Stucco as a Building Material - A Study of Its Composition, Use and Scientific Analysis

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Abstract: *Stucco is primarily a compound of quick lime and sand. In India, ingredients of stucco composition differ from region to region depending on their respective availability and non-availability. Due to its phenomenal plastic quality, stucco was used for making images in ancient time. But its remarkable application as building material from third century BCE onwards no doubt brought a new phase in the structural activities of India. It is found that Harappan people knew the technique of burning lime and stucco during this time was used as building material. Stucco was used variously as mortar, cementing the brick or stone structures, preservative coating and plastering the structure. In India its greater use has been noticed in Buddhist structures. The stucco materials, collected from different sites have been scientifically analyzed through laboratory testing. These examinations have given us some very significant information and have raised some serious issues. In the present article two laboratory reports of stucco materials of two Buddhist sites namely Mogholmari and Kankandighi of West Bengal have been analyzed.*

Keywords: Stucco, Mortar, Plastering, Harappan, Rajbaridanga, Moghalmari, Kankandighi

Introduction

Stucco as an important building material was extensively used in ancient India through the centuries. Its compositional properties, colour content and plastic quality facilitated its use for different purposes especially in building construction either as plastering of the structure or as a strong mortar in case of brick or stone construction. Owing to its plastic quality the material was also employed in making sculptures and relief works on the religious structures of India and in many other countries. We come across its phenomenal use in making images in India and many other countries. Some unique and exquisite stucco images have been recovered from, Gandhara in northwestern region. Stucco images are found in Nalanda, Moghalmari, Rajbaridanga and other sites in eastern India. West Bengal is a riverine and monsoon faded region which is not suitable for large scale production of stucco images, but despite of this climatic limitations, stucco images have been recovered from a number of Buddhist sites in Bengal. Stucco became one of the most essential materials for both constructions and

plastic art. The archaeological evidences provide us some significant information regarding its use in India in different geographical horizon, be it in older alluvial or new alluvial plain or in dry arid regions.

