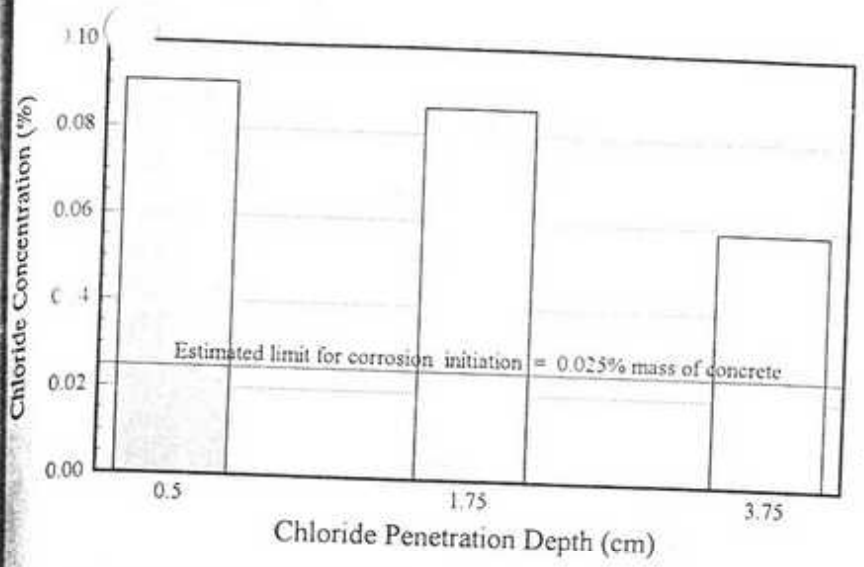

Figure 6. A typical chloride concentration profile in beams

دراسة وتحليل هبوط بعض المباني في عدن (دراسة ميدانية)

د. فيصل شمشير

أستاذ مساعد كلية الهندسة – جامعة عدن – اليمن

تعتبر مدينة عدن من اقدم المدن اليمنية ، تحيطها الجبال البركانية والتي تكون معظم تربتها ، ولديها منفذ واحد الى بحر العرب . في الأونة الأخيرة ظهرت بعض الشروخ والتصدعات في بعض المباني القديمة مما أدى الى الإضرار بأجزاء مكونات المباني مثل الجدران الحاملة ، الجدران الغير حاملة والفتحات (النوافذ – الأبواب).وفي هذه الورقة نتناول ثلاث حالات متفرده من المباني كعرض حاله وحيث تشمل الدراسة طبيعة الإنشاء ، مواد البناء وكذا نوعية الشروخ / التصدعات تشمل الدراسة أيضا التحري عن التربة بواسطة اخذ بعض الجسات لمعرفة نوعية التربة ، طبقاتها وخواصها وكذا حسابات الهبوط وتحليلها . استخلصت الدراسة الميدانية طبيعة الشروخ وكانت شروخ أفقيه ، راسية وذات زاوية سببها هبوط المباني غير مستوى وحفر اساسات لمباني حديثة قريبة من المباني القديمة .

ANALYSIS AND STUDY OF SETTLEMENT OF SOME BUILDINGS IN ADEN – A CASE STUDY

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Aden city is one of the oldest cities in Yemen surrounded by volcanic mountains which formed most of its land , open from one side to the Arabian sea . In the recent time, some of the old buildings exhibit cracks and structure failure in its member's e.g.. Load bearing walls, partition walls and opening (windows / doors). In the present study considered three typical buildings as a case study, the investigation study included: the type of structure, construction materials and type of cracks /damages. Soil investigations also conducted by some B.H to know type of soil, its properties and thickness of stratum as well as settlement calculation. The study reveal that some cracks are horizontal, vertical and angular which causes due to uneven settlement and excavation close to the existing old building.

INTRODUCTION

The term settlement indicates the sinking of a building due to the compression and deformation of the underlying soil. When a load (weight) of the structure, is placed on the surface of a soil mass, the soil deflect, resulting in settlement of a structure. This is not a unique property of soil but one shared by all materials, the settlement of loads is

b- Differential Settlement (A structure footing is said to undergo differential settlement if one of its parts settles more than the other. Major amount of damages to the structures take place due to the uneven settlement between the elements of the same structure. The damage limit increases very much if the rate of settlement is very low. Differential settlement doses not occur only due to differences in loading but also due to differences in soil condition. Causes of differential settlement are: (1) variation in soil strata (2) Variations in the loading of different parts of foundation. (3) large loaded areas on flexible foundations and (4) Difference time of construction of adjoining parts of a structure

c-Tilt: A structure is said to undergo a tilting if the entire structure rotates as a consequence of non-uniform settlement (Fig.2). A classic example of tilt is the leaning Tower of Pisa. The much tilt in a tall building represents a potentially unstable, dangerous situation.

d- Angular Distortion : Angular distortion is the ratio of the differential settlement between tow columns (δ) to the spacing between them(l), that is δ/l as seen in Fig.3.

