CONSTRUCTION SUSTAINABILITY WITH ADOBE BRICKS TYPE ELEMENTS

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Abstract. Sustainability is a criterion defined in the 80, which is essential in all fields of current activity. At the moment, it can not talk about development without being taken into account sustainability criteria. It presents the ensuring for an harmonious development, in line with current needs, without to endanger the possibility to develop and satisfy the needs of future generations. The buildings of adobe bricks-type elements ensure successfully the conditions imposed by this criterion. This type of construction ensures the responsible use of renewable natural resources, the possibility of reuse and recycling of materials, contributes to environmental protection and to pollution reduction, to energy saving and it provides a cleaner and healthier living environment. Not least, the buildings of this type are accessible in terms of cost and can contribute to the development of other fields such as eco-tourism.

Key words: sustainable development, clay building, eco-tourism

1. Introduction

To define sustainability is not easy and, over time, it spawned to several controversies and debates. In general acceptance, according to the Brundtland Report (Suciu and Suciu, 2007; WCED, 1987), the term "sustainability" or, as is known, "sustainable development" represents "satisfying of today needs without sacrificing the ability of future generations to satisfy their own needs". In any direction or development strategies of an

organization or a product, the imposing of sustainability criteria leads to the avoidance, reduction and / or to the harmful impact control on the environment and population, in terms of compliance with existing legislation, satisfying, in the same time, the user demands.

Although, seemingly simple, according to the Brundtland Report (WCED, 1987), the sustainability definition has a powerful impact in terms of equity between generations. Thus, it is envisaged the use of resources both in terms of benefits for present generation and the costs and "legacy" left for the future generations. This legacy, depending on the awareness level of the present generation, can be a value or a burden. Thus, according to Hartwick's rule, it has identified an interconnection that can be generalized in any field between two attitudes: "I now" vs. "others, now and later" (Suciu and Suciu, 2007). Therefore, at present, they are preferred the preventive development directions, type "win-win" to the detriment of alternative ones, type "reactive post-factum".

The sustainable development elements are: the Eco-Efficiency, the Cleaner Productions, the Eco-design, the Green Chemistry, the Life Cycle Analysis and Losses Minimizing. The concept of eco-efficiency, as it was introduced in 1992 by the World Council for Sustainable Development of the business, was defined as "offering of goods and services at competitive prices, that satisfy human needs and to give quality of life, reducing the environmental impact to a level that is consistent at, least, with the estimated capacity of supporting of Earth planet" (Suciu and Suciu, 2007; EEA, 1999; WEC, 1995). Therefore, eco-efficiency includes the process optimization, the waste recycling and providing new services. The Cleaner Production involves an increasing productivity, the implementation of the energy efficiency principle, the materials flow management, application of the prevention principle, the sustainable use of natural capital and achieving a compliance with legal requirements. The Eco-design represents the product development which aims to complete its life cycle, taking into account the environmental aspects in all process stages and promoting the products with the lowest environmental impact throughout the entire cycle life. Green Chemistry consists in promoting the products and the technologies which reduce or eliminate the using and the generation of hazardous substances. Life Cycle Analysis involves an assessment of the environmental impacts that a product has throughout its lifetime. Losses Minimizing is defined as the elimination or reduction, to a feasible level, of generated waste, that, otherwise, would require a further treatment, storage or elimination.

In the construction stages and using of an buildings, it distinguishes three determinants phases: the pre-construction phase, the construction phase itself and use and the post-construction phase and post-use. Each of these phases must meet minimum criteria to meet the sustainability principles, as it is shown in Figure 1.

Considering the cumulation of all concepts and strategies which define the sustainability, it was identified the opportunities to satisfy these concepts by making constructions using adobe

bricks-type elements. There are some researchers (Marques and Salgado, 2007) who declare that, in terms of sustainability in construction, the main objective is the continuous development. Starting from this statement, we can say that one of the methods that lead to continuous development can be the innovation based on traditional.

The traditional buildings represent an architectural style based essentially on the needs and on the available local building materials, reflecting, in the highest level, the local tradition. Currently, over 50% of the world population lives in traditional buildings made of local materials (Pacheco-Torgal and Jalali, 2012). The buildings made of adobe bricks-type elements can be found mainly in rural areas, in less developed countries, but also in economic developed countries such as Germany, France, UK, Spain, USA, Brazil, Australia and New Zealand.

The purpose of this paper is to present an analysis of the construction of adobe bricks-type elements, which combines the concept of sustainability with defining requirements of Romanian legislation concerning the quality in construction.

2. The environment impact

Marques and Salgado, according to Sperb, indicate the five impact means of construction materials on the environment: extraction of raw materials, processing of raw materials and getting the finished material, the transport of raw materials and finished materials, use of materials in construction process, the waste treatment resulting either from construction processor or repair or demolition of existing buildings (Marques and Salgado, 2007).

