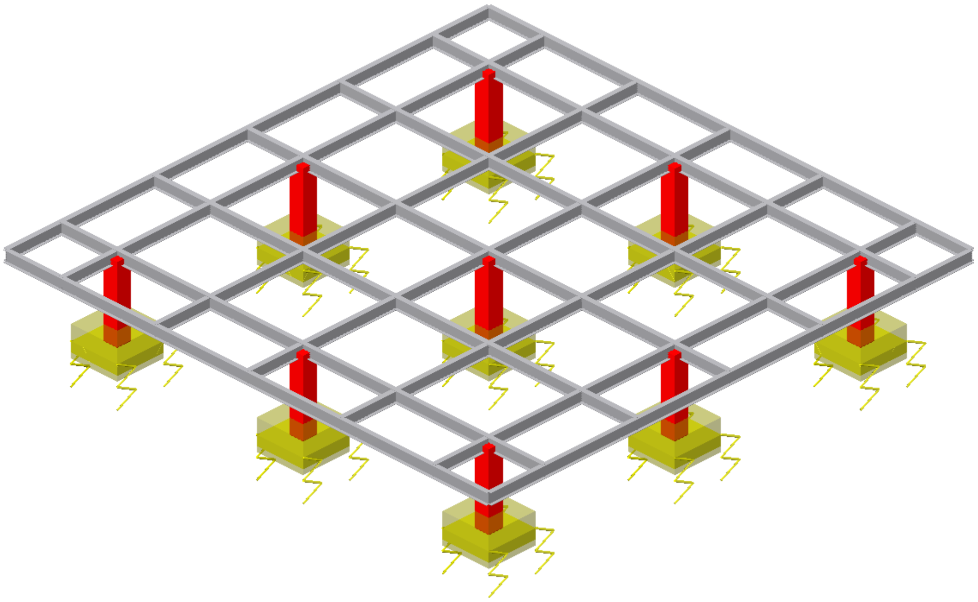

Fig. 2. Aluminium grid structure on the shallow foundation

In Fig. 2, a numerical model of the rigid aluminium grid structure is represented. Characteristics of the grid system are like following: concrete C 25/30, aluminium alloy EN AW-6082-T6 (f_0=260MPa), distance in both directions lx = ly = 4×4.0 m = 16.0 m with cantilevers l = 1.20m. The cross-section of the aluminium beams is I profile h = 220mm high, b = 100m with, with the flange t_f = 8mm thick and web t_w= 6mm thick. Cross-section of the columns is 30/30cm, uniform gravitational load by each beam 5.0 kN/m' and self-weight of each element used in the structure is taken into account by software. Used finite element software for numerical modelling is Tower 3D model Builder. Dimension of the foundation are 100cm x 100cm x 60cm, and the mesh density is 0.20mx0.20m.

For the purpose of the comparison of the results, the numerical model of the soft grid system is made too. On that soft system, the beams from the opposite directions are separated like in the paper [2] in the way that they are not transmitted the twisting (torque) moment.

4.2. Results of the analyses

All the parameters required for numerical modelling of the aluminium rigid and soft grid are known. For the purpose of the result comparing the basic, rigid or soft, numerical model will be the one for which the average value of the subgrade reaction coefficient is taken. Diagrams of moments for the rigid aluminium grid are shown in Fig. 3, vertical displacement in Fig. 4 and stress under the foundation in Fig. 5. Small jumps in the bending moment of the rigid grid show the small influence of the torque stiffness impact from the other direction [20].

