MODELLING AND ANALYSIS OF THE ANCIENT CHAPTER HOUSE LOVAMAHAPAYA

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ABSTRACT

This paper investigates about the ancient chapter house Lovamahapaya, which is one of the gigantic ancient structures constructed in Sri Lanka. This was constructed as a nine storey building, but only the stone pillars in the ground floor and the second floor which believed to be the 9th floor of the original building remain today. Limited information about this structure is available in the literature and the actual behavior of the structure during that time is not known. This research gathered the available information in the literature and three-dimensional (3D) architectural modeling was carried out using the Revit architectural software to predict the behavior of the building during the ancient time. Detailed information about the architectural model including the plan views, sectional views and the 3D view are presented in this paper. An analytical calculation has been carried out to see the suitability of the columns used for the ground floor. It is clear that the ancient builders have carefully selected the sections of the stone pillars where the bigger sections are used at the middle of the building where the axial load is higher.

***Key words*:** Chapter House, Revit Architecture, Stone Pillars, Structural Analysis

1. INTRODUCTION

The architecture of ancient Sri Lanka displays a rich variety of architectural forms and styles from the Anuradhapura Kingdom (377BC–1017) through the Kingdom of Kandy (1469–1815). Even in their ruined condition, buildings of ancient Sri Lanka reveal that our ancestors had a superior technology which can even compete with the modern technology. Buddhism had a major influence on architecture, as in many aspects of Sri Lankan life. There were more than 25 styles of panchavasa monasteries that have the five main ritual buildings: “Chapter House”, “Image House”, “Bodhighara” (Bodhi Tree Shrine), “Stupa” and the “Sangharamaya” or “Sabha”.

These ancient buildings (or structures) were constructed without the modern machinery available today and yet are perfect in dimension and structurally sound. Ancient builders of Sri Lanka have taken great care in the selection of the sites, geometries, architecture, structural stability, materials, setting out, construction supervision and management, and sustainability during the design and construction of ancient structures. This paper investigates about the ancient chapter house Lovamahapaya, which is one of the monumental structures constructed in Sri Lanka during ancient time.

In the 3 B.C. King Devanampiya Thissa built a chapter house on the instructions by Mahinda Thero who brought Buddhism to Sri Lanka. After 100 years later king Dutugamunu (161-131 BC) redesigned it as a “Sima Hall” for the Maha Viharaya, which came to known as the Lovamahapaya. Lovamahapaya is situated between Ruvanveliseya and Sri Mahabodiya in the ancient city of Anuradhapura. Figure 1 shows a Google map locating the Lovamahapaya.

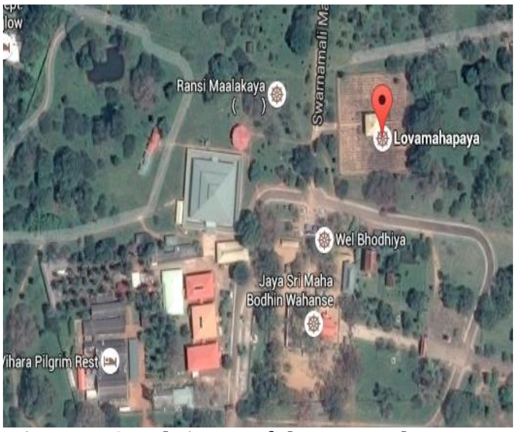

Figure 1: Google image of the Lovamahapaya

Lovamahapaya was a nine storied massive structure with a height of 30m (100ft) where each floor height is about 3.3m. This was a symmetric structure, having a square shape in plan where length of each side is about 74m (242ft).The building was supported by 40 rows of stone pillars each containing 40 pillars, total of 1600 pillars. They are decorated with corals and precious stones and its roof was covered with copper-bronze plates, because of which it is also known as the Brazen Palace or Lohaprasadaya. The columns in the upper floors and the beams of the structure were built with wood.

All nine floors had apartments. First floor was for the student monks. Second floor was for the monks who knew Tripitakaya. Third, fourth and fifth floors were for the monks who had achieved Sovan, Sakurdagami and Anagami states. The top four floors were for the monks who had reached the state of Arahath. Figure 2 shows the front view of the Lovamahapaya.