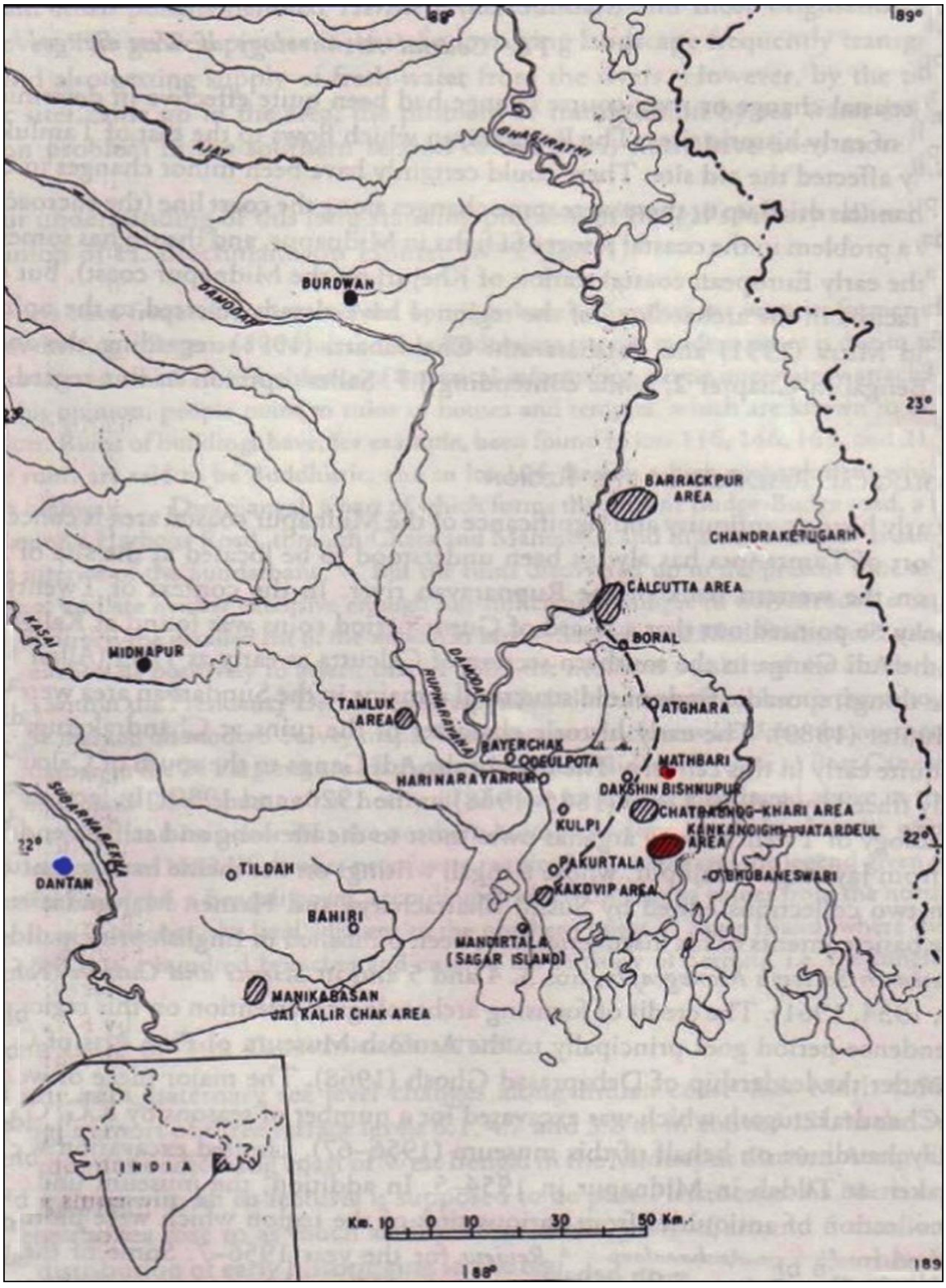


Figure 1: Showing the sites of Kankandighi and Mogholmari

The application of stucco in ancient monuments or structures was mainly restricted to various coatings useful for both the exterior or interior walls as a weather repellant coating. With the introduction and development of heavy timber or light wood framed constructions and also brick structures in ancient time stucco was adopted to protect the buildings from rain water and also from fire. Moreover, in many ancient sites especially in India its use had been noticed to be restricted, at times, to the drains and floors where more water resisting plastering was required. It had worked as a preservative for such places where water had a constant flow. In many early historic and early medieval sites of India, the use of locally made stucco - mortar has been noticed (Basu 2008). Thus, Stucco as a mortar has opened up a new study area in the field of Archaeology with its scientific analysis and laboratory testing which will help us to understand various constructional techniques of ancient building and the purpose of using different ingredients for making stucco materials on a regional basis. The present study is an attempt to highlight varied uses of stucco as building material in India with special emphasis on two Buddhist sites in coastal region of West Bengal where stucco was employed for various purposes. These sites are a) Kankandighi, in South 24 Parganas (Sites pointed in red) and b) Moghalmari in Medinipur District (Site pointed in blue) (Figure 1). Both these sites flourished during early medieval period. The laboratory testing, along with scientific analysis and interpretation of stucco mortar of these sites have been done recently which have raised some important issues for future studies.

Composition

Stucco is an Italian word which is said to have been derived from the old high German word 'Stucchi', meaning crust or coating (Sengupta 1981: 91). It is a kind of compound formed by mixing dehydrated lime or gypsum or glue, pulverized marble or stone chips and sand with water. During its traditional use in India, it has been found that stucco (slow- setting plaster) was primarily made of lime, sand and water. It is said that the composition was made on the basis of local custom, religious beliefs, environment and locally available materials. So in several cases stucco had shown a mixture of substantial amounts of mud or clay, marble dust or saw dust and even organic materials. Gypsum was not a regular element in the stucco mixture in some parts of the country. Gypsum, the dehydrated calcium sulphate in the mixture of stucco was used in north western region, especially in Pakistan and Afghanistan where it was frequently used in stucco material (Verma 1983: 11). It should be mentioned here that composition of stucco and its process of admixture of different ingredients in different ratio vary from region to region. The process of making this material also depends on the indigenous knowledge. Significantly, in India we have several instances where stucco was used for protection of brick structures from water leakage, indicating a skillful use of the material. For obtaining the best result of the material, a highly technical knowledge was required for selecting suitable ingredients in measured proportion for preparation of the stucco because the stucco mortar with a large portion of lime to sand is more likely to crack because of greater shrinkage.

Regarding stucco composition, K.M. Varma who has done a pioneering work on Indian stucco, has identified the material as a compound of quick lime and sand (Verma, 1983:9). Sometimes in the composition of stucco, substantial amount of clay had been introduced in order to foster a strong binding property and plastic quality. Stucco can be applied directly without lath to the stone or brick structures. In a recent scientific analysis, the fine brick dust, charcoal and other materials have been noticed in the mixture of stucco discovered from various archaeological sites in India. In ancient Bengal brick- dust was universally used for the preparation of the stucco compound. Evidently, lime burning is an ancient practice and it was a part of process for making quick lime to produce stucco material as mortar. Lime burning was known to the Indus people. In 1926-27 Daya Ram Sahni indicated the existence of a mortar pit in Mohenjo-daro by stating that "… in the middle of room 135 is what appears to be a brick built mortar pit stilled filled with gypsum lime which may have been used for plastering the walls as patches of it are still adhering to the inner walls of room number 134". In other archaeological sites in India, the evidence of lime burning has also been detected. In regard to this, we may mention here two important archaeological sites, one is the early historic urban settlement site of Chandraketugarh in West Bengal and another is the great stupa site of Amaravati in Andhra Pradesh. At Amaravati lime burning is evidenced near its great stupa area. It is reported that Alexander Rea while excavating this site, discovered a place very close to the great stupa which he identified as a kiln for lime burning (Verma.1985).Similarly, an archaeological record coming from stratum - IV of Chandraketugarh shows a room stuffed with burnt lime, indicating its use as an ingredient of building material for plastering the wall of the temple, discovered at Khanamihirer dhibi (Indian Arch- A Review, 1962-63).

Quick lime i.e. Calcium oxide is obtained from lime stone by heating it at a very high temperature in the absence or limited supply of air. This process is known as Calcination. The calcium oxide is found either in lump or in dust form. Generally, the resulting product bears white colour but sometimes due to the presence of impurities it shows different shades of colour.

