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RESEARCH ARTICLE

SELECTION OF ADHESIVES AND FILLERS IN CONSERVATION OF WOODEN MONUMENT DETERIORATED BY TERMITE WITH REFERENCE TO DHARUMAVANTHA RASEGAFANU MOSQUE AT MALE, MALDIVES

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ABSTRACT

The selection of the appropriate adhesive and filler is always an important issue in conservation of wooden artifacts of Cultural Heritage. A poor adhesive can cause further and sometimes irreversible damage, both aesthetically and mechanically to an already deteriorated object. Hence, before selecting a potential adhesive, its performance is assessed by several criteria including i) long term stability ii) reversibility iii) characteristics after curing such as colour, hardness, brittleness and sensitivity to relative humidity (RH) and temperature (T) iv) bond strength v) physical characteristics such as open and closed time, viscosity, concentration vi) health and safety issues and vii) cost and ease of application[11-14]. The functional requirements of gap-filling adhesive for use in the structural conservation of Dharumavantha Rasgefaanu Mosque impose considerable constraints on the choice of material for this purpose. Some degree of flexibility in the adhesive is considered an important material characteristic. Adhesive types considered include natural and synthetic, water based materials such as acrylic and polyvinyl acetate. The paper presents an evaluation, based on accumulated personal experience from the practice of wood conservation and performance of a range of adhesive systems for gap-filling application.

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INTRODUCTION

Maldives is a group of islands extending nearly 750 km from North to South in the Indian Ocean in the South-West direction from India (Fig-1-2). Today there are twenty-eight mosques in Male, the capital of Maldives and Dharumavantha Rasgefaanu Mosque of Male is considered to be the oldest existing mosque in the Republic of Maldives. The Maldives boasts a cultural fusion with a history that extends to 300 BCE, and an interesting interaction between different religions and importantly between Buddhism and Islam. The local people practiced Buddhism until the conversion Islam in 1153 CE. Construction in ancient Maldives was mainly dependent on the local availability of materials. Coral stone and timber were the only long lasting materials available and coral stone became the primary building material for monumental buildings.

The Dharumavantha Rasgefaanu Mosque was a one-room structure measuring approx well decorated with lacquer work[9]. 13x6.6m with a 1.8 m wide covered veranda in the front and an open corridor of 1.5 m wide all around the main area. The main building is on the podium of about 3.5 feet height from the ground level. There was a well inside the campus for drawing water for ablution etc. Main building of mosque is constructed out of coral stone blocks up the height of six feet. The walls have been white washed with several layers of plastic paint in the past. The interventions to conserve Dharaumavantha Rasegfanu mosque, one of the oldest mosque the historic timber structure was initiated in the 80% of the structural components. Interventions were based on proper studies and assessments. The most important phase of the conservation of the mosque was the assessment of the extent of deterioration near to exact assessment of the extent of deterioration caused by termite (Fig-3-4) and selection of proper adhesive lays the foundation for proper execution of the project[4-5].

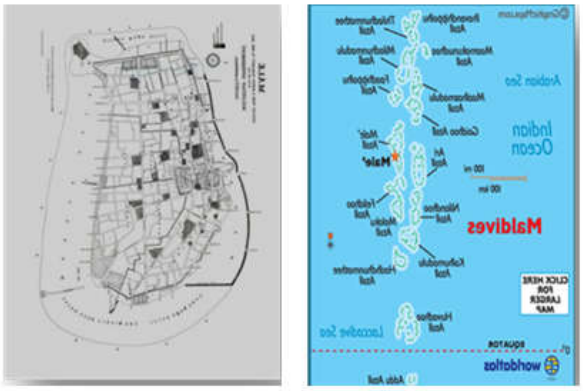

Fig 1. Geographical Location of Maldives

Fig 2. General View of Dharumavantha Rasgefaanu Mosque before conservation

Fig 3. Frame inside the mosque deteriorated by termite- (a) before (b) during and (c) after conservation

Fig 4. Documentation of Extent of deterioration by termite in beam

Fig 5. Filling of frame inside the mosque deteriorated by termite- (a) before (b) during and (c) after conservation

Fig 6. Shown bonding process

Conservation issue: In this mosque the major damage was caused by termite and it was found that termite lives in nests independent of the wood attacked by them, but sometimes may be hidden inside unfrequented areas of the building itself. In the case of Dharumavantha the colony was 85 meter far from the monument. One nest may forage for food 30 meters hidden from light, mostly underground, hidden in structural gaps, settlement cracks, electrical, plumbing, sidings or building shelter tubes made of soil and digested cellulose. These termites are especially attracted cellulose materials[1-2]. In nature, termites function as decomposers that break down dead wood, log or timber. Termites attack wood and manufactured wooden goods as well as paper Drywood and subterranean termites are the most destructive insect pests of wood causing more damage Responsible for most of the damage in Male[3,5-7]. Apart from termite damage, another type of damage was caused by physical forces and pressure on the hollowed components because the termite eaten away all the cellulosic material inside of the wooden beams, painted panels, loads bearing components and rafters. There was left only debris which made all the components widely shrink and cracked[6]. This paper will deal with the adhesive and fillers applied in a condition of sea costal areas where this mosque is situated and where relative humidity is almost at saturation point throughout the year.

