# ANCIENT COMPOSITE MATERIALS: AN EXPERIMENTAL APPROACH TO "ARTIFICIAL LATERITE" FROM EARLY HISTORIC POPULATION CENTERS IN ODISHA

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**Abstract**

The chemical and physical properties of natural materials, when combined in novel configurations or treated through processes such as fire, provide scope for humans to develop new and distinct substances. The sophisticated use of composite materials by ancient people (including concrete, plaster, and glass) enabled greater creativity in art, a greater range of architectural forms, and a more rapid production of daily-use goods. Composite materials also can be highly cost-effective as they are amenable to techniques such as molding that enables the production of novel shapes, and can make use of discarded materials as an efficient form of recycling. This paper examines the use of a composite process that was developed by ancient people to mimic solid stone at the ancient city of Sisupalgarh and its satellite town of Talapada during the Early Historic period (3rd century BCE-4th century CE) in eastern India.

## Introduction

The first human artefacts were made from durable materials directly derived from nature such as stone, wood, and bone. In many cases, those materials were used just as they were found to assist in tasks related to acquiring food or providing shelter. Simple modifications subsequently enabled people to enhance the inherent properties of those materials, such as the removal of rough cortex to make a sharpened stone tool, the shaping of wood to straighten a tree limb for architectural construction, or applying friction to make a sharpened bone point. After a long period in which materials were simply used "as-is" from nature, our ancestors began to create tools and other objects by combining one type of material with another. Stones were hafted onto twigs to make axes and adzes; bone needles were used to join together sinew and leather; and sharp blades were encased into wooden handles. These composite tools became a hallmark of the Upper Palaeolithic age, an era that also saw the development of non-utilitarian items such as beads that constitute evidence for social interaction and trade (Stiner 2014).

The next significant shift in the human use of the natural world came through the combination of materials to make entirely new creations. The earliest such transformations would have been through the process of cooking, which physically alters foods and creates new flavors when ingredients are combined to make stews, soup and gravy. The finished products of cuisine often involves many steps of input including chopping, grinding, mixing, and heating such that the final product is distinct from any of the initial ingredients. The cooking pots that were essential to this process of cooking were themselves the result of a process of combinatorial experimentation in which clay was mixed with water and with different kinds of temper. Other composite materials were later developed: tin and copper were smelted together to make bronze, and shells were transformed into powder through firing and then mixed with water to produce plaster.

Composite materials such as bronze and plaster represented the advent of new human-made substances that enabled people to stretch their material repertoire and provide new opportunities for technological change and innovation (see Schiffer 2011). Composite materials also afford opportunities for creativity and innovation through the creation of different "recipes" for similar-looking products (e.g. Miller 2008) and through further innovations such as molding that accelerate the production and consumption processes (Smith 2015). In contrast to the relatively static parameters of wholly natural materials, the human capacity for combinatorial manufacturing facilitates a

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continual opportunity for experimentation and novelty.

Composites provide a particularly distinct mode of expression when used in architecture, as seen in archaeological cases worldwide. In some regions, the development of composite materials enabled new structural forms to be envisioned and built, such as the apartment buildings and artificial harbors of the Roman Empire that were constructed with cement (Lechtman and Hobbs 1986). In other regions, the use of composite materials enabled people to scale up the size of existing architectural forms into larger monumental structures, as seen in the pre-Columbian pyramids of the ancient city of Teotihuacan in Mexico (Cowgill 2015). In addition to their practical advantages, composite materials such as lime plaster also enabled new forms of architectural aesthetics in which the bright white colour and smooth texture of human-made constructions presented a stark contrast to the rough surfaces and muted earth tones of the natural world.

Composite materials have other attractive properties in addition to allowing for creativity, experimentation and the expression of individual prowess. Composites can be made of relatively cheap and widely-available materials, transformed into finished products through the application of human labor. One particularly good example is the use of three of the earth's most abundant materials (water, clay, and organic fuel) for the production of pottery which can be done in an almost unlimited number of shapes according to the skill of the potter. Similarly, glass is a composite that is made of easily-available materials (sand, soda, and lime) that can be transformed into items with unique properties such as transparent vessels as well as mass-produced goods such as glass beads.

