IMPROVEMENT USING STONE COLUMN & GEOSYNTHETIC

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Abstract: *stone columns technique is widely used in many parts of the world. It is considered as a successful tool for improving the carrying capacity of soft saturated soil and controlling the settlement and accelerating the consolidation process. The term soft soil reinforced with stone columns is the common term used in literatures for this kind of improvement. This technique was developed in Germany about 60 years ago. (Hughes and Withers, 1974), reported that stone columns were well known in France in 1830. Hence stone columns have been regularly used in Europe since 1950 and in North America since 1972. Stone columns are most often used to improve the behavior of soil with undrianed cohesion c_u, in range of 15-25 kPa (Greenwood & Kirsch, 1983), below this strength the lateral support provided by the surrounding soil may be insufficient to prevent excessive radial expansion (bulging) resulting in columns failure. Despite of this, the literature reports the use of conventional stone columns in soil with c_u as low as 6 kPa (Barksdale & Bachus; Raju, 1997). In recent years, encasement has been used to provide additional lateral confinement to stone columns, extending their use to very soft soil (C_u< 15 kPa).This technique has been employed on numerous projects throughout Europe (Raithel et al., 2005) and more recently, South America (De Mello et al., 2008). The clay particles get clogged around the stone columns thereby reducing radial drainage. To overcome this limitation and to increase the efficiency of the stone columns with respect to strength and compressibility, stone columns are encased using geosynthetic to improve the lateral support (Kempfert and Gebreselassie, 2006), the major portion of the cost owes to the cost of stone. If replacing a portion of stone by some other cheaper material, without affecting the performance, can reduce the total cost in the present work experimental studies are carried out to evaluate the behavior of stone column encased with geotextile, in which stone is replaced by cheaper crush dust.*
Keywords: *stone column, geosynthetic, quarry dust, bearing capacity, settlement, arching, modules of elasticity, soft clay, degree of consolidation, ultimate bearing capacity, stabilization.*

УЛУЧШЕНИЕ ИСПОЛЬЗОВАНИЯ КАМЕННЫХ СТОЛБОВ И ГЕОСИНТЕТИКИ

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Аннотация: *метод укрепления мягких почв каменными колоннами был разработан в Германии около 60 лет назад (Hughes and Withers, 1974). В Европе каменные колонны регулярно используются с 1950 года, а в Северной Америке - с 1972 года (Greenwood & Kirsch, 1983). Чтобы повысить эффективность применения каменных колонн с точки зрения прочности и сжимаемости, их заключают в оболочку с использованием геосинтетических материалов (Kempfert and Gebreselassie, 2006). В последние годы оболочку используют для дополнительного бокового удержания каменных колонн. В настоящей работе приведены экспериментальные исследования и оценка поведения каменной колонны, заключенной в оболочку с геотекстилем.*
Ключевые слова: *каменная колонна, геосинтетика, несущая способность.*

Introduction: There are a lot of methods available to improve ground conditions like as stone columns, jet grouting, compaction grouting, short pile, dynamic compaction, lime stabilization etc. Before using any of these methods or others, we should know the ground improvement in detail. In simple words-ground improvement can be defined as “the process of enhancing the quality of soil. “Ground improvement mainly refers to the improvement of soil layers but in some cases it also refers to the improvement of rock layers. The ground improvement techniques applied are tools used by the geotechnical engineer for «fixing» the problems of weak ground, when a weak ground exists at the construction site (Ghanti & Kashliwal, 2008). Soft clay deposits are extensively located in many coastal areas and they exhibit poor strength and compressibility. Stone column that consist of granular material compacted in long cylindrical holes is used as a technique for improving the strength and consolidation characteristics of soft clays. Load carrying capacity of a stone column is attributed to frictional properties of the stone mass, cohesion and frictional properties of soils surrounding the column, flexibility or rigidity characteristics of the foundation transmitting stresses to the improved ground and the magnitude of lateral pressure developed in the surrounding soil mass and acting on the sides of the stone column due to interaction between various elements in the system.

