Δελτίο της Ελληνικής Γεωλογικής Εταιρίας, Τομ. XXXIV/5, 1749-1754, 2001 Bulletin of the Geological Society of Greece, Vol. XXXIV/5, 1749-1754, 2001
Πρακτικά 9ου Διεθνούς Συνεδρίου, Αθήνα, Σεπτέμβριος 2001 Proceedings of the 9th International Congress, Athens, September 2001

CONDITION OF THE SEA WALL AT FARM COVE, AUSTRALIA

D. DRAGOVICH[1]

ABSTRACT

The history and present condition of the sandstone sea wall at Farm Cove, are described. The wall has cultural and historical significance and forms the seaward margin of land reclaimed for the Royal Botanic Gardens over the period from 1849 to 1879. The landward fill reaches to high tide mark and the wall extends about a further metre above this level. Both stones and mortar are subject to very active salt weathering. Maintenance has involved block replacement, repointing, cementing over numerous lower course blocks, use of epoxy cement, and infilling of weathered surfaces. Pitting/hollowing is most frequent in the top course of stones. Past unsympathetic repairs include use of a weatherable reddish sandstone, and sawn blocks of durable pale sandstone.

KEY WORDS: sandstone, sea wall, heritage conservation

1. INTRODUCTION

The sea wall at Farm Cove forms part of the Royal Botanic Gardens and associated public space in Sydney, Australia. The wall has historical and cultural significance due to its association with the development of Sydney and the Royal Botanic Gardens in the 19th century. As noted by Wilson (1991), the scale and quality of design of the sea wall and its use of local materials make it unique among various early reclamation projects. Its importance to the Royal Botanic Gardens and its sound construction have resulted in it remaining mostly intact. Because the sea wall was built of sandstone blocks which were placed in in a salt-exposed environment, repair and maintenance of the wall has been undertaken at various times, with the most recent work being completed in 2000.

Farm Cove is a small sheltered inlet which was used as anchorage for sailing vessels in the 19th century and formed a site of early European settlement. Part of the area at the head of the Cove was cultivated for food crops - the "Governor's kitchen garden" - and this later became part of the Royal Botanic Gardens. The wall extends beyond the Gardens proper to Mrs Macquaries Point within the Domain, an adjacent area of public parkland.

In 1848 Charles Moore was appointed Director of the Royal Botanic Gardens and he proposed that intertidal flats be reclaimed for the Gardens. The following outline of the sea wall project is based mainly on information presented by Gilbert (1986) and Wilson (1990). Before the sea wall was constructed, progressive reclamation was effected by building a dyke and then infilling the landward side. The dyke would then provide the base for a stone wall. This process was undertaken in various sections around the Cove and at different times (Figure 1). At first it seems that refuse was included in the landfill but after about 1855 much of the infill was comprised of silt that had been deposited by the Tank Stream into the neighbouring inlet of Sydney Cove. The silt was transferred in barges and the saline sediment later manured to form part of the Lower Garden. However at certain times barge sediment was being deposited without the protection of a dyke, and infill was lost by tidal action. The sea wall itself was built slowly. Initially Moore had requested permission to re-use stone from demolished remains of Old Government House but the Governor refused. Moore continued to seek funding to maintain work on the reclamation project. Eventually Edward Moriarty of the Department of Public Works planned the most seaward dyke, completed in 1869, on which the final sea wall was constructed. On completion of this wall was removed. The outer wall, which became known as the "Thirty Years Wall", was finally completed in 1879.

2. THE SEA WALL

The sea wall is constructed of sandstone blocks with mortar-filled joints. In cross section, the lowest blocks are set on boulders and gravel, with the base block being approximately 1.4 metres wide (McBean and Crisp, 1990). Resting on the footing course are four usually 80-cm wide blocks, with the third of these extending just

1. University of Sydney, Geography F09, Sydney 2006, Australia.

above high water mark. A further two courses of blocks rise above this; the upper-most block has a width of approximately 60cm. The lowest three courses contain stones that are about 60cm high, with the upper three courses being between 30cm and 40cm high. The clay, silt and gravel infill behind the wall extends to the high water mark, so the wall generally has a height of about 1 metre above the infill. This infill is now sealed by a wide bituminised pathway. Drainage slots have been provided at numerous intervals along the wall, in order to allow runoff from the surrounding higher ground to drain into Farm Cove as well as ensuring that seawater from over-topping storm waves is not trapped behind the wall. During storms and high tides seawater also enters the reclaimed area directly through the drainage slots. Despite potential ground settling and instability from the mixed nature of infill materials, the wall is structurally sound.