Calcination: Calcium Carbonate ($CaCO_3$)+ Heat =Calcium Oxide (CaO) i.e., Quick Lime + Carbon dioxide (CO_2)

Hydration: Calcium Oxide (CaO)+ Water (H_2O) =Calcium Hydroxide Ca $(OH)_2$ i.e., Slaked or Hydrated Lime (Figure 2) + Heat

Carbonation: Calcium Hydroxide $Ca(OH)_2$ + Carbon dioxide (CO_2) = Calcium Carbonate ($CaCO_3$)+ Hydrogen(H)

Varied uses

In India, stucco as an important building material, had been adopted for constructional works for different purposes. The importance of its physical properties had been realized by the ancient people who used this material primarily as mortar for

cementing the brick or stone structures. Stucco had also been used for plastering the walls and most importantly the material was applied to the drains where more protection was required due to seepage. Archaeological evidences have proved its application in the brick structures from third millennium BCE. (Verma.1983: 69). It is believed that the Harappan people knew the burning of lime for the preparation of mortar and they had the technical knowledge for the preparation of stucco. During this time, though its use restricted to the floors and drains where more resisting mortar was needed, it also worked as a preservative for such places where water had a constant flow. Recent archaeological evidences have come from another mature Harappan site, Rakhigarhi (Subramanian.2014) in the older alluvial plain (Bhangar) in Haryana. From its granary area significant traces of lime and decomposed grass are found on the lower portion of the granary wall, indicating that lime was used as insecticide and grass was mixed with this material for preventing moisture. The mortar has also been scientifically analyzed and the report says that stucco materials contain *kankar*. *Kankar* or the calcareous nodules which are widely distributed in northern India, even today constitute an important source of lime mortar (ASI. AR-1929-30.209).The chemical analysis of several stucco materials, discovered from two great sites of Mohenjo-daro and Harappa of Indus civilization had been done by Sana Ullah in 1913-14, onwards which will be highlighted in our scientific analysis section(Verma.1983:86-87).

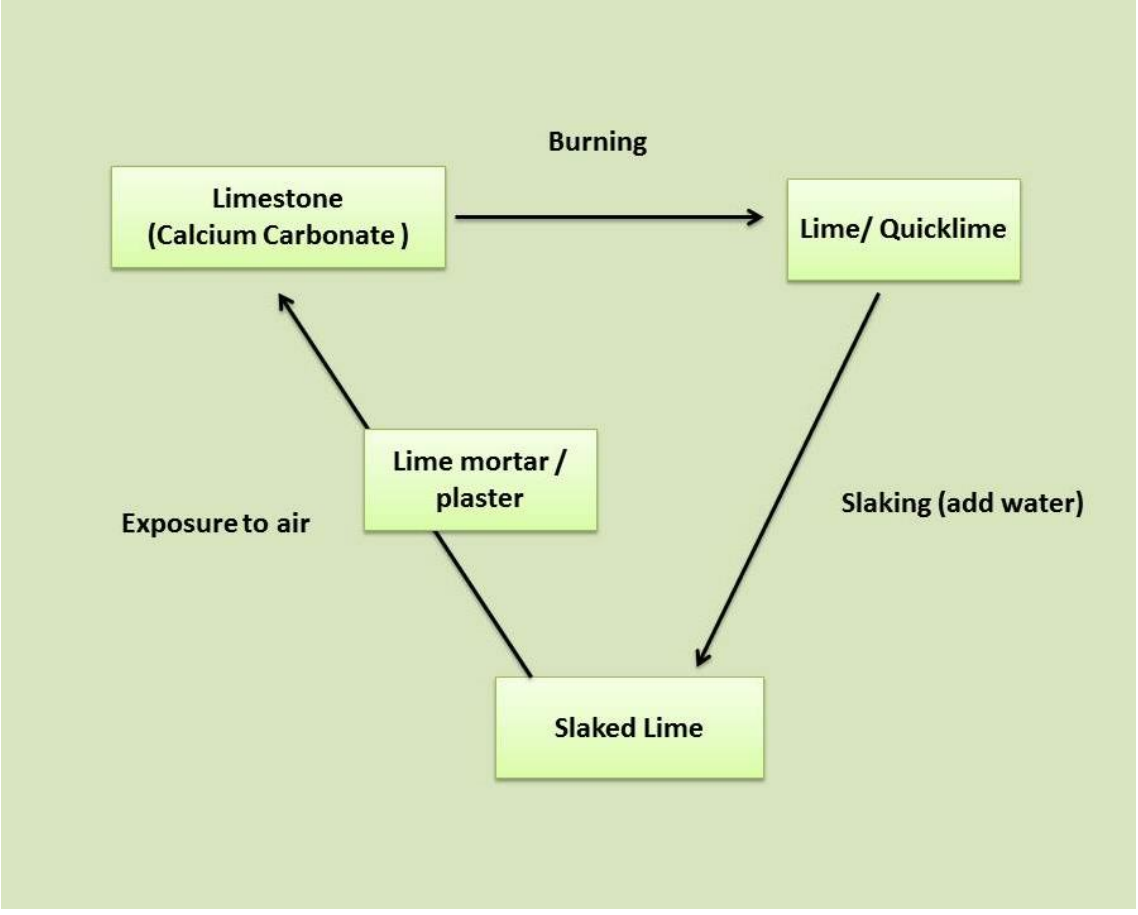


Figure 2: Preparation of slaked lime

Another interesting evidence of using lime (stucco) as plaster coating has come from the site of Bharuch, in Gujrat (Figure 3). Trial excavations have been undertaken at Bharuch, by the excavation branch-v, Vadodara, in 2013-14 of the Survey. In the Soneri Mahal area, excavation has revealed an oval shaped water structure or a tank which was built with burnt bricks with lime mortar and coating (IAR 2013-14).

