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LIFE17 NAT/IT/00619 GREENCHANGE
Green infrastructures for increasing biodiversity
in Agro Pontino and Maltese rural areas



TECHNICAL DOCUMENT FOR RUBBLE WALLS RESTORATION IN MALTESE PILOT AREAS

Action A2

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ABSTRACT

The deliverable provides a summary of construction techniques that are normally used in the building of dry stone walls, describing the building procedure, the main components of dry stone walls (foundations, courses, taper, coping) and the basic requirements for their workmanlike realization.

It also details the works and unit prices for rubble walls building/restoration works, per typology of intervention, namely A) final prices for works made by companies awarded with a call for tenders, and B) costs for dayworks by landowners/users to build or restore rubble walls.

Accordingly, the deliverable includes a sample data sheet where the works and unit prices for rubble walls restoration in the sample Maltese area of Wied il-Mizieb are described, and the total price (in euro/linear meter) is calculated in two cases: 1) Restoration works assigned to a specialized company through a call for tenders, for a rubble wall built by using 30% materials owned by the Client, and 70% materials from quarries; 2) Restoration works involving direct labour, carried out by landowners/farmers.

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1. INTRODUCTION

Rubble walls in the rural landscape

Thanks to traditional agriculture and construction practices and techniques, passed down from one generation of workers to another, rural areas often display material evidences of their original landscape, which have also contributed to the preservation of the natural environment.

The building of rubble walls - dry stone walls built in loose unhewn or rough-dressed stones, which stand by gravity and friction without the use of mortar - as either border walls or retaining walls, is one of the most widespread countryside traditional building techniques all around the world. Indeed, all the great cultures of the past used this technique – from Greeks, to Romans, to other Mediterranean populations, up to continental Europe, Latin America (especially Peru) and China.

Dry stone walls have been traditional landscape elements for centuries: they have not only an historical value, but also give an important contribution to biodiversity protection in the rural environment. The interstices in these walls provide microhabitats to various plant communities, insects, reptiles and amphibians – due to the contextual presence of warm, cool, damp, dry, sunny and shady areas - as well as breeding sites for birds. They represent valuable stepping stones and insular biotopes in the agricultural landscape and, due to their linear structure, act as ecological connections. They also have a filtering function (rainwater flowing from a plot to another passes through the walls' interstices capturing organic matter and leaving at the bottom of the wall a useful humus for soil regeneration) and allow excess rainwater to drain from the fields, benefiting agriculture production and minimising soil erosion.

Recently, the UNESCO Convention Intergovernmental Committee for the Safeguarding of Intangible Cultural Heritage has inscribed the art of dry-stone walling in the Representative List of the Intangible Cultural Heritage of Humanity, upon the presentation of a transnational candidacy by Italy, Cyprus, Croatia, France, Greece, Slovenia, Spain and Switzerland. The Committee agreed that the candidacy met the criteria of intangible cultural heritage; in particular, because the technique is a 'living' one, and plays a fundamental role in maintaining the environment and landscape.

Though Malta was not involved in the abovementioned candidacy, rubble walls are found everywhere in the Maltese islands – where they mainly serve as borders between fields

and farms – and the Government issued a dedicated regulation (Legal Notice 160 of 1997 'Rubble walls and rural structures (conservation and management) regulations') to protect them. This regulation declares rubble walls as *'protected, in view of their historical and architectural importance, their exceptional beauty, their affording a habitat for flora and fauna, and their vital importance in the conservation of the soil and of water'*. It also identifies the characteristics of 'sensitively executed repairs' to existing rubble walls, which: *'(a) are carried out exclusively using the same type of drystone rubble walling that composes the existing wall; (b) satisfy all the protective conditions and safeguards contained in these regulations and in the Development Notification Order; and (c) do not increase the height or extent of the existing wall or significantly modify the general site topography or the overall profile or character of the wall'*.

