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Characterization of Tenth century seenakesavaperumal temple building materials

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This paper presents the analytical characterization study on 10[tof]century seenakesavaperumal temple, Yelagiri, Tamilnadu. The samples from the temple were extracted from walls from, the inner sanctum, brick masonry mortar, and cement mortar at the specific spots on avoiding structural damages under the Hindu religious and charitable endowment governance, Tamilnadu, temple authorities, and conservators. From the external visual observation and present state, the ancient structure has prone been to a few degrees of inclination from its original state due to weakened soil structure interaction and catastrophic environmental conditions for more than centuries. The analytical method, such as X-Ray diffraction, was used to investigate the mineralogical interaction and its crystalline growth to establish the computable construction materials. The XRD results on the extracted samples have affirmed the stone samples have better performances with quartz and feldspar at high ranges. Further the brick mortar from the exterior walls revealed the complete transformation of CSH and CAH peaks into carbonate polymorphs. High range portlandite peaks in cement mortar sample affirmed the incomplete transformation of calcite due to the absence of external exposure conditions to the atmosphere. This study also worked as a base for the state archaeology and modern conservators to restore ancient wisdom and national integrity.

Keywords: Material characterization, Lime mortar, Building materials, Hydrated phases, Restoration

1 Introduction

The diverse cultural history of India is rich in numerous types of historic buildings and architectural landmarks created by skilled artisans. Typically, ancient monuments are buildings with archaeological interest or artistic value that have been standing for many years. According to the recent studies, the holistic approach towards making the repair mortar to simulate the original mortar or construction materials is reviving the conventional technique to fortifying historic buildings and monuments.[1]. Since Portland cement was invented in the 19th century, which increased the velocity of construction but did not successfully address issues of lifespan, durability, and exposure to the elements, the reverse methodological technique has become increasingly important in this century.To improve the strength and durability of ancient constructions, natural organic herbs and locally accessible additions were incorporated into the mortar. According to research, natural organics enhanced the carbonation phases as curing times lengthened. The selection of the proper component and method could guarantee improved performance of the lime mortar throughout time[2]. The historic Ottoman baths historic mortars were examined to understand whether the binder was hydraulic or not, using modern analytical methods such as XRD, FT-IR, TGA and SEM-EDS. Since the analytical methods are confirmatory, the brick dome mortars were hydraulic. The vadukkanathan temple, Kerala, has sourced locally available organic herbs such as Oonjalvalli, Kulamavu, Pannachikkai and jaggery as admixtures during the production technology, which was identified by analytical and quantitative analysis. Padmanabhapuram Palace, Kerala, has also sourced kadukkai, jaggery, neelamari, hibiscus and aloe vera as organic additives to strengthen the mortar[3]. Two case studies on historic structures were done in Lisbon amid harsh seaside environmental conditions. This research served as a foundation for the conservationist to replicate the mortar on even more deteriorated conditions. Mortar samples from these two case studies are characterized, and the relationship of their mineralogical-chemical composition showed better performance and high durability upon using the natural hydraulic lime. Hence, based on the recent studies, adopting the modern characterization methods can reveal the material used and long-time time altered properties of the samples extracted sites.

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In order to research the material characteristics of a bulged stone masonry wall and its computability of construction materials to model repair mortars and restore the masonry walls, this study used ancient building materials from the seenakesavaperumal temple. One of the oldest Perumal temples in Tamil Nadu, India, is the Seenakesavaperumal Temple, which is close to 1000 years old. Between 1100 and 1150 AD, during the Chola and Pallava eras, it was built. The temple is flanked by Jawadhu and yelagiri hills in Tamil Nadu, southern India, not far from the yelagiri highlands. Its coordinates are 12°52'30" N latitude and 78°15'00" E longitude. Due to the harsh weather circumstances, the temple is in a very bad condition and has nearly sunk 5" feet below the original surface. The stone wall has also been dislodged.

To complete the restoration process, a characterization study of the building materials and the technologies used is required. The temple was built using stones from the enormous crushed boulders from the yelagiri hills, as evidenced by the fact that it is only a few meters from the hills. (SeeFig. 1).

