TECHNICAL note

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Durability of Masonry Mortar

Durability of masonry mortar

INTRODUCTION

The majority of masonry structures exhibit excellent long-term performance with comparatively low maintenance cost. Durability of a masonry structure is influenced by many factors including the durability of both the masonry units and mortar, as well as proper installation of a damp proof course; the durability of the mortar contributes significantly to the overall durability. Mortars used in masonry structures exposed to aggressive environments are designed to resist a range of possible physical and chemical degradations. The physical forms of degradation may be caused by abrasion from wind action, salt crystallisation and freeze-thaw action; the chemical form of deterioration is usually caused by reactions with soluble salts. In Australia, masonry degradation is more likely to occur as a result of the physical effects of salt crystallisation or abrasion from wind action[1].

To assess the potential long-term performance of masonry mortar, a durability test, based on a controlled scratching of the mortar surface, has been successfully developed[2].

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Mortar scratch test in progress

The penetration into the mortar is measured and called the *scratch index*. It is noted that the test simulates and accelerates the physical forces that can cause mortar degradation in service in typical Australian environments. A set of performance criteria has been developed from a comprehensive laboratory and field evaluation programme and included in the Australian Standard for Masonry Structures, AS 3700[3].

CURRENT STANDARD

The durability performance requirement in AS 3700 is that a masonry member or structure shall withstand the expected wear and deterioration throughout its intended life (taking into account the exposure environment and the importance of the structure) without the need for undue maintenance.

The standard recommends the use of a range of classes of mortar for different exposure conditions. It also gives deemed-to-satisfy mortar compositions for each class of mortar. For other compositions, performance limits in terms of scratch indices are given for all classes of mortar.

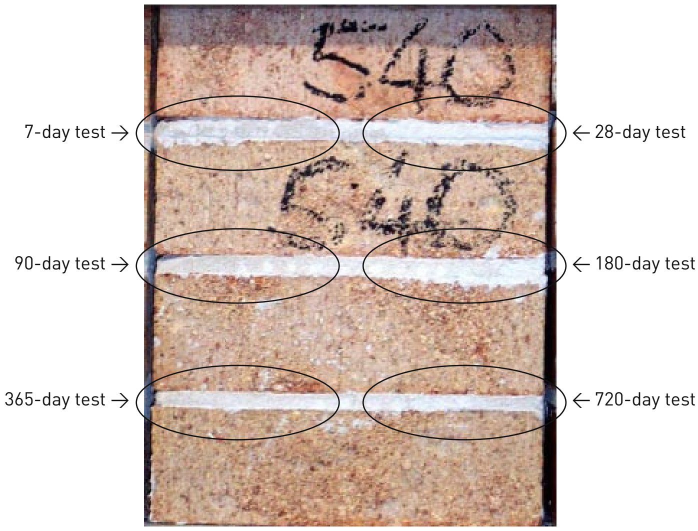
FACTORS AFFECTING DURABILITY

A major research program to investigate factors affecting the durability of masonry mortar has recently been completed[4].It examines the influence of masonry unit, mortar (cement type, sand and mix proportions) and joint finish on the potential durability of three classes of mortar in two exposure conditions. Durability is measured as scratch index taken after various periods of exposure from 7 days to three years. The factors investigated were:

Mortar class:	M2 (1:2:9), two M3 (1:0:5, 1:1:6) and M4 (1:¼:3)
Cement:	Three commercial cements GP, GB1, GB2 Two laboratory blends GL1, GL2
Sands:	Dune, Fatty bush and Coarse sand
Joint finish:	Ironed, Raked and Flush joints
Masonry unit:	Dry-pressed and Extruded unit
Exposure:	Indoor and severe marine.

TABLE 1 Deem-to-satisfy mortar compositions and scratch index for each class of mortar (extracts from Tables 5.1, 10.1 and 10.2 AS 3700)

Mortar class Example of exposure	**Deem-to-satisfy mix proportions** (by volume) Cement (GB/GP)	Building lime	Sand	**Scratch Index** (mm)
M2 Mild, interior	1	2	9	0.5
M3 Wetting and drying, marine	1 1	1 0	6 5	0.3
M4 Below dpc in aggressive soil, severe marine	1 1 1	0.5 0 0–0.25	4.5 4 3	0.1



Brick pier showing test locations

Marine exposure

Typical cement:lime:sand mortar compositions were chosen with one exception of an M3 mix of cement and sand without lime. A range of cements, complying with the Australian Standard AS 3972 *Portland and blended cements*, was investigated. The cements comprised three commercial cements: a GP and two GB, and two laboratory blends representing the upper bound of addition of fly ash (50% by mass) and slag (70% by mass). Newcastle Beach 'dune' sand is largely single-sized fine sand whereas the Bricklayer's White 'coarse' and the fatty bush sand are well graded sands. The fatty bush sand has a large amount of very fine particles passing 150 μm. The three sands represented commercially available sand used for masonry construction.

