An analytical study of infrastructure failure and sandstone pylon collapse causes of Ramses ll temple pylon (Ramesseum) in Luxor city

دراسة تحليلية لمسببات تهدم البنية التحتية وتصدع صرح معبد رمسيس الثاني (الرامسيوم) من الحجر الرملي بمدينة الأقصر

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Abstract:

This study sheds light on the dynamic and static collapse causes of Ramses II pylon side by side an analytical study of the pylon construction system, causes such as, seismic loads, wind loads, the destruction of sandstone, by calculating the impact earthquakes and winds that have struck the pylon and relationship with construction stability also the impacts of bearing capacity, also the pressure force that generated by its loads over the foundation soil and relationship with infrastructure failure, a set of tests and analyzes were conducted on a deteriorated sample, the study found that the nubian earthquake force (27-28 BD) had led to a total failure of the upper half, with structural cracks, wind loads incapable to collapse the pylon before earthquakes but in the current situation can affect and associated with the extreme material weakness of infrastructure and the inability of soil to bear the loads, found that wind loads above the foundation level £F=2,570 kn/m, and from foundation £M=44550 kn/m, current bearing capacity founded is equal to 91.8 kn/m^2, not suitable for its-loads it was also found that earthquake loads on the pylon = 437533.9 kn that demolished the pylon, and through sandstone testing showed low-coherent, presence of brown impurities, irregular extended and incoherence molecules, foundation soil at 3-4 metres shows solid severity crystal with gaps, high smoothness mud, sandstone was analyzed, found (Quartz 89.8%, Kaolinite 8.9%, Halite 0.9%, Anatase 00.5) hence sandstone was deteriorated due to the agricultural waters adjacent to the pylon.

Key words: Ramses ll temple pylon, construction technique, pylons collapse, Infrastructure failure, Seismic loads, structural.

الملخص:

تسلط الدراسة الضوء على أسباب تصدع وإنهيار صرح معبد رمسيس الثاني من الأحمال الديناميكية والإستاتيكية والحالة الراهنة للبنية التحتية له، هذه العوامل التي تسببت في إنهيارصرح معبد رمسيس الثاني، وإستناداً إلى دراسة تحليلية لنظام بناء الصرح، ومن أهم هذه الأسباب، أحمال الزلازل، أحمال الرياح، وتدهور بنية الحجر الرملي المستخدم في بناء الصرح وخاصة الأساسات، و حساب قدرة تحمل تربة تأسيس الصرح، وعلاقة هذه الأحمال بكل من الإستقرارالإنشائي والإنهيارات التي حدثت للصرح واستنساج قدرة الأحمال الذاتية، تم إجراء مجموعة من الفحوصات والتحاليل على عينات من أساسات وتربة بناء صرح معبد رمسيس الثاني، توصلت الدراسة إلى أن قوة زلزال النوبة على الصرح أدت إلى إنهيار كلي للنصف العلوى من الصرح والواجة الشرقية منه وتصدع كلي للصرح من الواجه الشرقية والغرب والجنوبية، مشاركاً في ذلك تفتت مادة بناء الأساسات وحالتها الضعيفة جنباً الى جنب فقد التربة قدرة التحمل المطلوبة للأحمال التشغيلية، حيث كانت قوة أحمال

الرياح أعلى مستوى الأساسات تساوي 2,570 كيلو نيوتن/م، ومن أسفل منسوب التأسيس وجدت إنها تساوي 44550 كيلو نيوتن/م، أما قيمة قدرة تحمل التربة للوضع الحالي تساوي 91.8 كيلو نيوتن/م^2، وهي غير مناسبة للأحمال التشغيلية للصرح بالنسبة للحالة الكاملة للصرح بالقسمة على معامل الأمان المطلوب بسبب تأثيرها بالأراضي الزراعية المجاورة، وكانت الأحمال الزلزالية على الصرح ,437533.9 كيلو نيوتن هذه القوة كانت كافية لتدميرالصرح، وأظهر الفحص الميكروسكوبي أن نسيج الحجر الرملي يعاني من ضعف ترابط الحبيبات و يحتوي على نسبة كبيرة من الفجوات بين حبيبات الكوارتز، وتبين من نتيجة تحليل عينة من الأساسات أن نسبة الكوارنز 89.8% ،الكاولينيت 8.9%، الهاليت 0.9%، ثاني أكسيد التيتانيون 0.5% وعلى ذلك تفتت الحجرالرملي والأساسات من المياة الزراعية حيث يلاصق الصرح الأراضي الزراعية مباشراً من الناحية الشرقية له.

الكلمات الدالة: صرح معبد رمسيس الثاني، تقنية البناء، تصدع الصروح، إنهيارالبنية التحتية، أحمال الزلازل، إنشائي.

1. Introduction

The seismic loads of earthquakes and the foundations soil failure side by side sandstone deterioration were the main factors causing the collapse of the infrastructure and the demolition of the structural elements there two types of collapses, one of which was a total failure from the eastern side because of the seismic loads strikes and presence of the agricultural soil its destroyed the pylon and evident in the fall and the total destruction of the east side from the pylon the other part was the western, an analytical study was conducted firstly on the construction system of the Ramses II pylon, to conclude how the Egyptian engineers was built, carried out in a method of interconnecting the elements and the strength of its cohesion, obliged the establishment of the combiner structural planning, hence the analytical study of the pylon explained ancient methods of building and distributing the areas therefore inclinations made the structural system in a one mass by cohesive and harmonious architecture, but the influence of the agricultural soil at the long term making the infrastructure of the pylon a failure and fragile mass when the destructive force of the earthquake began to demolish and many of the Ramses II pylon parts have fallen, accordingly through mathematical equations and Egyptian code coefficients, loads were deduced[1] the strength of the nubia earthquake was deduced, as well as the strength of the desert winds in the vicinity of the pylon, the earthquake destroyed the structure elements, the other proof was by inferring the load-bearing capacity of the current soil, it was very low in relation to the safety coefficient of the soil, the pressure force on the soil was calculated in order to determine strength of the wind loads; a sample was taken from the foundations and parts of the main construction sandstone to conduct an testing and analysis accordingly found that the sandstone contains Halite salts and titanium dioxide, and through testing show that it is very brittle and weak, to the point that when touched by hand it dissolves and turns into sandstone powder[2].

[1] Rabie Al-Safadi: *The effect of changing the floor mass on studying the impact response model on adjacent buildings under the influence of earthquakes*, Al-Baath University Journal, Vol 43, Issue 51, 2021, p. 96.

[2] Abdullah Muhammad Al-Saadi: *Considering wind and earthquake loads on buildings in the design of concrete structures*, Libya 2022, pp. 12-16.

The study aims to analysis the reasons for the collapse and failures of Ramses II pylon and find out whether the structural system helped to failure and collapse or whether the structural system was steadfast and strong towards this loads, through this research it can be derivation analyzing many of loads, no doubt that Ramesseum temple is the funerary temple of Ramses II (1292 - 1225 BC) from the twentieth dynasty, Its area is 600 x 220 feet[3], and distinguished by its wide halls, huge columns, corridors, and great pylon, as well as statues and decorations on the walls, as the first courtyard is in a state of complete collapse, and it had two rows of columns on the southern side the pylon is a huge building about seventy meters wide has many inscriptions relating to the campaigns attacked by Ramses in the year 1288 BC, in the fifth year of his reign[4] on the façades of its two towers were four flagpoles topped with flags fluttering in the air, and his inner façade was decorated with scenes of the famous battle of kadesh, moreover on the northern tower found a list of the 18 cities names that of Ramses II conquered in the campaign with views of the prisoners, and then come the scenes of the campaign that launched against the Houthi in the fifth year of his rule, and it continues on the tower[5].

Failures of any kind, technical, structural, infrastructural, are the main obstacles the archaeological pylons must overcome, several of pylons suffer from structural failures, including structural cracks and collapses, furthermore its very risky towards structural elements, such as Ramses II pylon, derivation the maximum bearing capacity of the current deteriorated soil relationship of all this loads to the overall stability of the archaeological pylon, aim of the study is to diagnose one of the most important ancient Egyptian pylons which suffer from all failures that can affect any archaeological pylons and architectural heritage, through this study causes of structural and architectural failures determined[6] to determination the maximum bearing capacity of the soil and ensure the safety factor from any failures, relationship of all these loads to the overall stability of the archaeological pylon, aim of the study is to diagnose one of the ancient Egyptian pylons, which suffer from all aspects of the failures that can affect any archaeological pylons, architectural heritage, through this study, causes of structural, architectural failure, degradation are determined in different means[7].

[3] Khairy Marai: *Ancient Egyptian Architecture and History of Architecture*, faculty of Architecture and Planning, King Saud University, 2020, PP. 19-20.

[4] Mahmoud Garhy: The effect of religious belief on the evolution of Gods' temples design in Ancient Egypt International, Design Journal, Volume 7, 2019, Issue 2, P. 2.