Figure 2: Front view of the Lovamahapaya

The information available in the literature about this structure is limited and its behavior during the ancient time is not known. This research therefore intends to model the Lovamahapaya by accounting for the information available in the literature. The 3D architectural model of the structure is created by using the Revit Architectural software. The arrangement of the stone pillars at the ground floor and the use of different column sections at different locations are also analyzed to compare how the engineering principles and technology used in ancient time tally with the modern technology.

2. LITERATURE SURVEY

As stated in Mahavansa [1], this building was destroyed by a fire during the time of king Saddhatissa (137-119 BC) and it was built to seven stories later. King Sirinaga II (240-242 AC) restored the Lovamahapaya again to five stories. Later, King Jettatissa (266-276 AC) built up the building to seven stories. King Mahasena (276-303) demolished the Lovamahapaya and gave its material to the Abayaghiri Viharaya after having a conflict with the monks in the Mahavihara. Sirimeghavanna, who is the son of King Mahasena rebuild this mansion again.

However, this building was destroyed again by the Pandayns from South India who invaded the Anuradhapura city in the 9th century. The building was rebuilt again in the same century by king Sena II. Colas from South India invaded the Anuradhapura city again in 10th century, which finally saw the fall of the Anuradhapura as the capital of Sri Lanka after over 1400 years. The great king Parakramabhu I who reigned from Polonnaruwa (1153-1186 AC) raised the 1600 pillars again and partly restored it, and that is what can be seen at the Lovamahapaya site today.

Field Survey

As it was hard to find the detailed information about the structure of the Lovamahapaya, a field survey was conducted to find the required information to carry out the modelling. The structure has a square plan view, and due to its symmetry, one fourth of the structure could be used to predict behavior of the entire structure. Since it was hard to find the section sizes of the columns, column height and the spacing between the columns from the literature, dimensions of the 400 stone pillars (quarter of the entire structure) were measured during the field survey. Figures 3-10 illustrates some of the pictures captured during the field survey.

Figure 3: Aligned arrangement of the columns

Figure 4: Base of a granite column

Figure 5: Top of the columns are cut to place the wooden beams

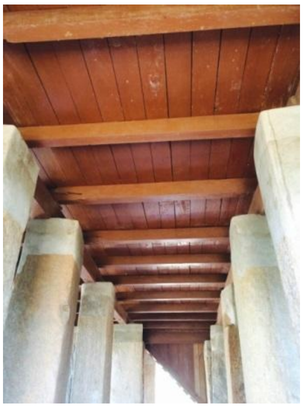

Figure 6: Bigger columns used at the middle of the structure

Figure 7: Second floor of the existing building

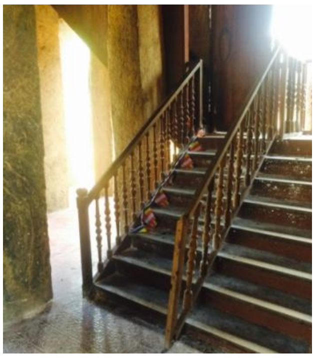

Figure 8: Staircase

Figure 9: Taking measurements at the site

Figure 10: Taking measurements at the site

3. ARCHITECTURAL MODELLING

By considering the data gathered from the field survey and the information collected from the literature survey, 3D modeling of the Lovamahapaya was carried out using the Revit software. The plan views at the each floor level, sectional views and the 3D views of the structure are presented as follows.

