CONSEQUENCES OF THE SUBGRADE REACTION COEFFICIENT CHANGE ON THE WOOD GRID STRUCTURE

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ABSTRACT

During the structural construction on the distant locations, it is necessary to make the foundation with as little ground impact as possible. One of the usual choices is the wood grid construction on the shallow concrete foundations. To define the connection between the soil and foundation, it is necessary to find out the subgrade reaction coefficient. Many authors worked on that problem which in its essence represents the behaviour of the ground, the relation between the stress under the foundation and displacement of the settlement. The paper shows the effects of different modelling of the soil reaction coefficient on the wood grid structure. The structural response is represented in a worked-out example.

Keywords: *Wood grid structure, subgrade reaction coefficient, foundation*

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1. INTRODUCTION

After researching the influence of the subgrade reaction change on the steel [1], concrete [2] and aluminium grid structure, it was interesting to go one step further and investigate the structural response of the wooden structure. Since we assumed that this kind of structure would be built on a distant location, the laminated structure was out of our research interest. The reason lies in the fact that it would be easier to use local, basically treated wood elements.

The shallow foundation system is used since it has low cost and low environmental impact. For modelling of the structure, the software [3] uses Winkler's spring model to define the soil characteristics. The rigidity of the spring is defined trough the subgrade reaction coefficient [4]. Many authors investigate this problem and each of them gives us different equations [4]. Because of that, we used the software SE_Calc [5], [6] that gives the different values of subgrade reaction coefficient by different authors.

After defining the subgrade reaction coefficients, it was interesting to watch the response of the wood grid structure. In this case, the grid represents the rigid base structure for the main upper structure, which is for now out of our interest. Its influence is represented only through the load.

Here we are dealing with a wood grid structure based on the concrete foundations. For the practical reason square, shallow foundations are also used here. In the next step, the value of the subgrade reaction coefficient was entered into the software, in this case, Tower 3D Model Builder [3] as numerical input for Winkler's spring rigidity given by the software SE_Calc [5]. After the calculations, the behaviour of the wood grid structure is monitored.

2. SUBGRADE REACTION COEFFICIENT

As mentioned before, software SE_Calc was developed for the determination of the subgrade reaction coefficients value for the square shallow foundation by different authors' equations [1], [2]. The software is closely explained in the references [7], [8], [9].

