Cob seismic rehabilitation

G. Scudo[1] & A. Drei[2]
[1]*Department BEST, Politecnico di Milano, Milano, Italy*
[2]*Department Ingegneria strutturale, Politecnico di Milano, Milano, Italy*

Abstract

Among the different earth architectural techniques largely diffused in the Italian regions – rammed earth, various types of "adobe", light earth and cob – the last one is the less known due to its prevalent use in traditional rural buildings and in a few small settlements in Central Italy, partially abandoned in the last 50/60years. Only recently the administrations of the Regions where the majority of this cultural heritage is located developed an interest in the cob technique and earth architecture, mainly in the Marche and Abruzzo regions.

Conservation and ecological interest are the main aim of the local groups which have to face the very "heavy" task to cope with national technical norms, particularly seismic ones which do not include traditional earth based building technologies.

A detailed study has been carried out to assess the technological and structural pathologies of a typical rural residence in Treia (Macerata Council, Marche Region) now abandoned in critical conditions due to the lack of maintenance and to the destructive use of concrete and bricks in previous repair interventions.

An appropriate technological and cultural sound restoration was proposed along with a structural improvement taking into account the seismic hazard of the area, by means of a wooden grid included into the outside façade of the cob structure.

Seismic forecast performance of the proposed system is based on the experience of the Colombian research group "Tierra Viva Foundation" and was also studied by means of a numerical modelling.

Keywords: earth construction, seismic rehabilitation, cob technique, rural residence.

www.witpress.com, ISSN 1743-3509 (on-line)
doi:10.2495/ARC060371

1 Context

The understanding of earth building seismic behaviour is an important issue also in Italy, where existing large earth built Cultural Heritage stimulated a proposal to introduce into the new seismic national regulations earth material and techniques.

The rehabilitation design of an earth building has been the occasion to study its antisismic performance through specific "consolidation" techniques.

The opportunity came from the interest of the Treia council in Macerata County (Central Italy) and local architects to preserve the cultural heritage of an almost disappearing earth technique common in that area.

The local Council promoted an agreement with the property to repair one of the few still standing cob buildings ("atterrato" Cerioli) in Treia through a "learning by doing" process which involves researchers, architects, local technicians and builders in the frame of a larger rehabilitation programme.

2 Cob technique

The unique earth technique used in Treia is the cob ("massone" in Italian, "bauge" in French) which is relatively uncommon in Italy where the most diffused earth techniques are rammed earth and earth blocks.

In Italy cob technique is limited to few areas in the hinterland of Marche and Abruzzo regions (central Italy), while in France, Belgium and Great Britain the cob cultural heritage and new cob buildings are much more diffused and studied [1, 2].

The existing cob architecture in Marche region – built between the second half of the XIX century and the beginning of the XX – is mainly rural isolated buildings, now almost completely abandoned; a unique example of row houses – Villa Ficana settlement – now inglobated in Macerata town and undergoing to a rehabilitation programme – is still existing [3].

Cob is based on the traditional ingredients of many other earth techniques: aggregates (vegetal fibres, small stones, gravel, sands and silts), binder, which is the clay fraction of the soil, and water. When the wet mixture is done, walls are built directly without any shutter or formwork. In the traditional technique the cob mixture is used to prepare the "massoni" (big "earth loaves"), which are put beated on the wall. The single course is more or less one meter high and has to be enough dried to "carry" the second course. Up to two/three courses, the vertical surface is then pared with special cutting devices used in agricultural works (mattocks, slashers).

3 Seismic protection of the "atterrato" Cerioli

The building is completely built with the earth cob technique, from which comes the local name "atterrato". The southern part of the building, the oldest one built around the middle of the XIX century, is single store, while the northern two stories part was added later defining a non regular typology uncommon in the area (Fig 1).

Figure 1: The cob built “atterrato” Cerioli in Treia (Macerata Council, central Italy).

When the design analysis and restoration proposal were carried out (2 years ago), the building was in a very critical physical decay due to structural and technological pathologies determined by a long period of lack of maintenance, wind and rain actions and soil yielding (Figs 2, 3).

