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"Dry stone perspectives: challenges after the UNESCO inscription"

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The dry-stone huts typology.

Summary:

Structure from Motion (SfM) photogrammetry is a technique of massive data capture that allows to generate three-dimensional models from two-dimensional image sequences of an object. The 3D model obtained makes it possible to generate exhaustive plans. Generally, this technique has been used thoroughly in built heritage, being especially useful in building with many texture, since it uses to be more complex and this technique allows to register the current state of constructions fast and safe.

The photogrammetry applied to dry-stone constructions allows to obtain accurate surveys that with the dimensions and the texture of the external faces with the colours and distribution of visible stones. The investigation presented is framed in the investigation about the use of photogrammetry in the registration and study of dry-stone constructions in the area of river Ebro in Catalunya.

The study presents the results of using the photogrammetry to register and analyse the dry-stone huts mainly located in the municipality of La Fatarella. The dry-stone huts are a shelter and crop storage covered by a barrel vault. The typical stone typology of the area is the jigsaw stone. This stone allows to be worked easily,

obtaining flat surfaces for the construction. According to oral sources in this area should be about 1000 dry-stone huts. These constructions were very important to develop the work in the fields.

Specifically, in this case, the registration and subsequent analysis has been applied to 30 dry-stone huts from which it has been possible to differentiate construction typologies, analyse measures and proportions, observe the apparatus of the different construction elements that make up the back of the "cabana".

One of the main advantages of using photogrammetry is the ease of use and fast data collection. For example, in one day it is possible to register between 10 and 20 dry-stone huts. Therefore, this technique allows to obtain high precision information easier and faster than what would be possible to achieve with traditional surveying means. Once the 3D models are generated, a methodology based on the assessment of the point clouds is proposed in order to study the construction typology.

Keywords: *dry-stone hunts, photogrammetry, register, analysis*

INTRODUCTION

Dry stone constructions are a clear example of vernacular architecture, described by Rudofsky (Rudofsky, B. (1976)), as an anonymous architecture in which the figure of the architect or master builder is blurred and the heritage of the construction transmitted from generation to generation, of which there is no record in architectural treatises.

The dry stone constructions that represent the implementation of the technique are specific to each area, although the construction principles are the same. In the Iberian Peninsula, most of these constructions date between the end of the 18th century and the beginning of the 20th century. The different typologies are the result of the resolution of the needs that agriculture requires, the weather conditions, the natural resources, the characteristics of the stones of the territory and the constructive heritage. These constructions are part of the built heritage that defines the agrarian landscape and are highlighted as a representation of the identity of a place. Despite the value of dry stone constructions, the last century has

seen how the progressive abandonment of work in the fields has led to their deterioration in an accelerating process.

In this context, the aim of the research proposes the use of digital photography based on Structure From Motion (SFM) to record and analyze dry stone constructions. For this a specific typology has been selected, the “cabanes de volta”, located in the municipality of La Fatarella (Tarragona - Spain).
Fatarella's “cabanes de volta” is the terminology used to describe dry stone constructions covered with a barrel vault. In the southern area of the area of Tarragona, these constructions predominate in a significant way around the municipality of La Fatarella and its limit with the municipality of Ascó and Villalba i els Arcs. The function of these "cabanes de volta" is to protect people and animals from weather conditions, dry or store the harvest or work utensils.
The survey techniques allow new ways of documenting and studying vernacular heritage. The article presents the results obtained from the study of 30 "cabanes de volta" (Figure 1.). The most significant distinction is that according to use, the "cabanes" are open, when the entire front is a single opening, or closed, when the front is covered per a wall and there is a wooden opening to access the interior. The three-dimensional model obtained has allowed us to study the dimensions and the presence or absence of proportions among the cases analysed.

The study carried out on the “cabanes” of the Fatarella vault makes it possible to systematically record a specific typology of dry stone constructions and extract precise data on the formal characteristics. The methodology applied to the “cabanes” could be used for the registration and study of any type of constructions spread throughout a territory.

