

Architectural Ruins: A geoheritage of the anatomy of buildings as illustrated by Casa Ippolito, Malta

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Research article

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Abstract

Ruins are a statement on the building materials used and the construction method employed. Casa Ippolito, now in ruins, is typical of seventeenth-century Maltese aristocratic country residences. This paper scrutinises these ruins as a primary source in reconstructing the building's architecture. The methodology involved on-site geographical surveying, including visual inspection and non-invasive tests, a geological survey of the local lithostratigraphy, and examination of notarial deeds and secondary sources to support findings about building's history as read from its ruins. The results are expressed from three perspectives. The anatomy of Casa Ippolito is revealed in its ruins, which provide a cross-section of its construction history and show two distinct phases in its construction. The tissue of Casa Ippolita – the building elements and materials – addresses the knowledge of raw materials and their properties among the builders who worked on both phases. Finally, the geoh heritage of Casa Ippolito – how it met its inhabitants' needs for shelter, water and food – is examined. The case study aims to show that such ruins are not just geocultural remains of historical built fabric. They are open wounds in the built structure; they underpin the anatomy of the building and support insights into its former dynamics. Ruins are an essay in the geoh heritage of material culture and building physics. Architectural ruins of masonry structures are geoh heritage rendered in stone which facilitate not only the reconstruction of spaces but also places for its users; they are a statement on the well-being of humanity throughout history.

Introduction

Built heritage is a geocultural statement of humanity. It is a lithological, industrial, archaeological and historical testimony to sustainable architectural science. It is composed of geological materials derived from nature such as dimension stones hewed from igneous, metamorphic and sedimentary strata or processed geoproducts such as clay bricks and clay tiles. In the literature on the history of architecture the significance of primary sources, notably archival material, is emphasised. Less importance is generally given to the physical context, the building itself and its immediate environs. These are significant resources of crucial importance and comprise principal sources par excellence. This applies also to architectural ruins. As architecture is an essay in the anatomy of a building, architectural ruins are an open surgery revealing its mechanics.

Malta as a case-study

Malta, the smallest Member State of the European Union, is an island in the Central Mediterranean rich in cultural and natural heritage. It is the seat of the oldest known free-standing architectural buildings predating the pyramids of Egypt by a millennium. Some of these sites, together with other edifices constructed throughout the island's history, are included in the UNESCO World Heritage List; among them are the island's megalithic temples [1] and the Late Renaissance capital city of the Island, Valletta, one of the most concentrated historical areas in the world [2]. The architectural evolution of the island is based on the use of local limestone. For millennia, the lithostratigraphic formation outcrops have been exploited for construction and in the manufacture of household features such as stone shelves and stoves [3].

By the time geology became recognised as an academic discipline, the builders living on the island had gained sufficient knowledge regarding the properties of local limestone resources to distinguish between the various geological strata. However, even the megalithic builders of Neolithic Malta differentiated between the outcropping lithostratigraphic formations. From time immemorial to the present day, a corpus of oral tradition based on empirical observations gradually developed. Builders became able to distinguish between one formation and

another, and between diverse beds in a given lithostratigraphic stratum, on the basis of physical properties such as strength and durability. The latter aspect was considered significant not only in the building of military and public edifices but also in civil structures, most notably residences belonging to the wealthy and the aristocracy.

By focusing on the ruins of seventeenth-century residential architecture in Malta, this paper appraises various elements in building construction exposed in the remains of Casa Ippolito (Fig. 1), the theme of a recent publication [4]. Mario Buhagiar, an academic versed in the history of art and architecture in Malta, considered this building the “most interesting example of seventeenthcentury Maltese rural architecture” [5: 260]. Generally, when a building is erected, its structure veils certain parts, rendering them no longer visible. Consequently, a partly demolished wall offers not only an insight into the causes and process of its collapse but also provides a cross-section of the construction history of the building. Such a wall is effectively an essay in building engineering and construction details, delineating the history of architecture through building materials, both local and imported, and how they were brought together to form the anatomy of the building.

Methodology

The study site

Casa Ippolito was an aristocratic rural residence erected in ashlar masonry [4]. Historically, this mode of construction was utilised in monumental architecture and in higher-quality residential buildings [6]. It was the residence of Ippolito Novantieri, a wealthy aristocrat from Syracuse [5]. The site of the house was probably at the artistic garden known at the time as “il Ġnien ta` Ċiakra”. [1] The original inscription above the main entrance of the building bore the date 1664. This would typically be the year the construction works were completed. A publication on old towers of Malta issued a century ago included Casa Ippolito as a fortified house [7]. Such a claim was reiterated nearly half a century later in the Protective Inventory of the European Cultural Heritage: “A fortified country house with a basement and two floors, consisting of a large courtyard, a mill, stables, a cow sty divided in two parts, four rooms and a kitchen”. [2] From the provenience of the roots of title dated to a century ago, there was no mention that any portion of the land forming part of the same property was sold or transferred to third parties. [3]

The site is located on the flank of Żembaq Valley, west of the Roman ruins at Ta' Kaccatura in the limits of Birżebbuġa (Fig. 2a). By the time it fell into disuse, circa 1919, the inscription on the main doorway was already weathered, the text “almost entirely illegible due to atmospheric erosion”. [4] Since then, the building has been left abandoned and is now reduced to a ruin with most of the roofs, some floors and various walls having collapsed, while others are in a dangerous state (Fig. 2b). By 1967, the main fabric, subsidiary portions, roof and the interior were already in a bad state of preservation [5] and vandalism had added its toll. In 1998, it was scheduled as a Grade 1 building [8]. Architecturally, the building is rectangular in plan; on its south-west boundary there is a yard which had a separate access from the public country road. The path from the access ran through to the opposite side of the yard and led to the surrounding fields that form part of the property. The yard was located at a lower level, following the natural gradient of the site topology, otherwise rainwater and soil dampness would have percolated to the upper levels. The south-east elevation of the building runs alongside the public road (Fig. 3) whilst the opposite side, facing north-west, overlooks agrarian land (Fig. 4). Adjacent to the house, along its north-east elevation and to the right of the entrance, there is a ruin, and adjacent to the south-west facing wall of the yard, at the corner with the road, there was an underground cistern. Now partly collapsed, it had been hewed manually and roofed over by masonry slabs supported by masonry ribs.