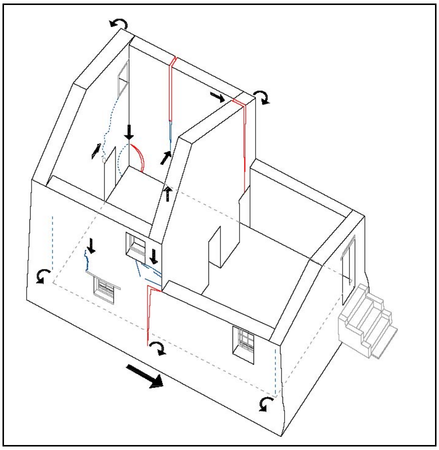

Figure 2: Analysis of the structural pathologies due to soil yielding and lack of maintenance.

Figure 3: Analysis of wall erosions due to wind, rain and lack of maintenance.

Earth building techniques generally give structural elements which have a lower carrying capacity in comparison to other poor conventional techniques such as multiple-leaf walls. Further on the flexural behaviour of earth cob structures, even if it can be considered a monolithic element, without mortar joints, is not good because of the low tensile resistance of the material.

Therefore the overall structural performance requires a high thickness of the earth structure, usually not less than 40 cm.

Nevertheless earth structures have a relatively good ductility behaviour, which is very important to resist seismic actions, while masonry structures have generally very low ductility factors.

The plan to insert earth structures in the national seismic code came up against a certain opposition, mainly based on the critique (or pre conception) that it was very difficult to include in a technical regulation the great variability of mechanical properties of earth structures due to the local differences of soil ingredients and craft-men culturally oriented building abilities. It is a typical example of local/global technological conflict in which the dominant methodology have to rule over the local knowledge and experience: i.e. durability standard analysis (as defined by RILEM standards) requires an elevated number of water immersions which is good for water resistant building materials (i.e. concrete for dams, etc.) but not for many other which are never exposed to continuous flooding.

The critical problem of conventional earth building technologies performances – such as cob or other earth technologies – needs to be faced through a transdisciplinary and culturally oriented approach which keeps together local experience with architectural, technological and structural requirements.

Focusing on seismic protection of diffused earth architectures, since a few years many proposals and experimental techniques have been carried out.

The first studies on seismic reinforcing of earth buildings have been performed in South America where earth blocks ("adobe") and rammed earth ("tapial") techniques are largely diffused in highly seismic areas. The main researches have been done by the group CERESIS [4], by the Getty Institute and by Gernot Minke [5]. The results where diffused also through very simplified guidelines which are very useful in such contexts.

More recent studies have been carried out by a professional group ("Tierra Viva Foundation") in a collaborative research project with the Getty Institute. The group experimented with a seismic reinforcement made by a wooden lath grid which can be integrated in different parts of the earth structure (outside, inside, only in corners): the wooden grid reinforcing system is easy to fit to the existing earth structures, and therefore it is a valid alternative in seismic areas to the diffuse inappropriate use of reinforced concrete or steel elements additions, which are not physically compatible with earth structures and often produce damages in earth buildings by strong earthquakes.

4 Rehabilitation and seismic reinforcing technology

The proposed rehabilitation follows two guidelines: first the preservation of the original architectural characteristics, (dimensions, position of inner walls, doors, windows, stairs) through conservation and repair; second a more invasive but anyway reversible and low-cost structural consolidation to increase load carrying capacity in case of earthquake.

The preservation of the original building implied the limitation of the technical plants inside and the location of services out of the cob building, the ridding of degradation causes (ventilated French drain, outside drainage, renewal on the roof) repair and reinstatement with cob of the heavy dilavated external walls. A special earth stabilized plaster has been studied to protect by water erosion the outside cob walls.

Consolidation design involved also the site of the building with a soil retaining wall, to avoid further yielding causing heavy structural cracks.

Following the basic design choices and to eliminate the inconformity among materials, every additional previous intervention (brick, concrete, etc.) to close cracks and cavities was removed and replaced with the traditional cob.

The stairs, previously a brick structure, and the intermediate floor were completely rebuilt, using only wood elements. The floor beams were connected to the walls with an intermediate wood plate, in order to distribute the load and to prevent stress concentration on the earth walls. The same solution was adopted for the new roof.

The proposed intervention was aimed to use materials and techniques suitable with earth structures and to avoid any structural hardly reversible superimposition such as brick buttresses, concrete columns, concrete slabs applied on the walls, corner brick reinforcements, reinstatement with steel grids and concrete, etc.

All these "hard" techniques, very often used to reinforce masonry structure, are non suitable for the conservation of earth buildings or for their seismic upgrading. The very different stiffness of the coupled materials strongly modifies the overall physical and structural behaviour of the building.

