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The Collapsible Soil, Types, Mechanism, and identification: A Review Study

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ABSTRACT

Collapsible soil has a metastable structure that experiences a large reduction in volume or collapse when wetting. The characteristics of collapsible soil contribute to different problems for infrastructures constructed on its such as cracks and excessive settlement found in buildings, railways channels, bridges, and roads. This paper aims to provide an art review on collapse soil behavior all over the world, type of collapse soil, identification of collapse potential, and factors that affect collapsibility soil. As urban grow in several parts of the world, the collapsible soil will have more get to the water. As a result, there will be an increase in the number of wetting collapse problems, so it's very important to comprehend these soils' collapse mechanisms under different conditions such as reduction in capillary rise force upon wetting, the concentration of the soluble salts, deficiency of clays and under compaction that attributed the collapse potential to the nature of character of the porous fabric of loess soil.

Keywords: collapse soil, inundation, bonding, loess soil, problematic soil, gypsum soil.

التربة القابلة للانهيار, الأنواع والآلية والتعريف: دراسة مراجعة

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الخلاصة

تتميز التربة القابلة للانهيار بهيكل غير مستقر يكون عرضة لانخفاض كبير في الحجم الكلي أو الانهيار عند الغمر. تساهم خصائص الانهيار في مشاكل مختلفة للبنى التحتية التي أقيمت عليها مثل الشقوق والهطول الكبير الذي تم العثور عليه في المباني وقنوات السكك الحديدية والجسور والطرق. الهدف من هذه الورقة هو تقديم مراجعة فنية لسلوك التربة الانهيارية في جميع

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أنحاء العالم، ونوع التربة الانهيارية وتحديد إمكانية الانهيار، والعوامل التي تؤثر على قابلية التربة للانهيار. سيكون هناك المزيد من فرص الحصول على المياه لهذه التربة مع النمو الحضري في أجزاء مختلفة من العالم مع رواسب التربة القابلة للانهيار. نتيجة لذلك، سيكون هناك زيادة في عدد مشاكل ترطيب الترب الانهيارية، لذلك من المهم جدًا فهم آليات انهيار التربة في ظل ظروف مختلفة مثل انخفاض الخاصية الشعرية عند الترطيب، ذوبان الاملاح القابلة للذوبان، نقص الطين وتحت عملية الرص حيث يعزى احتمال الانهيار إلى طبيعة خاصية النسيج المسامي للتربة المفككة.

الكلمات الرئيسية: الترب الانهيارية، الترطيب، الروابط، تربة الراسب الطفالي، تربة ذات المشاكل

1. INTRODUCTION

There are several definitions for soil collapse. (**Barden et al., 1969 and 1973)** defined collapsible soil as." Any metastable structured soil, that an increase in pore-water pressure cause a reduction in volume for this soil, while an increase in pore-water pressure may cause swelling in an unsaturated stable, structured soil". While (**Clemence and Finbarr,1981)** defined collapsible soil as any unsaturated soil that undergoes radical particle rearrangement and significant volume loss following wetting with or without additional loads. (**Hansen et al.,1989)** discussed the collapsed soil and found that the tubular and honeycomb structures in the soil led to a very low dry unit weight. According to test results, **(John C. Lommler, and Paola Bandini, 2015)** found the disturbance of the sample reduced the predicted collapse potential by the laboratory for situ soils, whereas for compacted soil the laboratory-predicted collapse potential is increased. Testing for soil activity was also was found to be the best indicator for the nature of these types of soils than determining the plasticity Index just.

2. Soil Collapse.

When evaporation rates exceed rainfall in arid and semi-arid areas, collapsible soils can be found; arid-zone deposits are frequently associated with collapsibility soils such as loess soil, soil transported by gravity (colluvium), and soils transported by water (alluvium). Naturally, Debris flow (e.g., alluvial fan materials) is the most common source of collapsible wind-blown sediments, for example, loess soil, residual tropical soil, and cemented metastable soils with a high level of salt concentration such as sabkha soil. (**Al-Taie, et al., 2019**). Furthermore, compaction without engineering specification with a lower moisture content artificially collapsible soil can be made from content or waste materials. **(Madhyannapu et al., 2006; Jefferson and Rogers, 2012).**

(Fredlund, 1996; Ng and Menzies, 2007) refer to the result of different salts, oxides, soil suction, and dried clay led to naturally generated collapsible soils that may be heavily or lightly concentrated. They can be found in loose, poor fabric states with low density and moisture content.

