

## **CALCULATION AND DERIGN OF FOUNDATIONS ON LYOSS SOIL BASES WITH VERTICAL ARMO – ELEMENTS (VAE)**

<sup>1</sup>Kurbonov Bakhodir Irkinovich,

<sup>2</sup>Ortikov Shodiyor

<sup>1</sup>Doctor of Philosophy (PhD) in Technical Sciences, an Acting Associate Professor  
Samarkand State Architectural and Civil Engineering University (Uzbekistan),

<sup>2</sup>Assistant Teacher, Samarkand State Architectural and Civil Engineering University  
(Uzbekistan)

### **Abstract**

The research looks at bases with pile foundations, bases reinforced by vertical reinforcing elements, and bases made from compacted soil pads. The research presents the findings of the modeling of vertical armo-elements on loess subsiding soils and foundation pads. The authors propose techniques for computing the fundamental parameters of bearing armo-element capacity and foundation pad. The study also includes the outcomes of actual base and foundation construction using this technique in Uzbekistan's soil conditions.

**Keywords:** Vertical armo-element (VAE), foundation, ground, soil, loess, loessal (loessy)

When designing and constructing buildings and structures on loess subsiding soils in seismic conditions, the designers often face the problems of lowering non-uniform sediments, subsidence, and increasing the rigidity of the base. When artificial bases are arranged using the most popular technique, compacted ground pads, the cost of a zero-cycle erection in construction increases and the reliability requirements are not fully met. Besides, the production of base construction work is closely connected with seasonality, i.e., its disadvantage in winter-spring periods or, on the contrary. In the process of a building's exploitation, due to water leakage from communication systems (networks), foundation pads are saturated by water, which leads to a lowering of their stiffness and an increase in their soft-plastic properties. Geotechnics experts are fully aware of the characteristics of soils that, despite their compactness, may reduce their reliability during earthquakes.

Due to technical, technological, and regional peculiarities, other techniques of setting up artificial bases, notably the process of tamped foundation trenches, ground piling, pre-soaking, and so forth, were essentially not used in construction in Uzbekistan. The method of soil compactness by hard tamping started to be used sparingly due to the crowded metropolitan settings.

The alternate urban construction technique still involves using pile foundations to build bases and foundations.



Yet, as demonstrated by experience, using pile foundations increases the price of zero-cycle construction for small-story buildings with no more than 5–9 stories. Instead of driven piles, which had previously been utilized traditionally in soil conditions with high groundwater levels and weakly water-saturated soils, the method of building on continuous or solid slab foundations and compacted ground pads was increasingly adopted. Also, in this instance, finely crushed stone or grave preparation are employed as the material for ground pads.

Vertical armo-element (VAE) base preparation has been popular in recent years, along with ground pads in construction.

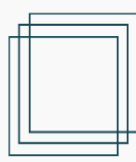
Practice, however, demonstrates that rigidly reinforced concrete piles and reinforced elements from compacted or strengthened soils nevertheless differ. According to us, these are the key distinctions between them:

For a building or structure, grillage and reinforced concrete piles combine to form a single (monolithic) foundation. Practically all external loads are distributed to the piles when considering pile foundations. Piles of soil, soil-cement, and concrete piles are not regarded as structures and relate to the elements of a foundation's soil strengthening, which perform the function of its reinforcement. Compared to reinforced concrete piles, VAE redistributes pressure throughout the soil mass rather than using bending loads. The VAE controls contact stiffness and pressure (the deformability of a ground base under a foundation). VAEs, unlike conventional piles, are not divided into racking piles and hanging piles, according to the conditions of work in the soil. This is because VAEs are substantially more bendable than reinforced concrete piles because they are relatively weaker (the strength of the VAE material is an order of magnitude less than the strength of reinforced concrete and much greater than the strength of the soil). For this reason, there is a more intense dissipation of pressure in depth under the impact of external loads at the base (foundation). The foot of the grillage foundation receives the external force at the time of first loading. As loads continue to rise, the VAE eventually participate in works that include the ground in the base's deeper layers. There is also a significant difference in the working conditions on the contact between the lateral surface of the VAE and the sinking loess soil. For instance, in the case of cement-soil piles, the diameter of the piles is determined roughly from the center to a conditional boundary that is equal to the diameter of the screw (working body) or the zone of impact of the water-cement jet (injection technology). The parameters of interaction change at the contact as a result of the surrounding soil "sticking" to the soil-cement pile.

Our research has demonstrated that in order to accurately determine the bearing capacity of soil-cement piles on loess soils, it is required to account for both friction (shear) and the hanging of a specific volume of soil that is situated a distance from the wall of the armo-element. The range of the influence is (2-5) D and is based on the structural and physical features of the soils. The gravitational pressure of the soils reduces during the process of subsidence caused by hanging, preventing the emergence of subsidence deformations.

