DRY STONE BUILDING

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CONTENTS:

1. INTRODUCTION.

1.1. DRY STONE

Dry Stone is a constructive technician that has been employed since prehistoric times, when the people began to look for settlement and to practice the agriculture. The needs of this new way of life has to be resolved with the recources of the surrounding environment. The zones where there was abundance of rocks, began to develop the culture of the dry stone. In the second half of twentieth century, technical of the dry stone ceases to employ mostly, being substituted by the new technical and materials that go appearing.

Which reasons cause the abandonment of the use of the traditional technicians?

_____

_____

_____

The dry stone predominates in rural zones, in comparison with the urban zones, given the abundance of thin matter in this medium and the relative novelty of the cities as we understand them today in day. Although to the Mediterranean arch find the greater quantity of buildings, also exist examples in almost any rocky zone of the world.

In which zone have you seen dry stone buildings?

_____

_____

They exist many environmental and social profits at the time to employing this constructive technician. Enumerates two environmental profits and two of social that you know:

_____

_____

1.2. APPLICATIONS AND DIVERSITY OF BUILDINGS

In the rural field, the dry stone has used to order the territory and solve the derivative functional needs of these activities. Between the big variety of buildings, resolved by means of different shapes and structural typologies, establishes this first classification as the function that develop:

-DELIMITATION AND CIRCULATION: wall, cripple hole, stair, ramp, paviment, milestone...
-AGRICULTURAL: margin, ditch
-HIDRIC: cistern, pit, ditch, drainpipe, laundromat, fridge of ice
-INDUSTRIAL OR ARTISAN: paviment, era, oven of lime, bridge, aqueduct, fridge of ice
-SHELTER: farmyard, integrated shelter, "walling" cave, *caseta*.

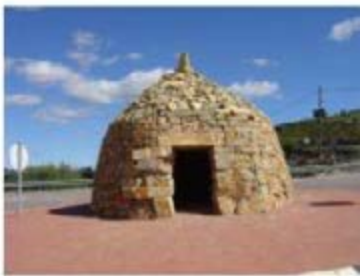
Margins conforming terraces

Stairs

cistern of two desposites

Of the uses related with the water, highligth cisterns and pits, for his abundance and the wit at the time to resolving the needs of drainage and waterproof in at same element.

With regard to the buildings with funcion of shelter it is necessary to highligth a typology of the most known and abundant in mani territories: *casetas*.



This typology, that observes in the lateral photo, in each region has a different name. It writes how calls to your region:_____

Apart from the uses described related with the agriculture and livestock, also finde buildings with residential function, how the Italian village of *Alberobello* (photo of cover), or others more recent how the *bombos manchegos* built by *Pablo Moreno "El Cota"* in *Llanos del Caudillo* to half of the XX.

In *Vistabella*, he had occasion to realice a retaining wall of a street, by dry stone. This wall, reconstructed with concret afew years ago, had fallen for the excess of water that recived. We try to built only with dry stone and, for the moment, works properly.

Recently, in a village of *Burgos*, incorporated the dry stone to realise the structure of pilasters of a social building for the village. The pilasters wanted them do with dry stone, bearing the vegetal cover of the main space.

Retaining wall of a street

Pilasters of the social building

2. THE ROCKS

In this chapter describes the thin matter employed in the buildins of dry stone, of way very general, with the purpose to establish some parameters for his observation and recognition. It is important to know the characteristic of the rocks for employ them properly.

The sedimentary rocks, form by means of the union of sediments accumulated to the bottom of the valleys, lakes or seas. An example of this are the clays, sands or limestone. They form landscapes stratified.


limestone (sedimentary)


Sandstone (sedimentary)


Granite (magmatic)


Blackboard (metamorphic)

The magmatic rocks originate to the cool and solidify a magma, formed by silicates melted, that finds to the interior of the Land. An example of this are the granite and basalt.

The metamorphic rocks originate from the sedimentary rocks, that transform to the be subjected to processes of increase of temperature or of pressure. An example of this are the marble, that comes of the limestone, or blackboard, that comes of the clay.

The two types of rocks that find usually in this zone are the limestone and the sandstone. The first presents sufficing uniformity to his composition, which thing facilitate his work and allow to give him shape of fast and precise way. It is harder than the sandstone. This last, in being less hard, employes to work the stones for decorative and corners. The aspect of grain and rough of the sand, allow to recognise it easly.