Collapsible soils can carry a large load with only a small amount of compression or deformation if dry, but they lose a significant amount of volume when wet (**Al-Naje et al., 2020**).

(Dudly, 1970, Clemence and Finbarr, 1981 and Das, 1990). (Jefferson and Rogers, 2012) referred to both change in volumes and the degree of wetting that will occur are two important challenges that collapsing soils will experience.

(Dully, 1970, Bardan et al., 1973, Clemence and **Finbarr, 1981, Rogers, 1995, Al-Taie, 2002, Al-Taie** and **Al-Shakarchi, 2016)** found there are three main types of bonding mechanisms in collapse soil: -

1- Soil with sands particles with meniscus water binder or sands particles with fine silt binder under capillary or matric suction force, as shown in **Fig. (1 a, b).**

2- **Knight, 1960** showed that if the clay particles and or silt particles have coarser particle interactions, it produces a randomly flocculated structure, providing a buttress to the bulky grains, as shown in **Fig. (1c)**. Nevertheless, most of the collapsing soils included the effect of clay plats, which act as the bonding between the bulky sand and silt grains. Anthogenesis can cause the clay to form, and as a result, parallel plate onion skin effect around the quartz particles, as shown in **Fig. (1d)**. On the other hand, when the clay particles are suspended in pore-water, continuous evaporation is led to the clay plates withdrawing with the water into menisci at interparticle contact.

3- Chemical cementing agents, such as calcium carbonate and iron oxide, sometimes other chemical agents frequently the main agent in lost soil, may have a significant bonding effect in some collapsing soils, as shown in **Fig. (1e).**

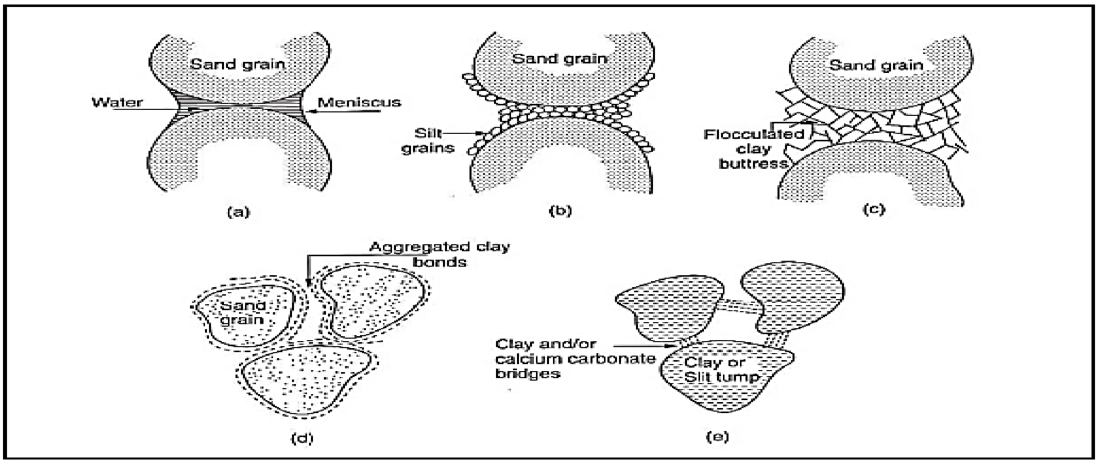

Figure 1. Types of bonding arrangements in collapsible soils, as cited in **(Jefferson** and **Rogers, 2012).**

According to **(Barden et al., 1973)**, the formation of collapse mechanism needs (3) conditions: partly saturated open structure and unstable, soil stress, and sufficient bonding caused by soil suction or another cementing agent.

(Lefebvre, 1995) found that in the presence of a stress condition, a soil particle shear resistance before the collapse is sufficient to hold up the soil structure at the specific porosity or void ratio. The low inter particular shear resistance will be led to the change in the equilibrium that will happen between the void ratio and the stress state when the mass of the soil is will be compressed to a new level of equilibrium

Moisture-sensitive soils are found in many places globally, particularly in Russia, the Middle East, China, Europe, and North and South America. As a result, it's important to comprehend the collapse process and determine whether the problems of the collapsible soils may be reduced or avoided

3. Mechanism of Soil Collapse.

Many researchers have invested the last six decades studying the mechanism of collapse for the different collapsible soils when wetting. Approaches that are based on soil mechanics, microstructure approaches, and traditional approaches have been used to describe this behavior.