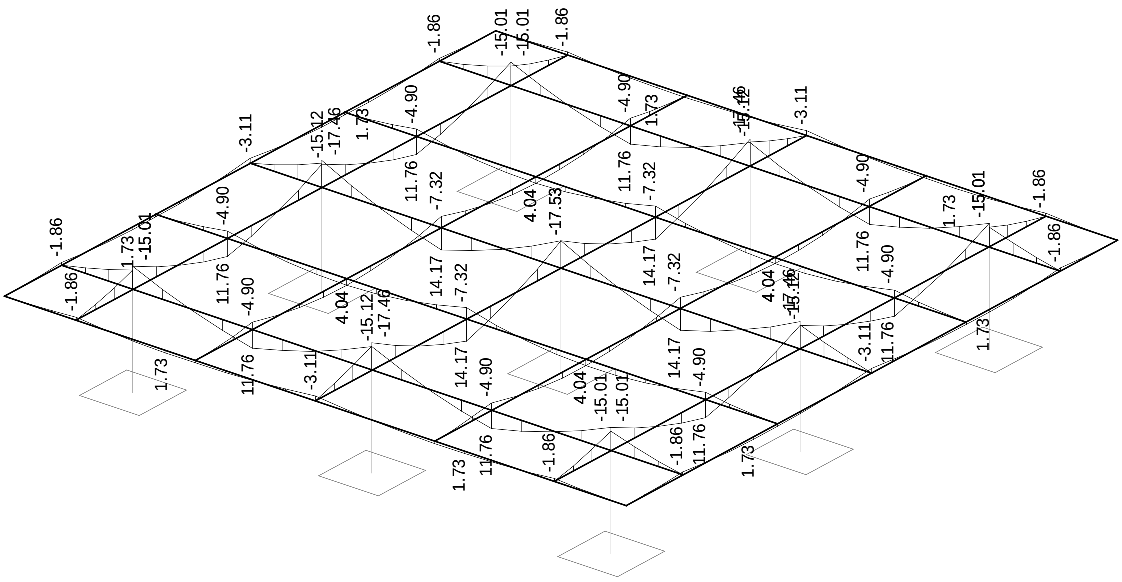

Fig. 3. Moment diagram of the aluminium rigid grid

Table 3. Comparison of the characteristic values of the middle beam of the rigid grid

Author	Column near cantilever - left	Max. in the field	Above column – middle	**Displacement Zp max**
	kNm	kNm	kNm	**mm**
Vesic	17.46	14.17	17.54	**-8.40**
Biot	17.47	14.17	17.52	**-8.73**
Meyerhof & Baike	17.46	14.17	17.53	**-8.55**
Kloppe & Glock	17.45	14.17	17.55	**-8.27**
Selvadurai	17.47	14.17	17.51	**-8.95**
Average	17.46	14.17	17.53	**-8.50**

