wjert, 2021, Vol. 7, Issue 4, 370-391. Review Article ISSN 2454-695X

World Journal of Engineering Research and Technology

WJERT

www.wjert.org SJIF Impact Factor: 5.924

MECHANICAL ENGINEERING IN ANCIENT EGYPT, PART 100: TEMPLES-COLUMNS INDUSTRY

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Article Received on 18/06/2021 **Article Revised on 08/07/2021** **Article Accepted on 28/07/2021**

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ABSTRACT

The objective of this paper is to investigate the development of mechanical engineering in ancient Egypt through the study of the temples-columns industry. The study presents outstanding designs of temple-columns in ancient Egypt during time periods from Old Kingdom to Ptolemaic-Roman periods. It investigates the design methodology used by the ancient Egyptian architect and how he could simulate the local plants around him to design and produce stone columns with wonderful design, decoration and inscription.

KEYWORDS: Mechanical engineering history, ancient Egypt, temples-columns industry, palm columns, lotus columns, composite columns.

INTRODUCTION

This is the 100th part in a series aiming at investigating the mechanical engineering technology in ancient Egypt. It investigates the design and production of giant temple-columns during the ancient dynastic era of Egypt. This work was really difficult because of the discrepancy in the opinion of the Egyptologists about the ancient Egyptian columns. They sometimes name a column as lotus while others name the same column as papyrus. Beside too many divisions of the lotus column. I traced the ancient Egyptian columns used in their temples constructions and presented them under only three categories: palm, lotus and composite columns.

Pratt, 1880 in his paper about the column architecture of the Egyptians investigated the connection between the 'proto-Doric' pillars in Egypt and the columns of the Doric style in Greece.[1] Gulas, 2007 in his paper about the Osirid pillars and the renewal of Ramses III at Karnak investigated the meaning of Osirid pillars in the Amun-Re temple of Ramses III at Karnak. He presented reliefs for the inscriptions of some Osirid pillars.[2] Sullivan, 2010 in her paper about the development of the temple of Amun-Re at Karnak provided detailed survey of the current understanding of the temple chronological development based on published excavations reports, interpretive articles and recent discoveries at the temple's site. She presented a 3D visualization of the fourth pylon showing 14 columns in the Wadjet hall of the temple, double peristyle column of Thutmose IV, 3D visualization of the columned 'Bubastite court' in front of the second pylon, pillars of Khons Temple, columns in the kiost of Tharqo in the second pylon, columns in the Hakoris bark shrine.[3]

Hassaan, 2016 investigated the use of ancient Egyptians models of their houses to authorize their housing industry. He presented a house model from the 12th Dynasty with a pillar supporting the roof, a house model from the 12th Dynasty with pillars in the entrance and pillars supporting the roof of its second story, a house model from the 13th Dynasty with pillars supporting the roof of the first floor.[4] Azad and Barua, 2017 in heir paper about case studies of ancient Egyptian architecture stated that from the Old Kingdom onward, stone was generally reserved for tombs and temples. They presented drawings for the types of the columns capitals, a photo for the Hypostyle Hall of the Karnak Temple showing some of its columns.[5]

Sharafeldean, 2019 stated that Christians when began to erect their churches, they adopted some architectural features from the ancient Egyptian temples such as the Hypostyle Hall which was considered the prototype of the Basilican Plan of the church. She presented one of the Philae temple columns with Coptic Cross on it.[6] Braud, Feleg and Murnane, 2019 presented a view for the Great Hypostyle Hall at Karnak showing its columns and a line diagram for the Hypostyle Hall showing its main architectural divisions and the location of 134 columns in its third pylon North and South Towers.[7]

Hassaan, 2020 presented colored scenes for some of the pillars in the tomb of Senefer from the 18th Dynasty,[8] tomb of Pharaoh Seti I from the 19th Dynasty and tomb of Pharaoh Ramses IX from the 20th Dynasty.[9] Wikipedia, 2021 in their article about ancient Egyptian architecture presented a photo for the columns of the Great Hypostyle Hall in the Temple of