MATERIAL AND METHODS

Selection of Adhesive and filler: Choosing an adhesive is one of the basic parameter played a vital role in the stability of conservation of wooden monuments. Though principally it should be worked well in advance but it comes in focus when the need of the assembly was felt after completed all the cleaning process and moved towards the joining of components.

It begins by considering the types of wooden adhesives available around us along with their strength, durability, mode of preparation, usable characteristics and lastly their applications[1-3]. Their relative strength and durability are characterized into levels of structural integrity. Adhesive selection for joining as well as filling of voids in wood is very significant for the longevity of the treatment and for the stability of structure. The selection process starts by taking into the consideration the compatibility with the physical and chemical properties of the adherent, particularly their surface properties i.e in case of Dharaumavantha Rasegfanu Mosque the different wood of different density were used and it was noticed that one adhesive was not equally effective on all the woods[8-9]. The polar and non polar adhesives were tried. The aqueous wood adhesive must be capable of wetting the usually polar wood surface within normal variations in its thermodynamically favorable surfaces. As the adhesive wets, it must have flow properties that enable it to spread over surfaces of variable roughness and to go through wooden structures that differ in its moistness, with respect to grain orientation at the bond edge. The adhesive under selection should make molecular contact with the grain direction and structure of wood and go through deeply enough to instinctively interlock with the wood's cell structure. Metals and plastics cannot be penetrated[8], so these materials generally cannot be bonded with aqueous wood adhesives and in the conservation of Dharumavantha Rasegefanu Mosque it was kept in mind not to apply resinous wood adhesive on the surface which needed to be joined further. However, non-aqueous, 100% solids adhesives, including epoxy[10-11], iso-cyanate, and polyurethane are capable of strong bonds to non-wood and wood materials. Different types of adhesives and fillers are used in the conservation of wooden monuments/objects[2,12]. Classification of adhesives on the basis of their chemical behavior is shown in table -1. Assessment of adhesives and fillers on the basis of their properties shown in table-2 and 3 respectively. These adhesives/fillers were used to fill the voids in wood due to low contraction or depression after drying (Fig-5-6). The structural dependability desired of the adhesive bond under expected service loads in the presence of expected environmental exposure conditions should be one of the foremost considerations. To suitably select an adhesive for a given bonded assembly, it is necessary to have a rough calculation of the nature, direction, level and duration of loading that the assembly and bond surfaces would be exposed. Furthermore, it is essential to know the range and duration of temperature and moisture content levels to which bond lines will be subjected. These factors were kept in mind while application of adhesives/fillers were espoused to ensure the structural stability of the bonded assembly would be at risk, even severe personal injury may be anticipated[13-15].

Bonding Process: The bonding process involves a good number of factors which determines the successfulness of an adhesive bond after its application and how it will ultimately perform.

The better these factors are understood and controlled, the fewer bonding problems will be encountered along with their attendant expenses[16]. It is not necessary to be an adhesive expert to manufacture acceptable bonds, although more knowledge is always helpful and to achieve the perfect bonding and further more to attain perfect bonding by creating desired pressure a system of clamping was devised as shown in fig-1. It is essential that the user follow the instructions of the adhesive supplier during the entire bonding process.

RESULT AND DISCUSSION

Based on the results obtained by testing different types of properties of adhesives and fillers bond created by polyvinyl acetate emulsion (water resistant) was the strongest bond both in pasting and joining of component and epoxy putty was found best suited for filling the voids and gaps in the prevailing environmental conditions of Maldives[4,15-18]. The greatest wood failures as adhesive and filler were presented by Methyl Cellulose Carboxy Methyl Cellulose followed by Maida paste[19]. However, repetition of some experiments using more than four replicas is considered necessary in order to obtain less variable results with lower standard deviation values.

Further research is, also, required to investigate the impact of adhesives' concentration to the type and degree of wood failures. Finally it is considered important to state that there are no good or bad materials in conservation but only suitable or not for a specific case[20]. When a wood conservation treatment, requiring the use of a flexible gap filling material is undertaken, it is vital that the monuments and artifacts be protected and isolated from the added material to the greatest possible extent and that the newly added material mimic the mechanical properties of the adjoining substrate and remain stable over time retaining these properties. Attempting a conservation treatment requiring adhesive/filling process without first understanding every component of these process wood isolating layer/file resin and bulking agents is a practice fraught with unnecessary risks[21]. Based on the experience in conserving wooden monuments and objects I rank the option for flexible gap filling adhesive in my own work water resistance Poly Vinyl Acetate emulsion should be used as adhesive and Epoxy Putty should be used as filler for conservation of wooden monuments and objects[13].