[5] 2- Khairy Marai: *Ancient Egyptian Architecture, History of Architecture*, 2020, PP. 19-20.

[6] Reso, typ: *Seismic wave behavior, effect on buildings*, iris, 2022, P.4.

[7] Anant Saini, and Jitendra Singh Yadav: *Bearing Capacity of Circular Footing Resting on Recycled Construction Waste Materials using ANN Method*, Journal of Mining and Environment (JME), Vol. 15, No. 1, 2024, PP.93-115.

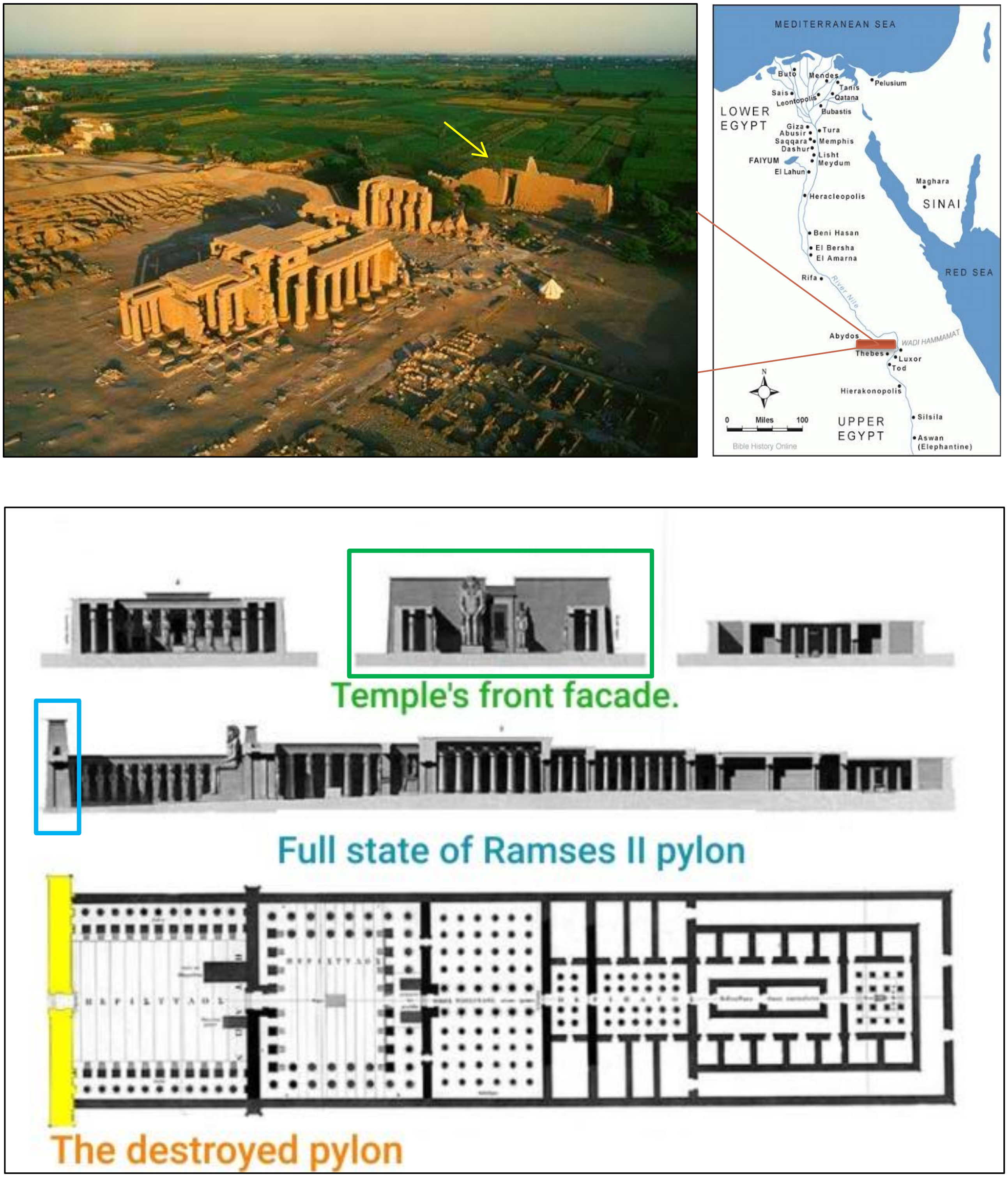

Fig. (1). A horizontal projection and front view showing the pylon and the temple in its complete state, a general map of the temple location, showing the current state of the temple and the demolished pylon, with an aerial view

2. Materials and Methods

To begin conduct an analytical studies on Ramses II pylon in detail to conclude the construction system of temple's pylon, field study was conducted to examine the sandstone pieces which built the pylon. side by side, a sketch with web application (Revit) was used for documentation, data was transferred to the computer until it analyzed to find out how the ancient engineers built the pylon and the strength of its elements, the (ECP 202-2001) Egyptian code of soil mechanics (design and implementation of foundations) and reliance on the Egyptian code for loads and forces to infer the value of wind loads and seismic loads that hit the pylon in the past.

Derivation of bearing capacity through "Karl von Terzaghi" formula based on some of the specifications of the (ECP 202-2001), utilized a pyramids geometric shape to determine the volume of the Ramses II pylon.

The construction material tested through the scanning electron microscope (SEM otago LEI 30.0 KV WD 11.9 mm) to testing a deteriorated sandstone samples from the foundation and at 75 cm altitude from the ground surface, stereo microscope (Meiji EMZ zoom 7X 45X Magnification X200) to identify the morphological sandstone shape, also used to testing a infrastructure sample, 3-4 meters underground, the implementation of full state-of the pylon forms utilized a 3D-Max and Prisma 3D Web application to study the structure system of Ramses II pylon.

Through the following coefficients (q=0.05.p.V 2 .c t .c s) - (P e = c e .kq) affiliate to the Egyptian code used for derivation seismic loads forces and wind loads (code no. 201), based on indicative values from the code the values of the wind loads affecting a unit area, measured in units of kn/m^2, In the process of finding the value of the forces affecting the pylon due to earthquakes, it was $(F_b = \gamma_I \times \lambda \times S_d(T_1)\ (\frac{W}{g})$ used based on Heuristic values from the code[8].

3. Construction System

Ramses II pylon was a huge building about seventy meters wide, built from nubian sandstone, by raising stones to construction courses, after the foundations building were

[8] Egyptian Code *: Soil Mechanics, Design and Implementation of Bases, Part 3, shallow Foundations*, 2007, Egypt, National Centre for Housing and Construction Research, Code No. 202, 2001,PP. 17-40.

composed of 3 courses bond and main units, and other was made of one independent course, the thickness of the course was 86 cm (Fig. 1) and depth of the foundation in soft soil was about 3.48 meters used pulleys, ropes winches and sleds in land transportation, accompanied by the use of relationship between the sides of right-angled, triangle in constructing the pylon, engineers used protection system for the foundations from impact of earthquake by sand due to its flexibility and absorbs the horizontal and vertical earthquakes waves upon completion of the foundation and floors, which did not exceed four feet and were hidden underground[9], in addition to caustic triangle to control inclinations[10], foundation begins by making a cavity broader than the thickness of the wall of the pylon that will be built on the foundations; blocks are trimmed after compacting it and leveling their upper surface.

The foundation surface is leveled; leaving its rough outer vertical surface to be trimmed after the pylon is built, its blocks were connected with interlocking (Fig. 2), auxiliary mortar of lime, sand, and gypsum, their upper surfaces were marked with what is called the construction lines, and the foundations were joined together, the technique of stacking stone blocks by different systems were applied in arranging stones in all parts of the architectural elements, through flemish bond (Fig. 2) and dutch bond[11] (Fig. 3) header with stretcher this were in one architectural element, hence a row of stones 53 cm wide, topped by a row of stones 75 cm wide, and alternately two or three rows of less wide stones, then two or three rows of stones, this methodology was the most suitable way to employ and operate all stones, while making a connection between these stone blocks gradually over the surface of the stone, which gives the architectural elements strong bonding and cohesion between architectural elements[12].

[9] Abdu al-Derby: *Architectural conservation and maintenance of some ancient Egyptian temples with tribal face*, analytical study of damage factors and manifestations and treatment strategy, application of selected models, doctoral research, conservation department, faculty of archaeology, Cairo University, 2004, PP. 43 - 156.

[10] Abdussalam Ahmed: *Ancient Egyptian architecture and the theory of Pythagorean*, magazine of architecture and art, vol VII, No 6, 2022. P. 96.

[11] Kheri Mori: *Ancient Egyptian architecture, history of architecture*, P. 19-20.

[12] Maha Ali Mohamed: *Sustainability in Old Egyptian Architecture*, Master degree Helwan University, College of Fine Arts, Department of Art History, 2021, PP.23-54.

