The mortars of Coliemore harbour: comparison with other 19th century mortars of harbours and fortifications in Dublin Bay.

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Abstract. This paper investigates the mortars used to build Coliemore harbour in 1869: their materials, sources, technology and current condition. It compares their composition with other Dublin harbours and fortifications in Dublin Bay including Howth harbour (1813); Dún Laoghaire harbour (1817-1842) and Martello towers (early 19th century). All the mortars were made with eminently hydraulic limes and local sand. The original binders of Coliemore and Dún Laoghaire and the Martello towers are similar, consisting of carbonated lime and cementing hydrates with abundant iron oxides and opaques. However, the Howth harbour mortars are different: their binder, an eminently-hydraulic Lias lime, largely consists of cementing hydrates with scarce iron oxides and some calcium silicates (pyroxene).

Coliemore harbour was built with local granite quarried in the Dalkey hill, bound with mortars made with hydraulic lime and local sand. The harbour fabric is in good condition, and several generations of hydraulic mortars are evident. Their physical properties are comparable to other eminently hydraulic mixes made hydraulic lime, Roman cement and Portland cement. Despite their strong exposure, the mortars remain cohesive, with absorption/porosity comparable to other eminently hydraulic materials. Occasionally, biodeterioration is strong, blocking pores, hence some porosity values are slightly underestimated. Modal percentages indicate proportions of 2: 1 (sand: binder), consistent with traditional and historic mortars. Siliceous sand consisting of granite and quartz predominate, and limestone generally accounts for 15-20% of the total sand.

KEYWORDS : Hydraulic-lime mortars, 19th century mortar technology, Harbours, Martello towers, Lias lime, eminently hydraulic lime.

1. Introduction

Coliemore Harbour is situated on the south tip of Dublin Bay, in the town of Dalkey, 15 km from Dublin city centre. Coliemore Harbour and the Dalkey Sound have been used as a landing point for passengers and goods since the thirteenth century (de Courcy Ireland 1986; Smith 1996).
The access to Dublin port was hazardous due to shallow sandbanks in the bay. The prevailing westerly winds also made it difficult to reach Dublin port, located in the river Liffey at Wood Quay (de Courcy Ireland 1986). The Dalkey Sound was used in bad weather, for unloading both passengers and goods to lighten the ships before navigating to Dublin. There was a small landing stage at a creek in Dalkey Sound which became known as Coliemore Harbour (Smith 1996). Initially, it was little more than a sheltered, sandy cove with a rudimentary pier. The area became a centre for fishing, exporting to the Chester and Bristol ports in the UK. According to Smith, the sound was also used for smuggling as there was no customs station adjacent to Coliemore, the nearest being in Dublin.

The importance of Coliemore Harbour diminished in the 17th century owed to the gradual walling of the river Liffey, and to the Dublin port being moved towards the sea (to Ringsend). Over the following two hundred years, Dalkey Sound and Coliemore became obsolete due to the construction of Howth Harbour (1813), the enhancement of Dublin Port with the completion of the Bull Walls (c.1800) and the construction of Dún Laoghaire Harbour (1817-1842). The reasons for the construction of the present harbour at Coliemore in 1869 are unclear, but it was probably built to provide a sheltered landing point for pleasure boats of the Dublin gentry who were building large houses in the area (Ryan 2004 pers.com). It also provided a safe point of departure for the tourists to visit Dalkey Island.
2. Materials and construction

The harbour, as it now stands, was constructed under the Towns Improvement Act of 1854 which states: “The Commissioners [of Dalkey Town] may construct two piers at Coolamore Harbour on the site of the present landing place, extending into the sea one hundred feet ... in a north-easterly direction.”

The original plan and sections of the piers, referred to in notice and bill, are included in figure 2. The structure was built of local Dalkey granite (Pearson 1998), held together with a hydraulic lime mortar, and some granite pins are wedging the blocks in place. The original project was drawn up by Mr B. B. Stoney, the Dublin Port and Docks Board chief engineer. Mr. Stoney later submitted a second plan (now lost) which provided a much greater capacity (Dublin Port and Docks Board Journals 1867). The construction methods outlined in the original plans involved the use of granite as a facing stone and a wall core of mixed limestone, waste granite and crushed stone rubble. The facing granite masonry of the piers and retaining walls are of roughly cut and roughly coursed granite, while the surfaces and edges are of cut granite masonry (figure 3).

