The development of water-based consolidants for Sydney sandstone in heritage buildings

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By

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CERTIFICATE OF ORIGINAL AUTHORSHIP

I certify that the work in this thesis has not previously been submitted for a degree nor has it been submitted as part of requirements for a degree except as part of the collaborative doctoral degree and/or fully acknowledged within the text.

I also certify that the thesis has been written by me. Any help that I have received in my research work and the preparation of the thesis itself has been acknowledged. In addition, I certify that all information sources and literature used are indicated in the thesis.

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LIST OF ABBREVIATIONS

AA	Acrylic acid
Am	Acrylamide
B67	Paraloid B67
B72	Paraloid B72
BMA	Butyl methacrylate
BSE	Backscattered electrons
CR	Capillary rise absorption
DSC	Differential Scanning Calorimetry
DW	Distilled water
EA	Ethylacrylate
EMA	Ethyl methacrylate
FTIR spectroscopy	Fourier transform infrared spectroscopy
KPS	Potassium persulfate
Lascaux	Lascaux 498 HV
PAA	Polyacrylic acid
PAA100	Polyacrylic acid (100,000 g/mol)
PAA250	Polyacrylic acid (250,000 g/mol)
PAm	Polyacrylamide
PEG	Polyethylene glycol
PEG25	Polyethylene glycol (25,000 g/mol)
PEG35	Polyethylene glycol (35,000 g/mol)

PEO	Polyethylene oxide
MA	Methylacrylate
MMA	Methyl methacrylate
MMT	Montmorillonite
MMTa	Acidified MMT
RT	Room temperature
SE	Secondary electrons
SEM	Scanning Electron Microscopy
Silres	SILRES® BS OH 100
TEM	Transmission electron microscopy
TGA	Thermogravimetric Analysis
TG-MS Analysis	Evolved gas analysis using Thermogravimetric
TI	Total immersion
WVT	Water vapour transmission
XRD	X-ray Diffraction

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ABSTRACT

The work presented in this Thesis assesses the suitability and capacity of the aqueous consolidants designated for more compatible consolidation treatment of Sydney's yellow block sandstone. The aqueous consolidant systems investigated included polymer consolidants, polymer-montmorillonite composite consolidants and in situ polymerisation consolidation. Polymer consolidants incorporating montmorillonite (MMT) were prepared by aqueous solution intercalation method and demonstrated the fast and efficient preparation of composites at the wide range of MMT concentrations from 2.5 to 90%, dispersed in the water soluble polyacrylic acid (PAA), polyacrylamide (PAm), or polyethylene glycol (PEG), or in situ polymerised PAm. While the intercalation behaviour, MMT dispersion, structural variations, intermolecular interactions between polymer and MMT and thermal stability were affected by the polymer-MMT ratios and the nature of polymers; the polymer-MMT ratios determined the trend in these changes, but the extent to which these occurred depended on the nature of polymers. PAA, PAm, PEG and in situ polymerised PAm produced the interlayer separation of MMT in the range of 13.1-19.6, 15.2-26.9, 14.2-19.7 and 20.3-28.1Å with the 50 to 60% MMT threshold incorporated into the polymer matrixes. The interlayer separation of MMT were similar for PAA and PEG, while PAm and the in situ polymerised PAm increased the interlayer expansion of MMT.

The consolidant performance of PAA, PAm, PEG, the polymer-MMT composites and in situ polymerised PAA or PAm was compared with the commercial consolidants, hydrophobic Paraloid B67 (B67) and B72 (B72), water soluble Lascaux and the ethyl silicate Silres by their penetration ability, uptake, water vapour permeability, colour change and bending strength. The polymer-MMT ratio of the composite and the concentrations of polymer or monomer were critical. Practically, the composites containing less than 20% MMT were suitable and the polymerisation at greater than 10% Am or AA was unusable. Increasing the polymer concentrations reduced penetration, induced colour changes and reduced water vapour permeability. PAm and polymerised PAm showed the best performance, whereas PEG reduced mechanical strength and AA and PAA caused colour changes. In comparison, the hydrophobic commercial consolidants caused increased darkening and significantly reduced permeability although

the water soluble Lascuax did provide some beneficial effect. The consolidants developed in this research represented mild consolidation action with minor changes in the characteristics of the treated sandstone. Encouraging results were observed for the performance of these water based polymer consolidants, in particular, PAm demonstrating the best consolidant of water based consolidation systems in the conservation of heritage sandstone.