The residence was a load-bearing masonry structure erected in a traditional building style dating from mediaeval Malta. It was constructed on four levels: a lower floor, ground-level floor, mezzanine and second storey, the lower floor being accessible from the yard (Fig. 5). The entrance led to a hall and a corridor ending with an open balcony overlooking the agrarian land. The second room on the right upon entering the hall was used as a kitchen/dining room, indicated by a built-in chimney embedded in the wall and running up to the roof of the first level. The walls are thick (Fig. 6a) and on the south-west there is a buttress-like structure (Fig. 6b) which suggests the premises might have been fortified, justifying Mifsud's inclusion of it in his publication [7]. The lower, ground and mezzanine levels were roofed over by masonry slabs (Maltese: *xorok*; singular: *xriek*), now mostly collapsed, supported by semi-circular masonry arches (Fig. 7a) whilst the second storey was roofed in a similar manner but supported instead by timber beams (Fig. 7b). The various levels were linked by a staircase, while the second storey was accessed from the roof. This explains why the roof overlying the ground floor had a parapet wall whilst no such wall is present at the roof level of the second storey, a roof laid with falls in the west-facing direction. This orientation could be inferred from the masonry drain element which directs the rain water from the roof of the second storey to that of the ground-level floor via a clay pipe. It is then drained via masonry water spouts located along the north western elevation (Fig. 4). An uncovered flight of stairs ran from the stairwell to the yard.

Fieldwork and desk studies

The fieldwork undertaken involved surveying supplemented by visual inspection and effective on-site non-invasive tests. To comprehend the building and its physical environment, a detailed evaluation of the ruins was undertaken and the extant site mapped out. Given the existing health and safety hazards, the survey was supplemented by photographs taken from the ground and by drone. An assessment of the geological and pedological features of the immediate environs was undertaken. This study was complemented by the latest geological map [9] and an old but highly accurate soil map [10]. During this study, elementary but effective empirical analyses were undertaken. In the case of the geology, use was made of (i) potable water, useful in identifying local limestone on the basis of surface porosity, (ii) geological hand lenses (10x folding pocket magnifier), for quick, effective examination of the limestone and of the hardness of the respective host fabrics; and (iii) a geological hammer, which was used on the surrounding natural landscape but not on the build fabric to avoid any potential damage. The water and lens, together with the *Munsell Soil Colour Charts*, were utilized to study the soils in the area and the infill of the exposed section of the double-leafed walls. The desk studies undertaken involved consulting:

1. Ordinance Survey sheet 5666 of 1973 and 1988, both plotted at scale 1:2,500;
2. official aerial photographs and orthophotos available at the Mapping Unit of the Planning Authority, Malta, the latter available online at <http://geoserver.pa.org.mt/publicgeoserver>; and
3. the case file on Casa Ippolito available at the reserve collection of the National Museum of Archaeology (NMA), Heritage Malta, Valletta.

No archival sources on the building were available other than a number of notarial deeds, the earliest and latest dated 1726 and 1899 respectively; however secondary sources were drawn upon to aid in the interpretation of the findings, notably [11], [12] and [13].

[1] NMA: *Note on roots of title to ownership of Casa Ippolito*, p. 1 (in Italian).

[2] NMA: *Council of Europe Monument Number*.

[3] NMA: *Note on roots of title to ownership of Casa Ippolito*, p. 1 (in Italian).

[4] NMA: *Note on roots of title to ownership of Casa Ippolito*, p. 1 (in Italian).

[5] NMA: *Council of Europe Monument Number continued*.

[6] NMA: Facade to East.

[7] NMA: Facade to West.

Literature Review

The geoheritage context of Malta

Located 100km south of Sicily and 300km north of Libya, Malta is approximately in the centre of the Mediterranean Sea. It is the main island of the Maltese archipelago; the second largest habitable island is Gozo, the legendary Homeric island of Calypso (Fig. 1a). Malta's semi-arid climate is characteristically Mediterranean: mild, wet and humid winters and warm, hot and dry summers [14, 15, 16]. Annual rainfall varies between 400 and 700mm whilst the predominant wind direction (40%) in winter is north-westerly, with speeds varying between 1 and 20 knots (2 and 37 kph). Due to its geographical position, Malta has throughout its history been, metaphorically speaking, at the crossroads of the various civilisations which reigned in the Mediterranean. It was a trading post between the northern and the southern shores of this basin. Its built heritage reflects these diverse civilisations, with the oldest sites dating from the Neolithic Age. The period when the Island was ruled by the Hospitaller Order of St John (1530-1798) is generally recognised as being the richest phase in terms of art and culture, including architecture.

The limestone of Malta

The geology of Malta is of shallow marine Oligo-Miocene sedimentary origin [17]. The main lithostratigraphical subdivisions are given in Table 1 [9]. There are three limestone formations, namely the Upper Coralline, the Globigerina and the Lower Coralline, all having diverse physical, textural, chemical and mineralogical compositions. The use of the former in seventeenth and eighteenth century Malta had been addressed in [18]. The latter two formations are present at Casa Ippolito, each having a number of members. The Casa is located on the Lower Globigerina Limestone Member (LGL) (Miocene, Aquitanian) which overlies the Il-Mara Member (MM) (Oligocene, Chattian), the upper member of the Lower Coralline Limestone (LCL) (Fig. 1b). Along the flank of Wied Dalam, west of the site, there are signs of industrial archaeology. Old open-pit mining operations were present and the limestone used in nineteenth-century country houses in the vicinity has been attributed to quarries in this area [19].

Beds of LGL and MM occur in the immediate vicinity, south of the site, and their diagnostic properties and uses in the building industry are given in Table 2. LGL is pale cream to yellow in colour and is composed of planktonic foraminiferal packstones rapidly becoming wackestones above the base, whilst MM is composed of tabular beds of pale-cream to pale-grey carbonate mudstones, wackestones and packstones. The LGL is characterized by calcareous plankton [20]. The dominant mineralogy is calcite with minor inclusions of quartz, feldspar, muscovite, kaolinite, illite, smectite and glauconite. The percentage of the non-carbonate content increases with decreasing

quality [21]. LCL, with calcite as the bulk mineral, is more compact and less porous than LGL. The latter is one of the soft building limestones found in the Mediterranean Basin. Collectively known as 'franka' (translated as 'freestone'), LGL outcrops occur over a significant part of the island. Whilst franka is used as a generic term for LGL, inferior quality lithostratigraphical beds known as 'sol' (also written as 'soll') occur within this member. Sol is present regularly at circa 12m of the more absorbent best quality franka [22]. There are two types of sol: 'sol aħmar' (red sol) and 'sol ikħal' (blue sol) [23, 24]. Both are less weather resistant than the best quality franka; the former is appropriate for use as dimension stone in foundations and at building levels over 1.2m above the ground whilst the latter does not withstand exposure to the elements. The first comprehensive research on the petrographical, mineralogical, geochemical and physical characteristics of LGL was undertaken at the University of Leicester [21]. Such material characteristics, together geohistorical retrospective analysis, are useful to identify the provenance of LGL in cultural heritage buildings [25, 26].