Pattern of Cracks:

The crack pattern depends on whether the center of the building or its edges settle more. Figure 4a illustrate types of failure that occur. The concave settlement is the usual pattern for a uniformly loaded structure on a compressible soil. The zone of settlement is saucer – shaped and extends well beyond the limits of the structure. Nearby buildings may be affected by the zone of settlement and develop new cracks.The convex pattern develops with wall – bearing structures or structure on loose sand Fig 4b. Cracks often occur when footings are eccentrically loaded. This puts a bending moment in to the base of the column / bearing wall and cause failure (Fig.4, c and d). Tipping is serious in narrow, tall structures such as chimneys and bridge piers. It is occur when the soil compressibility is not uniform. It can also develop when the major cause of the settlement is a heavy load at some distance from the tall structure, as shown in Fig.5a. Sagging settlement profile develops beneath the larger load, and the tall but lighter structure tilts in that direction (8) as shown in Fig.5b. Excessive settlement usually leads to the building cracks and in same cases structural failure. The engineer should recognize the cases of different types of cracks in order to correct them before structural failure results.

Uniform Settlement : Will produce no cracking except of water and sewer lines in to the structural

Differential Settlement : The inclination of cracks provides clues regarding the differential settlement which produced them as shown in Fig. 6I indicate that the wall AB must have moved downward in respect to CD from its original position A'B'. This elongated the diagonal CB' to CB produced tension in the direction of that diagonal and formed the cracks. The same effect could be obtained if the wall A'B' stayed in its original position and the wall CD moved upward, because dry clay beneath the foundation swelled most under the corner during a rainy season and lifted it (9). Similarly, the pattern of cracks shown in Fig.6II can be produced either by the grater

often the controlling factor in foundation design. Although this is the most common type of settlement, other types are important enough to deserve consideration. They include settlement due to increasing the load on the surrounding soil, to excavation in the vicinity, to lowering the ground water table and to vibrations (1). Several investigations and analysis have been studies settlement of buildings and the causes of settlement. Settlement of floating – pile foundation, can cause appreciable damage to adjoining building (2) (3). Settlement of structures and method of observation (4). Anew five – story storage building for liquid was separated into small units, the old structure is split up into four such units (5). Observation and analysis of the tilt of Aden Menarite (6). Analysis of settlement due to excavation in the vicinity (7). In the present paper some of the old buildings in Aden City exhibit cracks and structural failure in its members. In the present study considered three typical buildings as a case study, the investigation study included: the type of structure, construction materials, type of cracks &damages and soil investigation. The settlement and its causes have been studied in depth.

MECHANISMS OF SETTLEMENT AND CAUSES

Settlement of soil /rock caused by load comes from two mechanisms: (1) distortion or change shape of the prism of material beneath the load, and (2) the change in void ratio. The first is distortion or contact settlement; the second is compression settlement termed consolidation settlement. Both mechanisms are related to the stresses produced by the foundation or other external loads as well as to the stress already in the soil, due its won weight or other body forces. Both the compression and distortion settlement depends on the stresses produced in the soil by the foundation or other surface loads. By making simplifying assumptions about the physical properties of the soil, the stresses can be computed by the theories of elasticity. Therefore settlement calculation can be found, This is the most common type of settlement, other types are important enough to deserve consideration like increasing the load on the surrounding soil, excavation in the vicinity, lowering the ground water table and vibrations (1).

Modes of Settlement:

Settlement can cause unseemly crack in exterior masonry walls and interior plaster walls of buildings. It can cause a structure to tilt which may become noticeable in high building. However settlement can be of different patterns under different conditions and the effect caused on the structure will itself depend on the type of settlement. The modes of settlement will be explain hereafter.

Uniform Settlement : A structure footing is said to undergo uniformly settlement if the entire parts of footing settle uniformly as shown in Fig.1 However, the settlement would limit damage to the structure. The amount of settlement which can be tolerated varies widely, it depends on the type of the structure, its rigidity or flexibility, its both function and elevation. A structure can usually tolerate a fair amount of settlement if the deformation is uniform throughout the structure.