2 Materials and Methods

2.1 Present status

The present status of the ancient temple is with bulged stone masonry walls of the andardbamantapa with outstanding dislocated. The terrace of the mandapam was provided with a cement paste slurry finish to avoid leakages, followed by the inner flooring level of the maha mandapa has been bulged, and cracks are visible, which needs the restoration works. The matamata was reconstructed with RCC finish in 2007.

2.2 Sampling of material

Figure 2 Extraction of masonry wall samples was conducted in Hindu religious and charitable endowment board and regional conservators with temple authorities. Fig 3. In accordance with Fig. 4, the HR & C Department approved the temple layout for detailing and restoration reasons. The samples were taken from interior and exterior areas of the Seenakesavaperumal temple and categorized as (SKP-1, SKP-2, SKP-3, and SK-4) correspondingly. The descriptions of the samples were given, and Table 1 displayed the sampling sites. To prevent the capillary rise, the extracted samples were taken from

Fig. 1— Location of Seenakesavaperumal temple (a) Tamilnadu district map, and (b) the google earth location of the temple.

Fig. 2 —Sampling locations (SKP1-4).

the tops of the structure4. To repair the edifice, raw materials from the temple, such as stone, bedded mortar, brick, lime mortar, and cement mortar, were gathered. On the unaltered areas, extreme caution was used to prevent nearby cracking.

3 Results and discussions

In order to determine the mineralogical phases, the extracted materials were sieved to a size of 75 µm using a Rigaku Smart Lab II diffractometer operating at 9 kW and 9 mA with oriented sample holders in polymethyl methacrylate or silicon of diameters 25 and 20 mm, depending on the amount of material (2-5 mg). The XRD patterns were acquired by scanning from 5° to 90° 2 locations at a rate of 1°/minute for 2 hours with increments of 0.05°G. Cultrone (2005). The XRD graphs were investigated using the expert high score software included with the JCPDS library.

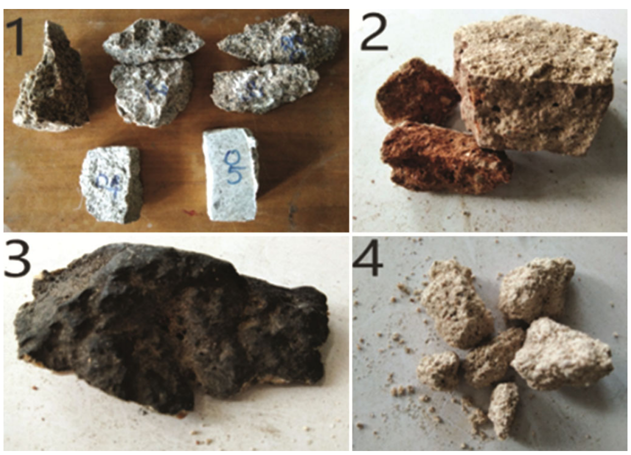

Fig. 3 — (1) Sampled from walls, (2) brick mortar sample, (3) garbhagriha temple sample, and (4) cement mortar (SKP-4) sample.

3.1XRD Interpretation of stone masonry wall

Since the historical samples have a greater number of peaks due to the variety of crystal orientations, the mineralogical characterisation suggests that they are amorphous polycrystalline. Figure 5 (a-b) shows the significant quartz peaks with JCPDS diffraction file (085-0797) with the d-spacing angle of 3.34 at 12.34°, 26.64°, and 26.95° were explored with the expert high score software with 2 position's library based on the XRD data of the SKM-1 outer wall and inner sanctum brick wall. Furthermore, the feldspar's minor range peaks, which are located at 31.65° and 35.63°, reveal the cause of the product's hardness, longevity, and resistance to chemical corrosion. Magnesia peak (078-0430) and olivine peak (075-1156) were also discernible at 47.04° and 68.15°, respectively. These peaks serve as refractory materials that act as thermal resistance in the building units. [5-6].

3.2 Computability of regional stones to ancient stone

Figure 5(c) revealed the results obtained from testing the locally available stone samples from nearby local stone quarries across the 50-100 Km distance from seenakesavaperumal temple, evidencing that the sample retrieved from the wall of the temple and the discarded stone outside the temple matched similarly with the NS-1 & NS-2 samples which were locally procured from the nearest quarries of tirupattur village from Fig. 1. XRD results of locally procured

Table 1 —Sample spots from Seenakesavaperumal Temple

Sampling	Description
SKP-1	Exterior of the wall (1-4) stones samples Fig (a, b)
SKP-2	Brick & bedding mortar at exterior walls-2.
SKP-3	Garbhagriham-3 (stone sample).
SKP-4	Cement mortar samples from interior temple joints-4.

