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A Review To Study The Performance Of A Ring Foundation Resting On Gypseous Soil

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Abstract— This literature review of research on evaluation performance of ring footing as well as circular footing and squaire footing that rest on gypseous soil treated with materials to improve its properties. Review the available experimental tests to calculate the bearing capacity and discover the behavior of ring footing rested on soil under load and investigate the relationship between (load, settlement) under the effect of the load as well as improving the properties of gypseous soil is the goal of this study. Ring footing is more cost-effective than other geometrical footing designs, its used in many applications, and it's critical to look into gypseous soil, especially since much of Iraqi areas are covered in it (by more than 12 percent). The gypsum in the soils leached out when the water arrived from (rain, rising water table, sewer, or another source), causing several difficulties and damage to the structures built on gypseous soil, thus the properties of these soils must be examined and addressed

Keywords— gypseous soil, collapse potential, ring footing, bearing capacity

1. Introduction

Gypseous soils cover a large portion of Iraq. Gypseous soils are widely spread, particularly in Iraq, where gypsum covers about 12% of the total surface. Gypseous soils cover 31.7 percent of Iraq's total land. Quantity of gypsum (hydrated calcium sulfate) in gypseous soil ($CaSO4.2H2O$) Consider problematic soils, which have metastable structures with different properties depending on how much water is present [24]. Due to the cementing ingredient, the collapsible soil has great strength when dry, but when wet, it loses this strength and settles excessively, and this process occurs quickly [7]. Rising groundwater, rushing surface water, heavy rainfall, sewer, or another resource can all cause flooding. When these soils become wet, they lose shear strength and volume, particle rearrangement occurs, agent bonding dissolves, and the binder is dissolved; as a result, the soil suffers from severe deformation and unexpected volume change, and collapses suddenly. The gypseous soil is hazardous because it damages the structures that are built on it. This damage, such as cracks and collapses in specific parts of a building or sinking roadways, can cause deep sinkholes and caveats underground, which can be threatening to people's lives. Various types of research and experiments have been carried out to investigate different techniques for treating gypseous soil collapsibility, such as excavating and replacing portions of the soil, and mitigating it with nanomaterials such as ((nano-silica, fly ash, nano clay, nano-silica fume), treated with iron powder, quicklime, biopolymers of xanthan gum, treated with polymers, Compaction, and cement mixing.

There are many foundation types used for different sorts of structures, foundation is the lowest portions of constructions that carry their weight to the fundamental soil. A shallow foundation carries the structural weight to the soil. In a shallow foundation, the ground depth ranges from 1.5m to 3m. There are several types of foundations, and the appropriate type is dependon the structure load that the footing will support [16]. Tower silos, water storage tanks and oil, towers of radio-television, bridge piers, and offshore structures all use ring footings to support tall and huge structures with axisymmetric geometry. The advantage of ring footings over circular footings is that the amount of volume. Furthermore, when compared to circular footings with same area, the ring footings provides a higher stabilizing moment arm. Ring footings are a good solution for superstructures that are subject to substantial lateral loads and moments. [11]