Computation: The settlement of this (was calculated the effect of the weight of the surrounding building constructed in 1980 at a distance of 7.2m from the existing old one plate3. This study may or may not proved whether the weight of the new building causes the settlement of the old building. The additional pressure or stress increment calculated by using superimposed Fadum method (10) for computing stress distribution in the soil for points P and Q as shown in Fig.9. Settlement calculation was done by the equation ($s = mv.H\Delta\sigma$) at points P and Q, the settlement calculations at these points are S_P = 3mm and S_Q= 30 mm respectively. Therefor the differential settlement equals to 27mm.

Discussion: Based on the computation of the settlement and observation of the cracks it may be reveal that the differential settlement was occurred but it is relatively small. The construction of the new existing building in (1980) may be help to increase the cracks due to differential settlement (27mm) and the cracks also may be due to the oldest of this building. In this case there is no effect of ground water table.

Case Study 2:

In this case study, it was a residential building located in Khormaksar region in Aden city. The site plan given in Fig.10. In the present case study it had been found that it is an old building constructed in 1956, occupied an area of 25m x 12m having five stories. The building elements consist of a load bearing walls of thickness 40cm, R.C.C beams and slabs are supported to the load bearing walls connected with a ring beams at the parameters of the walls. The load bearing walls are supported to a R.C.C strip footing of width 2.0m with 60cm thickness. The depth of the footing is 1.2m as shown in Fig. 11. The soil investigation conducted by making a B.H in the vicinity area found that a uniform loose sand with some micka up to a depth of 6.0m which is poorly graded fine sand having minimum silts. The water table found at a depth of 1.5m. The soil profile shown in Fig.11.

Description of Cracks: In the present case study the cracks are take place in vertical, diagonal positions and appear in different sides of the building (plate4). Diagonal cracks are observed in the corner of the building which is started from the edge and continue as shown in plate4. The vertical cracks are observed in the entrance of the building column (only one column) and load bearing wall as shown in plate 5. From plate 5 it can be seen that the vertical crack appears on the walls and meet feiw horizontal cracks which causes the separation of stone.

Computation: In this case, the calculation of settlement considered both immediate and consolidation settlement because (1) the structure founded on sandy soil and (2) the present of silt particles which may be consolidated under the effect of applied loads. Immediate settlement calculated by equation $Se=qB/E(1-\mu^2)I_s$ given by Timoshenko and Goodier (11) the computed value of immediate settlement found 60mm.The pressure increment ($\Delta\sigma$) at the middle of the silty soil below the center of the loaded area is founded by Boussinesq's equation. The computation of the consolidation settlement at the center founded by equation $S_c = C_c/(1+e_o) H \text{Log}(\sigma_o+\Delta\sigma)/\sigma_o$ which is around 150mm. The consolidation settlement at the corner by the same equation found 18mm. Therefore, it is clearly observed that there is a differential settlement of 132mm.

settlement of th ter of a wall due to the natural compression of underlying soft clay layers, or by the rater swelling and lifting power of dry clay near the edges of a foundation.

Temperature Deformation: observation of cracks in masonry can also provide indications of whether settlements are continuing. Once a crack has been formed because of excessive structural deformations, it immediately becomes a temperature expansion joint. If plaster telltales are placed across a masonry crack and also crack slightly, this may be due to temperature deformations only. Thermal expansion and contraction are important causes of cracks in exterior wall, such cracks can be identified their op ing and closing with temperature changes.

Shrinkage Cracks: Shrinkage of mortar or of concrete blocks and similar masonry units is a common cause of cracking. Plaster is likely to shrink differently from the wood or masonry base which supports it. Shrinkage cracks are usually vertical and horizontal and are of uniform width or become narrow at both ends.

Other Types of Cracks: Vibration, shock and earthquakes can cause cracking, usually, these have an(x) pattern at the end of walls and a (*) or (+), at the middle(8).

CASE STUDY

An attempts have been made to study three different existing buildings in Aden city as a case study. The study depends on the actual site visit, observation and measurement of the settlements. The investigation study included: the type of structure, construction materials and types of cracks/ damages. Soil investigation also conducted by same B.H in the vicinity to know type of subsoil, its properties and thickness of strata. The computation of stresses and settlements based on the elastic theories and on a know equations of settlement respectively. The results of this study are given below:

Case Study 1:

The case study was, of one building from Technical Institute, located in Maalla town in Aden city. The site plan given in Fig.7.This building constructed nearly in fifties as a class rooms for teaching purposes, occupied an area of 48.35m x 8.35m as shown in plate 1. The building consists of two stories with asbestos covered ciling, the walls constructed of masonry stone of 40cm thick, the first floor made of timber joists and a timber boarding covered by plain concrete of thickness 10cm. The foundation type is strip footing with a width of 1.6m and depth of 1.8m, the base of footing is of plain concrete slab with depth of 60cm as shown in Fig.8. The soil investigation in the vicinity reveal that the subsoil below the footings was a compacted mixture of medium sized gravel with sand and silt. The vicinity surrounding by a volcanic mountains as the lowest bed is rock strata as shown in Fig.8.