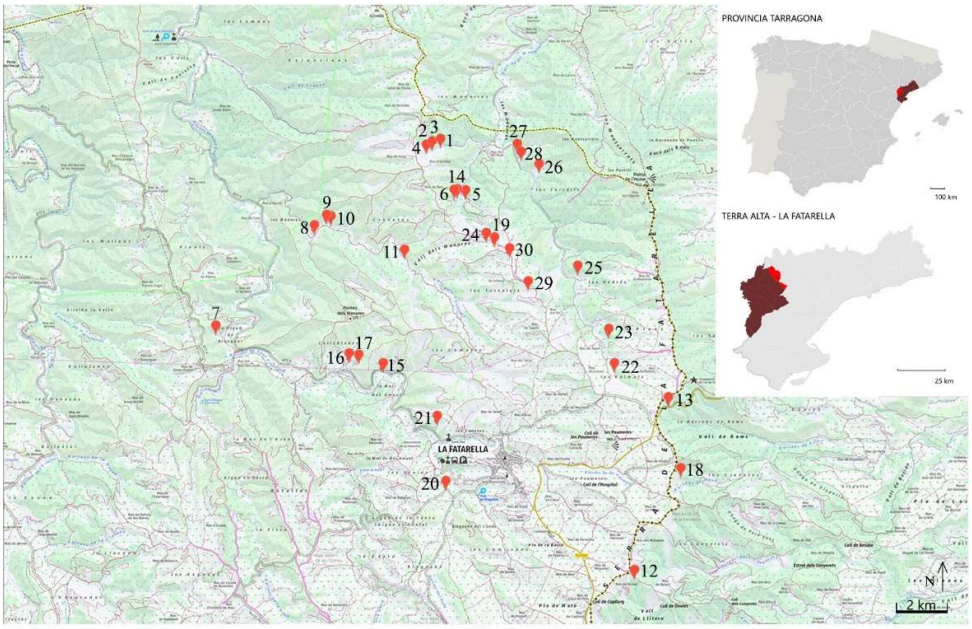

Figure 1. Location of the "cabanes" analysed.

STATE OF THE ART

Dry-stone constructions

Throughout the 20th century, different architects and historians have studied, classified and inventoried dry stone constructions in Spain. Specifically, in Catalonia, the architect Joan Rubió i Bellver (1870 – 1952) carried out a study entitled Construccions de pedra en sec (Rubió, J. (1914)) where construction typologies are classified and the structural behavior of domes is analysed. More recently, the architects Miguel García Lisón and Arturo Zaragozá Catalán published Primitive rural architecture in secà (García, M. & Zaragozá, A. (2000)). In this publication they expand the number of construction typologies named by Joan Rubió and detail the construction processes used. Other authors (Vegas López-Manzanares, F., Mileto, C., & Cristini, V. (2010)) have also reviewed the origins of the construction technique in the Iberian Peninsula, where they also explain some typologies such as huts, barracks, wells and also bridges.

The different types of constructions have been studied from a local scale, Les barraques de Llucmajor, a popular architecture (Calviño, C. & Clar, J. (1999)), regional, La pedra seca. Evolution, architecture and restoration (Congost, R., et al. (2010)). The construction of dry stone in Mallorca (Reynés, A. (2000)) and through national congresses, I National Congress of Rural Architecture in Dry Stone (García

Lanciano, J. (2003)), and international ones, Acts of the 1st Col·loqui Internacional de Construction of dry stone (Tarragó, S. (2006)).

Massive data techniques

The methods used to record and catalog dry stone constructions have hardly evolved since the first studies at the beginning of the 20th century. In the field of built architectural heritage, the digital technique of Photogrammetry, Structure From Motion, used as a massive data capture tool, has had a considerable impact on the recording and representation processes. This technique has been used to record plants and to allow the geometric study of different constructions. In this context, Photogrammetry allows a rapid representation of the 3D colorimetric characteristics of the studied object and is a useful method for dry stone buildings, which often have irregular geometry with complex access. Another very widespread massive data capture technique has been the terrestrial laser scanner, being compatible and complementary to each other.

An example is the various recent investigations in the scientific field that have registered and analysed geometrically and constructively dry stone constructions using the terrestrial laser scanner (Restuccia, F. (2012)). The study by Rossi and Lesserri (Rossi, G., & Massimo, L. (2013)) delves into the difficulty involved in carrying out an accurate survey of dry stone constructions, and tests different graphic approaches based on massive data capture techniques in different construction typologies in Italy. (pa-gghiaras and trulli) and highlight the importance of these graphic bases for the conservation of constructions. In addition, photogrammetry has been used to allow the geometric study of different constructions (Chen, J.-H. et al. (2017); Mineo, C. et al. (2019)). On the other hand, the study led by Barroso (Barroso, C. E. et al. (2018)) proposes the use of the terrestrial laser scanner of dry stone constructions with false domes located in the Geres-Xurés area between Spain and Portugal, where the construction technique is very useful due to the great irregularity of the constructions.

