DETERIORATION OF CONCRETE FOR UNDER-GROUND STRUCTURES IN SAMAWA CITY

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Abstract

Concrete is a relatively durable building Materials, it may be failed or damaged due to the effect of some properties of soil components, such as salt, sulfate and underground water, especially when the concrete used in construction of the underground structures. Sulfate and salt (which are dissolved in water) try to penetrate through the concrete and attack it. The attack effects will be on the strength characters of concrete and rebar reinforcements.

The aim of this work is to study the effect of soil components on strength of concrete (for 28 day age) when the concrete is buried in the soil. For achieving this aim of the work, the compressive strength of concrete specimens was tested before and after burying in the ground for the same concrete mix design. The specimens were grouped to be tested under the condition of different periods of burying in the soil for 5 months starting from the casting date. In addition to that, it was investigated the effect of saline degree on the compressive strength of the embedded concrete in the soil. The results of the tested specimens were compared with the reference specimens, i.e. those which had been tested without burying in the soil. The area in which the specimens were buried divided into three zones according to the degree of salinity, this area is in Samawa City (270 km south-west of Baghdad) . It was found that the compressive strength of concrete specimens exposed to Sulphate attack in zone A for a period of 79 and 102 decreases from 25.7 MPa to 22.25 MPa, while the others in zones B and C showed a decrease in compressive strength from 25.7 MPa to 17.5 and 18 MPa respectively.

Keywords: Concrete, Compressive Strength, Saline Degree, Sulphate Attack

تلف الخرسانة للمنشآت تحت الأرض في مدينة السماوة

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الخلاصة

الخرسانة ذات ديمومة جيدة في مواد البناء، ولكنها قد تعاني من الضرر أو التلف خلال فترة إنشاءها نتيجة لأسباب عديدة . احد تلك الأسباب هي تأثير مكونات التربة على الخرسانة وخاصة عند استخدام الخرسانة في الأسس الضحلة أو العميقة، هذه المكونات تتألف عادة من الأملاح والكبريتات والمياه الجوفية. إن الكبريتات والأملاح الذائبة في الماء تحاول أن تخترق الخرسانة وتتلفها وهذا التلف يؤثر عادة على خواص الخرسانة وحديد التسليح الداخل في الخرسانة.

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يهدف هذا البحث إلى تسليط الضوء على مقاومة الانضغاط للخرسانة عندما تكون مطمورة في التربة (كالأسس) أو تحت تأثير المياه الجوفية،كما يستفاد من حصيلة البحث معرفة مدى التأثير الذي يمكن ان يحدث على المنشأ الخرساني خلال فترة الاستخدام وخاصة في اوقات الجفاف والرطوبة القاسيين التي تتزامن على الخرسانة, حيث تم استخدام مجموعة من المكعبات الخرسانية تم طمرها داخل التربة لفترات مختلفة، وأنواع مختلفة من التربة استخدمت في هذا البحث. جميع المكعبات الخرسانية تم فحصها لحساب مقاومة الانضغاط لها وعمل مقارنة بين مقاومة الانضغاط للخرسانة قبل وبعد الطمر في التربة، كما تم تكوين علاقة ما بين وقت الدفن (الطمر) تحت التربة ومقاومة الخرسانة مع الأخذ بنظر الاعتبار نوع التربة المدفونة فيها تلك المكعبات الخرسانة. كما يهدف البحث إلى معرفة مدى حجم التلف في الخرسانة المدفونة داخل التربة ليكون لدى المهندس المصمم فكرة بسيطة عن مدى التلف والانخفاض في المقاومة لخرسانة الأسس ليأخذها بنظر الاعتبار عند افتراض المقاومة التصميمية لها .