3. Present Condition

The general condition of the structure is good, principally due to the strong material used, the quality of construction and the harbour foundation being the local granite bedrock. However, there are areas where damage is evident, including missing mortars and pins leaving dry joints. The worst affected areas are those of most difficult access, including the outside of the south pier, south-west wall and west wall, where granite pins and blocks are lost (figure 4). These parts have seen fewer repairs than others probably due to the difficult access. Repairs were undertaken at different stages, and they now display varying quality and condition. They include recent Portland cement mortars re-pointing the pier surfaces, and a replacement step in the south pier made of concrete (figure 5). The capping stones on the edge of the pier and the top three steps were replaced with new granite (probably not local).

In 2001, a sewer was constructed under the north pier to facilitate the expansion of a neighbouring hotel. During the sewer’s construction, the granite on the surface of the pier was removed and, upon completion, it was replaced with Portland cement mortar (figure 7). This has decreased the structural integrity of the pier due to subsequent cracking of the cement patch, and it has partially destroyed the aesthetics of the harbour. There is biological growth on the structure below the high-water mark (fungi, seaweed, algae and crustaceans), and in the splash-zone (principally lichen).
Figure 2. Coliemore Harbour. Plan and sections of piers in the Notice and Bill and location plan. Cornelius Carmony c. 1860 (Dublin Ports and Docks Board 1867).
Figure 3. The facing granite of the West wall showing dry joints and the loss of granite pins.

Figure 4. The outside of the south pier at low tide showing dry joints and missing pins. The dashed line shows the high-water mark (repairs above).

Figure 5. Steps of the south pier showing contrast between original (pink) and new (grey) granite and a concrete step. Strong biological growth of seaweed, lichen and algae.

Figure 6. The granite bedrock foundation and the south-west wall, of difficult access, showing mortar failure causing dry joints and loss of stonework.

Figure 7. Portland cement mortar patch replacing original granite slabs.
4. Properties and composition of the original masonry mortar of Coliemore harbour

Ten mortar specimens were tested to determine their physical properties. Petrographic analyses were carried out on specimens taken from the south pier foundation (outside, accessed at low tide) and from the interior of the north pier. They were partially dyed with potassium ferrocyanide and alizarine to distinguishing between carbonate minerals. The visual analysis showed variation in the properties including mix ratios, colour, aggregate size/shape and condition. However, the type of aggregate remains consistent, with granite, shell and fine sand present in most samples. Therefore, the original construction and some of the subsequent repairs used a similar aggregate. The densities, porosity and water absorption were measured according to RILEM recommendations (RILEM 1980)- Table 1. The difference between the real and bulk densities evidenced open porosities comparable with other eminently hydraulic mortars made with hydraulic lime, Roman cement and Portland cement (Table 2). Despite the strong exposure of the harbour, none of the samples have particularly high absorption/porosity, and the values are comparable to other eminently hydraulic mortars previously analysed with the same method (Table 2). However, the site and microscopy studies occasionally showed strong biological colonisation blocking pores, thus the values of open porosity, measured with physical testing, can be slightly underestimated (figure 8).

![Figure 8. Biological colonization (hollow, yellow coating) on the mortars and granite. Left: Mortar, natural light. Right: granite pin, polarised light. Field of view c. 5 mm.](image)

Modal percentages were assessed using a 10X lens according to St John et al. (1998). According to these, the amount of binder is high (25-50%) indicating a mix of roughly 2: 1 (aggregate: binder) which is consistent with traditional and historic mortar mixes. In most mortars, siliceous sand consisting of granite and quartz predominates. However, limestone accounts for 15-20% of the total sand, except for mortar 17 where limestone sand predominates at 40%. Shells are present in over a third of the mortars, making up 5% of the sand (occasionally 10%). Coarse and fine sand, and pebble-sized aggregate are present in all the mortars. The most common grading ranges from 1 to 15/20 mm.
Table 1. Physical properties of the original mortars. P- open porosity; WA-water absorption.