In some essays done on several types of rocks, find some comparative data:

PROPERTIES	LIMESTONE	GRANITE	MARBLE	BLACKBOARD
Apparent density	2,18 g/cm3	2,66 g/cm3	2,71 g/cm3	2,77 g/cm3
Resistance to compression	24,18 MPa	134,94 MPa	79,8 MPa	104,69 MPa
Resistance to bend	3,5 MPa	10,77 MPa	28,3 MPa	49,41 MPa

Which conclusions can take out of this data?

3. BASIC CONCEPTS OF THE DRY STONE BUILDING

In the dry stone building, the only material that employs is the stone, without adding mortars to join the individual pieces. This constructions resolve the funcion required by means the correct disposal of each stone, forming a sistem, not a bunch of stones. This condition of sistem, supposes a conjoint work of all the stones, how an only element, purchaising a big structural estability. The combination of the diverse shapes and sizes of each stone, allow that adjust how in a puzzle.




The stone buildings, into a wider prospect, includ also those that employ any type of mortar between the stones, called masonry. His use is more usual in houses than in other type of buildings, because of his insulating and breathable properties. It is important to have in consideration that the function of the mortars is this one, not a resistance funcion. The resistance of the building will come considered the correct disposal of the stones. First is convenient to learn to put the stones propertly with the technical of dry stone. Next, it will be possible to build masonry walls properly, employing these same knowledges.

They exist many essays and studies on the properties of rocks and also on other types of walls, but no find practically data on the resistant properties of dry stone walls. When an architect projects a structure, the calculations are based in these essays normalised, which will guarantee his structural capacities.

Which variables think that influence in the resistance of dry stone building?


One of the variables that more influence in his resistance is the way to place the stones, called bond. Roughly speaking, we have to take into account six parameters at the time to place each stone, having to accomplish all without exception:

1.-The external suface of the constructive element has to fulfil the quality of:
Beauty: ( )
Regularity: ( )
Continuity: ( )

2.-The stones that place to the external surface of the construction call face stones. If needed stablise them puting one wedge, this will have to enter for:
The back part (interior): ( )
The front part (surface): ( )

3.-The joints to the surface of the wall have to be narrowest possible. Which of the two options is more suitable to achieve it?
To fit into the irregular shape of the stones as if it was a puzzle: ( )
To work the stones in order to do them fit into the hole: ( )

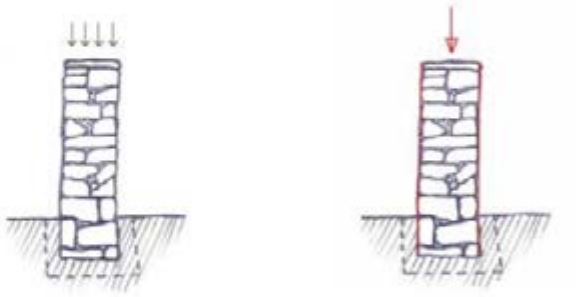
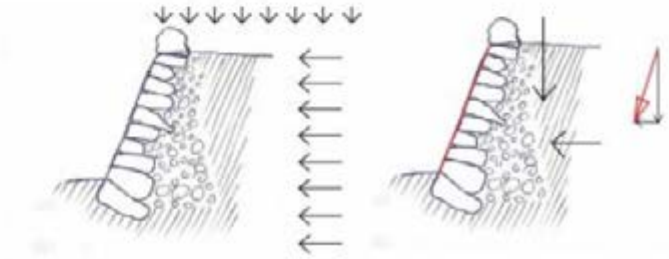
4.-All the stones have to be in contact ones with other, well placed on the spun inferior and...
Putting the stones transversal to the surface: ( )
Putting the stones longitudinal to the surface: ( )

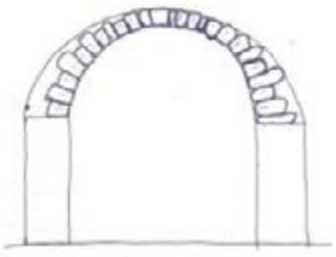
5.-The upper face of the stones will have to remain...
Horizontal: ( )
Bent to the inside (interior): ( )
Bent to the outside (surface): ( )

6.-It is necessary to avoid the continuous joints in the face of the wall, putting a stone on of other two and two stones on of one. Why is it necessary, what do you think about?

4. STRUCTURAL TYPOLOGIES

The structural typologies classify according to the model of transmission of the loads, which have to go through within of the structure until arriving to the ground. This transmission of the loads is defined by a vector with his own numerical value and direction. It is very convenient to know this vector and put the stones in keeping with his structural requirements. According to it, we classify the structures of dry stone in four typological models, two of these are vertical typologies and the other two are horizontal, corresponding to walls and covers, respectively. Later, we will study it in more detail, but for the moment highligth the following basic aspects of each one:

VERTICAL TYPOLOGY	
LOAD BEARING WALL: -Vertical linear element -Subjected to vertical load. -Compression efforts in the wall.	
RETAINING WALL: -Vertical linear element, sightly bent. -Subjected to vertical and horizontal load. -Compression and cutting efforts in the wall.	