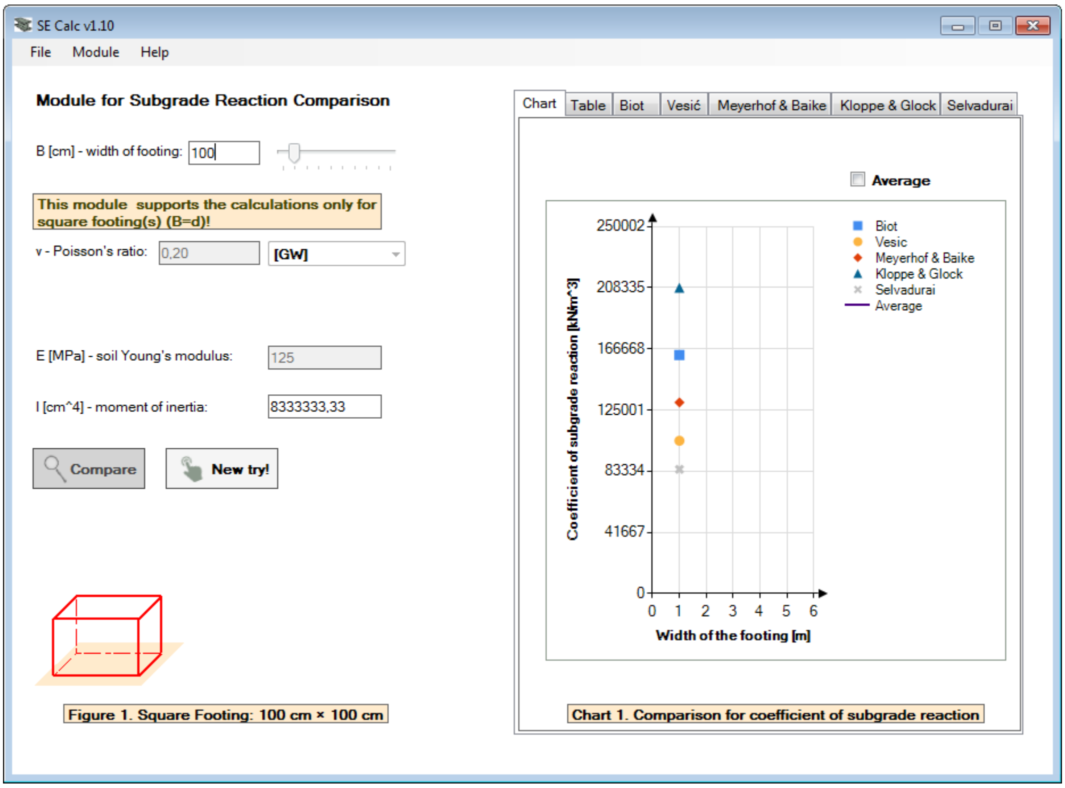

Fig. 1. Graphically interpretation of the subgrade reaction coefficient

As it could be seen from the literature [6] it was tested on some examples and was upgraded with the option of the mean value calculation. That value represents the average of the subgrade reaction coefficient for all the authors considered by the software.

In this paper, we used the values from Table 1. The average value will be the starting point for tracking the behaviour of the wood grid structure. The subgrade reaction coefficients for a base dimension of the square 100 cm × 100 cm × 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. WOOD

3.1. Generally about wood in structures

Wood products are suited for almost all new and reconstructed structures. Wood structures could be used in different applications in buildings like tall tower blocks, large industrial buildings or bridges. Modern timber construction systems allow the building of a structure in a very simple and competitive way, especially in relation to the time required for construction operations [10]-[15]. However, this paper is dealing with the simple traditional way of building a wood structure on a grid foundation.

Log construction is a traditional method of wood construction, especially in countries where there is enough suitable wood (by cross-section and straightness). In a log house, load-bearing parts of structures are made of log. The types of log used in log buildings are:

- Round log,
- Squared log,
- Deadwood log, and
- Laminated log.

Squared log represents traditional labour-intensive construction.

3.2. Material properties

Wood has many advantages over other construction materials: high strength in relation to its weight, easy handling, low construction costs, multiple eco-benefits, etc. With modern wood construction techniques, it is possible, and often advantageous, to build even larger structures in wood. The material properties of wood are crucial when designing the load-bearing structure. Wood is anisotropic, which means that its properties are different in different directions. There could be growth defects that impair the strength and the material is under the influence of moisture fluctuations and the duration of the load. In relation to its weight, the tensile strength of the wood fibre is comparable with high strength steel, as long as the timber is of good quality so that the wood fibres are not disrupted by knots and other defects.

Strength and hardness are at least five times higher along the length of the fibres than it is perpendicular to them. If a wooden structure does have to be placed under stresses perpendicular to the fibres, the effect can be countered by reinforcing with steel fixings or an intermediate layer of a harder wood such as oak.

4. TESTING EXAMPLE

4.1. Rigid grid

The grid structures [16] 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 as in Fig. 2. Type of the connection determines the way of the static response of the grid. If the beams from the 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.

