Structural Analysis of Historical Constructions, New Delhi 2006
P.B. Lourenço, P. Roca, C. Modena, S. Agrawal (Eds.)

Conservation of a Sandstone Monument at Kanchipuram, Tamilnadu, India

Ranee Vedamuthu
School of Architecture and Planning, Anna University, Chennai, Tamilnadu, India

D. Jayanthi
School of Architecture and Planning, Anna University, Chennai, Tamilnadu, India

ABSTRACT: Kailasanatha temple, a sandstone monument located at Kanchipuram, Tamilnadu, India built during 674-800 A.D. The sandstone used in the monument has undergone an extensive weathering. The paper deals the reason responsible for the weathering of sandstone. Further the paper deals with stone analysis, forms of weathering occurred on sandstone surfaces which will be useful in future restoration and conservation work.

1 INTRODUCTION

Kailasanatha temple is a sandstone monument located at Kanchipuram 71 km from Chennai, the capital city of Tamilnadu, India. This royal temple built of sandstone belongs to the Upper Gondwana age.

Kailasanatha temple is a protected monument of the Archaeological Survey of India, and certain conservation measures have been taken up by the same organization for this monument. But intensive research is required in order to save the monument from further deterioration as the material of construction i.e., sandstone has undergone severe weathering due to the action of natural forces. Hence this paper concentrates on the investigation and conservation of the sandstone used in the monument.

2 HISTORICAL BACKGROUND

The Kailasanatha temple at Kanchipuram was built by the Pallava ruler Rajasimha during 674-800 A.D. This ruler achieved notable progress in the construction of stone temples using cut stone blocks and in lying down and defining certain fundamental norms for subsequent temple architecture in the southern part of India. This temple is the first of its kind in this region as it is a structural temple of sandstone. Since the sandstone used is of a softer variety the craftsman involved in the temple construction could execute fine and intricate details.

3 ARCHITECTURAL VIEW

The temple faces the east, and is rectangular in plan. The main sanctum has a linga as the main deity for worship. Externally a lofty tower rises in tiers diminishing in size as they approach the summit. The sanctum sanctorum is approached through the Mahamandapa and a Mukha mandapa (Pillared halls). A wall encloses this arrangement, the inner face of which has a series of shrines sculpted with statues and animal figures.

Figure 1 : View of Kailasanatha Temple.

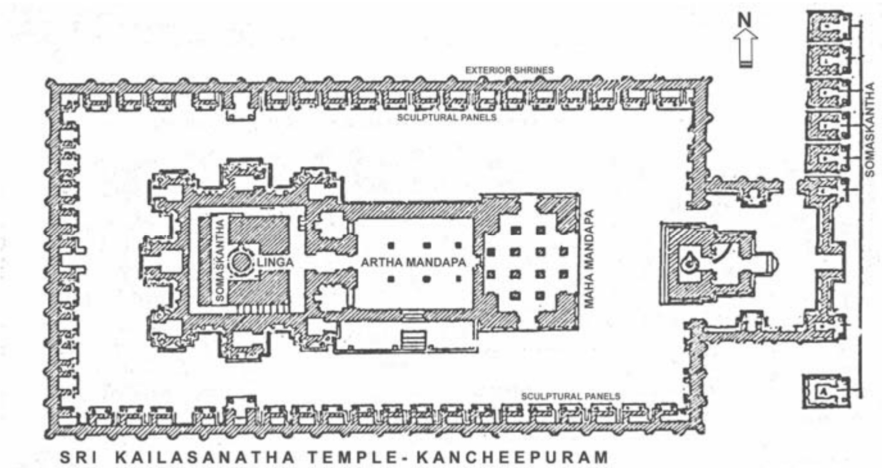


Figure 2 : Plan of the Temple with outer enclosure.