Figure 11: 3D view

Figure 12: Front view

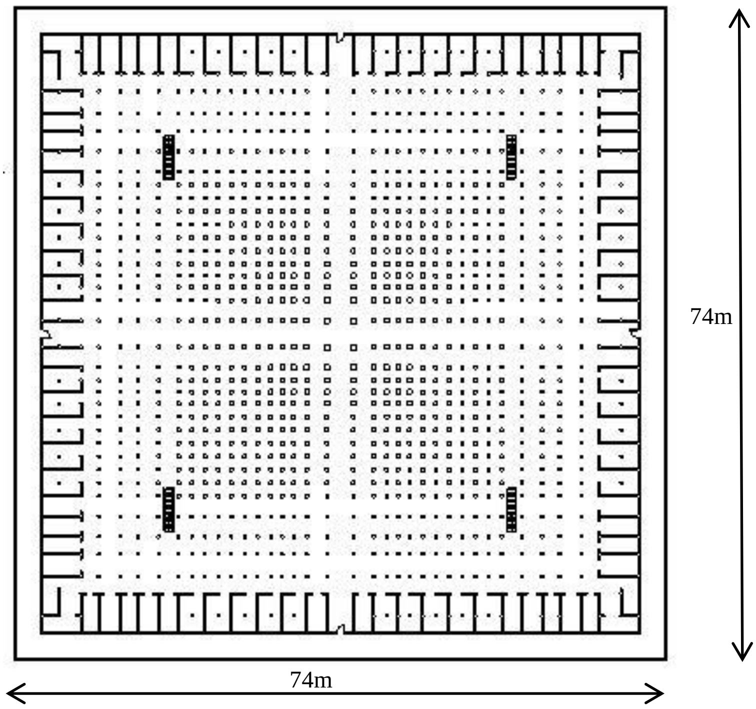

Figure 13: Plan view of the ground floor

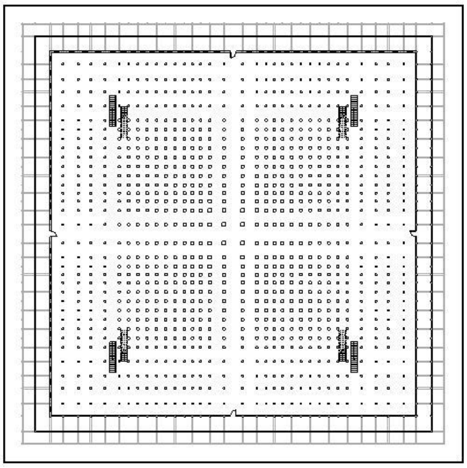

Figure 14: Plan view of the first floor

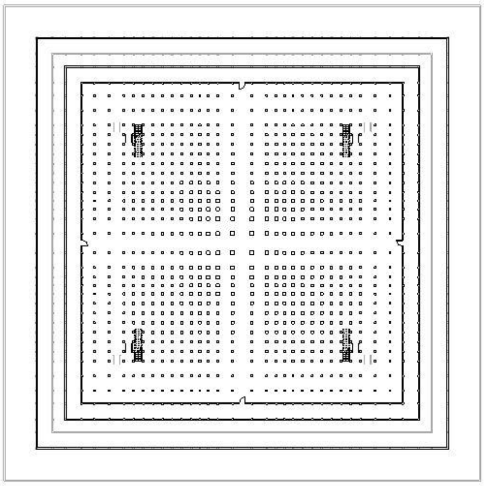

Figure 15: Plan view of the second floor

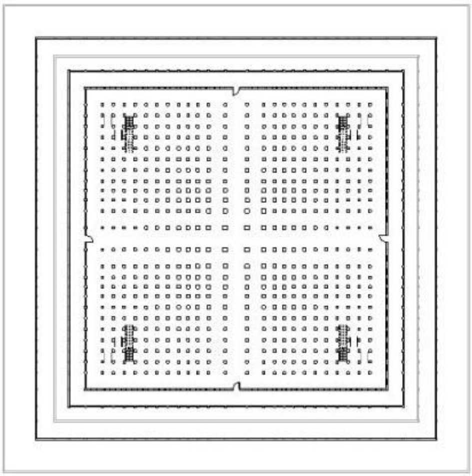

Figure 16: Plan view of the third floor

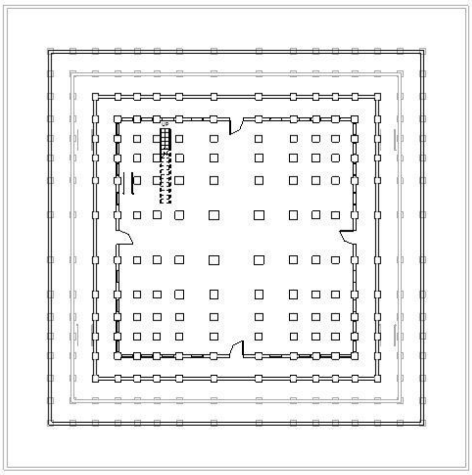

Figure 17: Plan view of the seventh floor

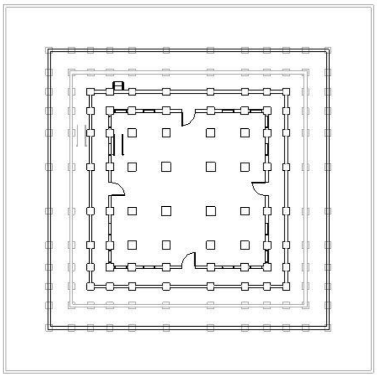

Figure 18: Plan view of the eight floor

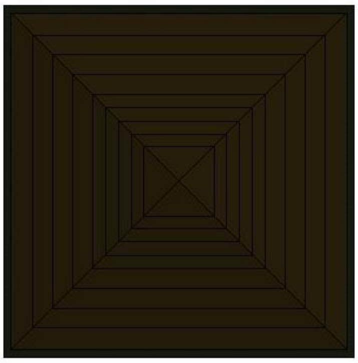

Figure 19: Plan view of the roof

4. STRUCTURAL ANALYSIS

During the field survey it was identified that granite columns with different sizes were used at the ground floor level. Figure 20 shows the column arrangement at the ground floor level in the quarter of the building. According to the shape of the structure a column at the middle of the building (column A_{20}) gets loads from eight floors while that at the outermost corner (column A_1) gets the load only from the roof. The column A_{11} as shown in Figure 20 gets load from four floors.

It is evident that the ancient builders carefully considered the loads getting for each column when selecting the column sizes in the design. A theoretical calculation has been carried out as follows to investigate the suitability of the columns used at the selected places.

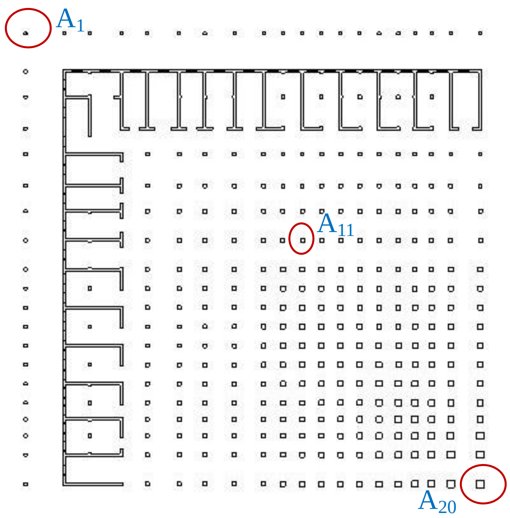

Figure 20: Quarter of the plan view at ground floor level showing column identifications

Material properties used in the analysis [1,2]

- Compressive strength of granite = 130MPa
- Tensile strength of granite = 4.8MPa
- Density of granite = 2800kg/m^3
- Density of wood (teak) = 800 kg/m^3
- Density of Cooper = 8790kg/m^3

Member section sizes used in the analysis

Floor to floor height = 3.3m
Granite column size A1 = 0.2m x 0.2m
Granite column size A11 = 0.37m x 0.37m
Granite column size A20 = 0.6m x 0.6m
Wooden column size = 0.25m x 0.25m

Beam depth = 0.3m
Beam width = 0.2m
Woodn slab thickness = 50 mm
