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Archeological Excavations: the "Trauma" and Other Consequences on Structural Conservation of Buildings and Sites

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Abstract Previous infill, unearthed and archeological excavations have a major influence on the structural and physical status of buildings and ruins in urban and archeological areas. Archeological excavation is like an "anaphylactic shock" on the excavated structure. Mortar, stone and wood quickly change their performance and bring about a dramatic transformation/alteration in the structure's elements and its whole stability. As in a state of anaphylactic shock if you do not intervene promptly the excavated structure can "die off" explicitly and completely disintegrate.

Archeological excavation also reveals peculiar structural elements that were in use but never viewed or studied from the engineering point of view. These elements of the buildings and sites could be either structural connections in strange angles or unstable structure-stone- frames in current day standards and/or static calculations, that did not collapse in the past earthquakes.

Studying this archeological-engineering issue might result in a better understanding and therefore implementation of the conservation of excavated sites and buildings.

Keywords: Excavation; conservation; building; site

Introduction

Archeology and engineering have a lot in common, but in the day to day life, the engineering topics are viewed and assigned a secondary and relatively minor role. But, as we shall see, the engineering conservation approach can contribute to the findings a lot more than its current role today. We shall highlight only a few of the topics related to the relationship of the archeology & engineering fields.

Archeological Excavation- Trauma of the Ruined-Structure

The first issue deals with archeological excavations which are implemented under the responsibility of the archeologists. Only if they want or need aid they will call for engineering-structural assistance for the temporary stabilization and other structural support. Generally, it is only in a later stage that the design team of architects and perhaps the engineer will be involved. This attitude has resulted in many cases to unneeded demolitions as well as loss of some structural elements and of structural evidences that possibly only the "experienced engineering eye" could catch. We do not know how much we have lost, but it most certainly is the general case and not a rare isolated one. Moreover, there is a second issue related to the way in which and the actual implementation of the archeological excavation of a structure, especially if it is a large one.

This second issue is less known and I will call it "THE TRAUMA OF ANAPHYLACTIC SHOCK DURING AND AFTER THE ARCHEOLOGICAL EXCAVATION". The building, like a human being, undergoes in a short time a change in its inside core and is not able to adapt to this change, and thus enters into a" failure stage" that could bring about its end. A structure which has been excavated after hundreds or thousands of years of infill and earth covering, all of a sudden is "seeing the light of the sun" even though for a short time.

Then after a short or long time, in the best case scenario, there is an implementation of an engineering survey and a conservation and structural intervention. But who can tell us that the state of the structural and engineering at this exact moment of survey is the same state as immediately after the excavation? Only the structural engineer who is in charge of carrying out the work can do this, but he was not involved in the first stage! To better understand this concept, we have to

comprehend the life cycle of the excavated structured ruin and take the common case study known to most of the professionals:

First Cycle: A building has been erected and afterward had minor changes or uses.

The building's erosion and failures occurred over a period of time. It underwent major repairs and changes. A major event destroyed the building [natural disaster as earthquake or flood or human hand disaster such as war, fire, urban changes]. The ruin deteriorates with time, having increased erosion as result of its unused, fragmented structural frame, open walls and roofs, in short a “not closed building” (Fig. 1)

Second Cycle: A new building is erected by using a large part of the previous ruin. Again there is a use, erosion and large or small changes. Again a major event destroys or creates the abandonment of the building. The ruin deteriorates, is covered for time with earth and debris, and stays so as a small tel for many years (Fig. 2).

Third Cycle: A new building is (raised on the top of the small tel [archeological artificial hill] above our previous ruined building and again the life span and cycle of the new building: use life-abandonment-destruction-ruin deterioration and earth covering. (Fig. 3)

Fourth Cycle: In this moment, there is a change implemented by modern man- **The Archeological Excavation of the Site.** In this case, the excavation is not to recover material or clean area for a new development- this time the excavation is for research, conservation and may be reuse of the ruin as a monument or for other uses. From this point of time we can start our "Trauma of Anaphylactic Shock of the Excavated Structure".

As it first emerges the identity, size, structural and physical condition of the ruin and its importance are unclear to the team. Quickly enough those details will be raised, and the right questions asked if a representative of the Conservation Engineering is included in the team, but in most instances, as mentioned, a Conservation Engineer is not yet part of the team.

Here starts the last and "Fourth Cycle": More and more of the ruin-structure is discovered and the structure's stabilization needs, if identified at all, are temporary and satisfying for only the continuing of the excavation with the structural conservation "in deep" left for the unknown future. What happens to the excavated ruin-structure?