1.1 *Previous research into enhancing the properties of gypsum soil*

Many studies have been conducted using laboratory work to improve the behavior of gypseous soils by mixing them with other materials quicklime was used to improve the gypseous Soil below foundations by using two soils with different percentages of gypsum content taken from the Tikrit region (25 percent gypsum content) and Al-Dour region (66 percent gypsum content), the result was if the gypseous soils mixed with quicklime it could be successfully treated, the treatment percentage is 2.5 percent for Tikrit soil and (25% gypsum) and 1.5 percent for Al-Dour soil (66% gypsum), the increase in quicklime content causes an increase in the optimum moisture content and decrease in maximum dry unit weight, in the collapse tests, for both soils which use in this research, the collapse potential will decreasing with increasing the percentage of quicklime, till it reaches a very small value at 1.5 percent for Al-Dour soil and 2.5 percent for Tikrit soil so that the strain of the soil reduces by increasing the percentage of quicklime[27]. the efficacy of employing liquid asphalt to improve the qualities of gypseous soil was investigated by minimizing the influence of water on gypsum particles and enhancing strength parameters; two types of treatments were utilized in the experimental study. Gypseous soil treatment (mixing technique) was the first type, and gypseous soil treatment (grouting technique) was the second. When the binder content increased 6%, the optimum moisture content increased by about (28%), the maximum dry density decreased by about (9%). The results of the collapsibility test showed that as the binder content rises to 6%, the collapse potential decreases about (90%), the initial void ratio decreases to nearly (45%). Implying that if the binder content increases to the optimal value, the compression index decreases. According to this study, mixing technique is superior to injection technique because mixing technique coats approximately all particles with a very thin layer of asphalt. The injection, on the other hand, fills the voids in the soil with asphalt [22]. Compaction and Cement Addition for gypseous Soil improvement are used. The goal of the research was to explore if it was possible to improve gypseous soil by reducing its collapsibility while wet, portland cement was added in varying amounts to gypseous soil as (1.5 percent, 4 percent, 6 percent, 7.5 percent, 10 percent). With increasing soil density up to (14 kN/m^3) and a maximum percentage of cement utilized in this study of 10%, the outcome was a reduction in the percent of collapsibility to (95%) for the treated model, resulting in a deformation ratio S/B percent of 0.01 and an improvement of more than 10%. (95 percent). However, the amount of cement utilized was difficult to follow and justify in realistic engineering projections. The use of a substantial amount of cement minimized the likelihood of gypsum soils settling and collapsing. As a result, a maximum practicable limit of 5% cement addition may be used to minimize settlement to 75%, compact the soil to 14kN/m3, and utilize 4.5 percent cement by weight of gypseous soil to lower the deformation ratio (S/B percent) from 0.22 to 0.01 [26]. In terms of bearing capacity, the behavior of shallow footing by using compacted infill dune sand, on reinforced gypseous soil was investigate. A modern technique is use to investigate the performance of replacement and, geosynthetic reinforcing materials to improve the gypseous soil behavior in this study. When the soil is reinforced with one layer of geotextile and two layers of geogrid, it appears to be a successful solution in the improvement of collapse soil because the collapse settlement reduction factor increases to (72 percent) [8]. study the effect of mixing fly ash and silica fume on the collapsibility of gypseous soil with a 58 percent gypsum concentration were tested using gypseous soil from the Salah El-Deen Governorate. Three crushed gypseous soil percentages (1%, 2%, and 4%) by weight were used. Single collapse tests demonstrate that the collapsibility lowers dramatically to over 83 percent at the optimum percent of fly ash and nanomaterial (2 percent fly ash) and (4 percent silica fume), indicating an improvement in collapse potential. As a treatment material [9]. Gypseous soils mixed with iron powder. The findings of single oedometer trials show that raising the soil unit weight or adding iron powder at a specific ratio decrease the collapse potential. The appropriate iron powder ratio, added to collapsible soil is between 5% and 6% of the soil weight. The collapse potential (C.P.) lowers when the iron powder is added in a specified ratio or the soil unit weight is increased, according to the results of single oedometer studies. The recommended iron powder ratio for mixing with collapsible soil is between (5%, 6%) from the total soil weight. The reduction ratio run from (11 percent to 41.3) in the case of adding iron powder six percent, the improved portion of the soil unit weight was the same as natural soil, according to the experimental test results. When 6 percent iron powder is added to the improved area of the soil and compacted, the same ratio ranges from 78 to 86.86 percent [2]. mixed gypseous soils with different levels of (xanthan gum) and percentages of (2,4 and 6). Xanthan gum enhances the optimum moisture content while lowering the maximum dry density, according to compaction studies. The xanthan gum-treated, a low collapse potential obtains for gypseous soils which is more than 30% to 45%, and the direct shear findings of the biopolymer-treated soils revealed considerable shear strength improvements. The suggest results of this study are that using a biopolymer like a xanthan gum can improve the engineering qualities of gypseous soils while still being environmentally benign [5]. To investigate the issue of gypseous soil collapse, laboratory experiments were undertaken with two types of nanomaterials (nano-silica and nano-clay) mixed with gypseous soils (Bahar Al-Najaf). The trials show a significant change in the geotechnical qualities of the soil; as the amount of nanomaterials increases, the collapse potential decrease. The engineering qualities of gypseous soils were improved even with a little percentage of nanomaterials. The collapse potential (Cp) fell by 91% when nano-silica was increased to 1%, and the additive (nano-silica) effect changed the classification of collapse severity to (no problem) case instead of (moderate trouble) case. They discovered that adding nano-clay to the soil reduced the collapse potential (Cp) by 73.75%, making the soil non-problematic [7]. By conduct many tests to improve the engineering properties of high gypseous soil, combine the gypseous soil with silica fume and nano-silica fume. The test is carried out mostly under soaking conditions; increasing the amount of silica fume in gypseous soil improves engineering properties. However, the hydration process necessitates additional water, which may have led to a disastrous outcome. As a result, using nano-silica fume to improve engineering properties is strongly recommended. Nano-silica fume outperforms nano-silica in terms of increasing the engineering properties of gypseous soil. Where only 3% nano-silica fume is mixed to improve the gypseous soil [1]. By use soil from southwest Baghdad with 36 percent gypsum content was used in the study improving gypseous Soil Properties by using nontraditional additives. To increase the permeability, collapsibility, and compaction properties, the materials were combined with (3 %, 6 %, and 9 %) Copolymer and Novolac polymer. The findings of the experimental work revealed a considerable improvement in permeability as well as collapsibility of the soil treated with the polymer materials as compared to untreated soil. In 3 hours, adding 3% of a polymer, such as a the Novolac polymer or copolymer materials, resulted in a significant improvement in collapsibility (44.5 and 46 %) respectively. Permeability improved by 86.2 percent Novolac polymer and 98.6 percent copolymer in just one day [11].