(Zhang, 2002, Fan and Guo, 2003, Song and Wang, 2004, Chen et al., 2006, Yuan, 2009, Al-Busoda, 1999, Al-Busoda and Khdeir, 2018, Al-Damluji et al., 2019) found that collapsibility was usually evaluated using one specific factor in traditional techniques. For example, the collapse has been attributed to reducing capillary force or the soluble salt solution. Furthermore, **(Ayadat and Hanna, 2007, Zorlu and Kasapoglu, 2009, Noor et al., 2013)** referred that many researchers investigated the impact of soil parameters on the collapsibility of loess soils, (e.g. grain size distribution, Atterberg limits, density and clay content). A significant number of empirical equations relating collapsibility to conventional soil parameters have been developed in the researches. Almost all of these empirical equations enable to be applied to the specific soil for whom they were designed. In other words, suggested empirical equations don't apply to conventional geotechnical engineering practice because soils have varying microstructures and, as a result, different mechanical behavior despite having similar physical properties.

(Alonso et al., 1993) showed that microstructure plays an important role in controlling collapse behavior; nevertheless, there is no basic quantitative descriptor for evaluating collapse deformations. In recent years this limitation has been treated and then reduced to a significant limit by developing image processing techniques that made quantitative analysis of the microstructure of soil feasible.

(Gu et al., 2011) pointed out that the image processing programs are often dependent on the principle of binary grey segmentation to supply adequate, realistic results, especially for coarse soils, while these applications for fine-grained soil haven't been well validated**.** According to the currently available programs, digital photographs are not easy to distinguish between grains and pore sizes. The third category of approaches explains the collapse behavior using soil mechanics concepts. Collapsible soil is usually unsaturated with considerable collapse happening before the soil becomes fully saturated. As a result, mechanics concepts to the unsaturated soil are more realistic to the analyzing behavior of the collapse **(Chen,1999, Pereira and Fredlund, 2000**).

(Fredlund and Morgenstern, 1977) showed that two stress state variables approached to describe a mechanical behavior for the unsaturated soils has been extended to investigations of changing the volume due to loading with wetting for a collapsible soil.

Collapse is associated with a reduction in strength due to decreasing suction due to wetting. Because of this reason, collapse behavior was determined widely by using suction-controlled wetting tests. Based on that, **(Tadepalli et al., 1992, Fredlund and Gan, 1995, Pereira and Fredlund, 2000, Pereira and Fredlund, 1997)** proposed various models for describing the collapse behavior concerning different stress states variables, for example, matric suction**.** The behavior of volume change for collapsible soil has been interpreted for these models. If the stress path reaches the elastic zone or yield surfaces, collapse is considered part of deformation in these models. Elastoplastic models provide a more realistic method for estimating collapse deformations concerning various stress state variables for quantitative analysis. However, in suction-controlled tests, several parameters are required to be addressing some scenarios of collapse

4. Collapse Soil during Inundation

Any soil typically was compacted at optimum dry condition exhibited collapse behavior at wetting, whereas the soil is compacted at wet optimum condition showed no collapsibility **(Lawton et al., 1989**). During inundation, unsaturated collapsible soil when unsaturated condition refers to both dry and partially saturated, had a sudden volume reduction (collapse settlement) with no change in the stress level, because of the fast volume change behavior of collapsible soil, predicting the performance of the foundation in the collapsible soil during inundation is difficult.

Collapsible soil has a highly porous unsaturated structure in its initial condition and low unit weight (**Al-Taie, 2017**). Unit weight and porosity (unsaturated) are about 12–15 kn/m^3 and 0.8–1.0, respectively **(Grigoryan, 1997).** The microstructure of collapsible loess soil that was formed by the wind action can be shown in **Fig. (2**). As shown in **Fig. (3)**, collapsible sediments had a honeycomb-type particle arrangement**.**

