World Journal of Engineering Research and Technology
WJERT
www.wjert.org
SJIF Impact Factor: 5.924

MECHANICAL ENGINEERING IN ANCIENT EGYPT, PART 89: MANAGEMENT OF A COLOSSAL STATUE TRANSPORTATION PROJECT

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Article Received on 29/04/2020 **Article Revised on 19/05/2020** **Article Accepted on 09/06/2020**

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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 management of the transportation project of Nomarch Djehutihotep of the 12th Dynasty. This study presents how the ancient Egyptian artists gathered a lot of management and technical information in a single scene. It presents the objectives of the statue transformation project, management of the statue lashing process, management of the hauling force, transportation project supervision and management of the project documentation.

KEYWORDS: Mechanical engineering history, ancient Egypt, project management in ancient Egypt, Colossal statue transportation, Dynasty 12.

INTRODUCTION

This is the 89th part in a series aiming at investigating the mechanical engineering technology in ancient Egypt. It investigates the application of the ancient Egyptian mechanical technology in transporting a 6.75 m height colossal statue from the quarry where it was carved to its final place where it was erected.

El-Marashly, 1990 in his investigation of project management during the era of ancient Egypt studied the stones transport management. He presented how the ancient Egyptians had a top awareness of planning, organization and control aiming at safe transportation. He

summarized the management of the 150 ton (!) statue transport in 8 steps.[1] Bloxam, 2003 in her Ph.D. Thesis referred to the transportation scene of Djehutihotep statue as painted in his tomb at El-Bersheh. She outlined that sledges were used in moving statues and shrine. She re-stated the statement of Newberry that Djehutihotep transport scene is probably the most referred to depict exploring stone transport from quarry.[2] Willems, Peeters and Verstraeten, 2005 in their paper about the erection position of the colossal statue of Nomarch Djehutihotep of the 12th Dynasty outlined that the scene in his tomb at Deir el-Barsha is one of the very few sources informing how the ancient Egyptians managed to transport large stones over land. They presented a translation for the text accompanying the scene.[3]

Fall et.al., 2014 in their letter to the Physical Review Letters handled the sliding friction on wet and dry sand based on their investigation of the colored scene in the 1880 BC tomb of Djehutihotep of the 12th Dynasty. They investigated experimentally the variation of the coefficient of friction with load and percentage witness of the sand under the load. They concluded that their investigated optimal friction value is 0.3 while that of the ancient Egyptians was 0.33 based on the tomb drawing.[4] Ayrinhac, 2016 in his paper about the transportation of the Djehutihotep statue studied the scene in Djehutihotep's tomb as a lubrication application and reviewed the physical parameters involved in the transportation process. He estimated by calculations that the coefficient of friction during the statue transportation process was between 0.05 and 0.26.[5] De Meyer and Willems, 2016, 2017 investigated and presented not only the transportation scene of Djehutihotep but also the surrounding scenes including 13 columns text just behind the transportation scene. They presented texts within the scenes including evidence that the colossal statue of Djehutihotep was erected in his Ka-Chapel near the Eastern Bank of the Nile at Tjerty of Deir al-Bersha.[6] Siemens, 2018 in his paper about bridging the gap between research and practice regarding the investigated soil mechanics, he presented a small part of the extensive scene in the tomb of Djehutihotep painted during the 12th Dynasty of ancient Egypt. He outlined that 30 % reduction reducing in pulling load was found for the optimized moisture content compared with dry and wetter sand.[7] Wikipedia, 2020 outlined that Djehutihotep was a Normach of the 15th Nomos of Upper Egypt during the reign of Kings Amenemhat II, Senusret II and Senusret III of Dynasty 12. They presented the scene in his tomb and how his statue was transported. They outlined that the scene was destroyed in 1890 (but they didn't say how).[8] Monnier, 2020 in his paper about the transportation of Djehutihotep statue provided photos for the transportation scenes and the texts associated with it. He presented a description for

the scene and a French translation for its text. He described the technique used in the transportation process.[9] Hassaan, 2020 investigated some important aspects in the project management of the Great Pyramid constructed by the ancient Egyptians during the 4th Dynasty. He explored the application of project management technologies such as planning, design, construction, logistics and documentation by ancient Egyptians more than 4500 years ago.[10]