1.2 *Ring Foundation*

foundations must distribute the weight of superstructures over a broader area So that the soil beneath foundations does not fail to shear and settlement. Vertical, horizontal, and moment loads and rotation, as well as excessive settlement, must be resisted by the foundations. Foundation design is an important aspect of geotechnical infrastructure design. There are several types of foundations for collapsible soil, depending on the possibility for collapse and the type of structural loading. A safe foundation can support the loads without shear failure or settlement during or after construction. By using ring footing the cost of construction and the amount of material needed are both reduced. Because ring footing is more cost-effective than other geometrical footing designs, its used in many applications such as (liquid storage tanks, radar stations, cooling towers, silos, towers of transmission, T.V. antennae, chimneys, bridge piers, underground stops, towers of water, smokestacks, mine, and liquid storage tanks), The ring footing have been used extensively in several projects over the last decade [24].

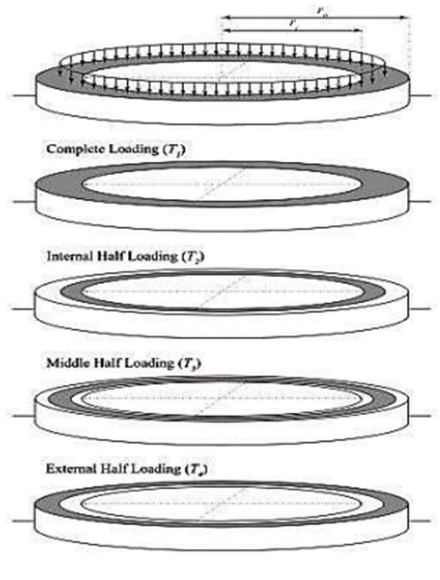

Figure 1: variation of loads location on the ring footings (Vali, Ramin, et al 2019)

