# MEMNONIA

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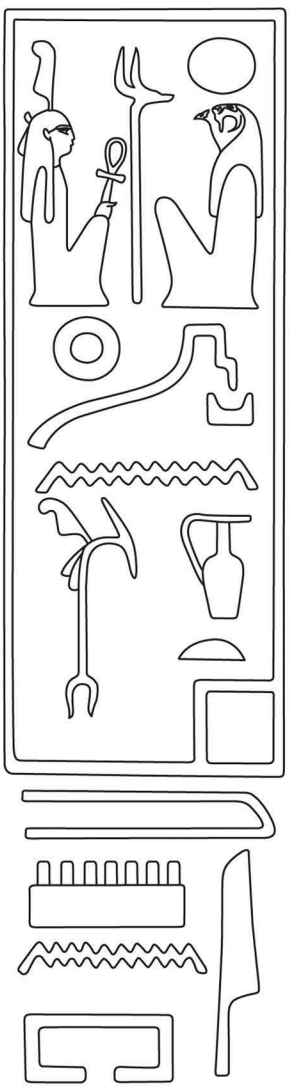

III - 1992

*Hany Hellal*
*Simulation of the probable Cause of Collapse of the First Pylon of the Ramesseum*

Le Bulletin MEMNONIA traite, en priorité, des études et recherches effectuées sur le temple de Ramsès II longtemps désigné sous l'appellation de *Memnonium*. Périodique annuel d'archéologie et d'histoire régionales, il contient également des études spécifiquement consacrées à Thèbes-Ouest, aire géographique connue sous le nom de *Memnonia* à l'époque gréco-romaine. Financé et édité par l'Association pour la Sauvegarde du Ramesseum, il est adressé gratuitement aux Membres d'honneur, aux Membres donateurs, bienfaiteurs et titulaires.

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# SIMULATION OF THE PROBABLE CAUSES OF COLLAPSE OF THE FIRST PYLON OF THE RAMESSEUM [Pl. VI-VII]

Hany HELAL*

## I.— INTRODUCTION

The Ramesseum, Ramesses II's "million years temple" with its economic complex spread on an area of about five hectares, is located on the west bank of the Nile, at Luxor. It was built during the 13$^{th}$ century B.C., and was considered the most beautiful architectural realization of the Ramesses II's reign. Unfortunately, this famous monument was damaged by various actions of time, man and nature.

The main entrance wall of the temple called by the Greek, "Pylon" is actually collapsed. It's eastern wall is completely failed (Pl. VI-A) while the western one has, till now its principal elements (Pl. VI-B), but it has been subjected also to severe deformation and distortion (Pl. VII), to the extent that its probable failure could be expected.

The general plan for the preservation of the temple includes an important phase of pylon restoration. Before any decesion could be taken concerning the adopted technique of restoration or reinforcement, a realiable and sound understanding of the probable causes and origin of the present state of collapse the pylon deems necessary.

Numerical modelling has been proved to be one of the powerful tools in identifying similar parameters [Helal et al., 1992 ; Verdel 1993].

The present work has been essentially planned to clarify the phenomenological character. It's main objective is not to quantify the collapse parameters but rather to describe and explain the mechanism of collapse and the role of different parameters in this process.

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## II.— STRUCTURAL CHARACTER OF THE PYLON

The structure of first pylon of the Ramesseum is not very well known because of its collapse. However, assuming similarity with other pylons on the east bank in Karnak and Luxor temples, together with site investigation of its ruin, a schematic diagram of the pylon could be deduced as shown in fig. 1. It's walls are made of sandstone blocks, each has an average volume of 2 $m^3$. The pylon was filled in its lower part by irregular blocks of limestone covered in the upper part by a ground filling of crushed limestone and Nile silt. Because it was built at the limit of the green valley and the desert, so it is believed by many authors [CEDAE et al.,], that the western foundation is completely founded on limestone bedrock, while the eastern one is laid on Nile silt.