Fig. 1 - Examples of rubble walls: the stones arrangement, dimension and finishing vary greatly, depending on the country and on the specific zone of construction



Rubble walls in Sardinia (IT)

Rubble walls in Sicily (IT)



Rubble walls in Apulia (IT)

Rubble walls for vineyards terracing in Tuscany (IT)



Fig. 2 - Rubble walls in the Ghadira area, Malta (MT)

2. BUILDING DRY STONE WALLS

Summary of construction techniques

Being rubble walls self-sustaining structures built without binders (mortar or cement), the main building challenge consists in ensuring the stones' stability and balance when superposing them.

The first step is to dig a foundation trench of the same length as the wall under construction, where the foundation will be laid using the same stones and the same 'dry' technique (Figure 3).

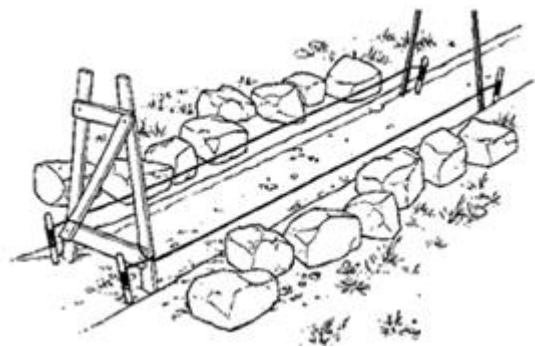


Fig. 3 – Excavation and positioning of the tracks

The first layer of stones shall be laid on compact, solid soil: like in concrete buildings, the overall stability of the final structure strictly depends on the solidity of its foundations (Figure 4).

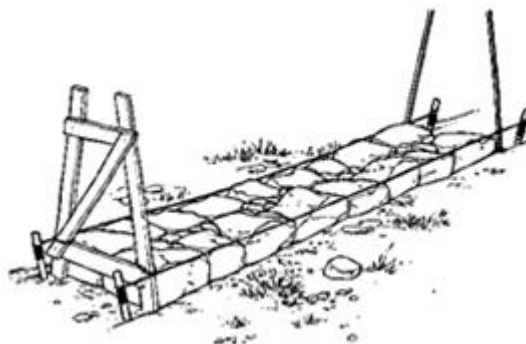


Fig. 4 – Positioning of the first layer using larger-sized stones

Stones have to be regularized and squared off by means of a mallet. The larger ones will be placed at the bottom, with smaller ones on top of them – their dimension gradually decreasing while going up. In some cases, stone flakes can also be used to fill in the interstices (Figure 5).

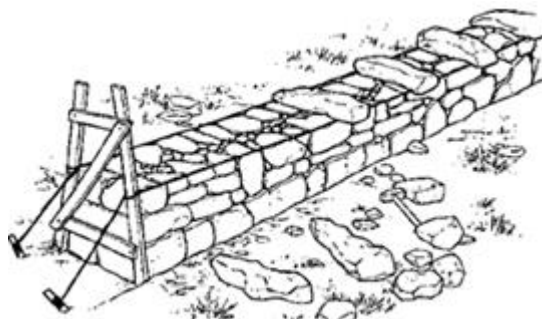


Fig. 5 – Positioning of the upper layers using smaller-sized stones and transverse stones

Dry stone walls can have either a tapered upper part ('truncated cone profile' – see Figure 8), allowing for greater stability and height, or both sides perpendicular to the ground (as in Figure 9), in case of smaller structures (not higher than 80-100 centimetres) (Figure 6).

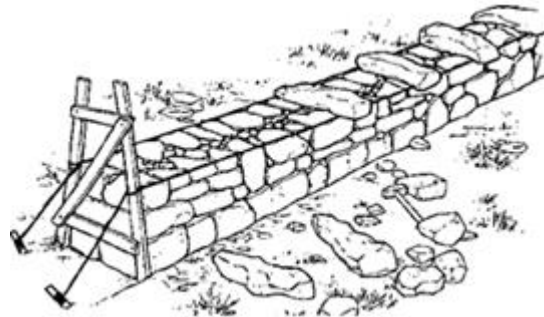


Fig. 6 – Completion of the wall, aligned to tapered, truncated cone-shaped jig

There is no standard rule for building rubble walls: each wall – being integrated in the landscape – has to be adapted to its surroundings, and its features (exposition, structure, composition, etc.) are mostly determined by the stonemason's know-how. Generally speaking, all rubble walls are formed by four main elements: a basis or foundation, a middle level, a tapered upper part, and a coping or top (Figure 7).