CABANES OF LA FATARELLA

Description

According to oral sources, throughout the municipality of La Fatarella there may be approximately 900 vault “cabanes”. The construction of these depended on the amount of stone and the possibilities offered by the land to be able to build it (Figure 2.). The territory is fragmented into small parcels that belong to one owner. In 80% of the plots or farms there is a "hut" and, in some cases, more than one. For this reason that it follows that there may be between 900 and 1000 "cabanes".

In relation to the anthropological and historical context of the "cabanes" it is observed that the complexity of the construction itself depended on the knowledge and skill of the execution plan of the peasant. According to the constructive knowledge of the builder, help was requested from relatives or neighbours. The construction of the "cabana" was carried out in one batch. The construction time was approximately 3 or 4 weeks depending on the dimensions and the knowledge of the builders.

Figure 2. Front view of an open and close “cabana”.

Constructive technique

For the construction of the “cabanes” the stone obtained from the same farm or from nearby farms was used. This stone was either obtained from carving the field or from calcareous rocky faces. It is a construction typology that to favour its construction and its stability is linked to an unevenness of the land, a wall or margin. The result of the construction can be divided into five parts: the side walls, the barrel vault, the front, the rear enclosure and the interior cavity.

The location of the "cabana" within the farm is not random. For its construction, the southernmost orientation possible is chosen and it is located in a place where there is a drop in the ground. When the location of the "hut" has been determined, the lateral walls perpendicular to the front face are built. Subsequently, the space

between the two side walls is filled with soil that is taken advantage of from the same unevenness and is compacted until it gives the shape of a barrel vault. Third, the vault is completed. Fourth, the abutments on the two sides of the “cabana” are built and compacted, which must assume the thrusts of the vault. Fifth, the soil is removed from the interior of the "hut" and poured on top of it. In some cases on the vault, before pouring the earth in the upper part, it was customary to put a whitewash or mortar to give more solidity and waterproof the interior (Figure 3).

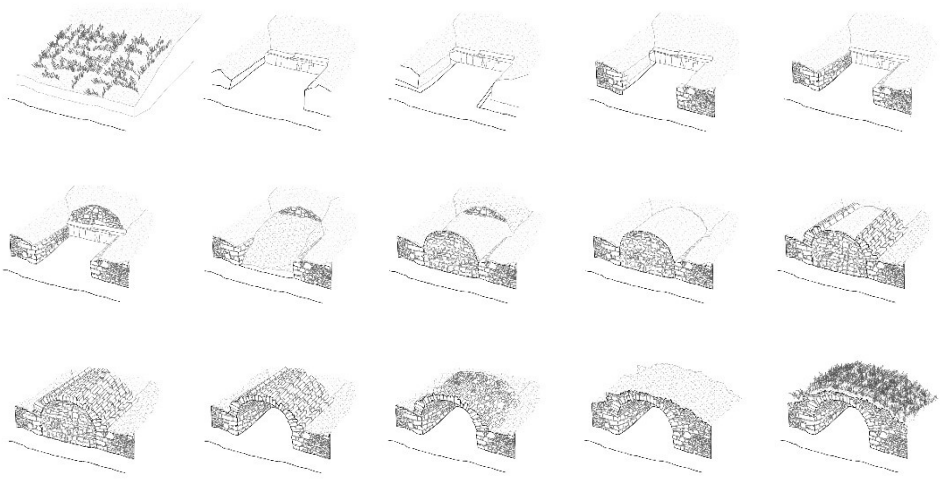

Figure 3. Constructive process

GEOMETRIC ANALYSIS

Methodology

The analysis has been developed two-dimensionally and three-dimensionally. The “cabanes” have been recorded using the Structure From Motion technique, with the aim of putting into practice an easy and agile methodology in a context where the construction situation, in most cases, is difficult to access. The camera used in the survey was a NikonD7000 camera with a Tamron LD XR DI AF 17–50 mm lens. To establish the scale and the vertical axis, a 1.40 meter pole with measurements every 20 centimetres has been used, which also allows taking control points. They have been georeferenced using GPS coordinates. Once the coordinate system was established, the Agisoft Metashape Professional 64-bit program was used with a Windows 10 operating system to obtain the three-dimensional models with millimetre precision.

