Calculation of the Strip Foundation on Solid Elastic Base, Taking into Account the Karst Collapse

R Sharapov, N Lodigina
Vladimir State University, 23, Orlovskaya str., Murom, 602264, Russia
E-mail: info@vanta.ru

Abstract. Karst processes greatly complicate the construction and operation of buildings and structures. Due to the karstic deformations at different times there have been several major accidents, which analysis showed that in all cases the fundamental errors committed at different stages of building development: site selection, engineering survey, design, construction or operation of the facilities. Theory analysis of beams on elastic foundation is essential in building practice. Specialist engineering facilities often have to resort to multiple designing in finding efficient forms of construction of these facilities. In work the calculation of stresses in cross-sections of the strip foundation evenly distributed load in the event of karst. A comparison of extreme stress in the event of karst and without accounting for the strip foundation as a beam on an elastic foundation.

1. Introduction
For construction of residential and public buildings are often complex are removed from the point of view of the geological structure and processes of the territory. One of these dangerous and poorly studied karst processes is widely distributed on the territory of Russia. The most widespread manifestations of karst processes are characterized by Vladimir, Kaluga, Kursk, Moscow, Arkhangelsk, Novgorod region, Republic of Bashkortostan, Tatarstan and Mari El Republic [1, 2, 3]. Such rocks as gypsum, and other conglomerates, dissolve and disintegrate under running water. In them formed karsts, and on the earth's surface - flops, karst subsidence, which over time transformed into sinkholes, subsidence or subsidence [1].

Karst processes greatly complicate the construction and operation of buildings and structures. Due to the karstic deformation at different times there have been several major accidents, which analysis showed that in all cases the fundamental errors committed at different stages of building development: site selection, engineering survey, design, construction or operation of the facilities [4, 5, 6, 7].

Foundations must meet the following basic requirements: have sufficient strength, resistance to overturning and sliding in the plane of the sole to resist the influence of groundwater and aggressive treatment, as well as the impact of weather conditions (frost), comply with durability term building service, be technologically advanced in manufacturing and economical.

The design of foundations are: solid, strip, bar and pile. Primers are used as bases of buildings and constructions, divided into: clay, sand, coarse, rocky, peaty.

The most important tasks of engineering and geological research is the study of patterns of development of karst, its assessment of the current status and future growth opportunities. Based on
the research must be identified areas where karst processes do not cause and will not cause significant difficulties in the construction and constitute a danger for the construction [8, 9].

In order to solve specific engineering and construction tasks necessary to have not only the general information regarding the presence of karst and the general laws of its development within the construction site. It should also possess detailed information on microdistrict all his ties with neighboring regions, within which the projected construction.

For the calculation and design of measures to ensure the stability of the buildings necessary information about the current state of karst processes on this construction site with sufficiently accurate for engineering purposes the presence of caverns, sinkholes, underground tunnels and the like, rather than random sampling of finding the passage borehole [10].

Needed such geotechnical data on the karst, which would have created a solid basis for the calculation of measures to ensure the reliability and stability of the buildings. This is the main issue to be determined in the production of engineering and hydrogeological survey.

In the presence of data required for the design, you can confidently tackle the issue of the construction of buildings in the karst area. It is also possible resolve the question of the degree of stability and reliability in the roof strata discovered caverns, need and opportunities to strengthen the bearing capacity of the column or unloading it at the desired degree, termination of karst processes in terms of thickness of the roof voids, ensuring normal operation of buildings.

Figure 1. Karst collapse in Guatemala.

Construction in karst areas is associated with considerable difficulties, as the karst rocks are fragile base. Emptiness reduces the strength and stability of the rock foundations of buildings and structures. The development of karst forms can cause harmful rainfall or even complete destruction of structures. Karst process is especially dangerous to hydraulic structures. Karst cavities are possible leaks of water from the reservoirs, canals.

During construction in karst areas is necessary to carry out a series of measures aimed at halting the development of karst forms, increasing the stability and strength of rocks [11]:

- Protect the soluble rocks from the impact surface and groundwater;
- Reinforcing the karst rock.

For proper design of buildings and structures in karst areas requires detailed geotechnical study, which should be comprehensive. In this study the climate, vegetation, hydrology, geology, ground, groundwater and including everything related to karst forms [12, 13].

2. Calculation of the strip foundation

Design bases and foundations of buildings erected on the karst territories, carried out in accordance with the general requirements of SNIP 2.02.01-83. At the same time provide for measures that exclude the possibility of the formation of karst deformation and reduce their adverse effects on the building.
However, implementation of these measures does not always rule out the possibility of development of karst deformation, and in some cases becomes technically impossible or impractical to use them.