Table 1 Lithostratigraphical subdivisions of the geology of Malta [9, 27]

| Formation | Member | Age |
|---------------------------|--------------------|------------------------|
| Upper Coralline Limestone | Gebel Imbark | Messinian |
| | Tal-Pitkal | Messinian |
| | Mtarfa | Messinian |
| | Għajjn Melel | Messinian |
| Greensand | | Messinian |
| Blue Clay | | Tortonian/Serravallian |
| Globigerina Limestone | Upper Globigerina | Langhian |
| | Middle Globigerina | Burdigalian |
| | Lower Globigerina | Aquitanian |
| Lower Coralline Limestone | Il-Mara | Chattian |
| | Xlendi | Chattian |
| | Attard | Chattian |
| | Magħlaq | Chattian |

Table 2 Beds of LGL and LCL present on the Casa Ippolito site and its surrounding environs [3, 28]

| Formation | Bed | Characteristics | Uses |
|-----------------------------|----------------|--|--|
| Lower Globigerina Limestone | 9 ₂ | Dark stone; does not withstand exposure | Foundations and other instances where protection from the atmosphere is present |
| | P | 9 ₁ | Pale yellow limestone, turns into light reddish-brown colour after some time; composed of minute fossils; easily split into thin slabs; hardens when exposed to air; weathers very well; no fossils are present except for remains of saurians etc. and a few shells |
| Lower Coralline Limestone | 1 | Transition (Scutella) bed; soft; often mixed and merging into the calcareous sands of the overlying stratum; fine-grained; not durable; Echini project outwards when stone decays away | Not much used in building |

Results And Discussion

From the fieldwork, desk studies and analysis of geological and soil specimens from the building and the adjacent environs, the results and discussion were grouped under three themes discussed hereunder, namely:

1. the anatomy of a building,
2. the tissue of architecture and

3. geoheritage as wellbeing.

The anatomy of a building

A public deed dated 1893, when the residence was still fit for habitation, states that the house and surrounding lands forming part of the same property had a superficial area of 36 tumoli, 4 mondelli and 2 misure^[1] equivalent to just over 41,000m². The same document includes the following concise description of the property:

“... the space occupied by the house consists of fourteen fields with walls, a cistern, and a house containing a large courtyard with two doors, one facing the road and the other on the ground, a cow sty (Italian: bovine) divided into two, one uncovered staircase leading to a room of part of the said sty, a horse mill, two stables, a flight of uncovered stairs led to the floor at road level, which becomes the ground floor, and a warehouse that has ingress from the said ground.

“The ground floor, which is above the aforementioned amenities, contains an entrance with a door onto the street – two side bedrooms, a kitchen, a staircase leading to a room above the horse mill, and a continuation of the staircase to the terraces, and from these you go to two rooms, and to an open loggia, overlying the ground floor, plus a ‘remissa’ with a door to the street, and a stable with entrance from the fields; ...

The description of the ‘remissa’, essentially a permanent roofed-over space used to garage carts and as a store, fits the present ruin adjacent to the house although not shown on the site plan attached to the said deed. This implies that up to 1893 this structure was still in a good state of repair.

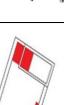
The survey of Casa Ippolito established the main configuration of the building. Two queries emerged: when was the remissa erected, and what was the extent of the collapsed boundary walls of the yard? In the ruin of the remissa one can still read the spring of the arches from the wall of the house, but was this space erected prior to, simultaneously with or after the dwelling? Factual observations indicate that it was constructed post-1664. There was a well-formed window in the wall which overlooked the site of the ruin and that was blocked prior to roofing the remissa. It was not a dummy aperture; it was realised in fine ashlar on the exterior and unfinished on the interior. The current remains of the walls of the yard coincide with the plot on the 1988 Ordinance Survey sheet. The sheet issued in 1973 shows the wall of the yard parallel to the public country road extending further south but there were no traces to show whether or not this ran the whole length of the yard or how it joined the wall running along the road. The site plan attached to the deed of 1893 confirmed that this was the length at the time and that was joined through a straight line.^[2]

A visual inspection of Casa Ippolito identified two construction phases in its erection. The latter phase included the stairwell, the mill and its overlying room, the mezzanine level. This phase is recognisable by:

1. an absence of bond stones both on the exterior (Fig. 8) and on the interior up to the level of the lintel of the door of the room on the left upon entering the main entrance;
2. a change in the quality of the LGL used; and
3. the fact that the internal wall common with the mill and the overlying room is the same thickness as the external walls, implying that it was originally an external wall. The internal walls elsewhere in the house are narrower.

To plot the progressive collapse of the roofs, aerial photographs and, where available, orthophotos were used. Although the latter were derived from the former, orthophotos are more accurate than unprocessed photographs due to distortions arising from the aerial survey. The present state of the ruin was established from drone images (for example, Fig. 2b). The period over which the collapse took place and the percentage area of the total roof are included in Table 3. Given their weak resistance to impact, when the xorok collapsed they caused the subsequent collapse of the underlying floors. The earliest collapse took place between the years 1967 and 1978 and the latest between 2008 and 2012.

Table 3 Gradual collapse of Casa Ippolito (denoted in hatched colour)

| Year | Scale of photos | Demolished roof/s | % of total roof |
|-------|-----------------|---|-----------------|
| 1967 | 1:4,000 |  | 00 |
| 1978 | 1:10,000 |  | 05 |
| 1988 | 1:6,000 |  | 11 |
| 1994 | 1:4,000 |  | 16 |
| 1998* | 1:10,000 |  | 16 |
| 2004* | 1:15,000 |  | 20 |
| 2008* | 1:4,000 |  | 52 |
| 2012# | Not available |  | 56 |
| 2016* | 1:10,000 |  | 56 |

* Orthophotos were consulted; # Only orthophoto exists

The tissue of the architecture

All walls of Casa Ippolito were composed of two leafs of ashlar masonry. The average thickness of the external walls was 1.2 m. Stone off-cuts and other chippings, together with soil, were used as infill. Historically, the cavity wall was introduced in Malta in the nineteenth century in an attempt to solve the problem of external walls being perpetually wet, producing dampness which eventually reached the inner face. However, the local situation is very different. Rainfall is generally seasonal, with long dry periods which allow the porous local stone to become bone dry quickly. Even during the rainy season, the pattern is high intensity precipitation during short periods of stormy weather followed by long dry periods, providing ample time for the stone to dry.