Composite creations also can blend more-valuable materials with less-valuable materials to increase volume at low cost; for example, cement is mixed with aggregate (stones or gravel) that increases volume, provides stability to the mixture as it dries, and mitigates unwanted fracture patterns (Chen and Liu 2004). The aggregate is no longer visible once the cement surface is "finished" and the consumer is unaware of the proportions of aggregate to cement in the finished product. The use of composite processes also can transform low-value or discarded items into high-value items through recycling, as in the case of lime-slaking from shells discarded after food consumption.

**Composite materials in South Asia**

Archaeological sites in the Indian subcontinent provide ample evidence of the development of composite products. Clay composites such as pottery, mudbrick and pisé were part and parcel of Neolithic lifestyles starting as early as the eighth millennium BCE (Hazarika 2013). By the mid-third millennium BCE, there is evidence for lime plaster in pre-Harappan levels at Kalibangan (Thapar 1975); the subsequent development of urbanization in the Harappan period was accompanied by the manufacture of other composites including bronze (Park and Shinde 2014) and faience (Miller 2008). By the mid-second millennium BCE, glass was added to the repertoire of composites made and used in the subcontinent (Kanungo 2004).

The Early Historic cities of the Indian subcontinent were thus developed at a time when all of the major composite materials known from South Asia had already come into existence. The presence of cities as diverse locales of economic, social and political activities provided the opportunity for people to intensify their use of composite materials, and also provided the opportunity for continued innovation in composite materials. In the case study below, we identify the use of one such composite material in the form of "artificial" stone that was made from laterite waste products and used in the construction of monumental public architecture.

**Excavations at Sisupalgarh and Talapada**

For the past decade, a joint research project has been carried out between Deccan College and the University of California, Los Angeles to investigate the urbanized landscapes of the coastal Odisha region. Following on the pioneering work of Prof. B.B. Lal in the region (Lal 1949, 1991), fieldwork has been carried out at the urban site of Sisupalgarh (Smith 2005; Mohanty and Smith 2008), the town-sized settlement of Talapada (Mohanty, Smith and Matney 2014), and the village-sized settlement of Ostapur (Figs. 1 and 2). These efforts have been integrated with other projects in the region, including excavations at the Neolithic site of Harirajpur, the Neolithic site of Golbai Sasan (Mohanty *et al*. 2012-13), and surveys of additional Neolithic and Early Historic sites (Behera 2013). The integration of information from these projects provides the opportunity to compare the architectural, artefactual and environmental components of the regional transition to urbanism.

In their architecture, the ancient inhabitants of Sisupalgarh and Talapada made use of a variety of naturally-available building materials. The landscape of Odisha's coastal zone is characterized by a laterite substrate with occasional outcrops of sandstone. Sisupalgarh is located in an alluvial area one kilometer away from a laterite upland that rises gently to the west, with the nearest sandstone outcrop four kilometers away at the site of Dhauli. Talapada is similarly located in a landscape