Karnak and the columns in the entrance of the Temple of Isis at Philae. They presented also a colored drawing for the types of capitals of some ancient Egyptian pillars drawn between 1849 and 1859 and a photo for a colored composite capital for a column in the Temple of Khnum at Esna.[10]

Design and Production of Palm Column-Capitals

The ancient Egyptians were pioneers in designing their products simulating physical plants around them in their society. An example of this is their design of column-capitals. They simulated palm leaves, lotus flowers and papyrus plant. Typical Egyptian palm leaves are shown in Fig.1 as captured from an Egyptian Oasis.[11] The ancient Egyptian architect used this palm tree to design his column-capital as shown in Fig.2 during the 5th Dynasty of the Old Kingdom, 2353-2323 BC as displayed in the Metropolitan Museum of Art.[12] The ancient Egyptian smart architect simulated the palm tree head through a series of palm leaves carved around a cylindrical core with circular bands in the bottom of the capital representing the origin of the leaves. The application of the palm column-capital design through Dynastic Egypt is investigated through the following examples:

The first example is a 4.94 m height granite palm-capital column from the 4th Dynasty of the Old Kingdom, 2524-2250 BC reused during the by Ramses II, the 3rd Pharaoh of the 19th Dynasty of the New Kingdom, 1279-1213 BC and his son Merneplah, the 4th Pharaoh of the 19th Dynasty, 1213-1203 BC in display in the Museum of Fine Arts at Boston and shown in Fig.3.[13] The capital has nine leaves ended by the abacus of the column and was transferred from the Temple of Harsaphes at Ihnasya el-Medina, Bani-Sweif, Egypt to the USA and erected in the Museum of Fine Arts. Its shaft was inscribed in a bounded column for Ramses II and Merneptah of the 19th Dynasty.

Fig.1: Palm tree in an Egyptian Oasis[11]

Fig.2: Palm column capital from the 5th Dynasty [12].

The second example is 6.65 m height granite palm-capital column of Sahure, the 2nd King of the 5th Dynasty, 2487-2475 BC, in display in the Metropolitan Museum of Art at New York and shown in Fig.4.[14] The design of the capital is similar to that of the 4th Dynasty shown in Fig.3 while the column-shaft has no inscriptions in the view shown in Fig.4.

- The third example is a granite fragment of a palm-capital column from the 5th Dynasty, 2494-2345 BC, in display in the Metropolitan Museum of Art at New York and shown in Fig.2 [12]. The design of the capital is similar to that of the 4th Dynasty shown in Fig.3 while the column-palm leaves supports the abacus of the column.
- The fourth example is granite palm-capital column inscribed for Ramses II, the 3rd Pharaoh of the 19th Dynasty, 1279-12135 BC with late inscriptions for Ostracon II, the 5th Pharaoh of the 22nd Dynasty, 872-837 BC in display in the British Museum at London and shown in Fig.5.[15] The design of the capital is similar to that of the 4th Dynasty shown in Fig.3 while the column-shaft has inscriptions for two pharaohs from the 19th and 22nd Dynasties and the palm leaves support the abacus.

Fig.3: Palm-capital column from the 4th Dynasty[13]

Fig.4: Palm-capital column from the 5th Dynasty[14]

The fifth example is a palm-capital column in the Temple of Isis at Philae of Egypt which was constructed beginning from 280 BC and shown in Fig.6.[16] The design of the capital is similar to that of the 4th Dynasty shown in Fig.3 while the column-shaft has no inscriptions and the palm leaves support the abacus.

The sixth example is a palm-capital column in the Hypostyle Hall of Edfu Temple (Temple of Horus) which was constructed beginning from 237 BC in display in the British Museum and shown in Fig.7.[17] The design of the capital is similar to that of the 4th Dynasty shown in Fig.3 while the column-shaft has bounded column inscriptions carved on the shaft and the palm leaves support the abacus.