Characteristic of the geologic substratum, two soil types occur in the immediate vicinity of the Casa: Xaghra Series and L-Inglin Complex, overlying the MM and the LGL respectively [29]. Using the *Munsell Soil Colour Charts*, it was found that both types were utilized in the construction of double walls in Casa Ippolito, but the presence of the former – a semi-natural reddish brown clay soil which is distinct from the latter, which is anthropogenic [10] – is more frequent in the exposed sections. Unlike other heritage buildings, the internal walls were not single leaf. The external walls were designed to satisfy a significant structural engineering consideration: to accommodate the thrust of the masonry arches (Fig. 9). The thickness of the internal walls is 0.8m. Given that the second storey was roofed by horizontal timber beams which did not generate side thrust, the width of its external walls was less than those which form the room beneath. The construction of the buttress was not a military design. It was introduced to take the side thrust generated by the masonry ribs of the mill and the overlying room.

Spanning openings of apertures and roofs had been one of the biggest challenges in architecture. The spanning solutions for apertures in Malta’s traditional architecture are listed in Table 4. LGL can withstand compression but not tension; the rule of thumb was that a stone lintel could be loaded without failure in tension up to a 0.9m maximum span; any longer than this and a relieving arch would have had to be introduced (Fig. 10a). When such an arch was absent, “the stones directly above the lintel were often notched out so that they did not rest on the top corners of the lintel” [11: 198] (Fig. 10b). Another solution used at Casa Ippolito was to increase the depth of the lintel by 50% for a 0.9m span (Fig. 10c). Failures in masonry lintels for spans less than 0.9m occurred due to corrosion and the subsequent expansion of the iron grills, which causes typical cracking in stone masonry – lintels, jambs, etc. – when the inserted metal corrodes. For larger openings, masonry arches were used.

Table 4 Spanning solutions for apertures in traditional architecture in Malta

| Span (s) | Spanning solutions |
|------------------------------------|--|
| $s \leq 0.9\text{m}$ | <ul style="list-style-type: none"> • masonry lintel. |
| $0.9\text{m} < s \leq 1.1\text{m}$ | <ul style="list-style-type: none"> • relieving arch • notching of dimension stone exactly above lintel • depth of lintel increased to 1.5 times the depth of a masonry lintel for a 0.9m span |
| $s > 1.1\text{m}$ | <ul style="list-style-type: none"> • masonry arch |

The masonry roofing slabs were LGL dimension stones, 76mm thick on average. These were used to traverse between masonry arches or ribs, to use anatomical terminology, or between timber beams (Fig. 7b). Masonry ribs were stronger, were not vulnerable to biological rot and were more fire-resistant than wood. The fire rating of a 300mm square section is considerably higher than for a steel beam, which is also incombustible. The thermal

expansion of timber is much lower than that of steel, with the result that during a fire, even a major one, a timber beam may start to smoulder but the fire will be self-extinguishing. In the case of a steel beam restrained on the supports, very high stresses would be acting on the metal resulting in longitudinal failure: that is, it will bend. The length of a xriek is the crucial factor in this type of construction. The typical length in Maltese residential properties erected prior to the Second World War was around 700mm. The strength of the slab in tension was minimal and their stability against failure due to excessive moments was marginal, although point loads were the crucial factor. The moment generated on a slab 700mm wide was minimal and could be generated by a point load or a distributed load. But in general, only in the first case would failure occur. Impact loads could be very problematic. Only the overlying layer of about 250mm of fill, locally known as 'torba' and intended to spread the load, made the construction viable. Longer slabs were available but only used where the upper floor was inaccessible. Their factor of safety against failure was extremely low. The length of a xriek varied between 0.7m and 2.0m. A xriek of the maximum size was known as xriek tal-qasba, which translates into a cane-length roofing slab where one cane was equivalent to 2.1m. In cases where xorok tal-qasba were utilised, a crossbeam was often introduced as a secondary support; this was especially useful should a xriek fail. The xorok were bevelled along their length and, once placed on the ribs or beams, formed v-shaped grooves where they met. They were wedged in on all sides. The grooves were filled with a mix of lime, LGL powder and wet fine stone chippings. A layer of torba stone chippings and LGL flagstones were subsequently placed on top to uniformly distribute the load on the otherwise weak-in-tension slabs [11] since no alternative material was locally available. The use of LGL slabs as flooring material was problematic. The stone was very soft, resulting in uneven wearing of the surface; moreover, the stone was very porous, so dirt penetrated the surface and was almost impossible to remove.

Roofs exposed to the elements were constructed in a similar manner but were finished with a hardened paste of a hydraulic mortar mix, known as 'deffun', comprised of lime, crushed earthenware and water. This cover acted as a waterproof layer against the ingress of rainwater [30]. To ensure optimum performance, roof areas were kept small, resulting in the building's various roofs being at different heights. This was intended to keep the amount of fill needed to create falls to a minimum. In addition, it served to keep the size of the overlying deffun layer small to avoid cracking due to thermal stresses, which generally peaked during July and August when, between 12:00 and about 16:00, the intensity of solar radiation may be about $1\text{kW}/\text{m}^2$. An outline of the roof engineering solutions and construction details in traditional Maltese architecture is given in [13: 79-80] and [11: 196-197] respectively. These solutions and details are reproduced in Table 5 and Fig. 11.

LGL was easily available locally and the labour involved in quarrying it was cheap, as was the extraction of Coralline Limestone (CL) and its processing for the production of lime. Both types of limestone were quarried by the insertion of timber wedges in grooves cut in the stone face, which were then wetted so that the timber expands and cracks the bedrock. Timber, pozzolana and iron had to be imported. The island did not have an adequate supply of woodland, nor mineral deposits suitable for the production of pozzolana or iron.