تمت الدراسة على ثلاث أنواع من التربة لموقع مدينة السماوة، حيث إنها مقسمة إلى ثلاث مناطق (A,B,C) حسب تحريات التربة التي أجريت في 2004، حيث تم صب المكعبات الخاصة بهذا البحث في وقت واحد، بعض تلك المكعبات تم معالجتها وفحصت بعد 28 يوم والمكعبات الأخرى تم طمرها داخل التربة وبعدها فحصت بأوقات مختلفة. إن مقاومة الانضغاط للخرسانة هي المعيار في المقارنة ومعرفة التغيير في المقاومة بعد الدفن.

Introduction

The concrete is the most widely used building material due to its satisfying performance in strength requirements but when one deals with the durability aspects of concrete, the chemical attack, which results in volume change, cracking of concrete and the consequent. Deterioration of concrete becomes an important part of discussion [1]. Reports on behavior of field concrete tend to confirm the detrimental for instance, many authors reported marked losses in compressive strength for concrete structures exposed to sulfate-laden soils or sea water [2]. Sulfates may occur naturally in soil and groundwater, industrial effluents and wastes from chemical and mining industries, as well as in sea water.

Sulfate attack is defined as the: “deterioration of concrete involving any type of sulfate interactions with cement paste independently of the curing temperature and sulfate source”[3]

The reaction of sulfate ions (SO_4^{-2}) with hydrated cement products is a volume increasing reaction and denoted as sulfate attack on concrete. Most soil contains some sulfates in the form of calcium, magnesium, sodium, and potassium. Ammonium sulfate is frequently present in agricultural soil and water. Decay of organic matter in the marshes, shallow lakes, mining pit and sewer pipes often lead to the formation of H_2S[2].

The movement of salts into and through the concrete foundation can damage flooring placed on top of concrete foundations. Typically the water and salts damage the flooring by attacking the adhesives that connect the flooring to the concrete. New adhesives are being developed but even the best on the market are still susceptible to damage from water and salt accumulation [4].

Without taking adequate precaution, concrete structure such as floors, foundation, drainage pipe, and lower parts of canal structures may completely disintegrate in only and a very few years when exposed to water containing dissolved sulfate. The severity of the attack can be affected by the presence of other dissolved substance in the water, but generally increase as the concentration of sulfate in the water increases, and becomes even more sever if the concrete is subjected to frequently alternating period of wetting and drying. On the other hand, concrete exposed to dry sulfate-bearing soil will not be attacked.

The source for the sulfates involved in the chemical reaction may be either external or internal to the concrete. In the case of the external attack, the sulfate may originate from groundwater or from sulfate leached from adjacent soil as the reaction progresses from the surface into the interior of the concrete [5].
The concrete is the material to be fairly solid, but over time, be eroded and damaged due to some side effects resulting from the presence of certain actors in the concrete. The concrete used in most construction projects and the giant task, it requires the manufacture of concrete with high resistance and non-porous. most of foundation are of the concrete, the most buried concrete elements such as piles and footings are likely to be kept moist throughout their service life, parts of some of them (e.g the top of footings and pile caps) may be exposed to periodic wetting and drying conditions, so it naturally are exposed to the effect of soil attack. So, it is Necessary to study the effect of soil on characteristics of concrete, especially the compressive strength of concrete.

Mechanisms of Soil Sulfate Attack

When the ferrous sulfides are exposed to air and produce sulfuric acid, they are known as actual acid sulfate soils. The soil itself can neutralize some of the sulfuric acid. The remaining acid moves through the soil, acidifying soil water, groundwater and, eventually, surface waters [6].
The salts in Iraqi soils come from the normal weathering of minerals, the upward movement of shallow groundwater containing soluble salts and from the water we use to irrigate. Some salts, such as those containing chlorides, sodium and sulfate, are more damaging to concrete structures than others. Although most soluble salts can be effectively removed or leached from the soil profile, other salts such as calcium carbonate are less soluble and not as easily removed. When these salts are present, it is best to leach these salts before construction or use soils for fill that are known to be low in salts[4].
Also when many of these waterlogged soils are drained their gel-like iron sulfide layer dries out and the soil can actually shrink and subside. This may make farmland more prone to flooding and water logging. In Fig. (1), it is obvious the deterioration of concrete.