Table 1. Classification of Adhesives in respect of conservation of wooden monument/object

Thermo setting adhesive	Thermoplastic adhesives	Elastomeric adhesives	Composite	Plant based	Animal based
Silicone	Cyano acrylates	Natural rubbers	Plastic wood paste	Carbohydrate (wheat flour paste)	Animal glue
Epoxy	Poly acrylates	Silicones	Plastic wood paste		
Epoxy putty	Polyvinyl Acetate (PVA)Water resistance and ordinary	Acrylonitride butadiene(nitrile)	Epoxy+Polyurethane+Clay	Resins/ Gums	
Polyester		Neoprene			
Polyimides		Polyurethane			

Table 2. Assessment of adhesives on the basis of their property

Adhesives → / Property ↓	Maida Paste	Animal glue	Epoxy	Poly Vinyl Acetate emulsion (water resistance)	Polyurethane	Carboxy Methyl Cellulose	Methyl Cellulose
Filling ability	Low	Low	Good	Low	Good	Low	Low
Adhesion ability	Low	Moderate	Excellent	Excellent	Very good	Poor	Poor
Reversibility	Excellent	Very good	Low	Excellent	Low	Excellent	Excellent
Curing temp	>18°	>18°	>10°	>28°	20° - 30°	20°- 30°	20°- 30°
Curing time	20-60 m	20-60 m	24 hrs	20 m	24-48 hrs	20 m	20m
Coating thickness	400-800µ	200-400 µ	100-200 µ	100-300 µ	4000-8000 µ	300-700 µ	500-700 µ
Workability	High	High	Low	Very high	High	Very high	Very high
Pressure	Little pressure	Moderate pressure	High pressure	High pressure	Very high pressure	Moderate pressure	Moderate pressure
Flexibility	Flexible	Little hard	Very hard	Flexible	Hard	Flexible	Flexible
Environmental resistance	Less	Less	High	High	High	Less	Less
Chemical resistance	Less	Less	High	High	High	Less	Less
Shrinkage	High	High	Moderate	High	Low	High	High

Table 3. Assessment of fillers on the basis of their property

Fillers → / Property ↓	Animal Glue	Animal Glue+Saw Dust	Epoxy	Epoxy Putty	Polyurethane	Pva+Saw Dust+Coral Powder
Filling ability	Low	Moderate	Good	Excellent	Good	Very Good
Adhesion ability	Moderate	Moderate	Excellent	Excellent	Very Good	Very Good
Shrinkage	High	Moderate	Moderate	Very Low	Low	Moderate
Curing temp	>18°	>20°	>10°	>24°	20° - 30°	>18°
Curing time	20-60 m	45m	24 hrs	6-8 hrs	24-48 hrs	10-14 hrs
Workability	High	Moderate	Low	High	High	Moderate
Pressure	Moderate pressure	Moderate pressure	High pressure	Low	Very high pressure	High pressure
Environmental resistance	Less	Less	High	Very High	High	Less
Chemical resistance	Less	Less	High	Very High	High	Less

CONCLUSION

The most common problem of filling materials concerns their compatibility with wood, mainly susceptibility to moisture and the relating dimensional changes, as well as mechanical properties. Excessive shrinkage or swelling of fills in response to humidity fluctuations, different from wood behavior may threaten the integrity of wooden monuments/artifacts[13,15-17]. The same relates to differences in flexibility, compression or tensile strength. Another serious drawback involves poor adhesion of fills to the wood surface or insufficient cohesion of the fill itself; they can lead to gap formation between wood and filling mass or within a fill, further microbial infestations due to the presence of water collected in new cracks and, as a consequence, degradation of the wooden object[13-15,17].

Therefore, there is a constant need to develop new, more effective gap-fillers to properly protect priceless historical wooden monuments/objects for future generations[22].Broad research has been conducted recently on composites based on both natural and synthetic components for various purposes that proves the possibility of developing materials with desired characteristics[24]. However, it should be remembered that such filling composites, should be considered as a system and its properties are not a sum of the properties of its components, because individual ingredients a bulking agent, an adhesive and a solvent–affect each other, modifying the resulting material and its reactions to the surrounding environment[23].

Therefore, close cooperation between scientists and conservators is necessary to understand both the needs of cultural heritage artifacts and the properties of materials proposed for their conservation and make all the process being in line with conservation ethics, because conservation practice seeks to understand and preserve tangible cultural property, whereas conservation ethics seek to understand and preserve intangible cultural property[13,18-24].

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