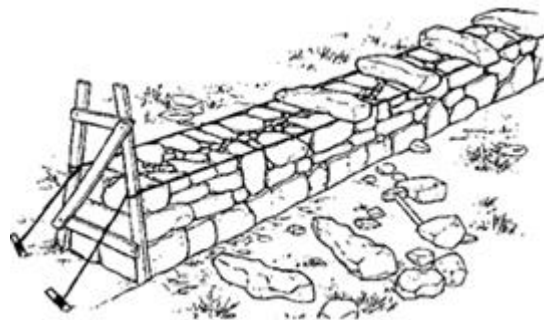


Fig. 7 – Placing of the topping stones (coping)

*Fig. 8 – Rubble wall
with tapered structure*



*Fig. 9 – Rubble wall
with parallel sides*



3. DETAIL OF CONSTRUCTION TECHNIQUES AND INTERVENTION METHODOLOGIES

‘Rubble wall’ or ‘dry stone wall’ means a structure built in loose unhewn or rough-dressed stones which stands by gravity and friction without the use of mortar. The height and length of such walls can vary, the first depending on the slope they are built on, and the latter on the slopes’ characteristics, as well as on the land apportionment.

When the materials for rubble walls construction have been collected, they must be divided in three groups: large-sized stones (mostly employed to build the external wall surface), small-sized stones (mainly used for internal filling), and soil (that, when not reused, has to be placed in its original position, close to the wall). Stones have to be reshaped and regularized by means of a mallet. Moreover, they shall be positioned in such a way as to have the highest possible number of mutual points of contact - in order to increase stability - and to form a most regular and “tidy” structure, thus avoiding the generation of internal forces that can amplify the thrust from the ground. Stability can be increased by chocking stone flakes between larger stones. Whenever possible, the stones’ smoother sides should be placed facing outward, while the more irregular ones should face inward, thus increasing the mutual binding of the wall’s elements.

A) FOUNDATIONS

The substratum that can be found during the preparatory excavations in the site, is the element that mainly contributes to define the characteristics of the foundations. It can be formed either by the rock’s alteration outcrop, or by the eluvio-colluvial layer that covers – even with notably thick layers - the rock itself. In case of a rocky substratum, the preparation of the foundation level includes the removal of the earthy materials that cover the rock and, if necessary, of the altered rock portions that can compromise the anchoring of the wall.

B) COURSES

The making of courses is the safer and more 'natural' way to build a wall, and strongly depends on the capacity of stone masons and on the available types of stones. The procedure regards both the wall surface and its filling, albeit the construction of the latter is usually a little slower, since the filling material has to be maintained slightly below the level of the external surface in order to allow for the insertion of stone flakes under the upper course. The height of each course is determined by the height of the larger stones used for the external surface. The courses of the external surface should be formed by stones of similar thickness, in order to ease the laying of the stones of both the current course and the upper one, and to reduce the need to insert stone flakes between the courses. When erecting the wall, it is crucial to offset as much as possible the vertical joints between stones in superposing layers. This allows for a better distribution of loads in the wall, making it more solid and able to resist to the shocks the structure is naturally prone to.

C) TAPER

Another typical element of rubble walls is the taper, i.e. the batter of the wall surface, obtained by the stonemason by slightly retracting the elements of the external surface in each course, and by arranging these elements on planes that are slightly inclined towards the interior of the wall. This helps increasing the wall's resistance to overturning, while the associated inward inclination of the stones prevents them from slipping outwards when receiving thrusts from the ground.

D) COPING

The top of the wall shall be built with large stones placed on the external surface of the last course. Larger and most suitable stones will be used at the corners. The stones' narrowing should be normally around once and a half their height and, however, not smaller than their height.