Fig.(1). Deterioration of concrete by sulfate solution

Sulfuric acid produced by acid sulfate soils corrodes concrete, iron, steel and certain aluminum alloys. It has caused the weakening of concrete structures and corrosion of concrete

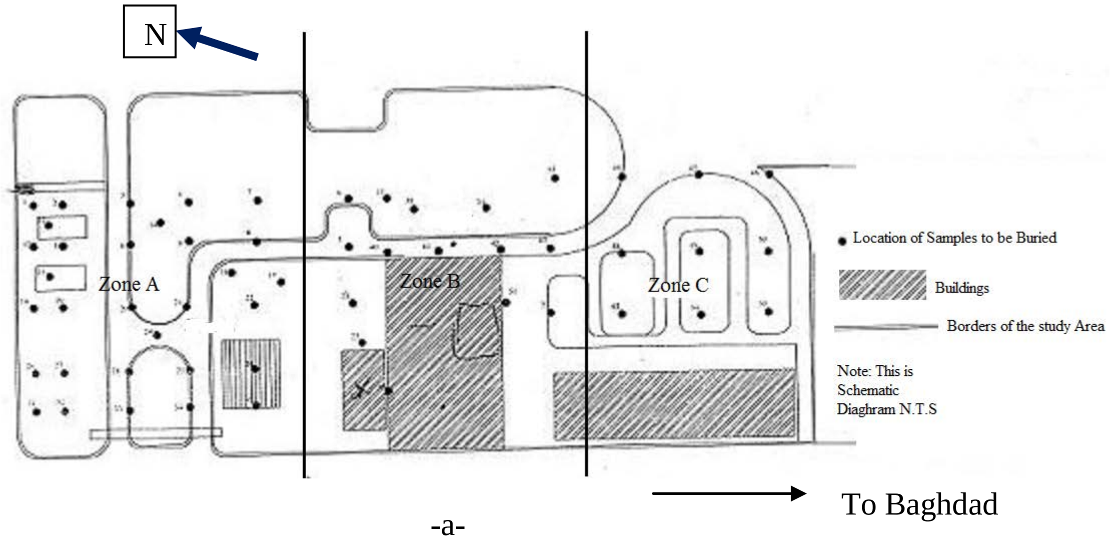
slabs, steel fence posts, foundations of buildings and underground concrete water and sewerage pipes [6].
The deterioration of concrete exposed to sulfate is the result of the penetration of aggressive agents into the concrete and their chemical reaction with the cement matrix. The three main reactions involved are:

1. Ettringite formation – conversion of hydrated calcium aluminates to calcium sulfu-aluminates.
2. Gypsum formation – conversion of the calcium hydroxide to calcium sulfate, and
3. Decalcification – decomposition of the hydrated calcium silicates. These chemical reactions can lead to expansion and cracking of concrete, and/or the loss of strength and elastic properties of concrete. The form and extent of damage to concrete will depend on the sulfate concentration, the type of cat ions (e.g sodium or magnesium) in the sulfate solution [7].

Sulfate salts only attack concrete when they are in solution. There are two types of sulfate attack, according to the type of cat ion associated with the sulfate ions, which are magnesium sulfate attack and sodium sulfate attack [8]. So, it can be considered that most risks which may be face the concrete is the exposure to water containing sulfate salts and acids such as reinforced concrete in the foundations and some concrete reservoirs for some of the portfolio of solutions in chemical plants, therefore necessary to know the behavior of concrete when it is buried under the soil and are subjected to various side effects presented by loads of soil itself and also the effects of groundwater containing salt, acid sulfate, in addition to the difference in level of underground water. The compressive strength test is often used to evaluate concrete deterioration caused by sulfate attack. Compressive strength was used to compare samples that were exposed to various sulfuric solutions and the degree of deterioration was quantified by a loss of strength. The results of compressive strength test showed that the use of a high W-C ratio with Type I cement produced weak concrete with a loss of compressive strength up to 50% after 15 months of sulfate exposure. Using a rich mixture with Type V cement and a low W-C ratio produced dense impermeable concrete that showed no losses of strength even after 15 months of sulfate exposure in a hot humid environment [9]. Kathirvel and Hameed, concluded that the compressive strength of cubes (QD) placed in water and 5% of Sodium Sulphate solution decreases by average of 0.5% at 28 days. The decrease in compressive strength continuous as the duration of immersion increases. So it is necessary to discover an effective treatment to rid of the impacts of those materials and solutions on compressive strength of the concrete. The physical resistance of concrete is usually achieved by specifying mix design parameters such as maximum water–to-cement ratio and minimum cement content and the chemical resistance is by the use of sulfate resisting cement [10].