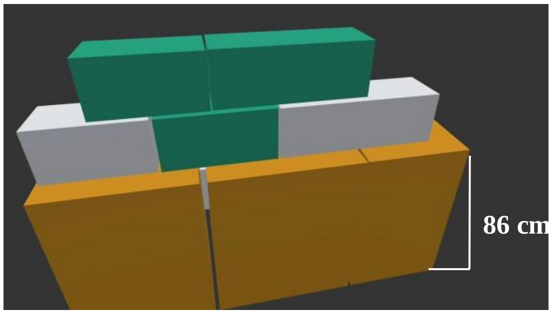

Fig. (1). the brown color shows the shape of the foundations that were used in the ancient Egyptian design, they by three blocks in height and a little wider than the blocks that were used in the construction process of the pylon.

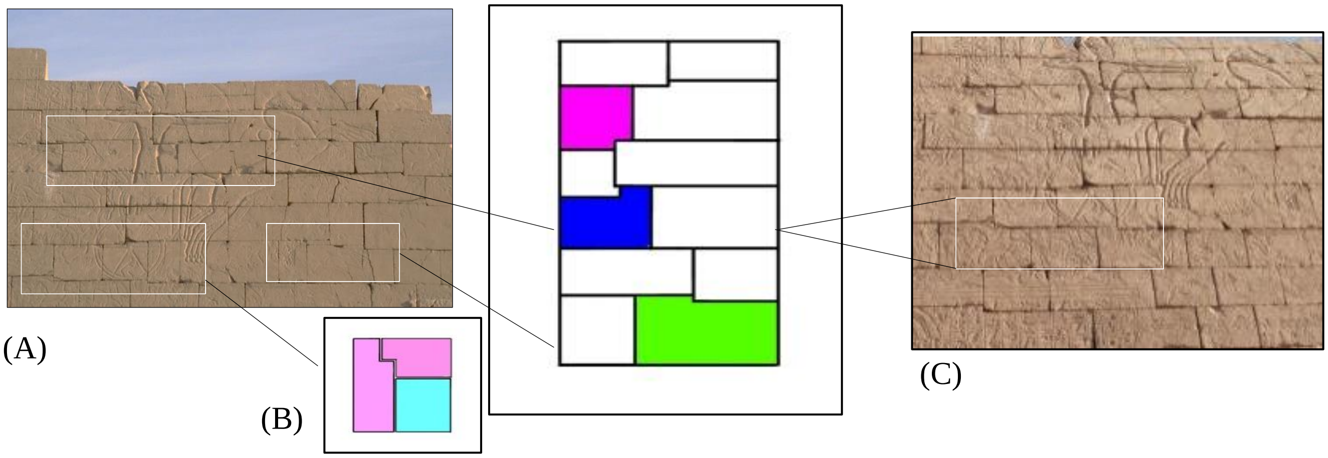

Fig. (2). (A) and (C) the ancient Egyptian method used partially in the pylon by separating part of the stone piece surface and keeping the other (interlock) to more connect and increase the strength of cohesion, (C) colored illustration to clarify this method that used in the pylon building

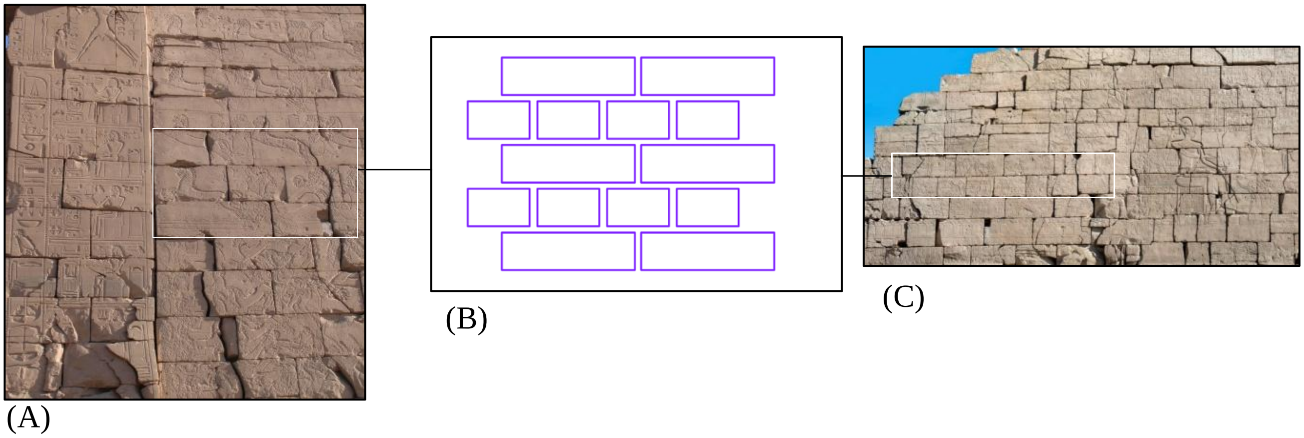

Fig. (3). (A) illustrated to clarify additional method that used in the pylon building by shenoids that the width of the pieces repetition in succession and some area of the pylon being different, (A) and (C) pictures from the pylon clarify methodology of pylon building by using pieces of stones with a width of 40 cm in one row and using pieces of stones with a width of 70 cm in the next row, with some of the pieces being offset so that they interfere with each other. this gives greater bonding strength, tightness and stability to the building

Then placing a tool-shaped wedge under one side of it and moving it until the stones raised, then putting other similar ones under the other side and moving until it tops other[13], as for the top of the pylon it consisted of huge slabs loaded on lintels resting on the walls of the pylon horizontally[14], in some accounts by using several woods[6], the stone was raised to the required level, a wooden tool was used to move the stone during its refinement, and the stones overlapped together in the corners of walls, which helped to hold them together[15], after the building was completed, the levelness of the stone were tested first with a tool (Fig. 4,5A) consisting of two short pieces of wood, the same length tied with a thread at the top, holding it on the face of the stone a third similar piece was moved on the stone along the stretched wall to see how flat its surface was and what should be completely leveled, hired gypsum and lime mortar to improve cohesion with sand 3:1, where the gypsum acts as a binder and the sand acts as a diluent, tested the surface of the stone again to make sure it was completely flat with a tight thread[16], often stones were dragged over slides on bridges and then lifted them with wooden crowbars, the ancient Egyptians applied shovels for carving and leveling the surfaces of blocks from top to bottom, which ensured the use of many workers groups in different places and levels, which saved time[17] were removed upon completion of construction, hence the system of the pylon construction was accreditate on securing the building pieces according to the law in several ways, as the engineers applied the inclination angle (Fig.5C) about 10 degrees in the four sides represented in the pyramid shape plan this system gives the structure system strength of bonding to its constantly advancing elements. Side by side the round cavities (fig.5D) at the end of each external angle for all external ribs to increase the limit of connection between the ribs to each other and to play the role of preventing the ribs from separation in the basic facades, moreover sandstone cutting method, by hooks collation was used which banding the sandstone blocks, whoever the ancient Egyptians used the strongest construction rules and had no relationship to failures.[18]

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[13] Popker Mereki: *The influence of religious belief and social construction on the evolution of architecture in ancient Egypt*, Ph.D., University of Algiers, Faculty of Human Sciences, History, 2018, P. 54.

[5]Capart J: *L'exaltauon du livre, Chronique d'Egypte*, No 177, 1946, P. 25.

[15] Abdou al-Derby: *Architectural conservation and maintenance of some ancient Egyptian temples with tribal face*, P 43 - 156.

[16] Capart J. : *L'exaltauon du livre, Chronique d'Egypte*, P. 25

[17] Jéquier G.: *Manuel d'archéologgie égyptienne*, PP. 89-158.

[18] Mohammed Adel Salama: Egyptian architect's identity, Engineering Research Journal No.51, 2022, P. 55.