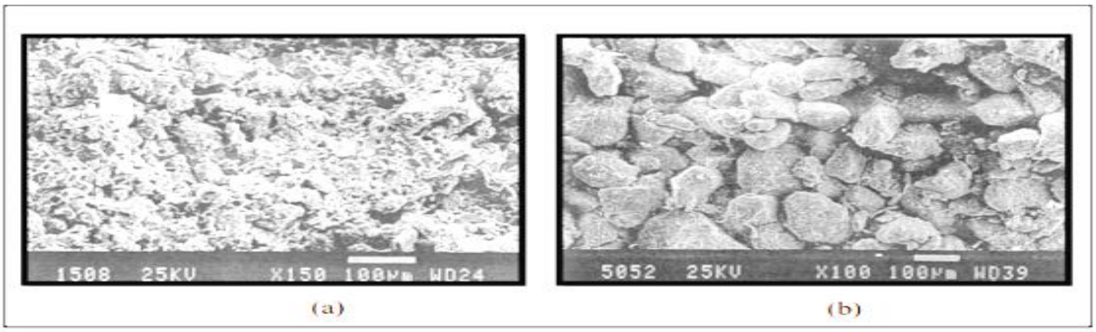

Figure 2. Skeletal microstructures; (a) typical loess soil, (b) sandy loess soil **(Klukanova and Frankovska, 1995).**

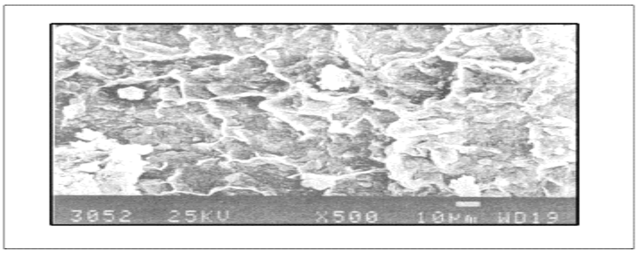

Figure 3. Microstructure of Honeycomb type for loess like sediments **(Klukanova and Frankovska, 1995).**

(Kakoil, 2011) mentioned that the negative pore-water pressure (-uw) develops in the unsaturated soil matrix due to capillary action (at very low moisture content in unsaturated collapsible soil). Matrix suction is defined as a negative pore water pressure (-uw) subtracted from atmospheric pressure (ua - uw). The higher the matric suction in unsaturated soil mechanics, the additional bond strength will increase due to capillary forces. As a result, the combined action of interparticle bonding (cementation and capillary bonding) between coarse particles resist soil grain slip and maintains the collapsible soil's flocculated structure. An increase of water (or water pressure) in the pore induces a reduction in matric suction (or negative pore water pressure, -uw) of any unsaturated soil. Matrix suction decreases continually after inundation, reaching zero when the soil has reached complete saturation. The collapsible soil experiences an immediate volume decrease during the inundation. The bond strength is lost due to matric suction reduction. The changes in the unsaturated soil property (such as shear strength parameters and permeability) occur in all unsaturated soil during inundation, including metastable and stable structured soils.

(**Udomchoke, 1991)** studied the reduction of apparent cohesion in natural unsaturated conditions during the inundation, apparent cohesion was found (30 kPa and 10 kPa) when the soil had (5% and 15%) moisture content, respectively, as shown in **Fig. (4).**

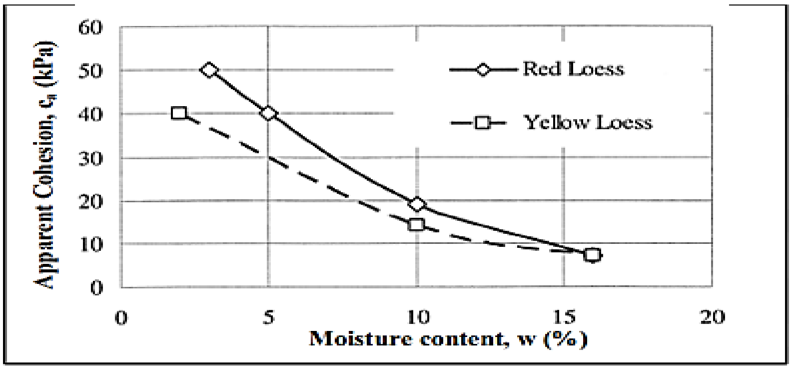

Figure 4. The relationship between apparent cohesion and moisture content of the Khon Kaen loess soil (**Udomchoke, 1991).**

Inundation of any soil occurs either naturally or by accident. Surface runoff, rainwater percolation, poor drainage, floods, and other factors contribute to top inundation. Inundation from the bottom results from an increase in groundwater table and a capillary rise from the groundwater table.

