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Irish Medieval Mortars: Implications for the Formulation of New Replacement Mortars

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Abstract  This paper provides an overview of medieval lime mortars in Ireland, based on comparison of the petrography and microstructure of 110 lime mortars from 35 archaeological sites in the Republic of Ireland. These comprise bedding, plastering and rendering mortars from a range of secular and ecclesiastical buildings including castles, churches, round towers and city walls. The paper outlines current gaps in knowledge of Irish historic mortars, and the challenges in using the data gained from analyses to specify repair and replacement mortars.

1 Introduction

The analysis of historic mortars in Ireland is carried out from three distinct, though interlinked, perspectives:

- Conservation: focusing on understanding the characteristics of a mortar, its degradation and interaction with the rest of the building fabric, and most often to obtain specific information to formulate a compatible repair mortar.
- Archaeology: focusing on determining the provenance of raw materials, on production processes (lime burning, mortar mixes, use of additives etc.), and also to provide absolute and/or relative dating evidence for a particular site or structure.
- Historic Materials Research: analyses aim to increase knowledge and understanding of burning, mixing, hydration and carbonation processes, and identifying the different minerals formed.

This paper, focusing on mortars from the medieval period, provides an overview of the key findings from studies of the petrography and micro-structure of 110 bedding, plastering and rendering mortars from 35 archaeological monuments gathered during research and consultancy work from the late 1990s to
2010. The paper also addresses some of the issues encountered in transforming analytical data into useful knowledge to conserve historic structures.

2 Historical architectural context

Lime mortar technology was introduced to Ireland sometime towards the end of the early medieval period (AD 500-1000). Prehistoric (pre-AD 500) Irish building technology is based on the use of dry-stone, earth, timber and other organic building materials. The arrival of mortared masonry building techniques is directly linked with the development of the early Christian church in Ireland, and the technology of lime production and building with lime mortar was almost certainly brought from elsewhere in Europe. Timber churches predominate in the early medieval period, and the first historical references to ‘damliac’ or ‘stone houses’ appear from AD 724 onwards. These may have been dry-stone buildings, and it is not until the ninth or tenth centuries that secure evidence for mortared masonry structures appear, such as Clonmacnoise Cathedral, built c. AD 909 [1].

![Fig. 1](image-url)

Fig. 1 The north wall of Clonmacnoise Cathedral, Ireland, constructed c. AD 909, with an elaborate perpendicular Gothic doorway inserted at the western end of the wall c. AD 1460. Recent conservation of the cathedral focused on repointing the ruined structure (above right).

Early stone churches in Ireland tend to be simple, single-celled buildings, rectangular in plan and with little (if any) decorative detail. However, the advent of masonry mortar allowed the introduction of new architectural forms within these rectangular churches such as round arches, barrel vaults and stone roofs. Perhaps the most striking new building type made possible by masonry mortar technology were tall, tapering, free-standing ‘round towers’ which appear from the tenth century onwards at ecclesiastical sites. The twelfth century saw the transformation of the historical built landscape with the introduction of significant new masonry building types including the adoption of Romanesque architectural forms at many sites, the arrival of the formal architecture of European monastic orders such as the Cistercians, and the new towns, fortifications and other buildings which developed following the arrival of the Anglo-Normans c. AD 1170. The vast majority of mortared masonry medieval buildings in Ireland survive as ruined structures, and relatively few form part of a site which is still in
use, for example as a place of worship. The most common conservation intervention is mortar-based (e.g. repointing and/or grouting), and the determination of a compatible repair mortar to preserve both the character and the fabric of the ruined structure is integral to conservation work at medieval sites.

3 Petrography of medieval Irish lime mortars

The usefulness of studies of the petrography and microstructure of historic lime mortars has been widely recognised [2, 3, 4, 5, 6] for both archaeological and conservation work. Surviving mortars from the medieval period in Ireland comprise bedding and pointing mortars, external renders and internal plasterwork, and special purpose mortars (e.g. chimney flue lining, wicker-centred vaulting). In some cases, such as Stradbally Church, Co. Waterford and the 13th century Bishops Palace at Kilteasheen, Co. Roscommon built in 1253 and destroyed in 1258 [7], lime mortars were used to coat the internal and external surfaces of clay-mortared masonry walls. Medieval mortars in Ireland were therefore originally intended to perform a wide range of functions.