In this case, provide construction measures, appointed on the basis of the foundations and underground structures construction calculation, taking into account the possible development of karst deformation [14, 15].

Construction of the foundations of buildings erected on the karst areas have their own characteristics. The calculations of foundations made on the basis of forecasting the size of karst manifestations and the probability of their formation at the base of the projected building.

The calculated location of failures vary and are assigned based on the most adverse operating conditions of the foundation construction. Challenges calculation bases on the karst grounds taking into account the joint work with the above-ground structures are solved on a computer.

Known crash buildings and civil engineering development in karst areas included geotechnical hazard category. Deformation due to subsidence of the earth's surface is transmitted form of subsidence. In this superstrate structure is not cut off vertically and laterally compressed displacement into a free space. Because rock displacement towards the center of gravity of the hollow space is also formed along the horizontal movement to vertical, which may cause lengthening or shortening of the surface structures on the site location leads to the effects that the construction of a stretching or compression. These or other process elements move differently act on the structure as a whole or to its separate structure. Accordingly, the required various safety measures or special work. Uniform deposition does not create additional stresses in the construction of buildings and therefore not taken into account in the design and calculations. However, it can have an impact on the conditions of sanitation and the relative rise of groundwater to the surface, leading to hydration base facilities. In addition, there may be problems with underground utilities.

The difference in the sedimentation rate results in the slope of the base structure, which accounts for a maximum of the transition from the convex portion to the subsidence of the concave portion. In this regard, skew additional horizontal component forces arise along with the usual vertical forces which cause bending moments in building constructions. Stresses arising from bending moments depend on the flexural and bond strength structurally interconnected parts of the structure. Most buildings have some stiffness so that they can follow a curvature to some extent without damage. When more rigid support structure may be a higher concentration of stresses [16].

With the sudden formation of the failure on the ground in some parts of the structures are formed by the base spans and console. In these cases a stress redistribution and therefore uneven load distribution of structures on the substrate, wherein the load cannot be redistributed in part. In the construction having compressive and tensile stresses which can be perceived only to a certain degree, the tensile strength in excess of the formation fracture.

In static analysis of structures must be applied reasonably estimating failures diameter, while also takes into account the depth and frequency of karst. The research programs have the following objectives: a high karst-a failure risk facilities should be thoroughly protected structurally, it is necessary to conduct monitoring of possible deformations. For large lesions often more economical to dismantle the construction and start new construction [17, 18].

Theory analysis of beams on elastic foundation is of great importance in construction practice. Specialist engineering facilities often have to resort to multiple designing in finding efficient forms of construction these buildings. This primarily relates to buildings on soft ground, strip foundations reinforced concrete viaducts, floating bridges, tall foundations of knowledge, crane paths, floors of industrial buildings, concrete pavements and airfields [19]. On the construction of such facilities leaves almost half of the concrete used in construction. Such huge material and financial costs require careful attention to the issues of structural analysis on elastic foundation. The problems associated with the study of structures, lying on an elastic foundation, represent one of the most urgent, complex and interesting problems of structural mechanics. In recent years attention to these problems increasingly growing. On the one hand this is due to the pressing needs of engineering practice, and on the other the development and improvement of methods of calculation. A major role is played by
modern computer technology. In its calculation model structure analysis on an elastic foundation is first set and reviewed the terms of its contact with the ground, and then calculates the [20]. Normally, structures are made of a homogeneous and isotropic material. Their contact with the ground under all combinations of external influences considered continuous, that is supposed to match the vertical movement of construction and surface of the base over the entire contact area.

In engineering practice frequent beam lying on a continuous elastic foundation. Elastic base called base beams such that the beam is deformed by the weight and the load situated on it, and thus renders the elastic sag resistance. Beams, lying on this basis, called beams on an elastic foundation. These beams railway sleepers can be attributed path strip foundations of various structures that transmit the load to the ground, the foundations of dams and others. Static equation allows only find the overall reaction on the part of the base and makes it impossible to determine the law of distribution of the reaction along the length of the beam. The value at each point of the reaction depends on the beam deflection, and the deflection of the beam in turn depends on the response from the base.

![Figure 2. Collapse under the house foundation.](image)

To solve the problem commonly accepted hypothesis linking the value of reactions to the draft base [21]. One of the most common hypothesis is the hypothesis of proportionality between the reaction and the draft of the base. Such a hypothesis regarding the properties of the soil, was first proposed N.I. Fuss in 1801 and applied to the beams on an elastic foundation used E. Winkler. According to this hypothesis base reaction at each point is proportional to the elastic precipitate at this point. In other words, the greater the deflection, the greater the resistance and reactance. Thus, the elastic base reaction with respect to the beam is a changing along the length of the beam intensity of the load:

\[ q_0 = -k \cdot y, \]

\[ k = k_0 \cdot b, \]

where \( k_0 \) – constant factor characterizing the rigidity of the base, called the coefficient of bed; it is reactive force per unit area of 1 cm\(^2\), and emerging from the base at a deflection of the beam is equal to 1 cm. This ratio is determined from experiments and the dimension of its N/cm\(^2\); \( b \) – width of the sole of the beam.