Soil Description of the Study Area

The site of Al Muthanna University it be considered one of the sites which contains a composition of three types of soils, as well as, the elevation of underground water is high, and it contains some solvents, salts and acids, also the elevation of the region is low. This soil was left for many years without buildings constructed on it, so it be considered good site to conduct this study.
A soil investigations were carried out on the area of Al Muthanna University in 2004, this investigation divided the area into three zones according to soil classification and depth of groundwater, as shown in Fig (2-a).



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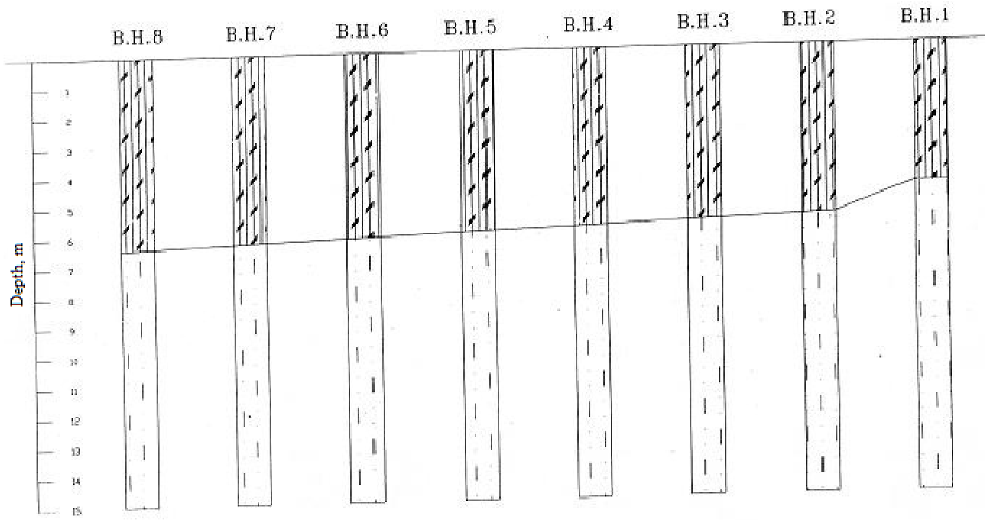

-b-

Fig: 2; -a- Schematic Diagram for the Study area
-b- Profile of soil of zone A

1. Zone (A) the composition of the soil in this zone is silty clay, extending from the upper layer to 4.5 m depth down, and in some cases to 7m. The elevation of underground water is 0.7 m from the natural ground level. The underground water contains a proportion of solved sulfate in water by (286.85mg\L), the soil contains a percentage of sulfate about 1.626% and a high proportion of salt, the basal (PH = 8.5), so it affects the concrete, the bearing capacity of this zone is 0.67 kg/cm2 . The profile of this zone was shown in Fig (2-b).

2- Zone(B), the composition of the soil is mostly silty sand, extending to 5.5 m depth down, the elevation of underground water is 0.8 m from natural ground level, this underground water contains a proportion of sulfate in water about (210 mg\L). The soil has percentage of sulfate is 0.726% and high proportion of salt, the basal (pH = 8.25). The bearing capacity of this zone is 0.62 kg/cm^2.