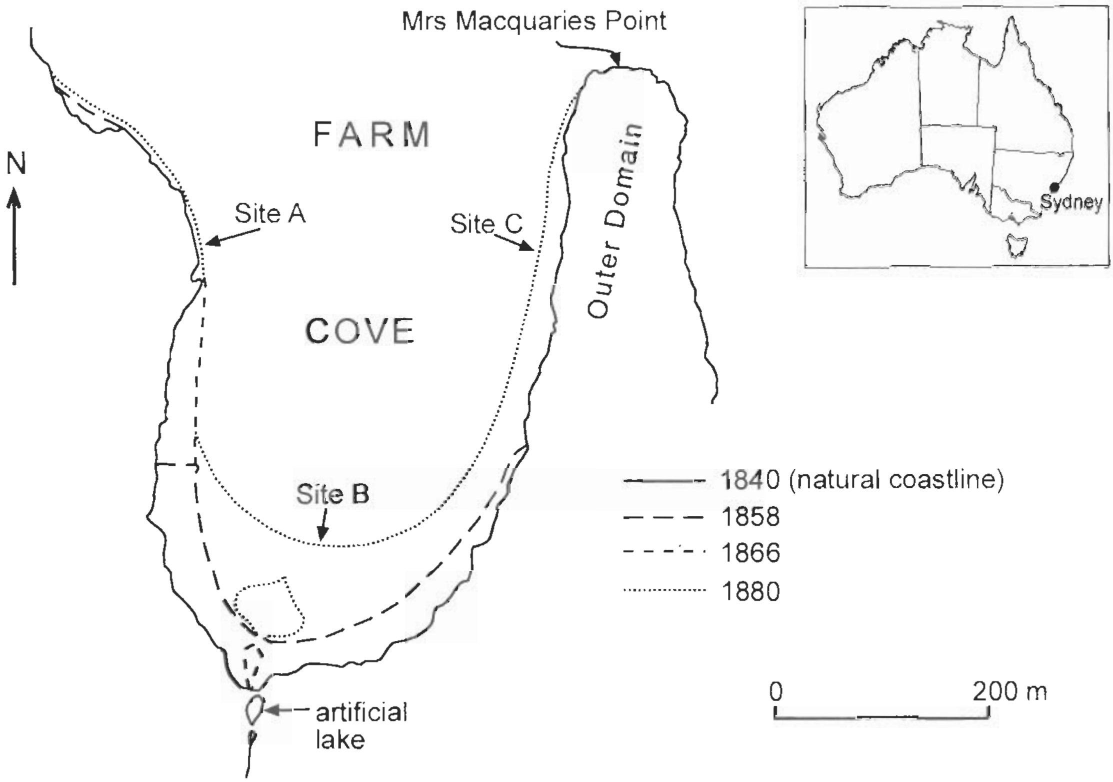

Fig.1. Location of Farm Cove, showing successive reclamation since 1849 (based on Wilson, 1990), and the location of Sites A, B and C of this study.

3. NATURE OF STONE

All blocks are sandstone, with the majority being the Triassic Hawkesbury sandstone found throughout the Sydney Basin. This rock is a fine- to coarse-grained sandstone with varying ratios of quartz to clay matrix. The high quality "yellow block" variety has been used extensively for major public buildings. Once this stone is cut it develops a mellow yellow-brown colour. At Farm Cove most of the sandstone is not yellow block but a strongly siliceous, medium- to coarse-grained variety with a quartz content of 70-80% and clay of 8-14%. This stone is durable because of its secondary quartz cement. Following exposure, it remains close to its quarried colours of white, grey or pale yellow (Franklin, 2000). The inner-city quarries from which this stone was derived have long since been closed, creating difficulties in identifying suitable replacement stone.

The wall is constructed of a single row of stone blocks which are all about 60cm thick in the exposed, above-water sections. Block lengths are variable, with some stones up to 160cm long. The height of individual blocks also varies, from about 21cm to 60cm. Towards Mrs Macquaries Point the wall has only two courses above the bitumenised walkway surmounting the infill, with the top course being an average 22cm high and the lower course about 40cm high. Only 10cm or so of the next course is visible above the walkway surface.