Measures and proportions

By means of the two-dimensional sections of 30 "cabanes", 6 measurements corresponding to each one of the "cabanes" have been obtained. Figure 5. Of each "cabana", the width (A) and height (B) of the front facing of the vault, depth (C), width (D) and height (E) in the middle of the vault, the thickness of the "hut" in the central part (F). By means of the three-dimensional volume of each one of the "cabanes", the interior volume (G) and the radius of the circumference arc that forms the barrel vault (H) are obtained.

The results obtained have been analysed to check if there are standardised measures or if they are proportional to each other.). Analysing the dimensions of the width of the front facing of the "hut" (A), it is observed that in the 28 "huts" analysed have an average width of 3.02 meters, of which 28.57% of the "huts".”Its width measures between 2.60 and 2.80 meters. The average interior height of the "hut" in the middle of the vault (E) is 2.38 meters, of which 32.14% measure between 2.20 and 2.40 meters. The thickness of the “hut” in the central part (F) has an average of 0.45 meters, of which 46.43% measure between 0.40 and 0.60 meters.

The measurements obtained by means of the three-dimensional model are the radius of the vault and the interior volume. The mean radius is observed to be 1.56 meters. In relation to the volumes, they have been divided into three bands: 53.57% of the “cabanes” the interior volume of air is between 10, 00 and 19.99 m3, 25.00% of the “cabanes” the volume The interior air volume is between 20.00 and 29.99 m3 and for 17.86% of the “cabanes” the interior air volume is 30.00 or more m3.

Table 1. Measurements obtained from the three-dimensional model

"cabana"	Medida A (m)	Medida B (m)	Medida C (m)	Medida D (m)	Medida E (m)	Medida F (m)	Medida G (m^3)	Medida H (m)
1	3,60	2,75	4,67	3,67	2,69	0,56	39,44	1,95
2	2,49	2,00	2,65	2,62	1,99	0,59	11,10	1,35
3	3,29	2,05	3,22	3,22	1,97	0,39	15,24	1,63
4	3,94	2,98	2,96	3,95	2,85	0,69	28,40	1,98
5	3,07	2,40	4,37	2,99	2,32	0,35	21,75	1,60
6	2,90	2,72	3,95	2,98	2,40	0,25	22,99	1,54
7	2,77	1,96	2,83	2,74	2,09	0,32	12,46	1,40
8	3,23	2,10	4,18	3,17	2,14	0,56	23,08	1,67
9	3,35	2,45	3,37	3,39	2,40	0,37	25,55	1,73
10	2,87	2,47	3,13	2,86	2,46	0,34	17,52	1,51
11	3,08	2,18	2,65	3,08	2,17	0,41	16,10	1,60
12	4,42	2,85	6,63	4,33	3,51	0,41	74,75	2,16
13	2,75	2,32	2,56	2,73	2,39	0,44	16,73	1,43
14	2,79	2,77	3,13	2,72	2,59	0,42	17,06	1,45
15	2,84	2,04	3,75	2,97	2,23	0,32	19,53	1,49
16	3,93	3,02	4,30	3,92	3,10	0,55	44,14	2,02
17	4,23	3,18	4,72	4,25	3,01	0,42	57,74	2,16
18	2,27	1,42	2,79	2,17	1,84	0,58	8,52	1,11
19	3,59	2,65	6,47	3,92	3,12	0,38	56,19	1,91
20	2,80	2,21	3,49	2,74	2,26	0,61	15,13	1,42
21	1,99	1,76	3,37	2,11	2,07	0,48	9,96	1,14
22	2,42	2,46	2,78	2,77	2,30	0,60	10,82	1,18
23	2,74	2,47	3,17	2,86	2,48	0,39	18,15	1,45
24	2,74	2,13	3,35	2,76	2,02	0,33	15,83	1,41
25	2,19	1,96	2,98	2,29	2,11	0,36	11,09	1,19
26	2,92	2,70	3,39	2,98	2,64	0,64	22,89	1,50
27	2,48	2,01	3,36	2,51	1,95	0,56	12,21	1,28
28	2,77	2,34	4,19	2,71	2,24	0,50	20,45	1,40
29	3,85	2,87	4,82	3,99	2,57	0,26	37,28	1,98
30	2,71	2,03	3,09	2,83	2,26	0,47	13,78	1,43

If the proportionality between the measurements obtained is analysed, it is observed that dividing the height (E) by the width (D), an average of 0.8 is obtained, where 39.30% of the "cabanes" are formed by this proportion. (Table 1.) If the width (D) is divided by the depth (C), an average of 0.9 is obtained, where 25.00% of the "cabanes" are formed by this proportion.