Fig.5: Palm-capital column from the 19th Dynasty[15]

Fig.6: Palm-capital column from Isis Temple[16]

Fig. 7: Palm-capital column from Horus Temple.[17]

Design and Production of Lotus-Column-Capitals

The Egyptian lotus flower is a white water lily or a blue lotus used by the ancient Egyptians for decoration and simulation processes as in column-capital design.[18] The lotus flower has the capability to open its petals (open bud) or close them (closed bud). Fig.8 shows an open white lotus flower.[18] Fig.9 shows an open blue lotus flower.[19] The actual appearance of those flowers was the guidance of the ancient Egyptian architects to design wonderful column-capitals simulating the lotus flower. A lotus flower with closed bud has the shape shown in Fig.10.[20] The ancient Egyptians drawn symbols for both open and closed lotus buds as shown in Fig.11.[21]

Fig. 8: White lotus flower.[18]

Fig. 9: Blue lotus flower.[19]

Fig. 10: Closed lotus flower bud.[20]

Fig. 11: Symbol of open and closed lotus buds.[21]

The ancient Egyptian architect simulated a partially cut locus closed flower bud as a basis for his design of the lotus-closed-bud column capital as illustrated in Fig.12.[20,22] He simulated a partially cut locus open flower bud as a basis for his design of the lotus-open-bud column capital as illustrated in Fig.13.[20,23]

Top-cut closed bud lotus flower closed-bud

column capital in Karnak Temple.[22]

Fig.12: Design of closed-bud lotus capitals[20,22]

Top-cut open bud lotus flower.[21]

Open-bud column capital in Karnak Temple [23].

Fig.13: Design of closed-bud lotus capitals [21,23]

In both designs of Fig.12 and Fig.13, the ancient Egyptian architect made the column-shaft thicker than the lotus plant shaft to overcome the load acting on the column and transferred to the ground. This exploits how the ancient Egyptians were pioneers in planning, design and production.

Design and Production of Lotus-Closed-bud-Column-Capitals

The idea of closed-bud column-capital design as presented in Fig.12 was applied to columns used in a number of temples in ancient Egypt as will be illustrated by the following examples:

The first example is a column with lotus closed-bud capital erected in the Great Hypostyle Hall of the Karnak Temple Complex built during the 2055 BC - 100 AC Period in Luxor of Egypt and shown in Fig.14 [24]., It has the characteristics:

- The shaft is smooth and cylindrical.
- Both shaft and capital are decorated by carving hieroglyphic texts defining historic events in the time of inscription.
- The column supports an abacus and an architrave to transfer compressive load to the ground.

The second example is a sandstone column with lotus closed-bud capital erected in the Festival Temple of Thutmose III, 6th Pharaoh of the 18th Dynasty, 1479-1425 BC inside the Karnak Temple Complex in Luxor of Egypt and shown in Fig.15 [25]., It has the characteristics:

- The shaft is smooth, cylindrical and coated by mud bricks.
- The mud bricks were decorated by blue bands.
- The column supports an abacus and an architrave to transfer compressive load to the ground.

Fig. 14: Closed-bud-capital column in Karnak Temple.[24]

Fig. 15: Closed-bud-capital column in Thutmose III Temple.[25]

The third example is a column with lotus closed-bud capital erected in the Hypostyle Hall of Amenhotep III, 9th Pharaoh of the 18th Dynasty, 1388-1350 BC inside Luxor Temple in Luxor of Egypt and shown in Fig.16.,[26] It has the characteristics:

- The shaft is smooth, cylindrical in some of its parts.
- The other parts of the shaft were decorated by plant stacks.
- The capital was decorated by plant stacks as well.
- The column supports an abacus and an architrave to transfer compressive load to the ground.

The fourth example is a column with lotus closed-bud capital erected in the Hypostyle Hall of the Ramesseum Mortuary Temple at Luxor built by Ramses II, 3rd Pharaoh of the 19th Dynasty, 1279-1213 BC shown in Fig.17.,[27] It has the characteristics:

- The shaft is smooth, semi-cylindrical along its length.
- The capital was smooth without any decoration or inscription.
- The column supports an abacus and an architrave to transfer compressive load to the ground.

