INVESTIGATION OF THE BINDING MATERIALS PROPERTIES AND ASSESSMENT OF DURABILITY ISSUE IN FASIL "GHIBBI" PALACE IN GONDAR, ETHIOPIA

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ABSTRACT
Conservation of ancient monuments is a process which will lead to the prolongation of the life of cultural property for its utilization now and in the future. But, before practicing conservation, one must have a broad understanding of the field itself. This is of course to ensure that any action carried out during the conservation work is properly performed and is in accord, not only with the building requirements, but is within the scope of contemporary knowledge of the subject.
Today, these historical structures are in different physical state, some are in relatively good condition, while many are in a deplorable state.
The purpose of this study is to identify the method of construction and analyze the construction materials which were used in Royal palace construction in order to define their characteristic properties, durability and to consider the properties of original materials, thus enlightening the usability of them in repair of such buildings. For this purpose, samples of the construction materials like binding mortar, which were used in Fasil Ghibe Palace construction, and Extracted in Ethiopian Geological Survey Laboratory using General Silicate Analysis, it includes: LIBO2 FUSION, HF Attack, Gravimetric and AAS.
The type of binding material which was used during the construction of the Fasil Ghibbi palace is identified as Lime (CaO) or by its local name Nora. And also the method of construction was by stone masonry.
The major cause of deterioration of the Royal Palace is due to various reasons, some of which are long life, lack of periodic maintenance, unchecked growth of trees, grass, algae & mechanical impact on the wall surface by Visitors.

KEYWORDS: *Durability, Gondar, Heritage, Lime, Royal Palace*

I. INTRODUCTION

For the period of several centuries, the influence of several distinct cultures produced rich and diverse cultural heritage that we see today in East Africa countries. The most tangible remains of these heritages are stone built buildings and structures including, palaces, mosques, residential houses and tombs. At present, these heritages are in different physical state, some are in relatively good condition while many are in an appalling condition. The presence of these historical monuments has benefited these countries economically and culturally therefore, it is essential to ensure that these monuments continue to exist.
Ethiopia, one of culturally rich countries in the world with oldest civilizations and unique geographical features, is situated to the Horn of Africa. Recent studies witnessed that ancestor of the modern human used to live in Ethiopia over three million years ago. Hence the nation has been a cross roads of civilizations and peoples for thousands of years.
Through this long process of civilization and history, quite a number of towns and cities had flourished. Of these, Gondar is a medieval royal city which was ascribed by UNESCO as the" World Heritage Site"

in 1978.

The origins of the Royal palace can be found in the old tradition of the Ethiopian emperors to travel around their possessions, living off the produce of the peasants and dwelling in tents. Reflecting this connection, this precinct was frequently referred to as a *katama* ("camp" or "fortified settlement") or *makkababya*, the name applied to the imperial camp in the *Royal Chronicle* of *Baeda Maryam.*[7] Gondar is positioned in Northwestern part of Ethiopia, at about 740 and 175 kilometers away from Addis Ababa and Bahir Dar respectively. Its altitude is 2200 meters above sea level.

Founded by emperor Fasiladas in 1636, the city of Gondar had been the seat of the Ethiopian state for about 250 years. The foundation of this Imperial city witnessed a period of optimism and renaissance of the golden days of *Aksum* and *Lalibela*. Architecture, literature, education, music, painting commerce that had been perished after the fall of ancient *Aksum*, rose to prominence.

The Royal compound lying within 70,000 m.sq, it encompasses six lofty castles and many different purposed buildings like the royal archive, house of the musicians, the lion cage, the horse zoo, the sauna bath, house of the spinners etc. The earliest and grandest of all edifices is that of Emperor Fasiladas, which is 32 meters high and with battlemented square tower. Today, these historical structures are in different physical state, some are in relatively good condition, while many are in a deplorable state (see figure 1 and figure 2).

Moreover, due to the existence of these historical structures, this township has become tourist attraction. Due to that, this township and the country as the whole have benefited by promoting their culture and by emerging economical growth. In view of the above benefits, it is essential to ensure that these historical structures continue to exist. Pursuant to this, there is a need to establish the actual conditions of these historical structures with a main purpose of evaluating the possibility of conserving this cultural heritage, which has great historical value and is a potential tourist attraction.