Therefore, \( k = k_0 b \) represents a linear coefficient of the base. It is numerically equal to the base of the reaction per unit length of the beam at a deflection of 1 cm. The dimension \( k \) N/cm\(^2\) coefficient.

Theory analysis of beams on elastic foundation is very detail was developed by Krylov using the method of initial parameters [20]. The advantage of this method lies in the fact that for any kind of load and any method of fastening the ends of the beam equation of the bent axis of the beam on an elastic foundation comprises four primary parameter, which is the deflection, tilt, bending moment and
shear force in any cross-section of the beam, is taken as the origin. Two of these parameters are always known. To find the other two have to solve a system of two linear equations with two unknowns.

Strip foundation in this paper is considered as a beam on an elastic foundation under the action of uniformly distributed load it (fig.3).

In figure 3: $q$ – the load of the weight of the structure and strip foundation; $l$ – the length of the strip foundation; $l_1$ – the length of the strip foundation over karst collapse; $M_0, Q_0$ – initial parameters: the bending moment and transverse force of the construction and foundation weight activities over karst collapse.

Two cases are considered:
- The load acting on the entire length of the strip foundation $l$;
- Load acts over a length $l - l_1$ ($l_1$ - diameter karst failure [22]).

Accordingly, the expression for the deflection angle and the bending moment can be written as:
- Without karst failure (initial parameters $M_0 = 0, Q_0 = 0$)
  
  $y(x) = 91.18 \cdot 10^{-2} q \cdot Y_1 \cdot (l - 10.95 \cdot 10^{-5} \cdot x)$; \hspace{1cm} (3)
  
  $\phi(x) = 33.3 q \cdot Y_2 (10.95 \cdot 10^{2} \cdot x - l)$; \hspace{1cm} (4)
  
  $M(x) = 10.95 \cdot 10^{2} q \cdot Y_3 (l - 10.95 \cdot 10^{-5} \cdot x)$; \hspace{1cm} (5)

- Taking into account the failure of karst (initial parameters $M_0 = q \cdot l_1^2 / 2, Q_0 = q \cdot l_1$)
  
  $y(x) = y_0 Y_1 + 1095 \phi_0 Y_2 + 1.04 q \cdot l_1 Y_3 + 911.8 \cdot 10^{-2} q \cdot l_1 Y_4 - 998.38 \cdot 10^{-2} q \cdot Y_1 \cdot x$; \hspace{1cm} (6)
  
  $\phi(x) = \phi_0 Y_2 - 0.365 \cdot 10^{-2} (0.125 l_1 Y_2 + 10.95 \cdot 10^{2} Y_3)$; \hspace{1cm} (7)
  
  $M(x) = 0.12 y_0 Y_3 + 130 \phi_0 Y_4 - 3 \cdot 10^{3} q \cdot (1.5 \cdot 10^{3} Y_1 + 10.95 \cdot 10^{2} Y_3 - 1199.025 \cdot 10^{-2} q \cdot Y_3 \cdot x)$. \hspace{1cm} (8)

Here, $Y_1, Y_2, Y_3, Y_4$ are A.N. Krylov function are widely used in engineering calculations, and therefore their values are made up table for values of $\xi$ argument. A numerical study of deflections, angles of rotation and bending moments, depending on the argument $\xi$ (fig. 4).

Using the obtained expressions, numerical studies were performed to strip foundations of buildings. Calculations showed that the stresses in the cross-sections of the strip foundation under karst holes may some cases increased to 21 times.
3. Conclusion

Analysis of beams on elastic foundation is of great importance in construction practice. The problems associated with the calculation of structures lying on an elastic foundation under karst failures, represent one of the most urgent, complex and interesting problems of structural mechanics.

The paper calculated the stresses and strains in the cross sections of the strip foundation evenly distributed load in the event of karst. The state of stress and deformation of the strip foundation on an elastic foundation depends on the load and the stiffness of the foundation and the elastic foundation. A comparison of extreme stress in the event of karst and without accounting for strip foundation. The computational model of strip foundation - a beam on an elastic foundation. The stresses in the cross-sections of the strip foundation at Karst failure increased from 5 to 21 times. The calculating formulas for determining the parameters of the stress-strain state of strip foundation in any of its cross-section in case of karst and without registration. This calculation method can be applied to the strip foundations of various structures that transmit the load to the ground and to the foundations of dams.

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