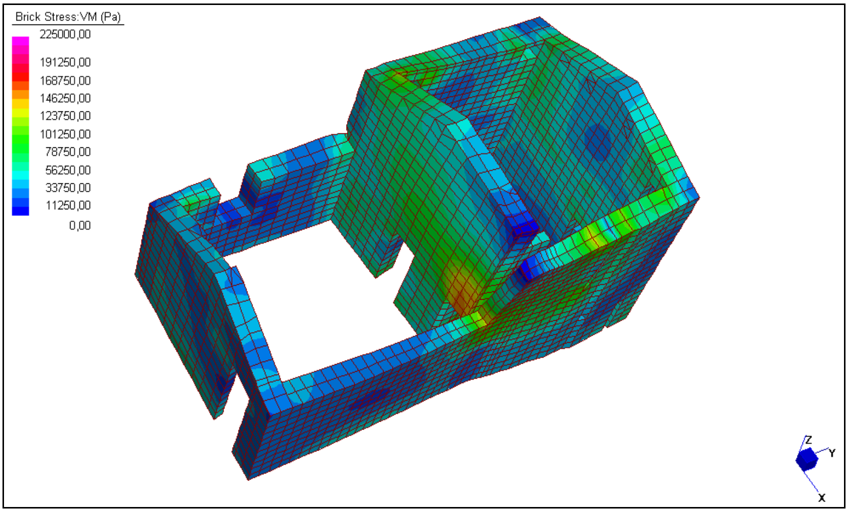

Figure 4: Seismic action on original earth structure - VM stress.

The enhancement of the performance to seismic actions is based on the adoption and deepening of the techniques proposed and experimented by the Columbian research group "Foundation Tierra Viva". A numeric modelling confirms the effectiveness of the adopted methodology (Figs 4, 5).

A reinforcement grid made by vertical and horizontal wood joists at a distance of about 100÷120 cm is applied to the external walls. It can be modified following openings position but anyway maintaining the density of reinforcing grid almost uniform in the different walls; some diagonal joists are inserted for bracing (Fig 6).

Moreover, in order to obtain a better global box behaviour, the wood frame should be connected by screws to the wood beams of the intermediate floor and to those of the roof. This last union is important for the reinforcing of the tympana, which are generally the first elements to collapse in the experimental tests performed by the research groups previously indicated.

The critical details of the grid system are the joist joints, the connection at the building angles, the fixing to the ground of the vertical wood elements.

The joist union was designed as a simple placement side by side on a wood table under them, fixed to the table with wood pins. The grid connection at the angles is made by steel angle bars.

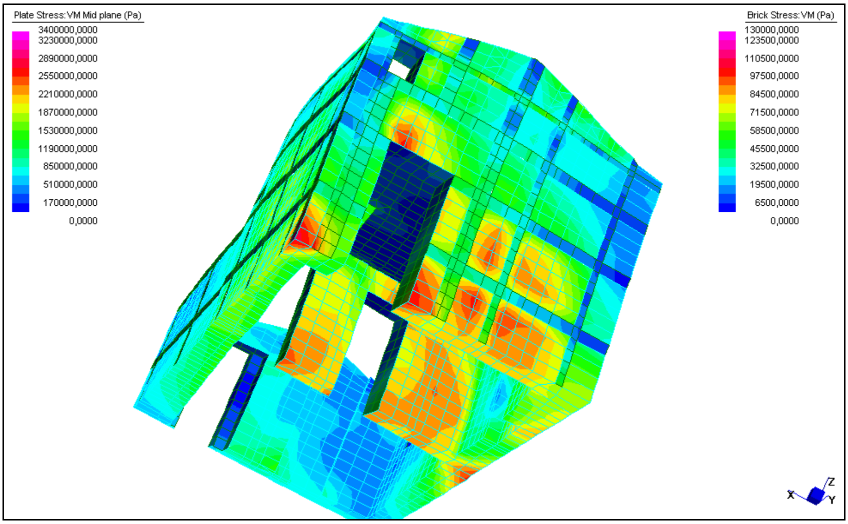

Figure 5: Seismic action on grid reinforced earth structure – VM stress.