Table 5 Roof-building engineering solutions in traditional architecture in Malta

| Span (s) | Roof building engineering solutions |
|------------------|--|
| 0.7m < s ≤ 2.00m | <ul style="list-style-type: none"> • 2.0m is the maximum span of a xriek without failing in tension |
| 2.0m < s ≤ 2.75m | <p>The effective span of the space at roof level is reduced to 2.0m (and thus can be roofed by a xriek tal-qasab) by:</p> <ul style="list-style-type: none"> • either sloping gently the walls • or adding corbelling (Maltese: kileb) below the roofing slabs |
| s > 2.75m | <ul style="list-style-type: none"> • At ground floor level, masonry arches are used at circa 1.2m intervals with xorok spanning from one arch to the other; • At upper levels: the masonry arches are replaced by timber beams. |

Limestone dimension stones were often quarried at the building site, which had the added advantage of producing space for a lower level and/or cisterns for rainwater collection. [31] claimed that the site of the cistern adjacent to the yard provided the building stones for Casa Ippolito. A closer inspection of a section of the exposed limestone at the cistern and the dimension stones of the house revealed that the limestone was identical. However, this is not incontrovertible proof that it came from this specific location, as no historical or other empirical evidence was found to support this claim. Utilising construction stones which originated close to the environment of deposition ensures a more stable environment for the fabric once it forms a component of the structure.

Lime-based mortar was used to level and fill in the spaces between the two leafs in the double walls. Lime was used for its permeability, flexibility and aesthetic effect [32]. Permeability allows the movement of moisture, especially in porous limestone such as LGL, regulating the humidity of the fabric and limiting the impact of rising damp by allowing the stone to 'breathe' [33]. However, this argument is contested by Joseph Falzon, the former dean of the Faculty of Architecture and Civil Engineering, the forerunner of the Faculty for the Built Environment, of the University of Malta. Falzon argues rising damp was limited by the capillary pressure in the stone pores. Irrespective of the mortar used, it was present to about 1m above ground level. The deformation of the mortar may be more likely to be plastic than elastic. The most important aspect in the control of movement was the typical situation with masonry. The components were small, which meant that deformations were very small and easily accommodated. Stone is not hygroscopic and, besides protecting the built fabric, lime complements its natural texture. Traditionally, buildings exposed to rising damp would have the whole or the first 3.0m of the walls whitewashed [11: 196]. In addition, the interior walls would be lime washed, using a traditional mixture of lime and water resulting in a white texture, after they had been smoothed down. In the past, plastering was generally absent from local building construction.

Traditionally, LGL powder, known as xaħx, wash was applied to the exterior. Although this was typically washed away after a few years, an amount was absorbed by the mortar joint, making the wall more uniform in colour. The present state of the external walls of Casa Ippolito might be due to either never having been xaħx-washed or the xaħx wash having been obliterated by rainfall over several centuries. Other treatments would have attracted attention, especially in a landscape close to the sea. However, by the late seventeenth century, when the Casa was erected, the Ottoman Empire had ceased to be a threat in the central Mediterranean [34: 135], an opinion not shared by [11: 4]. Concrete with reinforcement and cement-based pointing and plastering dating to the later part of the twentieth century were applied to the external walls of the mill and the part of the stairwell which belonged to

the later phase of the building, overlooking the yard. Such interventions enabled damp to rise to higher levels, preventing LGL from 'breathing' thus resulting in further deterioration of the host fabric.

Selective intra-burrow cementation and preferential erosion of the surrounding poorly cemented sediment account for the observed alveolar weathering [35]. The preferential weathering occurs in areas close to burrows. The mineralogy of the burrow infill is both qualitatively and quantitatively different from the host sediment [36]. The unlithified sediment introduced through bio-retexturing modified the permeability and porosity of the original depositional fabric and thus effected the capillary intake of water from the ground, which impinged on its weathering [36, 37]. Severe honeycombing has been observed to occur when moisture penetration is present. The sculpting of freshly quarried LGL has to take place within the first four years, after which point the stone forms a hard crust. If not used within four years, the stone would either be left uninscribed or replaced. If the hard crust is damaged, the fabric deteriorates, with negative effects on the adjacent limestone [11: 199]. The damaged inscription on the main doorway – which a century ago was still decipherable despite the stone being heavily weathered[3] – and the surrounding fabric exhibit such a failure (Fig. 12a).

Honeycombing is present notably at circa 1.3m above ground level. Differential weathering on the elevation along the public road is evidence that inferior lithostratigraphic beds of LGL were used in the later phase of the building (Fig. 8). This is in contrast with the clarity of choice of fine LGL and CL ashlar blocks in the early phase of the building, where the exposure was similar. This change in the choice of stones could also imply the involvement of different masons, one being more versed in the craftsmanship of building material than the other. The dimension stones on the exterior of the elevation dating to the early phase have weathered well, showing the type of weathering that is usually associated with limestone initially naturally treated through quarry sap; once it dries up, the fabric is at its hardest and at maximum weather resilience (Fig. 10a). The state of preservation of this part of the south-east facing elevation further reinforces the view that the LGL used during the later phase was of poorer quality as it has deteriorated faster than the corresponding LGL used in the early phase (Fig. 4b); stone surfaces exposed to the south generally deteriorate much less than those exposed to the north.

Geoheritage as wellbeing

Given the rural character of the area and its close proximity to the sea, security for the residents against unauthorised entry into the dwelling was a priority. Timber apertures, all opening inwards, were used, enhanced with iron grills. The frames of these apertures, circa 70mm in thickness, were fixed directly onto the stone rebate. In contrast to the door leading to the open balcony, there is no evidence that the main entrance door had an independent fan light to allow air and light into the hall. Such a detail was probably integrated into the design of the aperture; otherwise, unlike the other spaces of the house, which were well lit and ventilated, the hall would have been dark and poorly ventilated. This main door was bolted at three levels:

1. At the top: There are two channels, both 50mm wide and circa 370mm long, set at the same height on either side of the door jamb (Fig. 12b). These grooves vary in depth along their length: the one on the right is 0mm at the top and 40mm at its bottom; the one on the left ranges from 0mm at the bottom to 80mm at the top; they appear to mark the outer edges of a circle. This implies they accommodated the clockwise motion of a bar, most likely made of timber, which revolved around a pivot set into the inside of the door. When the bar was in a vertical position the door was unlocked, and when swung clockwise into a horizontal position, its ends would lock into the grooves, securing the door. This mode of bolting was rare in Malta, although a similar mechanism can be found on the old entrance door of the Kitchen Garden (adjoining the official residence of

the President of Malta, a building dating to the early part of the seventeenth century [38: 180-186]. There is no evidence the door was secured from the outside.

2. In the middle: a bar (most likely timber) was manually placed across the door.
3. At the bottom: a horizontal bar (most likely timber) was manually placed from the wall jamb to the middle of the door.