1. In most cases the interior sub-earth water content of the structure is different from the open air one and there is large scale evaporation with evident signs- white patches of salt in the exterior layers with possible local layer stone detachments of 2-5 cm width.

2. Elements already detached from the main structure are in the process of collapsing.

3. Columns, pillars and vaults, which have been stressed to horizontal and vertical out-to-in forces educed by the earth and been for long time in this static condition, are now without them – clearly stressing in-to-out forces which create a disintegration of the pillars.

4. Interior mortar disintegrates in these hundreds of years, further weakening the structural elements' core. Adding the quick evaporation from mortars, cracks and stone, many of the structures then lack the interior tension forces due to the complete dysfunction of the interior mortar.

5. The reinforcement, also if with a conservative planning and materials, starts much later, towards the completion of the excavation. In the meantime, study, research, planning and preparation for implementation are time-consuming activities. Local strengthens or conservative intervention on the structure cannot be carried out instead of the main conservative engineering intervention (Fig. 4).

What then are the results? The excavated ruined structure receives in a relatively short time, quick structural and physical changes which alter without reversibility the building – cracks open that can not be closed anymore, the "still good mortar" deteriorates, temporary reinforcements create a local static equilibrium that is irreversible and we lose important materials including layers of stone in pillars, columns and vaults. (Figs. 5, 6)

Suggestions from many case studies dealing with archeological excavation of ruined structures are as follows:

a. For the temporary stabilization of a structure, an engineer with knowledge of old buildings and their building technologies and structural behavior is needed.
b. From the moment a ruined structure emerges, a conservation engineer has to be involved in the team.
c. Although the archeological excavation is the responsibility of the archeologist, the engineering-conservation competence has to be stressed in the speed, quantity, stages, and conditions, emphasizing the implementation of the excavation and its practical needs.
d. It is the responsibility of the conservation engineer to be aware of the dangers of the way the excavation is carried out in terms of the short, medium and long term effects to the ruined structure. The tools for a good intervention, in addition to the always present economic considerations, are most importantly, the right approach:
    1. To be in possession of the first data what the earthed ruin structure can be from the architecture and structural viewpoint.
    2. To create a scenario of the possible archeological excavation's possibilities coordinated with the main needs that are the archeological ones.
    3. To create a scenario of the possible structure interventions, conservative influencing structural interventions.
    4. To create from the very beginning a monitoring engineering system including the static, physic and chemical physical and climatic ones.
    5. To keep in mind that the archeological excavation is full of surprises and all the designs mentioned previously are due to many changes.

The archeological excavation 1991 -2000 of the Hospital-Order Castel in Old Akko, Israel