Main aims:

-Increased strength of soil to improve stability, increasing the bearing capacity, reducing the settlement

-Reduced deformation due to distortion or compressibility of the soil mass,

-Reduced susceptibility to liquefaction, and reduced natural variability of soils. And other parameters

Of many techniques of ground improvements, stone column has gained lots of popularity since it has been properly documented in the middle of the last century. Potential applications of stone column include stabilizing foundation soils, supporting structures, landslide stabilization, and reducing liquefaction potential of fine sands. If we take in to account cost of stone column, the major portion owes to the cost of stone. If we used some other cheaper material, can replace the stones, without affecting the performance, the cost of construction can be reduced. Here an attempt is made to replace the stone partly with quarry dust and the performance is studied in terms of load settlement behavior. The effect of geosynthetic encasement is also studied the use of geo synthetic reinforcement at the base of embankment along with stone columns provides an economic and effective solution when rapid construction and small deformation are required. Geo synthetic reinforcement reduces the maximum as well as differential settlement and helps to transfers stresses from soft soil to stone columns. The design engineer’s ideal geosynthetic reinforcement would possess the following characteristics:

high tensile modulus (low strain values compatible to the common strains in soils, rapid mobilization of tensile force), low propensity for creep (high long-term tensile strength and tensile modulus, minimum creep extension, lasting guarantee of tensile force), high permeability (lowest possible hydraulic resistance and as a result, no increasing pressure problems), little damage during installation and compaction of contacting fills, high chemical and biological resistance. The application of reinforcement materials in the soil is considered as a method for strengthening the soil engineering characteristics. The soil can be determined as quadruple main type mixtures: sand, gravel, and silt. The soil has some characteristics such as tensile strength and is highly reliant environmental (Table 1).

Table 1. Characteristics of the soil

Methods of improving	The disadvantage	Type of soil
Compaction	No change in water content.	Well-graded granular soils or silt soils. Clays of high plasticity
Vibro compaction	The maximum depth of 165 feet may be considered a disadvantage	effective only in granular, cohesion less soils
Deep soil mixing	High cost of mobilization of mixing equipment, Cost of accompanying auxiliary batch plants, Uneconomical for small projects	cohesive soils
Soil stabilization with lime	1-Higher costs due to extra equipment requirements. 2-May not be practical in very wet soils. 3-Not practical for drying applications.	Cohesive soils
Micro piles	it used to prevent the excessive settlement of raft foundation	Clayey soil
Lime piles	1-The technique requires installation equipment of high initial cost 2-Special care is also needed in the handling of quicklime, a caustic chemical.	Saturated soils

Lime column	Ground temperature is increased by the heat generated during the slaking	soft soil
Improving by freezing	Temporary ground support	Soft ground conditions
Thermal treatment	The grouting pressure on average are 1.5 times the atmospheric pressure Heating temperature can vary between 300 to 1000 Co In saturated soil the permeability must be large enough to allow the evacuation of steam produced.	High permeable cohesion less soil
Jet Grouting	Our properties of soil has clay more than 50%	Sands and gravels, with less than 18% silt and 2% clay
Electro-osmosis	improving strength and deformation only	soft fine grained soils
Water table lowering	Temporary method of improving For high water table	Saturated soils
Sheeting and opining pumping	Temporary method of improving Has disadvantage high pressure in the wall	Saturated soils
Sumps and ditches	Temporary method of improving For small excavation	Saturated soils
Drainage by elector	Temporary method of improving Only for fine grained soils	Saturated soils
Well point system	Temporary method of improving For not more than 5m	Saturated soils

1. Method of using stone column with quarry dust identification

1. Stone column. The stone column technique was adopted in European countries in the early 1960s. Stone columns in compressive loads fail in 2 main different modes: bulging (Hughes and Withers, 1974) [1] and general shear failure (Barksdale and Bachus, 1983) [2]. McKelvey, et al. (2004) [3] carried out experimental studies on a group of five stone columns and reported that the central column deformed or bulged uniformly, while the edge columns bulged away from the neighboring columns. Many researchers have developed theoretical solutions for estimating the bearing capacity and settlement of foundations reinforced with stone columns. Priebe (1995) [4] proposed a method for estimating the settlement of foundations resting on an infinite grid of stone columns. The stone column technique is mostly adopted because they furnishes the primary function of reinforcement and drainage [1]. It improves the strength and deformation behavior of the weak soil deposits [2]. Another great advantage is the simplicity of its construction method. Stone column achieve their load carrying capacity by bulging. It thereby induces a near-passive pressure conditions in the surrounding soil. The load carrying capacity of stone column is highly influenced by the characteristics of the surrounding soft clay [3]. Hence the load carrying capacity cannot be increased more than 25 times the strength of soft clay [4]. In such cases the performance of the stone columns itself need to be enhanced by suitable methods the performance of the stone column can be improved by three methods such as;

- Encasing the stone column;
- Lateral reinforcement of stone column and
- By providing granular mat over the column.