5. Collapsible Soil Identification

The double Oedometer (DOT) and single Oedometer (SOT) methods are often used in Oedometer-collapse to determine the collapse potential. The result of these tests can be represented in **Fig. (5)**. The (DOT) method was proposed by **(Jennings and Knight, 1957**). Two samples identically will be prepared, then are tested individually in the Oedometer device; the first sample will be tested under natural moisture content, whereas a second sample will be tested under saturated conditions. The same loading sequence will be applied in both cases, as illustrated in **Fig. (5 a).**

The collapse amount is determined using a stress-strain curve when increasing the stress level. **(Houston et al., 1998)** whose modified this procedure subsequently and standardized by the American Society for Testing and Materials (ASTM) under code number ASTM D5333 (2003) According to (ASTM D5333,2003), a single Oedometer test was conducted using samples under unsaturated conditions. The sample is subjected to pressure to 200 kPa or the pressure field; this is suggested by **(Jennings and Knight,1975)**. At point (B), the sample was inundated to reaching saturation condition and left for 24 hours. The loading increment was continuous following inundation that lasted overnight or until primary consolidation was completed. The difference between the strains level before and after the inundation with water (points B-I) refers to the amount of collapse deformation at a specified stress level that is equal to 200 kPa, as shown in **Fig. (5 b).** The collapse potential can be calculated from the equation (1): -

$$Ic = \frac{eB - eI}{1 + eo} \qquad (1)$$

Where: -

e_B= void ratio before wetting at a specific stress level.

e_I= void ratio after wetting at a specific stress level.

e_O= initial void ratio

I_c= collapse potential.

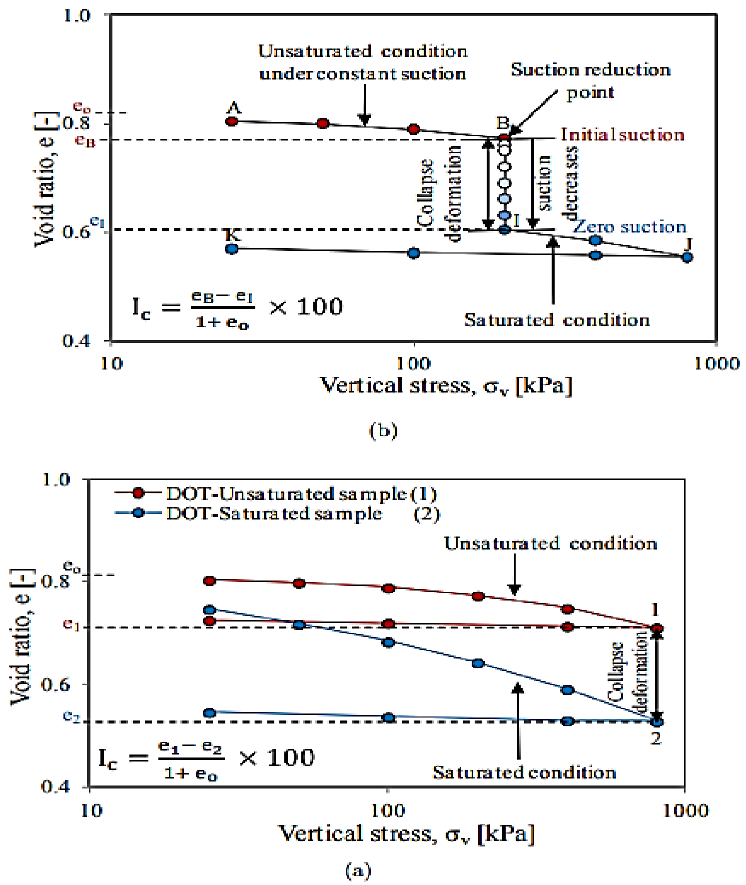

Figure 5. Results of the Oedometer collapse tests: (a) (DOT) test and (b) (SOT)test.

The collapse potential of soil can be assessed and used to identify the severity of the problem based on the Oedometer-collapse test. **Table (1)** represents a comparison between ASTM D5333 (2003) and **(Jennings and Knight, 1975)** for the range of collapse potentials according to the severity of the problem.

Table 1. The severity of the collapse potential.

