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Conceptual Reconstruction of the Rock-cut Cave Excavation Process – A Case Study of Shelarwadi Caves, Maharashtra, India

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Abstract: *Rock-cut caves of ancient India, from Barabar and Nagarjuni hills in Eastern India to Ajanta, Karla, Bhaja in the western Deccan are an architectural marvel of ancient India. This technology can be seen from as early as 3rd century BCE right until the 14th century CE. Many theories have been proposed on architectural proficiency, variations in plans, stone sculpting techniques, stylistic variation, and chronology of evolution. Sources like epigraphs and literature have also contributed to these theories. Due to entirely different process of creation, which is excavation, these caves differ from the temples in architectural and structural designs, planning and execution and in theories of their evolution. Unlike built form, the process of excavation offers less scope for rework or replan. It thus indicates that the excavation must have been very well planned and managed to avoid any runtime changes. Present experimental research is an effort to understand and conceptualize the basic processes involved in the excavation of a cave. It includes the parameters considered in the process of excavation such as planning, effort/cost estimation, labour issues, change mitigation planning and actual execution. Understanding the planning part involves the processes of site/rock identification, basic cave design, and effort estimation. In this preliminary work, we propose to use modern-day project management approach to explain these parameters which are devoid of attention in the historical, stylistic or evolutionary studies of rock-cut architecture within India.*

Keywords**:** *Rock-cut cave, process, reconstruction, planning, effort, excavation, project management*

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Introduction

Rock-cut architecture of peninsular Indian land has been an area of interest for many research scholars, both native and foreigners. Though majority of these monuments belong to Buddhist faith, there are

quite a few examples of Brahmanical and Jain caves. The main topics of study have revolved around evolutionary theories based on architectural features and stylistic affinities, stylistic and sculptural studies, relationship between ideologies and architecture and comparative studies. Another important topic is inscriptions found on these walls and thus building historiographic context of these material remains based on epigraphic studies. However, when it comes to the realistic estimates about cost and efforts required for execution of such massive projects, scanty references are available. Knowing that these were conceptualised, planned, executed, managed, decorated and finished by our own ancestors, investigating these as large-scale construction (excavation in the case of caves) projects of pre-modern technology and hence understanding the human planning and effort aspect of those is worth exploring.

Location map - Shelarwadi (Ghoradeshwar) caves – Larger context and specific location

Present case study proposes an effort estimation process for the cave excavation project. These estimates are driven by the amount of work and required effort. The study is designed based on the modern-day project management practices. Chaitya-Vihara at Shelarwadi cave group, also known as Ghoradeshwar caves due to its location on Garodi hills near Pune, (Maharashtra - India) is selected as a case study. The driving factors for selecting this site are accessibility to the site, simple and basic design, almost lack of decorative motifs and relatively small size. Applying the framework of present-day project management concept and 3-D visualisation at different stages is an important aspect.

Background

In case of temple or other structural forms, the processes involved are related to construction type of work. Individual components such as masonry stones, bricks, wood and other required material is shaped or manufactured and are later built or assembled into an architectural form as designed by the Architect. Abundant literature, both ancient and contemporary, is available which discusses terminologies and details related to building material, measurements, stages of constructions, styles, and standards. However, in case of rock-cut caves, literature has superficial information. As an example, Sarkar (1966) notes that, texts like *Chullavagga,* mentions about different types of residences such as *viharas, addhayogas, pasadas, hammiyas, guha* etc. Vinaya rules mention *Navakammika*, one with the knowledge of monastery building belonging to different sanghas, would be appointed for directing the constructional operations. They were probably assisted by *Silavaddhakis, Mithikas and*

Avesanins. Mahavagga mentions clearing up of mountain cave to make it a dwelling place. However multiple interpretations of these terms by scholars like Buddhaghosha, then recent scholars such as Coomarswamy, Huntington, Sarkar, the mentions in inscriptions, the details in Amarakosha and their depictions on stupas and railings leave us in complete uncertainty. Detail studies on Barabar and Nagarjuni group of caves suggests modification of natural rocks to complete manmade rock-cut caves is possible (Gupta, 1980). Moreover, Budhani caves in Madhya Pradesh and Sitabenga and Jogimara caves in Ramgarh hills are examples of natural caves being adopted with some modification. Sonbhandar near Rajgir is another example of rock cut caves retaining basic features of natural cave. Barabar caves are a culmination of this long process, and it is evident that the planning and efforts required would have been drastically different. It will also change in different typologies such as Viharas and Chaitya with variations in plans, ceiling, facade, pillars. Hence the studies on reconstruction process of rock-cut architecture will be based upon several parameters impacting the overall project execution.

Planning and Execution of Cave Excavation

The planning phase must have involved site selection driven by identifying ideal rock portion, cave design, and logistics related to human and animal effort estimation, tool procurement etc. A significant aspect is source of water for work as well as consumption. Though accessibility is an important point, the historical context of many of these excavations narrates the use of these caves by Buddhist or Jain bhikkhus who have renounced the material life and hence are away from settlements.

