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Case Study

Scientific studies on decorated mud mortar of Ajanta

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ABSTRACT

This study is an attempt to reveal the decorated earthen plaster of Ajanta. The mud plaster of Ajanta caves has been analyzed with the help of physical and analytical tools. The results indicate that high silt (>70%) low clay soil may have been mixed purposefully with lime (calcite) for the reason to enhance the cementing characteristics. The presence of calcium oxalate was detected from FTIR spectra may have been the resultant product of proteic materials presented in mud plaster. Ferrugineous silicate along with rarer gluconite–celendonite and white zeolites were also perceived from SEM and FTIR spectral analysis. The existence of quartz and sepiolite in mud mortar was also detected from XRD and SEM studies. The vegetal matter might have been added to tailor the construction behavior. The analytical results authenticate the similarity of earthen plaster of Ajanta and alluvion deposits of Waghura River just in front of caves, probably used as raw material in improvement of new material that suits for restoration for optimize performance and compatibility with the existing materials.

1. Introduction

Ajanta caves (World Heritage Site) have beautiful murals of 2nd BCE to 4th AD that represent highest point of artistic and technical achievement in India's greatest cultural fluorescence – the Golden Age (Walter, 2009). The present study approach to conserve the wall murals of Ajanta is based on proper understanding of materials, technology and causes of deterioration that favors minimal intervention and preventive conservation (Sharma, 2007). The conservation studies so far carried at Ajanta include monitoring of macro- and micro-environments of the caves, engineering geological surveys, rocks and minerals analysis (Sinha, 2010) along with bio-deterioration studies (Cacace et al., 2008). In addition the research investigations have also been conducted about the pigments and paintings technique at Ajanta (Artioli et al., 2008). As there is hardly any publication available on the materials and techniques used by ancient Indians to create Ajanta wall paintings, a dedicated investigation of material composition, structural support, plaster, paint layer, etc. is needed for better understanding.

Traditional mud plaster is made with soil composed of sand, silt and clay with straw sometimes added to prevent excessive cracking during drying. For earthen support to function well, an equal distribution of silt, sand and clay is desirable. Too much silt is neither a good binder nor an aggregate and produces a material that is prone to shrinkage and cracking. Clays also called phyllosilicates is a term related to grain size (<2 μm) and grain shape in most cases is that of a sheet much thinner

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than wider and attracted to one another by electrolytic forces (Basma Adnan et al., 1996). The non-clays are of grain size greater than clays and are generally divided into the grain size categories of silt (2–50 μm in diameter) and sand (50 μm–2 mm in diameter). Non-clays materials have relatively small attraction for water because of their small surface as compared to their volume and are also non-plastic. The non-clays grains are shaped in more irregular manner with grain to grain contact surface area is reduced and contact cohesion is much lower (Prost et al., 1998).

The clay minerals in general consist of equal parts of expandable clays (smeitite and mixed layer illite/smeitite) and non-expandable clays (kaolinite or chlorite) with minor quartz, calcite and feldspar (Smith and Austin, 1989). The expandable clay minerals are sticky than non-expandable clay and are effective in binding silt and sand particles together. In order to overcome the inadoptability of local resources, other materials are often added to the earth such as vegetal matter (Miller, 1934; Roberto, 1994) or calcite or perhaps lime (Jerome, 1993; Austin George, 1990). In this way the shrinkage of the clay is significantly reduced as calcite or lime may also serve as binder. However, possibility of using reactive fillers in earthen grouts has still not been fully explored. It has been observed that materials such as calcite, silica, ferric oxide, and so on. act like a cementing agent forming chemical bridges between clay micelles that may reduce swelling of clays (Forth, 1990). It has also been observed that some clay materials are generally frequented by zeolites, gluconites or iron oxide minerals indicating the existence of high silica activity in aqueous solution, affecting silicate crystallization. Iron oxides are also very strong coloring agent for clays. Besides, protein may react chemically by the process of exchange of inorganic cations in the clays with organic one – a mechanism relating to the ability of amino acids to encourage clay flocculation (Griffin, 1999).

This paper focuses on in situ examination of Ajanta painted plaster along with scientific investigation on its nature and characteristics. The analytical techniques used for characterization are optical microscopy, laser light scattering, polarized light microscope, scanning electron microscope, XRF, X-ray diffraction, FTIR, sieve analysis, etc. Some research was also carried in the field relating to earthen plaster and paint layer which has provided base for conservation in this specialized area of work.

2. Materials and methods

Particle size analysis by laser scanning was carried out for only a few representative sample of mud plaster of Ajanta. Understanding the characteristics and properties of earth as building material requires to go through range of analysis and test. In the present study particle size analysis, XRD, microscopy and thin section analysis were used to assess the mineral composition of earthen support and local materials at Ajanta. Aggregates in the earthen plasters were identified by dissolving the sample in 15% dilute hydrochloric acid and sieving it after complete dry. The aggregate components were subjected to petrological analysis to confirm their composition and grain size. The chemical composition of the plaster was analyzed through XRF for the range of samples extracted from different caves under geotechnical investigation of Ajanta caves. The components of the earthen plasters were also identified through XRD, SEM and FTIR techniques. CHN analyzer and microscopy were adopted to identify organic additives and performance characteristics were assessed through plastic and liquid limit testing.

3. Results and discussion

The chemical composition of mud plasters in the form of major oxides was determined using X-ray fluorescence spectroscopy. From the chemical analysis it is observed that lime has invariably been added to influence shrinkage of the local material that also acts as binder for the Ajanta's earthen plaster. The addition of lime into the mud plaster of Ajanta has also been confirmed by the reaction with dilute hydrochloric acid which gave effervescence. Calcite was probably added to overcome inadaptability of local resource material as it acts as cementing agent in the earth mixture forming chemical bridges (Rodríguez-Navarro, 1800). The remarkable color of the earthen plaster is due to the presence of iron oxide. It is also observed that in some of the earthen plaster more of the organic additives have been added since proteins can chemically react with clays (Theng, 1982, 2012). However, with time the proteineous material might has now been transformed into calcium oxalate which is also observed under the FTIR spectrum of Ajanta plaster. Besides, in most of the plasters organic fibers and seeds were admixed to improve tensile strength and reduce cracking.

The organic percentage of samples was determined by using carbon, hydrogen, nitrogen (CHN) analyzer. The combustion products (NO_2, CO_2, SO_2, H_2O) were separated by chromatographic column which was detected by thermal conductivity detector (TCD) that gave output signal proportional to the concentration of the individual components. From the result (Table 1) it is observed that proteic materials mixed with vegetal fibers and seeds have been added to the earthen plaster of cave No. 21 along with calcite. The calcite and proteic materials might have enhanced the binding properties of the earthen plaster of Ajanta.

The earthen plasters of Ajanta were observed under petrological microscope and the principal mineralogical components expressed were of Plagioclase, pyroxene, mica (tr), quartz (tr), and iron oxide. The earthen plaster by virtue of the exclusive prevalence of plagioclase associated with pyroxene indicates a composition of an 'eutectoid' nature, attributable to the original basaltic formation form which majority of the starting materials have been derived. With regard to traces of plaster of Paris in some samples, it may be due to its use in modern time for consolidation of decorated surfaces. Further, with regard to the presence of phyllosilicates, iron oxides and iron hydroxides in various samples, it is due to preparatory materials in clay which is made up of crystalline and amorphous phases rich in ferrous substances.