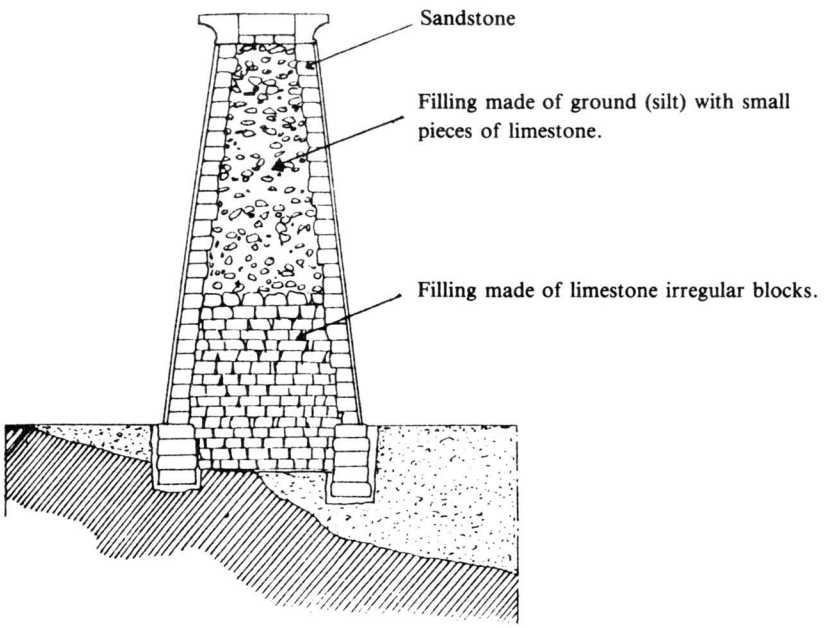



Fig. 1 - Structure of the pylon.

## III.— ASSUMED MECHANISM OF COLLAPSE

Regarding the actual state of the pylon, a description of collapsing mechanism has been assumed by the Architects and Egyptologists [CEDAE et al.] as shown on fig. 2. Such mechanism could be described as follows :

The original regular shape [A] of the pylon started to change most probably by settlement of the soil or by degradation of the foundation blocks due to the Nile flood. It's eastern wall showed, then, a more and more visible deformation [B] as it is observed actually in the pylon of Luxor temple. The filling of the upper part started to creep, exerting pressure on the eastern wall leading, with time, to the collapse [C].

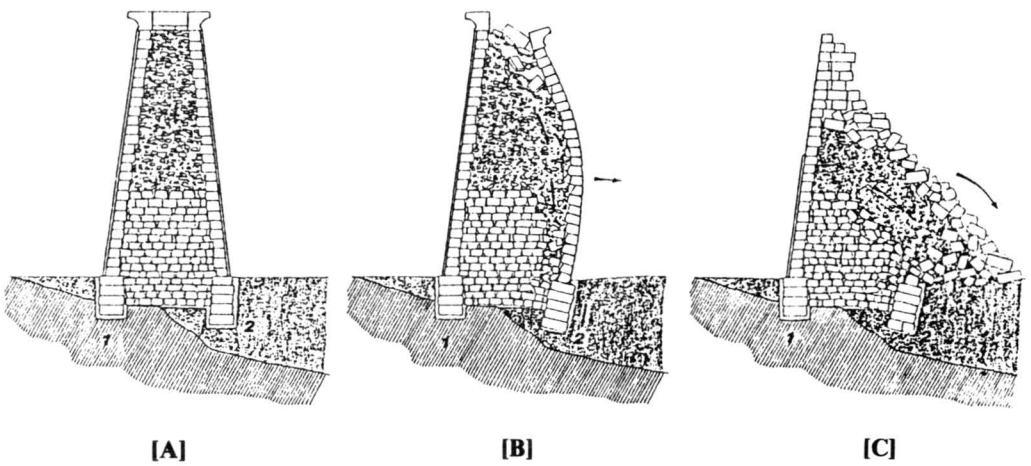



Fig. 2 - Assumed progress of pylon collapse.

## IV.— SIMULATION OF COLLAPSE

The assumed mechanism of collapse was based on the architectural concepts and observational conditions of the actual state of the pylon.

No evidences, e.g. measurement of geotechnical analysis, are availabe to confirm or infirm these assumptions of collapse.

No doubt that the proper restoration project should be based on a more realistic base, confirmed by field and analytical data. Thus computer simulation, text of present work, using numerical modelling could be the best tool to validate the assumed mechanism at the present stage of data-limited problem.

### IV-1. ADOPTED METHODOLOGY

From a mechanical point of view, the pylon could be considered as an assemblage of blocks grouped together under certain conditions of loading and deformation. The best suitable method of stability calculation of such

blocky structure is that of distinct elements on which the Universal Distinct Element Code UDEC [Itasca, 1988] is based. It allows the calculation of displacement and rotation of each block of the structure. A block could also be completely detached and new contact with other blocks could be established during calculation. UDEC uses an explicit resolution method and the blocks could be either rigid or deformable.

Since two-dimensional problem could only be treated with this code, a representative section of the pylon is used as shown in fig. 1, and plane – strain conditions are assumed (length/width ratio is about 5).