The geosynthetic encasement imparts lateral confinement and avoids lateral squeezing of the stones in extremely soft soils. But the column encasement has minute effect for an elastic column. It plays its role only after column yielding. The efficiency of the encasement is directly associated to its stiffness. Therefore encasing stone column is advocated in soft soils using stiff encasement and under moderate loads. Because under heavy load, the encasement reaches its tensile strength and does

2. Soil Soft soils are characterized by their low un drained shear strength and high compressibility. These soils cover most likely the southern and middle parts of Mesopotamia (Iraq). Several improvement techniques are available to increase the bearing capacity, control settlement and accelerate the consolidation process of soft soils. Among these techniques is the stone columns. Soft soil sample will collect from my country Iraq, most of Iraq soil from group CL (clay-low plasticity) (L.L ≤50%) Accordion to the eq ;- A line = 0,75(L.L-20) from plasticity chart we can find plasticity index PI=L.L-PL , PL=25% , also for CL group of soil . We have the clay present age more than silt soil.

3. Crush Waste crusher dust is acquired as soil solid wastes while crushing of stones to get aggregates. Crush dust shows higher shear strength which enables it to be used a geotechnical material. It possess good permeability and changes in water content does not significantly influence its desirable properties. Crush waste is used as a replacement in stone column too.

4. Geosynthetic The use of geo synthetic reinforcement at the base of embankment along with stone columns provides an economic and effective solution when rapid construction and small deformation are required. Geo synthetic reinforcement reduces the maximum as well as differential settlement and helps to transfers stresses from soft soil to stone columns. The design engineer's ideal geosynthetic reinforcement would possess the following characteristics: 1-high tensile modulus low strain values compatible to the common strains in soils, rapid mobilization of tensile force) low propensity for creep (high long-term tensile strength and tensile modulus, minimum creep extension, lasting guarantee of tensile force) high permeability (lowest possible hydraulic resistance and as a result, no increasing pressure problems) little damage during installation and compaction of contacting fills high chemical and biological resistance.

2. Statement of problems

Firstly, the term soft soils include soft clay soils, soils with large fractions of fine particles such as silts, clay soils which have high moisture content, peat foundations, and loose sand deposits near or under the water, it can be seen that the site sits on low hemic gluey soils, which is poorly drained soils deposited over coastal plains and in the valleys and flood plains of the larger rivers, of very variable fertility (Soil Map of Malaya, 1962). Soft soils pose high moisture content, low shear strength and exhibits high compressibility. Utilizing such materials as a foundation material is almost impossible without some means of improving the adverse properties. So I will used stone column to improved soft clay soil.

Secondly: If we used stone column-supported embankment resting on soft foundation soil it will be have another problem which is (soil arching effect in stone column) Soil arching is a common phenomenon in pile or columnar supported geosynthetic-reinforced or unreinforced embankments resting on soft soil. Due to soil arching, stress acting on soft soil or geo synthetic reinforcement decreases and stress on piles or columns increases. Arching initiates a reduction of the vertical stress acting on the relatively soft soil while increasing in the vertical stress on the stiffer columns. As pointed out by Low et al. the arching effect induces a no uniform distribution of vertical stress on the ground surface.

First stage; Preparation of Clay soil the air-dried and pulverized clay sample will mix with required quantity of water to achieve a consistency index of 0.1. It will take in to account that the soil will keep for 48 hours in order to achieve uniform consistency. After 48 hours of hydration, the soil will mix and kneaded well and checked for moisture content. Loss of water, if any due to evaporation was compensated by adding water before forming the bed... Care was taken to avoid the entrapped air by tapping the clay layers gently with a wooden plank.