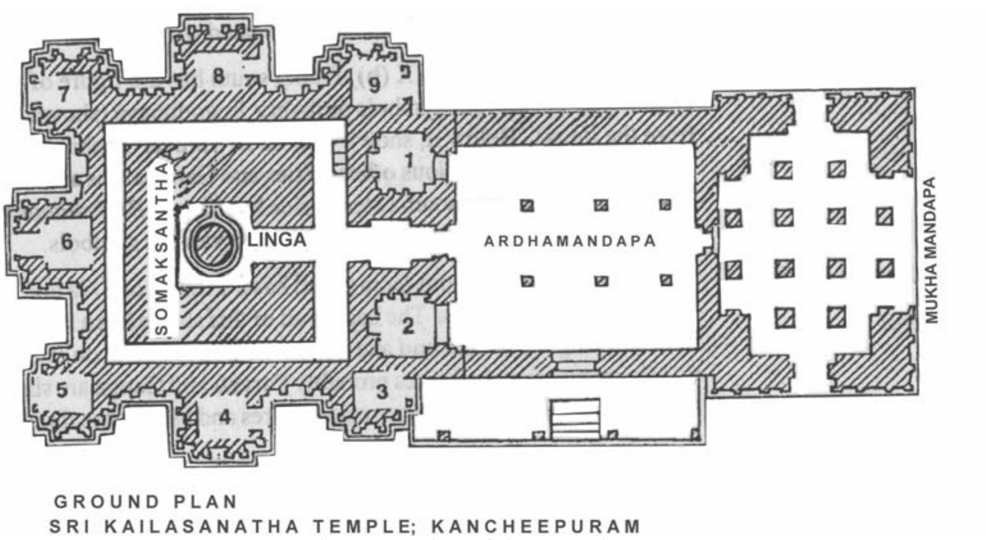


Figure 3 : Plan of the Temple.

4 SCIENTIFIC OBSERVATIONS

4.1 Climatic data

The Kanchipuram town is located in the Latitude 12º 50” N, Longitude 79º 42” E and at an altitude of 83.82 m from sea level. The town receives an average annual rainfall of 1125 mm. The average temperature ranges from 20.5 ºC to 37.5 ºC.

4.2 Stone analysis

From a sandstone sample collected from the monument with the help of Archaeological Survey of India, a thin section was prepared for the microscopic analysis. Rest of the sample was used for chemical analysis to find out the major elements present in the sandstone.

4.2.1 Petrological analysis

The microscopic analysis of the thin section of the sandstone revealed the following:

- The sandstone is classified as medium to fine grained calcareous sandstone; the fine-grained matrix indicates that it is essentially calcareous material with minor amount of shale (clay minerals).
- Most of the grains are more or less rounded in nature, larger in size and indicate very short duration of transportation.
- The large grains are composed of quartz, plagioclase feldspar, and minor amount of microcline.
- Most of the feldspar is highly weathered and quartz shows sericitization (strong minerals transferred in to lighter minerals).
- Presence of perthite and microcline, quartz and plagioclase feldspar, indicate that they should have been derived from a granitic terrain.
- The bent twined lamellae indicate that the protolith has undergone deformations and metamorphism.
- The quartz indicates wavy extinctions.

Authenticated historic records say that the sandstone used in the temple construction is of Upper Gondwana age which confirms that the sandstone could be obtained from fresh water basins.

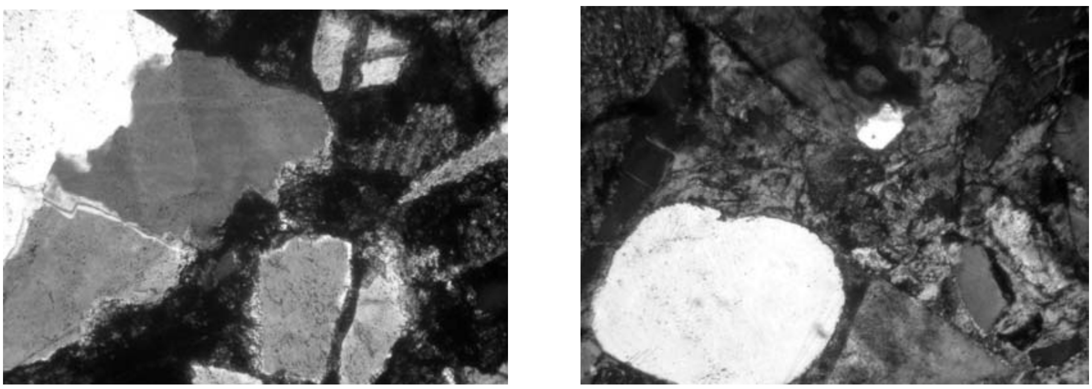


Figure 4 : Photographs of the thin section under microscope.

4.2.2 Chemical analysis

Table 1 : Chemical Analysis.

Constituents present in the sandstone	%
SiO_2	40.02
Al_2O_3	10.85
Fe_2O_3	4.40
FeO	0.39
MgO	1.02
CaO	19.75
Na_2O	2.02
K_2O	2.57
MnO	0.50
TiO_2	0.51
P_2O_5	0.17
LOI	17.40

Stone analysis done in Petrographic lab and Chemical lab at Geological Survey of India, Chennai, Tamilnadu, India.