Jennings and Knight, 1975		ASTM (D5333-2003) standard	
Ic,(%) at σv=200 kPa	Severity of problem	Ic,(%) at σv=200 kPa	Degree of collapse
0-1	No problem	0	Non
1-5	Moderate trouble	0.1-2.0	Slightly
5-10	Trouble	2.1-6	Moderate
10-20	Severe trouble	6.1-10	Moderately severe
>20	Very severe trouble	>10	Severe

6. FACTORS AFFECTING COLLAPSE

The soil type, stress level during the inundation, compaction effort, initial water content, and clay percent are most factors that affect the collapse potential soil. (**Houston and Houston, 1989, Ayadat and Hanna, 2007, Al-Taie and Al-Shakarchi, 2017).**

According to **(Lawton et al. 1992)**, collapse potential could be determined depending on several factors. The most important factors are initial water condition and dry density **(Al-Busoda, 2009)**, whereas **(Tadepalli and Fredlund, 1991)** concluded that with an increasing dry density and water content of the soil, the percent of collapse reduces before wetting.

(Lommler and Bandini, 2015) listed that according to test results, the sample disturbance might decrease a collapse potential of in situ soil, whereas a potential collapse increases for compacted soils

Many researchers studied the effect of inundation pressure on collapse potential with an inundation pressure ranging from (50 -60) kPa. **(Lawton et al., 1992, Kezdi, 1974)** concluded that a collapse potential reaches a peak value at a specific inundation pressure level, after which a collapse potential is kept constant despite increased vertical stress. These researches prove that when inundation pressure increases, the collapse settlement increases, up to a stress limit that depends on the packing and arranging of soil particles.

Fig. (6) represented load settlement curves of the bearing plate in collapsible soils for both saturated and unsaturated conditions, as mentioned by **(Grigoryan, 1997).** When unsaturated soil was subjected to full inundation, reaching 100%, it was observed the settlement increased linearly with increasing load pressure until a specific value of pressure (300 kPa). Then the collapse or settlement increased rapidly to a value larger than the unsaturated condition. So, it could note that a higher inundation pressure led to an increase in the amount of collapse. The results might be interpreted as follows. In the case of unsaturated soil, a small volume change may occur when loaded at initial water content. In contrast, when the soil becomes saturated during the inundation, it loses its strength, and the bonds of soil particles begin breaking due to the increase in water content. Therefore, it was noted that the soil when it was unsaturated, could support pressure up to 500 kPa, but exposed to failure at a pressure of 300 kPa in the case of 100% inundation. On the other hand, under constant pressure on the bearing plate, the settlement of saturated collapsible soil was more than unsaturated soil.

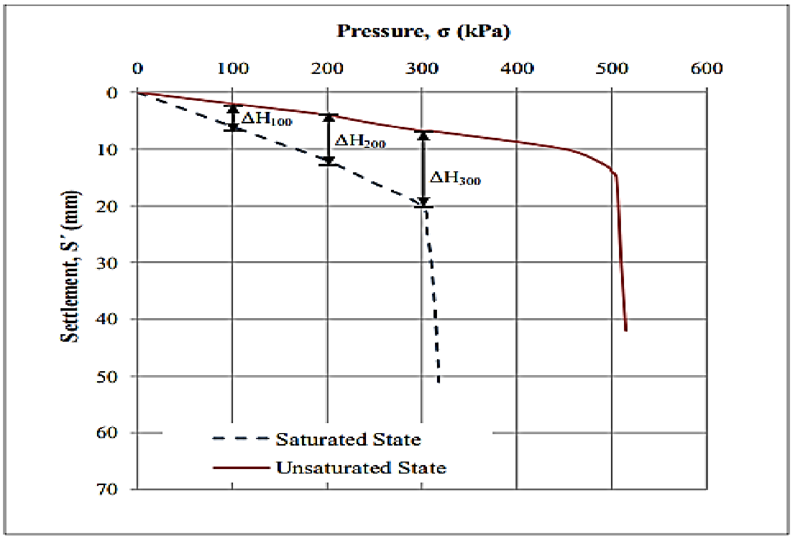

Figure 6. Relationship between Load and settlement for collapsible saturated and unsaturated soil **(Grigoryan, 1997).**

(Al-Obaidi, 2014) use three samples of collapsible soil: -

1- Soil symbol GI (referring to gypseous soil from Iraq).
2- Soil symbol LG (referring to loess soil from Germany).
3- Soil symbol 70G30S refers to the mixture of 70% artificial gypsum-30% Silber sand

It had been studied study the volume changes of soil under suction control for the wetting path and found: -

1- The collapse deformation is affected by the initial void ratio, the degree of saturation, net vertical stress, and applied suction value.

2- The final soil collapse is reached with a low range of suction that has been applied beyond hours (few hours) of wetting with the degree of saturation range of (30-50%). Whereas, beyond the final collapse in gypseous soils, creep deformation is developed, and it was negligible in the loess soil.