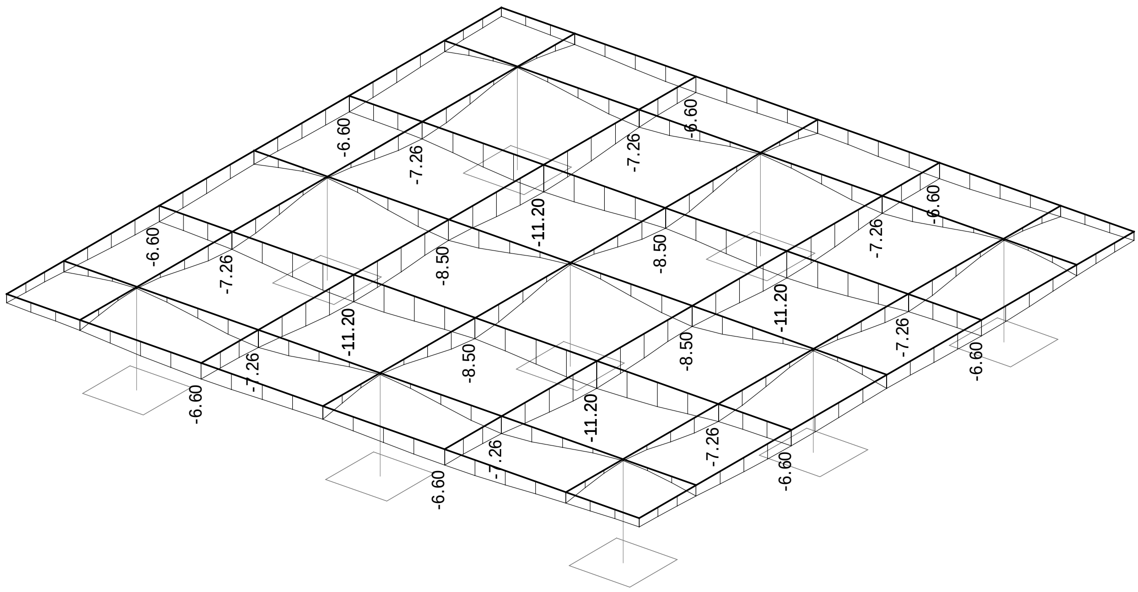

Fig. 4. Vertical Zp displacement diagram (mm) for the aluminium rigid grid

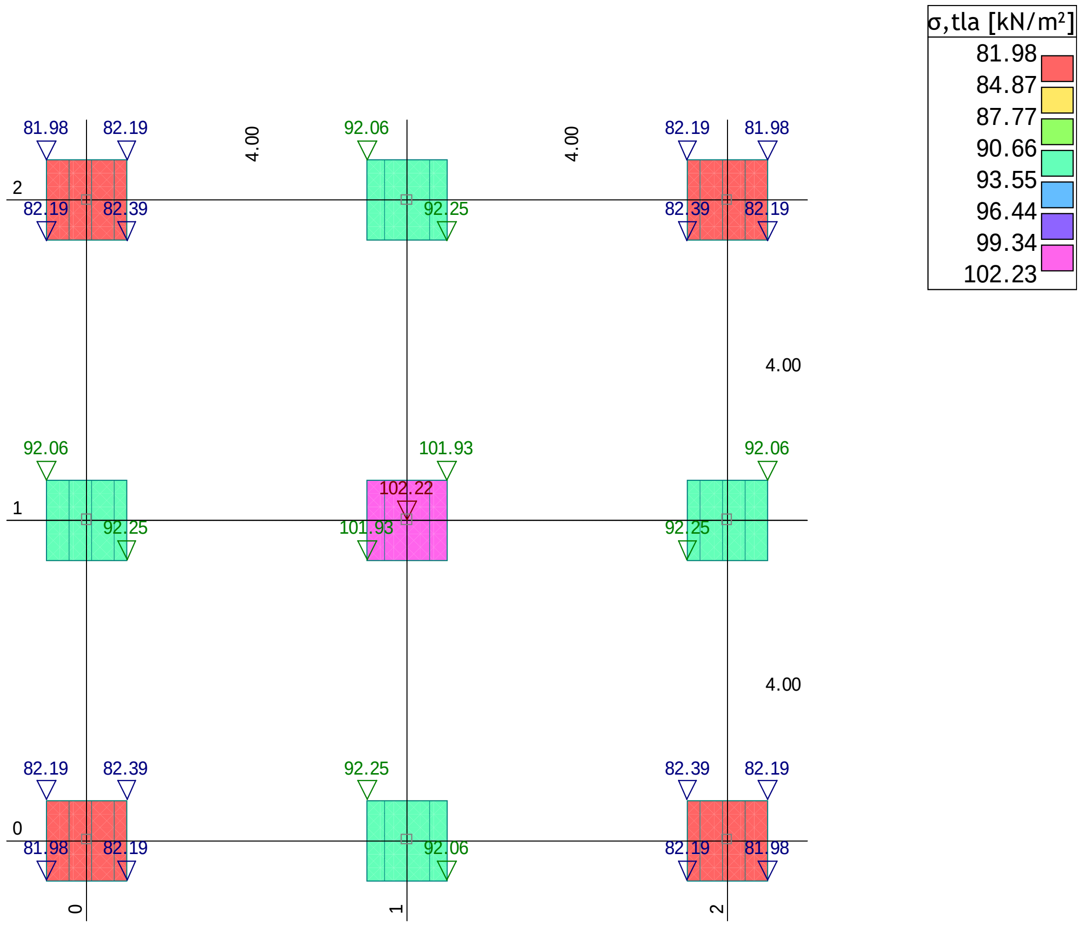

Fig. 5. Stress distribution diagram of the rigid grid

Table 4. Comparison of the stress and vertical foundation displacement of the rigid grid

Author	σ (max)	σ (min)	s (max)	s (min)
	kN/m^2	kN/m^2	mm	mm
Vesic	102.26	82.06	-0.51	-0.63
Biot	102.16	81.87	-0.79	-0.98
Meyerhof & Baike	102.21	81.96	-0.63	-0.78
Kloppe & Glock	102.33	82.04	-0.39	-0.49
Selvadurai	102.11	81.79	-0.97	-1.21
Average	102.22	81.98	-0.59	-0.74

For comparison, a parallel soft grid model has been created in which the beams from the opposite directions are separated from each other for transmission of torsion moments. Due to the space constraint, plot diagrams are not drawn, but the values of the moments in the special points of the soft grid, as well as the maximum displacements, are given in Table 5.

Table 5. Comparison of the characteristic values of the middle beam of the soft grid

Author	Column near cantilever - left	Max. in the field	Above column – middle	**Displacement Zp max (field)**
	kNm	kNm	kNm	**mm**
Vesic	26.96	18.26	20.68	**-9.70**
Biot	26.95	18.26	20.68	**-10.13**
Meyerhof & Baike	26.96	18.26	20.68	**-9.89**
Kloppe & Glock	26.96	18.26	20.68	**-9.53**
Selvadurai	26.95	18.25	20.68	**-10.41**
Average	26.96	18.26	20.68	**-9.84**

5. CONCLUSION

For most numerical simulation, it is necessary to know the soil characteristics for the Winkler spring's soil model. The paper deals with the rigid and soft aluminium grid structures supported by the short columns on the square shallow foundations. These structures represent the kind of building with the minimum environmental ground impact since only the area of the shallow foundation is put into the ground. The rest of the grid structure doesn't touch the ground.

The rigidity of the ground is defined by the subgrade reaction coefficient. The software SE_Calc was used. It gives different values of subgrade reaction coefficient for different authors' equations, as well as the average value. Since the aim of the paper is to show the influence of the soil rigidity change on the behaviour of the grid structures, the results of the calculation are shown in the corresponding tables.

The basic model was the one that used the average subgrade reaction coefficient. The calculation results show one interesting fact. Because of the small spans and small loads, the influence on the moments was small or none. This wasn't the case with the large spans in steel and concrete grid structures. In those cases, the higher value of the soil reaction coefficient gives fewer peak moments and fewer vertical displacements of the structure. If we are talking about soft grid systems, because of the decrease of the rigidity, the displacements are increased. Generally speaking, they have almost the same behaviour of results dissipation because of subgrade coefficient change.

The approach of using the average subgrade reaction coefficient value seems to be correct according to the results. Anyway, we must always be aware that it is the statistical value. For further research, the other kind of structures should be analysed.

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