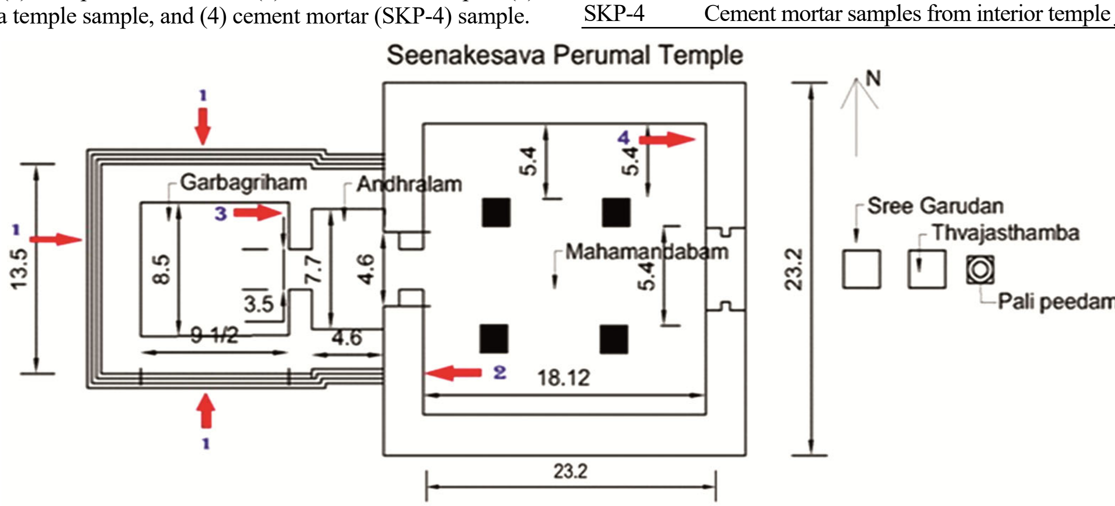

Fig. 4 —Seenakesavaperumal temple plan and sampling spots, Yelagiri, Tamilnadu (Source: HR &C, Tamil Nadu)