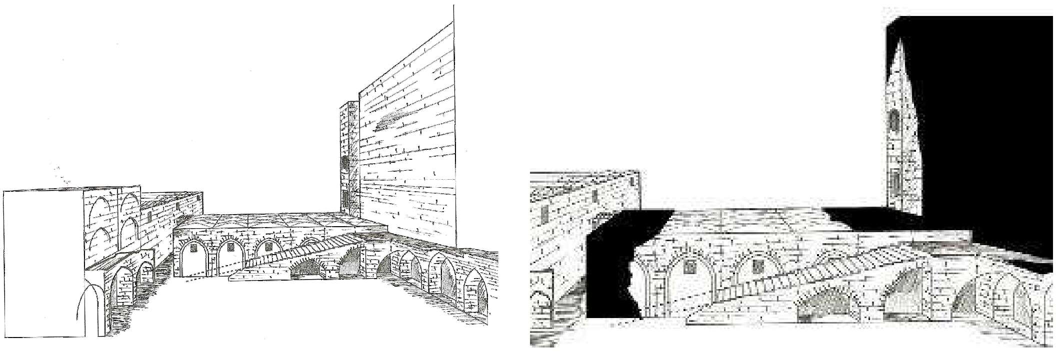

Figure 1

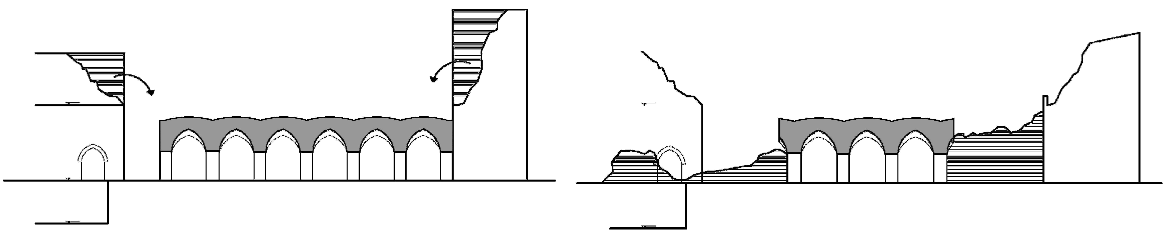

Figure 2

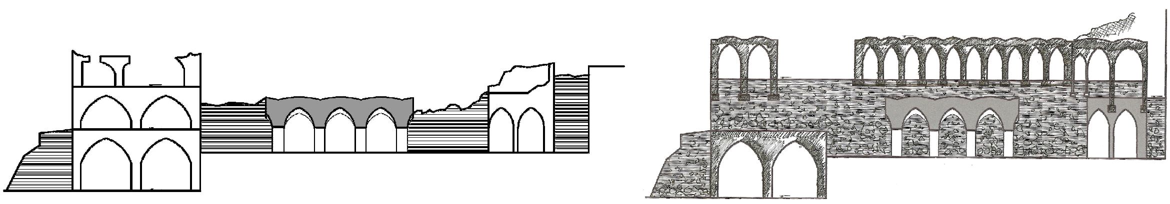

Figure 3

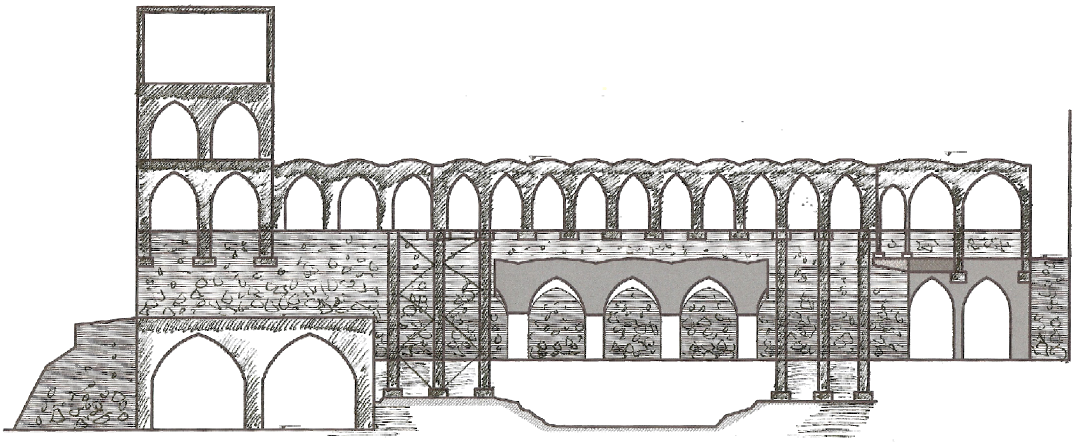

Figure 4

Figure 5 *Figure 6*

Peculiar Structural Building Details and a Lesson for Us

The conservation engineer working in and with the archeological excavation is in full posses of the knowledge of the different technologies, details and materials of the past. In the "look" from the engineering angle of view, many events and details which seem to be "different" are "understandable". Things that are very simply explained by the archeologists and architects and historians, are a lot more sophisticated or even the opposite of their explanations. A few examples are as follows.

Buildings and structures with walls linked by stone arches and covered by stone slabs creating flat roofs or pavements. A recurring phenomenon is the diagonal arches of the sites from the Roman-Byzantium and Early Islamic periods [300A.D. – 1100 A.D.]. One to two storied structures were erected with parallel and perpendicular walls, constructed with rubble or cut stones and lime or lime-earth mortar. Contrasting the previous archeological periods in which walls had widths of up to 100 cm, in Byzantium and Early-Islam periods walls had average widths of 50 cm – 70 cm. The arches to link the walls and support the roofs or intermediate floors were used more frequently than in previous periods. And here the "engineer view angle" has come into play. Almost all the arches starting from the wall's perpendicular level are built in an angle between 15% - 30%, giving the feeling of a "construction building failure or mistake".

When asked about the peculiarity, the answer has always been: a construction building non regulatory or mistake, a secondary erecting stage, local reparation. In buildings where the arches began not from the upper part of the wall, but from an out-wall pilaster, the arches are non in a diagonal angle relative to the walls. But seeing this phenomenon in many sites, including abroad, we realized that they were built on purpose in the diagonal way. Different sites with the same and very clear evidence: all the Nabataea-Byzantine sites, the Byzantium Corazim site, the Tiberia Abbasid Water System, San Stefano in Italy, and many other sites.