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Because of this, the distance between vertical elements used to reinforce bases must be calculated, taking into account external loads, but not exceeding 5D.

The proper choice of a mechanical model of the reinforced soil's material is of utmost importance. In particular, Mohr-Coulomb's theory of strength applies to the strength of both fixed and compacted soil. In contrast to coherent and incoherent compacted soils, cement-soil and concrete VAE are characterized by strong structural strength, which is enhanced adhesion. The strength limit of these materials is defended similarly to the prism strength of concrete, according to the results of uniaxial compression. The strength of the VAE corresponds to the prism strength of the material, which must be at least 700 kPa. The calculated model of such materials can be adopted as an elastic-plastic one.

The longitudinal stiffness both of cement soil and concrete VAE are considered provided when conditions are met: the ratio of the diameter to its length is  $D/L \geq 0,05$ . In dependence on the volume of loads and the power of weak soils, the partial reinforcement (on the fixed depth) or the reinforcement of the entire depth of the spread weak soils.

Reducing the impact of reinforced concrete raft foundations of strength and longitudinal rigidity, the VAE are archived by a damping sandy layer of 15–25 cm (See Fig 1). The width of the damping layer is assumed to be equivalent to 1,4 b, where "b" is the width of the grillage.

To calculate the reinforced VAE's learning capacity and deformability, engineering calculation methods are provided in [1, 2]. For instance, loess soils with the following physical characteristics:

The density is  $\gamma = 16-18 \text{ kN/m}^3$ ; the porosity ratio is  $e = 0,88-0,95$ ; the humidity is  $W = 17-19\%$ , and the plasticity number is  $I_p = 6 \div 8\%$  with deformation and strength characteristics of

$$\frac{E}{E_{sat}} = \frac{(70 \div 100) \text{MPa}}{(40 \div 50) \text{MPa}}; \varphi = 22 \div 28^\circ \quad c = (20 \div 30) \text{ kPa}$$

An empirical formula can be used to estimate the bearing capacity of a single concrete VAE with a length of more than 3 m:

$$F_d = \frac{A \cdot Lk}{m} \tag{1}$$

$$L_{Optimal} = \frac{F_d - A \cdot p_{st}}{q - p_{st} \cdot B} \tag{2}$$

where ***k*** and ***m*** are, respectively, the coefficients of the equation, depending on the technology and the type of soil. Determined for specific soil conditions *A* and *L* are, respectively, the transverse area and length of the VAE; *p<sub>sl</sub>* is, the initial subsidence pressure (kPa) or design resistance of a weak subgrade or *R*; *q* is, the externally distributed load on the raft foundation; and *B* is, the width of the raft foundation. For instance, on the basis of multiple studies, it was discovered that the coefficients *k* = 0,5 and *m* = 0,003 m<sup>3</sup>/kN for the same type of loess soils in Uzbekistan.

The calculation of grillages is made on the model of Winkler and Pasternak as a beam on an elastic foundation with two parameters, *C<sub>1</sub>* and *C<sub>2</sub>*, and the coefficients of the beds (elasticity) are determined by the known expression [2], as the average pressure ratio ***P*** under the title block to the sagging ***s***.

$$C_1 = \frac{P}{s}, \quad C_1 = \frac{E}{(1-\mu^2)\omega\sqrt{A}} \quad (3)$$

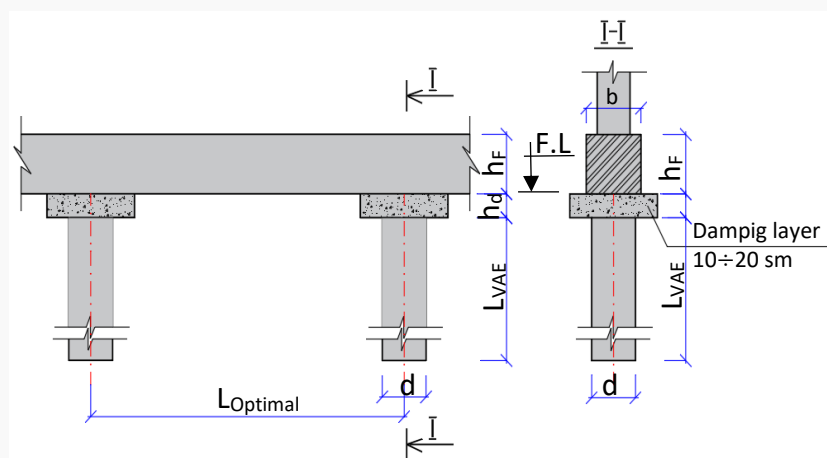
Or

$$C_1 = \frac{\pi}{2} \frac{E}{(1-\mu^2)B \ln(4\alpha)} \quad (3^1)$$

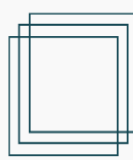
The VAE in these calculations includes both elastic deformable supports and those installed along the beam with *L* VAE sleep.