The top course of stone has a triangular cross section on its upper surface. The main face of each stone has a convex shape with a rough rock-faced finish; margins are chisel-draughted. Other courses are similarly margined and finished on the main face. Joints are infilled with mortar. In places where joints and adjacent stones are relatively unweathered, joints are approximately 6mm to 12mm wide. Additional mortar has been used where weathered rock occurs adjacent to joints, with mortar-covered areas in these cases exceeding 10cm in width. Tool marks are common on the central rough rock finish section of each block, and some marks have been enlarged by weathering. Many blocks have a central (surface) hole that was used when hoisting the stones into place.

4. WEATHERING ENVIRONMENT

Sydney is located on the coast in a warm temperate climate. Annual rainfall averages 1222 mm, with a uniform seasonal distribution showing a slight maximum in autumn. Mean maximum and minimum temperatures in summer (December, January, February) are 25.5°C and 18.2°C respectively. Winter temperatures have a mean maximum of 16.9°C and a minimum of 8.7°C. Due to the coastal location, frosts are absent and the lowest temperature recorded is 2.1°C (Australia, Bureau of Meteorology, 2001).

In terms of stone deterioration, the weathering environment of the sea wall is dominated by salt input and its consequent acceleration of stone decay. The tidal range is approximately 2 metres, with high water mark being about 1 metre below the top of the sea wall. With strong winds and waves, sea water can over-top the wall and be deposited directly on stonework. At other times wind carries spray and (salt) aerosols, delivering saline solutions to the wall. A high number of daily sunshine hours - 6.8 hours on average - ensures rapid evaporation of salt solutions, resulting in frequent crystallisation/ solution cycles.

Salt weathering has led to uneven and significant surface recession, round-edged hollowing, small-scale pitting, and honeycombing. Salt has affected both the stone and the mortar. Because of the substantial hollowing of stones and serious loss of mortar, various repairs have been carried out on the wall.

5. NATURE OF REPAIR WORK

Stone

Individual stone blocks have been replaced at different times, although the most substantial repairs were carried out in the late 1980s and in the late 1990s. Stones in the top course are relatively easy to replace because they are accessible and their removal does not affect structural stability. However stones in the lower courses can only be replaced by removing stones above them, necessitating more major associated work for replacement.

Selection of replacement stone should ideally take into account both durability and colour. Most of the original blocks are pale buff to yellow in colour, with replacement blocks also being variable in colour. Local banded sandstones have generally been avoided as they often have low durability in coastal environments. Even so, major block-by-block variations in durability occur in local sandstones when stone is purchased in "quarry runs" rather than on an individual block basis. Earlier repairs allowed for replacement of original stone with a weatherable reddish sandstone (from Queensland) whose colouring is not in accord with that of the overall structure; rapid deterioration of this stone has been documented over periods as short as a decade. Stone finish is now standardised to convex rough rock faces and chiselled margins.

Mortar

The original lime mortar used in joints has needed repair. Mortars and epoxy cement of varying quality have been used to infill hollows weathered in the stone, to coat the exposed top surface of the uppermost course of stones, to repoint between blocks, and in some cases to re-coat entire faces of weathered stone. Because sandstone in the sea wall is relatively permeable once weathered, the most recent repairs had a stipulation that the mortar employed be more permeable than the stone and that specified proportions of cement, lime and sand be utilised (Tender Document, extract, no date). Older replacement mortar often persisted longer than the stones it surrounded, suggesting that it behaved as a relatively impermeable material which concentrated moisture along the permeable/ impermeable boundary, to the detriment of the stone.

Numerous stones in the lowest course of the wall on the western side of Farm Cove have been cement-coated. Many of the blocks had deteriorated badly, showing hollowing and honeycombing before being repaired in this way (some photographs of the pre-repair condition are presented in McBean and Crisp, 1990). The lowest course is vulnerable t[illegible]anic salts and it is likely that salts may also be derived from the infill sediments. In addition, occasional seawater incursions through drainage slots add to the salt load.

Cement/mortar coatings, usually less than 1cm thick, appear in some sections on the top surface of the uppermost course. Where this coating has deteriorated and exposed the underlying stone, the rock surface appears to be uneven but not excessively pitted. Wide re-pointing has been undertaken between many of the older blocks. Mortar extends over the stone margins, probably to infill previous pitting or surface loss. Joints between new blocks are narrower and pointing is correspondingly thinner.