3- Zone(C), this zone was classified as a sandy silts clay, extending to 5.5m depth down, the elevation of underground water is 0.8 m from natural ground level, this underground water contains a proportion of sulfate in water about (275.63 mg\L). The concentration of sulfate in

the soil about 1.45 % and it has high proportion of salt, the basal (pH = 8), the bearing capacity of this zone is 0.62 kg/cm^2.
These differences in the composition of soils and the high percentage of sulfate in underground water allows to study the attack of soils on the concrete, where the concrete surface is exposed to a wetting and drying condition, it also will be subjected to a physical sulfate attack. the concrete are affected by sulfate in two way, one comes from the penetration of water, while the second comes from effect of the surrounded soils.
Table (1) shows the chemical analyses for underground water, where B.H (38) in zone (A), B.H (40) in zone (B) and B.H (42) in zone (C). Also Table (2) shows the chemical analyses of soil samples extracted from B.H (38).

Table (1) chemical analyses for underground water

Zone	No. of B.H	Depth of sample	PH	SO_4^{-2}(mg/l)
A	38	1.5	8.5	286.85
B	40	1	8.25	210
C	42	2	8.0	275.63

Table (2) chemical analyses for soil in B.H 38

No. of B.H	Depth of sample	SO3%	Gyp.%	TSS.%	Org.%	Caso3%	CL(%)
38	1-1.5	0.318	0.685	0.95	-	37	0.248
38	2-2.5	0.726	1.544	1.99	-	39	0.079
38	3-3.5	0.654	0.872	1.21	-	31	0.055

Procedure of work

The work involves studying the changes in the strength of concrete when it are buried in soil, where it are subjected to effects of sulfate in both soil and underground water, so it is the best way to recognize the decrement in strength of concrete. a samples of concrete has been cast as cubic in dimensions of (15*15*15) cm, mixing ratio of (1:2:4) by using Sulfate-Resistant Concrete (SRC), some of samples were tested after 28 days to determine the compressive strength of concrete before attack of sulfate, which are to be reference to explain the decreases in the strength, other samples have been curried for a period of seven days in drinking water to attain some of rigidity, after that all samples have been buried in soils. Where a bore holes have been drilled by hands at the three zones (A, B, C,) in appropriate depth as shown in Figures (3) and (4), all bore holes were below underground water level. Three pits (one in each zone) of 1.5x1.5 m and varying depth from 1.5 to 2.0 m were excavated and six concrete specimens were laid in each pit. The concrete specimens were covered by the excavated soil and a slight compaction was carried out to ensure a full contact between the soil and concrete specimens. Figures 5&6 show the positions of concrete specimens in pits.
The procedure of burying concrete specimens will expose concrete surfaces for Sulphate attack from both the soil and the underground water. Three of the six specimens in each pit

were removed after 79 days and the remaining were removed after 102 days of burying. Specimens that were removed from the pit were directly tested to determine their compressive strength.

Results and Discussions

The buried samples have been extracted for different periods to create a relationship between the exposure time and compression strength of the concrete itself. Some of the samples were extracted from soil after 79 days of burial, and others samples after 102 days. These samples were completely surrounded by underground water and soil which contain high percentage of sulfate. After that all sample are tested by compression machine immediately after the extracting in the Structural Laboratory.
From the comparing between the results of the compression test for the samples extracted from the soil, and the results of the compression test for samples before burying, it is found that there is a decrease in compression strength and this decline varies depending on location and soil quality. The concrete specimens that exposed to Sulphate attack in zone A for a period of 79 showed a decrease in compressive strength from 25.7 MPa to 22.25 MPa (a decrease of 13%) as shown in table (3) . The same decrease in compressive strength was noted for those exposed for 102 days. In other words time of exposure between 79 to 102 days has little if any effect on compressive strength. The concrete specimens in both zones B&C showed the same behavior. The exposure to Sulphate attack for 79 days resulted in decrease of compressive strength from 25.7 MPa to 17.85 MPa. Increase of exposure period from 79 days to 102 days has no significant effect on compressive strength of concrete specimens buried in zones B&C. figure 2 shows the relationship between period of exposure and compressive strength of concrete specimens. The figure shows that the decrease of compressive strength occurred until 79 days of exposure. After 79 days of exposure. No further decrease was noticed. This proposes that the time of exposure has a time frame behind which the exposure has no effect.