Basic requirements for the workmanlike building of rubble walls can be summarized as follows:

1. When partially or totally reconstructing rubble walls, their draining capacity must be ensured.

2. In case of total reconstruction of collapsed rubble walls, their original typology and dimensions must be maintained.
3. The rubble walls interstices must be filled exclusively with small-sized stones.
4. Rubble walls reconstruction activities must be performed by hand, without using mechanical means.
5. Consolidated vegetation on the rubble wall's path and sides must not be removed. Only lower branches of trees can be loped off to allow workers to restore the wall.
6. Small tunnels – not smaller than 30x30 cm - must be realized every 30 meters at ground level, to allow for the passage of small animals. Alternatively, openings/interruptions in the wall can be foreseen every 100 meters, in order to break the continuity of the stone barrier.
7. Materials for rubble walls restoration must not come from heaps where spontaneous shrubs and trees have grown. Instead, materials resulting from collapses can be used, as well as those spread in the site or in its surroundings, emerged from ordinary groundworks.

4. LIST OF WORKS

Description of works and unit prices for rubble walls building/restoration works, per typology of intervention

A) FINAL PRICES FOR WORKS MADE BY COMPANIES AWARDED WITH A CALL FOR TENDERS

A1) Retaining walls

- 1) Stabilizing and restoring existing retaining rubble walls, including the re-chocking of visible interstices by means of the insertion of slivers of compact limestone, the replacement of missing stones, the scaffolding, and all the costs needed to complete the works in a workmanlike manner, at any height and depth.

€/sq. m 38.00

- 2) Masonry in selected stone from quarries for retaining walls, squared and flattened on all sides, laid dry, proportionate to the wall to be built and to the result to be obtained, straight, oblique or curved, both in foundation and in elevation, including all the costs needed to complete the works in a workmanlike manner, at any height and depth.

2.1 Stones with visible surface area less than 0.25 sq. m **€/sq. m 155.00**

2.2 Stones with visible surface area less than 0.16 sq. m **€/sq. m 170.00**

2.3 Stones with visible surface area less than 0.10 sq. m **€/sq. m 200.00**

- 3) Manual clearing of crumbled stones through the following activities:

- Preparation of the construction site: cleaning, eventual trimming of the area, levelling of the ground and removal of collapsed stones;
- Demolition of the unstable parts of the wall subject to restoration, including any possible excavation;
- Preliminary selection of the stones to be put in place, and of the soil for the filling upstream of the masonry.

Considering that a cubic meter of traditional masonry, characterized by small-sized stones, generally corresponds to a structure 2 metres long, 0.85 metres high and 0.6 metres thick, clearing activities can be quantified in 2 hours' work of a common worker, with a hourly fee of 27,00 €/h and a total unit price of

€/mc 54,00

- 4) Formation of dry stone walls in hard limestone with one or two heads, straight, curved or variously shaped, of thickness and height suitable to the configuration of the site, interstices chocked with slivers, co-planar sides, battering, at any height or depth, including: the purchase of stones and of all other necessary materials; the removal and re-installation of collapsed or unsafe stones; fixed and mobile scaffolds and their disassembling; removal of weeds and shrubs; all that is needed to build corners, offsets, copings, rainwater and runoff water drainage channels, as well as adequate foundations not to be realized with landfill. The contractor must: i) use all stone materials laying in the construction site that come from old collapsed rubble walls before purchasing new material; ii) move the soil resulting from the excavation of foundations on the terraces, so as to form co-planar surfaces; iii) load on vehicles and adequately bestow waste materials. All these activities must be carried out manually or by those means that are considered adequate by the works supervisor. The price includes all the costs needed to complete the works in a workmanlike manner, at any height and depth, only excluding the topping crosspieces – to be counted separately.

€/mc 175.00

A2) Double-faced dry stone walls

- 5) Double-faced dry masonry made of rough-hewn limestone or sandstone not perfectly refined at the joints, of adequate size, arranged by hand in a rectangular or trapezoidal section, at any depth or height, for walls of any thickness, including: the preparation of the material in the construction site; its transportation to the place of use; its installation - taking care to obtain smooth visible surfaces, without voids and other irregularities, but with regular and uniform appearance; the levelling of foundations; the tracing of the sides; the closure of the topping and all the costs needed to complete the works in a workmanlike manner.

