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Rediscovered earth heritage becomes motor for local change
The Guérande Peninsula (France)

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Topic: T1.1. Study and cataloging of vernacular architecture

Abstract
In the northwest of France, raw earth has been broadly used, especially in Brittany where cob dwellings have been built since the sixteenth century. Today, cob buildings represent 20 % of the built heritage on this territory (Bardel P., Maillard J-L. 2009). The cob technique is also found in the Vendée marshes, where squat dwellings ("bourrines"), dating back to the fourteenth century, bear witness to the use of local, natural resources (Patte E., Streiff F. 2006; Bonnet S., Alzeort D, Poullain P. 2021). Between these two well-documented earth-building territories lies the Guérande Peninsula where earthen heritage, until recently little-known and neglected, has become the object of study. As a result of several inventories undertaken by earth-building professionals, a part of this heritage has been recorded and mapped (Hilton A. 2016; Miranda Santos M. 2016; Humblot D., Josset F., Marquis B. 2018). Two main research methods have been used: a general audit of the specific areas of the peninsula where earth buildings exist; a targeted audit of certain villages and their buildings.
This latter entailed a comparison of historical maps with current cadastral maps, followed up by on-site verification. Following this inventory work, a sense of the nature and extent of local earthen heritage is beginning to emerge, feeding synergies with renewed local interest in earth construction. The Maison Neuve eco-district in Guérande presents a clear example of this: its objective is to reuse several thousand tonnes of its own site-excavated earth in earth-building projects over the next 5 years. The results of the inventory work helped this local project to understand the nature of the earth available and the different relevant earth-building techniques. The inventory work has also fed into local educational and awareness-raising activities to raise awareness of local earth-built heritage and disseminate best practice in the renovation of earthen walls.

Keywords: *Heritage; earth construction; cob.*

1. Introduction

Of all human activities, construction is one of the biggest consumers of global energy, depleting over 40% of all energy consumed in the economy (Dixit, 2019; Keefe, 2005; Ding, 2004). It also consumes 40% of the world's production of natural aggregates, 25% of the world's virgin forests and 16% of global water annually (Keefe, 2005; Ding, 2004; Dixit et al. 2010). The European Commission estimates that the sector is responsible for 50% of extracted raw materials in Europe (European Commission, 2011). It is also a major generator of waste (Dahlbo et al., 2015).

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About 75% of building sector waste is made up of mineral soil, the raw material used in raw earth construction (Cabello Eras et al., 2013). Raw earth is a local resource with low embodied energy (Dixit, 2019) and possesses reversible characteristics (Hamard et al., 2016). For these reasons, raw earth stands out as a key building material in addressing the climate crisis.

In many higher income countries, the emergence of industrial materials in the early 20th century led to the abandoning of traditional materials and skills, including raw earth and associated expertise (Erica et al., 2008; Villain, 2020). However, over the past few decades, raw earth has attracted renewed interest, due to its low carbon footprint. This can be seen in the growing number of building projects and studies involving raw earth (Morel & Charef, 2009).

Traditionally, raw earth was used extensively in buildings in the northwest of France. In Brittany, cob dwellings have been built since the sixteenth century and represent 20 % of the built heritage on this territory (Bardel & Maillard, 2009). The cob technique is also found in the Vendée marshes, where squat dwellings known as bourrines, dating back to the fourteenth century, bear witness to the use of local, natural resources (Patte & Streiff 2006; Bonnet et al., 2021). Between these two well-documented earth-building territories lies the **Guérande Peninsula** where earthen heritage (see Fig.1), until recently little-known and neglected, has become the object of mapping and inventory studies.

Sustainable in itself, thanks to raw earth's excellent carbon footprint (Dixit, 2019; Hamard et al., 2016), the vernacular culture of cob building is also a beacon of inspiration for sustainability projects in current times. As individuals and institutions look more closely than ever for genuine solutions in the face of our global climate emergency, these rediscovered buildings are already providing inspiration and encouraging renewed interest in earth-building on a local level. As practical, vernacular expertise around earth-building has almost totally disappeared in the region, every cob building still standing is a vital witness and example from which a new generation of earth builders can learn.