What would cause the builder to build such a phenomenon? From the detailing survey, we found that most of the arches have a width of 40cm-60 cm , cut stone, inserted in the wall, and with or without a similar arch in the rear part of the wall in the other room (Fig. 7). From a structural point of view, we can suggest some observations and explanations as follows:

First, about 1/5 to 1/3 of the horizontal reaction of the arch with the wall is parallel to the wall, decreasing the horizontal stress by the same 20%-30% and in practice – decreasing the wall thickness-weight needs for contrasting the horizontal stresses.

Second, the floor or roof stone slabs above the arches are parallel to the walls – do they contribute to the upper phenomenon?

Third, the structures with "diagonal arches": Are they connected in some way to the very seismic conditions of the areas where this phenomenon has been found?

All the above observations have still to be structurally analyzed, but what is certain is that the engineering angle-view has been the main reason that the definition of "a building mistake, a secondary erecting stage, and local reparation" is no longer valid. The reason for this peculiarity is more complicated.

Figure 7

Structures with very thin but high stone-walls, wood floors and large spans between the walls –are they unstable by modern standards but resisted well in the past earthquakes? Historical buildings erected in the last 120- 200 years in the costal areas have a different structure frame from parallel but similar buildings in other geographical areas. If the ground floor of these coastal buildings is always crossed or barrel vaulted, the upper one or two floors are built differently: very high walls up to 6.00 m, with a thickness of 25-30 cm and spans between supporting walls of between 5.00 m - 6.00m. The exterior façade is in cut stone, but the inner façade is of stone rubble filling the spaces in the rear of the cut stones. The mortar is a lime and lime-earth mortar. The floors are wooden joist slabs with marble slabs, lying freely on the walls without any connecting peripheral beams on top of the walls Figure 8).

At least three large earthquakes have struck these areas, with the last major one in 1927. The buildings, which in some old quarters are 90% of the stock, survived with only small damages.

Many changes occurred to these buildings in the last 100 years as large openings, additions of interior concrete galleries, additional floors and changes to the canter liver terraces (Figure 9).

But what is interesting to find is the strong elasticity and stabilizing ability of the original buildings to horizontal forces and that is only one part of this phenomenon.