Fig.16: Closed-bud-capital column in Luxor Temple[26]

Fig.17: Closed-bud capital columns in the Ramesseum Mortuary Temple [27].

The fifth example is a closed bud column in the Temple of Khonsu inside the Karnak Temple Complex constructed during the reign of Ramses III, the 2nd Pharaoh of the 20th Dynasty, 1186-1155 BC and shown in Fig.18.[28] They have the characteristics:

Fig.18: Closed-bud-capital column from Khonsu Temple[28]

- The design is similar to that in the Ramesseum Mortuary Temple at Luxor.
- The shaft is smooth and partially cylindrical.

- Both shaft and capital are decorated by damaged carving hieroglyphic texts and reliefs defining historic events in the time of inscription.
- Each column supports an abacus and an architrave to transfer compressive load to the ground.

Design and Production of Lotus-Open-bud-Column-Capitals

The idea of open-bud column-capital design as presented in Fig.13 was applied to columns used in a number of temples in ancient Egypt as will be illustrated by the following examples:

The first example is a column with lotus open-bud capital erected in the Karnak Temple Complex built during the 2055 BC - 100 AC Period in Luxor of Egypt and shown in Fig.19.[29] It has the characteristics:

- The shaft is smooth and cylindrical.
- Both shaft and capital are decorated by carving horizontal thin bands on its circumference.
- The column supports an abacus and an architrave to transfer compressive load to the ground.

The second example is two columns with lotus open-bud capitals erected in the Great Hypostyle Hall of the Karnak Temple Complex during the New Kingdom, 1550-1070 BC and shown in Fig.20,[30] They have the characteristics:

- The shaft is smooth, cylindrical and decorated by historical reliefs and inscriptions.
- The capitals had two rectangular plates with curved transition between them.
- Each columns supports an abacus and the abacuses support an architrave to transfer compressive load to the ground.
- The third example is columns with lotus open-bud capital erected by Pharaoh

Thutmose IV in the fourth Pylon of the Karnak Temple Complex, 8th Pharaoh of the 18th Dynasty, 1398-1388 BC and shown in Fig..21.,[31] It has the characteristics:

- The shaft is smooth, rectangular and decorated by historical reliefs and inscriptions on a mud layer.
- Each capital has two rectangular plates with different thickness with curved transition between them.

- The columns support architraves without abacuses to transfer compressive load to the ground without decorations.
- The columns have no base.

Fig.19: Open-bud-capital column in the Karnak Temple[29]

Fig.20: Open-bud capital columns in the Great Hypostyle Hall, Karnak Temple [30].

Fig.21: Open-bud-capital columns in the 4th Pylon of the Karnak Temple[31]

Fig.22: Open-bud capital columns in the Kom Ombo Temple [32].

The fourth example is columns with lotus open-bud capitals erected in the Hypostyle Hall of the Kom Ombo Temple at Aswan built during the Ptolemaic Period, 180-47 BC and shown in Fig.22,[32] They have the characteristics:

- The shaft is smooth, cylindrical without clear decorations.

- The columns support the architraves through abacuses emerging from the capitals to transfer compressive load to the ground.
- Each column has a base to reduce the bearing capacity of the column under the compression load.

The fifth example is columns with lotus open-bud capitals erected in the Hypostyle Hall of the Temple of Isis built by Nectanebu I, the founder of the 30th Dynasty of the Late Period, 380-362 BC and shown in Fig.23.,[33] They have the characteristics:

- The shaft is smooth, cylindrical with horizontal grooves on the circumference of the bottom 87 % of its length.
- The 13 % of its top length is decorated by papyrus stacks on all over the circumference.
- The capital is decorated by papyrus flowers on the whole circumference of the capital.
- The columns support the architraves through abacuses emerging from the capitals to transfer compressive load to the ground.
- Each column has a compound base to reduce the bearing capacity of the column under the compression load.