Window openings were secured by iron grills, implying that the windows opened inwards. Only two have survived but there were probably others, as evidenced by the corrosion-related cracks and/or anchoring holes present in the lintels and the jambs.

Rising damp occurs when water is drawn up through the material of the wall by means of capillary action. In a modern building, rising damp indicates either the absence of a damp proofing course (DPC), the bridging of the DPC, or failure of the DPC membrane. Casa Ippolito was erected around two centuries before the *Sanitary Laws and Regulations* [39] stipulated the mandatory use of DPCs to counteract the dire public health effects of humidity and rising damp. Nevertheless, the masons of the time knew full well about the problem of rising damp, and applied the technologies of the day to avoid it, choosing the more compact CL to construct the walls of the lower level underlying the corridor, thus providing natural damp proofing to the ground floor. The use of this fine hewed stone would have been a deliberate decision: it was harder to quarry and work into blocks than LGL. Some were not from MM and must have been imported to the site from other parts of the island. One may argue that the builders were recycling such stone but the decision to use it was not casual; to carry and handle such dense limestone was no mean feat. The seventeenth-century builders introduced such limestone not because they were compelled to by law but because they deemed it to be good building practice. Another method of limiting rising damp was through the introduction of a ventilated basement below the building, but this was not applied in the case of Casa Ippolito. Other cases of rising damp found in parts of the external walls may be due to bridging; given the absorption properties of LGL, the occurrence of water ingress with soluble salts from the ground deteriorated the dimension stones immediately above ground level. A rule of thumb traditionally used by the building trade is that dampness rises to approximately one meter above the source causing it.

A popular method of climatic modification, not utilised in Casa Ippolito, was the construction of an arched and roofed portico on south-facing facades which provided a buffer zone to the elevations exposed to direct sunlight and protection from rain. In addition, direct solar radiation could not penetrate the interior because of the roof of the portico. These considerations affected the physical and psychological well-being of the users. Warm, dry walls and the absence of dampness were important elements of a healthy building.

Geological materials in masonry heritage buildings might be freshly extracted (as with dimension stones), produced (in the case of lime) or recycled. At Casa Ippolito, no construction waste was evident on site. All quarried stone was utilised, either as building elements or as components in a mix. Double leaf ashlar masonry provided thermal mass and thus improved indoor climatic conditions; the thicker the wall, the higher the insulation value. The stone mass absorbed heat slowly, releasing it gradually during the colder season. The effect was that the extremes of temperatures were reduced and there was a time-lag between changes to the external and internal conditions. The more massive a building, the cooler it would be in summer and the warmer in winter. As the mass increases, indoor temperature fluctuations are reduced, and the time lag increases. Eventually, if the building is massive enough, such as in an earth building, then the indoor temperature would stabilise at the average temperature of the locality. The mass of masonry construction is a dynamic thermal insulant due to the properties

of the geological materials used – stone, soil and lime-based mortar. The thickness of internal walls has no bearing on thermal insulation but contributes to thermal mass; they adjust to the ambient temperature.

The primary needs of humans in Maslow's hierarchy are physiological; they include air, drink, food and shelter. Casa Ippolito was a self-sufficient, sustainable household in the sense that it harvested water and produced food from agrarian land forming part of the property, in a manner typical of the times. Historically, country residences were self-sustainable independent units for human survival grounded in zero-waste generation. Water, a primary need for survival, was recycled. Rain water was collected for potable use in cisterns and greyish water was mixed with nutrients to irrigate agrarian land. Less clean water was also used for the irrigation of growing crops and for animal husbandry as a supply of food for the occupants of Casa Ippolito. Ruins can provide insights not only regarding the shelter but also regarding potential sensory nutrition of the occupants.

Until the early twentieth century, agrarian land was higher value than built-up land. Fields were a resource which secured a person's living; in contrast, the value of developed land was negligible. Reducing the thickness of the walls on the second storey, and consequently gaining more floor space, was not thought about in terms of the fiscal value of built-up land, as such land was cheap. What mattered was the cost of building: the less stone used, the cheaper it was to erect the building.

[1] NMA: *Extract from the Deed of Notary Pietro Mifsud, dated 7th December, 1893* (in Italian, translated by the author).

[2] NMA: *Extract from the Deeds of Notary Pietro Mifsud 7th December, 1893.*

[3] NMA: *Note on roots of title to ownership of Casa Ippolito*, p. 1 (in Italian).

Conclusions

The history of building engineering and construction in the Mediterranean is a source for contemporary, contextual, architectural design solutions for the region [40]. Although an example of seventeenth-century architecture, Casa Ippolito is a typical architectural ruin which constitutes an essay in building, engineering and construction and a statement regarding the materials available at the time. Such ruins are the product of available geological building materials, skills and craftsmanship.

Architectural ruins are primary sources for built heritage; they are a laboratory of building physics. The elements of architecture are geoheritage expressed in masonry. Together with on-site evidence and historical documentation, an accurate reconstruction of the building in its original geophysical context can be undertaken. Structures are erected on bedrock and site selection dictated by the accessibility of building materials. Ruins offer insight into the anatomy of a building – its structure, layout and aesthetics – as well as its dynamics, which goes beyond building materials. Local climatic conditions, the orientation of a building on site and the position of apertures affected the influx of daylight, passive solar heating and cooling, and natural ventilation – all physical factors which had a bearing on the users.

Geoheritage enables the reconstruction of not only spaces from ruins but places for users. Architectural ruins are a geoheritage statement on the well-being of humanity through history. Heritage buildings were sustainable,

environment-friendly units wherein the natural properties of materials and cunning human artifice were brought together to optimise light, thermal insulation and ventilation to create a pleasant liveable space. Apertures, when open, allowed daylight/sunlight and ventilation for the comfort of the occupants. Understanding the dynamics and construction techniques of the past can provide useful insights into how to design or upgrade modern buildings to be more sustainable and environmentally sound. While a building lies in ruins, the construction methods and approaches to building dynamics illustrated in its remains provide invaluable lessons for sustainable architecture today. To use Gustav Mahler's words, "tradition is not to preserve the ashes, but to pass on the flame".