Heritage structures and historical monuments have a central cultural place in any society; old stone bridges, palaces, churches, cathedrals, monuments, etc., nevertheless, degradation processes generated by natural or human actions lead to deterioration, damaging or even loss of these inestimable treasures. Thus, regular maintenance and remedial works are unavoidable.[9]

Figure 1: Buildings in deplorable state

Figure 2: Buildings in good condition

Historical monuments are the precious signs of our past. They are non-replaceable fragments of our cultural heritage and their future depends on our attitudes and actions towards preserving them. Attitudes are undoubtedly changing in the ways we view our cultural heritage and people are becoming more conscious of the unity of human values and regard ancient monuments as a common heritage. Responsibility for conserving these monuments, and the appreciation of mental and physical skill applied to their erection is thus recognized.

The appropriate selection of the binding materials in the ambit of stone bridges, palaces, churches, cathedrals restoration and conservation of historical monuments is essential at the time of intervention. The physical and chemical properties of binding materials should match as close as possible to those of the unaltered original binding materials. This could be considered as a fundamental requirement in order to avoid incompatibilities of the replacement binding materials.

In order to have a sustained programme for maintenance and conservation of Fasil Ghibe palace we need to identify the physical and chemical properties of the binding materials, address the question of durability of the construction materials used at the time of construction and restoration and prevent further erosion of the integrity of the Fasil Ghibe palace. Additionally, means to address the existing conflicts to balance the conservation of the historic value of the Fasil Ghibe palace with the need to improve the traditional liturgical functions have yet to be implemented.

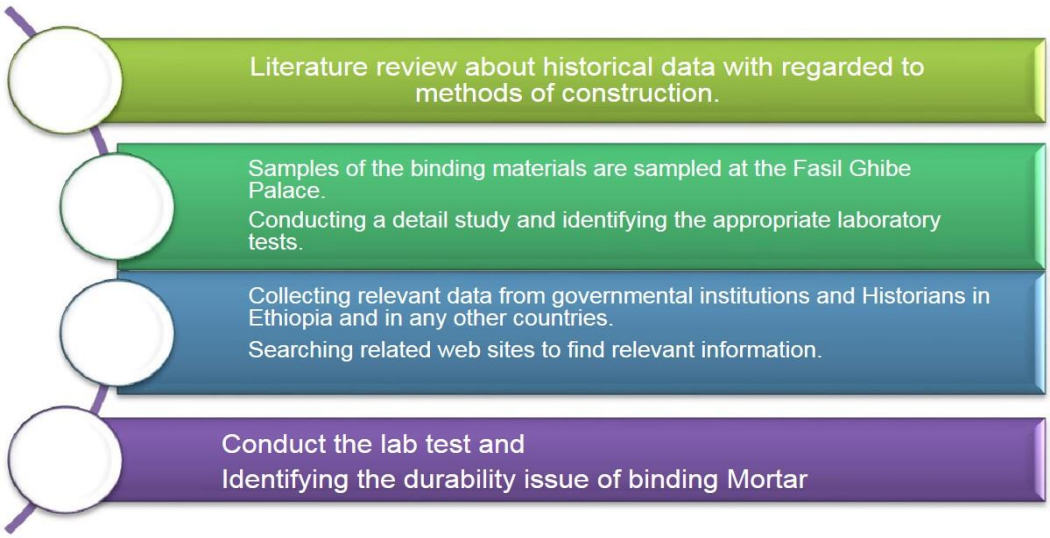
Like many other countries in which monument conservation seems to be a fairly new practice, Ethiopia faces several problems in dealing with the issues of historical monuments. First, there is no suitable system for discovering and recording historical monument in the country. The systems are quite important in monument conservation, particularly among other things, to locate the monument location, function and owner, to classify the monument into their functions, to assist the authority in keeping a record of the monument for future research and funding and to measure monument defects and suggest remedial measures. Secondly, there is lack of technical knowledge in repairing and maintaining historical monuments. This is a major problem because almost all conservation works, which involve both repair and maintenance stages require an understanding and analysis of monument defect diagnoses.

However, till now peoples did not have the exact information about the method of construction and type of binding material which is used during the construction of Fasil Ghibe palace. Some of them say, they are done using egg and fresh leather byproduct as a binding material and others says lime. So, the outcome of this research will address the above question.