It was realised that some tasks, acting as prerequisites must have been completed before the actual excavation work began at the site. Some of these can be anticipated as clearing up of site, debris disposal system, setting up a tool workshop and employing artisans with variety of skills, both skilled work and hard labour. Also, employing security personnel right after site selection throughout the project duration seems logical. For actual excavation, Gupta's (1980) work on the various stages in excavation are used as guidance (Referred as G in Table 1). However, while working in the 3-dimensional virtual environment, we have realised that few more steps (Referred as N in Table 1) are essential for correct sequence. The basis for effort estimate is based on an experimental study of undergoing restoration work at Ajanta cave group. As we understand that it cannot function as a ballpark figure, challenges related to it are discussed in following sections.

Table 1: Tasks, tentative excavated rock volume and required time; G as tasks identified by Gupta (1980), N as newly identified tasks

	Step	*Description*	*Volume (cu mt)*	*Man-hours*
N	Surface Preparation	Clearing up the rockmass to create the main entrance door or surface for facade	43	534
N	Entrance creation	Main door size excavation	5	55
N	Beginning of sequence	Careful excavation to maintain the outer wall boundary and then expand inside	1.4	17
G	Blocking	Remove matrix of rock to create hollow	221	2748
G	Rough Chiselling	For overall outline		128
G	Dressing	Chisel out rough surface		128
G	Pecking	Removing ridges made by chisel marks, removing roughness, angularities but still produces uniform rough surface		256
G	Grinding	Vigorous rubbing of surface with a mixture of coarse-grained stone, coarse sand and water; creates smooth but non-shining surface		256
G	Polishing	Fine grinding and probably no external agent, fine grained rubbing stone or sand used patiently for long time, if mineral content in rock is more it will have a glazing/ mirror like effect.		256

Along with the steps mentioned above, other parallel routine tasks such as daily supervision of work, optimal work distribution, wage calculation, tools repairing, food and medical facilities would have happened side by side. Issues of incorrect excavation, encountering rock deformities, water seepage could have forced changes in the original plans since there was no chance of rework. These would be handled under change mitigation in project management.

To visualise this effort estimation in conjunction with project flow, 3D models are created simulating the cave excavation progress in a sequential manner. The theories of caves' excavation sequence (Gupta 1980) from top to bottom (for western Deccan caves by Dehejiya, 2016) or bottom to top (theorised for eastern Indian groups by Gupta, 1980) are evaluated in a digital environment. As observed by Dehejia (2016) from the unfinished cave V at Ajanta, the sequence that usually followed for cave excavation was blocking, rough dressing, fine chiselling, pecking and eventually finishing to attain smooth surfaces. For the entire project, except for basic plan drawing in AutoCAD, we have made use of open-source applications.

3D Model creation

Scaled drawing of plan of main Vihara/ Shrine cave of Shelarwadi is prepared in AutoCAD (Fig. 1). It is later used for creating a 3D model. An imaginary hillock is constructed around the plan (Fig. 2, Fig. 3). Actual excavation in 3D space is done using AutoCAD and Google SketchUp. The three extra steps mentioned in the above table are outcome of this visualisation in 3D space (Fig. 4). Step-by-step excavation process is created simultaneously in project plan and 3D model. Volume calculation and required man hours are calculated for each step.