6. CURRENT CONDITION

The most severely weathered stones have been either removed and replaced, or cemented over. Less affected stones may have remained untreated. Existing weathering features therefore include both inherited and post-maintenance examples. Planning Australia Workshop (1998) lists a total of 172 stones for replacement, 163 of which were located in the lower course of sections with a three-stone course. The high replacement rate in this course was thought to result from unsatisfactory treatment undertaken in previous maintenance work, along with the strong exposure of this course to seawater.

Stone and mortar condition were examined for this study at three positions on the sea wall. At each site observations were made on a short section incorporating ten top-course stones and all stones in the courses below. One site was located on the western side (Site A), one at the head of the Cove (Site B), and the third in the Domain on the eastern side of the Cove (Site C) (Figure 1).

The presence of pitting, hollowing, honeycombing and general surface reduction was recorded, along with stone colour. The term "pitting" described pits that were usually between 10 and 20mm deep, and mostly with well-defined edges. "Hollowing" referred to round-edged, shallow and wider depressions on rock faces. As pits graded into hollows, making categorisation uncertain, results are listed for pits/hollows in one group and honeycombs in the other. The condition of all stones was described for their landward faces only. In addition, the presence of dark reddish replacement blocks with visible bedding was noted.

The use of cement-coatings on stones was taken to indicate substantially weathered surfaces. At Site A, all ten of the lower course stones were cement-covered (Table 1), a result consistent with the stone course described by Planning Australia Workshop (1998) as the most vulnerable to salt effects. At Site B, four of the ten top-course stones had a cement coating either on the top surface or face; only one stone in the lower course was cement-covered. At Site C a higher proportion of all stones were relatively recent replacements and cement repairs had not been made.

	Course	Total	Cement-covered
Site A	Top	10	0
	Middle	9	0
	Lower	10	10
Site B	Top	10	4
	Middle	11	0
	Lower	10	1
Site C	Top	10	0
	Lower	11	0

Table 1. Number of cement-covered stones on sea wall at Sites A, B and C.

Many stones are insufficiently weathered to warrant replacement or cement-coating but do show pitting or hollowing (Figure 2). Pitting/hollowing was most evident at Site A, where all stones in the top course were affected and six stones in the middle course (Figure 3). Five of the cement-covered blocks in the lower course showed fretting/pitting. At Site B, eight of the middle course stones were pitted/hollowed, along with others in the top and lower courses. Nine of the ten stones in the top course at Site C had pitting/hollowing. The lower course at Site C was artificially pitted with tool marks from stone working but a number of these marks seemed to show enlargement from weathering. In total, pitting/ hollowing was most evident in the top course of stones (Figure 3) with more than 80% of stones affected.

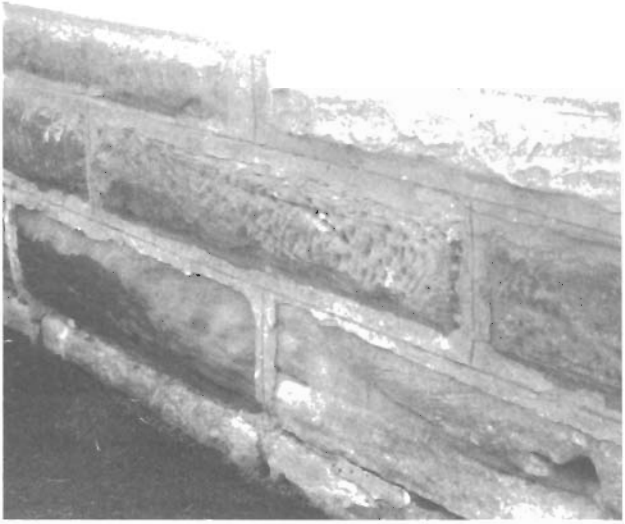

Fig.2. Cement-coated block in top course, pitting in middle course, and surface recession of reddish sandstone in lower course. Wide re-pointing has been used to cover weathering.

Some pitting appeared to be located at points or lines of weakness within the rock. Other apparently random distributions were probably initiated by tool marks. On many of the blocks in the uppermost courses at Sites A and C, lines of very small pits along the top section of the face suggested that preferential salt deposition occurred on the upper surface of the convexly-protruding rough rock face. At Site C these pits occurred both along the top and sometimes the bottom junctions, but rarely along the vertically-oriented side junctions. Both micro-locations allowed for preferential deposition (top) or retention (bottom) of salt transported to the rock surface.