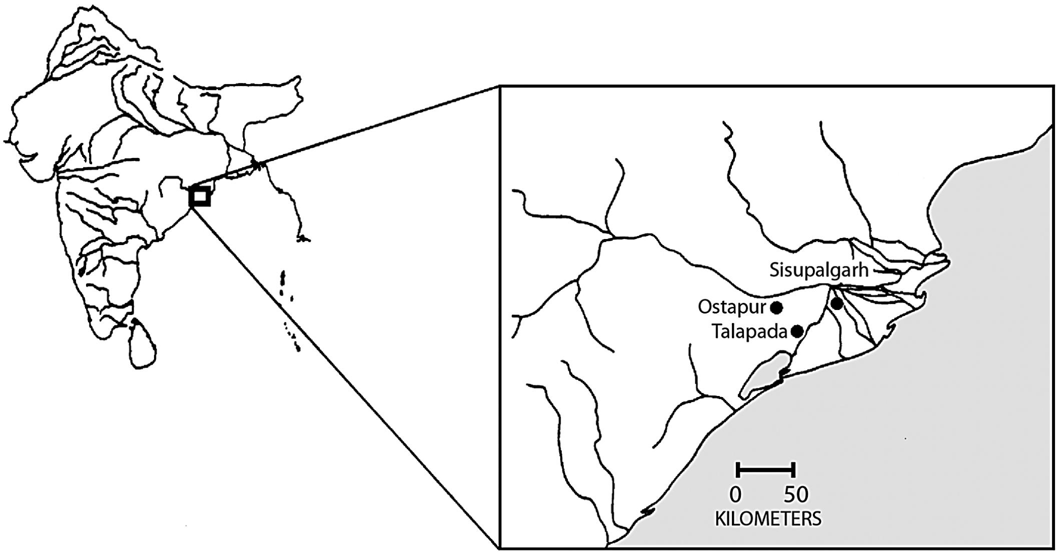


**Fig. 1**: Sisupalgarh, Talapada and Ostapur in Odisha

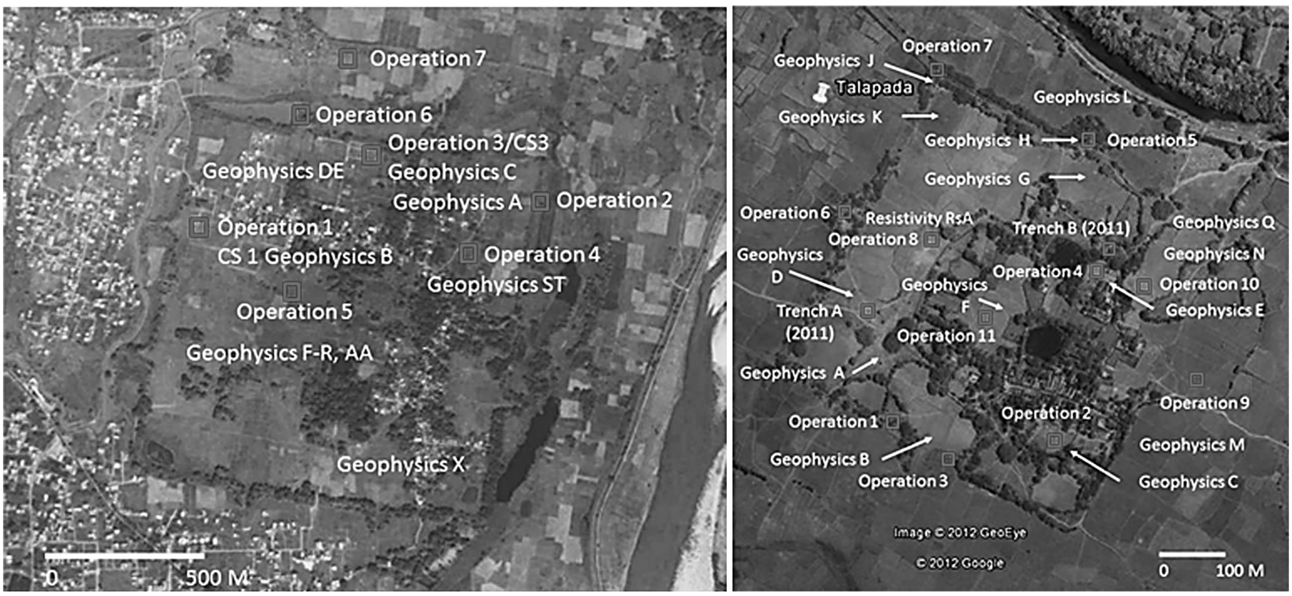


**Fig. 2**: Areas of investigation at Sisupalgarh (left) and Talapada (right)

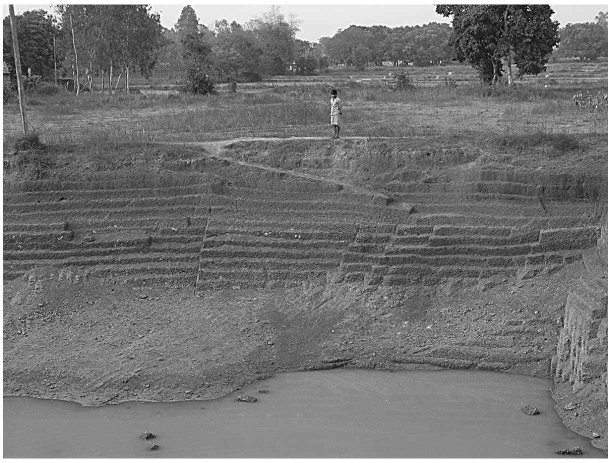

**Fig. 3**: Laterite quarry, Khorda District, Odisha

of alternating laterite outcrops and alluvial soil, with sandstone available within a fifteen kilometer radius of the site.