The Transportation Scene

Many resources presented the transportation scene of Nomarch Djehutihotep.[1,2,4,6-9] Most of this presentation did not include the 13 columns text behind the transportation scene and the scene of the main supervisor of the transportation process drawn just behind the 13 columns text.[6] Because of the destruction of the wealthy scenes of its owner's tomb in the 19th century some of the modern artists have drawn the transportation scene according to its original appearance as shown in Fig.1.[11]

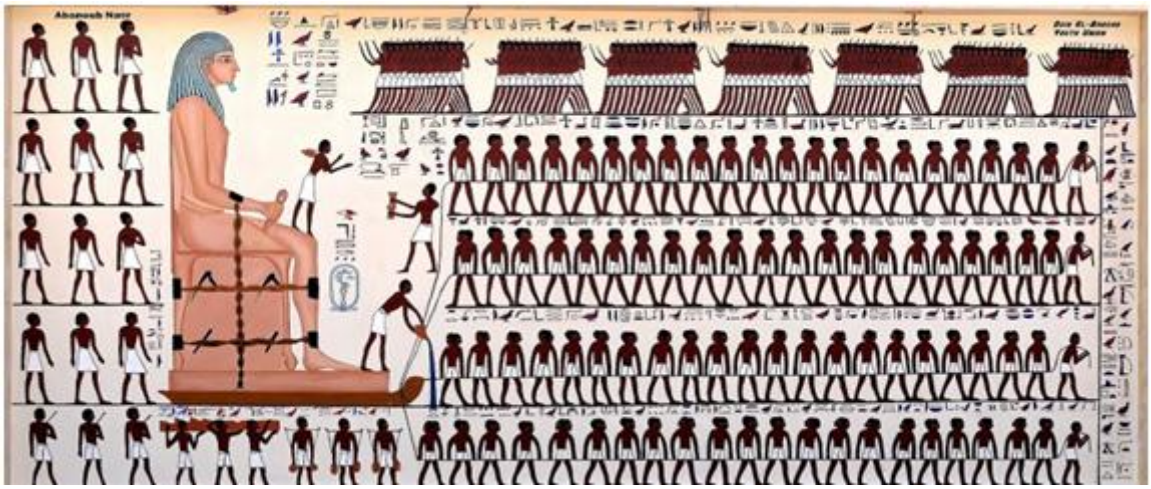

Fig. 1: Transportation of the Djehutihotep statue.[11]

The transportation scene of Fig.1 includes the following activities:

- Securing the statue on a sledge using 3 robes.
- Pulling the statue using 4 rows of 22 men each.
- Directing the haulers men by a foreman standing over the leg of the statue.
- Pouring lubrication water in front of the sledge by a labor standing over the base of the statue to reduce the pulling force by reducing the coefficient of friction.
- Burning incense by a man facing the statue to refresh the stone haulers.

- Supplying the lubricating man with water and the pulling men by drinking water by a team of three men carrying 6 water jars fixed by robes to yokes on the men shoulders.
- Providing a transportation problem solving wooden bar with beveled end carried by 3 men moving near the end of the statue.
- The water supply process and providing the wooden bars was supervised by three supervisors in back of the working men holding short scepters in their left hands as a tradition of work supervision in ancient Egypt.[12]
- The transportation process is supervised by 12 supervisors in 4 rows just behind the statue with probable 3 Chief-Supervisors putting their left hands on their chest (leading the first 3 rows).
- Celebrating the occasion of Djehutihotep statue transportation by 7 groups of troops and priests coming from some Nomos of Upper Egypt and holding palm-branches in their hands.
- This occasion was documented by hieroglyphic text written neatly in horizontal and vertical columns within the transportation scene and behind it (as will be seen in Fig.2). The text reflects high level literature and very advanced psychology. For example, the text above the 7 celebrating groups says: '*hearts are glad, elders are children, young are refereshed, children are ejoice*'.[13]
- The overall supervision of the transportation process was carried by a Superintendent (Chief Advisor) drawn in a separate scene after a 13 columns text shown in Fig.2 [6]. The scene depicts the following activities:
- Completing the documentation of the transportation process through writing in 12 bounded columns and one un-bounded column just after the transportation scene.
- Showing the Superintendent striding, looking to all the workers in the project and holding two scepters: a long one in his left hand and a Sekhem-Scepter in his right hand.