Table (3) compressive strength of concrete

Compressive strength of concrete MPa			
Zone	28 day	79 day	102 day
A	25.7	22.5	22.5
B	25.7	17.5	17.5
C	25.7	18	18

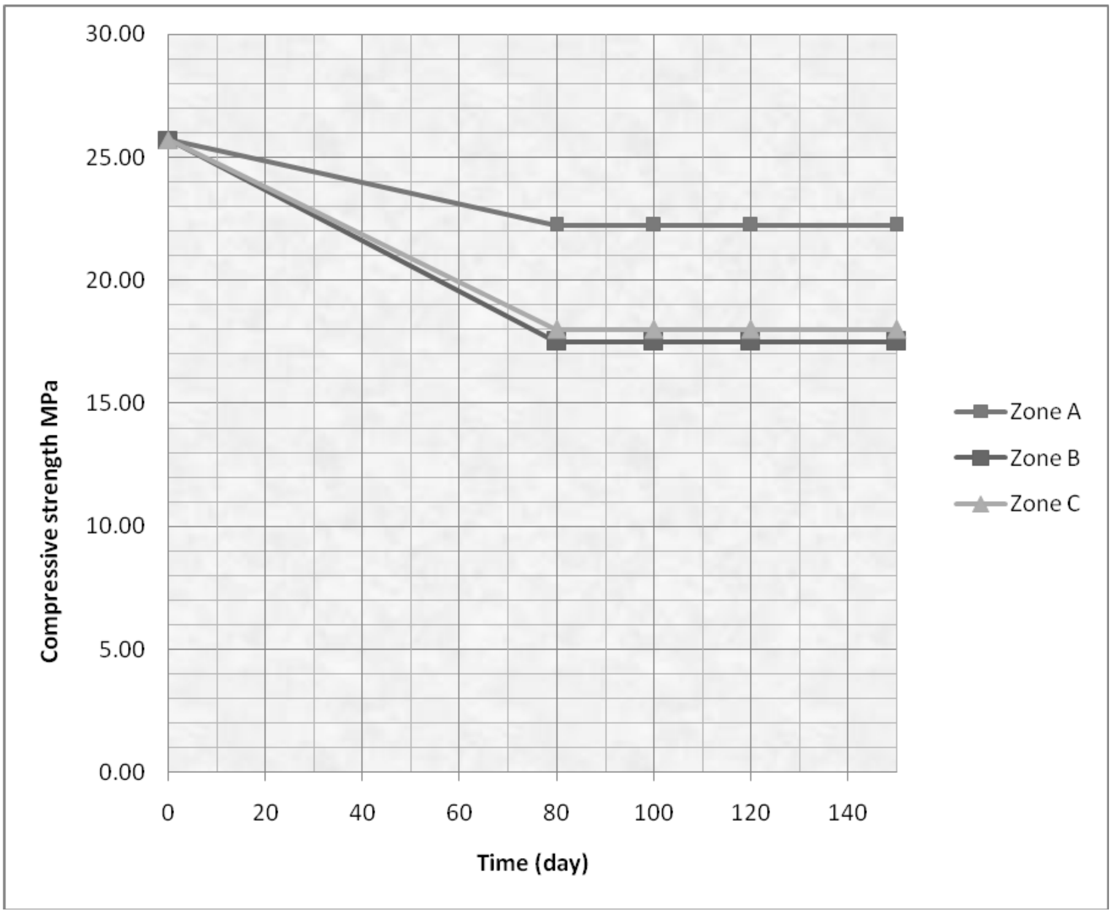

Fig (3) shows the relationships between the time and compressive strength for three type of soil.