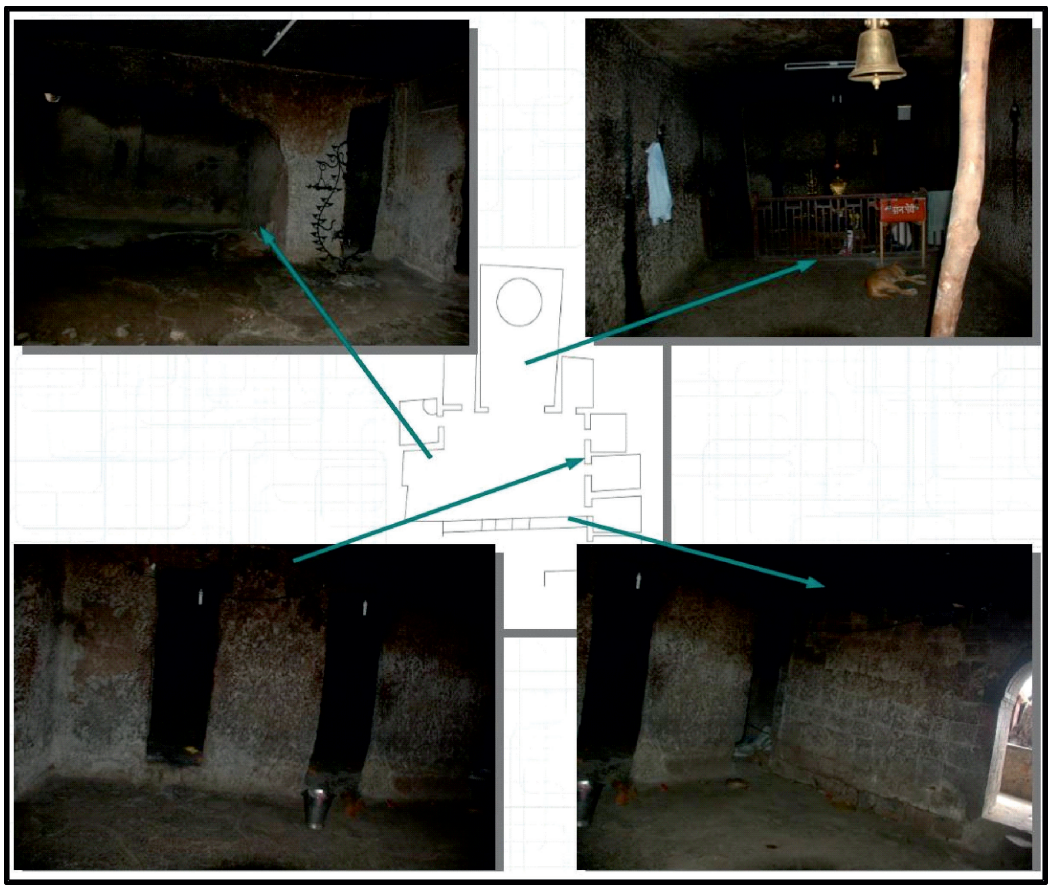

Figure 1: Shelarwadi cave plan with interior photos

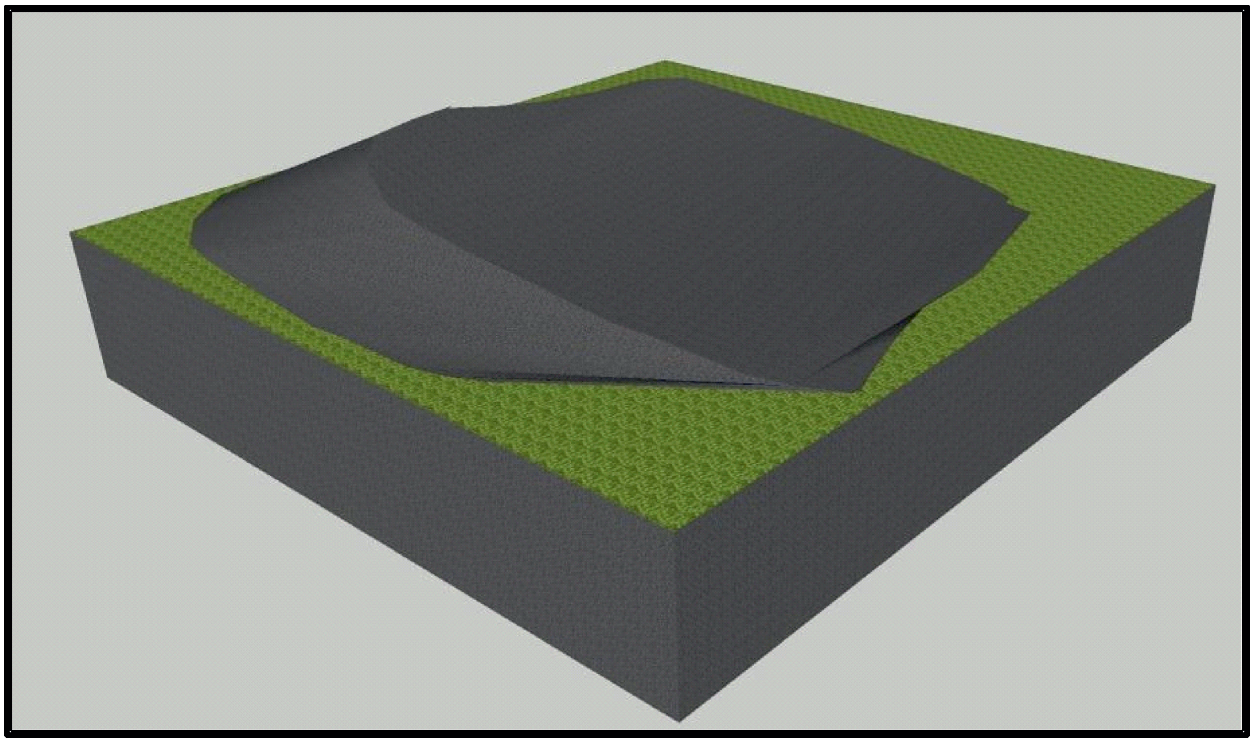

Figure 2: Imaginary hillock portion to accommodate the cave plan

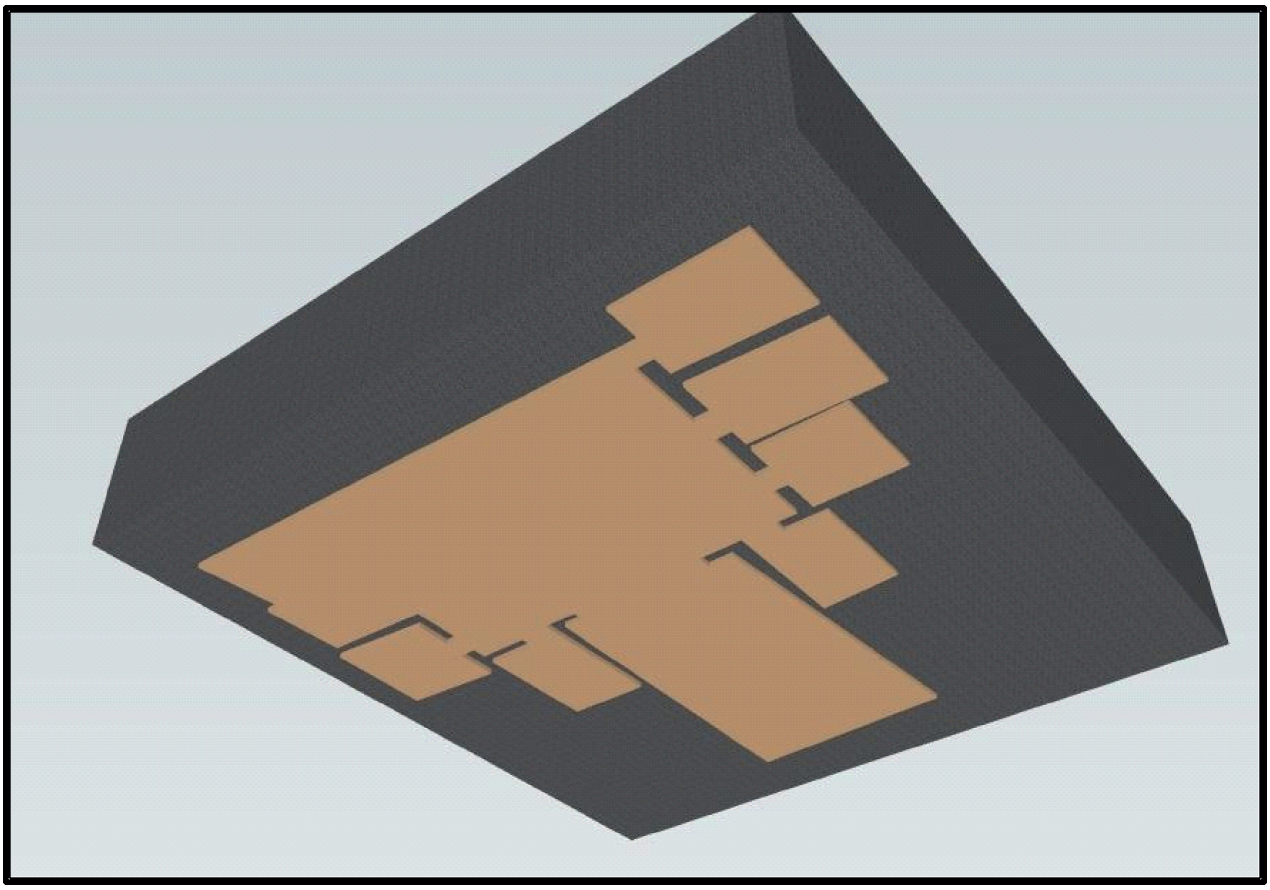

Figure 3: Cave plan in hillock

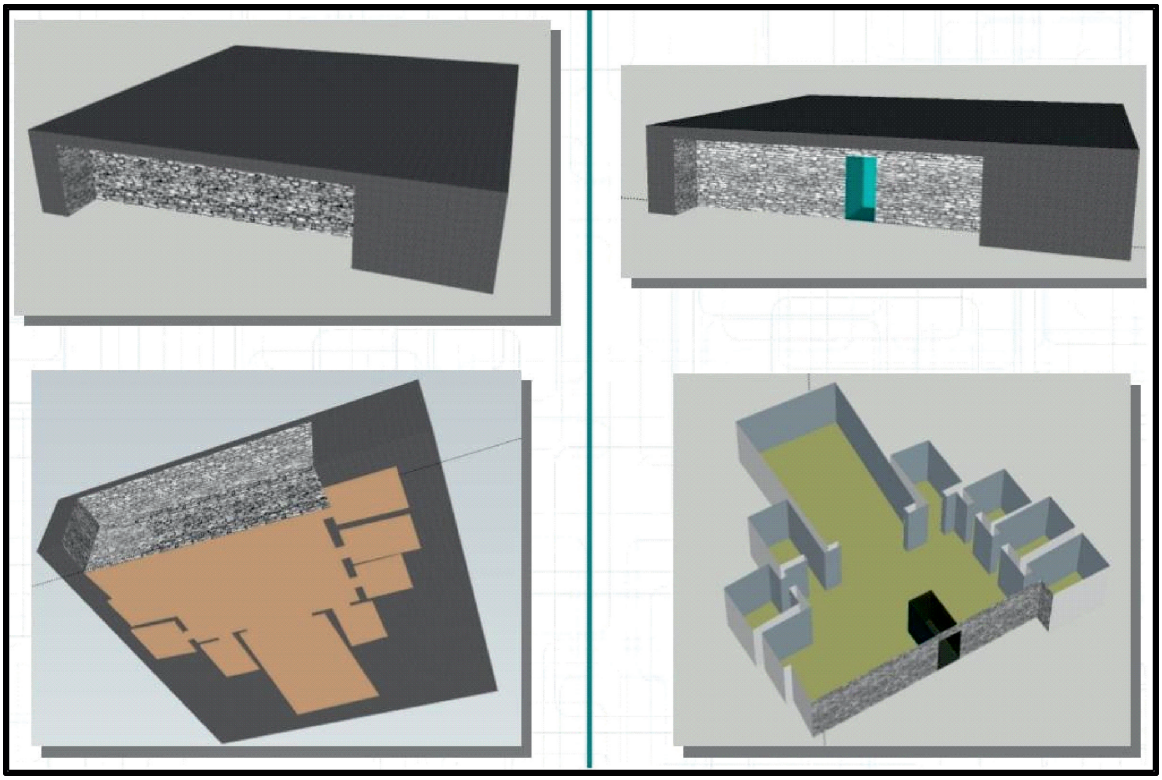

Figure 4: Surface preparation, entrance and excavation beginning

Challenges

The main challenge encountered is the basis for estimation for excavating the volume of rock and shaping the stone. Though this is achieved from a real-life experimental exercise studied at Ajanta caves near Aurangabad, a prominent World Heritage Site in India, it might change based on rock type, labour expertise and tools used. For all the tasks after blocking, tentative estimates are used.