The deformability (rigidity) of elastic supports is determined with the help of the rigidity coefficient ***k*** as the ratio of the force ***P<sub>z</sub>*** to the displacement (sagging) *s<sub>z</sub>*, according to the expression:

$$k = \frac{\Delta P_z}{\Delta s_z} \left( \frac{\kappa H}{M} \right) \quad (4)$$



**Fig 1.** Structural diagram of strip foundations



The findings of studies conducted under natural settings, using static loads and measurements of the VAE displacement, provide a more precise estimation of the coefficient of the VAE rigidity. The diameter, pile length, and deformative properties of the soil all affect how deformable (rigid) the VAE is. The damping layer in sand is considered an elastically plastic body.

Table 1 shows the numerical results of the foundation calculation for all considered variants.

In seismic areas, a sandy layer among others acts as a damper. It allows for a reduction in the impact of shear loads transmitted to the building. Since, a sandy layer of the damper obeys the law elastic-plasticity under shock loads, it at the moment loses its original strength and transmits into another, more stable equilibrium position. In this case, it is expected to reduce the thickness of the damper, lowering contact stresses under the raft and increasing the loads on the VAE. In summary, the VAE fulfills the job of short-term support at the impact of dynamic forces occurring during earthquakes, in addition to the other roles listed above. The construction of the VAE joint and a raft are presented in Fig.1 with the aim to reduce the coefficient values of friction and permeability, sandy soils of the damping in sandy soils.

Table 1

Name	Foundations on the natural base	Foundations—rafts; Bases—VAE	Coefficient of efficiency
Vertical displacement Max / Min, mm	54 / 46	21 / 13	2,5 / 3,5
Q (kN)	140	163	0,85
M <sub>y</sub> (kN*m)	650	300	2,2

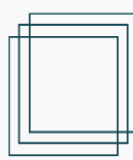
Layers are mixed with loam (15–20% of the composition). To reduce the concentration of contact stress occurring at the level of the VAE cap, a supporting concrete slab is provided, which also serves as a leveling layer. The note of the VAE level is controlled by using the level. The distance between the notes should not be more than 1-2 cm.

By this technology, more than 100 buildings, ranging from 2 to 7 stories, have already been built. As surveys showed, such buildings are explored without damage, even in the case of accidental soaking of a soil base. Over the last 5 years of operation, such buildings have also suffered 4-6 magnitudes of earth quakes. As the surveys of buildings after earth quakes showed, damages to buildings where the bates stabilized with the use of the VAE were applied were much lower than in buildings built on compacted ground pads.

Technical and economic comparisons of ground pads and traditional strip foundations have shown savings of resources and construction costs of zero-cycle erection of buildings of 20–35%.

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For comparison, when constructing buildings from 3 to 7 stories, the cross-section of rafts does not exceed 60 and 70 cm. The advantage of this method, besides the above-mentioned, is the lack of influence of seasonal prevalence (the winter and spring rainy seasons of the year) and water savings, which are needed to achieve optimal moisture in a dry, hot climate.

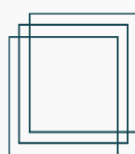
We can infer the following conclusions from the simulation of the VAE's behavior and the findings of actual building field observations:

1. A weak base made of loess soils can have its bearing capacity increased and uneven sagging can be greatly reduced by stabilizing the ground using VAE.
2. For soil conditions of type I and II in terms of subsidence  $H_{sl}$  10-15 m depending on the actual loads, the length of reinforced elements can be determined by calculation but not less than 4–5 m.
3. The approximate calculation of the bearing capacity of the concrete VAE with the diameter  $D$  and the length  $L$  for the described soils can be determined by expression (1).
4. In the case of the application of cement-soil piles, it is expedient to concrete the upper head to a depth of 1-2 m with lean concrete. Since it is in this area, maximum horizontal deformation came into existence.

On the basis of the results of the research carried out by Khasanov A.Z. and Khasanov Z.A., the authors have prepared a textbook on designing bases stabilized by the VAE, and advice on the application of this method can be found at 140147 Republic of Uzbekistan, Samarkand, Lolazor 70, Samarkand State Architectural and Civil Engineering University, LLC “Geofundamentproject”.

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