Declarations

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Competing interests

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Figures

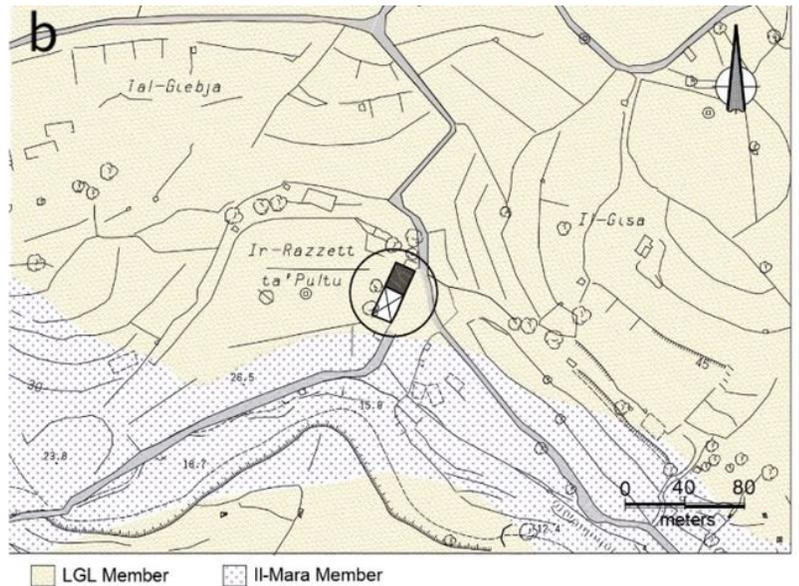


Figure 1

a Location of site marked in red (© Google Earth), b site location map: Casa Ippolito is circled (based on [9])



Figure 2

a Aerial perspective of the site (circled in red) including the surround environs (© Google Earth), b drone view of the site from the north-west (© Joe Fenech)



Figure 3

South-East facing elevation a in 1967 (© Heritage Malta), and b at present. Position of ruin of the 'remissa' is indicated by marker



Figure 4

North-west elevation a in 1967 (© Heritage Malta), and b at present. This elevation is exposed to the direction of the predominant wind; masonry water spouts are indicated by markers

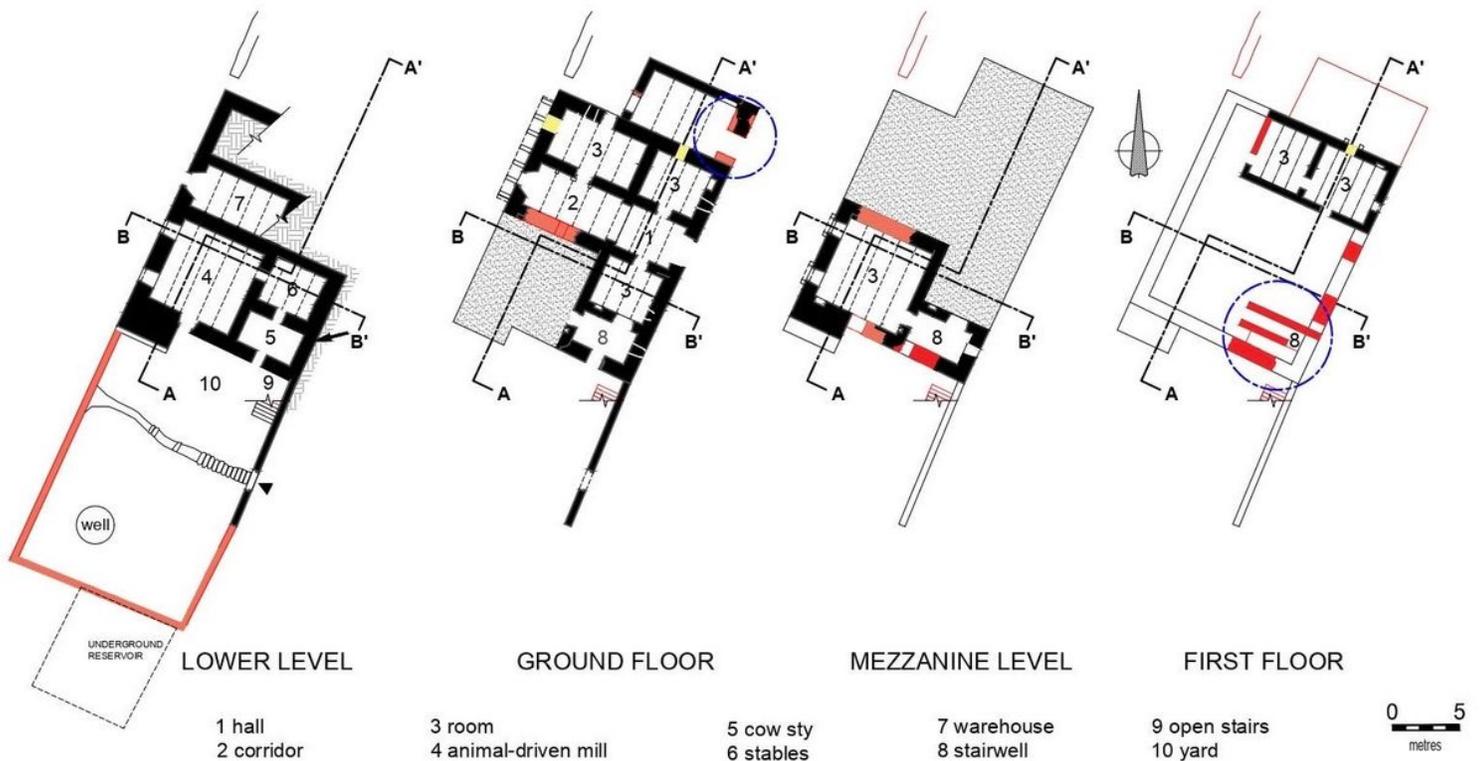


Figure 5

Plans; approximate layout is shown by the circle



Figure 6

a Section through the collapsed internal wall between the corridor and the mill (and the overlying mezzanine), b buttress-like structure along part of the south-west facing elevation



Figure 7

Collapsed roofs of a mill room and overlying space, and b first room on the right on entering the building; note timber beams at the uppermost roof (© Alessandra Bianco)



Figure 8

a Absence of proper mechanical bonding between stones along the exterior denoting a change in phase in the building construction, b detail of Fig.8a