Fig. 23: Open-bud capital columns in the Temple of Isis.[33]

Design and Production of Composite-Column-Capitals

The ancient Egyptian architects were genius and had great creativity in design, production and finishing. As we have seen in the previous sections, they used palm leaves, closed lotus buds, open lotus buds and papyrus flowers to design column-capitals. Regarding papyrus

flowers, they naturally look like those presented in Fig. 24.[34] The ancient Egyptians draw the papyrus flower as shown in Fig.25.[35]

Fig. 24: Egyptian papyrus plant.[33]

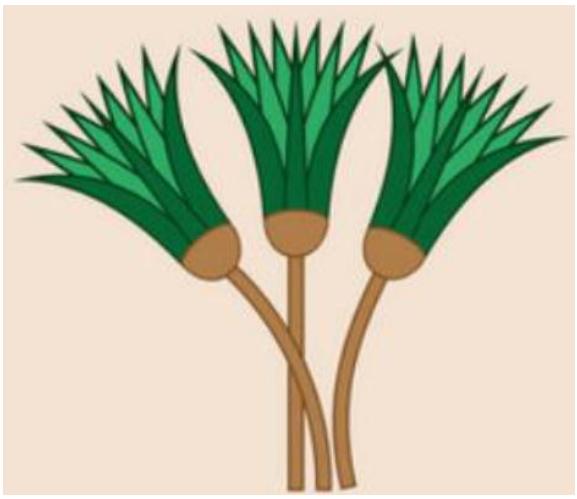

Fig. 25: Egyptian papyrus plant as drawn by ancient Egyptians.[34]

They could combine the four design origins to present new composite design for the column-capitals as will be illustrated by the following examples:

The first example is a column with a composite capital from the Mortuary Temple of Ramses III, 2nd Pharaoh of the 20th Dynasty, 1186-1155 BC located in Medinet Habu at Luxor and shown in Fig.26.[35] It has the characteristics:

- The capital has a main open-lotus flower shape in the top.
- The next level is composed of palm-leaves arranged beside each other.
- Then lotus-flowers arranged beside each other.
- Then lotus-flower-petals arranged beside each other.
- Then an array of lotus flowers having small size than that in the top.
- Then an array of papyrus flowers arranged beside each other.
- Then a papyrus stack on all over the circumference of the bottom part of the capital.
- The shaft is cylindrical and simulating a papyrus stack.

Fig. 26: Composite column-capital in the Mortuary Temple of Ramses III.[36]

The second example is column with composite capital in the Temple of Ptah at the Karnak Temple Complex at Luxor erected by Pharaoh Ramses III of the 20th Dynasty shown in Fig.27,[37] It has the characteristics:

- The capital has a main open-lotus flower shape in the top.
- Then an array of papyrus flowers arranged beside each other.
- Then a papyrus stack on all over the circumference of the bottom part of the capital.
- The shaft is cylindrical and smooth.

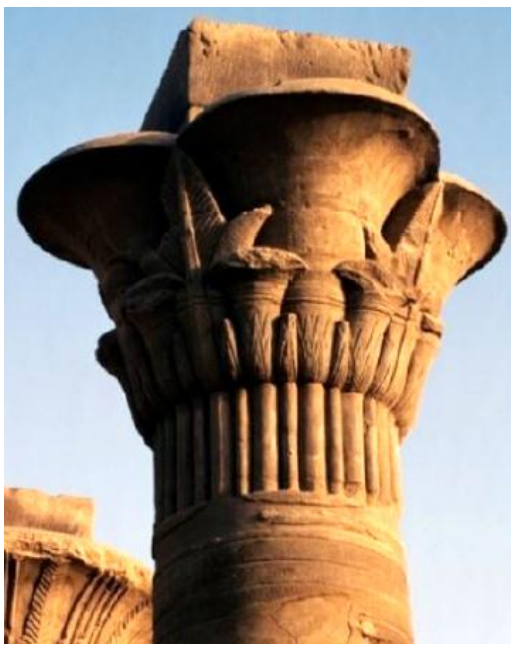

Fig. 27: Composite column-capital in the Temple of Ptah at Karnak.[37]

The third example is column with composite capital in the Temple of Isis at Philae near Aswan erected by Pharaoh Nectanebo I, Founder of the 30th Dynasty, 380-362 BC shown in Fig.28,[38] It has the characteristics:

- The capital has a main array of open-lotus flowers.
- Then an array of papyrus flowers in front of palm-leaves interchanging with the lotus flowers.
- Then a papyrus stack on all over the circumference of the bottom part of the capital.
- The shaft is cylindrical and smooth decorated by horizontal grooves directly under the column-capital.
- The column abacus supports an architrave where both are decorated by hieroglyphic texts including the Cartouche of the Pharaoh on the abacus.