Fig. 1. A cob outhouse at Kerhebé, dating from the mid-19th century (Source: Hilton, 2015).

Lessons gleaned from such buildings help assure best practice in earth renovation and construction projects. A number of local earth professionals and students have drawn significant understanding of the behaviour and qualities of local earth from studying the siting, conception and implementation of the existing cob buildings (Hilton 2016; Miranda Santos, 2016; Humblot et al., 2018). Recent inventory work, and the body of professional expertise developing from it, are already feeding into local initiatives. The new Maison Neuve eco-neighbourhood in Guérande is a good example (Ville de Guérande et Loire-Atlantique develop-pement, 2019). This flagship project aims to reuse several thousand tonnes of its own site-excavated earth in building projects in the eco-neighbourhood over the coming years. The findings of the inventory work in the Brière helped Guérande town council and the eco-neighbourhood's main developer, LAD SELA, to understand, firstly, that site-excavated mineral earth is not simply a waste product, but also a quality building material, and, secondly, that its reuse on-site is a neat, circular solution to the waste "problem" it presents. Also, drawing in part on knowledge of vernacular practices learned during the invento-

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ries, local earth-building professionals were able to advise this initiative on relevant building techniques, compatible with the qualities of the local, site-excavated earth (L'Echo de la Presqu'île, 2020).

The inventory work has also led Guérande's School of Art and Heritage and the Brière Natural Regional Park to develop new educational and awareness-raising activities around local earth-built heritage, plus, in the case of the Brière Park, to take several steps towards greater dissemination of best practice in earth building and renovation (Parc naturel régional de Brière, 2020).

The aim of this paper is to present the methods and findings of the recent inventories of cob buildings on the peninsula, undertaken by an interdisciplinary team of academics, researchers, university students, earth masons and a key regional partner, the Brière Natural Regional Park.

2. Investigation zones and methods

2.1. Investigated region

The region investigated in this work is the Guérande Peninsula, located in the west of France, close to Brittany (see Fig. 2). The area is known for its salt marshes, in the south-west of the peninsula, and, to the east, the Brière inland marshes. It is an attractive, touristic region and the peninsula is densely populated.

Covered with wetlands and famous for its many *chaumières* (thatched cottages), this territory also bears witness to significant use of earth in traditional construction. As well as many examples of wattle and daub[1] elements in both vernacular and noble buildings, the peninsula is home to an as yet unknown number of cob buildings.

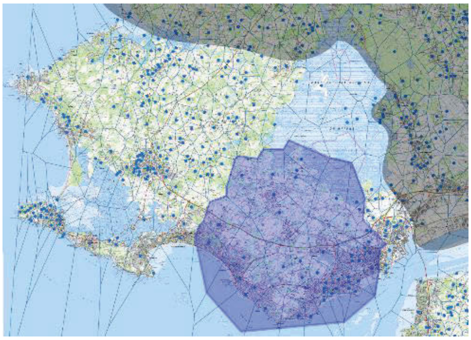

Fig. 2. Guérande Peninsula and Voronoi tessellation of the region based on the official names of locations (blue dots), with blue polygon showing the investigation zone.

2.2. Cob buildings

Various different techniques for building with raw earth exist, and generally developed in accordance with the qualities of the earth available in a given region. Cob, rammed earth, adobe, compressed earth blocks and wattle and daub (Houben & Guillaud, 2006) are all examples of earth-building techniques used in France. The cob technique is widespread in the north-west of France, especially in Brittany, Normandy and Pays-de-la-Loire (Bardel & Maillard, 2009; Patte & Streiff, 2006; Bonnet et al., 2021). As the Guérande Peninsula is located in this latter region, its cob buildings became the obvious focus for our research. The cob technique consists of stacking clods, or patties, made from a wet raw earth mixture with a fairly stiff consistency, in order to build a monolithic, load-bearing or free-standing wall. The earth is excavated on-site or nearby and may well be mixed with natural fibre additives such as straw, reed or hay. A cob wall is built in layers known as "lifts", as each layer of the fresh, wet material has to dry sufficiently before a further lift can be applied, in order to support the mechanical load of the upper layers. Cob building generally also comprises a stone foundation plinth, which protects the walls and floors from water damage from capillary rise and splashback from rain hitting the ground.