4.2.3 Interpretation from the chemical analysis

- The analytical results infer that the sample contains 40-41 % silica, 10-11 % alumina and 2-2.5 % of alkalis which clearly indicate that the sample contains more fine grained minerals/clay.
- The calcium content varies from 19-20 % which collaborated with prepositional LOI (16-17 %). Hence the sandstone is Calcareous in nature.
- The silica and calcium content infers that the sandstone used in the monument is Calcareous sandstone with fine grained matrix and ferruginous material.

4.3 Deterioration of sandstone

Deterioration is a law of nature; only the process may be slowed down by effective interventions. Understanding causes, processes and mechanisms of stone damage is a prerequisite for stone preservation. Any undesirable change in the properties of a material is termed as deterioration. The phenomena of stone deterioration embrace those factors, which operate to alter the appearance, strength, coherence, dimensions or chemical behavior of the material either as individual elements or as parts of structures.

4.3.1 Weathering of sandstone

Field study of the monument provides first hand information on deterioration types and also an insight into their causes. Following are the causes for weathering of the sandstone.

- Crystallization of salts on the material surface
- Wetting and drying cycles and thermal changes
- Bio-film formation due to dampness
- Human intervention

4.3.2 Photo atlas of weathering forms

Investigations were carried out to understand and classify the weathering forms in the sandstone monument. The location of weathering were identified and classified based on the cause and nature of weathering into four categories, namely physical disintegration, bio-deterioration, salt attack and human intervention (Fitzner and Heinrichs, 2004).

Table 2 : Physical disintegration.

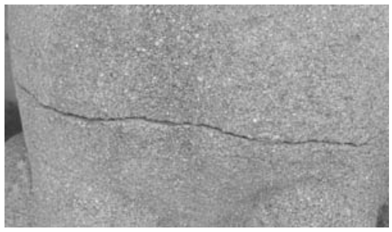
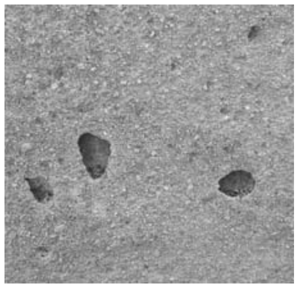
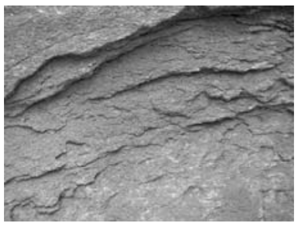
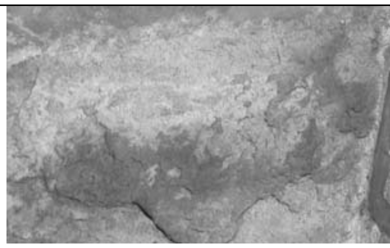
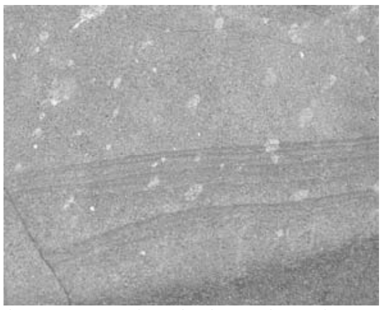
Decay feature	Description	Example
Granular disintegration	Physical damages caused due to lashing rain, wetting and drying cycles and thermal changes. Loss of cohesion of minerals causes disintegration and surface loss of material.	 Figure 5 : Loss of material on the external surface of the wall.
Honeycombing	The softy clayey part within the matrix is washed off by means of rain and wind. The iron skeletal form remains intact. This is mainly a surface phenomenon. But these holes provide access to insects and microorganisms and they thrive in it.	 Figure 6 : Honey combing found at plinth.
Cracks	Cracks are seen in the columns and other architectural features. Since the magnitude of the crack is minimal it may not lead to any structural problem	 Figure 7 : Cracks at the base of the column.
Pitting	Further damage caused after the surface erosion due to the action of sand and dust particles and manifested in the form of large holes.	 Figure 8 : Holes found on the exterior surface of the walls.
Flaking	This is caused due to salt attack. Thermal gradient and dampness increase the mobility of the salts and crystallizes within the structure near the exposed surfaces. Swelling of salt crystals below the exposed surface causes blistering and scaling of the outer layers.	 Figure 9 : Flaking of layers at plinth level.

Table 3 : Salt attack.