Figure 3: Tank with lime coating, Bharuch

Admittedly, due to its strong binding capacity and preservative quality, stucco whose main ingredient is lime was extensively used in various structures and house building works from very early time. In the early historic period, several Buddhist complexes gave preference to the application of stucco either for plastering the walls of the monasteries or for coating the stupa structures and also as mortar for cementing or joining the bricks or stones. The best examples have come from the Buddhist sites at Sanchi, Bodhgaya, Amaravati, and others (Basu 2008: 25). Almost from third century BCE, stucco material emerged as a strong mortar and as a preservative coating. A plastered (stuccoed) floor of Mauryan period was recovered in front of a chaitya at Sanchi (A.S.I.A.R.12-13 :19).

Stucco was extensively used in ancient Bengal. In a number of Buddhist monasteries, it was introduced not only for building decoration or sculptural representations, but it was deliberately applied as a thick coating for the protection of the structures. Sometimes stucco coating is found employed at the face of the drain where water flows

constantly. During early medieval period, West Bengal witnessed the growth of a number of small and large Buddhist sites in different geographical horizons (Sengupta 1991: 293). In most of these sites we find that stucco was extensively employed. The most important sites are Rajbaridanga in Murshdabad district, Moghalmari in Paschim Medinipur and Kankandighi in south 24 parganas, where this material was profusely used for cementing and plastering the walls. Proliferation of its application in the brick-built structures was due its easy production with local techniques and sufficient availability of local materials.

Rajbaridanga

It is located in the Murshidabad district as one of the great monastic complexes of the Mahayana Buddhists in West Bengal. The site has revealed stupa, small and large shrines and monastery. Rajbaridanga has been considered as a great stucco producing centre which is evidenced by a large scale use of stucco composed material for various purposes, such as, plastering and coating the walls, steps, pavements, floor and architectural decorations. The structural remains of phase-III and IV, of this site bore distinct evidences of lime plaster and decorative mouldings of stucco (Das, 1968). The outer walls of the temple structures were plastered with lime bearing red coating. Even the floors and pavements were coated with lime plaster. According to the excavator lime was invariably made of shells (Das, 2000).

Moghalmari

Mogholmariis a small village in Datan police station, in the district of Paschim Medinipur. Geo-morphologically, the area around Datan is primarily an extension of alluvium upland, formed by the pluvial action of late Pleistocene to early Holocene. It is known as Sijua formation. The excavation at this site was first conducted by the Calcutta University, under the directorship of Asok Datta in 2003-04 (Datta 2008) Again from 2006-2007, more extensive excavations were undertaken for a few successive years (Datta 2008). Later on, State Directorate of Archaeology took the charge of excavation at the monastic site of Moghalmari. Moghalmari monastic complex can be recorded as one of the best representative and productive sites of stucco works where its lavish use has been noticed in making images and embellishment of outer and inner walls of the monasteries as there were more than one monastery, reported by A. Datta. The most significant application of this compound as a strong building material, has been observed in thick plastering the outer walls of eastern side and traces of lime plaster on the structure of the southeastern corner. A unique stucco plastered floor to the interior of the eastern outer wall was also recovered (Figure 4). In the eastern side, an exquisite ornamental brick wall, veneered with stucco coating has been noticed (Figure 5). A stucco coated niche has been discovered in the northern side of the monastery (Figure 6). On the northern side, a drain has been discovered where in its surface stucco was deployed. Thus, the site is of great importance for providing us information regarding the varied uses of stucco in early medieval period in West Bengal.

Figure 4: Stucco coated wall and the eastern boundary wall of Moghalmari

Figure 5: Stucco coating on ornamented brick walls, eastern boundary, Moghalmari

Figure 6: Stucco coated wall and niche, northern side, Moghalmari

Figure 7: Stucco panel at Moghalmari

Date: 20.01.2017 *Sample No. WB/MGM/MOR-02/15*

Mortar Analysis

Site	Mogalmari Buddhist Vihar
Area	Midnapur (W.B)
Date/ Age of Mortar	8^{th} -9^{th} Century A.D
Function	Mortar
Sample Source	Mogalmari, Datan

Physical Examination

Sample received	Broken Pieces
Hardness	Moderate
Friability (dust)	Moderate
Binder type	Mortar
Binder Strength	Weak
Carbonated	Yes
Colour	5 YR 8/2 Pinkish White

Weight of Sample

Before Drying	54.55gms
After Drying	52.08 gms

Acid Dissolution & Filtration (24 hrs in acid)

10% HCl solution	Strong reaction
Lasting	30 mintutes

Aggregate Filtering and Drying

Weight of dried sub-sample after filtration 35.36gms.

Figure 8: Details of Mortar Sample

Admittedly, stucco as a most useful building material was adopted by the ancient society and perhaps its popularity was increased by the Buddhist monks who followed the instructions given by the Tathagata Buddha about the use of *sudha* for constructing

the roof. The Vinaya Pitaka mentions five types of material for roof and *sudha* or stucco is one of them. Stucco was highly preferred for plastering, cementing and also for protecting the structures. At this point, the most pertinent question is how these composite materials fulfilled all the aspects. So, for properly understanding its physical and plastic properties for such effective uses, it is necessary to conduct the scientific analysis of stucco materials. Recently, from two Buddhist sites of West Bengal, stucco materials have been recovered in substantial amount which were used both for constructional activities and sculptural representations (Figure 7). In Moghalmari stucco was used as a primary building material and the stucco mortar has been analyzed thoroughly by the "Kolkata Lime Centre" to identify its composition. The reports are given as figures 8-12.