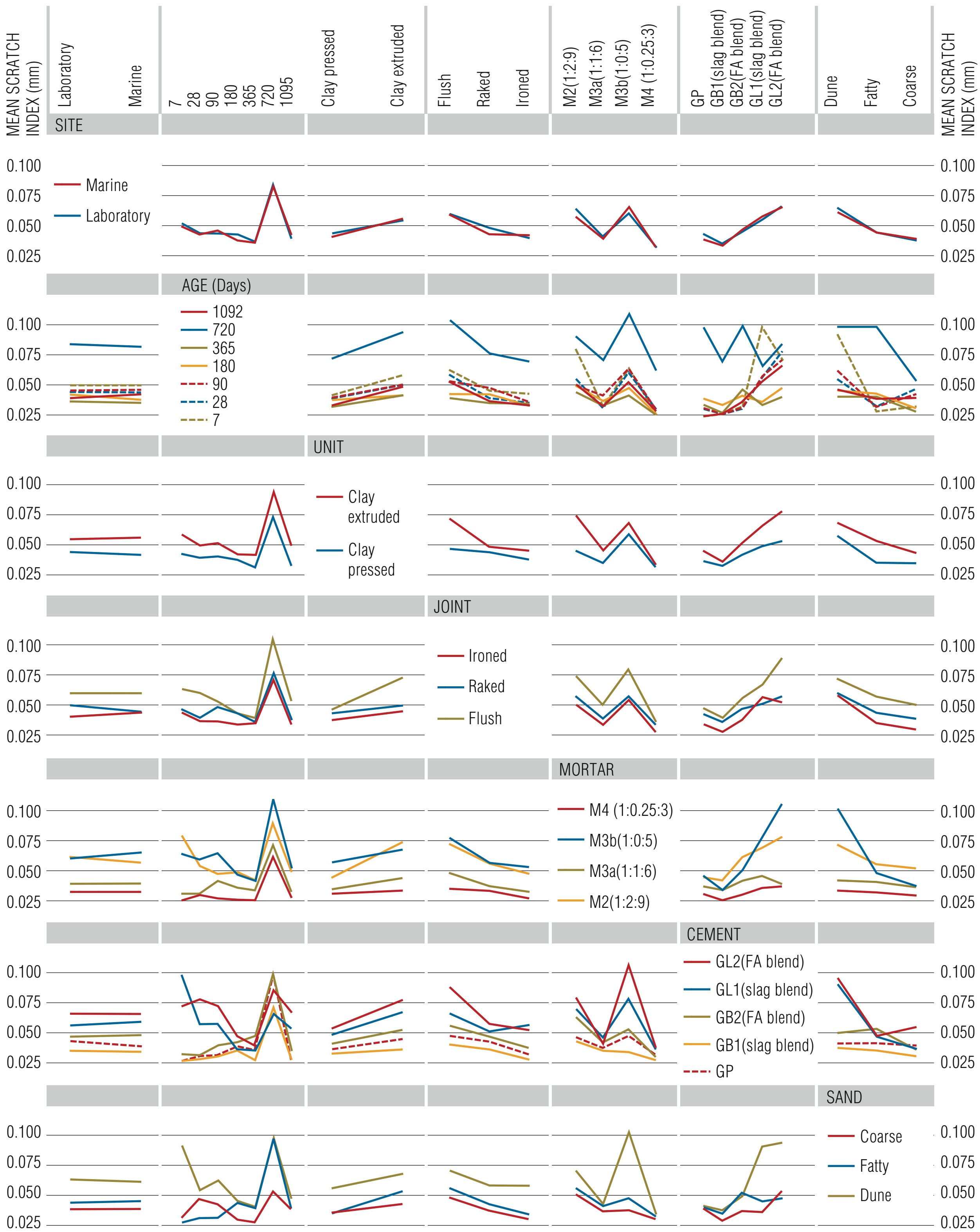
Indoor (laboratory exposure)

Overall Performance

All 360 mortar joints performed well in terms of scratch indices and visual observation of deterioration. The average scratch indices were in the range of 0.02–0.08 mm. This is well within the limits stipulated in AS 3700 for each class of mortar, irrespective of the type of cement, sand, joint finish and masonry unit.