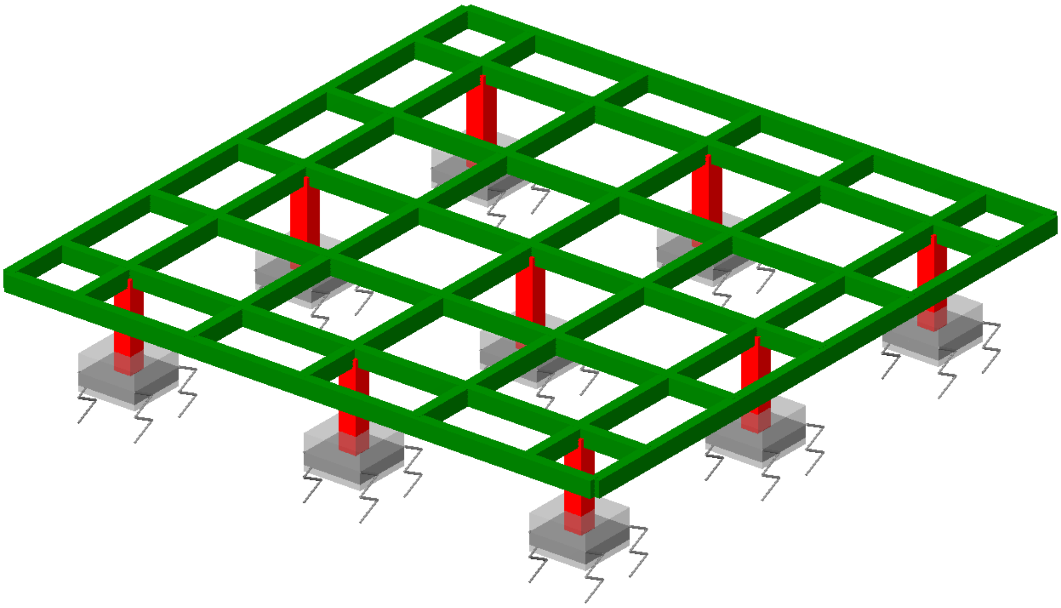

Fig. 2. Wood grid structure on the shallow foundation

In Fig. 2, the numerical model of the rigid wood grid structure is represented. Characteristics of the grid system are as following: concrete C 25/30, softwood quality C35 ($E=10^7$kPa), distance in both directions lx = ly = 4×4.0 m = 16.0 m with cantilevers l = 1.20 m. The cross-section of the wood beams is 18cm x 28cm. Cross-section of the concrete columns is 30/30cm, uniform gravitational load by each beam is 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 FE mesh 0.2 x 0.2m.

For the purpose of the comparison of the results, the numerical model of the soft grid system is also made. 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 wood rigid and soft grid are known. For the purpose of the result comparison the basic numerical, rigid or soft, model will be the one for which the average value of the subgrade reaction coefficient is taken. Diagrams of moments for the rigid wood grid are shown in Fig. 3. Small jumps in the bending moment of the rigid grid show the small influence of the torque stiffness impact from the other direction [16].