## IV-2. PARAMETRIC ANALYSIS

Various numbers of parameters could be responsible for the collapse of the pylon. Some of them could be easily evaluated such as material and joint properties, others could be estimated with difficulty, or even assumed such as the geometry of the pylon or the level of water table along the life-time of the pylon. Special events such as earthquakes are usually considered as dominant with reference to geotechnical parameters.

In the present work, simulation is focused only on degradation of foundation and its surrounding materials, as it appears to the author and other investigators as the most realistic factor regarding the frequent change of the Nile flood and its known effect on decreasing mechanical properties of materials. Further simulations have to be carried out in the future after investigating the role of degradation.

Simulation was carried out using UDEC [Itasca, 1988]. The geometry of the pylon represents one of the important factors for modelling. The used model shown in fig. 1 has almost kept the same character for all stages of simulations. The limestone filling was considered as large blocks and the upper filling as a mixture of silt and crushed limestone having very weak mechanical properties. The walls and the foundations are made of sandstone blocks.

The location of the surface separating the bed-rock and the valley silt with reference to the base of the pylon could influence greatly the stability of the pylon. Therefore, the present simulation, considers this relation, as shown in fig. 2, to touch the middle of the pylon base.

The physical and mechanical properties of materials and joints of the pylon of the Ramesseum are not available. No characterization were carried out on these materials. Therefore, average values for materials from similar sites as

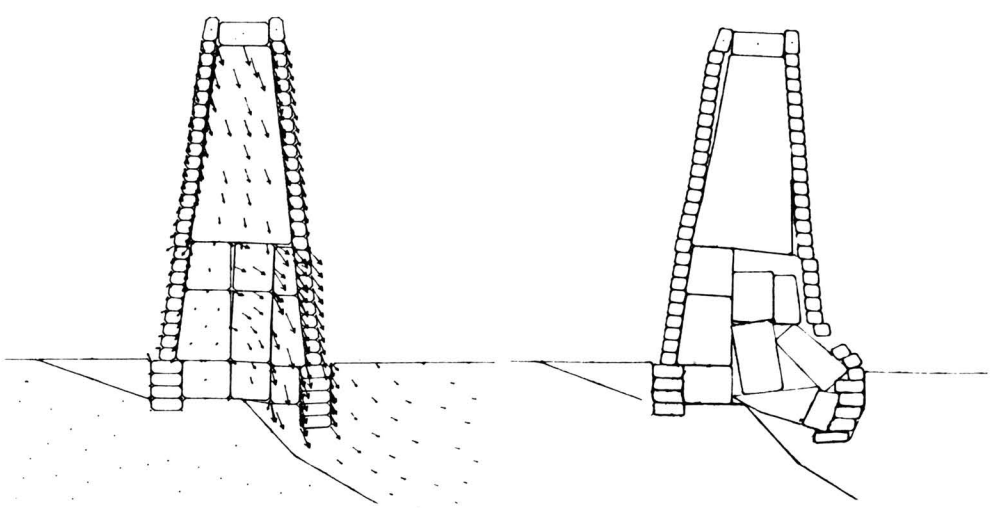
Karnak [Martinet, 1992] and El-Deir El-Bahari. [Helal and Abdallah, 1990] are used.

Degradation phenomenon was simulated by decreasing the mechanical properties of materials and joints. Degradation was assumed to affect the following parts of the pylon :

— The eastern foundation located in the valley side.
— The limestone filling.
— The Nile silt of the valley.

Several simulations were carried out on three stages :

— The first one concerned with single degradation of one part and the others are kept undergraded. No collapse was obtained.
— The second stage integrated two parts together. For example, degradation of both the eastern foundation and the limestone blocks and ... etc. Only great deformations were observed (fig. 3[a]) but not to the point of collapse.
— In the third stage, successive and simultaneous degradations were included which had led finally to collapse (fig. 3[b]).



[a]- Great deformation and settlement. [b]- Beginning of collapse.

Fig. 3 - Simulation of phenomenalogical collapse of the pylon using distinct element code [UDEC].

### IV-3. EVOLUTION OF COLLAPSE MECHANISM

Analysis of different simulation models revealed that collapse of the first pylon occurred in the form of a successive and simultaneous degradation process. The collapse mechanism could be outlined as shown on fig. 4.

It has been found that the initiating parameter is the degradation of the lower eastern part including both foundation and limestone filling. This is, may be, due to the Nile flood, which till 1964, reached this part of the pylon and could seriously, with time, degraded its mechanical properties.