Fig. 2: Master supervision of the transportation of the Djehutihotep statue.[6]

Project Objectives

- The project main objective was to transport a 70 ton[5] or 80 ton[3] mass statue from Hatnub Quarries (18 km South-West of Amarna[5] or 16 km over Hatnub-Amarna Road [14] to its erection location in the Djehutihotep Chapel at Deir el-Bersha.[3]
- Providing about 16 supervisors to make sure that the transportation process will succeed to take the statue to its destination location.
- Supplying the hauling team with all logistics required to complete the work successfully.
- Providing clear documentation clarifying the transportation process.

Fig.3: Statue lashing to sledge.

Management of the Lashing Process

- The lashing technique is shown in Fig.3 (taken from Fig.1).
- The lashing process is performed using 3 robes.
- The main lashing robe is the vertical where it is attached

- To the sledge through two rings on its top surface from
- Both sides. The robe goes over the two forearms of the
- Statue over a rough soft material such as palm fiber.
- Most probably the forearms were roughened by the carvers
- Near its middle for sake of transportation. After which
- It will be polished after erection in its final place. This
- Is simply to prevent the robe from slipping towards the wrests of the statue and to prevent scratching the forearms.
- One more point here is the design of the statue forehand and wrest. It was designed to be a fixed-fixed beam to give it more strength (in general) and during lashing with the sledge.
- What is about the two horizontal robes?. They look tightening the legs of the statue and its base. This looks not-logical. Speculations of their function:

- The sledge may have an L-shape and the two robes tighten the legs to the vertical part of the L-shape.
- The statue is carved as a separate part from its base and the robes tighten them together with strengthening parts fit behind the legs to prevent breaking during tightening. After transportation the two parts will be cemented together (it is easy for the ancient Egyptians to do this with this heave stone statue).
- Tightening the vertical robe by tightening the horizontal robes passing over it using torsion rods.

Management of the Pulling Force

- This is an Engineering Mechanics Problem. It is required to pull a M mass statue secured to a wooden sledge over a sandy soil with specific properties with speed v and coefficient of friction μ. What is the pulling force?
- Researchers handled this problem and proved that ancient Egyptians were very clever to solve this problem and hence allocate the number of manpower required to achieve this objective.
- To reduce the number of men required to pull the statue, they used water to lubricate the sand.
- They could set an optimal value for lubricant water to get a minimum pulling force.

- The configurations of the transportation process and the information data provided by the transportation-documentation helped the researchers to allocate the minimum friction coefficient achieved by the ancient Egyptians during the transportation process.[4,5,7]
- The mechanism used by the ancient Egyptians to apply sand lubrication is shown in Fig.4 captured from Fig.1. Sure, the Lubricant-Operator moves left and right to cover the whole area of sand in front of the sledge.
- They managed to keep water logistics as close as possible to the Lubricant-Operator.
- They planned to use 4 double rows (!) of hailers pulling robes secured to the Sledge.
- They used 4 haulers rows and 4 robes secured to the sledge to apply the pulling force uniformly in the motion direction and prevent any angular motion during the axial movement.
- Fig.5 shows one row captured from Fig.1. Counting the number of men in the row we get 22. With four double rows, the total number of haulers becomes 176. Researchers stated that they were 172.[15]
- It is a single row, and then the number of haulers will be 88.

Fig. 4: Lubrication mechanism.

Fig. 5: Haulers team in the second row.

Project Supervision

- The ancient Egyptians used extensively different levels of Project Supervision in most of their works.
- Modern management sciences say that site supervision has a major influence on the overall performance and efficiency of construction projects and inadequate supervision is one of the major causes of rework.[16]
- Now, did they know these advanced aspects related to Project Supervision?.

- In fact, one would say '*yes*'. Look for example to the application presented here regarding the transportation of Tjehutihotep statue.
- They have used three-levels of the transportation project supervision. The 3 levels of project supervision are shown in Fig.6 as captured from Fig.1 and 2.