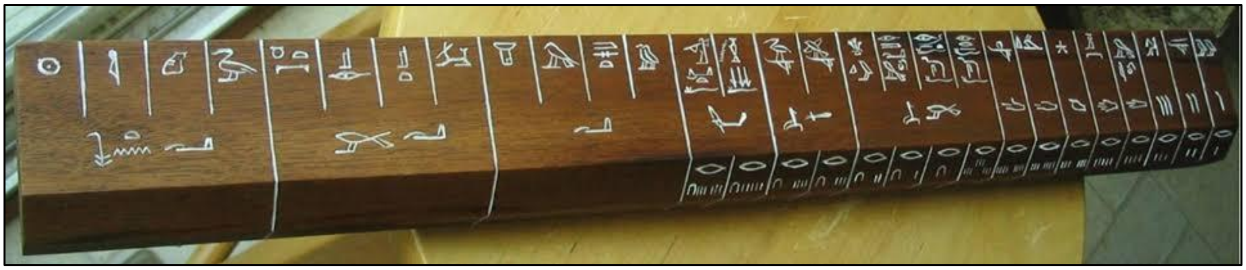
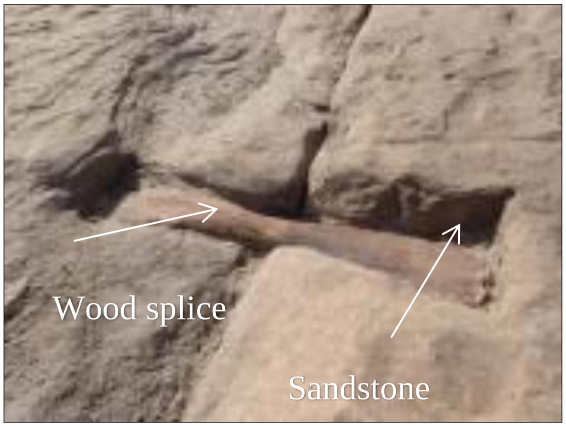
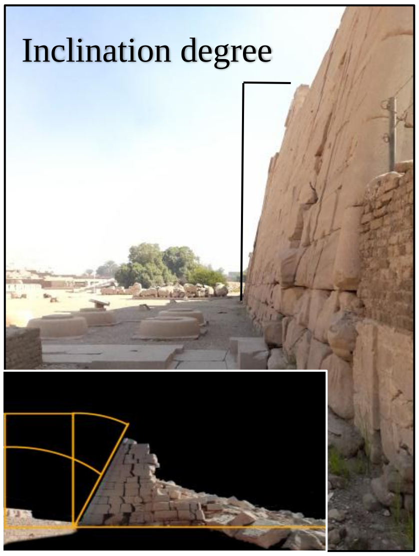


Fig. (4). the measuring ruler of the ancient Egyptians, which used to level the circumference of stone pieces and marked with ancient Egyptian language.

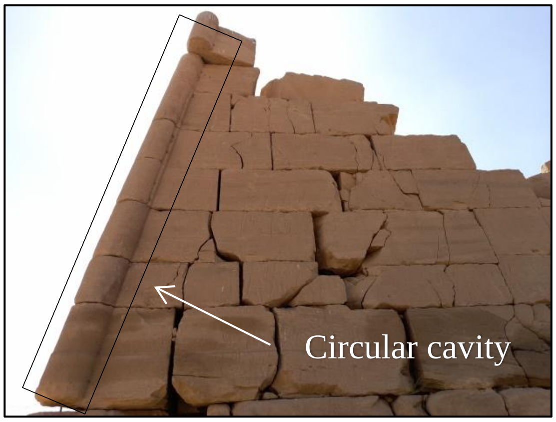
(A)



(B)



(C)



(D)

Fig: (5). (A) ancient Egyptian performance to measure stone and wall.(B),(C),(D) Stones stacking method showing the dove tail method for connecting the stone pieces opposite tangles method as an additional method to support and connect the stone pieces, connects stone each other of tower.

4. Static loads (pylon loads)

Stable loads are relatively stable and loads with stable origin as the weights of the building materials, the soil is affected by its-loading by other forces, it's loads in which changes are occurring very slowly and stable loads with constant origin, first, an architectural lift of the pylon was made to measure the width, length, and height of the current situation shown in the equations, as well as the actual dimensions in the overall case, in order to deduce the volume of the pylon to find the actual load through the actual weight of the sandstone, where (H) represents the height of the tower from the center of the base, (B) is the width of the base, and (A) is the width of the upper peak[19].

4.1. Derivatoin of right tower load

Whole case: top width A = 22 m. and the length of the base B = 31.32 m. the height H = 20 m,

Current case: top width A= 10.5 m. and the length of the base B=31.32, the height H=15 Fig. (6).

Table. (1). right tower loads coefficients

Lateral area		Total area	Volume
$2(A+B)\times\sqrt{H2\left(\frac{A-B}{2}\right)^2}$. $2(10.5+31.32)\times\sqrt{15^2\left(\frac{31.32-10.5}{2}\right)^2}$. $=2(45.19)\times\sqrt{225\left(\frac{20.82}{2}\right)^2}$. $=90.38\times\sqrt{225+10.41^2}$. $=90.38\times\sqrt{225+108.37}$ $=90.38\times\sqrt{333.37}$ $=90.38\times18.26$ $=1527.1$		Total Area=1527.1+A ^{2} +B ^{2} 1527.1+10.5 ^{2} +31.32 ^{2} 1527.1+110.25+980 =2618.3	$=\frac{(A^2+A\times B+B^2)\times H}{3}$ Volume= $\frac{(10.5^2+10.5\times31.32+31.32^2)\times15}{3}$ Volume= $\frac{(110.25+328.86+980.9)\times15}{3}$ Volume= $\frac{15153.2}{3}$ = 7100.2
Current case	1527.1	2618.3	7100.2
whole case	2243.9	3772.5	14930.8

Actual sandstone weight according to Egyptian code = 27 kn/m^3 (2700 kg/m^3)   Volume × actual weight (14930.8 x 2700) = 40313160 kg
Right tower loads is equal to 40313160 kg

[19] Hussein Aziz Saleh: *An integrated practical plan for managing disaster risk on cultural heritage sites*, the Institute Higher Institute of Seismic Research and Studies, Damascus University, Syria Arab, 2020, P. 5.

4.2. Left tower load

Whole case: top width A = 22 m. length of the base B = 31.32 m. the height H = 20 m**,** Current case: top width A= 11 m, and the length of the tower base B =31.32, the height H=12.5 Fig. (6)

Table. (2) Left tower loads

Lateral area		Total area	Volume
$2(A+B)\ x\sqrt{H2}\left(\frac{A-B}{2}\right)^{2}.$ $=2(11+31.32)\ x\sqrt{12.5^2}+\left(\frac{31.32-11}{2}\right)^{2}.$ $=2(42.32)\ x\sqrt{156}.25+\left(\frac{20.32}{2}\right)^{2}.$ $=84.64\ x\sqrt{156.25}+10.16^{2}.$ $=84.64\ x\sqrt{156.25}+103.23$ $=84.64\ x\sqrt{295.48}$ =84.64 x16.11 1363.3		Total area = 1363.3 + A^2 + B^2 1363.3+ 11^2 +31.32 1363.3+ 121+980.9 = 2465.3	Volume=$\frac{(A^2+A\times B+B^2)\times H}{3}$ Volume= $\frac{(11^2+11\times31.32+34.69^2)\times12.5}{3}$ Volume= $\frac{(121+344.52+980.9)\times12.5}{3}$ Volume=$\frac{12727.3}{3}$ 6026.9
Current case	1363.3	2465.3	6026.9
whole case	2243.9	3772.5	14930.8
Actual sandstone weight according to Egyptian code = 27 kn/m^3 (2700 kg/m^3) Volume× actual weight (14930.8 x 2700) = 40313160 kg			
left tower loads is equal to 40313160 kg			
The total load of the pylon			
= (40313160 ×2) + gate weight =(40313160 x 2) + gate area× weight of sandstone =80626320+ 2700×1.2×7.33×14 = 80626320+ 2700×123.1 = 80626320+2700×246.2 = 80626320 + 664977 =81291297 kg		Actual weight of pylon = the weight of the inner corridor - 81291297 The weight of the corridor = 30.5 ×2700 = 82350. The pylon weight = 81291297-82350=81208947 The actual and total weight of Ramesseum pylon =81208947 kg = 81208.9 Tons	

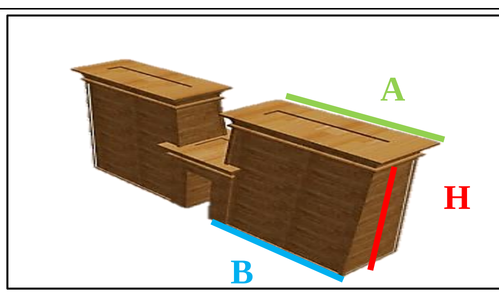


Fig.(6).volume measurment of pylon perimeter .

5. The generated pressure by the pylon on the soil

The increase in the proportion of loads on the soil at the bottom of the base is an increase in the pressure of vertical thrust, which sometimes does not equal the horizontal thrust; this leads soil for compression and distortion.

Table. (3) introductory table of pressure law

F	Power affecting the foundation soil
S	Total area
W	Pylon weight
G	Gravity wheel

Table.3 $F = W.g = 796387.7 \times 9.8 P = \frac{F}{S}$
$= 7804599.4\ kn$

$$P = \frac{7804599.4}{971.1} = 8037.6\ kp/m^{2}$$

6. Derivation of dynamic loads (horizontal loads)

Living loads are a term of engineering used in various fields and branches of engineering, carrying the power of an outside influence and the weight of this force is considered to be a kind of force; living loads are the strikes and the load of natural phenomena, such as: winds loads, earthquakes loads hence winds is the movement of air caused by the variation in air temperature from one area to another, resulting in a variation in atmospheric pressure, and wind surges from high to low pressure areas, in horizontal or vertical motion, wind speed is linked to the value of the difference between the pressure zones, and contributes to the slurry and the erosion of the archaeological walls directly or indirectly of the building materials, causing a weakness in the architectural elements of the pylon by its activities in a different directions especially since there are stones in the pylon about to fall.