The predominant construction stone in the region, even today, is laterite. Laterite is a leached, chemically weathered soil that is found only in tropical environments, and which is naturally compacted into a matrix that can be easily cut into blocks that further harden when exposed to the sun (Tarbuck and Lutgens 1999; Fig. 3).

In the course of both natural weathering and human activities such as quarrying and stone trimming, laterite disaggregates into smaller component nodules measuring from 0.1 to 4 cm in size that can be characterized as laterite "gravel" (Fig. 4). The use of laterite as a construction material had already begun by the Neolithic period in eastern India, as seen at sites such as Ostapur where laterite gravel had been pounded into floor layers measuring 1-3 cm in thickness.

By the time of the development of Sisupalgarh in the mid-first millennium BCE, ancient people had perfected the art of quarrying laterite into slabs over one meter in length. Laterite blocks were used both as upright placements for the creation of circular and linear features, as well as in house foundations and for the construction of formal gateway structures (Lal 1949; Mohanty and Smith 2008; Fig. 5). At the site of Talapada, laterite blocks were similarly used for the construction of structures within the rampart and in the northern gateway of the site. In contrast to the abundance of laterite blocks, sandstone was almost never utilized as construction material.

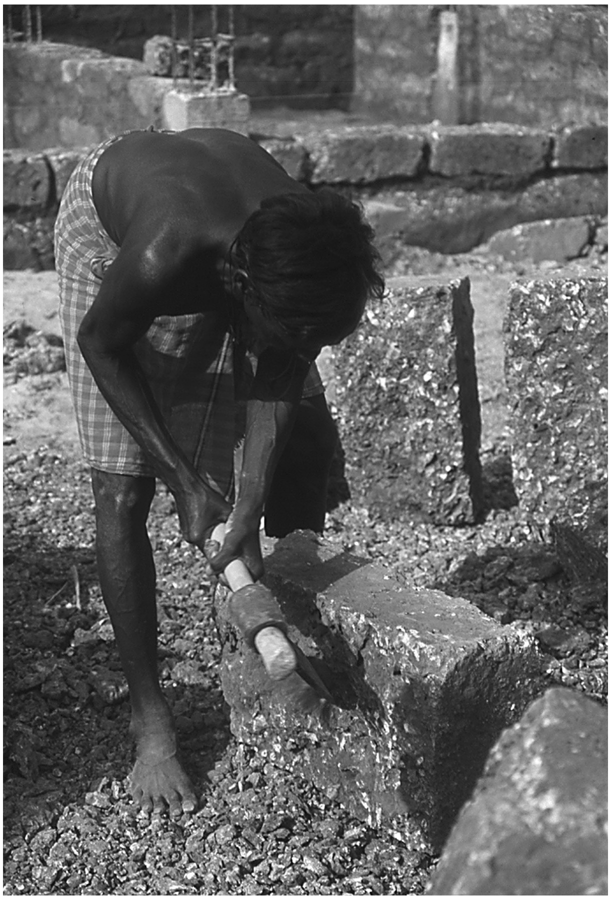

**Fig. 4**: Laterite block trimming, with small Crumbs and debris resulting underfoot

In addition to the use of solid stone, excavations at Sisupalgarh revealed the use of composite materials in both the habitation areas and the monumental architecture. In the habitation area adjacent to the northern rampart (Operation 3), one 20 cm fragment of conglomerate was revealed to consist of small laterite gravel combined with lime.