The results show that mortar class, cement, sand, joint finish, masonry unit and period of exposure are all statistically significant factors affecting the durability of the mortar joints. The type of exposure, however, did not significantly affect the scratch index. In the severe marine exposure, measurement up to a period of three years exposure did not show any significantly greater deterioration than corresponding mortar joints in the mild laboratory exposure.

Interpretation of the results was based on the trend in the mean values supported by statistical analysis. Average scratch indices reduced with length of exposure, indicating improved durability. This was probably a consequence of ongoing hydration of cement in the mortar. There was a consistent increase in the indices at the end of year 2, which was completely reversed at the end of year 3. This did not alter the pattern of relative effects from the various factors, as shown in the plots of two-way interactions *(page 4)* and discussed in the following.



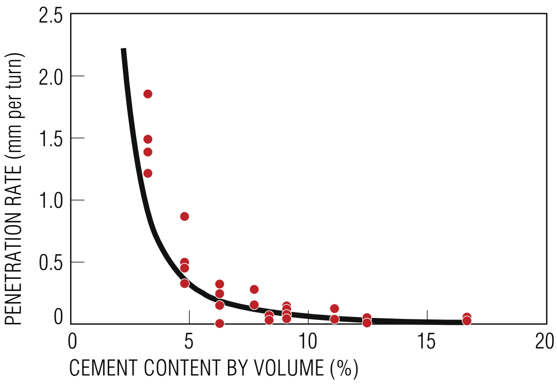
Two-way interactions for 7- to 1095 day data

Factors are shown in the top row and diagonally from top left to bottom right

Effect of Mortar

Class of mortar

The higher class of mortar provides better durability than the lower classes in the following order M4 (1:¼:3), M3 (1:1:6) and M2 (1:2:9). The higher cement content in the higher class resulted in lower scratch index. This confirms previous findings[1] of the relationship between penetration index and cement content. The M3 (1:0:5) mix, which contains no lime, is an exception, showing higher scratch index despite higher cement content and lower water-cement ratio. This was particularly the case with the dune sand and was partially caused by the absence of lime, which improves water retention and promotes continued hydration of cements. Another reason is that the other sands, even in a 1:0:5 mix, contain sufficient fines to produce a denser surface with a lower scratch index.



Relationship between penetration index and cement content

Mortar Mix Cement and Lime Contents

Mortar mix	Cement content (Vol %)	Lime content (Vol %)
1:2:9	8.3	16.7
1:1:6	12.5	12.5
1:0:5	16.7	0.0
1:0.25:3	23.5	5.9

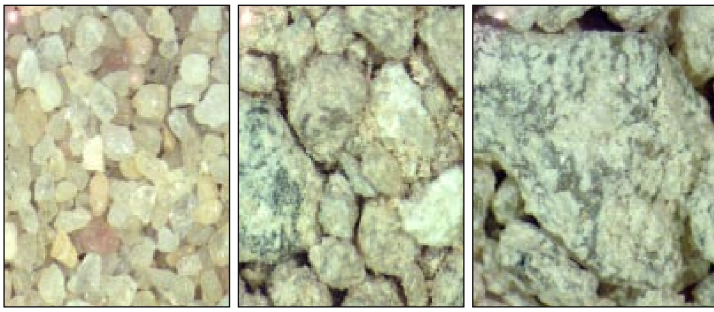
Irrespective of the class of mortar, all mortars investigated had scratch indices well below the AS 3700 limits. Thus the use of AS 3700 deemed-to-satisfy mortar compositions has been shown to provide durable mortar for masonry construction.

Type of cement

All five cements, three commercial cements and two laboratory blends, result in mortar with low scratch indices. The three commercial cements show better performance than the two laboratory blends which yield high initial indices but require 90–180 days before developing similar scratch resistance to the commercial cements. Thus all standard-complying cements are suitable for durable masonry mortar.

Type of sand

The dune, fatty bush and coarse sand represented the spectrum of sands used for masonry construction. All three sands resulted in durable mortars as indicated by the scratch indices. The use of coarse sand resulted in the best scratch resistance, followed by the fatty and dune sand respectively. This is so despite the relatively higher water-cement ratio found in mortars with the coarse and fatty sand compared with corresponding mortar with dune sand.