The phenomenon of ground vibrations is a series of ground tremors resulting from the movement of rock plates and is called the epicenter, followed by rebounds called seismic waves (earthquake) this is due to the breaking and displacement of rocks from accumulation of internal stresses as a result of geological influences that result in the movement of the ground plates, the earthquakes arise as a result of the presence of slides in the layers of the earth[20], hence on tuesday, january 23, 2024, the stations of the national seismic network of the national institute for astronomical and geophysical research recorded an earthquake 46 kilometers southeast of Luxor, and its data at local time was 1:18:42, with a magnitude of 4.4 on the richter scale, latitude 25.41, longitude 32.97, depth 9.78 this earthquake undoubtedly had a negative impact on the weak state of Ramses II pylon, as it suffers from a lack of cohesion of its architectural elements and is vulnerable to collapsing with the slightest external influence[21].

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[20] Abdullah Muhammad Ansell Al-Saadi: *Considering wind and earthquake loads on buildings in the design of concrete structures*, Civil Engineering, Derna City, Libya, P. 13

[21] Gad Muhammad Al-Qadi: *report on the national seismic network about earthquake near Luxor*, National Institute for Astronomical and Geophysical Research, Ministry Of Scientific Research Cairo, Egypt, 2024.P. 1.

6.1. Derivation the wind loads effect on structural elements

Calculating the strength of the wind loads on the pylon of Ramses II, which affect it after it was demolished by earthquakes the using a mathematical equation from the Egyptian code (P e = c e .kq) , (q =0.05.p.V 2 .c $_t$ .c $_s$) for wind loads, taking into account the geographical area, the high of the pylon Fig. (7) And type of building is as specified in the code.

Table. (4). guiding value of wind loads law

q	Basic wind pressure depends on geographical location.
P	Air density = (12.5kg/m^3)
V	Wind speed = 33 m/s according to Egyptian code Wind speed in Egypt(alkhamasin wind) = 140km/h according to meteorological authority, it indicates wind activity stirring sand and dust in southern upper Egypt[22]
C_t	Earth trophic coefficient ,(level) Ct=1.5, (moss) Ct = 1.2
C_s	So Cs is equal to 1 according to the Egyptian code
K	The wind exposure factor (small villages and cities), which depends on the area of presence by knowing the height of the building based on the Egyptian code, is less than30 metres higher so, K = 1.00

$q=0.05\times12.5\times33^2 1.2\times1 =680$
680.6
$680.6\div1000=0.680$ kn/m^2
$Pe=0.680\times k\times B\times H$
$Pe=0.680\times1\times69.37\times22$
$Pe=1037.7\div1000=1.03$
$F1=1.03\times1\times69.37\times10$
F1=714.5 kn
$F2=1.03\times1.15\times69.37\times10$
F2=821.6 kn
$F3=1.03\times1.46\times69.37\times10$
f3=1043 kn
£f=f total=2,570 kn
£M=M total=44550 kn/m

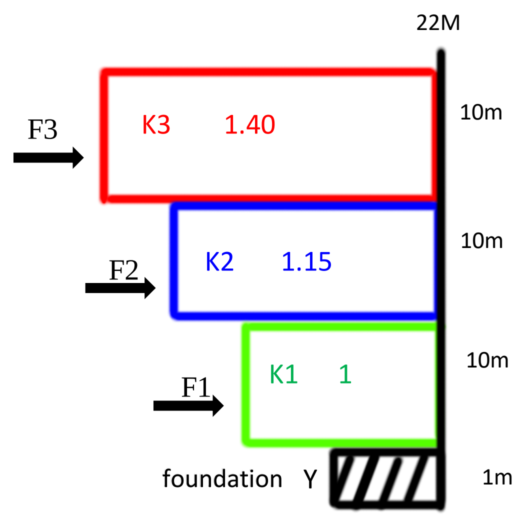


Fig. (7). Force of the wind loads.

Table. (5) Detected value of wind loads forced that affected on pylon

F(kn)	F	Y	M (kn)
F1	714.5	6	4287
F2	821.6	16	13145.6
F3	1043	26	27118

[22] Abdel Razaq Ibrahim: *Study and design of a fog control system in wind turbines to operate at high wind speeds*, Baath magazine, vol. 45, No. 12 of 2023,PP. 5-9.

Through the derivation process for wind loads, it was found that the force acting on the pylon by dividing high of the pylon into several levels (Fig.7), the total force above the foundation level is equal to 2570 kn, force from the foundation level is equal to 44550 kn, Table.5**.**

6.2. Seismic loads strikes on Ramses II pylon.

The seismic loads are so dangerous for the archaeological pylons that surprise the structural elements that stable and balanced together, when the earthquake hits the ancient pylons Fig. (8) lose stability and become failure, this sudden approach causes these architectural elements to be out of balance with each other and with its soil, and each element responds to the earthquake strikes, as a result of the vibration wave migration from seismic intensity[23] completely down to up, especially on the right or left direction[24] Ramses II pylon in luxor city hits by many earthquakes where it was the most important one is the nubia earthquake, there is no doubt that this earthquake led to the complete destruction of the upper half, with other assistance, such as the failure of the foundation soil beneath the pylon, due to the negative impact of agricultural land water on the eastern side of the pylon, this water is laden with salts and other chemicals elements that work to disintegrate the foundation materials sandstone, hence pylon failures appear clearly in eastern side that was affected and completely destroyed Fig. (9), this is in contrast to the western side of the pylon, the lower half of which remains[25].

(A) (B)

Fig.(8).(A) The northern facade of the Ramses II pylon failure, (B) an aerial view closed to the pylon showing the magnitude of failure that reaches to 60 % percent of the pylon

[23] perry rohn: *engineering geology and elation*, 2019, P -229

[24] Khalil Ibrahim Waked: *Earthquakes and the safety of your home*, Cairo, Engineering Library, 2022, P. 7.

[25] Mohammed Abdelhadi: *Scientific Studies in the Restoration and Maintenance of Inorganic Archaeology*, Cairo, Zahra al-Eshar Library, 1997, P. 253.

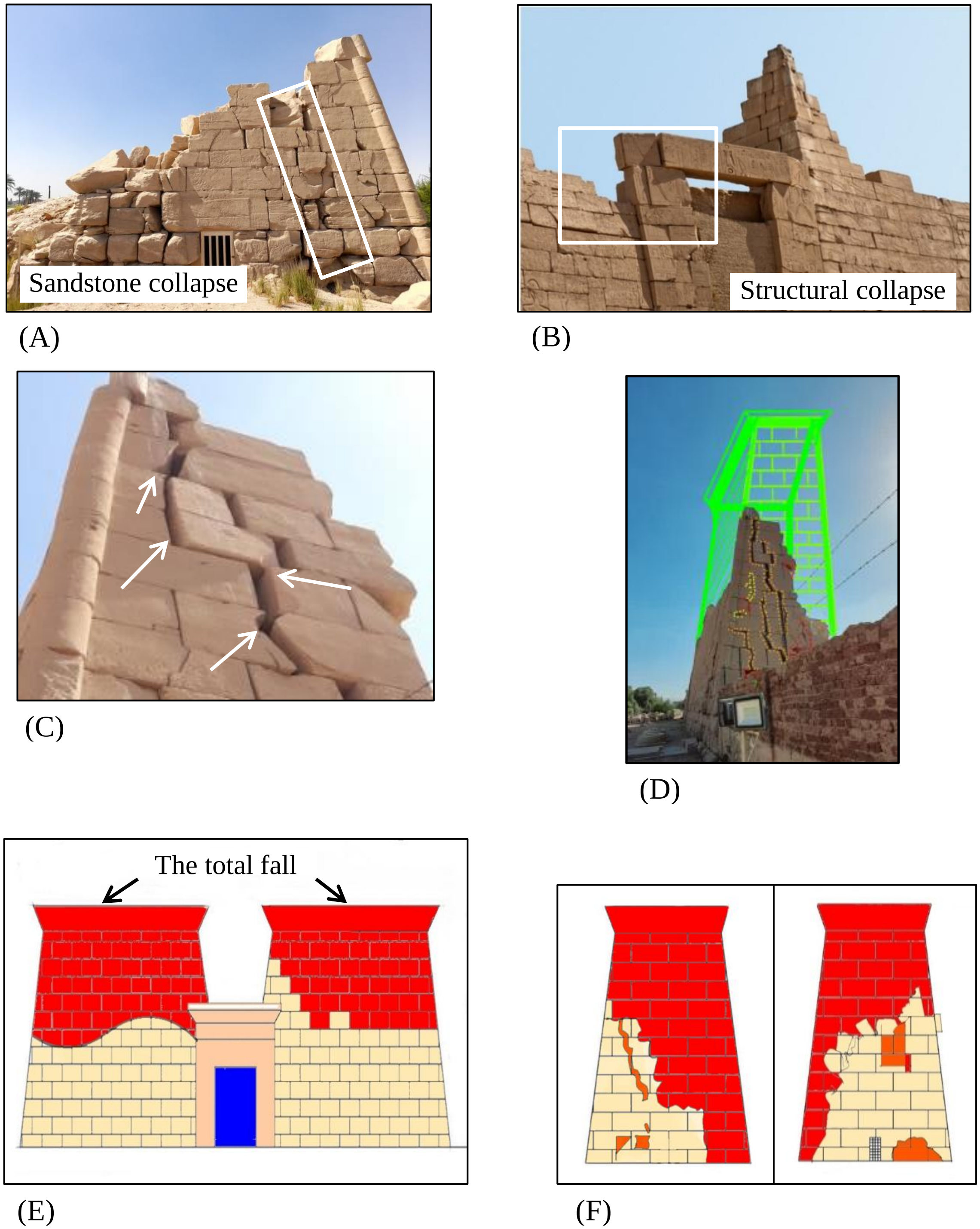


Fig. (9). (A), (B), (C) Ramses II pylon collapses and cracks through sandstone pieces and separation each other as a result of nubia earthquake, (D), (E) failures of the upper half , responded of the foundation soil to earthquake due to the danger of agricultural land on this side.