Cooper roof thickness = 10mm
Wooden wall thickness = 20mm

Loading and load factors

Design imposed load = 4kN/m^2
Factor of safety for dead load = 1.4
Factor of safety for imposed load = 1.6

Analysis Results

Loads acting on the selected columns were calculated manually accounting for the dead and imposed loads as explained above. The area of load transferred to each column was determined according to the plan view of the building, where those of A_1, A_{11} and A_{20} columns are 1.5m x 1.5m, 1.5m x 2.3m and 2.3m x 2.65m respectively. Axial loads and the compressive stresses acting on the columns are summarized in Table 1. It is clear that the compressive stresses acting on the columns are well below the compressive strength of granite which is about 130MPa.

Table 1: Axial loads and the compressive stresses acting on the selected columns.

Column	Axial Load (kN)	Compressive Stress (MPa)
A_1	442	1.23
A_{11}	174	1.27
A_{20}	12	0.3

5. SUMMARY AND CONCLUSION

A three-dimensional (3D) model of the ancient chapter house Lovamahapaya was developed using the Revit Architecture software. All the necessary architectural drawings of the structure were presented in this paper. A theoretical calculation was carried out to investigate the suitability of column sizes used at the selected locations. Granite columns with bigger cross-sections were used at the middle of the building where the axial load is maximum, while the section size of the column was reduced towards the outer perimeter of the building with the reduction of the axial load. It was proved that the compressive stresses of the granite columns at the ground floor were well below the compressive strength. The information presented in this paper therefore confirms that the ancient builder have had a superior knowledge, where the engineering principles and the technology used in ancient time tally with the modern technology.

6. ACKNOWLEDGEMENT

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7. REFERENCES

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