Dune sand *Fatty sand* *Coarse sand*

Three sands used in the study

Effect of Finishes

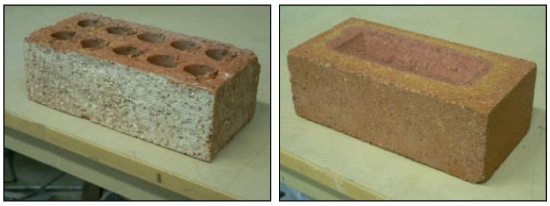
Raked and ironed finishes were found to give better scratch index than the flush finish. This is due to the tooling action which compacts the mortar as well as bringing the cement to the surface of the raked and ironed joints. Ironed finish gave the lowest scratch index with all combinations of sand and mix proportions.

Raked finish *Ironed finish* *Flush finish*

Three finishes used in the study

Effect of Masonry Unit

Pressed units show a lower scratch index than the extruded units, possibly due to the different water absorption characteristics and surface texture. The pressed units have a mean initial rate of absorption (IRA) of 5.4% compared to 0.71% found in extruded units. High water absorption may have resulted in a lower effective water-cement ratio in the mortar and hence lower scratch index.



Extruded unit *Dry pressed unit*

Masonry units

Effect of Other Factors

The study has also confirmed that the durability of masonry mortar improves with increased cement content. Increased air entrainment dosage from the recommended dosage by five to ten times did not appear to detrimentally affect the durability, possibly due to the reduction in water demand of air-entrained mortars. However, overdosing of air-entraining agent can result in reduced bond strength[6] and must therefore be avoided.

Post-construction masonry cleaning by acid washing or high-pressure water jet cleaning carried out in accordance with the CBPI guideline[7] did not influence the standard-complying mortar but did influence lean mortars.

SUMMARY

In examining the durability of a number of AS 3700 deemed-to-satisfy mortar compositions covering all classes of masonry mortars, a total of five cements and three sands were used. The cements cover the full range of GP and GB cements complying with the Australian Standard for portland and blended cement, AS 3972. The dune, fatty bush and coarse sand represent commercially available sands for masonry construction. Three joint finishing techniques: struck flush, ironed and raked were used with both the high suction dry pressed or the low suction extruded masonry units. Testing of 360 types of joint was carried out over a period of three years. All piers were exposed to both 'indoor' and 'severe marine' environments.

All the mortar joints performed well to the relevant durability class in term of scratch indices. All joints showed good penetration resistance throughout the three-year exposure in both the mild and severe marine exposure condition irrespective of the type of cement and sand used, joint finish method and type of masonry unit.

Amongst all the factors investigated, the type of sand had the strongest influence on the durability performance, followed by mortar class and the type of joint finish. The coarse sand resulted in the most durable mortar, followed by the fatty bush and dune sands. The improved durability performance in the higher classes of mortar is expected and is found to be highly dependent on the cement content. The presence of lime in mortars also contributes positively to the durability of the mortars as it improves water retentivity and thus promotes cement hydration. Raked and ironed finishes gave better scratch index than the flush finish due to the tooling action which compacts the mortar as well as bringing the cement to the surface of the raked and ironed joints.

The use of masonry mortar with dry pressed masonry units tends to result in better mortar durability than when used with extruded masonry units. This is possibly due to the higher absorption of the dry pressed units resulting in mortar with a lower effective water-cement ratio. It is interesting to note that better bond strength is also achieved with dry pressed masonry units[6].

PRACTICAL CONSIDERATIONS

All mortar joints perform well to the relevant AS 3700 durability standard in term of scratch indices for each mortar class, irrespective of the type of cement, sand, joint finishes and masonry unit. The benefit of the use of lime to improve the workability and water retentivity of fresh mortar, and the 'autogenous healing' of cracks in hardened mortar, appear to also contribute positively to improved durability.

Mortars proportioned to the Australian Standard AS 3700 deem-to-satisfy mortar compositions are shown to meet the durable requirement of the standard. These mortars can tolerate the overdosing of air-entraining agent as well as post-construction masonry cleaning. However, overdosing of air-entraining agent can result in reduced bond strength. The choice of specific cement type, sand and finishes can contribute to minor improvements in the durability of mortar joint. Therefore, there is a high degree of freedom of choice of mortar joints to satisfy other design considerations.

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