The fourth example is column with composite capital erected by Pharaohs Nectanebo I and Nectanebo II of the 30th Dynasty, 380-343 BC and now in display in the Metropolitan Museum of Art at New York and shown in Fig.29,[39] It has the characteristics:

- The capital has a main open-lotus flowers in the top.
- Then an array of papyrus flowers interchanging with the lotus flowers.
- Then a papyrus stack on all over the circumference of the bottom part of the capital.
- The column-shaft is cylindrical and smooth.

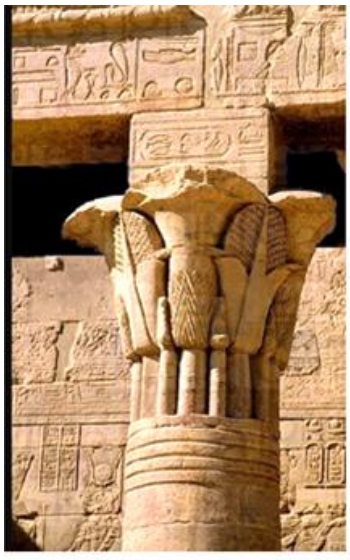

Fig.28: Composite column-capital in the Temple of Isis[38]

Fig.29: Composite column capital from the 30th Dynasty [39].

The fifth example is column with composite capital completed during the Ptolemaic and Roman Periods, 40-250 AC in the Temple of Khnum at Esna shown in Fig.30.[40] It has the characteristics:

- The capital has a main open-lotus flower decorated on the external surface by six arrays of plant elements.
- Palm rachises emerge from the bottom of the capital of the capital circumference towards the top edge of the capital.
- Palm leaflets constitute the first later of the capital decorations.
- Then, five layers of papyrus flowers foloow towards the bottom end of the capital.
- Then a papyrus stack on all over the circumference of the bottom part of the capital.
- Colored horizontal bands decorates the part just below the papyrus stacks.
- The column-shaft is cylindrical and decorated by colored inscriptions.

Fig. 30: Composite column-capital in the Temple of Khnum at Esna.[40]

CONCLUSION

- This paper investigated the evolution of mechanical engineering in ancient Egypt through the study of the design and production of temple columns.
- The oldest column-capital type was the palm capital. The paper investigated their origin and how the ancient Egyptian architects designed them.
- Palm columns from the 4^{th}, 5^{th}, 19^{th} Dynasties and from the Ptolemaic Period were presented.

- They designed and produced column-capitals based on the lotus flower with closed and open buds.
- The design methodology of column-capitals based on lotus flower simulation was investigated.
- Column-capitals based on lotus-closed bud from the 18^{th} and 20^{th} Dynasties were presented and characterized.
- Column-capitals based on lotus-open bud from the New Kingdom, 18^{th}, 30^{th} Dynasties and Ptolemaic Period were presented and characterized.
- They designed and produced column-capitals of composite nature based on lotus, palm and papyrus plants.
- Column-capitals based on composite designs from the 20^{th}, 30^{th} Dynasties, Ptolemaic and Roman Periods were presented and characterized.
- They designed column-shafts with circular and square cross-sections with or without decorations
- They decorated some of their column-shafts to look as papyrus stacks.
- They used some of the column-shafts, abacuses and architraves as panels for events documentation through scenes and texts.
- Some of the columns were transferred from Egypt to some National Museums such as the British Museum and Metropolitan Museum of Arts.

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BIOGRAPHY

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