<table>
<thead>
<tr>
<th>Mortar</th>
<th>δ-Bulk density (kg/m$^3$)</th>
<th>δr-Real density (kg/m$^3$)</th>
<th>P (%)</th>
<th>WA (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2190</td>
<td>2590</td>
<td>15.31</td>
<td>6.27</td>
</tr>
<tr>
<td>2</td>
<td>2060</td>
<td>2530</td>
<td>18.55</td>
<td>7.91</td>
</tr>
<tr>
<td>4</td>
<td>1770</td>
<td>2460</td>
<td>27.85</td>
<td>12.50</td>
</tr>
<tr>
<td>6</td>
<td>2040</td>
<td>2540</td>
<td>19.57</td>
<td>8.35</td>
</tr>
<tr>
<td>9</td>
<td>2170</td>
<td>2550</td>
<td>15.02</td>
<td>5.62</td>
</tr>
<tr>
<td>11</td>
<td>2050</td>
<td>2540</td>
<td>19.23</td>
<td>8.21</td>
</tr>
<tr>
<td>13</td>
<td>1890</td>
<td>2530</td>
<td>25.46</td>
<td>11.66</td>
</tr>
<tr>
<td>17</td>
<td>1990</td>
<td>2520</td>
<td>21.13</td>
<td>9.27</td>
</tr>
<tr>
<td>granite</td>
<td>2602</td>
<td>2655</td>
<td>1.96</td>
<td>0.74</td>
</tr>
</tbody>
</table>

The sand is of local origin, containing granite, limestone and shell (figure 9-10). The limestone shows the typical features of the Carboniferous limestone (Dublin bedrock), and the granite is probably the Leinster granite which is the bedrock of Coliemore harbour, and was historically quarried at 1Km, in the Dalkey hill. The binder is very distinctive. It includes opaque areas alternating with abundant hydrates of low crystallinity and abundant iron oxides (figure 11-12). The aggregate is consistent with the sand on the harbour floor which includes granite (quartz, K-feldspar, muscovite and plagioclase) along with small amounts of limestone and shells.

Table 2. Comparison with other eminently hydraulic mortars (Roman cement, NHL and PC) previously analysed with the same methods. * Pavía and Durcan 2014; Kozłowski et al. 2012; LMM 2007. ** Hanley and Pavía 2008; Cosgrove and Pavía 2009; Costigan and Pavia 2010; Pavía and Durcan 2014. *** Pavía et al 2006; Pavia and Brennan 2013; Pavía and Durcan 2014.

<table>
<thead>
<tr>
<th>P %</th>
<th>δ (kg/m$^3$)</th>
<th>δr (kg/m$^3$)</th>
<th>Compressive strength (MPa)</th>
<th>Flexural strength (MPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roman Cement *</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22</td>
<td>1946</td>
<td>2508</td>
<td>6 - 9</td>
<td>1 - 2.5</td>
</tr>
<tr>
<td>18 - 22</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>23 - 40</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Natural hydraulic lime- NHL 5 **</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>22 - 25</td>
<td>1879-1933</td>
<td>2474</td>
<td>3 - 9</td>
<td>1 - 2.4</td>
</tr>
<tr>
<td>Portland cement- PC ***</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>2069</td>
<td>2511</td>
<td>9 - 10</td>
<td>3.5</td>
</tr>
<tr>
<td>20 - 23</td>
<td>1840</td>
<td>2390</td>
<td>16 - 24</td>
<td>2.9</td>
</tr>
</tbody>
</table>
5. Sources of raw materials and mortar making technology.

As aforementioned, the sand of the Coliemore harbour mortars is of local origin. To determine the binder source, the Coliemore harbour mortars are compared with other hydraulic mortars of similar age (19th century), from Howth and Dún Laoghaire Harbours and the Martello Towers in Dublin Bay (figure 13). The Coliemore mortar binder shares common features with Dún Laoghaire Harbour (4 Km North of Coliemore), built between 1817 and 1842. The binder is very similar, with opaque areas alternating with hydrates of low crystallinity and abundant iron oxides (figure 14). Like Coliemore, Dún Laoghaire Harbour was built with local granite from the Dalkey Hill, and the sand includes local bedrock types (granite and Carboniferous limestone with chert)- figure 15. The presence of lime inclusions including abundant iron oxides and hydraulic phases (figure 16) and the remnants of unhydrated ferrous clinkers (figure 17) agree with the hydraulic nature of the binder. The main difference is that the Dún Laoghaire mortars contain more abundant chert sand and un-hydrated (iron-rich) clinkers.
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Figure 13. Location of the harbours and Martello towers in Dublin bay (Space Radar Image ©NASA).

Original mortars of the West pier of Dún Laoghaire Harbour

Fig 14. Binder with abundant hydraulic phases, iron oxides and opaques like the Coliemore binder in fig. 11-12. Natural light.10X. Field of view 1.42 mm.

Fig 15. Local limestone and chert sand. Natural light 2X. Field of view 7 mm.

Fig 16. Lime inclusion with hydraulic minerals and iron oxides. Natural light.10X. Field of view 1.42 mm.