1 Wattle & daub: plant structure with a fibered earth infill, which can be used to build walls or ceilings.

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2.3. Investigation method

In order to locate the cob buildings on the Guérande Peninsula, we combined several sources of information and open source digital tools. The first step was to demarcate sub-zones for investigation. To do so, we imported the digital map of the region from Géoportail, a government website[2], into the geographic information system application QGIS. Each place (hamlet, village, district, etc) is already assigned a location and a name on the Geoportail map. These locations were used as nodes to perform a Delaunay triangulation, from which we obtained Voronoi cells (Fig. 3).

Delaunay triangulation is an optimised method to join the nearest nodes and create a triangular mesh. The Voronoi tessellation method allows us to create a tiled partition of the surface in which each vertex of a given polygonal Voronoi cell is equidistant to the vertices of the Delaunay triangle it belongs to. Each Voronoi cell on the map is an investigation sub-zone.

As this method is based on location names, and as the number of dots on location maps is greater in denser zones, it allows us to delimit the investigation zones according to building density. This is the reason why the investigation zones (Voronoi cells) are larger in the countryside than in the towns.

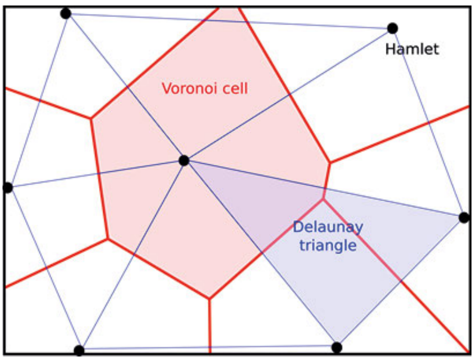

Fig.3. Delaunay triangulation and Voronoi diagram to define the investigation zones

2 www.geoportail.gouv.fr.

It should be noted that the area of study, to the north of the port town of St Nazaire, suffered large-scale destruction due to bombing during the Second World War. Surviving old buildings are scattered amongst the many post-war, modern buildings. In order to assess the importance of the cob heritage, which we assume to have been built before WWII, we therefore had to look at general maps dating from 1850 (IGN Institut). The next step was to import these maps from Geoportail into QGIS, and to superimpose the 1850 map and the modern map. This allowed us to identify matching constructions which were then circled and numbered (see Fig. 4). Then, using Google Maps and Google StreetView, we carried out virtual visits to the different locations identified, which allowed us to ascertain whether the constructions were old or recent. These visits enabled us, firstly, to eliminate certain locations where old buildings had been razed, and secondly, to note if matching buildings were old or recent. Once identified, matching old buildings were inspected closely via StreetView to try to detect the construction materials used (stone, cob or both). This preliminary screening stage was followed up by field visits to confirm whether the buildings identified as being potentially built of cob were indeed so.

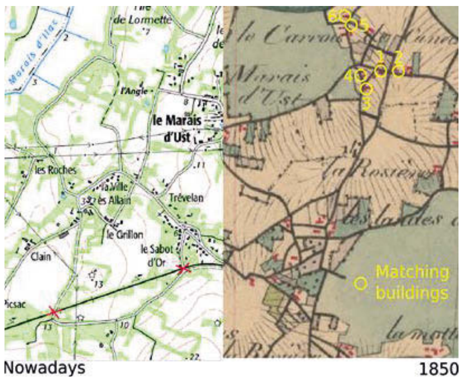

Fig. 4. Comparison of the maps and matching buildings – Focus on the "Carrois de Cuneix" hamlet.

Once a cob building was identified, we took photographs and noted certain data : type of building (dwelling, outbuilding, etc.) ; state of

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preservation (based on pre-established parameters) ; building dimensions ; height of the stone foundation plinth ; height of the cob lifts. These data were finally keyed into QGIS to complete the database.