This manuscript comprises seven sections. Section one is the introductory section which provides basic information about the research including back ground and statement of the research problem, research objectives and limitations of the research. The methodology followed during the research is presented on section two. It presents an overview of the research process, the research's approach and instrument, the research sample selection and methods of analysis of the research's data. Section three presents result and discussions related with the objectives of the study. A brief discussion on the method of construction, major cause of deteriorations and its remedial measure to resolve this problem in Fasil "Ghibbi" Palace is presented in section Four, Five and Six respectively. The last Section is presents to the research's conclusions.

II. METHODOLOGY

The major steps to be followed while conducting the research are presented in the following flow chart:



After identifying the durability of the construction materials; the question of safety will be addressed. Based on the above methodology the objectives of this research will be addressed.

III. RESULT AND DISCUSSION

3.1 Characterization of Historical Mortar in Fasil Ghibbi Palace

3.1.1 Sampling with Associated Information Recording

Appropriate sampling of historical binding materials can be very difficult due to culturally precious nature of the materials. However, it is always necessary to collect samples for analysis, which will be representative of the material under investigation and also provide enough material for all the laboratory tests analysis.

Therefore, binding materials' samples specimens were taken from sections of interior walls of the buildings in accordance with obtained permit from the Royal Palace Administration and tested in the laboratories at the Geological Survey of Ethiopia, Central Geological Laboratory for chemical analysis properties respectively. The Sample specimens were taken from the walls by using a hand cutting tool but since it's not in a harden state the sample specimens from the restoration site where taken simply by hand.

The aim of sampling was to get a complete representation of mortar variations regarding materials composition and physical condition from different ages. As such, sampling was performed considering the different construction periods and physical conditions.

Description and pictures of the samples collected:

Description: Internal Wall
Weight (gm.): 9.95
Sample Label: G1

Figure 3: Sample taken from the internal wall

Description: Restoration Site
Weight (gm.): 10
Sample Label: R2

Figure 4: Sample taken from the restoration site

3.2 Experimental Results and Discussions

3.2.1 Analytical Results for the Original Binding Material

Table 1: Analytical Results for the Original Binding Material in Percent

Analytical Results for the Original Binding Material in Percent													
Field No.	Lab. No	SiO_2	AL_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	MnO	P_2O_5	TIO_2	H_2O	LOI
G-2	20205/14	35.46	7.98	11.02	18.70	5.48	2.64	<0.01	0.18	0.24	1.80	5.12	12.38

3.2.2 Analytical Results for the Binding Material in the Restoration Site

Table 2: Analytical Results for the Binding Material in the Restoration Site

No.	Sample No.	Lab. No.	TW/HWT (gm)	Magnetite	Ilmenite	Ilmonite	Calcite	Quartz	R.F of carbonate and Basalt	Remark
1	G-1	20209/14	10/9.95	Tr	Tr		*50	2	46	*= Clay size Calcite
										R.F = Rock Fragment
										Tr =Trace Element

- ✓ G1 represent for sample which is taken from the internal wall of the palace, R1 represent sample which is taken from the restoration sites. Samples are processed using different characterization method and analyzed individually.

IV. METHOD OF CONSTRUCTION OF FASIL GHIBBI PALACE

Masonry construction has been used for at least 10,000 years in a variety of structures homes, private and public buildings and historical monuments (International Building Code 2003).

Fasildas's castle is made of stone and shows a unique combination of Portuguese, Axumite and even Indian influences. The ground floor consists of receptions and dining areas. The walls are decorated with the symbol similar to the Star of David, which became the emblem of the Ethiopian royal family after the Solomonic dynasty reclaimed the throne in the 13th century. The first floor roof of the castle was used for prayer and religious ceremonies and it is also were Fasildas's addressed the towns folk. Fasildas's prayer room, also on the first floor, has four windows, every one of which faces a church. Stairs lead from the roof to the small second floor that Fasildas's used as his sleeping quarters. Above this is an opening balcony which was probably the watch tower.

This third floor platform, 32 meter above the ground, offers views in all directions; on a pure day, you can even see lake Tana on the horizon, emphasizing the strategic advantage of choosing Gondar as a capital. The construction materials used for the constructing the palace wall system is wooden floor.