Recently, in January 2024, an earthquake hits the pylon with a magnitude of 4.4 on the richter scale; there is no doubt that it affected many of the upper parts, the archaeological pylon was negatively affected due to collapsed state, therefore calculating the force of the earthquake on the pylon, using a mathematical equation from the Egyptian code $F_b = \gamma_I \times \lambda \times S_d(T_1) W/g$ for earthquake loads, taking into account the geographical area, type of soil, depth of the foundations, and type of building material with the building height is as specified in the code table (7), as in the following equations

Table. (7) guiding value of seismic loads law

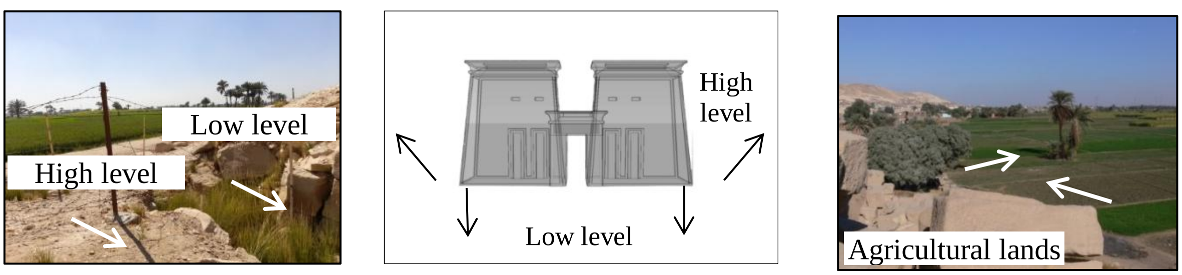
(ag)	The earthquake zone for the shortest is 1 according to the Egyptian code and the value of the design seismic wheel = 0.1g
γI	The significance of the building is a normal building is equal to 1
B	Soil area classified as Area (B)
T1	$=0.05\times h^{0.75}$ $T1=0.05\times 22^{0.75}$ T1=0.507sec
Tb	is equal to 0.10
R	Depends on the construction system of the portable walls R is equal to 3.5
λ	According to the Egyptian code T1, ≥ 2TC, so equal 1
S	is equal to 1.5
Tc	Soil-type constant value = 0.25
Td	is equal to 1.2
W	Total weight
$S_d t1$	$F_b = \gamma_I \times \lambda \times S_d (T_1)W/g \longrightarrow S_dT_1=ag.s2.50/R\times(T_c/T_1)$ $S_dT_1=0.1\times1.52.50/3.5\times(0.25/0.507)$ $S_dT_1=0.0528$ $F_b=1\times1\times0.0528\frac{81208947}{9.8}$ $F_b=437533.9$ kn

So the force of nubian earthquake loads that effect on the pylon is equal to (437533.9 kn) that affected on the structure elements of Ramses II pylon the earthquakes was sufficient to cause a serious fall, since the maximum resistance limits to the origin were linked to the permissible level of the dynamic and inflexible response.

7. Bearing capacity derivation of Ramses II pylon

The foundation has always been the most crucial component of any building, as it distributes the structural loads to the sub-surface soil layers Fig. (10), the loads should be distributed such that neither the foundation nor the earth layers will collapse, therefore it is essential to evaluate the underlying soil's ability to support pylon loads[26] based on this, the foundation and soil were affected by salt water from the agricultural lands adjacent to the pylon, and this is evidential from the difference in the level of the ground surface around the pylon, for the requirements, the bearing capacity of the foundation soil must be calculated to support loads so through the following equations, the maximum bearing capacity of the current soil can be calculated through (Terzaghi) coefficients and values specified with the code for the geographical area, table (8) shows the values of the foundation soil from this code.

From the Egyptian code for shallow foundations, this is in contrast to the soil of the foundation with the impact of agricultural lands Fig. (10), and land level difference Fig. (10), bearing capacity requirements, in this demand; the Egyptian code equation $qult = c.Nc + q.Nq + \frac{1}{2}.\gamma_b.B.N\gamma$ defined the bearing capacity of Ramses II foundations which is the equation for the maximum load-bearing capacity of the soil[27].



(A) (B) (C)

Fig. (10). (A) (B), the changes occurring in the level of the soil for the foundation of Ramses II pylon and the decrease in the bearing capacity,(C) the danger of agricultural lands on the side of Ramses II pylon.

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[26] Anant Saini and Jitendra Singh Yadav: *Bearing Capacity of Circular Footing Resting on Recycled Construction Waste Materials using ANN Method*, PP.97-114.

[27] Pan Li, Yang Xia and other: *Study on Vertical Bearing Capacity of Pile Foundation with Distributed Geopolymer Post-Grouting on Pile Side, Materials*,MDPI, Basel, Switzerland 2024, 17, 398 PP 2-5.

$$qult = c.Nc + q.Nq + \frac{1}{2}.\gamma_b.B.N\gamma$$
$$q = \gamma_{b.\ D_f}$$

Table. (8) guiding value Introduction of Egyptian code to derivation the bearing capacity

C	Soil cohesion capacity
Nc	The bearing capacity factor depends on the angle of sternum resistance
q	The weight of the soil which higher than the level of establishment
Nq	The bearing capacity factor depends on the angle of sternum resistance
γ_b	Soil density below foundation level (t/m^3)
B	width of the foundations
Nγ	The bearing capacity factor depends on the angle of sternum resistance
γ_b	Soil density at the highest level of establishment (t/m^3)
D_f	Foundation depth in metres
According to the Egyptian code of bearing capacity then. C=5 Nc=11 q=3.25 Nq=4 γ_b=2.65 $B = 18$ Nγ =1	$q=\gamma_b.D_f$ q=2.65×1.2 q=2.65 $qult = c.Nc + q.Nq + \frac{1}{2}.\gamma_b.B.N\gamma$ $qult = 5 \times 11 + 3.18 \times 4 + \frac{1}{2} \times 2.65 \times 18 \times 1$ qult = .9157 kn/m^2

Which equal 91.57 kn/m^2, so the bearing capacity of Ramses II pylon misplayed according to Egyptian code, the safety factor for soil is equal to 91.57/2 = 45.7 kn/m^2, this value is the safety load of the current bearing capacity, the components of the building has an impact on the bearing capacity side by side soil failure hence soil loses resilience as a result of increased static and dynamic loads on the soil layer, as well as when groundwater levels, resulting in more effective stress, thus increasing stress on the soil, when the basis of building is exposed to an uneven decline, it means that the soil has lost bearing capacity

8. The infrastructure sandstone testing and analysis.

One of the crucial steps in checkup buildings and archaeological site, process of testing basic samples to determine its petrographic shape, the outcomes of testing methods greatly aid in guiding to construction status in the right direction by identifying the deterioration causing factors that contributed to building failure, the sample from Ramses II pylon was initially thoroughly described with the unaided eye, with the aid of a magnifying glass, ensuring that everything that could be seen in the sample was recorded while it was still in its original location, It was then taken to the laboratories to conduct tests which include numerous methods of examination with suitable devices, in order to do the petrographic study of the building material, a number of samples of the building material (Fig.11.12.13), soil (Fig.14.15) used to construct the Ramses II pylon material were obtained, and some of these materials were investigated and tested.

8.1. Testing of the infrastructure sandstone.

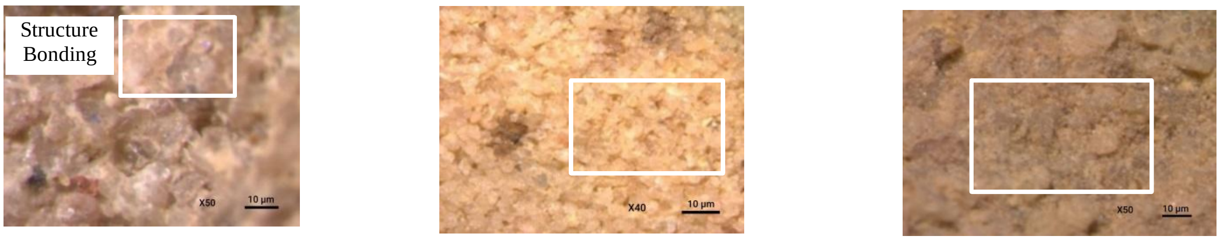


Fig. (11).Similar sandstone sample from quarry and through stereo microscope testing shows the structure in a well-established state with little vacuums, the petrographic study indicated that the sample consists mainly of semi-round and round grains of medium to large quartz.