Second stage; Stone Column Installation The center of the cylindrical tank will properly marked and a PVC pipe of the required diameter will placed at the center of the tank. Around this pipe, clay bed will form. The clay layer was tamped with a wooden tamper frequently and gently to expel air during the process of filling. The stone required to form the column was carefully charged in the tube in three layers. Each layer will compact. For reinforced stone columns the reinforcement was stitched and placed around the PVC tube. After preparing the clay bed, the tubes were charged with stone chips and compacted in layers. The PVC tube was withdrawn to certain level and charging of stones for the next layer was continued. The operations of charging of stones, compaction and withdrawal of tubes were carried out simultaneously. Further the bed thus prepared was left for 24 hours to obtain uniform bed, which also ensured proper contact between clay and reinforced stone column.

Third stage; Load Test for stone column without geosynthetic Tests will applied on a single column, for various proportions of the stone column and quarry dust on a standard loading frame as a strain-controlled test.

Forth stage; using geosynthetic and make the test with same dimension of stone column Stone column encased within geosynthetic of the same diameter as that of the stone columns alone. The load will applied through a proving ring at a maintained , the settlement of the plate will recorded by means of two dial gauges set diametrically opposite.

3. Simulation

1. Effect of crush dust.The stone chip in the stone column is replaced by quarry dust with varying proportion in order to reduction the cost of the stone column. The percentage of quarry dust varies as 30 %, 50%, 100%, Load bearing capacity for the system corresponding to the test conditions will increase.

2. Study the Effect of friction angle. According to the conducted modeling. By increasing the friction angle of stone columns materials, the bearing capacity of stone columns increases, that shown in Figure 1. Also by increasing the friction angle of clayey soil, the bearing capacity of stone columns increases, that shown in fig. 1.

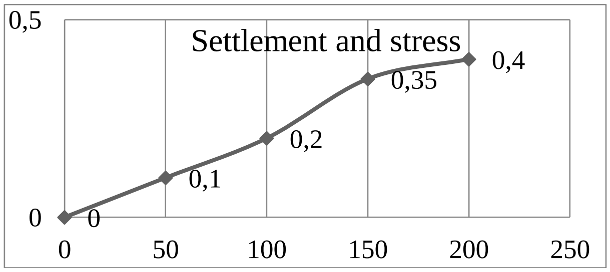

Fig.1. The Effect of friction angle

3. Study Effect of modulus of elasticity. According to the conducted modeling. By increasing the modulus of elasticity of stone columns materials, the bearing capacity of stone columns increases, that shown in Figure 2. Stress settlement behavior under loading for different modulus of elasticity of stone columns material.

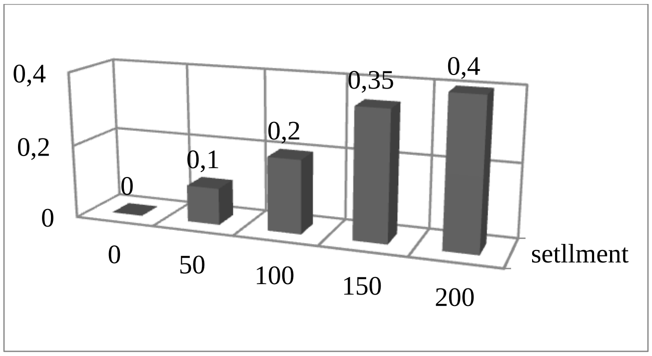

Fig. 2. The Effect of modulus of elasticity

4. Study Effect of ultimate bearing capacity of soft soil. Shows the effect of ultimate bearing capacity of soft soil. It has been observed that as the value decreases soil arching ratio also decreases. Thus, soft soil with lower ultimate bearing capacity enhances the development of soil arching as more differential settlement has been observed in case of soft soil with lower ultimate bearing capacity [10]. At non-dimensional height of the embankment (He/B) equal to 0.25, **as decreases** soil arching ratio is decreased by 70%. However, influence of becomes less important on soil arching ratio when value become lessees (Figure 3).