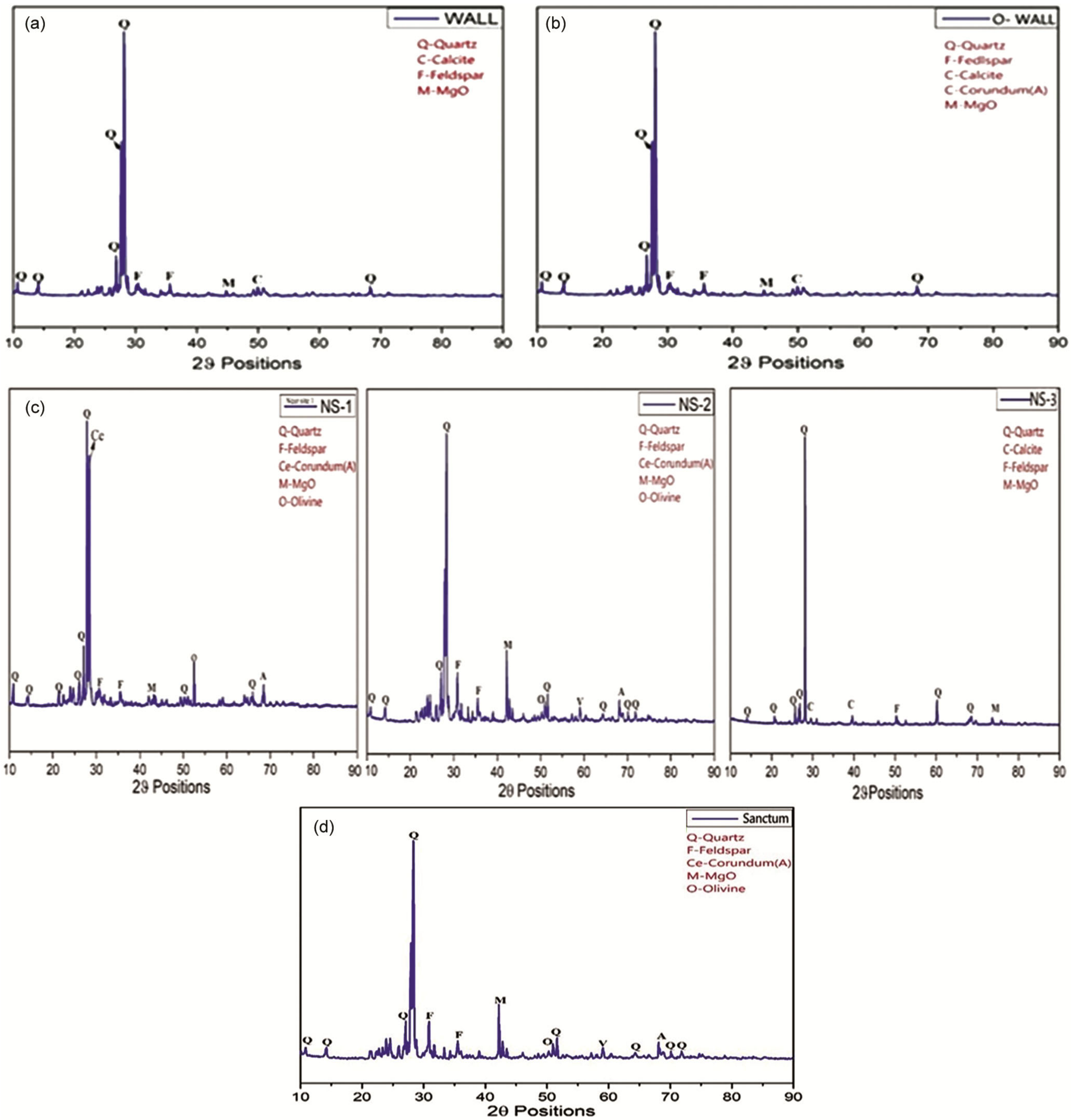

Fig. 5 — (a) & (b) XRD analysis of SKP-1 exterior wall stones, (c) Regional Quarry stone samples. NS-1, NS-2, NS-3. (NS-Near extracted site), and (d) Sanctum stone sample.

stone revealed similar peaks with the temple wall sample and the discarded stone of the temple.NS-1 & NS-2 stones revealed the high intense Quartz and Feldspar peaks, and low-intensity corundum and olivine peaks with a fraction of periclase(MgO) peaks.

were also identified in both the Quarry samples. The scientific study suggests that temple stones are high-ranged quartz and feldspar with a fraction of magnesium oxide. From the localgeological rock formation, hornblende Gneiss stone occupies the valley between yelagiri and javadi hills, Tiruppur, Tamilnadu. Hence the hornblende gneiss stones from the nearby mountain have been utilized in the construction practice. So as to replace the weathered and deteriorated stones, the Hornblende gneiss stone from the local quarry has to be utilized for restoration.

The XRD of Fig. 5 (d). the internal stone sample of the sanctum prone to heat on conducting temple rituals for several centuries, changing the stone to pitch black as shown in 3(c). The quartz peaks in Fig. 5(b) are distributed at two positions of 11.31°, 14.56°, and 26.64°, and the low-range olivine peaks, so-called magnesium iron silicate scattered at 52.34°, operate as high-pressure polymorphs and also increase the CO_2 absorption from the surroundings. The inner sanctum stone sample indicates that thermal resistant conditions exist and that a lot of heat has been absorbed in rituals for many years based on the higher ranges of feldspar and magnesia peaks. This could also be the cause of stone's deterioration. [7].

3.3 XRD Interpretation of brick mortar

The Fig. 6 XRD. The majority of the quartz peak in the brick mortar sample is positioned at 24.26°, 26.64°, 46.54°, 52.13°, 68.85°, and 82.34° with JCPDS diffraction phase identity (33-1161).
Due to the bedding mortar's interaction with the bricks, the XRD peaks also simultaneously show the calcite and silica peaks. The widely dispersed calcite peaks at 38.93°, 48.93°, and 49.92° with JCPDS file number were visible on the XRD graph (003-0670). The load-bearing phases and enhanced durability for a longer duration are indicated by the presence of high range in the complex compounds like feldspar, magnesia, and aluminum oxide peaks.[8].