In the area of the monolithic pillars, there was a lime-plaster floor that included thousands of quartzite river pebbles and that was visible both in the excavations and on the exposed western edge of the pillar mound. Subsequent investigations have assessed the means by which lime was likely to have been produced for the plaster, with the potential for lime manufacturing and trade to have been undertaken on the Indian Ocean coast at a

**Fig. 5**: Laterite stone features at Sisupalgarh (clockwise from top left: westernmost north gateway excavations in 2009; northernmost west gateway excavated by B.B. Lal in 1948, view from exterior of settlement; same gateway view from interior of settlement; pillars; tank with stone steps)

minimum distance of 45 km from Sisupalgarh (Thakuria 2012).

At Sisupalgarh, excavations in Operation 3 also revealed areas of very dense stone material that when encountered during excavation appeared to be solid laterite. When sectioned, however, this material was found to vary between 4-18 cm in thickness, and often too thin to have been a quarried slab of brittle laterite. At the same time, the material was too dense to be the accidental by-product of compacted laterite gravel, or of the decomposition of nearby blocks. Excavation of the material was challenging because it was very difficult to discern whether the gravelly material that was encountered was indeed a solid laterite block. While there was evidence for large continuous blocks of solid laterite at the site of Sisupalgarh in the form of monolithic pillars in the central portion of the site, there was no prior evidence of laterite blocks as thin as 4 cm or carved with a bend in the middle, as such pieces would have been very challenging to remove from a quarry and transport given the brittle nature of laterite.

At Talapada, the excavation of the northern monumental gateway (Operation 5) provided the opportunity to investigate the puzzling phenomenon of what we had described as "artificial laterite" at Sisupalgarh: extremely compacted matrix that had all of the physical qualities of laterite and could be broken apart into irregular chunks in the same way as a laterite block. At Talapada the shape of the material clearly indicated that it had been handled in a flowing state as a part


**Fig. 6**: Feature T6 in the northern gateway at Talapada

of the construction process. In the northern gateway, the curvilinear feature T-6 was over 6 m in length and served as a bund or retaining wall against the earthen core of the rampart (Fig. 6). It had all of the visible qualities of stone but without any seams, and presented a well-articulated curve that showed no sights of chinking, joins, or gaps. Our interest in this structure was compounded by the recovery of several irregularly-shaped pieces of what appeared to be stone up to about 30 x 30 cm in size interspersed with bricks and laterite blocks of the fallen fill of the gateway.

We conducted an experiment with the fragments as follows. An irregularly shaped chunk of "laterite" measuring 12 x 16 x 8 cm and weighing 1272 gr. was brought in from the excavation of the Operation 5 area. This material was weighed and photographed, and then immersed in a bucket of water. The mass immediately began to bubble as it released air, and over the subsequent 24 hours dissolved into a mass of silt interspersed with laterite gravel ranging from 0.2 to 3 cm in size (Fig. 7).

**Discussion**

The experimental treatment of what appeared to be a solid mass of stone from the gateway area of Talapada revealed that it was instead a human-made composite of laterite gravels mixed with earth and clay. The experiment provided an important insight about the creativity and strategy involved in the construction of architecture over time, and the importance of urban settlements in the development of new architectural concepts. Neolithic and Chalcolithic settlements have only perishable architecture as indicated by the presence of floors and postholes. Permanent architecture made with stone or stone foundations was distinct to the development of cities in the region, and signaled a shift in the way that

