Problems with Approximate Bearing Capacity of Gravel Soils

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Abstract. The publication aims to bring undoubted importance approximate table bearing capacity of gravel soils, which are used in the new constructions. Tabulated values enable to determine the estimated bearing capacity of foundation soil for a simple and inexpensive construction to a depth of 1 meter. In the publication there are compares particular class of gravel soils in depending on the width of the base and ingredients of fine-grained soil. Gravelly soils are the best foundation soil in terms of bearing capacity, but the amount of fine-grained soils or poorly grained gravel, or gravel with a low value of relative density can greatly reduce this value.

1. Introduction
Soil bearing capacity depends on many parameters. The primary parameter is the grain size. This may be a gravelly soil, sand or fine-grained soil. Gravelly soils achieve the best value in terms of bearing capacity and their properties are deteriorating with increasing contents of small grains. Approximate bearing capacity of gravel soils is given in the standard CSN 73 1001 [1]. Based on this standard, the soil is divided into classes G1 to G5.

Character of gravel soils depends on many parameters, such as sorting of grains, respectively presence or absence of grains of a certain size, the amount of fine-grained component and the predominance of silt or clay. Also, the state of compactness is an integral part in ascertaining the nature of cohesive soils.

2. Comparing values of indicative table bearing capacity of gravel soils
Approximate design bearing capacity of gravel soils represents an important part in assessing the bearing capacity of foundation soils for small and relatively simple structures that belong to the first category geotechnical, quoted in the standard CSN 73 1001. In other cases, the tests must be performed in-situ, where an assessment based on of indicative characteristics are insufficient.

Approximate table values the bearing capacity of gravel soils were determined to a depth of foundations 1 m and the width of square foundation 0.5, 1, 3 and 6 meters. Gravelly soils achieve the best values from the group of soils. As a gravelly soil is called soil with grain sizes from 60 to 2 mm
and containing finely grained soil to 35%. At the same time, the content of gravel grains must outweigh over the sand. The gravel is divided into five classes (Table 1). This is a class G1 (GW) well-graded gravel and G2 (GP) poorly graded gravel containing to 5% the fine soil. Class G3 (G-F) gravel with fine soil with a content the fine soil in the range from 5 to 15%. In the range from 15 to 35% of the fine-grained soil is the class G4 (GM) silty gravel and G5 (GC) clayey gravel.

Table 1. Classes of gravel soils according to [1]

| Class | Code | Description | Conditions |
|-------|------|-------------|------------|
| G1    | GW   | Well-graded gravel | fine-grained soil < 5%, gravel > sand, Cu > 4 ∧ Cc |
| G2    | GP   | Poorly graded gravel | fine-grained soil < 5%, gravel > sand ∧ non GW |
| G3    | G-F  | Gravel with fine soil | fine-grained soil 5 – 15%, gravel > sand |
| G4    | GM   | Silty gravel | fine-grained soil 15 – 35%, gravel > sand, below the line A |
| G5    | GC   | Clayey gravel | fine-grained soil 15 – 35%, gravel > sand, below the line A |

Class G1 and G2 are divided on the basis of number and curvature numbers not identical grains. They are determined on the basis of the grading curve. The coefficient of uniformity (Cu) characterizes the inclination of the central part of the grading curve. Gravels is called as equally grained according to the size of the coefficient of uniformity (Cu). These are from the perspective of building foundations less suitable. Furthermore, there is a group of medium-unequally-grained gravel and unequally-grained gravel. These are most useful in terms of building foundations.

Coefficient of curvature Cc is used to express the shape of the curve. On the basis of its size we infer the missing fraction. Such soils are usually tending to have poorer properties in terms of building foundations. Gravels group of G4 and G5 containing finely grained soils further divided by the content of silt or clay. This is determined by the diagram of plasticity, which expresses the dependence of moisture on the liquid limit of soil and plastic limit of soil.

Density of soil is also an important parameter in connection with non-cohesive soils (Table 2). Individual grains between themselves may be grouped differently. Smaller grains fill the space between the larger grains. If the grains are the same size, they may create large gaps between the grains in the wrong groupings. Density of soil is a function of porosity.