In real life scenario, the caves occupy a very small portion of the hillock so size of hillock is irrelevant for present study. However, the visualisation requires creation of space in 3 dimensions. For this, an imaginary block is used which can just encompass the total cave volume. Approximate volume of cave is based on plan and height measurement. This created the 3D working space for the present study. While visualising the process of excavation, it is realised that sequence and possibilities of simultaneous work vary based on the available working space. So as an experiment, three different working sequences are visualised on three working surfaces, i.e., from top to bottom, from bottom to top and complete block removal (Fig. 5).

As the excavation progresses inside, some distinct measurement technique must have been employed. In present case study, these caves are devoid of any pillars or decorative sculptures, therefore, so it is relatively simpler to plan and execute the excavation. The progress in block removal can be seen in Fig. 6. However, in presence of any such decorative features, the planning and execution effort will exponentially increase.

The 'Top to Bottom' or 'Bottom to Top' theories which are evaluated in the 3D modelling phase revealed following facts:

- The 'Bottom to Top' would require only digging the ceiling and collecting the debris as it would fall naturally on the ground. The 'Top to Bottom' involves digging, picking up and collecting debris as the work progresses. So even if scaffolding effort is saved in this case, it does have additional effort.

- It is very difficult to have only one type of sequencing so there has to be a combination. This would form a crucial part of cave design and excavation planning.

More detailed work on this with different types of rock-cut architecture will help define more robust theories.