With the weak properties of the silt and the settlement of the filling above the degraded part, the pylon started to incline towards the east (Valley) and a pivot of high compressive stress appeared shifted to the west, increasing the inclination of the pylon. The filling started to go down to the east, exersing horizontal pressure on the eastern wall and the pylon is no longer symmetric. The pylon became deformed, and because its internal structure was not rigid, collapse could be initiated by the movement of the eastern foundation.

## V.— CONCLUSION AND PERSPECTIVE

Restoration of the temple of the Ramesseum requires a realible understanding of the probable causes and origin of the collapse of the first pylon.

Several assumptions had been made concerning the mechanism of collapse based on visual investigation without any analytical or measuring methods.

When the present phenomenological analysis was performed with computer simulation using distinct element method, collapse was found to be a combined process of successive and simultaneous degradation of the eastern part of the pylon due to the action of repeated annual Nile flood.

The advantage of such phenomenological approach is its large capacity and flexibility of investigating the influence of several varying parameters at the same time, even with the data-limited problems as was the case of the first pylon of the Ramesseum. Also anticipated behaviour could be simulated.

Meanwhile, it should be stated, from engineering point of view, that the present phenomenological simulation will be of great help if real data concerning the material properties, the types of layers under the pylon and the geometry of the foundation, are available. The author believes that stage is necessary for future work of restoration.