Fig 17. Un-hydrated ferrous clinker surrounded by cementing hydrates and carbonated lime. Natural light.10X. Field of view 1.42 mm.
The Dún Laoghaire and Coliemore mortars share common features with the original masonry mortars of the Martello towers of Dublin Bay (figure 18). The Martello binders are similar to the binders in the harbour mortars above, showing extensive hydraulic areas with abundant hydrates and iron oxides (figure 19), and the sand is local (figure 20). The Martello towers in Dublin Bay were built in the early 19th century with the same technology. These cylindrical towers were built to defend the coast from the threat of Napoleonic invasion (Enoch 1975). According to Enoch (1975), their mortars were made with ground granite, lime, ash, hot wax and ox blood. Organic additives such as blood, beer, urine, and wax were added to historic mortars as workability aids, stiffening aids, air entrainers or structural reinforcement, but over time, organic additions mineralize making identification difficult (Pavia and Bolton 2000). However, the abundant iron oxides scattered in the binder can be the remains of mineralised blood (hemoglobin).

The original mortars used to build Howth harbour are also eminently hydraulic but completely different to the binders above. Petrographic analysis evidenced abundant relics of un-hydrated clinkers (rounded and hexagonal, mainly belite), both in clusters and as single grains partially
hydrated (figure 21). Like Dún Laoghaire, the presence of lime inclusions with silicates evidence the use of hydraulic lime (figure 22), but the binder largely consist of cementing hydrates with scarce iron oxides (figure 23), and calcium silicates (pyroxene) are common (figure 24). The sand is of local origin including limestone, shale, schist and occasional dolomite and volcanic rocks. Howth harbour sits across from Dún Laoghaire harbour, at the North tip of Dublin Bay (figure 13). It was completed in 1813. Built with Leinster granite (quarried at Dalkey Hill) and Howth quartzite, from the nearby Kilrock quarry (O’Flanagan and Pavia 2016). The construction of Howth harbour was advanced for its time, using slant-section piers built à pierre perdue and vertical-section piers built with the diving bell, being the first use of the diving-bell in Ireland (Rennie 1856). According to Rennie, a mortar comprising of one-part Aberthaw lime (from Wales), one-part pozzolan and two parts of sand was used in the construction of the harbour. The lime is eminently hydraulic and belongs the Blue Lias formation. The mortar largely remains in good condition above the high-water mark.

Howth harbour

Fig 21. Remnants of un-hydrated belite. 40X polarized light. Field of view 0.35 mm.

Fig 22. Lime inclusion with carbonated lime and calcium silicates (belite?) Natural light. 10X. Field of view 1.42 mm.

Fig 23. Dolomite (left) and limestone sand in a binder consisting of hydrates with scarce iron oxides. Polarisated light. 2X. Field of view 7 mm.

Fig 24. Cementing hydrates, calcium silicates (pyroxene) and carbonates. Polarised light. 10X. Field of view 1.42 mm.
6. Conclusion

Coliemore harbour was built with local granite form the Dalkey hill bound with mortars made with hydraulic lime and local sand. The harbour fabric is in good condition, and several generations of hydraulic mortars are evident. Their physical properties are comparable to other mortars made with eminently hydraulic binders such as hydraulic lime, Roman cement and Portland cement. Despite their strong exposure, the mortars remain cohesive, with no particularly high absorption/porosity, and values comparable to other eminently hydraulic mortars. In some specimens, biological growth blocks pores, hence some of the porosity and water absorption values are slightly underestimated. Modal percentages indicate proportions of 2:1 (sand: binder), consistent with traditional and historic mortars. Siliceous sand consisting of granite and quartz predominate and limestone generally accounts for 15-20% of the total sand.

The original masonry mortars of Coliemore harbour are compared with contemporary (19th century) constructions in Dublin Bay, including the harbours at Dún Laoghaire and Howth, and some of the Martello towers in Dublin Bay. All the mortars were made with eminently hydraulic limes and local sand. The original binders of the Coliemore and Dún Laoghaire harbours and the Martello towers are similar, consisting of hydraulic cements and carbonated lime with abundant iron oxides and opaques. However, the Howth mortars, made with an eminently hydraulic Lias lime, are different: their binder largely consist of cementing hydrates with scarce iron oxides and some calcium silicates (pyroxene).

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References


Board of Dublin Port and Docks Journals (1867). Dublin Port and Docks Board Journals 18/07/1867.


Enoch, V.J. (1975) The Martello Towers of Ireland, Dublin


Towns Improvement (Ireland) Act of (1854). The Dalkey Township Act 1867: Section 36,