5.1 Materials owned by the Client **€/mc 95.75**

5.2 Materials from quarries **€/mc 118.00**

- 6) Supply and installation of parallelepiped limestones or sandstones, of adequate size, to form the topping of the dry stone masonry, including all the costs for the entrapment on the end surface of the dry masonry, the perfect alignment of the elements, all the costs needed to complete the works in a workmanlike manner.

€/sq. m 90.20

A3) Additional works

- 7) Demolition of dry stone masonry, including the selection of the stones, their storage in the construction site, the propping up of the terrain and/or of adjacent wall parts, the handling of waste materials within the construction site.

Workforce cost (not subject to variations in the bid) €/mc 51.08

Other elements, general costs & profit (subject to variations in the bid) €/mc 23.08

Total unit price **€/mc 74.16**

- 8) Lifting of the soil resulting from demolitions for the filling of the new rubble wall, performed with mechanical means, including the compacting and the ramps built in compliance with current regulations, with the necessary protections and parapets (measured per compacted cubic meter).

Workforce cost (not subject to variations in the bid) €/mc 36.82

Other elements, general costs & profit (subject to variations in the bid) €/mc 17.46

Total unit price **€/mc 54.28**

B) COSTS FOR DAYWORKS BY LANDOWNERS/USERS TO BUILD OR RESTORE RUBBLE WALLS

Standard workforce costs

- 9) Hourly rates in price lists of building works normally include business profit (10% of unit costs), but this item must be deducted in case of dayworks, as follows:

Common worker: 27.00 €/h – 10% = **24.30 €/h**

Specialized worker: 32,00 €/h – 10% = **28,80 €/h**

Works for rubble walls restoration

Removal of collapsed stones

This preliminary step requires a common worker working for 2 hours, including:

- Preparation of the construction site by cleaning, eventual trimming of the area, levelling of the ground and removal of collapsed stones;
- Demolition of the unstable parts of the wall subject to restoration, including any possible excavation;
- Preliminary selection of the stones to be put in place, and of the soil for the filling upstream the masonry.

Restoration of the rubble wall

This step requires the joint work of a common worker and a specialized worker:

a) Common worker (3 hours' work per cubic meter):

- Supply of the stones to be installed by the specialized worker
- Assistance to the specialized worker in the installation of the stones
- Set-up of the filling soil upstream of the masonry

b) Specialized worker (2 hours and $\frac{3}{4}$ work per cubic meter):

- Reconstruction of the masonry with workmanlike arrangement of stones
- Construction of adequate works for rainwater draining, strictly connected to the stability of the restored structure.

Quantification of volumes

A cubic meter of traditional masonry formed by small-sized stones normally corresponds to a structure with the following dimensions: 2.00 m length x 0.85 m height x 0.60 m thickness.

Calculation of total costs

The following table displays the costs for the restoration of 1 mc of rubble wall:

Activities	Time (hours)	Unit cost (€/hour)	Total cost (€/mc)
Clearing of stones (common worker)	2.00	24.30	48.60
Rubble wall restoration (common worker)	3.00	24.30	72.90
Rubble wall restoration (spacialized worker)	2.75	28.80	79.20
Total cost per cubic meter			200.70

For an average thickness of the rubble wall of 0.60 meters, the following formula is applied: $200,70 \text{ €/mc} / 0,60\text{m} = 120,42 \text{ €/sq. m}$

The total unit cost is therefore

€/sq. m 120.42

5. SAMPLE DATA SHEET

Description of works and unit prices for rubble walls restoration in the area of Wied il-Mizieb (MT)