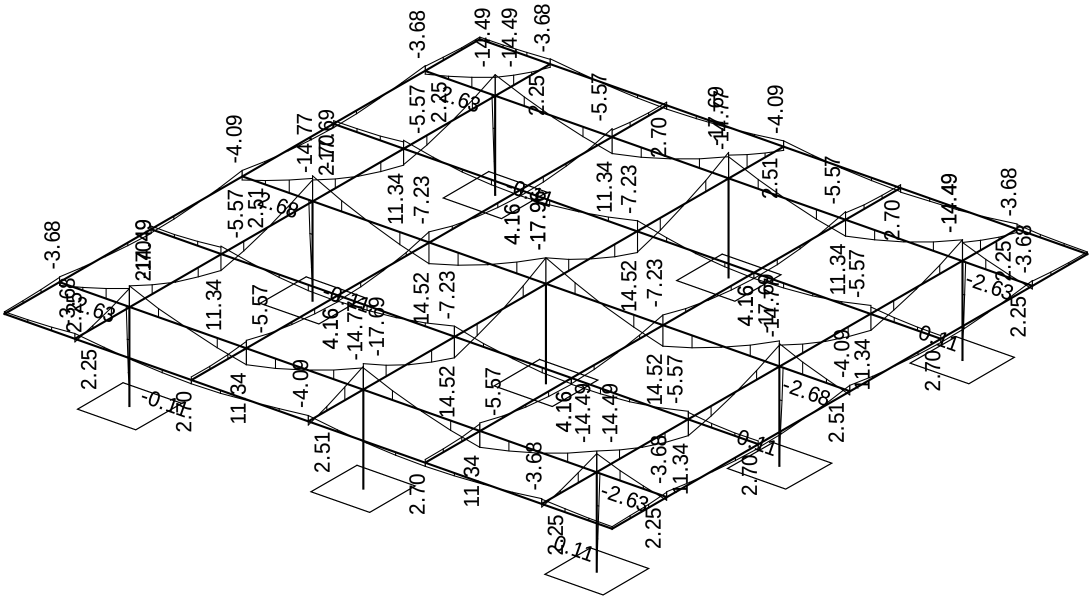

Fig. 3. Moment diagram of the wood rigid grid

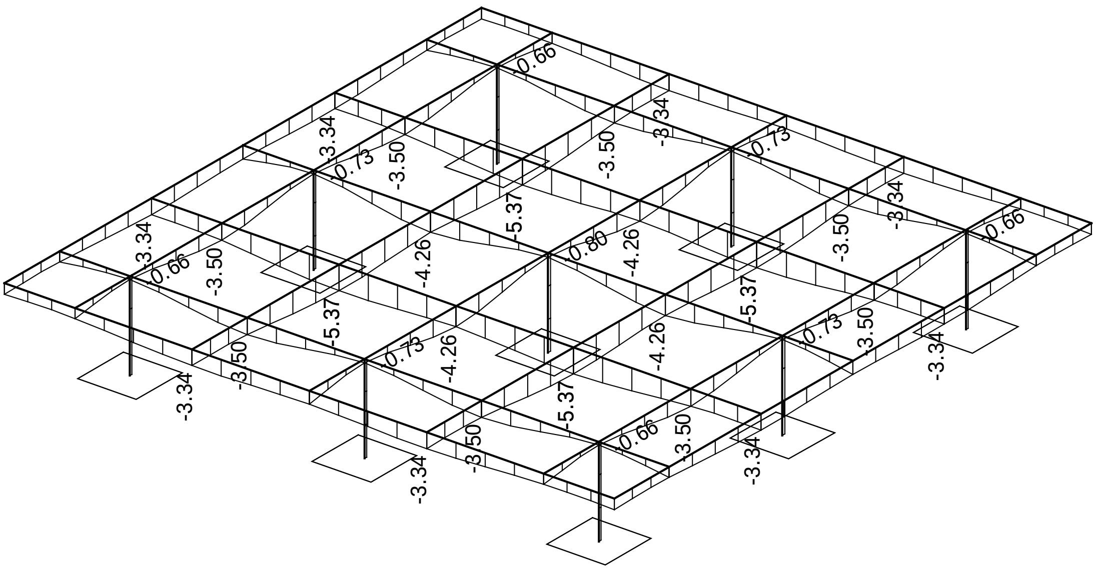

Fig. 4. Vertical Zp displacement diagram (mm) for the wood rigid grid

Table 2. 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	17.69	14.52	17.97	**-4.15**
Biot	17.70	14.51	17.94	**-4.50**
Meyerhof & Baike	17.69	14.52	17.96	**-4.30**
Kloppe & Glock	17.68	14.52	17.99	**-4.02**
Selvadurai	17.71	14.51	17.91	**-4.72**
Average	17.69	14.52	17.96	**-4.26**