1.3 *Previous research on ring footings' behavior*

There have been few experimental examinations of the carrying capacity of ring footing by using Terzahi's formula. The bearing capacity of strip footing and shallow foundation can be calculated as follows when the footing is loading with a uniform surcharge pressure qu = C Sc Nc + q Sq Nq + 0.5 B γ Sγ N γ. qu mean the ultimate bearing capacity and, C means the soil cohesion, ($q=\gamma * D_f$) mean surcharge above the base level of the footings, D_f mean the distance from the ground surface to the base of the foundation element, and γ mean the soil unit weight, and B mean the footing width, and Nc, Nq, N_γ mean the bearing capacity factors, which represent the effect of cohesion c, surcharge q, and unit weight, respectively. The equation above is for a strip footing; for other footings, the general bearing capacity equation is: qu = C Sc Nc + q Sq Nq + 0.5 B γ Sγ N γ. The ring footings behave similarly to the full circular footings with the same outer diameter as the ring footings, where Sc, Sq, and S_γ mean shape factors; in practical applications, this decision can provide cost-effective and economical solutions. The investigations are thought to have offered a useful foundation for future research, which will lead to a better knowledge of the ring footing application [4]. To evaluate the bearing capacity factors for ring footings, the roughness of the footing base is taken into consideration that including (smooth) and (totally rough) footing base. For a different (inner to outer) ring radii ratios, the computations were obtained by numerical simulation of ring footing using the finite difference method. With the increase in the inner to outer ring radii ratio, the value of all three bearing capacity factors Nc, Nq, and Nγ decreased. The reduction effect is more sensible for the Nγ factor. It can be seen that the roughness of the footing increases the value of the three bearing capacity factors. It was shown that using the proposed bearing capacity equation, which is based on the superposition of different plastic conditions, is conservative and safe with complete plastic analysis. The bearing capacity of ring footings was studied using the factors defined in the equation of Terzaghi's bearing capacity as well as numerical simulations using the finite difference method. The results of this study were found with focus on the effect of footing roughness. The factors Nc, Nq, and Nγ as a whole are influenced by the ring geometry, which is defined as (inner to outer ring radii ratio) as well as (the footing roughness). As the ring radii ratio grows, the ring narrows, and the value of the factors drops; the lowering effect is particularly noticeable for the Nc factor. Due to the footing roughness, the bearing capacity will rise, [12]

By conduct a case study on the design of ring footing for oil storage steel tanks. The findings show that ring footing rest on piles is a feasible and cost-effective method for supporting heavy-oil storage tanks on unstable soils. The reaction, shear, and moment forces on a footing-supported heavy oil tank were calculated using numerical analysis. In addition, the Meyerhof, Janbu, McClelland, and NAVFAC DM equations were used to implement the design. The standard equation's outcome appears to be consistent with the equations used by the majority of studies. The SAP analyses yielded results that were generally consistent with Meyerhof's analytical equation. The reactions, shear, and moment values are all acceptable after a finite element analysis using structural software. The outcomes of this study analysis were in general accord with Meyerhof's analytical equation; otherwise, structural software tools (feasible element analysis) were employed to produce acceptable reaction moment and shear values [26].