3- The collapse mechanism over the suction range can be divided into three phases called: Main collapse phase, Pre-collapse phase, and Post-collapse phase **(I. and Rogers, C.D.F., 2012).**

7. Type of Collapse Soil

Collapsible soils might be found naturally, for example, gypseous or loess deposits, or as a result of human activity all over the world (e.g., poorly compacted soil). Different types of collapsible soils were represented in the studies **(Dudly, 1970, Rogers, 1995, Al-Mufty, 1997, Houston et al., 2001, Jefferson and Rogers, 2012, Al-Busoda, 2008**). Among the most important types of collapsed soils, we will review some of their properties: Gypseous soil and loose soils.

7.1Gypseous Soil

Gypseous soils are widely distributed throughout the world. Due to its complex and unpredictable behavior, gypseous soil is classified as a type of problematic soil. Low dry density and moisture content are the properties of these soil in their natural state. Due to the presence of gypsum, this soil can handle any load when dry. The dissolution of the cemented gypsum bonds leads to gypsums soil deformation, which causes clear increasing compressibility of the soil and developed sudden collapse potential (cavities) in the soil structure when inundation under constant vertical stress. In other words, a high decrease in voids ratio of a metastable soil structure, tilting, rapid settlement, large deformations, and other great damages to the structures constructed on gypseous soil can occur **(Albusoda and Hessain, 2013, Albusoda et al., 2013, Zbar and Hessain, 2013, Al-Busoda and Al-Rubaye, 2015).**

(Al-Obaidi, 2003) listed that the gypseous soil in Iraq is widely distributed, particularly in the west, southwest, and northwest regions. Its covers approximately (20-30%) of Iraq's area, these soils have very high gypsum content in some zone, and they make up more than (60%) of the total dry mass of the soil sample

(Al-Rubaye 2014) listed that the term "gypsiferous soil" used by (**Van Alphen and Romero, 1971)** refers to soils with more than (2%) gypsum. **(Saaed and Khorshid,1989)** defined gypsiferous soil, as a soil containing more than (6%) gypsum". While civil engineering definition of the soil is "gypseous soil" when gypsum content is enough to vary the properties of the soil **(Al-Busoda and Alahmar, 2014)**, gypsified soil is a natural soil at which a predefined percent of gypsum is added. **(Barzanji, 1973)** classified gypseous soils concerning gypsum content as shown below in **Table (2).**

Table 2. Gypseous Soils Classification (After **Barzanji, 1973**).

Gypsum %	Classification
0-0.3	Non gypsiferous
0.3-3	Very Slightly gypsiferous
3-10	Moderately gypsiferous
10-25	Highly gypsiferous
>25	Gypsiferous soil to be described by the fraction, such as sandy gypsiferous soil

(Al-Farouk et al., 2009) studied the dissolution of gypsum in gypsiferous soil using experimental and numerical models. The axial strain of gypsiferous soils is affected by the initial water concentration. This may be to the effects of initial concentration on gypsum dissolution, which decreases when increasing initial concentrations in water. The Oedometer permeability leaching test results show that porosity has a significant impact on the behavior of gypsiferous soil. It was found that displacement continuously increased with time and decreased with depth. Large displacements occurred near the surface. Finally, the dissolution of gypsum decreases with depth.

(Al-Rawi et al., 2011) studied the influence of temperature, gypsum content, flow velocity, hole diameter, and the salinity of solvent on the value and rate of dissolution of gypseous rock that have gypsum content ranging from (16% to 90%) and was obtained from the Al-Fat'ha dam proposed site that located approximately 280km to the north of Baghdad city, with both increasing the temperature and the flow velocity, the amount and rate of gypsum dissolution is increasing. Increasing the salinity of the solvent (using low percentages of NaCl additives) has a large influence on the amount and rate of gypsum dissolution. A further increase in the salinity exhibited a very little amount increase of dissolution compared with the lower salinity concentration; more dissolution was exhibited with increasing the diameter of the hole along the center of the sample that led to increasing the inside area of exposed water.