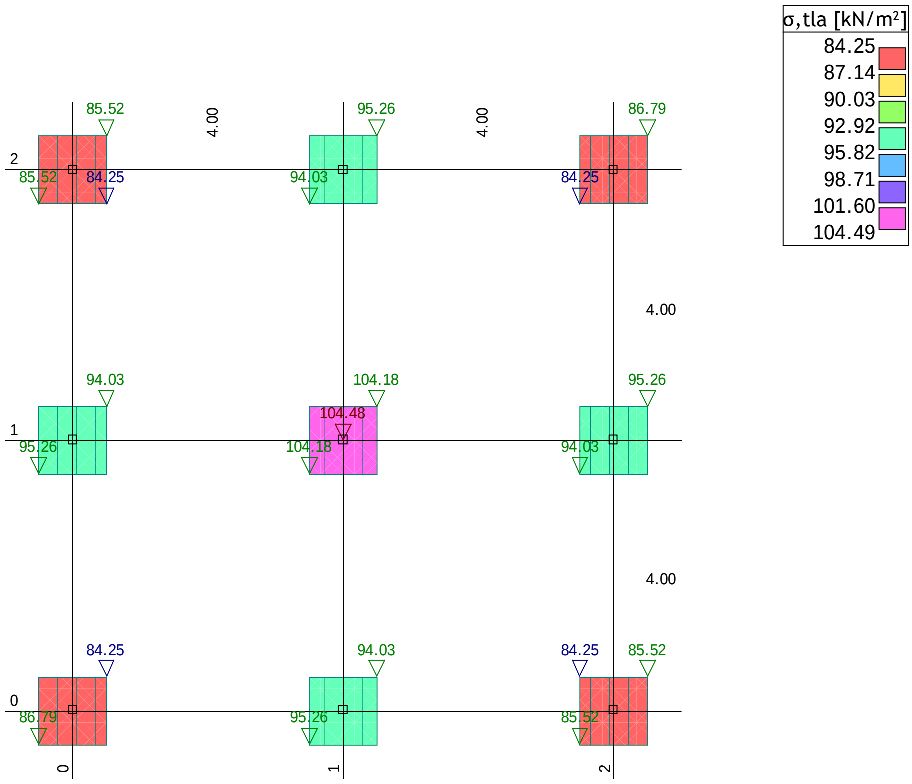

Fig. 5. Stress distribution diagram of the rigid grid

Table 3. 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	104.54	83.91	-0.52	-0.64
Biot	104.39	84.78	-0.81	-1.00
Meyerhof & Baike	104.46	84.37	-0.65	-0.80
Kloppe & Glock	104.62	83.35	-0.40	-0.50
Selvadurai	104.32	85.13	-1.01	-1.23
Average	104.48	84.25	-0.61	-0.76

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, no plot diagrams are 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 4.

Table 4. 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	27.56	18.65	21.13	**-4.78**
Biot	27.55	18.64	21.14	**-5.22**
Meyerhof & Baike	27.55	18.64	21.14	**-4.98**
Kloppe & Glock	27.56	18.65	21.13	**-4.61**
Selvadurai	27.55	18.63	21.14	**-5.51**
Average	27.56	18.64	21.13	**-4.92**

5. CONCLUSION

The paper deals with the rigid and soft wood grid structures supported by the short concrete columns based on the square shallow foundations. For numerical simulation of the soil, it is necessary to know the rigidity characteristics of Winkler spring's model.

The rigidity of the spring is defined by the subgrade reaction coefficient, defined by the values found trough the software SE_Calc. In its essence, those values represent the relationship between stress under the foundation and its deflection [17], [18]. SE_Calc gives different values of subgrade reaction coefficient for different authors' expressions, as well as the average one. The paper aims to show the consequence of the soil rigidity change on the behaviour of the grid structures. The results of the research are shown in the corresponding tables and figures.

The basic model was the one with the average subgrade reaction coefficient. The calculation results show one interesting fact, almost the same as in the case of the aluminium grid structure. The influence on the moments was small or none because of the small spans and small loads. If we are considering the soft grid system, because of decreasing the rigidity the displacements are increased as well as the moment values.

Consequences of the subgrade reaction coefficient change on the grid structure cause almost the same behaviour of the results dissipation.

Like in previous research, the approach of using the average subgrade reaction coefficient value seems to be correct from the point of departure of the results. For further research, it would be interesting to explore what kind of influence it would have on the spatial multi-storey structures.

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