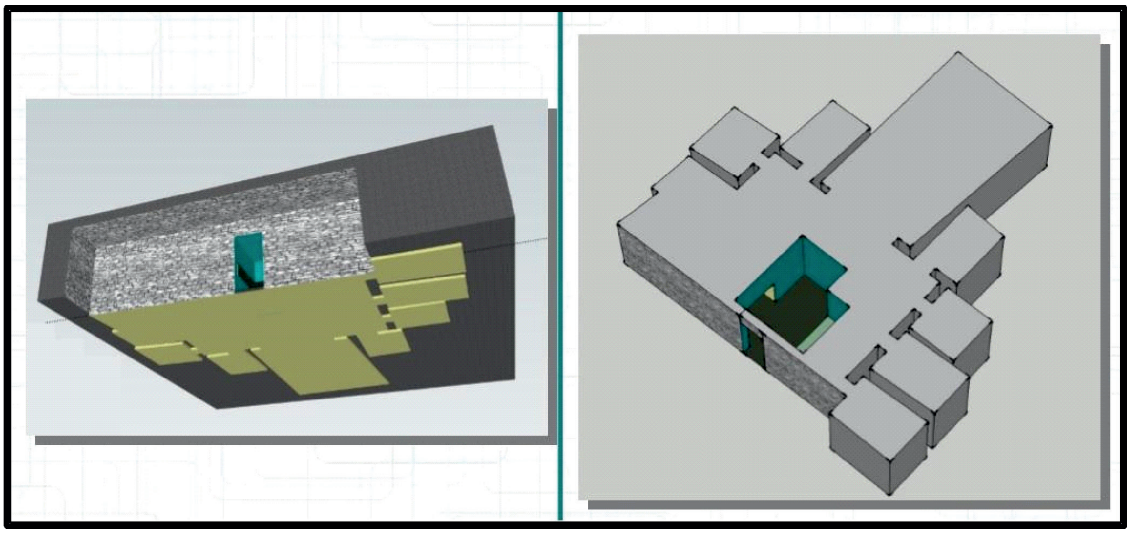

Figure 5: Working sequence experiment

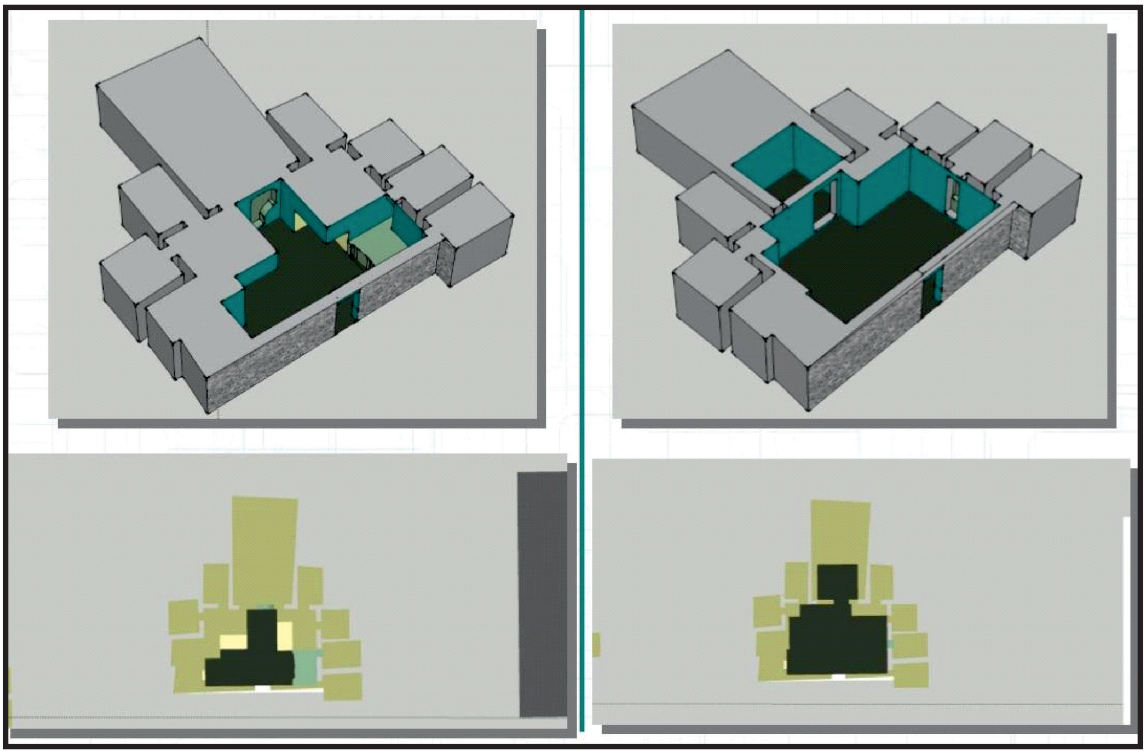

Figure 6: Progress in block removal

Treating rock-cut cave excavation as a modern-day project management exercise, has allowed us to consider parameters, both quantitative and qualitative. Adhering to the project management entities and flow, the entire exercise is split into planning and execution. The concepts of resource allocation, task dependencies, contingencies are incorporated. Besides these, as mentioned earlier, the

effort estimation is done based on few experimental studies and logical guess-work based on practical approach. As we employ project planning mechanism for the present case study, all vital aspects of project management such as planning, optimum labour distribution, task dependencies, parallel work are applied to the excavation project. Because of varied types of expertise required during planning phase, all the subtasks can be completed parallelly (Fig. 7). Though it is assumed that site selection follows cave design, it is realised that both are interdependent tasks and can influence each other. After preparing a primary layout design of the cave, suitable site must have been selected. Based on the site conditions, some modifications must have been incorporated within the design.

The main task of excavation or scooping out the rock mass is labour intensive and needs proper planning. Task dependencies in intermediate stages can be handled effectively. For example, , while working in block-removal Stage 1, all the three sides required different amount of time so this impacts beginning of work of block-removal Stage 2. All sides appear to have different schedules because of varying volume and working space.

Figure 7: Project plan with tasks, subtasks, resources and their allocation, time, dependencies

Discussion

The present case study is a complex piece of work amid lack of sufficient prior art and textual references. The core reason for this conceptualisation is understanding effort estimation for such projects. Though our basis for estimate of work calculation is a result of single experimental study, it can be refined based on ethnographic studies or more intensive analysis of literature. The recent cinematographic rendition of a real-life story of Dashrath Manjhi of Bihar (India) has shown an example of single-handed human effort with minimal tools. Detailed understanding of his efforts can help us refining the estimate. Time estimates for all the tasks before the beginning of actual excavation can be modified only if we get some literary references. The complete excavated view of the cave can be seen in Fig. 8.