Aggregate Grading			
Sieve Number	**Aggregate weight retained (g)**	**Remarks (under microscope)**	**Photograph (Under Microscope)**
2mm	1.06	Angular lime patinated aggregates probably brick bats. *Colour: 5 YR 7/4 Pink.*	
1mm	5.70	Angular lime patinated aggregates probably brick bats with traces of carbon. *Colour: 5 YR 7/3 Pink.*	
500 micron	9.69	Angular small brick bats in various shapes. Lime patination were seen. Carbon particles were increasing. *Colour: 7.5 YR 7/3 Pink.*	
250 micron	8.10	Angular tiny pieces of brick bats. Presence of carbon. *Colour: 7.5 YR 6/4 light reddish brown.*	
125 micron	6.16	Powder may be *clay or surki.* *Colour: 5 YR 5/6 light brown.*	
63 micron	2.71	Fine dust may be *clay.* *Colour: 7.5 YR 6/4 light brown.*	
Less than 63 micron	1.53	Very fine dust may be *clay or surki.* *Colour: 7.5 YR 6/4 light brown.*	

Figure 9: Mortar Analysis

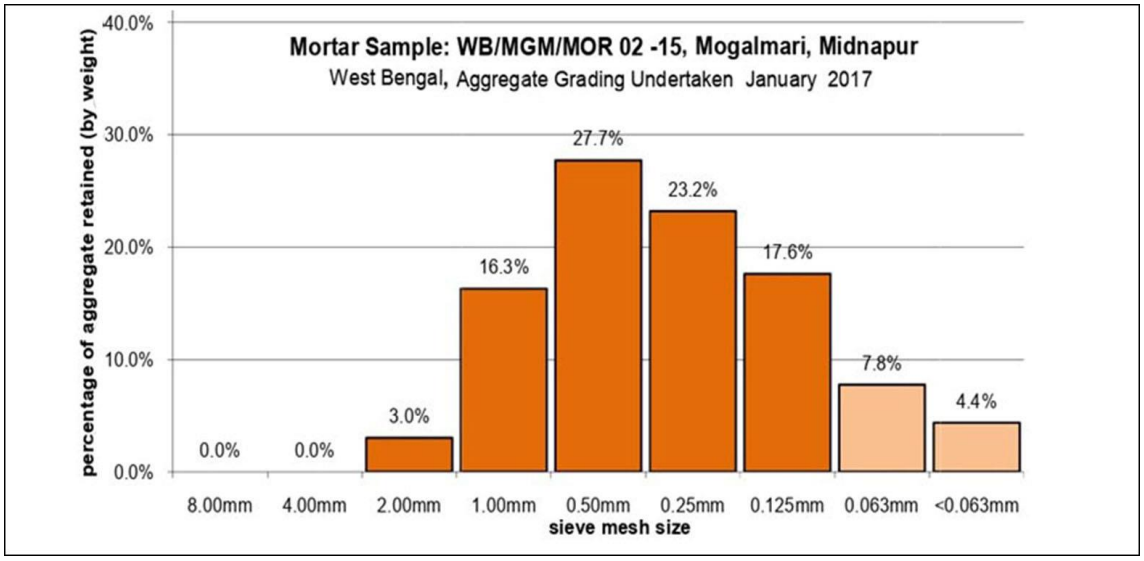


Figure 10: Aggregate Grading of Mortar Sample

Analytical Procedures

The selected sample of material was derived to a constant weight and examined under a microscope at x 25 magnification. Degree of carbonation of the sample was determined using Phenolphthalein indicator, which will react with any carbonated lime.

As assessment of the binder type was made by evaluating the physical characteristics of the mortar based on our own knowledge, experience and understanding of material.

Application of 10% Hydrochloric acid to the sample resulted in dissolution of the binder enabling relative proportions of the lime to aggregate to be determined, where appropriate proportions of insoluble binder were determined and factored into this calculation. Subsequent aggregate characterisation was undertaken by means of dry sieve analysis and microscopic analysis.

The analysis result and interpretations made from it provide information on the composition and characteristics of the mortar sample received by the KLC laboratory. Provided the sample was representative of the plaster generally the analysis will give a reasonable indication of the original material.

Procedure	Observation	
Preliminary visual analysis of sample	The sample was received as fully carbonated broken pieces of mortar. It was moderately firm and moderately friable. The total sample weighed 159.37 gms.	
Examination of prepared sample by microscope (x 25 magnification)	Once dried the mortar was found to be 5YR 8/2 red when assessed against the Munsell Soil Colour Charts. Microscopy confirmed the presence of small amount of brick dust, clay and carbon particles.	
Acid Dissolution and Filtration		
Procedure	**Observation**	
Dissolution Of Binder Using 15% HCl	On addition of the acid to the powdered sample there was strong reaction that lasted for few minutes (about 30 minutes).	
Filtration	Grade: HM2	Paper Type: INDICA Product No- 74041

Figure 11: Analytical Procedures

Summary and Interpretation of Analysis Results

Sample No. WB/MGM/MOR-02/15

About Specimen:

The selected sample (WB/MGM/MOR-02/15) is collected from excavated site of Mogalmari Buddhist Vihar, located in Midnapur district (West Bengal).