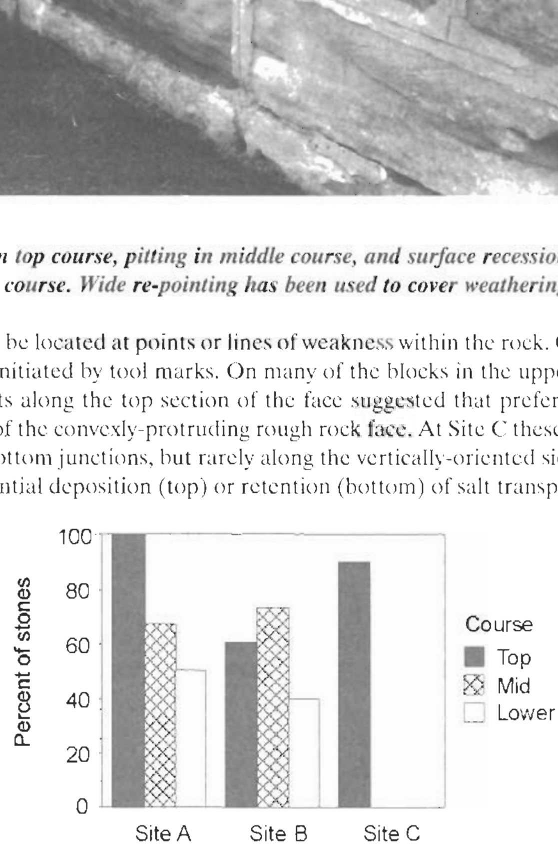

Fig.3. Percentage of stones with pitting/hollowing in the top, middle and lower courses at Sites A, B and C at Farm Cove.

Surfaces were described as having honeycombs only where a lattice-work of relatively sharp-edged pits had developed. Only five examples were noted, four at Site A and the fifth at Site C. Multiple pits which did not form part of a lattice-work, were not linked in a linear (bedding plane) pattern, and were not separated by relatively sharp-edged cell walls were classed as pitting features. Some of the hollowing recorded may have represented weathered and previously honeycombed surfaces.

On-going maintenance and repairs have meant that investigation of possible effects of aspect could not be carried out. Although some differential input of salts from prevailing winds may occur, the general salt loading on the wall is extreme in all positions. Current weathering condition seems strongly related to variations in the durability of both original and replacement blocks. The dark reddish bedded sandstone used as a replacement stone is unsuitable in relation to both colour and weatherability criteria. Strong etching and sometimes linear pitting develops along the bedding planes, accelerating surface retreat. The stone is a conspicuously different colour from the variatiants of white, grey and yellow which constitute most of the wall. Once they require replacement, these reddish sandstone blocks will be substituted with grey or pale yellow stone of greater durability.

7. CONCLUSION

Repair and maintenance work on the sea wall at Farm Cove now takes into account the cultural and historical significance of a structure located in an area with high salt load and intense weathering. Major recent work has involved block replacement and repair, with the remaining pitted/hollowed blocks being generally in the uppermost or middle course. Durability of original and replacement blocks is variable and visible deterioration can occur within ten years. In the longer term, previously replaced blocks which are unsympathetic to the appearance of the main structure due to their colour or form of preparation will be removed.

REFERENCES

AUSTRALIA BUREAU OF METEOROLOGY (2001) *Climate Averages.* http://www.bom.gov.au/climate/averages/tables/cw_066062.shtml (28 May 2001)

FRANKLIN, B.J. (2000) Sydney dimension sandstone: the value of petrography in stone selection and assessing durability. In McNally, G.H. and Franklin, B.J. (eds) *Sandstone City: Sydney's dimension stone and other sandstone geomaterials*, EEHSG of Geological Society of Australia, Springwood, pp.98-116.

GILBERT, L. (1986) *The Royal Botanic Gardens, Sydney: a history 1816-1985.* (Oxford University Press, Melbourne).

McBEAN and CRISP PTY. LIMITED (1990) *Study of Sea Wall, Farm Cove, Royal Botanic Gardens.* McBean and Crisp Pty. Limited, Sydney.

PLANNING WORKSHOP AUSTRALIA (1998) *Heritage Impact Assessment of Maintenance Works at Farm Cove Sea Wall, Royal Botanic Gardens, Sydney.* Planning Workshop Australia, Sydney.

TENDER DOCUMENT (undated extract) *State Projects, Section 3. The Works.*

WILSON, G. (1991) *Conservation Study: Seawall Farm Cove.* Prepared for the Environmental Design Section, Public Works Department, New South Wales.