While imagining the complete process in the present case study, it appears that, the number of workers engaged in the excavation process vary at different working stages. So, from project management point of view, optimum number of labours should be available at every stage of the

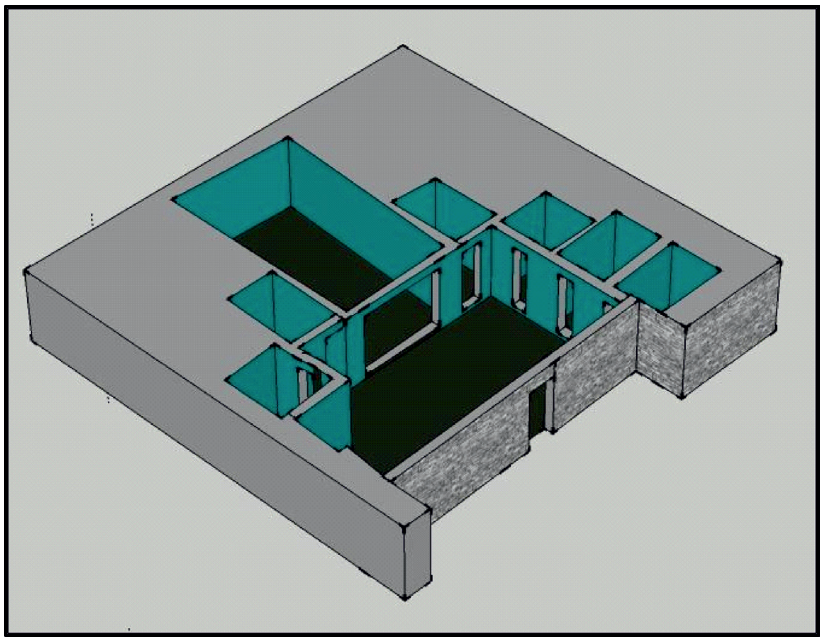

Figure 8: Final excavated view based on the plan drawing

project. Failing this, either there will be overhead of maintenance cost of extra labour or, unavailability of labour at the need of hour impending the overall progress of the excavation project.

As mentioned in the introductory passage of the paper, supporting activities for the labour force are prerequisite of such projects. Creating makeshift/ temporary residences for the labours, tool workshops, setting up of kitchen supplying enough food for all the members, mechanism for disposing debris from the excavated area, security provisions for the site must have been in place before initiating actual work. Absence of any of these would impact the smooth running of the project. Most of these would have functioned through the entire duration of the project. Though these might not impact the duration of the project, these do contribute in the total cost and effort. Knowing that such activities were unavoidable for the projects, these should be considered while doing archaeological explorations around the monastic establishments.

To accommodate unplanned events and their impact on overall schedule a contingency of 20% time of total estimated time is added. This can include break in patronage, unavailability of labourers, rock deformities, political hindrances, natural calamities, incorrect excavations etc. The same reasons could have completely halted some projects e.g., Ajanta cave numbers 14 and 24 presently seen in incomplete stage. This halt could have been sudden or gradual. As observed in these unfinished caves at Ajanta, we find specific space allocation depending on the working space, forming a grid like pattern. Part of walls were left in between the working areas which were carved out later. This further could have been used for calculating the amount of work completed by each worker and his wage. A possible unfinished view of Shelarwadi cave can be seen in Fig. 9.

As mentioned in *Chullavagga*, time estimate for small *vihara* was for 5-6 years, for *Addayoga* it was 7-8 years and for large *vihara*/ *prasada*, it was 10-12 years (Sarkar, 1966). Based on the estimate by S. Mizuno and T. Nagahiro, (Reddy et al, 1998) at Guntupalli, the time estimate for chaitya and viharas together would have been 4-5 yrs. Since there is a debate if these are structural or excavated forms, using these as guidelines for similar studies may be misleading.

The cost estimation of such projects would depend on the patronage provided by guilds or monastic establishments or royal families. In absence of sufficient information even for a tentative logical guess,