Ring footing can be more effective and cost-effective than circular footing. Although the two footings (the circular and the ring footings) are similar in appearance, their behaviors differ in some ways, such as the distribution of bearing pressure under the footings and settling. However, there have been no known unique theoretical calculations of the ultimate bearing capacity for ring footing. The bearing capacity of ring footing with the horizontal surface of the ground is coded by using the stress characteristics approach. Frictions at the soil-foundation interface are taken into account in the calculations. The bearing capacity factors Nγ, Nq, and Nc for ring footings were calculated using a written code based on the technique of characteristics. In comparison to the results of the principle of superposition, bearing capacity was determined for different soil conditions and varied ratios of radii. The results reveal that using the principle of superposition to turn a hyperbolic differential equation into an ordinary differential equations system is useful for evaluating the bearing capacity of a ring footing method of characteristic. The coding foundation for estimating the bearing capacity of (smooth ring footings) and (rough ring footings) bases are based on these equations. Bearing capacity factors Nc, Nq, and Nγ are determined for various soil conditions. Several formulae for these factors are proposed based on the analysis of these values. The results show that using the estimated bearing capacity factors in the superposition equation, the bearing capacity of the ring foundation may be determined. The differences in bearing capacity between these approaches are on average 10%. This study compares ring footing Nc values to those found in prior studies, however, no analogous studies comparing Nq and Nc of ring footing have been found. As a result, bearing capacity factors Nq and Nc determined by written code for circular footings (ri = 0) are compared to findings from other investigations [13].

The carrying capacity of ring footings was examined and discovered that the ring footing's maximum radius ratio had a substantial impact on the ring footing's bearing capability. When the radius ratio of the footings reached 0.4, the highest bearing capacity was discovered. The value carrying capacity of ring footings declined linearly after that. For the ideal radius ratio, several researchers came up with different figures. Reduced the ratio of the radius of the footing cause increases in the factors of bearing capacity, that means the surface area of the ring footings increased, especially the Nγ factor because the factor Nγ depends on the friction between the soils and the footings surface, so the factor (Nγ) will increase when decreased the friction angle and the radius ratio [22].

PLAXIS software was used to analyze the behavior of a ring footing subjected to an angled load. The model was used to simulate the effect of multi-layered soil, and the results showed that when the load's inclination angle exceeded (45) degrees, both horizontal and vertical stresses were affected, with a reduction of (40-80) percent when compared to those with an inclination angle of (0) degrees. The load's inclination angle and the ratio of (the inner diameter) to (the outer diameter) had an impact on the shear forces and bending moment within the footing (outer diameter) [26].

numerical simulations and the finite difference approach used to analyze the settlement of ring foundations that rest over elastic half-space. The study goals are to develop a closed-form solution for computing ring foundation elastic settlement. By defining displacement influence factors, the ring footing settlement may be calculated for any influence factors. The general mathematical expressions were used to examine the influence of the ring footing geometry on the radii ratio. Based on Poisson's ratio and (homogeneous, non-homogeneous soil) situations, this study can find the elastic settlement of arbitrary ring footings ranging from (flexible) to (rigid), drained (for the soils which cohesionless), and undrained (the cohesive soils) [21].

To investigate the impact of the depth and type of soil granulation and the bearing capacity of the ring footing FLAC software was use, the bearing cabacity of the ring footing on topsoil, sand, and clay was examined. The results found that the loading capacity will increases by granularity become coarser due to the increase of the contact area of the granulation, and the increase of friction and the soil structure stability. As well as the less the poorer soil depth by terms of granularity, the more limited subsidence will be, when the bearing capacity increases [19].

The approach stress characteristics use to calculates the bearing capacity factor N for both the smooth ring footings and the rough ring footings The study was based on the premise that the angle of friction (δ) between the base of footing and the underlying cohesionless material, grows progressively along the axis of symmetry from (zero) to (φ) along the outside border of the footing for a rough footing. With an increase in ri /ro, the value of N reduced dramatically, where (Ri) is the inner and (Ro) is the outer radii of the ring footing. The magnitude of N for a rough footing was higher than that for a smooth footing, as indicated in the results [15].

To investigat the eccentrically loaded for small scale ring footing sitting on cohesionless soil model experiments were conducted utilizing ring footing with ring diameter ratios (Di/Do) equal to 0.4, 0.6, and 0.8 for varied eccentricity ratios. Based on the findings of the experiments conducted in this study, the bearing capacity of ring footing is determined to be best at a ring radii ratio of 0.4, and it has the highest bearing capacity on the sand than circular footing with equal features.

the bearing capacity of circular and ring footings decreases as the eccentricity of the load increases for both reinforced and unreinforced soil, and the bearing capacity of circular and ring footings decreases as the length of reinforcement to diameter ratio (Lr/Do) grows, the bearing capacity of a ring footing improves as the eccentricity ratio increace; the settling of the ring and circular footings increace as the eccentricity ratio increace [6].