3.1 Mixes

Historical Irish lime mortars tend to be binder-rich with an open porous network, often 10-20% by volume [3]. The aggregate:binder ratio can vary significantly from 3:2 to 1:3 among general building and specialist mortars, while internal plastering mortars typically contain very scarce (<2%) aggregate ‘floating’ in a binder-dominated matrix.

3.2 Aggregate

The aggregate fraction of a mortar may consist of a number of elements, including inert and/or reactive sand aggregate, binder-related particles, and additives intended to improve the workability and durability of a mortar.

3.2.1 Inert aggregate

Historic lime mortars in Ireland normally contain a diverse range of inorganic aggregate due to the exploitation of naturally occurring sources of sand. Depending on the location of the building, the aggregate may have been derived from any of wide range of geological deposits and include sands from rivers, beaches, sand pits or crushed rock, which often poses challenges to sourcing matching aggregate for any new repair mortars. Aggregate tends to be unsorted, ranging in size from >15mm to < 0.004mm, and comprising a range of different
rock types. For example, the bedding mortar of the 14th century Hall-house of Moygara Castle, Co. Sligo contains three different varieties of limestone, two sandstones and quartz [8], while the 12th century priory of St. John in Waterford City contains conglomerate, sandstones, rhyolite, volcanic rocks, slate and some schist[9]. Limestones (fossiliferous, oolitic, dolomitic, micritic and sparry etc.) form a significant part of the aggregate fraction in most Irish medieval mortars, and were found in 86% of the mortars examined. In addition, lime lumps >1mm ø are a common feature of historic mortars; recorded in 77% of samples, where they form part of the aggregate fraction. Shell is also commonly found as part of the aggregate fraction.  Shell is also commonly found as part of the aggregate fraction. The frequent presence of calcareous aggregate in Irish medieval mortars confirm the lack of confidence in the appropriateness of acid digestion-based chemical analytical techniques for the study of historic lime mortars cited by other researchers[4, 5, 6].

3.2.2 Reactive aggregate

Reactive aggregate can contribute to the hydraulicity of a lime mortar, and were recorded in 18% of medieval mortars examined. Reaction rims are commonly found on siliceous aggregate such as chert, but have also been recorded on clay-bearing rock fragments such as shale and greywacke. However, reactive aggregate may only be one of a number of sources of hydraulicity within a mortar.

3.2.3 Pozzolana

Pozzolans are fired clay materials rich in reactive silica/alumina which react with Ca(OH)2 and water to form calcium silica and aluminate hydrates with cementing properties [10]. Fragments of pozzolanic fired ceramic fragments, often referred to as ‘brick dust’ are found in bedding, plastering and rendering mortars, and though occurring in only 18% of the mortars examined, their use is widely distributed throughout the country. In addition, fragments of fossil fuel (e.g. ash, charcoal, coal) are a common occurrence in historic lime mortars, found in 59% of the mortars examined. Their presence is usually interpreted as accidental contamination from the kiln fuel used in the production of lime. However, hydraulic reaction rims are frequently observed surrounding remnants of burnt fossil fuel, and can be considered as contributors to the overall hydraulicity of historic Irish lime mortars.

3.2.4 Other additions

A large variety of organic and inorganic additives were used in the past to enhance workability, act as mechanical reinforcement, accelerate hardening and to improve durability. However, relatively few of these have been observed from medieval Irish material. Evidence for hair is confined to plastering and rendering
mortars during the medieval period, where they appear to have been added as structural reinforcement and to minimise fracturing by retraction. Though the principle of adding hair was well-known, occurring in 24% of samples, its execution is often poor - clumps of hair are frequently observed while well-distributed hair appear to be a rarity in surviving mortars. Fragments of unburnt wood and straw are occasionally found in bedding mortars. However the wide range of additives known in the literature, and detected in later post-medieval mortars in Ireland [3], have not yet been identified from any medieval material.

### 3.3 Binder

Medieval lime binders are usually completely carbonated to calcite, and while binder-related particles are often present (e.g. lime lumps and under-burnt relict limestone), these form part of the aggregate fraction though can be useful in determining the source of the lime. In contrast to a widely held belief in the 20th century regarding the ‘purity’ of Irish limestones, many of these rocks contain clay-based and other impurities which impart hydraulic properties – a phenomenon referred to by 19th century authorities on Irish limes [11, 12] and confirmed by analytical research on material from medieval monuments [13].