However, the methods of construction for Fasil palace walls were by stone masonry. The type of construction materials which is used during the construction of the royal palace was mainly Rock because there was abundance of rock supplying sources around Gondar, Ethiopia.

It has been said that the type of rock that was used to construct the walls were of a kinds that is *Beha Dingay* and Basaltic Rock. The former was collected from a place called *Azezo* around *Kuskuam Mariam*; and the latter was collected from a place called *Gemenedba sellassie*.

Moreover, considering its height that is 32 meter and accessibility of modern Crane facility; the method of material transportation at the time of construction makes the construction more challenging. However, after inspecting the whole Palace sides, a traditional kind of pulling mechanism were used by the people at that time in order to construct the mason. It has been said that wooden beams were used as a ramp during the masonry construction.

These wooden beams are imported from a place called *Armachiho or Dembeca* local name *werk mider*.

The holes are positioned within 4 to 5 meter distance from the ground and also found within the same interval for the next level of the wall of the palace.
As it is seen in the (picture 5), it is possible to observe the holes. Meanwhile the holes were covered by the same kinds of stone probably at the end of construction for the aesthetical purposes. However, anyone can physically observe that the covered holes for the wooden beams are visible on different sides of the walls.

Figure 5: Covered holes for the wooden beams in the main Castel.

V. MAJOR CAUSES OF DETERIORATION OF MORTARS IN FASIL GHIBBI PALACE

It is well known that various deterioration mechanisms, due to environment interaction with building materials, can occur, in which water always plays a primary role.

Figure 6: Deterioration of rendering Mortar

In particular, it is better to classify the major cause of mortar deterioration in the Royal Palace compound:

I. ***Physical causes***: As in the case of crystallization of water soluble salts.

II. ***Chemical causes***: Due to ettringite and/or thaumasite production as a result of the reaction between sulfate salts and hydrated calcium silicates or aluminates which are present in mortars based on hydraulic lime or lime-pozzolanas; and (See the Figure below).

Figure 7: Mortar deterioration due to Chemical Reaction

III. ***Biological causes***: As in the case of formation of algae, lichens and fungi. These specific causes have been the chief problem in the external face of the walls.(See the Figure below)

Figure 8: Mortar deterioration due to Biological Causes

IV. ***Mechanical actions***: E.g. impact, overloading, vibration, blasting etc. hence the Royal Palace is located on the center of the city, vibration which is prompt by the nearby traffic load is one of the problem. Proper follow up and care has to be on check points, it is better to limit the number of visitor at a time for proper monitoring and reducing the mechanical impact caused by some irresponsible individuals. (See the Figure below)

Figure 9: Mortar deterioration due to Mechanical action

VI. MAJOR PROBLEMS AND REMEDIAL MEASURES

6.1. Tilting Of Masonry Walls & Damaged Masonry with Loose Bonding

The major case for leaning of the masonry wall in the royal palace may perhaps due to the existence of algae, shrub and different kind of Grass on unusual part of the wall. Lack of proper follow-up; for the last time restoration activities and restoration practices was done in the past around 1989 in collaboration with UNESCO.

Hence the upper portion of the wall was leaning out of plumb. Masonry damage was the result of aging of the structure and materials, poor water proofing, wrong loading conditions like vibration due to traffic load etc. The destabilization of older walls due to the deterioration of the inner core rubble between the exterior and interior faces of masonry needed proper attention. (See the Figure below)

Figure 10: Leaning Of the Masonry Wall in the Royal Palace Near to the Main Road

The second dilemma which is related to durability issue of the Royal palace is the loose bondage of mortar in between the masonry stone layer and also the removal of the top pointing surface due to a number of reasons; in addition to the above listed impact mechanical impact caused by human beings should also have to be considered. (See the figure below)

Figure 11: Mortar re-pointing in the internal and external appearance of the palace wall

VII. CONCLUSION

The method of construction for the Royal palace walls were by stone masonry. The abundant type of construction materials which was used during the construction of the Royal Palace was mainly by Basaltic Rock and Pumice or "*Beha Dingay*"; which is transported from"*kuskuam mariya"* and "*Azezo"* respectively; because there was abundance of rock supplying sources around Gondar, Ethiopia.
Moreover, considering its height that is around 32 meter and accessibility of modern Crain facility; the material transportation at the time of construction was challenging. But, after inspecting the whole building sides I concluded that:-