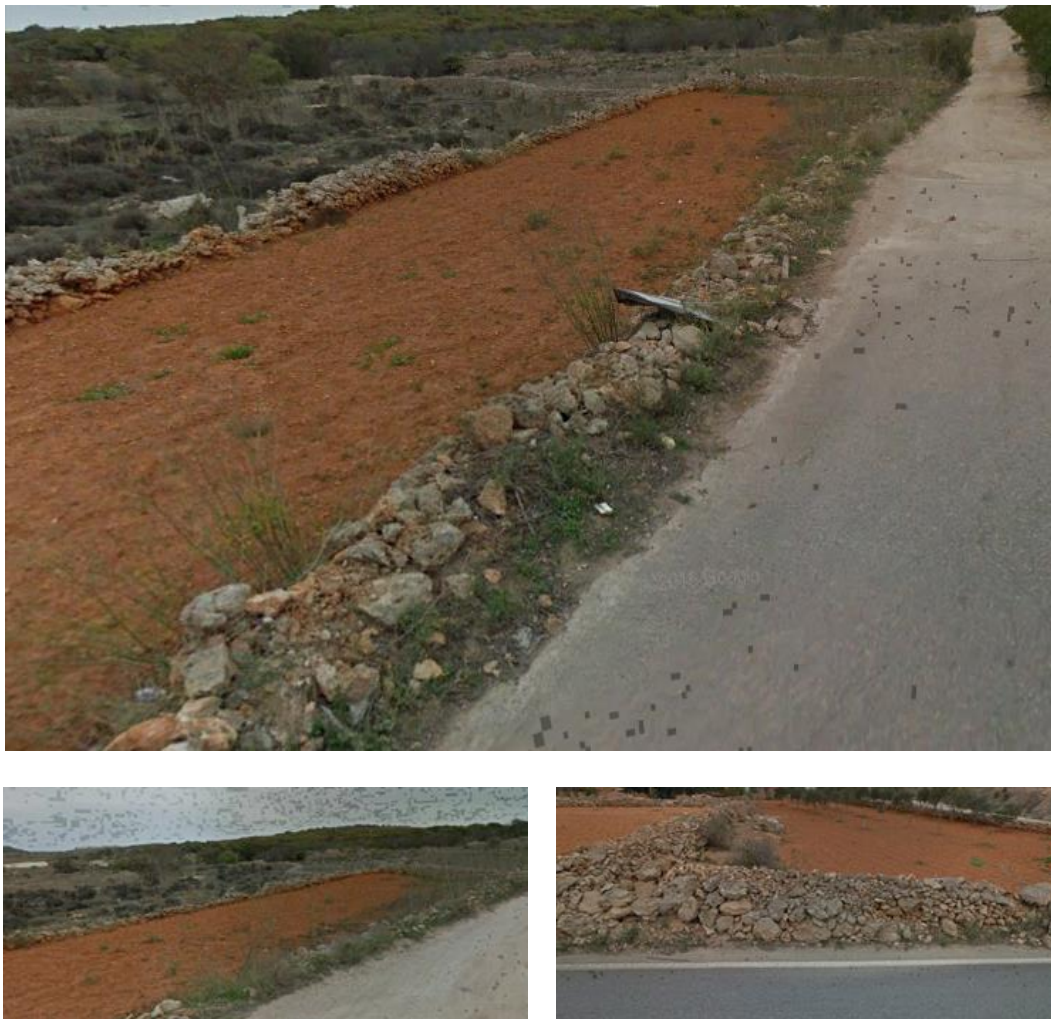


Fig. 10 - Existing rubble walls in the Wied il-Mizieb area

CASE 1) RESTORATION WORKS ASSIGNED TO A SPECIALIZED COMPANY THROUGH A CALL FOR TENDERS

List of works

- 1) Manual clearing of crumbled stones through the following activities:
 - Preparation of the construction site: cleaning, eventual trimming of the area, levelling of the ground and removal of collapsed stones;
 - Demolition of the unstable parts of the wall subject to restoration, including any possible excavation;
 - Preliminary selection of the stones to be put in place, and of the soil for the filling upstream of the masonry.