A study on the undrained bearing capacity of ring foundations resting on two-layered clays, as well as a numerical inquiry on the undrained vertical bearing response of rough ring foundations resting on two-layered clays. The following are the study's findings: The value of the bearing capacity factors Nc of ring foundations increases with decreasing shear strength ratio regardless of H/D (H) which mean values of top layer thickness, and (D) is the diameter of the footing, and the reduction of (Nc) value with (H/D) is shown for H/D less than (0.25) for soft-over-stiff clays, which is especially noteworthy for small values of Ri/R0. However, for stiff-over-soft clays, the Nc value increases as H/D increases, and this trend is more pronounced for lower Ri/R0 ratios. The shear strength of the clay bottom layer would not affect the foundation bearing capacity if the depth of this layer is sufficient [16]. field test was conduct to analysis ring footings the result was shown in Figure 1 that qu will decreases rapidly when d/D (ineer diameter to outer diameter) changes from 0.0 to 0.3 and then qu (ultimate bearing capacity) decreases at a slower rate when d/D will change from 0.3 to 0.6. 0.30 is the optimum value of d/D may visually be estimated from the curve as approximately [4].

Ring foundations are frequently used for large and tall structures to resist lateral loads and increase stability against overturning, to evaluate the bearing capacity of footing and find a relationship between (load and settlement) many researches are wroten. In some studies, the ring foundations bearing capacity has been estimated by using the finite element [22].

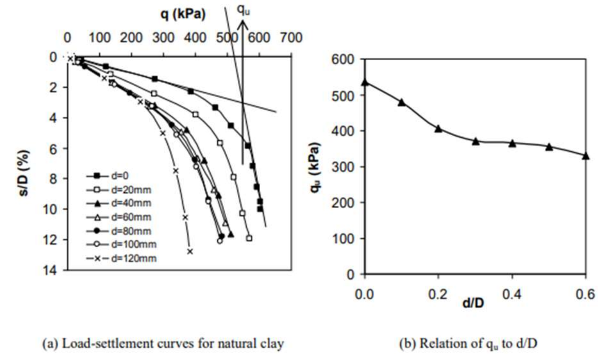

Figure 2: Test results for natural clay by use ring footing

1.4 *Previous research on the behavior of deffirent footings rest on gypseous soil*

Bearing capacity of circular footing that rested on gypseous soil before and after improvement was studied, the comparison determined by two different methods the first method compacted cement dust was used. at its optimum moisture content, the soil improvement was performed by created trench under the footing the trench filled with compacted cement dust, at three depths and made the trench with the same footing dimensions, the second method by used biaxial geogrids to reinforcing gypseous soil this method has been shown that its an effective method for improving the ultimate bearing capacity of granular soils. From the results, it was found that the compacted cement dust has large bearing capacity values than from the single layer reinforced soil but by using multi-layer to reinforced soil the bearing capacity value will be larger than dust cement improvement [18].

Research on the behavior of square footing surrounded by a sheet pile wall and resting on gypseous soil was conduct, the soil was subjected to (10 saturation cycles) and one-week drainage time to simulate the floods or the heavy rainfalls. It should be noted that the soaking water were added outside the area that surrounded by the sheet pile. To detect gypsum solubility (4) points were chosen, for results comparison, (3) of points were below the footing edge at vareous depths, and (1) will be outside the sheet pile wall. It has been found that less dissolved gypsum below the footing than the one outside the sheet pile wall. For each cycle of saturation-drainage the gypsum content is found to decrease from (3 % - 0.8 %) for the point outsider and for the average of the three points also.the recorded Settlement throght the first cycle of saturation and drainage was twice so that in the second cycle and aproxmatlly four times in the third cycle.As a result to this research its found to be that the sheet pile wall an effective protection to reduce the collapsibility of gypsum soil, as well as to reduce the settlement of the footing [20].