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**Fig. 2** Comparison of original in mortar (top right) and new replica mortar (bottom right) used for ongoing conservation work at the remains of Stradbally Church, County Waterford.
3.4 Weathering of the microstructure

The weathering of medieval mortar and its interaction with surrounding masonry has been a long-standing area of concern [2, 3, 7, 8, 9, 14]. Moisture is the key agent of decay of mortars in Ireland, while salt attack is relatively rare, and where it occurs is normally associated with later inappropriate repairs rather than naturally occurring salts or pollutants [15]. The most common weathering forms observed within the micro-structure of medieval mortars are micro-fracturing (32%), loss of binder:aggregate cohesion (27%), secondary porosity evidenced by pore-lining calcite (27%), and evidence of dissolution and recrystallisation elsewhere in the matrix (32%). Areas of ‘original’ binder not showing alteration are visible using optical microscopy, and reaffirm the importance of correctly interpreting the textural relationships within a historic mortar.

3.5 Relative and absolute dating of historic mortars

Historic lime mortars can provide absolute and/or relative dating evidence for archaeological sites and historic buildings, and are useful in differentiating between different phases of a site which may have been occupied and altered over a long period of time. While it is not yet possible to ‘date’ medieval or early post-medieval mortars with fine precision, mortars are useful in identifying changes to a wall fabric, as different mortars can be distinguished (through aggregate type(s), mix, character & texture, durability, porosity, and number and type of intentional additions such pozzolana) from one another. This allows mortars to be used as a tool to understand how a masonry wall has been altered or repaired over time, and can thus assist in relative dating a structure or site. In addition, extraction of the charcoal commonly found in historic lime mortars, if uncontaminated and present
in sufficient amounts, is a useful and well-established part of modern 
archaeological practice, though only occasionally used to date buildings in Ireland 
[8, 16]. For example, Moygara Castle, Co. Sligo is a complex fortification 
consisting of an enclosing circuit of towers and defensive walls following the ‘trace Italienne’, a gatehouse and a rectangular structure with no datable architectural features, but appeared to be earlier that the main defensive circuit [17]. Radiocarbon dating of bedding mortars from the site [8] suggested this rectangular structure may be a 13th or 14th century hall-house or hall-keep. This new information significantly altered perceptions and understanding of the site, and is currently guiding discussions of how the castle should be conserved.

4 Discussion

A wide range of Irish medieval lime mortars survive, and there are many unanswered questions regarding the introduction, adoption, preparation, application and curing of these complex materials. The majority of published work on lime mortars tends to arise from materials research science and conservation work. In comparison, there is relatively little published work on the archaeological significance of historic lime mortars, kilns and lime-clamps etc. [18], and great potential for researchers to discover new perspectives with which to re-evaluate and study historic building materials. Examining the data from different perspectives allows historic lime mortars to become much more powerful contributors to the overall conservation and archaeological processes which determine the preservation of a site, rather than as simply source material from which to formulate a new repair solution.

While analysis and interpretation of historic materials is an engrossing study in its own regard, using the data to formulate repair solutions adds additional layers of complexity. Ensuring compatibility and safeguarding the original material are key issues. Many (but not all) medieval Irish lime mortars show several sources for hydraulicity, including combinations of intentional pozzolanic additives, the use of reactive aggregate, reactivity from the residues of burnt fossil fuel used for lime production, and mineral impurities naturally occurring in limestones. However, it may not be appropriate to exactly replicate the properties of the original material as changes to the formulation may have to be incorporated to safeguard original material, especially in proximity to carved stonework. In addition, the majority of medieval buildings in Ireland survive today as ruined structures and a ‘fit-for-purpose’ repair mortar must also meet certain aesthetic needs as a poorly-formulated new repair mortar, though materially compatible with the original mortar, can significantly detract from the character of the structure, which also forms an important part of its historic value.
Fig. 4 The Romanesque portal of Clonfert Cathedral, County Galway (AD 1161-1171) showing the original white pointing mortar [19] and the red-coloured lime-based repointing mortar.

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6 References