1. The people at that time used a traditional kind of pulling mechanism in order to construct the mason. It is also possible to observe the rectangular holes which were covered by the same kinds of stone probably at the end of construction for the aesthetical purposes. However, anyone can physically observe that the covered holes for the wooden beams are visible on different sides of the walls.
2. The methods of construction for Fasil palace walls were by stone masonry. The type of construction materials which were used during the construction of the royal palace was mainly Rock for wall construction in combination with lime because there was abundance of rock supplying sources around Gondar, Ethiopia. Wood also used for the construction of floors, stair cases, windows and doors as well as balustrade.
3. The type of binding material which was used during the construction of the Royal palace is identified as Lime (CaO) or by its local name Nora.
4. The major cause of deterioration of the Royal Palace is due to various reasons, some of which are long life, lack of periodic maintenance, unchecked growth of trees, grass, algae & mechanical impact on the wall surface by Visitors, irregular inspection, material deterioration and weathering effect etc. Also, modern codes and building standards, observance of cultural context, conservation criteria, traditional and innovative methods pose major challenges in restoration of Royal Palace.

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REFERENCES

[1]. A.M.Neville. Properties of concrete: Longman scientific and technical series. London, 1986.
[2]. Adejumobi, Saheed A. THE HISTORY OF ETHIOPIA. Westport, Connecticut, London: Greenwood Press, 2007.
[3]. Avrami E., Mason R., Martade la Torre. Values and Heritage Conservation. Los Angeles: The Getty Conservation Institute, 2000.
[4]. Awaj, Mekonnen Worku. Heritage Based Planning Heritage Policy in light of Sustainable Urban Planning. Addis Ababa, February, 2008.
[5]. Beruto, D.T. and Botter. "Liquid-like H2O adsorption layers to catalyze the Ca (OH) 2/CO2 solid gas reaction and to form a non-protective solid layer at 20°C." In Liquid-like H2O adsorption layers to catalyze the Ca(OH)2/CO2 solid gas reaction and to form a non-protective solid layer at 20°C, by D.T. and Botter Beruto, 497-503. 2000.
[6]. Beruto, D.T., Vecchiattini, R and Giordani, M. Effect of mixtures of H2O (g) and CO2 (g) on the thermal

half decomposition of dolomite natural stone in high CO2 Regimes. 2003.
[7]. Botre, Sayali Sandbhor and Rohan. "A systematic approach towards restoration of heritage buildings- a case study." International Journal of Research in Engineering and Technology, March, 2013: 229-238.
[8]. Boynton, R.S. Chemistry and Technology of Lime and Limestone. New York, 1980.
[9]. Branko Glisic, Daniele Inaudi, Daniele Posenato, Angelo Figini and Nicoletta Casanova.
[10]. Monitoring of Heritage Structures and Historical Monuments Using Long-Gage Fiber Optic Interferometric Sensors – An Overview, SMARTEC. Switzerland, 2007.
[11]. Cazalla, O., Rodríguez-Navarro, C., Sebastian E. and Cultrone, G. " Aging of lime putty: effects on traditional lime mortar carbonation." In Aging of lime putty: effects on traditional lime mortar carbonation, by O., Rodríguez-Navarro, C., Sebastian E. and Cultrone, G. Cazalla, 1070–1076. 2000.

Web sites:

1. *(http://www.getty.edu/conservation/reserch_resources/charters/charter00.html)*

   (Accessed date: 20, 2, 2015).

2. (http://www.getty.edu/conservation/reserch_resources/charters/charter01.html)

   (Accessed date: 20, 2, 2015).

3. (http://www.getty.edu/conservation/reserch_resources/charters/charter00.html)

   (Accessed date: 20, 2, 2015).

4. (http://www.getty.edu/conservation/research_resources/charters/charter06.html)

   (Accessed date: 20, 2, 2015).

5. (http://portal.unesco.org/en/ev.php-URL_ID=DO=DO_TOPIC@URL_SE.)

   (Accessed date: 25, 9, 2014).

6. (http://www.icomos.org/Venice_charter.html)

   (Accessed date: 25, 9, 2014).

7. (http://en.wikipedia.org/wiki/Building_restoration.html)

   (Accessed date 19, 2, 2015).

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