3.4 XRD Interpretation of cement mortar

The Quartz mineralogical peaks are located at 26, 64, 50, and 59.94 degrees on the XRD graphs in Figure 7. In the past, according to Casadio (2005), the ratio of cement mortar's aggregate to binder could have been 1:3. (2005). It also demonstrates that calcite undergoes complete transition to generate the intricate silicate hydrate and alumina hydrate complexes. Vaterite and aragonite at higher ranges, which are meta stable chemicals, suggest the addition of shell lime to improve the mechanical qualities.[9-12]. The presence of portlandite peaks observed in the temple sanctum brick mortar was observed in the graph indicating the incomplete carbonation in the absence of contact between the external environmental condition to absorb carbon dioxide[7].

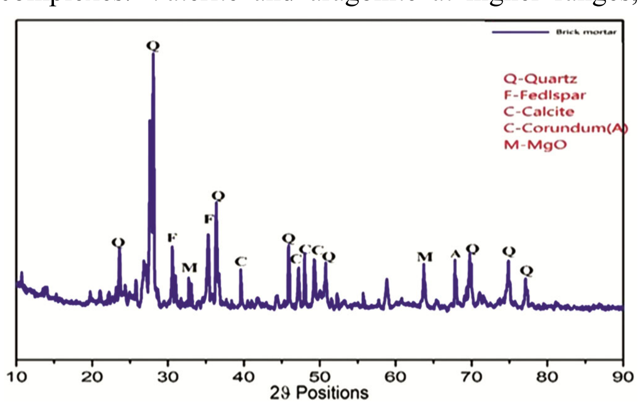

Fig. 6— Brick mortar sample XRD results.

3.5 XRD interpretation on dry and hydraulic lime

From Fig. 8, the XRD graphs of hydraulic and dry slaked powder, which was collected from the nearest

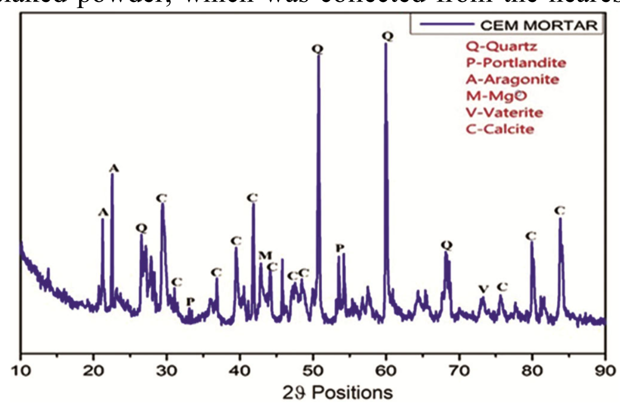

Fig.7—The inner roof ceiling (Cement mortar) of the temple.

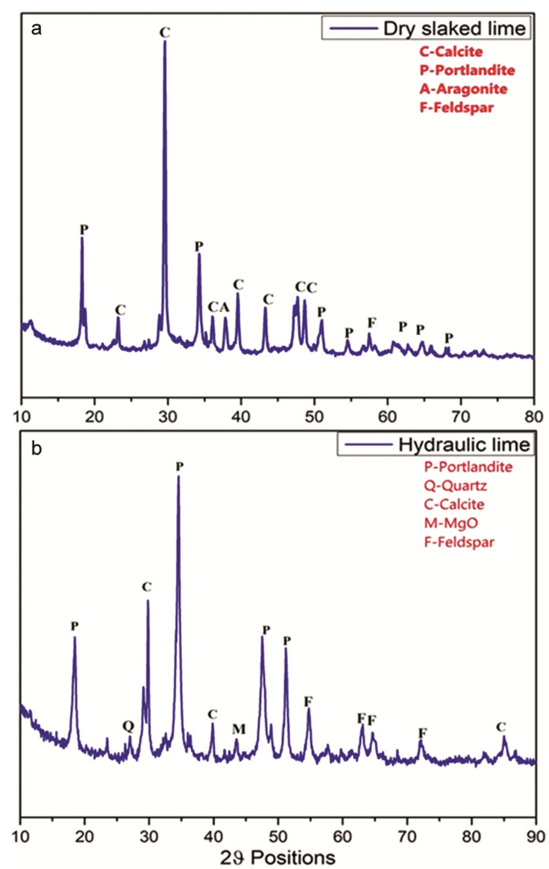

Fig. 8 — XRD analysis of(a) dry slaked lime, and (b) hydraulic lime.