HORIZONTAL TYPOLOGY	
FALSE DOME: -Spherical o cylindrical element. -Subjected to vertical load. -Compression efforts and bending stress.	
"VOUSSOIRED" DOME: -Spherical o cylindrical element. -Subjected to vertical load. -Compression efforts.	

The following five elements are the most usual that finde all over: wall, margin, *caseta*, cistern and pit. All the elements built in dry stone form from these structural typologies. We can simplify each element assigning him one or more than one of these typologies.

Which structural typologies can we find in each one of this elements?

Walls to delimit paths:

VERTICAL:
- LOAD BEARING WALL: ( )
- RETAINING WALL: ( )

HORIZONTAL:
- FALSE DOME: ( )
- "VOUSSOIRED" DOME: ( )

Margins:

VERTICAL:
- LOAD BEARING WALL: ( )
- RETAINING WALL: ( )

HORIZONTAL:
- FALSE DOME: ( )
- "VOUSSOIRED" DOME: ( )

Casetas:

VERTICAL:
- LOAD BEARING WALL: ( )
- RETAINING WALL: ( )

HORIZONTAL:
- FALSE DOME: ( )
- "VOUSSOIRED" DOME: ( )

Cisterns:

VERTICAL:
- LOAD BEARING WALL: ( )
- RETAINING WALL: ( )

HORIZONTAL:
- FALSE DOME: ( )
- "VOUSSOIRED" DOME: ( )

Pits:

VERTICAL:
- LOAD BEARING WALL: ( )
- RETAINING WALL: ( )

HORIZONTAL:
- FALSE DOME: ( )
- "VOUSSOIRED" DOME: ( )

4.1. VERTICAL STRUCTURES

The building of a new element begins to realise them foundations. First it is necessary to dig in the land until finding firm soil, withdrawing the loose material. At the time to doing them foundations, it is necessary to take into account the good constructive practices that explain for the rest of dry stone elements. It is convenient that, in this zone of the element, the stones employed are big, because the loads also are it.

Do you think that in foundations is convenient to increase the wide of wall with regard to aerial zone? _____

Which is the minimum depth for the start of foundations? _____

RETAINING WALLS RECONSTRUCTION:

The lateral of a retaining wall fallen, are the reference of the plane we have to reconstruct, therefore we will employe a guide line during the building. It sticks to lateral of wall, doing it climb whenever the spuns are built.

What do you think is more convenient?

To fasten new wall with laterals with continuity: ( )
To built ending laterals independent of existent wall: ( )

BUILDING FOR EVERYTHING TYPE OF WALLS:

First stones we put are face stones, that have to be line up with guide line, following vertical plane, adjusting them like in a puzzle. After puting face stones, we refill holes with stone progressively smaller, until fill out all the holes. For this last act, we use the smaller stone called fillings. This type of stone it is necessary to built like the other stones, adjusting it too.

LOAD BEARING WALLS:

Previously it was explained three variables that influence in the resistance of building. In load bearing walls is important to respect some **geometrical variables** that comes from traditional construction.
Mark if the next sentences are true or false:

- Density of final element have to be high: YES ( ) NO ( )
- Surface have to be vertical: YES ( ) NO ( )
- The throughstones are large stones placed across the width of a wall to tie the sides together, but in this type of wall are not necessary to use it: YES ( ) NO ( )
- Slimness of a wall has to be restricted to a coefficient between height (L) and thickness (e). Always slimness has to be less than 5, being it the result of height divided by thickness. An example: a wall of de 3m (height) and 30cm (thickness), has properly slimness: YES ( ) NO ( )
- Thickness has to be more than 60 cm: YES ( ) NO ( )

The **bond**, or way to place the stones, has to achieve the six parameters previously explained for all types. By now, we have to pay attention at this specifical requirements in this type of walls.
Mark if the next sentences are true or false:

1.-External suface, apart from being continuous and regular, it have to be:
Plain and sloping: YES ( ) NO ( )
Curved: YES ( ) NO ( )
Plain and vertical: YES ( ) NO ( )

2.-Joints at surface has to be narrow: YES ( ) NO ( )

RETAINING WALL:

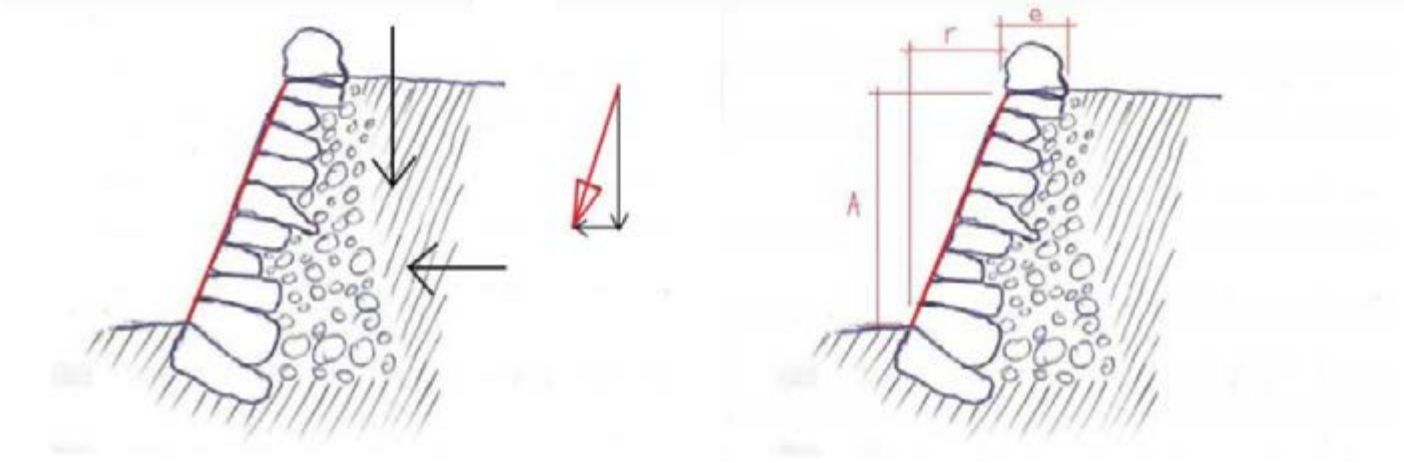
In previously chapters we explain that a retaining wall recive the laod of his own weight and soil weight, which is contained, like in margins, so the resultant force is slope. This sloped force tend to push out wall face stones, so the way to place it has to be diferent of another walls. At this point, we have to remember the need of stones work conjointly, forming a sistem, because that disposal can confront sloped force. If it is not properly built, structure can bend, and his own weight increases this efect and, finally, it fails.

Which aspects do you think have influence in stability of retaining walls?:

Friction rate: ( )
Stone's shape: ( )
Adjust of stones: ( )
Plain surface: ( )
Own weight: ( )

Is important to respect some **geometrical variables** that comes from traditional construction. In this type of wall, mark if the next sentences are true or false:

- Density of final element have to be high: YES ( ) NO ( )
- Surface have to be vertical: YES ( ) NO ( )
- In a margin of 2m height, setback has to be more than: _____
- The throughstones are large stones placed across the width of a wall to tie the sides together, but in this type of wall are not necessary to use it: YES ( ) NO ( )
- Slimness of a wall has to be restricted to a coefficient between height (L) and thickness (e). Always slimness has to be less than 5, being it the result of height divided by thickness. An example: a wall of de 3m (height) and 30cm (thickness), has properly slimness: YES ( ) NO ( )
- Thickness has to be more than 60 cm: YES ( ) NO ( )
- Thickness at base has to be more than aerial zone: SI ( ) NO ( )



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2.-Joints at surface has to be narrow: YES ( ) NO ( )

The third upper zone of the wall is convenient to built with two faces, one of them at interior part, because of his fragility at this elevation. What do you think is the reason of this fragility?

To built coping (upper line of stones) we have to bond the stones in a different way of the rest of the wall. Here we have three types of make it, more usuals than other:

1. Big, irregular and heavy stones placed across the width of wall.
2. Big slabs placed horizontally across the width of wall.
3. Slate rowlocks placed across the width of wall, with an irregular profile of the coping.

Next pictures show this three types of coping. Which is each one? Number it.

Number: ___

Number: ___

Number: ___

4.2. HORIZONTAL STRUCTURES

The most usual horizontal structures built in dry stone technician was curved forms: archs, vaults or domes. There are two basic types: false domes and "voussoired" domes.