Considering that a cubic meter of traditional masonry, characterized by small-sized stones, generally corresponds to a structure 2 metres long, 0.85 metres high and 0.6 metres thick, these clearing activities can be quantified in 2 hours' work of a common worker, with a hourly fee of 27,00 €/h and a total unit price of

€/mc 54,00

- 2) Double-faced dry masonry made of rough-hewn limestone or sandstone not perfectly refined at the joints, of adequate size, arranged by hand in a rectangular or trapezoidal section, at any depth or height, for walls of any thickness, including: the preparation of the material in the construction site; its transportation to the place of use; its installation - taking care to obtain smooth visible surfaces, without voids and other irregularities, but with regular and uniform appearance; the levelling of foundations; the tracing of the sides; the closure of the topping and all the costs needed to complete the works in a workmanlike manner.

2.1 Materials owned by the Client **€/mc 95.75**

2.2 Materials from quarries **€/mc 118.00**

Total price per cubic meter (1+2)

a) with materials owned by the Client **€/mc 149.75**

b) with materials from quarries **€/mc 172.00**

Transformation of the price to linear meter

Considering that a rubble wall 60 cm wide and 100 cm long has a volume of 0,60 mc per linear meter, the total price per linear meter is calculated through the formula: price per cubic meter x 0.60, totalling as follows:

- | | | |
|----|---|------------------|
| a) | with materials owned by the Client (149,75 x 0.6) | ml 87,45 |
| b) | with materials from quarries (172,00 x 0.6) | ml 103,20 |

CASE 2) RESTORATION WORKS INVOLVING DIRECT LABOUR, CARRIED OUT BY LANDOWNERS/FARMERS

Standard workforce costs

Hourly rates in price lists of building works normally include business profit (10% of unit costs), but this item must be deducted in case of dayworks, as follows:

- | | |
|---------------------|------------------------------------|
| Common worker: | 27.00 €/h – 10% = 24.30 €/h |
| Specialized worker: | 32,00 €/h – 10% = 28,80 €/h |

List of works

Removal of collapsed stones

This preliminary step requires a common worker working for 2 hours, including:

- Preparation of the construction site by cleaning, eventual trimming of the area, levelling of the ground and removal of collapsed stones;
- Demolition of the unstable parts of the wall subject to restoration, including any possible excavation;
- Preliminary selection of the stones to be put in place, and of the soil for the filling upstream the masonry.

Restoration of the rubble wall

This step requires the joint work of a common worker and a specialized worker:

- a) Common worker (3 hours' work per cubic meter):
 - Supply of the stones to be installed by the specialized worker

- Assistance to the specialized worker in the installation of the stones
 - Set-up of the filling soil upstream of the masonry to complete the restoration
- b) Specialized worker (2 hours and $\frac{3}{4}$ work per cubic meter):
- Reconstruction of the masonry with workmanlike arrangement of stones
 - Construction of adequate works for rainwater draining, strictly connected to the stability of the restored structure.

Quantification of volumes

A cubic meter of traditional masonry formed by small-sized stones normally corresponds to a structure with the following dimensions: 2.00 m length x 0.85 m height x 0.60 m thickness.

Calculation of total costs

The following table displays the costs for the restoration of 1 mc of rubble wall:

Activities	Time (hours)	Unit cost (€/hour)	Total cost (€/mc)
Clearing of stones (common worker)	2.00	24.30	48.60
Rubble wall restoration (common worker)	3.00	24.30	72.90
Rubble wall restoration (specialized worker)	2.75	28.80	79.20
Total cost per cubic meter			200.70

For an average thickness of the rubble wall of 0.60 meters, the following formula is applied: $200,70 \text{ €/mc} / 0,60\text{m} = 120,42 \text{ €/sq. m}$

The total unit cost is therefore **€/sq. m 120.42**

CONCLUSIONS

Case 1) Restoration works assigned to a specialized company through a call for tenders

In this case, considering a rubble wall built by using 30% materials owned by the Client, and 70% materials from quarries, the total price is **€ 98.00 per linear meter**

Case 2) Restoration works involving direct labour, carried out by landowners/farmers

In this case, the total price is **€ 120.42 per linear meter**