Description of Cracks: The cracks appear in this building are vertical, horizontal and diagonal, some of these cracks are of dangerous type as they are relatively wide. These cracks are clearly shown in plate 2.

settlement calculation at these points are Sp = 0.0 and S_Q =370mm respectively. Therefore the differential settlement equal to 370mm.

Discussion: The differential settlement obtained from the calculation of these case study which is found to be too large which may be due to the nearer end to the new building (right to the existing building) settled 370mm whereas the far end did undergo any settlement (left to the existing one) which is causes a failure damage as shown in plate 10. This is may be a reason of the differential settlement. But there are may be other reasons developed the increase of the differential settlement which are: (1) The oldness of the building, (2) the soil beneath the foundation, (3) the sewage condition is not maintained (plate.11) which may cause in saturation of the soil beneath the foundation and, (4) The excavation of the basement near the old building without any soil protection (in the left side plate7b) which may develop the further damage to the building especially that the settlement has already taken place after completion of right side new existing building.

CONCLUSION REMARKS:

Based on the observation and analysis studies of the three cases, studies found in Aden city, the computation of the total load, analysis of stresses and calculation of settlement reveal the following main remarks of conclusion:

1- Soil in vestigation is essential to determine soil profile, the weakness of the soil underlying the footing leads to excessive settlement, unless this loose/weak soil is densified or treated.
2- The effect of water table is an important factor leads to excessive settlement, this is due to absence of soil investigation.
3- The construction of footing in built – up areas should done, taking in to account the distance between the new footing and any existing one. This distance should be adequate. or the excavation of the new building footings should done in a such away to protect the existing one.
4- Mistakes in design are a direct reasons of settlement, foundation engineer must assure, that the foundation are safe, even though they satisfy the cods.
5- The type of the foundations should be selected carefully with respect to the type of soil.
6- The sewage system laying beneath the building should be done carefully considering space for maintenance, The leakage of sewage lines may cause changes to the conditions of the moisture of soil which in turn change the state of stresses.

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Discussion: In the present case there is more than one reason causes settlement, the computational results obtained that the immediate settlement of 60mm which is normally undergo this type of settlement. But due to the present of silty particles made the consolidation settlement calculation is necessary. The calculation of consolidation settlement observed at the center and corner is 150mm and 18mm respectively. The difference between these two values gives differential settlement that occurs between corner and center. Furthermore it can be observed that there are other reasons as: (1) The leakage of sewage pipes as shown in plate 6 ,results in saturated the loose sand. (2) The present of water table at shallow depth. (3) The oldness of the building, (4) No regular maintenance and (5) No care from the residents.

Case study 3:

In the present study an old residential building constructed in 1958. This building is located in Crater in Aden city. It is occupied an area of 46.3m x 14.7m having five stories the site plan is given in Fig.12 It is observed that at both sides of this building there are two new buildings were constructed at a distance not more than 6.0m from the existing one (R.H.S. Fig12) was completed in 1995 and the other one under construction as shown in plate 7.It has been observed that the old building undergo a failure damages, a numerous cracks were appear as shown in plate 8. This case is of the great interesting to be studied. The building elements consist of load bearing walls of stone masonry of thickness 60cm at the base up to ground floor then reduces gradually till 40cm. The load bearing walls are supported to the steps strip footing with a base of plain concrete of 1.98m width and 45cm thick. The step strip footing made of masonry stones with various thickness and depth as shown in Fig.13. The floor slabs are constructed of timber joists supported on I-section steel beam, the joist then covered by timber boarding, the plain concrete placed on it as a flooring. The soil investigation of the vicinity (B.H) shows that the subsoil is a layer of well graded and poor graded gravel of medium to small size. These gravel mixed with silt, sand and clay which may be produced during the volcanic activity (Aden History). In the region in which case 3 is their, named Al-Khosaf is a passage (drainage) of fall water comes from mountains during rain, which leads to washing up the soil particles and it is the reason of the presence of proportions of the different soils. The soil profile is shown in Fig.14.