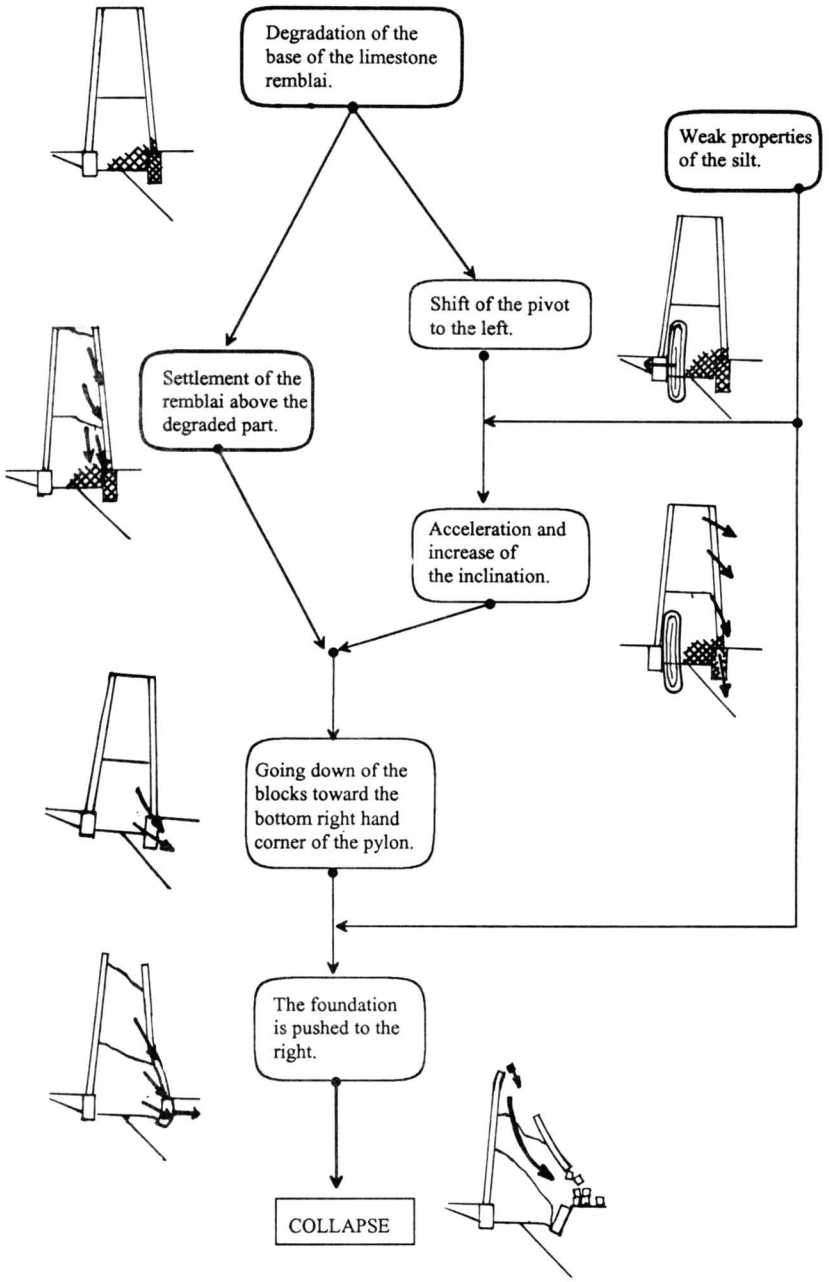



**Fig. 4 - Proposed mechanism of collapse phenomena.**

## VI.— ACKNOWLEDGEMENT

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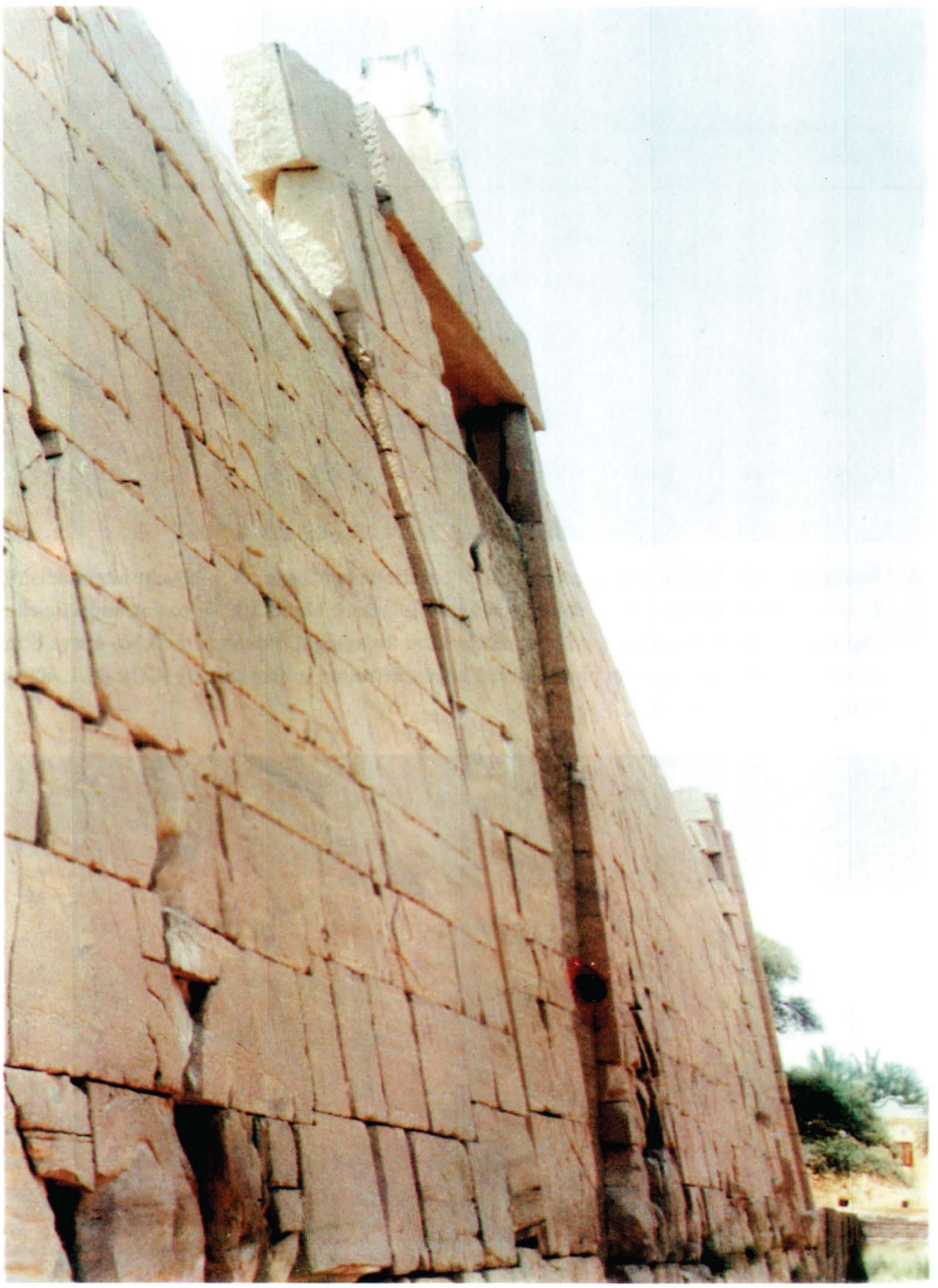
# planches

A.- Eastern side of the first pylon. (Cliché Hany Helal).

B.- Western side of the first pylon. (Cliché Hany Helal).



Deformation and distorsion of the western face of the first pylon. (Cliché Hany Helal).

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## Études



## Varia Thebaïca

Supervision montage et impression : Moustapha Fayçal Soliman.