Structural Assessment and Rehabilitation Option for YudaganawaDagoba in Buttala

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Abstract

Yudaganawadagoba in Uva province is one of the largest stupas in Sri Lanka which dates back to 2nd century BC. Presently, this colossal stupa with a diameter about 91.2 m and reaching a height of 13 m is undergoing several issues which necessitate it to be rehabilitated. The stupa was found in ruins and grown with vegetation until it has been preserved by subsequent restoration efforts in the recent past. However, it is not standing at its original height well-matched with the circumference at its base. Further, existing formation of the structure, existing foundation and ground condition are unknown. This paper presents structural assessment of existing stupa and proposal for rehabilitation in order to build the stupa to its full height.

A literature survey has been carried out to investigate the structural formation of stupas in ancient Sri Lanka. The geometry of the present stupa and the soil profile under the stupa were assessed. Material properties have been found with adequate laboratory testing. Present condition was modelled using finite element analysis employing SAP 2000 and PLAXIS 2D. The results show that the stresses generated within the existing stupa due to its self weight is well below than the compressive strength and the tensile strength of bricks. Based on the results, several alternative methods are proposed for rehabilitation and the options are analysed with respect to structural performance along with the existing condition and the religious beliefs, attitudes and rituals concerning the stupas. The possibility of cracking in the masonry due to the self weight in each alternative method was checked using a failure criteria developed based on the modified Von Mises theory. The final option was selected so as the stresses generated in the existing brickwork are satisfying the failure criteria and has the minimum intervention to the stupa in the context of ancient value and the concerns related to stupas. Consistent with that, it is shown; the existing stupa is capable of taking the load of proposed solid brick superstructure without showing any possibility of cracking.

Keywords: Ancient stupas, rehabilitation, finite element analysis, failure criteria, alternatives

1. Introduction[1]

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In Sri Lanka, the stupas hold a more venerable place among the Buddhists as they are monumental structures built to honor Lord Buddha. From the time when the Buddhism became the state religion in Sri Lanka, various Sinhala kings have built this religious monument to enshrine the sacred relics of Buddha and to mark spots at which an important event connected with the religion has taken place. Since then, these monuments are most venerated by the Buddhists and these possess an indispensable place among the features in a Buddhist temple.

Over a long passage of time these massive structures has started to decay as they were neglected due to foreign invasions and the shift of the capitals from place to place. Ancient chronicles reveal these stupas had been conserved and restored by several kings. In the latter half of the nineteenth century, British started documentation and reconstruction work on stupas. Some Buddhist organizations were established around the same time and conservation and restoration work on some important stupas like Ruvanveli was undertaken by them. Formation of Central Cultural Fund (CCF) in 1980 caused a revival of conservation and restoration of ancient stupas in Sri Lanka.

This research is intended to input the modern engineering techniques of structural analysis towards the restoration of YudaganawaDagoba in Buttala which has been identified as one of the largest stupas in Sri Lanka. After it was found in completely ruins, it has been conserved by the Dept. of Archeological during the last three decades of the 20th century. At present, the attempt is to restore the stupa with the help of modern engineering knowledge with minimum intervention to its ancient value.

1.1 YudaganawaDagoba

YudaganawaDagoba in Buttala is one of the largest stupas in Sri Lanka which holds an important place as far as its historic and archeological value is concerned. It is one of the significant structures located in Uva province which show the signs of ancient Uva. After thousands of years of negligence, efforts now have been taken to conserve this ancient monument and to give a renaissance to the area.

After the stupa was found in completely ruined over thousands of years (Fig.1), the first conservation and restoration works on the stupa were initiated in 1970s. After 13 years, in 1990s again some restoration works had been done on the stupa. Finally, in 2003 the conservation and restoration work on the stupa was continued by the archeological department. After all these efforts to conserve the stupa, now it is standing not to its full height but slightly above its basal rings (PesaWalalu) as shown in Fig.2.

Figure1: Before conservation of the stupa

Figure2: Present view of Yudaganawadagoba

2. Methodology

2.1 Literature Review

As stupas are of a complicated shape than any other structure, ancient engineers have shown much technological and management skills in construction of these large structures. A good description of these great skills and techniques used in construction of great stupas are revealed in ancient chronicles like Mahavamsa. Except from the ancient literature, many researchers have investigated the construction techniques adopted by ancient builders in the construction of large stupas.

2.2 Condition Assessment of the stupa

After this great stupa was found which had fallen into decay and become shapeless mound due to neglect and actions of nature, a large number of bricks have been removed from the fallen mound at that time and the stupa has improved towards the present condition by replacing removed old bricks by engineering bricks by the Dept. of Archaeology. Therefore, two types of bricks can be identified within the stupa where modern bricks are replaced around the old structure to form the dome as it can be seen today.