DISCUSSION

Geometric analysis has been developed using two-dimensional and three-dimensional analysis. Through the observation carried out during the registration process, it has been detected that, although no two constructions are the same, they do repeat common patterns among the "cabanes". For this reason, in the first place,

the measures have been analysed and compared between them and, in the second place, the proportionalities have been analysed.

During the data collection campaigns, "cabanes" have been identified that have collapsed due to the loss of consolidation land adjacent to the "cabana". Regarding the height inside the “cabana” (E), with an average of 2.38 meters, it must allow access for people, animals and proper food storage. If the minimum height is analysed, it is not less than 1.84 meters, which according to the body measurements developed in the book El Modulor by Le Corbusier (Le Corbusier. (1961)), can enter a person. The interior heights (E) are compared with the measurement of a person with the arm raised (Le Corbusier (1961)) corresponding to 2.16 meters, it is observed that 71% of the “cabanes” have a maximum interior height between 2.16 meters and 3.12 meters, the latter measurement being the largest recorded height recorded.

Regardless of the interior dimensions, the thickness of the roof (F), formed by the stones of the barrel vault and the earth, must ensure structural stability and prevent the entry of water into the interior. In addition, the own weight of each of the stones must be adequate to be manipulated for their correct placement.

Although El Modulor by Le Corbusier (Le Corbusier. (1961)) study are later than the dry stone constructions, they serve to relate the standardized measurements of the human body with the built samples.

Analysing the proportionality relationships, it is observed that there is a proportionality between the height (E) and the width (D) of 0.8 in 39.30% of the cases, a relation of 0.7 in 25% of the cases and a ratio of 0.9% in 21.4% of the cases. The proportionality relationships indicate that the "cabanes" are wider than they are tall.

CONCLUSIONS

After analysing the results obtained, it can be affirmed that the "cabanes" follow standards in relation to their measurements and proportions, although they are adapted to the characteristics of their environment: the orientation, the unevenness and the amount of stone in nearby places. The builder, who in most cases is the peasant, knows the construction technique of dry stone and is capable

of designing and building “cabanes” to solve the needs related to work in the field. The set of dry stone constructions is developed from the constructive inheritance acquired from generation to generation, from the observation and visual analysis of similar constructions, from the knowledge of the territory and the environment and from the properties of the stone and the skill in working them. The knowledge of measures, proportions and typologies have not originally been reflected in any graphic medium.

Not having planimetry or previous geometric studies has led us to carry out an architectural analysis from the construction samples that have remained until today. The deterioration and abandonment of this set of constructions, can mean a loss of structural and constructive knowledge that are capable of solving in a very intuitive, practical, anatomical, economic and ecological way different needs related to agriculture.

The anatomical dimensions influence the design and the construction process of the "cabanes". These constructions must meet the needs related to work in the field and their construction is also conditioned by the strength and physical conditions of the human body. This anatomical restriction is seen in the width where of the 28 counted samples, none exceeds twice the standard measurement of a person with an outstretched arm. During the construction process of the barrel vault roof, construction begins in parallel from the start of the vault towards the centre, for this reason, the half-vault span will be the size of a person with an outstretched arm.

The observation of the "cabanes" and their registration has allowed the identification of different typologies and proceed to classify them according to formal characteristics. Depending on the construction of the roof in the study area, they can be classified into barrel vaulted “cabanes” and false vaulted “cabanes” by approaching rows, the latter having very little presence. According to the front closure: open, closed or semi-closed. According to the link with the margin: integrated in the margin, exempt or semi-exempt. According to the relationship with other constructions: unique, twins, paired.

It is evident that the large amount of dry stone heritage located in the rural environment cannot be conserved or protected in its entirety, without associated use or constant maintenance. With an exhaustive analysis, protection protocols can

be established for the most representative constructions or characteristics of a specific typology or of representative groups in general.

The look and enhancement of the vernacular heritage and specifically the dry stone heritage is a way to contribute to sustainability: it favours biodiversity, minimizes degradation and erosion of the land, minimizes the risk of flooding and favours the use of natural resources. rainwater and finally contributes to landscape conservation, management and minimizes the risk of forest fires.

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