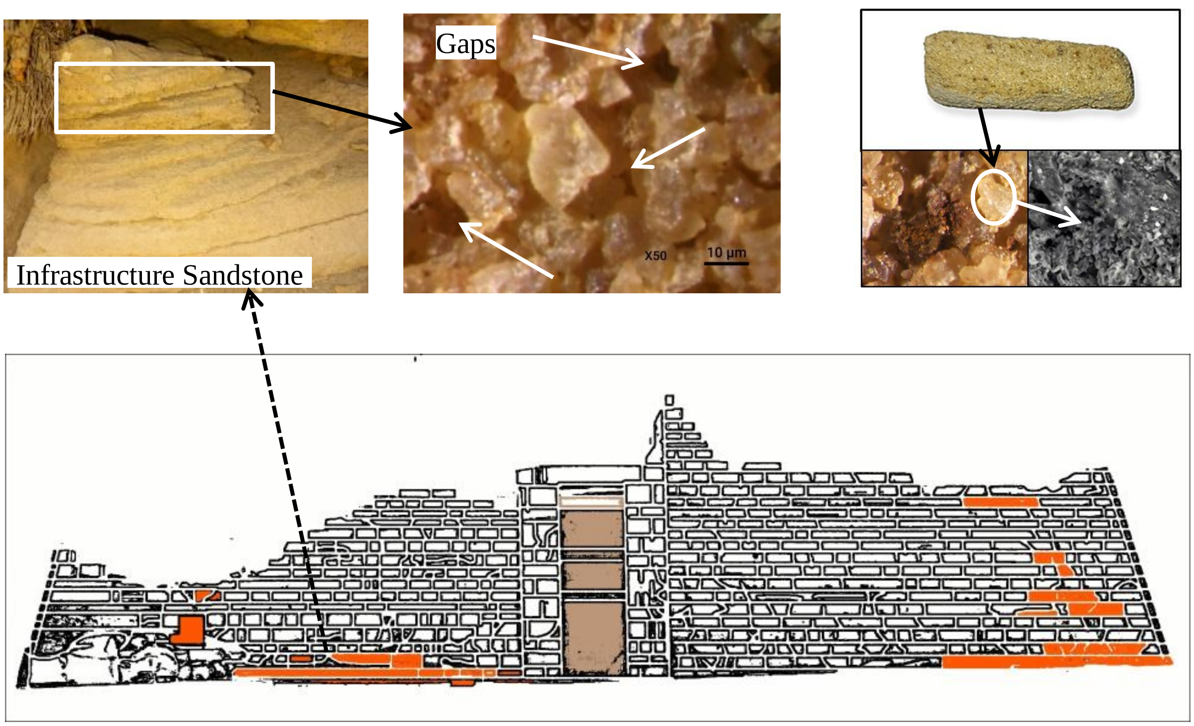


Fig. (12). the structure of deteriorated sandstone sample which low-coherent and yellow-colored sulfur, with parts which are gray-colored, also iron oxides with the weakness and incoherence, moreover mainly of extended granules and angles ranging small to medium-sized quartz.

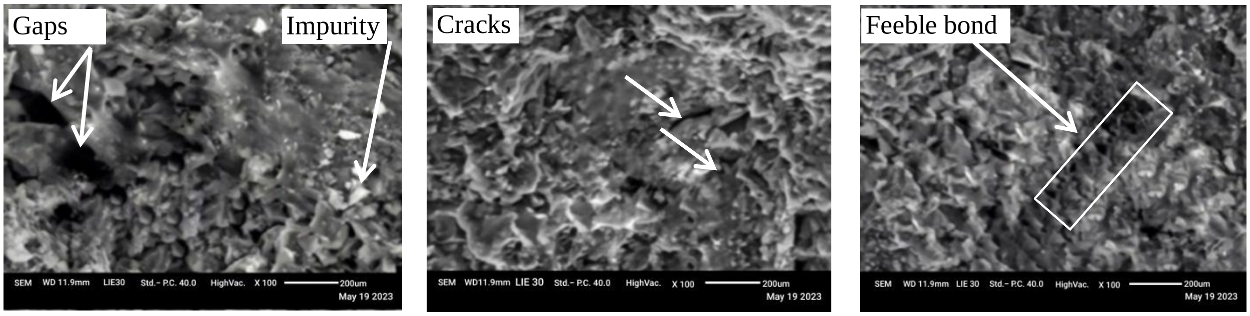


Fig. (13). sandstone through the (SEM) shows poorly molecules and appears to be weak in the particles of the from the microchips find out impurities as a deteriorations factor, as well as the feeble molecules.

Fig. (14). the infrastructure soil of Ramses II pylon and the samples on which tests and were conducted.

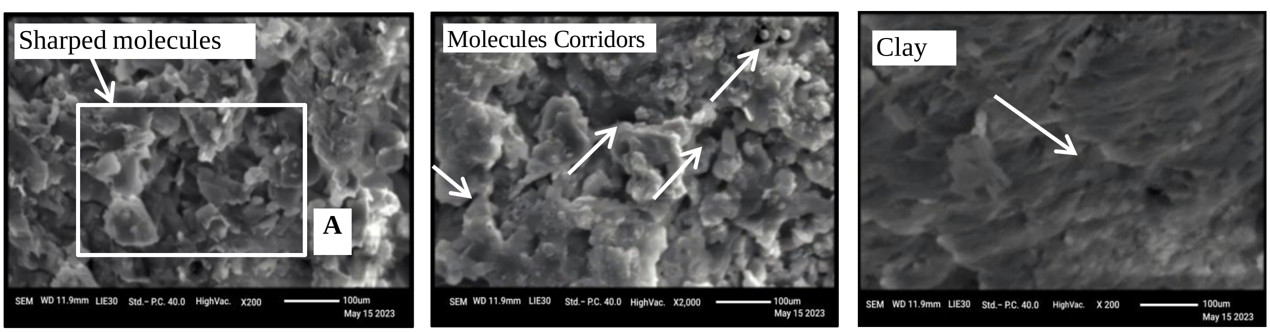


Fig. (15). foundation soil of the Ramses II pylon at 3 metres depth through testing shown the crystal severity and some of the gaps between the mud quartz, contrasting the mud crystals that appear as a smoothness.

9. Analysis of the infrastructure sandstone.

The analysis was performed by X-ray diffraction in the laboratories of the metals Research and development center in helwan, republic of Egypt, the analysis of the matrix sandstone powder from Ramses II pylon was conducted to calibration and determine basic components in general and secondary particular component, moreover concentration of main molecules in the present derioration, the sample preparation procedures were detailed and the raw results of the analysis for the sandstone samples are shown in Taple.1. using apparatus with the following specifications and operating.

Conditions: radiation: CuKα1 generator current (MA): 25, wavelength alpha1 (A): 1.54060, wavelength alpha1 (B): 1.54060, intensity ration (Alpha1/ Alpha2): 0.500, receiving Slit: 0.2, diffract meter type: PW 1840, anode: Cu, generator tube tension (KV): 40, monochromator used: full scale of recorder (K counts/s): 20, time cons tant of recorder (s): 0.5 SS/FOM: F(17)= 92.7 (0.0108, 17), and yet the results of the analysis by X-ray diffraction showed that the main component of the sample is quartz at a rate of 89.8%, with the presence of kaolinite as an impurity at a rate of 8.9%, as well as halite salt at a rate of 0.9%, and titanium oxide at a rate of 0.5%, the X-ray diffraction pattern Fig. (16). in the figure shows the indicated data side by side the table. (9).