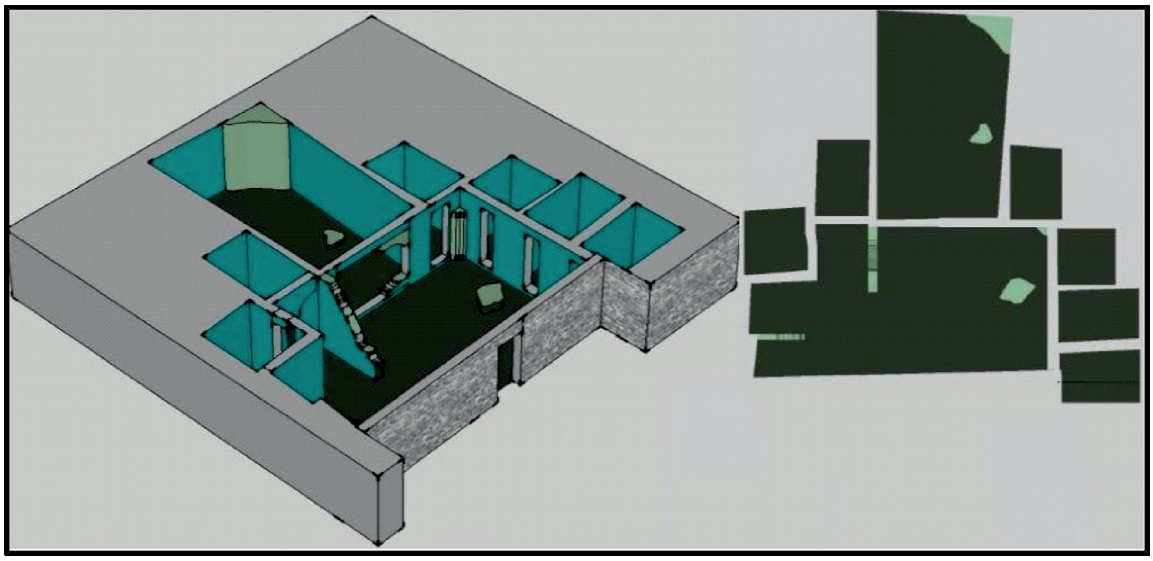

Figure 9: Hypothetical unfinished view

cost-estimation has not been included in the present scope of work. There exists a small inscription which mentions 'this *Lena* being a gift of a lady whose husband (and probably herself too) is *Kunabi* by caste and ploughman by occupation along with her householder son.' This or other mentions of *Sethis* in other caves may help us relate the socio-economic status of the donor and then probably the donations based on their capacity of expenditure.

Though this case study is based on experimental and hypothetical estimates, the factors which have been considered for overall project are realistic and logical. Hence, there are some conclusions which will help further research in this area. Issues of working space, debris disposal and individual work calculation emerged as critical factors.

Initial hypothesis about these projects being cost driven or resource driven is significantly modified. In majority of the steps throughout the project, availability of working space was a driving factor for the overall speed of the project. Cost or resources can be used only based on the available working space at different stages, in the present case, probably only one or two labourers in the initial stages of cave excavation (Fig. 10).

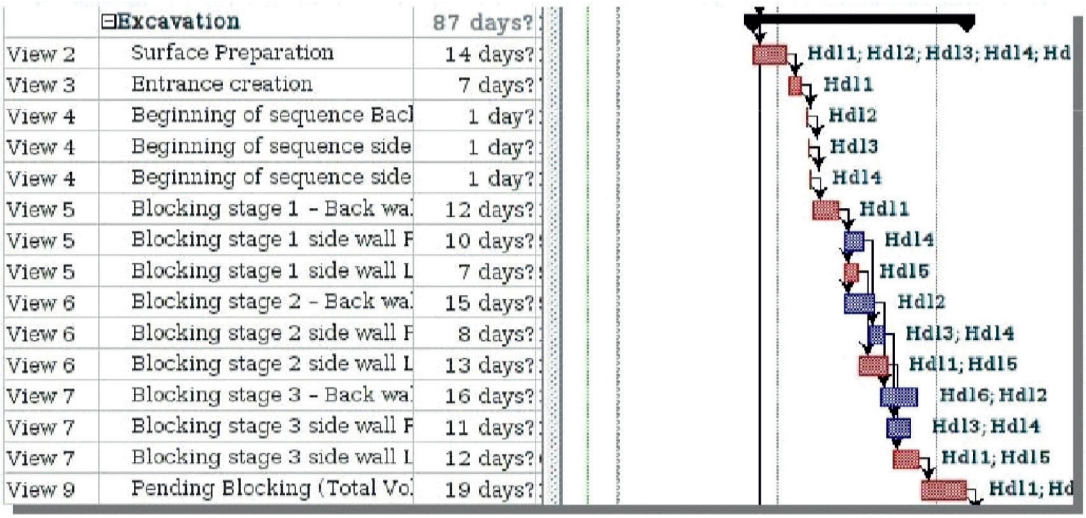

Figure 10: Resource allocation in excavation stages - dependency on working space Estimation

The Shelarwadi *Chaitya-Vihar* considered for present case study houses a *Shivalinga* at present. It clearly depicts Stupa shrine of the past, seen from the remains of base or roll mouldings and *Chhatravali* as important evidence. Our effort estimation has excluded the stupa carving work as well as any sculptural details if any. Hence, considering these being part of actual project, it would need more time for completion. Also, by examining the present-day site geography, our estimates about clearing up and initial excavation up to block-removal phase might have involved more effort. So, in all probabilities, in this case study, the time required for entire project can be more but probably not less than our estimate.

There are few aspects which have not been discussed in the present scope of work due to lack of information and limited time. However, those have been acknowledged as important factors. These include gender bifurcation and social hierarchy impacting work distribution, general demographics of labours, medical facilities at the site, use of contemporary technology etc. We feel that there is enormous scope to refine this work. More insights into the ancient processes will help in further study.

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References

Gupta, S. P. (1980). *The Roots of Indian Art: A Detailed Study of the Formative Period of Indian Art and Architecture, Third and Second Centuries BC, Mauryan and Late Mauryan*. BR Publishing Corporation.

Sarkar, H. (1966). *Studies in early Buddhist architecture of India*. Munshiram Manoharlal.

Dehejia, V., Rockwell, P. (2016). *The Unfinished: Stone Carvers at Work in the Indian Subcontinent*. Roli Books, ISBN: 9789351941149

Dutt, S. (1988). *Buddhist monks and monasteries of India: their history and their contribution to Indian culture*. Motilal Banarsidass Publishers.

Reddy, E. S. N., & Śivanāgireḍḍi, Ī. (1998). *Evolution of Building Technology: Early and Madieval [sic] in Andhradeśa* (Vol. 1). Bharatiya Kala Prakashan.