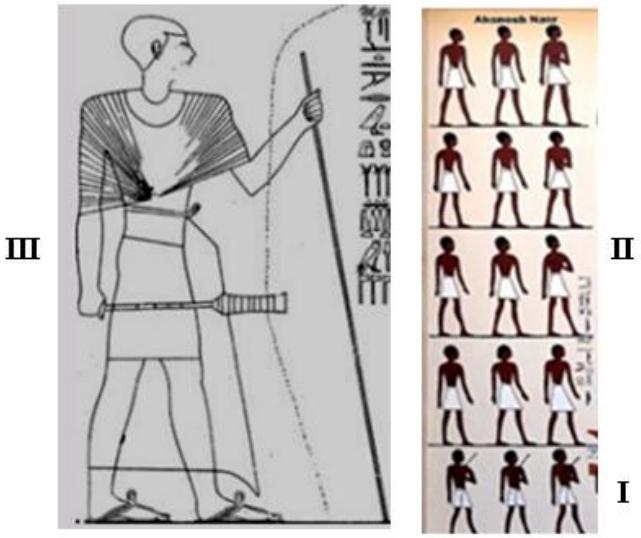

Fig.6: 3 levels of Project Supervision.

- Level I: A low level supervision consisting of 3 in one row supervisors supervising the logistics suppliers. The artist had drawn those supervisors with less size than the others indicating their less rank.
- Level II: 12 medium rank Supervisors in 4 rows supervising the whole transportation process.
- Level III: One superintendent (higher supervisor) leading the supervisors operation and making sure that the transportation process is going in the right track.

Management of the Project Documentation

- Is documentation of project information important in project management?.
- According to management experts: '*the documentation of information system is a component of communication, control and monitoring of the development, operation maintenance. It is important from the viewpoint of project management and of its development and operation*'.[17]
- The fact that the ancient Egyptians followed different ways of information documentation {[18]-[25]} makes any researchers say that they knew this modern definition of documentation importance and practiced documentation in broad and innovative ways.

- In the present application on project management, they documented the transportation of Djehutihotep statue through:

- Writing exactly above the 4 rows of the statue hailers, the festival-celebrators row in unbounded text-rows, water supply porters and wooden block carriers.
- Writing in vertical unbounded columns in front of the statue head, two columns in front of the head of the foreman directing the hauling process, one column above the head of the incense burning operator, one column in front of the leg of the statue in a bigger size font and a Cartouche and two long vertical colomns in front of the four hauling rows.
- One block of vertical information text written in front of the superintendent of the statue transportation process. It comprised 12 bounded text-columns and one unbounded vertical column of bigger font size.

CONCLUSION

- This paper investigated the evolution of mechanical engineering in ancient Egypt through the study of the management of the transportation of the colossal statue of Nomarch Djehutihotep during the 12^{th} Dynasty of ancient Egypt.
- The transportation scene of Djehutihotep was described highlighting most of the mechanical activities in it.
- The objectives of the statue transportation scene were clarified.
- Different aspects of the lashing technique of the statue on the wooden sledge were identified exploring some important mechanical features in this operation.
- The ancient Egyptians invented a pioneer technique to reduce the hauling force through lubricating the sand under the sledge by allocating an expert operator for this job. This lubrication process could decrease the hauling force by about 30 %.
- They used 4 rows of haulers pulling the sledge using 4 robes arranged horizontally and secured to the sledge front to apply almost equal 4 forces to the sledge resulting in moving the sledge in a straight path and avoiding any yaw motion.
- The project documentation was analyzed showing how the ancient Egyptians documented this project through the scene itself using hieroglyphic texts written in bounded and/or un-bounded horizontal and vertical columns in an innovative manner.

REFERENCES

1. El-Marashly, A., "Project management as perceived from ancient Egypt projects", In Reschke, H. and Schelle, H. (Editors), "Dimensions of project management", Springer-

Verlag, 1990; 275-289.