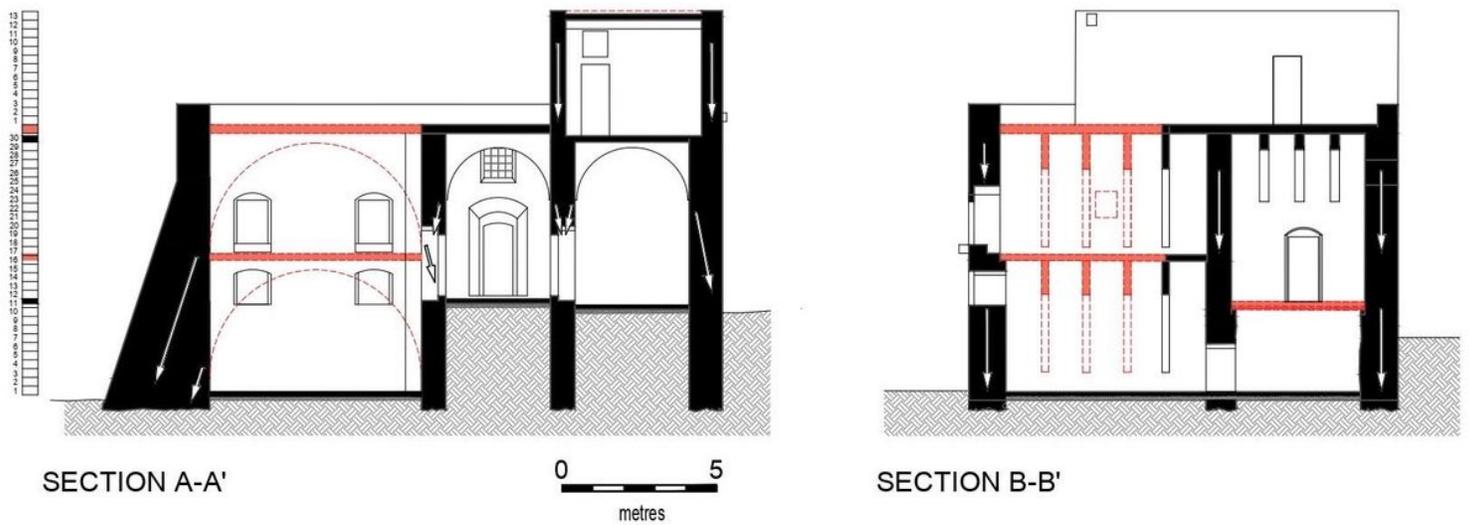


Figure 9

Section: The path of transfer of compressive stresses generated by the roofs are indicated by the direction of the arrows; for position of sections see Fig.5



Figure 10

Masonry lintels: a the lintel loaded without failure in tension up to a span $\leq 0.9\text{m}$; otherwise a relieving arch was introduced, b the stone above the lintel was notched, c depth of lintel increased by 50% the height of a building course

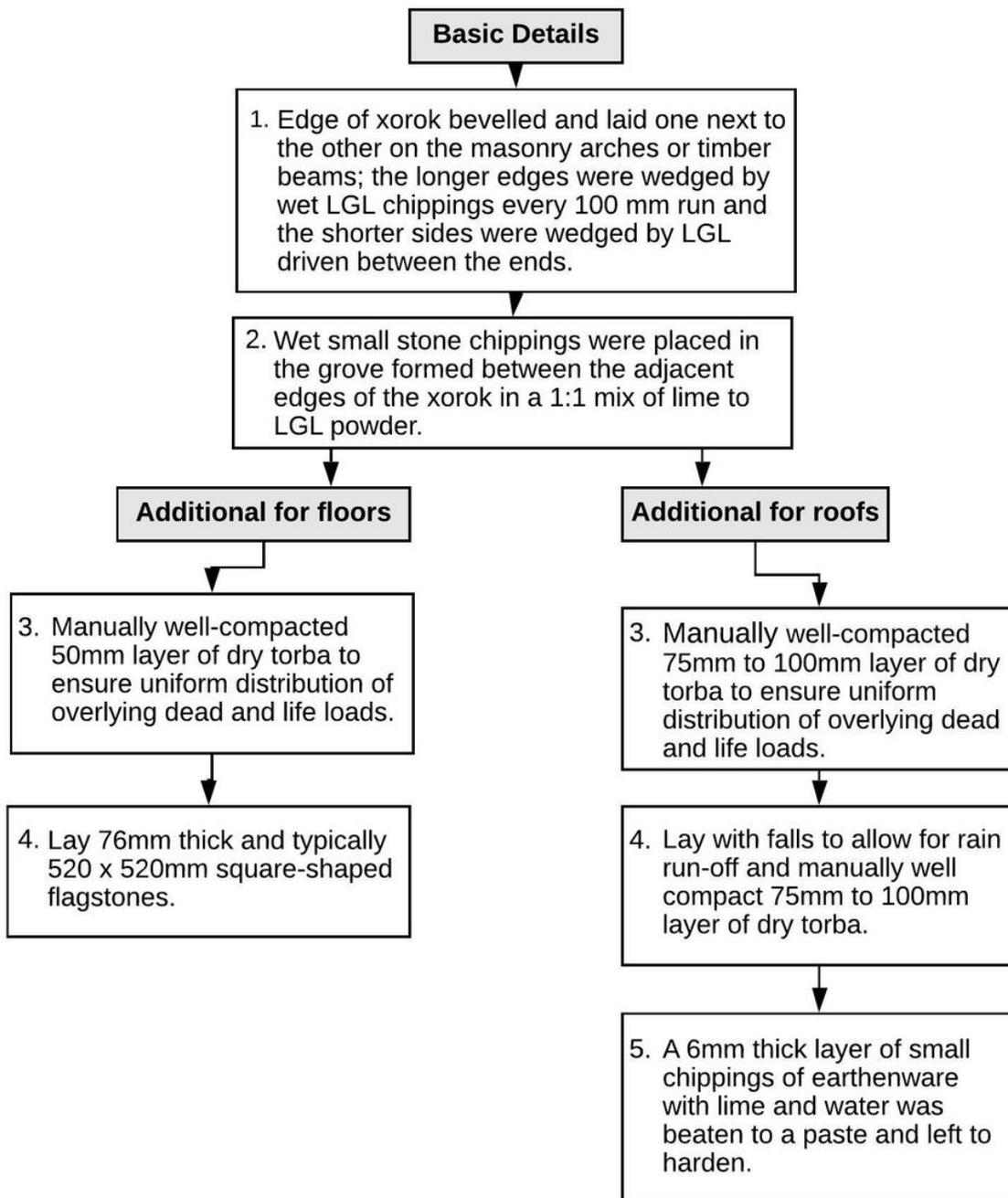


Figure 11

Floor and roof construction details in traditional architecture in Malta



Figure 12

a The damage to the inscription (indicated by marker) and the surrounding fabric on the main doorway, b The main entrance was bolted at three levels: by means of a bar pivoted on the one of the door leafs at the top (circled), a bar in the middle (triangle) and another at the bottom (square)