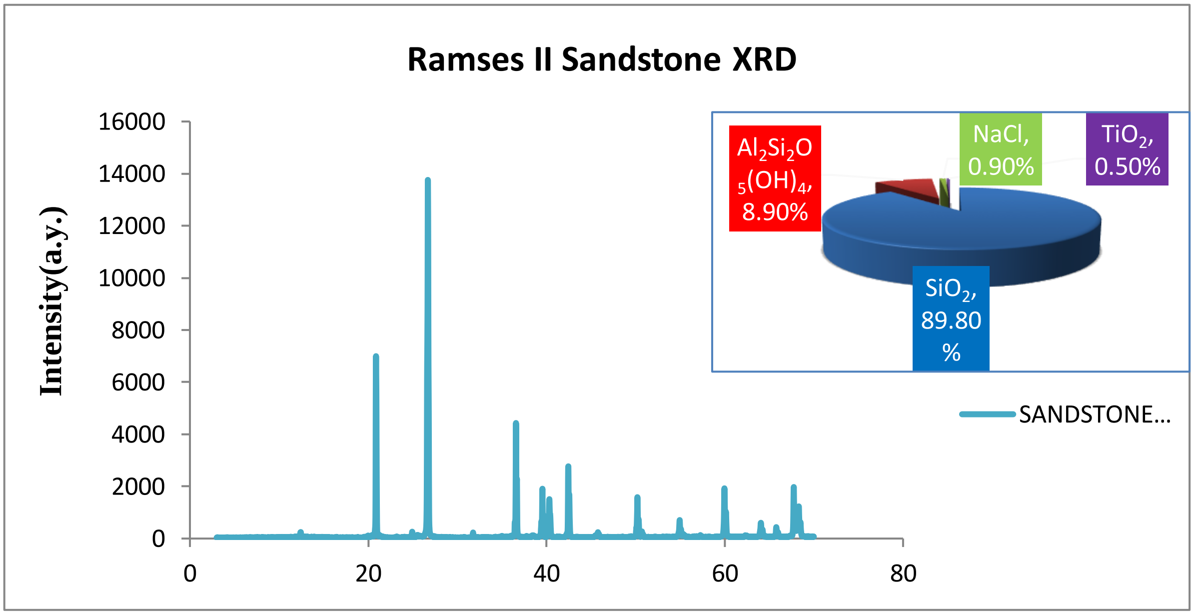


Fig. (16).X-Ray diffraction (XRD) analysis of sandstone sample

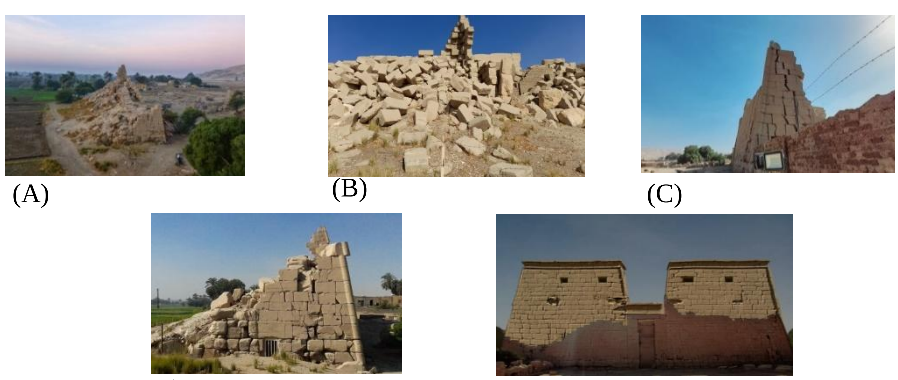
Table (9). XRD pattern result of pylon building material.

Visible	Icon	Colour	Index	Compound name	Formula	S-Q
Yes			1	Quartz, low	SiO_2	89.8%
Yes			2	Kaolinite-1A	$Al_2Si_2O_5(OH)_4$	8.9%
Yes			3	Halite, syn	NaCl	0.9%
Yes			4	Anatase	TiO_2	0.5%

10.Results and discussion

Premiely from construction system studies found that the ancient Egyptian engineers built the pylons by constrictive tightly structured system, but the power of live loads destroyed the pylon as follows, through outcomes of the various loads derivation that has already affected the structural stability of the Ramses II pylon, which has led to the demolition Fig. (17), owing the proportion of the perpendicular loads to height of the pylon, side by side bearing capacity mitigation through reflection of soil capacity to resist the seismic loads that was trying to dismantle the infrastructure, according to the Egyptian code for foundations and the founding, bearing capacity for sand mud soil is equal to 100-200 kn/m^2, and (Poisson ratio) of sand mud soil = 0.3 therefore by derivation the bearing capacity it was found that the qult is equal to 91.57 kn/m^2 furthermore there has been a significant relative with the safety factor for soil failure is 91.57/2 = 45.9 kn/m^2 this value is the safety bearing capacity of the Ramses II foundation soil This value should have been equal to 100-200 kn/m^2, so the foundation soil is Unable to bear the loads of the pylon so it demolishes further from the eastern side and led to the failure from this side, which also led to the scattering of the building sandstone blocks, in addition to cracking that occurred in the foundations of the pylon, It should be noted that the maximum resistance limits in the pylon were linked to the permissible level of the inflexible response, moreover the seismic strikes value was the magnitude of the earthquake, which had a force equal to 437533.9 kn, so this equity is very great and has been sufficient to cause a partial failure and totaler collapse in Ramses II pylon now the structure of the Ramses II pylon contained some of the short-term partial displacement, this is a form of structural instability, the wind loads incapable of demolish the pylon alone before seismic loads strikes, but in the current situation able to effect on the disintegrated architectural elements that is about to free fall, and when the wind loads is calculated in the temple, it was found that is equal to 44550 kn wind is a future factor that can destroy a lot of pylon elements.

Through SEM testing for deteriorated sandstone, shows that the molecule is poorly consistent and appears to be frailty moreover microchips and impurities in the particles as a deterioration factor of the sandstone, as well as the fragility and incoherence of the molecules, so the lower parts of the pylon were failure, the soil below pylon also had a participant in the failures of the construction material as a result that it is somewhat soft and contains impurities, salts and emptiness between its sweethearts, and very sharp crystal and some of the gaps between the quartz and the mud, contrasting the mud crystals that appear as a high-density smoothness, but some of them are soft, this was through SEM and Stereo microscope at 3 - 4 metres, Stereo microscope testing for a sandstone model brought out of the quarry, it was shown that the structure of the sample is coherent and strong with a full binding material, side by side a little of similar oxides that found in the deteriorated sample, petrographic study on the deteriorated sample from Ramses II pylon indicated that damaged and its binding material lost by agricultural water and salts disintegrated, the sample consists mainly of semi-round, yellow-colored sample with Low-coherent, parts of which are gray-colored, shown iron oxides as well as weakness and incoherence of sandstone structure, with mainly irregular and extended granules from small to medium-sized, after analysing the deteriorated sample of sandstone through XRD, It's a lot to lose the bonding material as a result of the halite salts in a large proportion hence salinity in the soil is high, along with kaolinite and titanium oxide founding it, the components and it's ratios = (Quartz, low, SiO_2, 89.8%) (Kaolinite - 1A$Al_2Si_2O_5(OH)_4$, 8.9%) (Halite, NaCl, 0.9%) (Anatase, TiO_2, 0.5%) that lead to failures, more than one kind of stress, such as pressure, hyperactivity on the pylon, which is illustrated by the angle magnitude of the pylon southern side, its slope at 1 degree from the north side moreover the change in length relative to the original height, through the safety factor and flexibility factor, which reflects the degree of flexibility of the structure elements hence elements are acting under loads furthermore pylon structure unsustainable against more loads.



(A) (B) (C) (D) (E)

Fig. (17). Ramses II Pylon failures and collapse and the relationship with the missing parts of structural elements.

11. Conclusions

There were three main factors that led to the demolition and collapse of Ramses II pylon infrastructure and architectural cracks and other parts of it, those motives paintings together to demolish and crack the pylon, the first is the chemical water of the agricultural lands adjacent to the pylon on its easternanese aspect, It is apparent that radius of the pylon turned into totally demolished, in contrast to the western aspect of it, which has become partially demolished which explains the effect of this agricultural lands on the pylon by salts and another chemical elements moreover partial soil subsidence, It has been happened for a long time, which in turn initially occurred in the form of agricultural waters and chemical solutions spread to the soil below the foundation and then to the foundations and above the foundations, this solution has the ability to crumble the building materials and make it lose the bonds, and through This process the solutions repeated by evaporation and then diffusion back over a long time, making the pylon's building material fragile, especially the lower parts, very vulnerability and very fragile, this became achieved with the assist of the wind, particularly the temple of Ramses II, it is positioned in a place that facilitates the wind unfold fast and easily due to the absence of buildings in its surroundings, moreover was found that there are herbs growing in the structure of the pylon material between the sandstones, whereas the building materials completely demolished due to the losses of its cohesion, as this was before the earthquake occurred and is still continuing until now, and when the nuba earthquake occurred.

The seismic loads affected the infrastructure as a result, the structural elements of Ramses II pylon was collapsed and demolished, resulting in fall of stones that built the pylon in addition to fall of parts of the columns and statues attached to the Ramses II temple, currently wind loads able to increase the fall of structural elements due to the current extreme weakness of these structural elements, it was found through the field study that stone blocks in the pylon about to fall with the slightest force, there is no doubt that the weakest earthquake at the present time able to cause this demolition again, and all the lower parts of the pylon suffer from complete disintegration at a height of about 75 cm from the floor surface of the Ramses II pylon, challenges can be overcome through structural and reconstruction intervention to preserve remains of the archaeological pylon or even a preventive process.

12.Acknowledgment

I would like to give my thanks and appreciation to reviews including thanks to supervisors.

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