2. Bloxam, E. G. "The organization, transportation and logistics of hard stone quarrying in Egyptian Old Kingdom: A comparative study ", Ph. D. Thesis, University of London, 2003.
3. Willems, M. H., Peeters, C. and Verstraeten, G., "Where did Djehutihotep erect his colossal statue ?", ZAS, 2005; 132: 173-189.
4. Fall. A. Sliding friction on wet and dry sand", Physical Review Letters, vol.112, issue 17, Letter, 2014; 125502: 4.
5. Ayrinhac, S., "The transportation of the Djehutihotep statue revisited", Tribology Online, 2016; 11(3): 456-473.
6. De Meyer, M. and Willems, H. "The regional supply chain of Djehutihotep Ka-Chapel in Tjerty", Cohiers de recherché de I'Institut de Papyrologie et d'Egyptologie de Lille ER, 2016-2017; 31: 33-56.
7. Siemens, G. A. "Thirty-ninth Canadian geotechnical colloquium: Unsaturated soil mechanics- bridging the gap between research and practice", Canadian Geotechnical Journal, 2018; 55: 909-927.
8. Wikipedia "Djehutihotep", https://en.wikipedia.org/wiki/Djehutihotep, 2020.
9. Monnier, F. "Lascene de tractendu collossede Djehutihotep: Description, traduction et reconstruction", The Journal of Ancient Egyptian Architecture, 2020; 4: 55-72.
10. Hassaan, G. A. "Mechanical engineering in ancient Egypt, Part 88: Great Pyramid project management", International Journal of Engineering and Techniques, 2020; 6(3): 1-14.
11. Curiosmos, "Wet sand and wooden sledges: Is this how ancient Egyptians moved massive stones", https://curiosmos.com/wet-sand-and-wooden-sledges-is-this-how-ancient-egyptians-moved-massive-stones/.
12. Hassaan, G. A. "Mechanical engineering in ancient Egypt, Part 87: Scepters industry" , International Journal of Research in Management, Architecture, Technology and Engineering, 2019; 5(9): 1-12.
13. Netcher, S. "Colossal statue of Djehutihotep", https://seshmedewnetcher.com/colossal-statue-of-djehuti-hotep/, 2014.
14. Shaw, I. "Retracing the roots between the River Nile and the Hatnub travertine quarries", in Forster, F. and H. Riemer (Editors), "Dissert road archaeology in ancient Egypt and beyond", Heinrich-Barth-Institut, 2013.
15. Kelly, R, and Thomas, D. "Archaeology", Wadsworth, 2010; 192.

16. Alwi, S., Hampson, K. and Mohamed, S. "Effect of quality supervision on rework in the Indonesian context", Asian Pacific Building and Construction Management Journal, 2001; 6: 2-6.
17. Oprea, D. and Mesnita, G. "The information systems documentation – Another problems for project management", Managing Information in the Digital Economy: Issues and Solutions, November issue, 2006; 332-338.
18. Hassaan, G. A. "Mechanical Engineering in ancient Egypt, Part 63: Palettes industry", World Journal of Emerging Research and Technology, 2018; 4(2): 168-194.
19. Hassaan, G. A. "Mechanical Engineering in ancient Egypt, Part 66: Stelae industry (Third Intermediate Period and Late Period)", International Journal of Emerging Engineering Research and Technology, 2018; 6(6): 25-32.
20. Hassaan, G. A. "Mechanical Engineering in ancient Egypt, Part 67: Ostraca industry", World Journal of Emerging Research and Technology, 2018; 4(4): 45-52.
21. Hassaan, G. A. "Mechanical Engineering in ancient Egypt, Part 69: Shabti boxes inscriptions", International Journal of Engineering and Techniques, 2018; 4(3): 436-448.
22. Hassaan, G. A. "Mechanical Engineering in ancient Egypt, Part 71: Labels and tags inscriptions", International Journal of Advanced Research in Management, Architecture, Technology and Engineering, 2018; 4(9): 7-12.
23. Hassaan, G. A. "Mechanical Engineering in ancient Egypt, Part 72: Seals inscription", International Journal of Emerging Engineering Research and Technology, 2018; 6(9): 14-23.
24. Hassaan, G. A. "Mechanical Engineering in ancient Egypt, Part 76: Alabaster products inscription", International Journal of Emerging Engineering Research and Technology, 2018; 6(10): 12-25.
25. Hassaan, G. A. "Mechanical Engineering in ancient Egypt, Part 77: Temples inscription", International Journal of Engineering and Techniques, 2018; 4(6); 113-132.

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