Physical Examination:

The weight of total sample was 159.37 gms. The selected sample was weighted 54.55 gms.(for testing). After Phenol test the sample was found to be fully carbonated. On fracturing it was found to be moderate and friable.

Under Microscope:

The selected sample of material was dried to a constant weight and examined under a microscope at x 25 magnification. The aggregates, mostly angular brick bats in various shapes. Traces of lime patination & carbon particles were found. The colour identified under the Munsell Soil Colour Chart was found to be 5 YR 8/2 Pinkish White.

Acid Dissolution test:

Sample when dissolved in 10% Hydrochloric acid showed a strong reaction that lasted for about half an hou . The type of the lime used in the mortar was hydraulic lime binder.

Advanced Laboratory report

Binder:	Hydraulic lime
Fine Aggregate:	Brick bats, clay or surki.
Conclusion:	Hydraulic lime and clay/surki mortar with a ratio of 1:2 (by weight).

Figure 12: Result of the analysis

Kankandighi

Kankandighi is located in the District of South 24 Parganas under the Jurisdiction of Raidighi Police station, on the bank of river Mani (Figure 13). On the basis of cultural materials and structural remains with moulded bricks, it has been suggested by the excavator that the whole structural complex flourished during tenth/ eleventh century. The structural remains unearthed during this excavation belonged to a Buddhist monastic complex (Basu, 2017). As a regular practice in early medieval monasteries in eastern India, the Kankandighi Buddhist monastery also marked with the use of stucco compound for the construction works. Unlike Moghalmari, its use was restricted to the building activities only. Stucco was found applied for plastering and cementing the bricks (Figure 14). The stucco sample has been collected and analyzed by laboratory testing which gives us some very interesting information about its composition and ingredients (Figures 15-17).

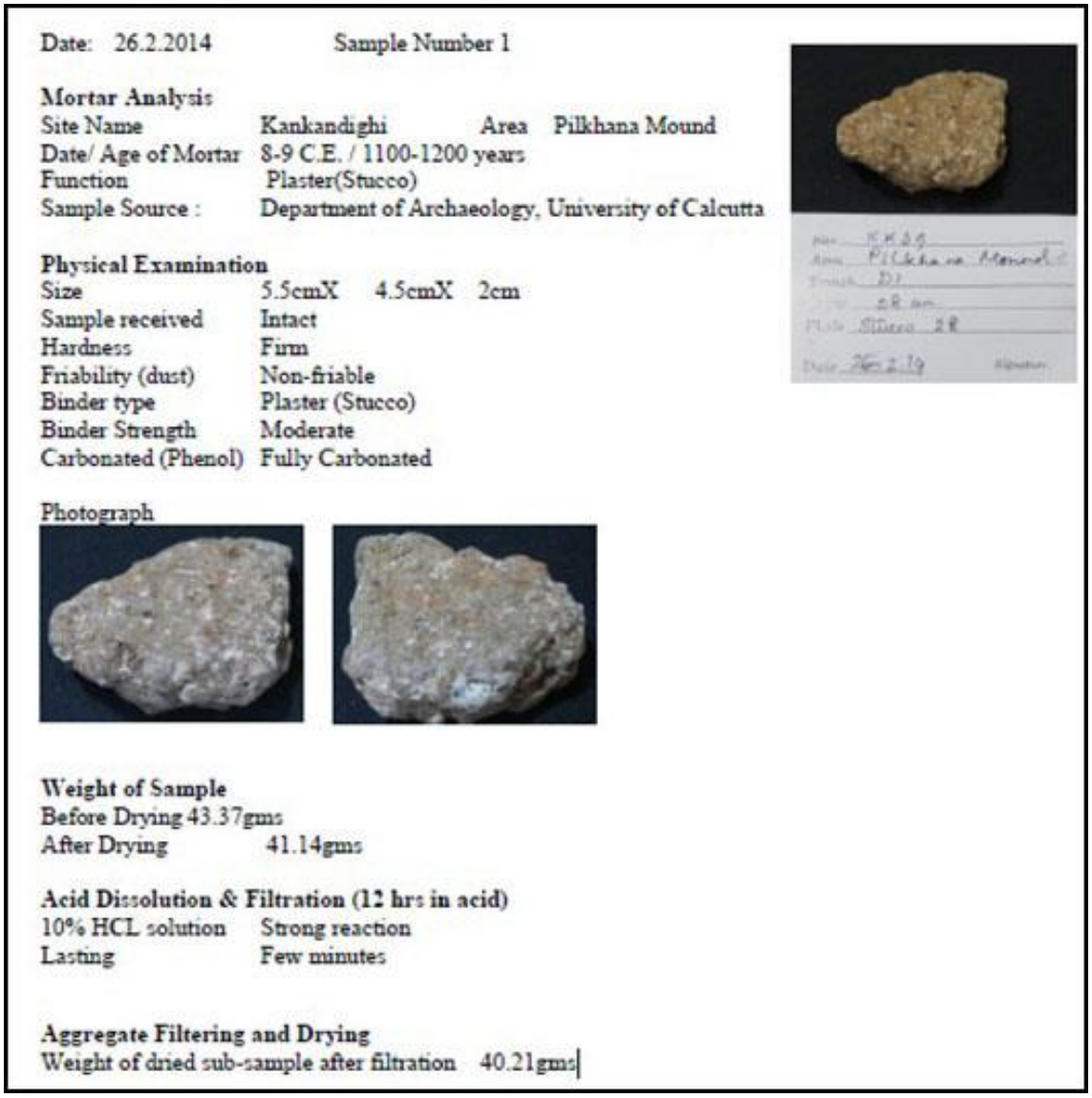
Figure 13: Excavated Trenches at Kankandighi