Description of Cracks: The cracks are vertical and diagonal have been observed (plate9) which are symmetrical cracks on the corners of the front elevation. In the one of the back elevation there is a huge failure of the corner started from the top and extended across all the stories as shown in plate 10.

Computation: In the present case similar calculation of settlement had been done as in case 1. In this case consider the effect of the weight of the completed new building (plate7) and the uncompleted one may be neglected as its effect may not significant but the effect of the excavation of the basement without protection to the excavation soil will be significant. The stress increment calculated by superimposed Fedum method (10) for computing stress distribution in the soil for points P and Q as shown in Fig.15. Settlement calculation was done by the equation ($s = mv H\Delta\sigma$) at points P and Q, the

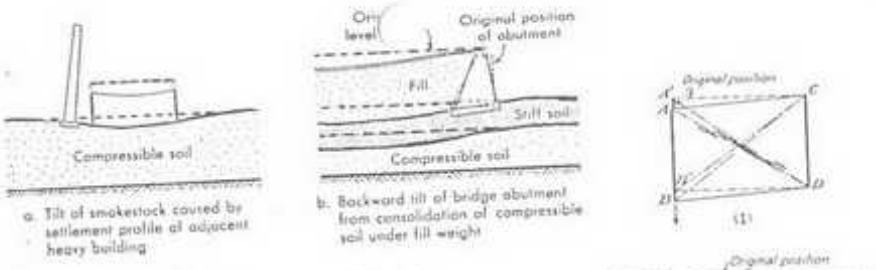

Fig.5 Tilting of structures

Fig.6 Inclination Cracks in Walls

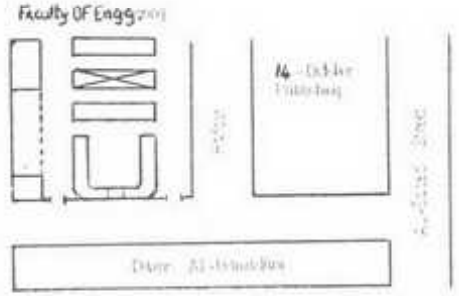

Fig.7 Site Plan of Case 1

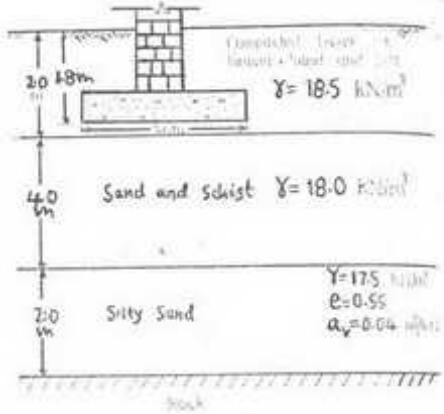

Fig.8 Soil Profile of Case 1

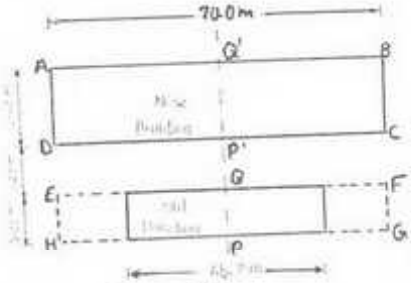

Fig.9 Plan of Two Buildings , Case 1

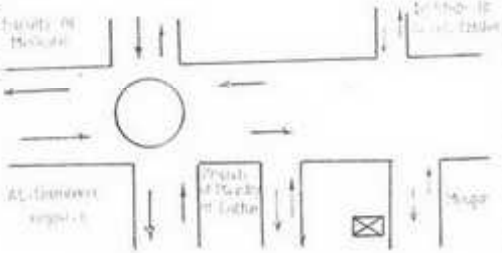

Fig.10 Site Plan of Case 2

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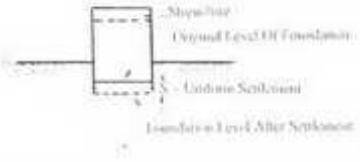