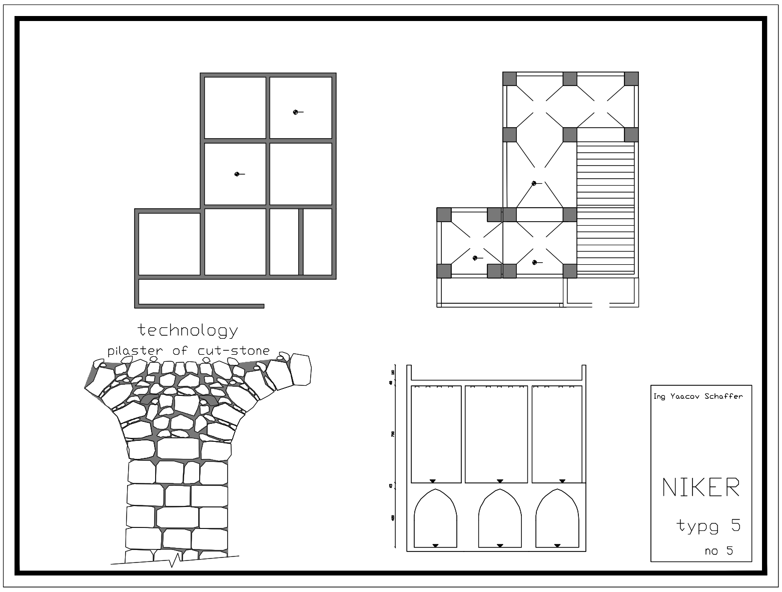

Figure 8

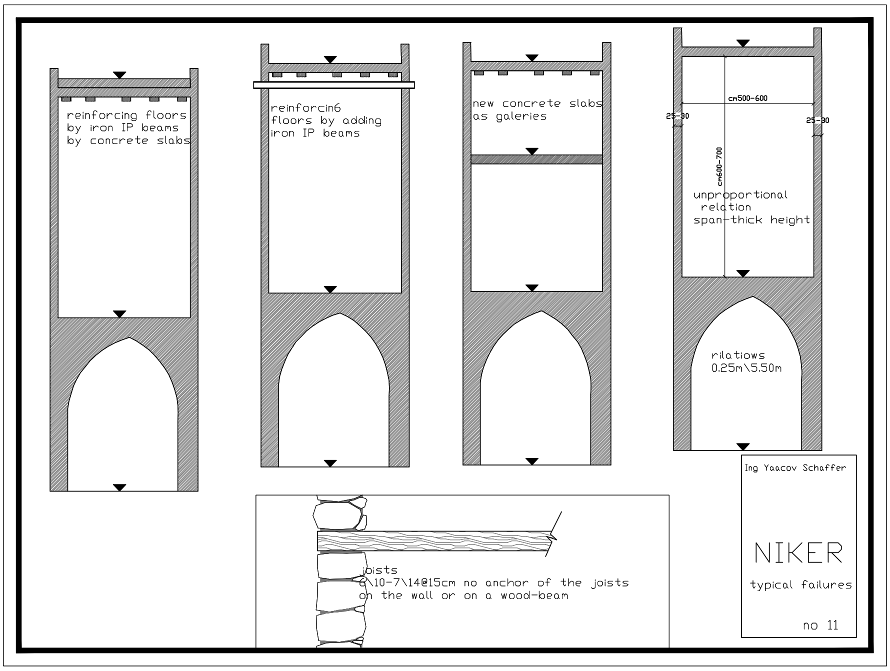

Figure 9

Historic architecture documentation used for the conservation and reconstruction - specific use in the engineering conservation. There is a large scale use of sketches, "romantic period" pictures and first photos in the conservation field of research, documentation and reconstruction. This is employed mainly by historians, architects-historians and architects (Figure 9). The comprehensive research on details, stages of buildings, and background landscape is within the full dominion and knowledge of these experts. But this same research has to be carried out with and by the engineers. Again, as seen in the previous sections, the "engineering angle-eye" is focused on other small details and elements in the existing picture or the missing part. Indeed, here and there are some engineering research interventions, but they are needed on large scale.

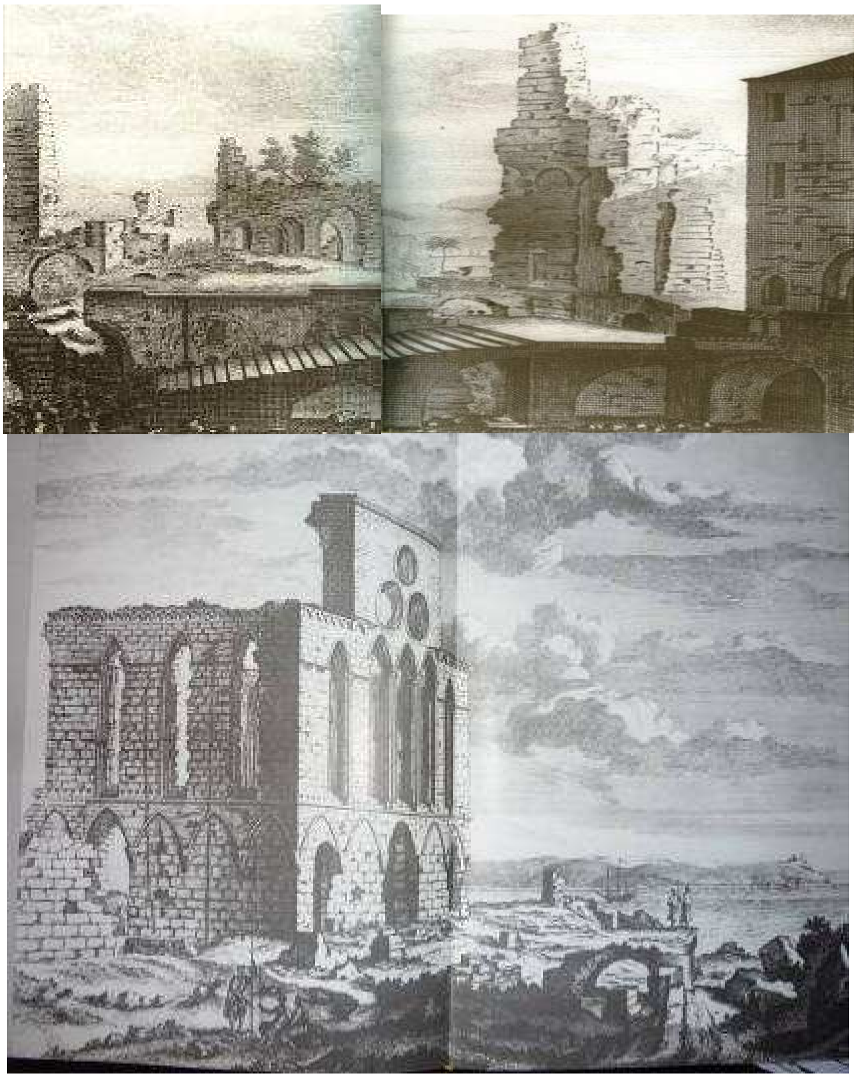

Figure 10

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