Fig. 5. Examples of Google StreetView investigation to find cob buildings - the numbers correspond with the circled buildings on Fig. 4.

The results presented in this paper concern buildings located on the eastern part of the peninsula around the towns of Saint-Nazaire, Pornichet, Saint-André-des-Eaux, l'Immaculée and La Baule (blue zone on Fig. 2). Other buildings outside the investigation sub-zones were also found by talking with inhabitants during field visits, by Hilton's work [4], and during heritage events, local festivals and other awareness-raising activities.

2.4. Statistical analysis

For the numerical parameters measured on accessible buildings, we determined the normalised distribution fX(x), i.e. the percentage of buildings for which the value of a parameter X (wall height, lift height) is lower than a given value x.

$$f_X(x) = \mathbb{P}(X \leq x) \qquad \text{Eq. 1}$$

To do so, we discretized the interval of variation of the parameter and we counted the number of buildings fulfilling the condition described by Eq. 1. Then we divided this number by the total number of buildings. We then derived the 25%, 50% and 75% percentiles that give a statistical description of the value distribution inside their range of variation. We also calculated the average and standard deviation for each parameter.

3. Results and discussion

3.1. The cob buildings, in numbers

Using the method described, we identified, in the investigation area, 802 buildings which we suspected to be old and potentially built from cob. For the moment, we have visited only 50% of the buildings identified.

Among these, we have identified 46 cob buildings, representing 6% of the total number of buildings. However, many more of the buildings visited have been classified as "suspected cob" because it was not possible during the field visit to determine whether they were definitely made of earth or not. This is because certain buildings were located on inaccessible private properties, the owners of which were not present at the time of the visit or did not allow us to enter their property. Nevertheless, remote observation of these buildings led us to believe that they were potentially made of cob.

Category	Number	Percentage
Total	802	100%
Still to visit	400	50%
Cob buildings	46	6%
Suspects	149	19%
Other buildings	207	26%

Table 3.1. The cob buildings in the investigation area

The 26% remaining buildings are either old buildings made of stone or wood, or new modern buildings. So, up to half of the buildings visited are potentially made of cob, a finding which validates our searching method.

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3.2. Cob building location

In order to better understand where the cob buildings are located, we used the automatic algorithm HeatMap implemented in QGIS. It creates a colour map corresponding to the number of entities in the investigation zone. The result is presented in Fig. 6. We can see that most of the buildings are located to the north-east of the zone (22 in Marais des Aurielles and Le Petit Marsac), on the edge of the Brière marshes.

A secondary group is located to the south-west (16 in Saint-Sébastien, Chaussepot and Le Guézy). Both these zones are poorly populated rural areas, which could go towards explaining the significant number of cob buildings remaining there. Pressure on real estate is lower in these areas compared to the towns of Saint-Nazaire, La Baule and Pornichet, where the increasing need for accomodation forces the municipalities to incentivise the construction of residential buildings, leading to the destruction of old ones. Even so, certain buildings are located in the old quarters of sea-side resort towns such as Pornichet.

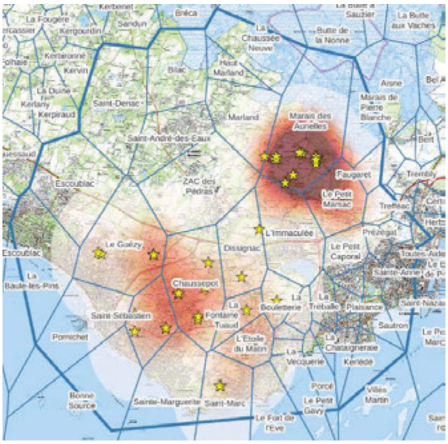

Fig. 6. Location of cob buildings in the investigation zone - the red zone represents the density of the cob buildings discovered.