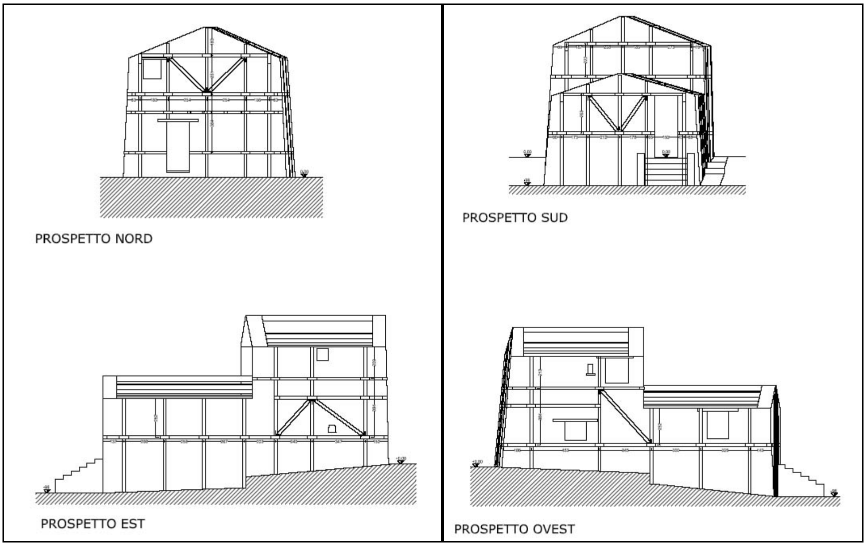

Figure 6: Design of the reinforcement wood grid integrated into the external walls.

The fixing to the ground of the vertical splints is made by means of bent steel plates fastened to the wood elements and drowned in a concrete stringcourse at the base of the earth walls. This buried external stringcourse is important also to reinforce the base of the "atterrato" which is completely made with earth cobs, and has no foundations.

In other cases, these kinds of earth buildings have a stone or a brick masonry basement, acting as foundation and protection from soil water.

The proposed reinforcing is for many aspects similar to the "sistema baraccato" a building system proposed by probably the first Italian seismic code, at the end of the XVIII century in the kingdom of Naples. It consisted, in brief, in timber frames well connected, with stone/brick masonry inside.

Another important detail is the protection and the strengthening of door and window openings by means of complete wood frames, connected to the external grid. Even if the external grid is not adopted, the protection of the openings is quite important, because the beginning of fractures and crashing happens generally at the angles of doors and windows, due to stress concentration.

Finally the grid can serve also as a support for the earth plaster.

The effectiveness of the intervention was evaluated by a numerical modelling, to investigate the most stressed zones of the structure and of the grid.

The analysis was performed considering the seismic spectra of the Italian norm for Treia.

The applied grid, assuming the adhesion of the joists to the earth walls and an effective fixing to the ground, yields a good performance; the model suggests also an additional reinforcing (other vertical elements) near to the angles, where there are larger stresses.

The global effect obtained by the grid is a 30- 35% lowering of the maximum stresses in the earth walls.

5 Conclusion

The conservation of the architectural heritage was the aim of the project as the "atterrato" Cerioli is protected by local regulations, therefore the original configuration was not modified. Guidelines of the restoration design were the use of eco-compatible materials, fit for earth cob constructions, and a structural intervention for seismic protection made with low-cost and low technology materials which can be removed.

Nevertheless the global good behaviour that can be obtained, depends especially from good craft-men capability and a high quality technical direction, that is in paying attention to the details of the project (mainly the connections between the elements and to the ground) and in an accurate work execution.

The house services and the technical plants, necessary for the use of the building, will be located in a new small construction made with pre-cast cob elements, in order to test also the modern evolution of this traditional technique.

References

[1] A.A.V.V., Architecture de terre en Ille-et-Vilaine, Ed. Apogée, Ecomusée du Pays de Rennes

[2] English heritage research transactions, Earth- The conservation and repair of Bowhill, Exeter: Working with Cob, Vol.3, English heritage Ed., London, 1999

[3] Saracco M., Architettura in terra cruda: il caso delle Marche, Alinea Ed.,Firenze, 2002. Scudo G., Sabbadini S., Le regioni dell'architettura in terra, Maggioli Ed., Rimini, 1997. Scudo G., Sabbadini S., Bonomini A., Drei A., Il recupero ai fini antisismici del massone, il Progetto sostenibile, n°8, Edicom 2005.

[4] CERESIS, Centro Regional de Sismología para America del Sur, founded in 1971 by Argentina, Bolivia, Brasil, Colombia, Chile,Perù, Trinidad, Uruguay, Venezuela.

[5] Minke G., Construction manual for earth quake-resistant houses built of earth, Ed. GTZ. Nuevas casas resistentes de Adobe, Pontificia Universitad Catolica del Perù Centro International de Investigation para el desarollo (CIID).