Fig .1 Uniform Settlement

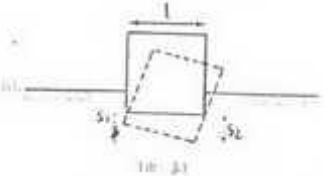


Fig.2 Tilt

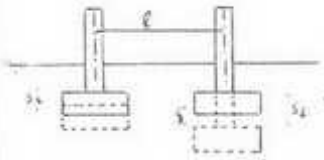


Fig.3 Angular Distortion

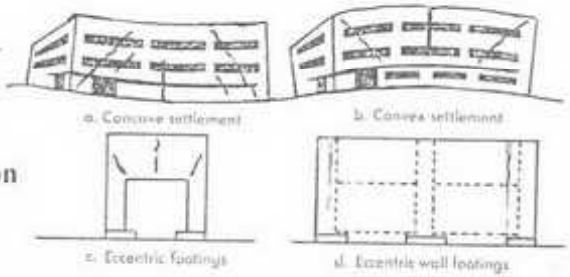


Fig.4 Settlement Crack Patterns in Buildings

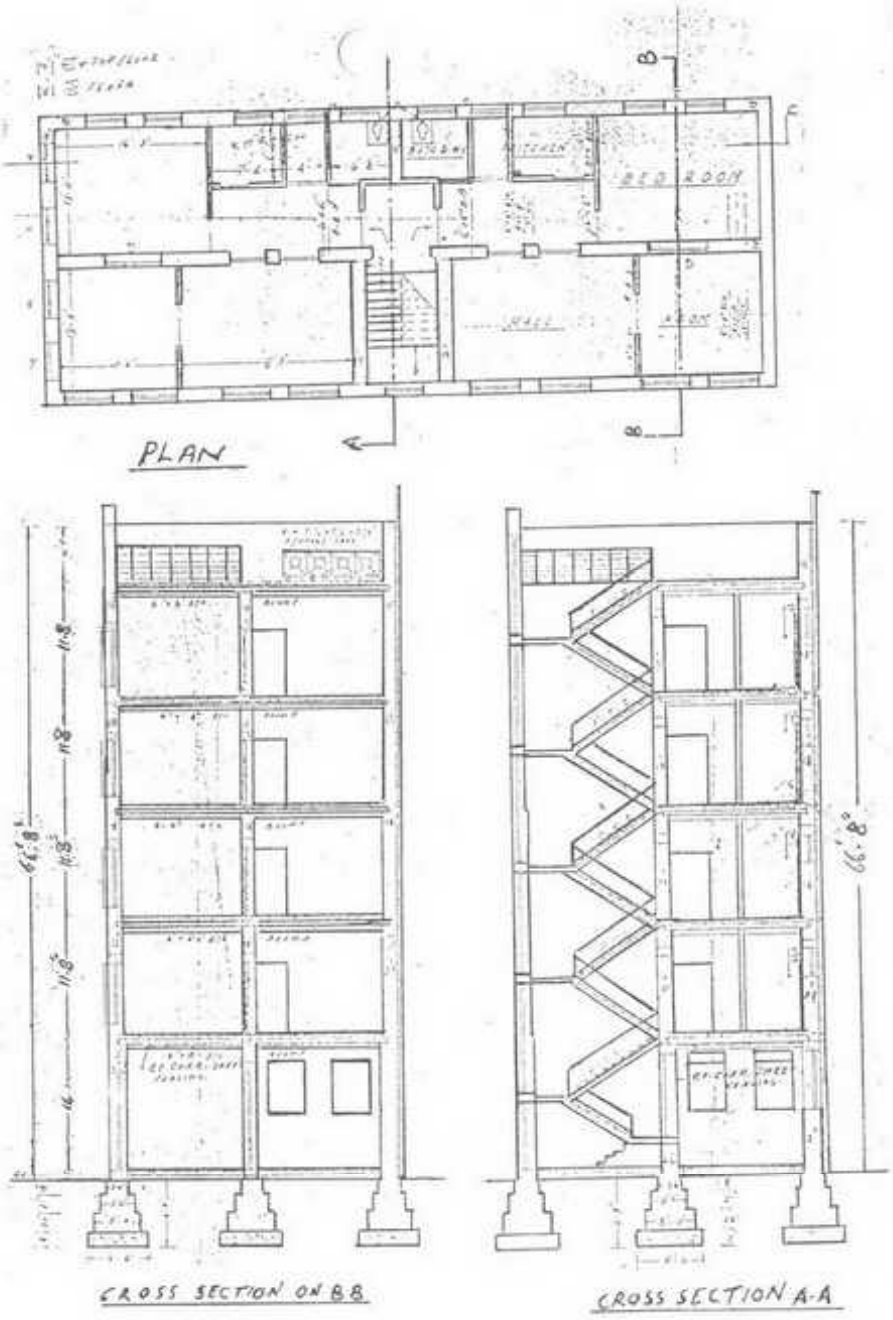


Fig.13 Plan and Cross Sections of Case 3

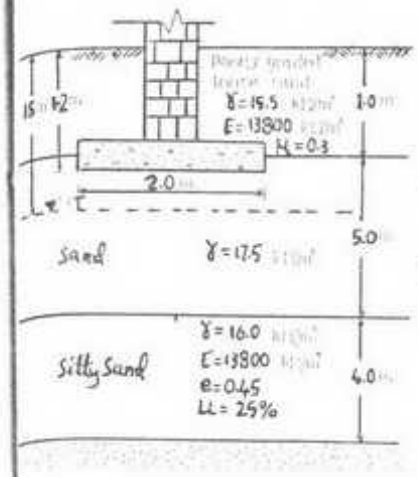


Fig.11 Soil Profile of Case 2

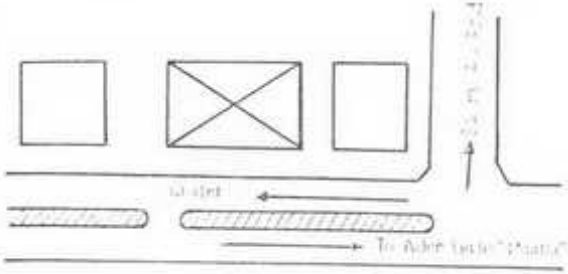


Fig.12 Site Plan of Case 3

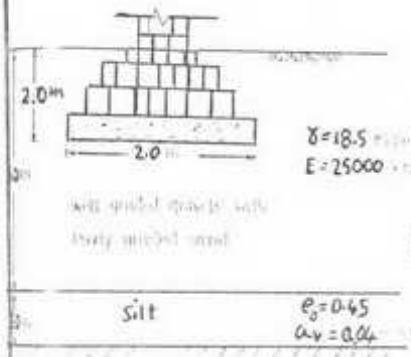


Fig.14 Soil Profile of Case 3

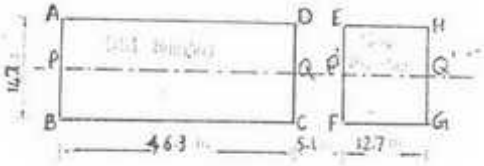


Fig.15 Plan of two Buildings, Case 3

Plate 3 View of the two Buildings

Plate 1 View of Building and No. of Storeies , Case 1

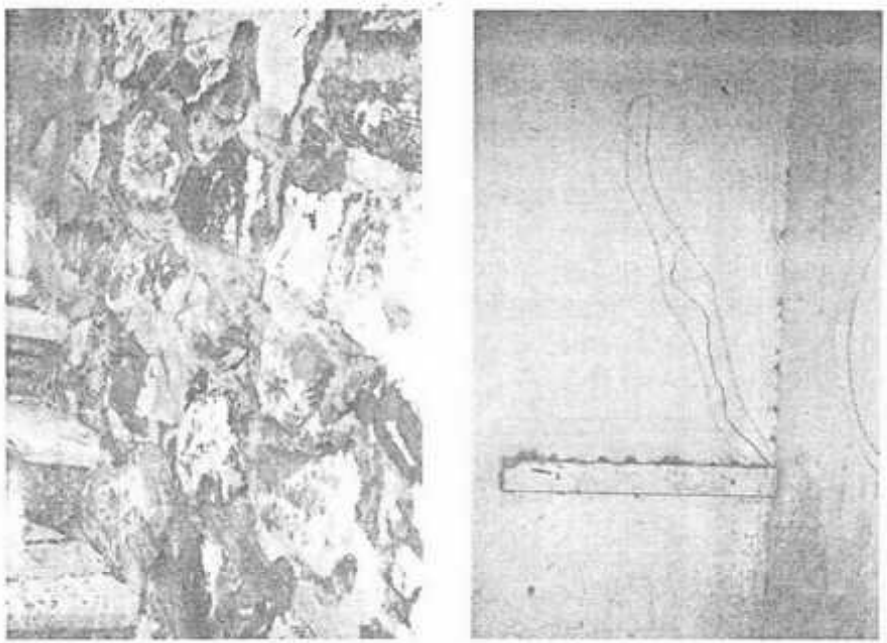


Plate 2 Different Types of Cracks

Plate 7 View of Existing Builing Surrounded by New Building

Plate 8 Failure Damage

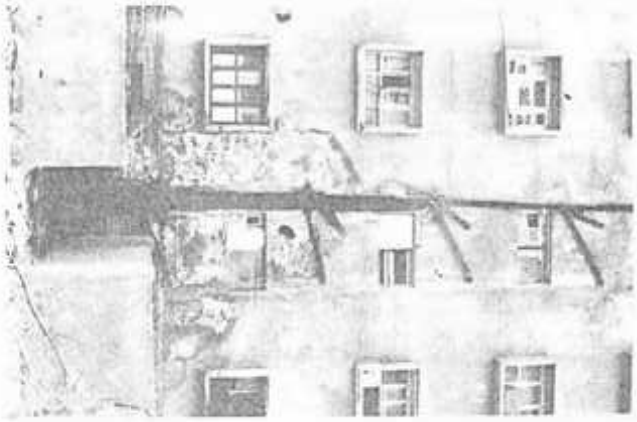
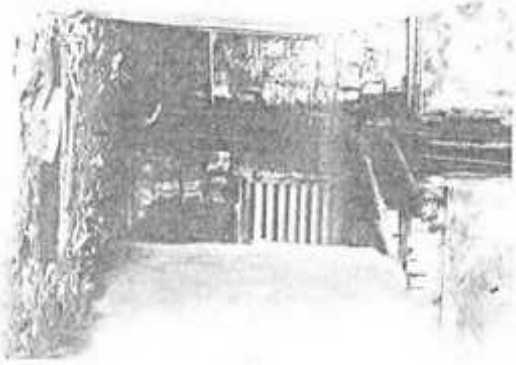


Plate 6 Leakage of Sewage Pipe



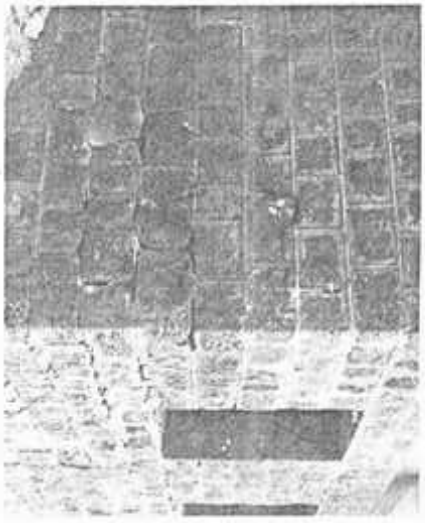


Plate 5 Vertical Cracks

مشروع ترميم وتوسعة وتحديث مدرسة « الحسينان الابتدائية
لتصبح مقراً لهندسة المنشآت العسكرية