(Al-Shamoosi, 2019) investigated the collapse deformation of gypseous soil under suction controlled by multi-step wetting using a soil model designed and manufactured with gypsum content of more than 70% from Al-Ramadi city (west of Iraq). The result showed that the reduction of matric suction led to large volume change and collapse deformation. The void ratio is dramatically reduced stepwise by reducing matric suction and increasing the degree of saturation by multi-steps wetting irrespective of the value of applied vertical stress. The experiments also showed that various factors influence the change in suction pressure from the maximum level at first suction (139280 kPa) to the lowest level (0 kPa). In contrast, the depth of groundwater, the dry density of the soil, and the applied vertical stress are the most important of these factors.

7.2 Loess soil

(Barden et al., 1973) defined loess soils as an aeolian quaternary deposit of predominately silt-sized particles ranging between 20-60 mm with clays, carbonates, and capillary water acting as bonding materials at particle junctions.

(Terzaghi et al., 1996) described loess soil as a light brown soil with particles size ranging from (0.01 to 0.05 mm) with uniform, cohesive sediment.

(Delage et al.,2005) studied the behavior of collapse and a microstructure for widespread aeolian loess deposits in Northern France. According to Microscan SEM studies, they had porous microstructure with the heterogeneous dissipation of clay accumulations that filled the intergrain pores and worked as a bonding agent between the grains in some areas. Sharp-edged angular silt grains about 15-30 mm in diameter with large intergrain pores have been seen in locations where there is no clay. The intrusion of mercury porosimetry showed that a change did not influence the smaller pores inside the clay accumulations in the intergrain of pores that happens during the collapse. A collapsed structure was more regular with the well-graded pore size distribution curve. According to **(Munoz-Casteblanco et al., 2011),** collapse by wetting is caused by the densification of the region where the grains of soil are clean and have large pores around them. Clay aggregation fills the porosity in these zones, making them more resistant to collapse and less sensitive to collapse locally.

(Li et al., 2016) prepared a review paper about the collapse triggering mechanism of collapsible soils due to wetting. The collapse mechanism studies are summarized under three different categories, i.e., traditional approaches, microstructure approach, and soil mechanics-based approaches. Traditional approaches are unacceptable to state the collapse behavior for all loess soil. The microstructure for loess soils might be analyzed using (4) factors such as bonding material, contact relation, pore form, and particle pattern. From these factors, two factors have a large effect on the collapse behavior, soil microstructure mechanics of unsaturated soils and they are pore form and bonding material, which not only demonstrate that the collapse is the result of changes in the stress state variables but provide an accurate way to predict the changing of volume relating to the collapse by appropriate constitutive relations. Elastoplastic models define the yield surface for unsaturated soils. It divides elastic and plastic deformations of the unsaturated soil. These models can also be used as tools to state the collapse phenomenon as soil yields, or the stress path crosses the yield surface due to either loading or wetting.

8. CONCLUSIONS

Collapsible soils represent challenges to geotechnical and structural engineering in the world. A soil that experiences a volume reduction as a result of increasing water content that could be normal or artificially, will produce a metastable structure because of the presence of a large void ratio. It is very necessary to know the behavior of such soil under drying and wetting conditions with or without external loads to avoid collapsibility soil problems such as crack, tilting, and excessive settlement. From the literature reviewed, the following points can be summarized: -

1- Collapsible soils can carry a heavy load with only a little amount of compression or deformation when they are dry, but they lose a significant amount of volume when they are wet. Low dry density, low Atteberag limit, high voids ratio and high settlement are the most physical properties of collapsed soil

2- The initial arrangement of soil particles in an open metastable packing through a suite of different bonding mechanisms bonds that are created via capillary forces (e.g., suction) and/or by cementing fine materials (e.g., various salts, oxides, dried clay). Upon wetting, the cementation bonds are weakened, and the initially loose fabric collapses and densifies, often resulting in dramatic and damaging settlement.
3- The collapse behavior was explained by three approaches, soil mechanics-based approaches, Traditional approaches, and microstructure approaches.
4- Most factors that affect the collapse potential of soils and could be estimated by using a single Oedometer (SOT) and double Oedometer (DOT) are stress level during the inundation, clay percent, soil type, initial water content, and compaction effort.
5- This review paper referred to two types of collapse soil, gypseous soil, and lost soil. The effect of flow velocity, hole diameter, gypsum content, the salinity of solvent, temperature, the amount and rate of dissolution of gypseous rock samples have been investigated, and the result showed the large volume change and collapse deformation occur upon reduction of matric suction. The void ratio was dramatically reduced stepwise by reducing matric suction and increasing the degree of saturation by multi-step wetting irrespective of the value of applied vertical stress.

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