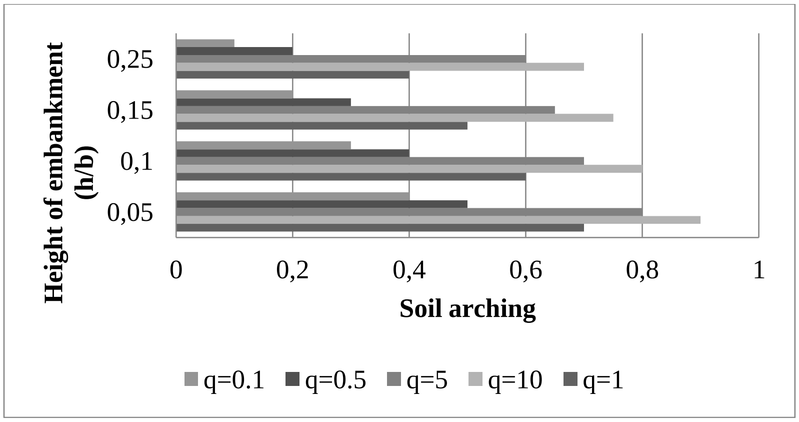

Fig. 3. The Effect of ultimate bearing capacity of soft soil

5. ***Study Effect of properties of embankment soil.*** It has been observed that as value increases soil arching ratio decreases. At non-dimensional height of the embankment (He/B) equal to 0.25, as increased soil arching ratio is decreased by 37% and increased in the degree of consolidation of soil. It has been further observed that embankment soil with higher ultimate shearing resistance helps to develop more soil arching in the embankment At non-dimensional height of the embankment (He/B) equal to 0.25, as increases ,soil arching ratio is decreased influence of becomes less important on soil arching ratio when value become lessees (Figure 4).

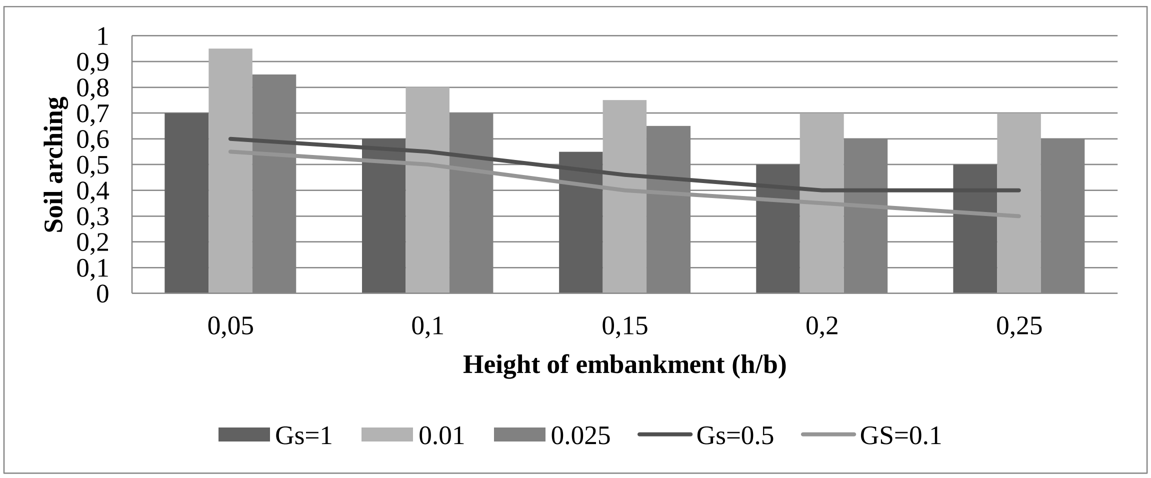

Fig. 4. The Effect of properties of embankment soil

6. Study the Effect of geo synthetic reinforcement shows the effect of geo synthetic reinforcement on soil arching ratio. More soil arching has been observed in unreinforced embankment as compared to the geo synthetic-reinforced embankment. This is due to the fact that use of geosynthetic reinforcement reduces the differential settlement, which causes less soil arching. At non-dimensional height of the embankment (He/B) equal to 0.25, in case of geo synthetic-reinforced embankment the soil arching ratio is increased by 22% as compared to the unreinforced embankment. It has been further observed that that as the height of the embankment increases up to 0.15B, the difference between the soil arching ratio for reinforced and unreinforced embankment also increases, whereas beyond this value the difference is almost constant. This is due to the fact that, as the height of the embankment increases up to 0.15B, the effectiveness of the geo synthetic reinforcement increases [8] and [29], whereas beyond this height no further effect due to geo synthetic reinforcement has been observed. The effect of geo synthetic reinforcement becomes level off when the embankment height exceeds 0.15B. Thus, as the height of embankment increases differential settlement is effectively reduced due to use of geo synthetic reinforcement as compared to unreinforced case and the development of soil arching is also reduced in reinforced embankment. Although as the height of the embankment increases, the differential settlement is increased (even with the use of geo synthetics). However, the increase in differential settlement is more in case of unreinforced embankment as compared to the geo synthetic-reinforced embankment.