The most common type are **false dome**, which are built with slabs placed in overlap circles, forming concentred rings that aproach to the center. Dome is finished with a big slab. Stones are placed in cantilever, concerning inferior spun for close the dome, but this corbel has to be small, less than ¼ or 1/5 of his length. Upper face of the stones has to be bend to external surface of the element, to drain rain water. Is important to know that slabs needs a counterweight so, when dome go up we have to built external wall and fill with small stones. The properties of this type of structures are:

- Only support his own weight, because are less resistant than "voussoired" domes. Why ?
  _____
- His execution is more easy than "voussoired" domes. Why ?
  _____
- Are waterproof. Why?
  _____

"Voussoired" domes are made by voussoir stones, placed over a formwork, until we put the last stone (keystone). After this, we can move away formwork and structure is self-resistance. Load is transmited stone by stone until inferior walls, supporting only compression efforts. For this reason are more resistance than false dome. Their use is more common in vaults and archs of strong structures. The properties are:

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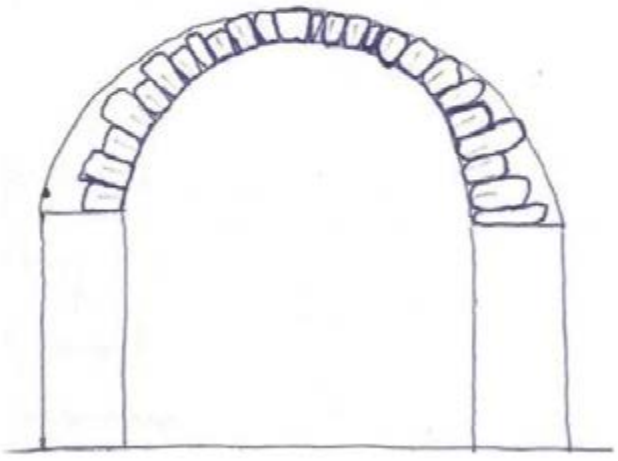
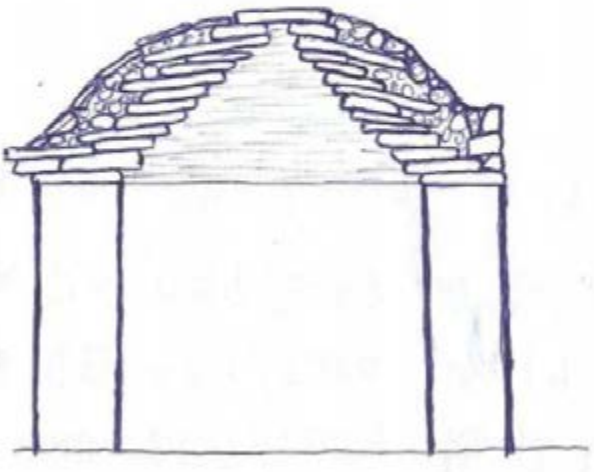
- Covers more resistance than false dome. Can support more loads than his own weight.
- Always needs a formwork to execut it, and is more difficult built this type of cover than false dome.



"Voussoired" dome



False dome

5. TOOLS

Tools used in dry stone building are a few and simple. They are classified by process in which are used. In practice we will make, only a few will be used, above all, dry stone hammer, guide line and basket.
We placed inside the parentheses the spanish name of tools.

EXTRACTION OF STONE:

Dry stone building uses only small stones, normally, because of his less weight, which is loaded by only one person in his movement and positioning in construction. Sometimes, it is necessary extract stones from the ground, pulling up from parent rock. At first, it is better take surounding stones from near terraces, after we can pull up it from near parent rock, and at last, we will go to quarry.

The most common tools in this process are: DRILL (BARRENA), PICK (PICO), WEDGE (CUÑA)

MOVE OF STONE:

After extract stones we need move it to work area, not only the big stones but the small one or the soil too. If distance is short, we can use a BASKET (ESPUERTA), or even round it over the floor. When distance is greatest, we need a WHEELBARROW (CARRETILLA). Ancient was uses the animal force to move it.

PREPARATION OF BASEMENT:

To start building we have to clean ground, removing loose material until found a resistance base. We use, normally, only a HOE (AZADA), RAKE (RASTRILLO) and SHOVEL (PALA)

BUILDING IN DRY STONE:

When we have to work stones to take shapes for decoration, for example, we need more than this few tools, but our work is not for take shapes or figures, but to adjust the irregular forms of stones in the holes of the element. To rough down the stones we use only a DRY STONE HAMMER (MARTILLO DE PICAPEDRERO). If we don't have it we can use a (MACETA). Another tools that are use in this process are TENDERISER (MAZO OR MALLO), CHISEL (CINCEL), PLUMB (PLOMADA) and GUIDE LINE (TENDEL).