Decay feature	Description	Example
Efflorescence	White patches on the surface of material cause unsightly appearance due to crystallization of salts on the material surface. The phenomenon mainly occurs in interior surfaces or sheltered areas of structures with low rate of evaporation or high humid environment.	 Figure 10 Presence of salt as white patches on the under side of the roof slab.
Rock meal	The salts which originate from the soil or atmosphere seeps into the structure by dampness. While drying, salts are deposited internally resulting in granular disintegration. This is a progressive damage, which renders the material soft and crumbling results in disintegration. Typically granular disintegration produces debris that is a mixture of salt and individual grains that is referred to as a ‘Rock meal’. And can often be seen accumulating beneath stone which is actively decaying.	 Figure 11 : Sandstone crumbling into powder form.
Black crusts	Fungi, algae, Lichen and micro-organisms growing on sandstone surface form a dark crust when dried. The mechanical pressure due to swelling and shrinkage of colloidal bio-film causes physical damage, resulting in weakening of surface grains of stone. Blistering or removal of this film causes partial damage of the surface.	 Figure 12 : Micro-organisms growth on the exterior wall surfaces.
Discoloring	The color of the sandstone turns to grey.	 Figure 13 : Discoloring of sandstone.

Flowstone	The discharge of water and oil from the sanctum stains the stone and promotes the growth of algae and other micro organisms.	 Figure 14 : Stains out side the sanctum.

Table 4 : Bio-deterioration.

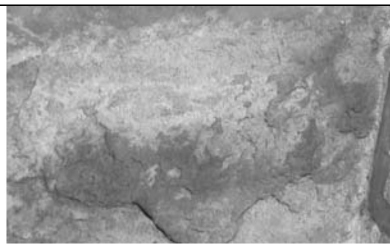
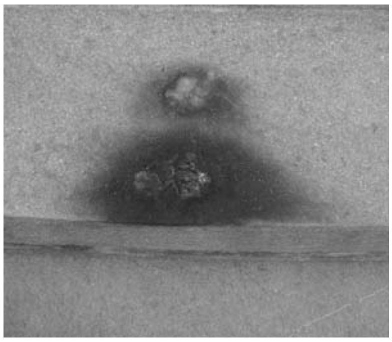
Decay feature	Description	Example
Bio-film Formation	Bio film formation takes place due to dampness. Damp surface of sandstone attracts dust, dirt and other micro organisms. If this is not controlled it will give rise to higher plants. It is green in wet condition and becomes dark in dry condition. The acidic secretion produced by the lichens induces bio- corrosion in sandstone.	 Figure 15 Bio-film on the external surface of sanctum wall.
Growth of plants	The micro flora provides nutrients for growth of plants. Since the sandstone has pores on the surface once the decay is initiated, the surface serves as the background for vegetation. The growth plants results in progressive damage.	

Table 5 : Human intervention.

Decay feature	Description	Example
Repair	Repair of sandstone using hard cement mortar and brick. Cement mortar creates a hard rigid boundary around the material. The expansion and shrinkage of the material due to thermal variation cycles within the hard rigid boundary leads to formation of cracks and disintegration of sandstone.	 Figure 16 : Restoration of sculpture on the compound wall.

Vandalism	Sandstone wall surfaces broken during Mohammedan invasion in the last century.	 Figure 17 : Broken sandstone at the outer enclosure.
Neglect	Stains caused due to burning camphor by the pilgrims create unsightly appearance and damage to the monument.	 Figure 18 : Camphor stains at entrance steps.

5 CONCLUSIONS

Petrological and chemical analysis reveals that the sandstone used in the monument is Calcareous sandstone with fine grained matrix and ferruginous material. This understanding and characterization of the sandstone is the first and foremost step in any conservation measure. Besides this data forms the basis for the selection of any replacing material / compatible sandstone to be considered for the restoration of this monument. This analysis also helps in understanding the causes and the forms of weathering of the sandstone used in the Kailasanatha temple and provide the primary data base for future restoration and conservation work.

REFERENCES

Srinivasan, C.R. 1979. Kanchipuram through the ages. Agam kala prakashan, Delhi.

Fitzner, B. and Heinrichs, K. 2002. Damage diagnosis on stone monuments - weathering forms, damage categories and damage indices. In Prikryl, R. & Viles, H. A. (eds): *Understanding and managing stone decay, Proceeding of the International Conference "Stone weathering and atmospheric pollution network (SWAPNET 2001)"*, Prague, p. 11-56, The Karolinum Press.

Fitzner. B, 2004. Documentation and evaluation of stone damage on monuments. In Kwiatkowski, D. & Löfvendahl, R. (ed.): *Proceedings of the 10th International Congress on Deterioration and Conservation of Stone*, Stockholm, 27 June - 2 July 2004, Vol. II, 677-690, ICOMOS, Sweden.

Fitzner. B and Heinrichs. K. 2004. Photo atlas of weathering forms on stone Monuments. http://www.stone.rwth-aachen.de/atlas.htm.

Srinivasan, K.R. 1972. Temples of south India. New Delhi, National Book Trust, India Book House, Bombay.