quarry of the temple to investigate the quality and computability of binder, revealed a high range of portlandite peaks and very few fractions of quartz, indicating its pure lime and few calcite peaks indicating the lime getting exposed to open curing through the atmosphere. Further, the hydraulic lime, which gets hardenedby air, showed calcite formation due to interaction with environmental moisture conditions A few major peaks of portlandite show the carbonation stages between the atmosphere and the surface of the binder[13-16]. The graphs revealed a good amount of crystallinity peaks to suggest the performance during the temple's restoration.

4 Conclusion

- This current study has characterized the 10th-century construction materials through the modern analytical tool and has resulted in the computability to alter the materials to protect the ancient wisdom and national integrity.
- The stone samples from the nearest local quarry of distance ranging between 50-100km, namely, NS-1 and NS-2 XRD results, indicated the similar spectral and crystallinity of minerals compared with the extracted sample, confirming the stone coarse-grained metamorphic hornblende gneiss rock.
- The XRD results of brick mortar from the temple's inner sanctum have revealed the complete transformation of hydrates into carbonate polymorphs with better-carbonated peaks. Further, the cement mortar extracted sample from the inner sanctum revealed the portlandite peaks, indicated the absence of exposure to the exterior environmental condition to carbonate the mortar to improve its strength and durability of the mortar.
- The XRD results conclude that the internal load-bearing stresses and the soil-structure interaction have completely failed due to environmental conditions for several centuries. The analysis performed on masonry stone samples of exterior wall has depicted the major quartz peak and feldspar peak, indicating the load-bearing capacity has better performances, but in catastrophic environmental conditions, the load-bearing capacity of the soil at the foundation has made the masonry wall deform from its original state causing the structure to lean.A few major peaks of portlandite show the carbonation stages between the atmosphere and the surface of the binder[13-16].
- The graphs revealed a good amount of crystallinity peaks to suggest the performance during the temple's restoration. Compared to unslaked lime, the slaked lime has shown the better growth of crystalline peaks,
- HR&C and temple committee revived and helped to extract the temple samples and providing the authorized archaeological plan for the work indicating the use of the natural hydrauliclime (NHL) for the restoration during the temple construction and restoring the same old mortar.

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References

1 T Selvaraj, & R Ramadoss *Int J Conserv Sci*, 9(2018)25.
2 S. Jayasingh and T. Selvaraj, *Structural Analysis of Historical Constructions*, Springer International Publishing, 18(2019)255.
3 M. Shivakumar and T. Selvaraj,*Eur Phys J Plus,* 123(2020) 1.
4 R. Ravi, T. Selvaraj, and S. K. Sekar, Int *J Archit Herit,*10(2016)714.
5 P Westgate, R J Ball, & K Paine, *Constr Build Mater,* 195(2019)115.
6 J.A Perez, Elia M Alonso-Guzman, Wilfrido Martinez, & M Sanchez, *Ge-Conservacion* 11(2015)292.
7 K A Gour, R Ramadoss, & T Selvaraj, *Constr Build Mater,* 164(2018) 255.
8 R Ravi, S Thirumalini, & N Taher, *J Build Eng*, 20(2017)30.
9 L Ventol, M. Vendrell, P Giraldez, & L Merino, *Constr Build Mater*, 25(2011)3313.
10 M Shivakumar, T Selvaraj, E Regattieri, & Rajan, *Advances in Construction Materials and Structures, Lecture Notes in Civil Engineering*, 111(2021)143-149
11 M Shivakumar, S Thirumalini, & S P S, Rajan, *Mater Today: Proceedings,* 45(2020)136.
12 S Thirumalini, S K Sekar, B Bhuvaneshwari, & N R Iyer, *J Struct Eng*, 42(2015)294.
13 S Jayasingh, & T Selvaraj, *RILEM Bookseries*, 18(2019) 421.
14 A Moropoulou, A Bakolas, & K Bisbikou, *J Cult Herit*, 1(2000)45.
15 L Ventol, M Vendrell, P Giraldez, & L Merino, *Constr Build Mater*, 25(2011)3313.
16 C Rodríguez-navarro, *Archaeometry and cultural heritage*, 12(1988)91.