Figure 14: Bricks with stucco mortar, Kankandighi

Conclusion

While summarizing, it may be mentioned that the antiquity of the use of Stucco as a building material goes back to Indus Civilization when lime burning and its application was well known. Even in pre-Harappan phase of Kalibangan, stucco was employed as a strong plaster in water storing pit (Carron 2012). Later on, this material was extensively used both as building materials especially as mortar, coating and making the images. As it is already mentioned that stucco samples collected from

Indus sites had been analyzed which unfolded the actual concentrations of different ingredients in varied ratio, in the stucco compound. Most of the sites have revealed calcium carbonate in high percentage and clay and sand with small percentage of water. In most of the samples gypsum was traced. Mohammad Sana Ullah examined a series of specimens, collected from Harappa and Mohenjo-daro in 1926-32. Among these materials, a very interesting specimen came from Mohenjo-daro, which has revealed a different picture. In most of these Indus sites, gypsum had been found only in traces but in this specimen a high percentage of gypsum (74.12%) had been obtained (ASI, AR.1928-29). From this analysis it is clear that in northwestern region, stucco compound consisted mainly of two important ingredients, gypsum and calcium carbonate. But in eastern India its conspicuous absence has been noticed in most of the sites. Now it is an established fact that stucco ingredients vary from region to region, since it always remained as a local product.



Date: 26.2.2014 Sample Number 1

Mortar Analysis

Site Name	Kankandighi	Area	Pilkhana Mound
Date/ Age of Mortar	8-9 C.E. / 1100-1200 years		
Function	Plaster(Stucco)		
Sample Source :	Department of Archaeology, University of Calcutta		

Physical Examination

Size	5.5cmX 4.5cmX 2cm
Sample received	Intact
Hardness	Firm
Friability (dust)	Non-friable
Binder type	Plaster (Stucco)
Binder Strength	Moderate
Carbonated (Phenol)	Fully Carbonated

Photograph

Weight of Sample

Before Drying 43.37gms

After Drying 41.14gms

Acid Dissolution & Filtration (12 hrs in acid)

10% HCL solution	Strong reaction
Lasting	Few minutes

Aggregate Filtering and Drying

Weight of dried sub-sample after filtration 40.21gms

Figure 15: Basic Details of Mortar sample

Aggregate Grading			
Sieve Number	Aggregate weight retained (g)	Remarks (under microscope)	Photograph (Under Microscope)
8mm	0		
4mm	0.31	Angular rock particles of lime stone mainly dolomite. Presence of low graded marble	
2mm	2.5	Angular rock particles of lime stone mainly dolomite. Presence of low graded marble with small quantity of charcoal, and brick bats, quantity increasing	
1mm	8.41	Angular rock particles of lime stone mainly dolomite. Presence of low graded marble with small quantity of charcoal, and brick bats, % of brick bats increasing	
500	8.05	Angular rock particles of lime stone mainly dolomite. Presence of low graded marble with small quantity of charcoal, and brick bats, quantity is less than previous	
250	4.44	Angular rock particles of lime stone mainly dolomite. Presence of low graded marble with small quantity of charcoal, and brick bats, quantity decreasing	
125	5.19	Dusty material, quantity increasing	
63	9.02	More fine dust	
Less than 63	2.29	Very fine dust	

Figure 16: Stucco composition

The sample collected from Moghalmari was examined by the Kolkata Lime Centre under the supervision of Dr. Neeta Das in 2017.The selected sample which was taken for testing, initially weighted 54.55 gms. After phenol test the sample was detected to

be fully carbonated. On fracturing, it was found to be moderate and friable. The sample was again examined under a microscope at 25 Magnification. The aggregates mostly had angular brick bats in various shapes. Traces of lime patination and carbon particles were noticed. This sample on dissolving in 10% Hydrochloric acid resulted in a strong reaction which lasted for half an hour. After analyzing the sample, it was found that the type of lime in this mortar was hydraulic lime binder. In this stucco composition we find the presence of brick bats, carbon, clay or *surki* powder and fine clay dust. The Hydrolic lime has been recognized as the binder.