Conclusions

From field works and laboratory tests for concrete samples buried in Al Samawa city, it is observed that the soils contaminated with sulfate have a high influence on the concrete. This influence is greater if coincided with underground water. To decrease this effect to protect the concrete from attack of sulfate and salts, so from field observation, the following can be concluded:

1- The influence of sulfate in soil on the compressive strength of embedded concrete begins after 79 days of backfilling the foundation with soil.

2- The influence of sulfate in soil on the compressive strength of embedded concrete samples was to a specified range, so the designer must take into account the potential decrease that may occur in compressive strength of foundation.

3- The decreasing in compression strength of concrete depending on the quantity and the concentration of sulfate in underground water and soil.

4- When implementing the foundation, it is required to protect the foundation by asphaltic material especially when is the elevation of foundation under the level of underground water, or it is recommended to cast the foundation above the influence and level of underground water

5- Increasing the density of concrete decreases the porosity, that leads to decrease the possibility of penetration the underground water to the concrete structures. According to that it is choose adequate ingredients and compaction during construction of underground concrete.

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Appendix: Some Photos Representing the Method of Burying of the Specimens

Plate (1) shows drilling hole in zone A of Al-Muthanna university

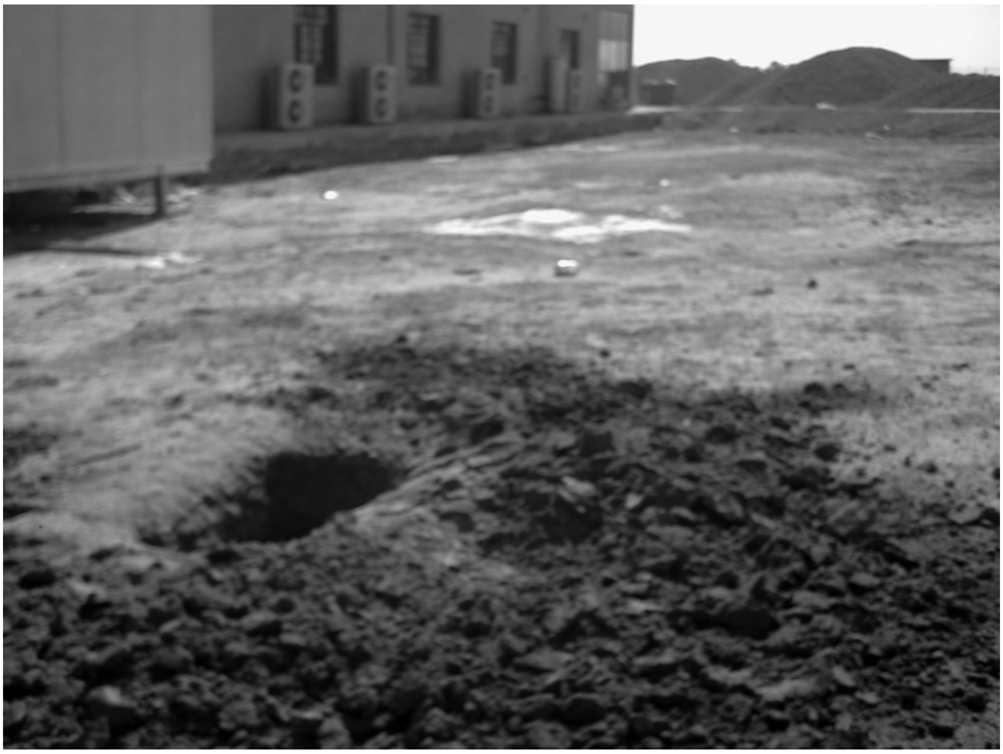

Plate (2) shows drilling hole in zone B of Al-Muthanna university

Plate (3) shows putting samples and backfilling hole in zone A

Plate (4) shows putting samples and backfilling hole in zone B

Plate (5) shows extracting some samples from soil

Plate(6) shows extracting some samples and preparing them for sending to laboratory

Plate (7) shows some samples were left to are extracted in next time for test

Plate (9) shows some samples were left to are extracted in next time for test