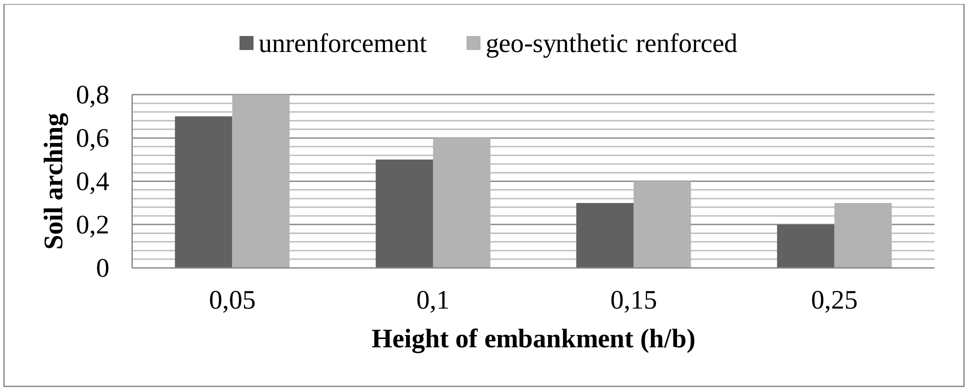

Fig. 5. The Effect of geo synthetic reinforcement

7. SR and the elasticity for quantify the results, the SR parameter that calculation is used. As can be seen in Figure with increasing the elasticity modulus of stone columns from 30,000 kPa to 60,000 kPa, the SR is reduced approximately 5 percent

$$Eq = \frac{average\ applied\ stress}{average\ applied\ strain} \quad (1) \qquad sr = Eo\ /\ Eq \qquad average\ strain = \frac{the\ settlement\ of\ footing}{thickness\ of\ clay = 10\ m}$$

Which, E_0 is Young's modulus of ground without stone column (30000, 60000) the equivalent secant modulus values (Figure 6).

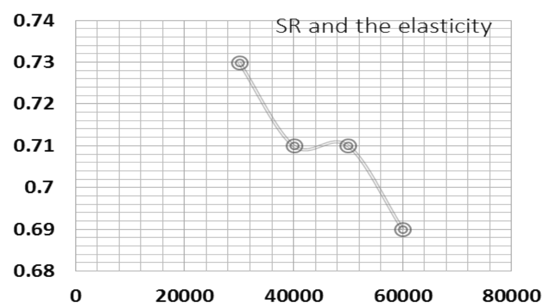

Fig. 6. Dependence SR and elasticity

***Conclusion*:** From the study area for different cases of reinforced soft clay soil by stone columns several validations have been drawn and can be summarized as follows:

-Inclusion of stone columns in soft clay soil considerably improves the axial stress- settlement characteristics.

-The ultimate bearing capacity of soft clay soil increases and settlement decreases with increasing the density of stone column, i.e. increasing the angle of internal friction (φ).

-The vertical stresses and the lateral displacement of stone column (bulging) decreases with increasing the value of internal friction angle (φ) of stone column material for the same stone column geometry and soil condition.

-The settlement of footing, the vertical stresses and the lateral displacement of stone column decreases with the increase of stone cushion thickness.

-With increasing the modulus of elasticity of stone columns materials, the bearing capacity of stone columns increases.

Less deformation due to compressibility. Use of geosynthetic reinforcement reduces the development of soil arching in embankment and the reduction is more in case of higher embankment height. Up to 20% degree of consolidation no soil arching has been observed, whereas beyond that stage as consolidation progresses more soil arching has been occurred. It has been further observed that as the height of the embankment and stiffness of the stone columns increase soil arching also increases. Smaller spacing between the stone columns enhances the development of soil arching. The ultimate bearing capacity of the soft soil has significance influence on the soil arching. Soft soil with lower ultimate bearing capacity causes more soil arching. However, influence of becomes less important on soil arching ratio when value exceeds 5×10^{-3}. In case of embankment soil with higher shear modulus and higher ultimate shearing resistance, more stress is transfer.

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