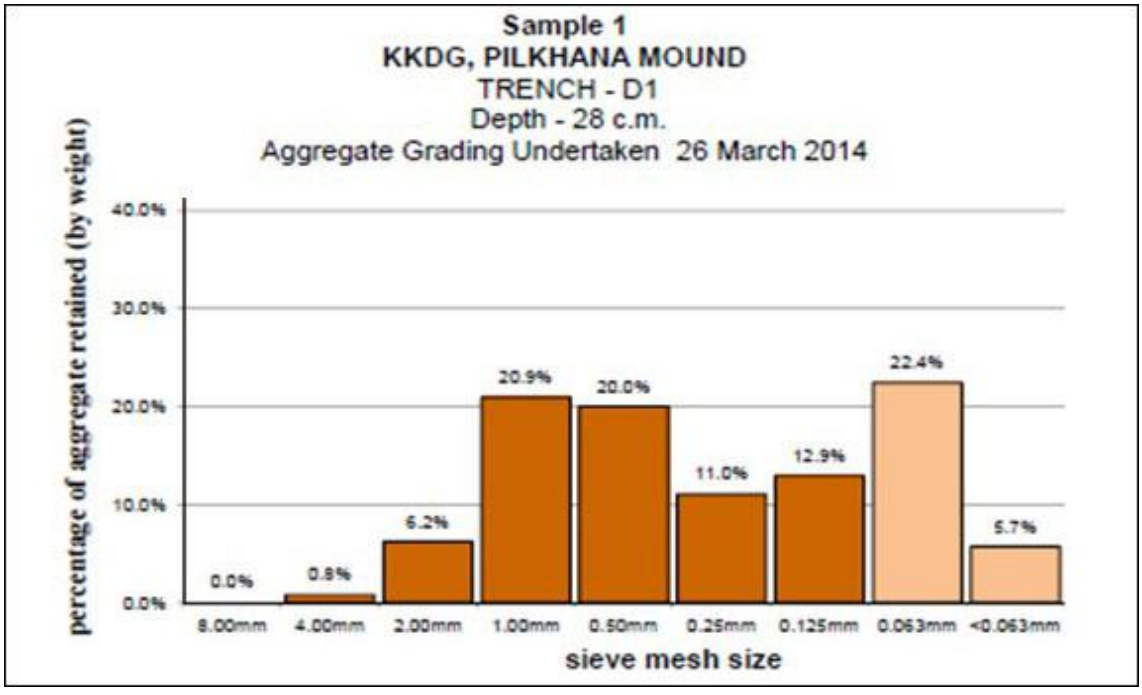


Figure 17: Aggregate Grading of Mortar Sample

Kankandighi sample has provided us some very interesting information. The laboratory analysis has been done by Dr. Das and Dr. Banani Bhattacharya. According to the report, the stucco sample contained angular rock particle of lime stone mainly dolomite and small quantity of charcoal and brick bats. In this compound, the most significant element is the presence of low graded marble. Now the question arises that what was the source of marble stones and from where were they collected by the ancient people. In this alluvial region there is no source of stone. So, people quarried it from the neighbouring Chotonagpur plateau regions (Sengupta.2012) where stone was easily available. Now the presence of marble stone in the stucco compound in this region raises some important issues regarding stone quarry, mobility, and trade connections. So, the scientific analysis of this material not only gives us its composition but it brought to light several other factors related to the ancient settlement, people and socio-economic conditions. In eastern India stucco became an integral element of Buddhist monasteries. So, its deliberate application over wall surface for plastering, cementing the brick structures and coating to the water prone areas such as drain, are visible which was a very common factor in the structural activities.

References

Archaeological Survey of India- Annual Report. 1912-13. Superintendent Government Printing – India, Calcutta: 19

Archaeological Survey of India- Annual Report. 1929-30. Superintendent Government Printing – India, Calcutta: 209.

Basu, D. 2008. Stucco Art. *Excavation at Moghalmari: First Interim Report 2003-04 to 2007-08.* A. Datta. (ed). The Asiatic Society. Kolkata. p.24-30.

Basu, D. 2017. A Brief Report on Excavation at Kankandighi. *Puravritta (*2), Journal of the Directorate of Archaeology and Museums. Govt. of West Bengal. Kolkata.

Carran, D., J. Hughes, A. Leslie, and C. Kennedy. 2012. A short history of the use of lime as a building material beyond Europe and North America. *International Journal of Architectural Heritage 6*(2), 117-146.

Das, S. R. 1968. *Rajbadidanga - 1962.*The Asiatic Society. Kolkata.

Das, S. R. 2000. Stucco Art – Creations in Eastern India. *Centre for Asian Area Studies*. M. A. Konishi and A. Uesugi. (Eds.). Rikkyo University. Tokyo.

Datta, A. 2008. *Excaavtion at Moghalmari.* The Asiatic Society. Kolkata.

Ghosh, A. (Ed.). 1965. *Indian Archaeology – A review. 1962-63:* Archaeological Survey of India. New Delhi.

Sengupta, G. 1991. Stucco Statuary in Eastern India. *Aksayanivi, Essays Presented to Dr. Debala Mitra in Admiration of Her Scholarly Contributions*. G. Bhattacharya (Ed.). Delhi: Sri Satguru Publications.

Sengupta, G. 2012. Archaeology of coastal Bengal. *Tradition and Archaeology Early Maritime Contacts in the Indian Ocean*. H. P. Ray and J. F. Salles (Eds.). pp. 115-127. New Delhi: Manohar Publishers.

Sengupta, R. 1981. Stuccos in Central Asia and India: A Reappraisal. *Puratattva (*12). Indian Archaeological Society. Delhi.

Subramanian, T. S. 2014. Ancient granary found in Haryana. Accessed on 20 Dec 2019 *www.thehindu.com/news/national/other-states/Ancient-granary-found-in-Haryana/article11632857.ece.*

Tiwari, R. (Ed.). 2016. *Indian Archaeology- A Review.2013-14.* Archaeological Survey of India. New Delhi

Verma, K. M. 1983. *Stucco in India*. Proddu: Santiniketan.

Verma. K.M. 1985. *Amaravati and the Beginning of Stucco Modelling in India.* Proddu: Santiniketan.