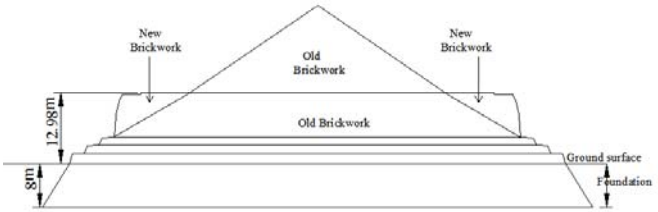

Figure 3: Existing YudaganawaDagoba

Since the data which describe the formation of the existing foundation are not available in the ancient literature and there is no any investigation done in order to find out the condition of the existing foundation, several assumptions regarding the foundation of the dagoba had to be made in the analysis of the dagoba as listed below.

I. The foundation is built from the bedrock
II. Main building block of the foundation is the same burnt clay brick used for the superstructure
III. The foundation and the superstructure are constructed as a one unit

2.3 Option for rehabilitation of YudaganawaDagoba

Several alternative models were developed considering the shape as bubble and heap of paddy and then considering the method of construction as hollow concrete structure and solid brick structure. The proposed alternatives are as follows:

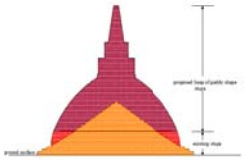

Figure 4: Alternative 1(Bubble shape solid brick)

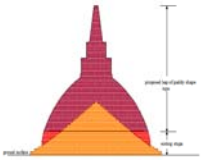

Figure5: Alternative 2 (Heap of paddy shape solid brick)

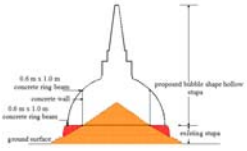

Figure 6: Alternative 3-1 (Hollow concrete)

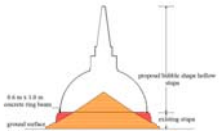

Figure 7: Alternative 3-2 (Hollow Concrete)

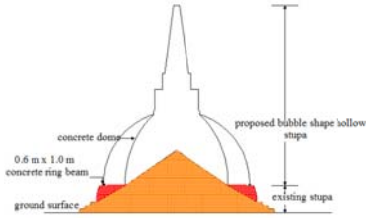

Figure 8: Alternative 3-3 (Hollow concrete)

2.4Analysis of YudaganawaDagoba

The above proposed alternatives were analyzed employing finite element computer software packages, SAP 2000 and plaxis 2D. In both analyses, a linear elastic analysis was carried out with appropriate material properties obtained from the tests conducted on bricks. Each alternative was analyzed under its self weight.

2.5 Failure Evaluation

In our study, the behavior of the masonry in stupa was assumed as proposed by Symarkesis (Symarkesis, Antonopoulos and Mavruli 2005) based on modified Von-Mises theory. A failure area developed based on modified Von-Mises theory was used to check the possibility of cracking in the brickwork of the stupa.

The maximum and minimum principal stresses σ_1 and σ_2 at each node in the finite element model were obtained from the SAP 2000 analysis. The principal stress values at each node were averaged in order to obtain one principal value. The averaged maximum and minimum principal stresses are then checked with the above failure criteria.

The following figures shows the principal stresses of the new brick work standing with respect to the failure envelop.

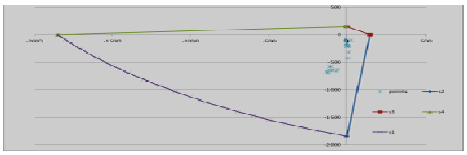

Figure 9: Principal stresses in the failure surface – New brickwork (Alternative 1)

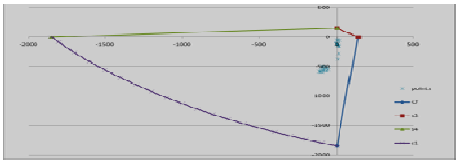

Figure 10: Principal stresses in the failure surface – New brickwork (Alternative 2)

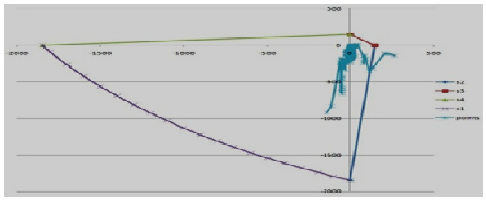

Figure 11: Principal stresses in the failure surface – New brickwork (Alternative 3-1)

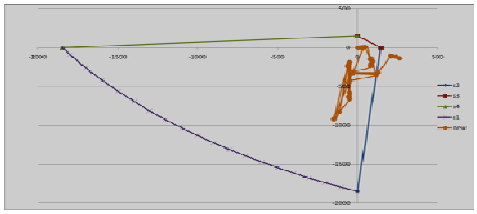

Figure 12: Principal stresses in the failure surface – New brickwork (Alternative 3-3)

3. Results and Discussion

From the results obtained from the failure evaluation it is seen that the solid stupas exhibits a safe structural behavior. In the hollow concrete stupas, principal stresses at the interface of concrete and masonry stands outside the failure envelop.

From these results, a solid brick stupa is proposed as the rehabilitation option of YudaganawaDagoba. If hollow concrete stupa is used alternative 3-1 and 3-3 can be recommended with remedial measures at the interface of the concrete and masonry.

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