Bright Spots in Literature

Few experimental investigations have been conducted on the computation of shallow foundation bearing capacity to assess the performance of a ring foundation resting on gypseous soil that has been treated with various materials to improve its qualities. Several points have been noticed when study the research on the gypseous soil and ring footing. Gypseous soil is problematic because it causes damages to the structures built on it, several experiments on gypseous soil samples have been conducted to improve its qualities and reduce the collapse potential. The researcher employs a variety of materials, some of materials cause significant reduction in collapse potential.

To test the effect of each addition, several experiments were conducted on gypseous soil. Some materials were inexpensive and varied, as well as environmentally friendly, while others were not. Few studies of ring footing under dynamic loading have been conducted. Even so, the majority of studies are carried out statically, which raises concerns about studies on the behavior of ring footing under eccentric loads. All of the prior research has pointed to the fact that the radius ratio affects ring footing bearing capacity and settlement. They discovered that a radius ratio of 0.4 is the ideal ratio and that any radius ratio greater than this diminished bearing capacity. The bearing capacity factors are another important factor discovered in previous studies. Most researchers consider ($N\gamma$) to be the most important element affecting the bearing capacity of rough ring footing.

Conclusions

1. Many studies have been conducted on gypseous soil to improve its qualities, particularly its collapse potential. The researcher adds a variety of ingredients to gypseous soil and conducts experiments to determine how its qualities alter.

2. Some materials, such as fly ash, silica fume, Nano – silica, nano clay, liquid asphalt, and quicklime, are successful in improving the collapse potential of gypseous soils, whereas other materials are less affected.

3. The percentage of additives is critical because some percentage can have a negative impact on the soil.

4. The majority of researchers who looked into the bearing capacity of ring footings found that the maximum radius ratio of the ring affected bearing capacity intensity. Because it is the best radius ratio of footings, the ring footings should be 0.4 for the highest bearing capacity. Even still, the bearing capacity of ring footings linearly decreases after this value. However, this ratio has not been thoroughly investigated for ring foundations resting on gypseous soil.

5. The roughness of the footing base is taken into consideration that including (smooth) and (totally rough) footing base because its effect on the behaivore of the footing.

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مراجعة لدراسة سلوك اداء الاساس الحلقي المستند على تربة جبسية

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الخلاصة – اعدت هذه الدراسة لتقييم اداء الاساس الحلقي وكذلك الاساس الدائري والمربع المستند على تربة جبسية وكيفية معالجتها بمواد لتحسين خواصها.الهدف من هذه الدراسة استخدام الفحوصات المختبرية الممكنة لمعرفة قابلية التحمل للتربة ومعرفة اداء الاساس الحلقي المستند على التربة و العلاقة بين (التحميل , هبوط الاساس) تحت تاثير اضافة الحمل وكذلك تحسين خواص التربة الجبسية . يعتبر الاساس الحلقي اقل كلفة من الاساسات الاخرى ويستخدم في عدة تطبيقات ومن المهم ايضا البحث في خواص الترب الجبسية , خاصة انها يغطي مساحة اكثر من (12%) من المساحة الكلية لدولة العراق . مادة الجبس الموجودة في هذه التربة تذوب عند جريان الماء ومصادر هذا الماء قد تكون (الامطار، صعود مستوى المياه الجوفية،مياه المجاري او اي مصادر اخرى للماء) , مما يتسبب بصعوبات عدة واضرار الى المنشآت المبنية على التربة الجبسية , وعليه يجب دراسة وفحص خواص هذه التربة .

الكلمات الرئيسية –تربة جبسية " قابلية التحمل "قابلية الانهيار "اساس حلقي " قدرة التحمل .