Table 2. Density of gravel soil [1]

| Density of gravel soil | Loose     | Medium dense | Dense    |
|-----------------------|-----------|--------------|----------|
| 0 - 0.33              | 0.33 - 0.67 | 0.67 - 1    |

Class G1 (GW) well-graded gravel, with a width of the base 3 m, achieves the best values i.e. 1000 kPa, as regards the approximate bearing capacity of gravel soils (Figure 1) (Figure 2). GC (G5) clayey gravel, with significant decrease to 250 kPa, for the base width of 3 meters reaching the worst levels. We can say that it is only 25%, if we relate the maximum value of 1000 kPa to 100%. The difference between the largest and smallest bearing capacity is thus 750 kPa, i.e. 75% of total capacity. The values are reduced within the individual classes about 150 kPa, i.e. 15% for the width of the base 3 m. Jump only between G3 (G-F) is more pronounced, which reaches 700 kPa (70%) and class GM (G4) which has a value of 400 kPa (40%), representing a difference of 300 kPa.
It is apparent dependence of approximate bearing capacity of gravel soils at a depth of 1 meter on the width of the base. The width of 6 meters is in second place in terms of the width of the base, within the highest values the whole range of classes of gravel. That is, the values range from 800 kPa (80%) for class G1 (GW) to 200 kPa (20%) for class G5 (GC). This represents a difference of 750 kPa. The same value of resistance is achieved when the base width of 1 meter, with the exception of G3 (G-F), where the value is about 50 kPa lower, i.e. 450 kPa than the the base width of 6 meters. Classes of gravel at the base width of 0.5 meters reached the lowest value within the bearing capacity. When comparing the values of the the base width of 3 meters the highest value reached only 50%. The values thus range from 500 kPa (50%) for class G1 (GW) to 150 kPa (15%) for class G5 (GC). Also important is the fact that, with decreasing bearing capacity from class G1, to class G5 differences for different widths of base within the individual classes reduced. If the difference between the highest and lowest values for different widths of bases in the class G1 (GW) is 500 kPa (50%) so for class G5 (GC) is a difference of only 100 kPa (10%).

The graph also shows that better parameters in terms of bearing capacity achieves well-graded gravel G1 (GW) than poorly graded gravel granules G2 (GP), even though both have a maximum of 5% of the fine component. It is up to 150 kPa (15%). This implies that an important role is played by not only the content of fine-grained component, but also heterogeneity of gravel grains. This means that as well-graded gravel considers the gravel with a grain size to the extent possible, i.e. from 60 to 2 mm. While poorly graded gravel is more or less heterogeneous. This means that prevails the same grain size. It is determined according to the grading curve.

![Figure 1](image-url)

**Figure 1.** Chart - Tabular values of the design resistance $R_{dt}$ in kPa for gravel soils, at a depth of foundation 1.0 meter for the width of square foundation 6, 3, 1, 0.5 m according to [1]

Increasing content of fine-grained component, that is the grain size of less than 0.06 mm is another reason for the reduction of bearing capacity. According to the graph, it is clear that it is a worse condition clay than silt in terms of fine-grained soils. When comparing silty gravel G4 (GM) and clayey gravel G5 (GC), the difference is about 150 to 100 kPa (15 to 10%) for the benefit of G4 (GM).
Figure 2. Chart - Tabular values of design resistance $R_{d1}$ in % for the most bearable gravel soils, at a depth of foundation 1.0 meter, for the width of square foundation 6, 3, 1, 0.5 m according to [1]

Bearing capacity of foundation soil consisting of gravel soils has been the subject of a number of studies. Bearing capacity of the soil is influenced by many factors, such as the already mentioned width and depth of the foundations of the foundations, but also the shape of the foundation and the depth of the groundwater. It is described in the publication [2] in connection with the construction of reservoirs and dams. Within foundations, they are also used grouting methods for improving soil properties respectively improving bearing capacity, as stated in [3]. Admixture of finer grains caused by contact with water a number of problems, but this is eliminated with a growing proportion gravel grains [4]. Characteristics of gravels of Pleistocene and Holocene period dealt [5]. The issue of bearing capacity of gravel soils is also featured in publications [6-10].

3. Conclusions
The study highlights the difference between the classes within gravel soils. Correct classification of the soil is the basis within the building foundation. Although gravelly soil has the best value in terms of bearing capacity in all types of soils, there are considerable differences within this group, which can be evaluated from several points of view. Gravelly soils are divided into five classes. The properties of the foundation soil from the perspective of bearing capacity are set within the CSN 73 1001 in tables. However, this applies only to simple and small structures. Bearing capacity up to 1 meter differs not only grain size of soil also to the width of the foundations. Foundations width of 3 m have the best values of bearing capacity in all classes of gravel. The largest value of bearing capacity 1000 kPa (100%) has G1 (GW) Well-graded gravel and smallest values of 250 kPa (25%) has a G5 (GC) clayey gravel. It is such a difference of 750 kPa. The worst values of bearing capacity are then in all classes of gravel soils at the base a width of 0.5 meters. Where G1 (GW) reaches a maximum value of 500 kPa (50%) and G5 (GC) is 150 kPa (15%).

Evident is also a significant difference in the size of grains of gravel. Large heterogeneity of gravel grains thus well-graded gravel represents bearing capacity from the viewpoint of much better soil than in the case of poorly graded gravel. At the same value of bearing capacity decreases with an increase in the content of fine soil. In the case of gravel, it is up to 35% of the total content of the soil. Clay significantly worsens characteristics within the fine-grained soils.
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