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وصف المشروع :

تم إستغلال فناء الوسطي للمدرسة على طابقين للتوسع الأفقي وذلك لإستيعاب أعداد الموظفين والفنيين الجـــدد لمواجهة خطة إعادة إعمار منشآت وزارة الدفاع الكويتية بعد الدمار الشامل الذي لحق بها مـــن جـــراء غـــزو الكويت .

تم إستغلال الفصول الدراسية حول الفناء بعد تغطيته كمكاتب للإدارة والمتابعة .. وتم إضافة مبنى آخـــر فـــي الجهة الغربية على نفس النمط لإستيعاب الإدارة العليا بحيث يعمل جهاز التصميم محيطاً به الإدارات والمتابعـــة سواء لخلية عمل واحدة وتم الربط بين الجزء الوسطي والفصول الدراسية التي أصبحت إدارات بمجموعة كباري ممرات وادراج لتسهيل الاتصال بين أفرع التصميم والإدارات المختلفة وبينهما استدعى الأمر عمل مجموعـــة أحواض زهور كبيرة يطل عليها الجزئين المذكورين ودعمت بمصادر طبيعية للضوء (انظر التقرير الفنـــي المرفق) .

تم صياغة كل ما سبق في إطار لا يخرج عن روح العمارة العربية والاسلامية والكويتية التقليدية وتم التعبير عن ذلك بأسلوب عصري محدث .

PROJECT DESCRIPTION. Recommendations were given to use the central courtyar of an existing school building to accommodate new members of the MEP staff, due t the expansion demanded after the liberation.

A Complete new two floored structure was erected inside, in the courtyard and hav been developed to attract daylight.

The existing school class rooms surrounding the newly built structure has been altered t suit offices for the Technical Managers and Controllers.

An additional structure has been constructed in the western side for the senio Management.

Since the Technical Administration and Technical Controllers surround the desig department and also, administration department surrounding area is more like th relation of a nucleus inside a atom i.e., its constant motion and the fact that all th activities take place with in it. Several channels of communication were constructed t facilitate easy movement. The final result is a productive and continuos unity separate by an internal green belt.

We have delineated our best efforts in designing the building complex which w preserve and identify the Islamic, Arabic and Kuwaiti cultural heritage, provide facilitie for the people to work in a gracious official atmosphere in view to serve the growi needs of the country.

Plate 9 Diagonal Cracks

Plate 10 Cleare View of Damage

Plate 11 Different Cracks , Leakage of Sewage Pipes .