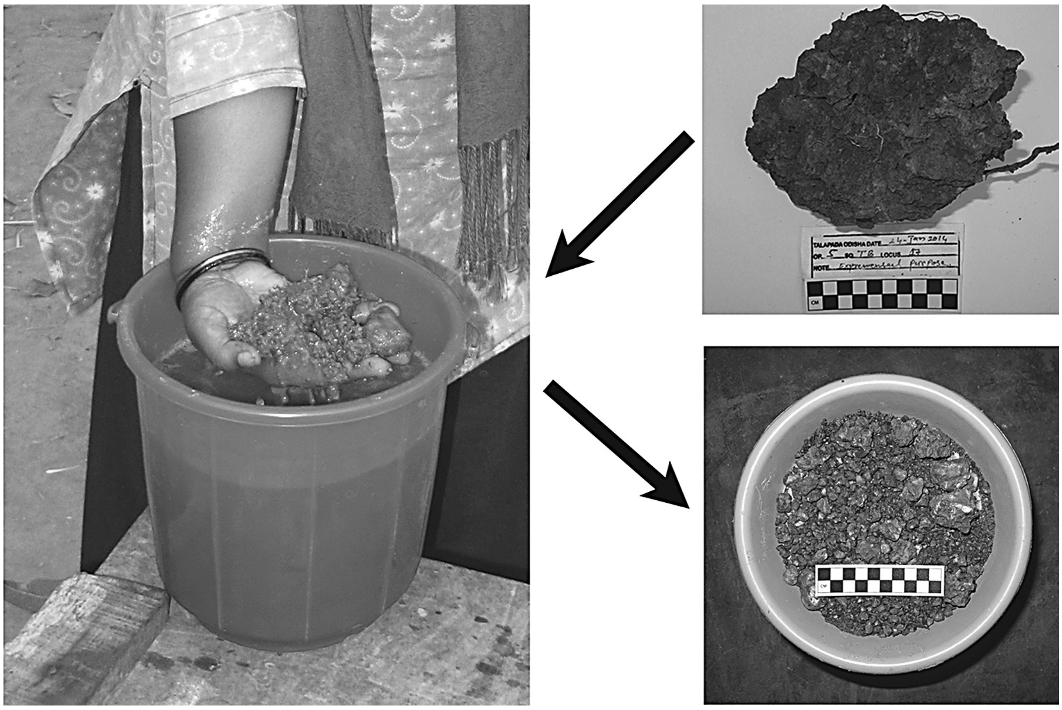

**Fig. 7**: Experiment with "artificial laterite" and outcome

people created the built environment not only from naturally-available materials, but through the manufacturing of composite materials that extended the architectural repertoire.

The use of composite materials such as plaster and "artificial" laterite enabled people to create new aesthetics in both form and appearance. The use of plaster provided an altogether new type of appearance as a stark white substance that could be applied to buildings and floors.

The use of "artificial" laterite could be used to make new shapes, but it also enabled builders to re-use readily available waste materials. The laterite crumbs that resulted from the trimming of stone blocks would have been plentifully available; in some cases the resultant composite could be used to make new forms such as the curvilinear shape at Talapada, or utilized in place of solid laterite as appears to have been the case at Sisupalgarh. Similar processes of reuse and recycling of waste materials are seen in the reuse of broken materials for wall foundations and pavements at Sisupalgarh, and in the use of broken fragments to make "brick jelly" floors at other Early Historic sites.

Composite materials are the result of a sophisticated understanding of the chemical and physical properties of unrelated materials that can be combined into new, human-made forms. As seen from the archaeological investigation of Early Historic sites in Odisha, ancient peoples' decisions about the use of composite materials came as the result of a variety of considerations including the desire for distinction in monumental architecture and the availability of waste products in the form of laterite trimmings that could be utilized to make composite construction materials. The result was an "artificial" laterite that had all of the same visual and physical properties as stone, but was perhaps more expedient to make and use. The use of this composite material was not extensive, but its presence in more than one site in the urbanizing landscape of Early Historic Odisha suggests that the concept was widely known and that composites formed an integral part of the architectural experience of town and urban dwellers.

Composite materials enabled ancient peoples to supplement the repertoire of natural materials to satisfy aesthetic, technological, and practical needs. Although attention often is drawn to composite materials that have a high intrinsic and display value (such as metals or terracotta), the research at Sisupalgarh and Talapada illustrates that composite materials have a significant role in everyday life and were utilized as a practical, cost-effective response to both household and civic needs. At Sisupalgarh, the majority of the plaster encountered was in the area of the central monumental pillars and the "artificial laterite" was found in the site's encircling rampart; at Talapada the "artificial laterite" was encountered in the area of the monumental stone gateway. All of these monumental constructions were organized at the civic level as their size and distinctiveness were beyond the capacity of individuals to develop at the household level. These configurations suggest that innovation may have been particularly sought out for collective endeavors, illustrating the capacity of population centers to serve as zones of technological innovation for the purposes of civic development.

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