3.3. State of preservation

We classified the 46 cob buildings identified according to one of four states of preservation (Fig. 7):

- *Destroyed*: present on old photographs collected from local inhabitants but not present on site
- *Ruin*: not usable, no roof, only the walls or part of the walls
- *Good*: usable as an outhouse, existing roof
- *Habitable*: the building is still used as a permanent dwelling

Fig. 7. Cob buildings in different states of preservation

The following table presents the results of the classification. We can observe that most of the cob buildings in the investigation region are still in a good state of preservation (63%) and two of them are occupied.

Category	Number	Percentage
Total	46	100%
Destroyed	3	7%
Ruin	14	30%
Good	27	59%
Habitable	2	4%

Table 3.3 State of preservation – Cob buildings

3.4. Statistical analysis

For each of the accessible buildings, we measured different characteristic lengths. Statistical analysis relative to the cob buildings' wall heights (for 28 buildings) and lift heights (for 20 buildings) is presented below. The distribution functions are given in Fig. 8 and the statistical parameters in the following table:

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Parameter	Wall height [cm]	Lift height [cm]
Average	262	61
Standard deviation	160	10
Q1	140	50
Q2	200	56
Q3	350	62

Table 3.4. Statistical parameters of lengths

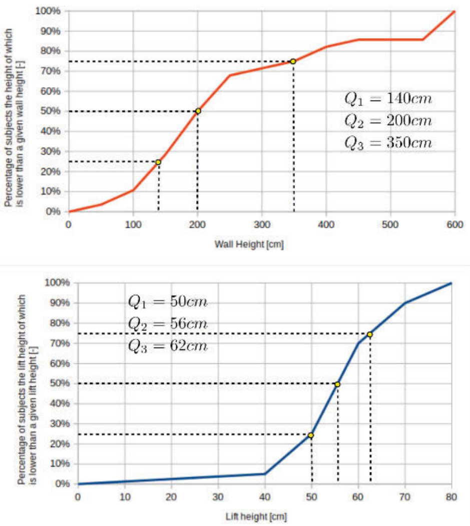

Fig. 8 : Statistical analysis of wall height and lift height for the different cob buildings

We can see that some of the buildings have walls as high as 600 cm. These are the habitable houses that are in a good state of preservation. However, some of the high values belong to ruins. The lower heights were all measured on ruins. 50% of the buildings have a wall height of between 140 and 350cm.

The lift height varies from 40 to 80 cm, with an average value of 61cm, which is in accordance with values available in literature (Hamard et al., 2016). 50% of the buildings present a lift height of between 50 and 62 cm. The lift height can generally be correlated to the properties of the fresh earth during construction and possibly also to wall thickness. This latter parameter is not presented in this study as only a few buildings were accessible for such measurement. It would nevertheless be interesting to correlate these different pieces of information to develop knowledge around the local technical specificities of cob construction.

4. Conclusions

In this article, we presented an original investigation technique based on a comparison of historical maps from 1845-1855 (IGN Institut) with current land registers to identify existing cob buildings and, thanks to digital tools and field investigation, to check whether the identified buildings are truly made of cob. The field investigation allowed us to confirm the validity of the technique and to gather complementary pieces of information relative to the buildings (type, state of preservation, wall height, lift height, etc). The analysis of the results using the software QGIS allowed us to show that the cob buildings are located in poorly populated rural areas where the real estate pressure is low compared to the neighbouring towns. The buildings identified are mainly in a good state of preservation and used as outhouses and in some cases dwellings. To date, we have also identified cob buildings in other parts of the peninsula, via different approaches. In future research we intend to apply the technique described in this article to analyse the other parts of the peninsula and verify whether the areas around the medieval city of Guérande comprise cob buildings.

The cob heritage on the Guerande Peninsula is still present but disappearing, and could vanish rapidly if people are not aware of the interest of this vernacular architecture. As a result of this research, the cartography of a centuries-old architectural culture is beginning to emerge. In recent decades, local institutions have carried out important work to protect the thatched cottages on the peninsula, as these vernacular buildings bear witness to local skills and ways of life. A similar approach could help to protect local cob heritage, and in doing so also highlight its many lessons for sustainable building practices today.

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