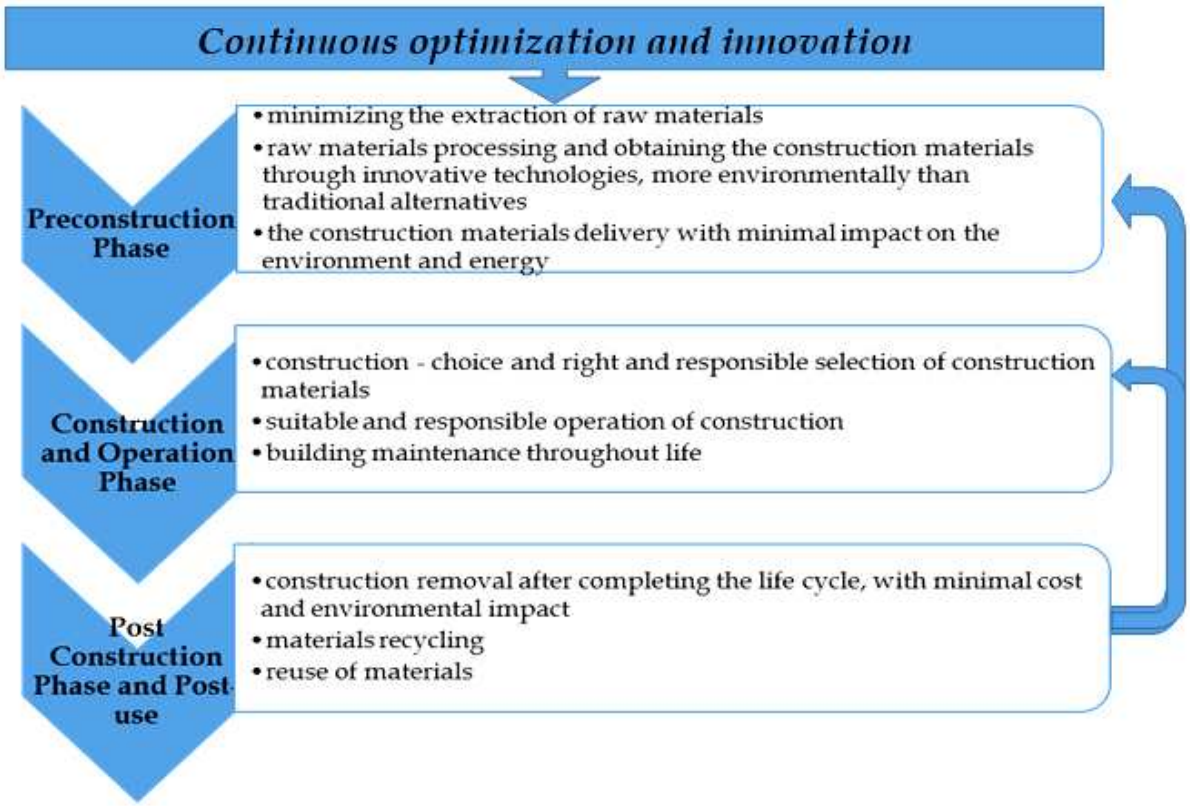

Fig. 1. Criteria for achieving sustainable construction

2.1. The air polution

The main pollutants elements for air are the CO_2 and dust emissions, but are not negligible nor N_2O, CH_4, SO_x, NO_x, NH_3, CO emissions. The Portland cement manufacturing contributes with 4-8% of total emissions with greenhouse effect (Marland *et al.*, 1999; Minke, 2005). In these conditions, the elimination or the substantial reduction of cement consumption is desirable.

Returning to Figure 1, and according to the literature, it can be appreciated that in the three phases of pre-construction, construction and use and post-construction and post-use, the extraction, the raw materials processing and delivery can be achieved through simple technologies, which involve either gross human effort or mechanical systems which have reasonable pollutants emissions. Generally, after these activities, it generates dust and, in the case of mechanized system use, a small quantity of gas, with a similar composition to those of exhaust gases. Also, based on references, it can be said that the construction realization with adobe bricks type elements can be performed without or with a ultra-low containing cement in composition (Blondet *et al.*, 2011; Pacheco-Torgal and Jalali, 2012). According to data reported in the literature (Shukla *et al.*, 2009) it has been estimated that using adobe bricks type materials, yearly, the CO_2 emissions could be reduced with about 101 tons.

2.2. Water pollution

Due to the fact that the production technology and put in place of adobe brick type construction elements uses clay as the main raw material, the impact on water pollution is reduced. The need to use certain additives to improve some performances does not induce a high pollutant impact because, they are generally natural materials, plant or animal, which decompose and reintegrate easily into the natural circuit (fats and vegetable or animal oils, vegetable fibrous materials, mineral salts) and they are used in small quantities.

During construction operation, the maintenance and repairs involve, mostly, the restoring of waterproof protection - the main disadvantage of these constructions being the low resistance to water action. The increasing of water resistance of adobe bricks type elements it performs through surface impregnating or coating with vegetable oils and / or animal fats respectively decorating / painting with natural mineral paints and oil additives. Therefore, the potential pollutant is reduced.

2.3. Soil pollution

Considering the above, the extraction, production, transport and installation of these materials do not indicate an polluting potential for soil. To the realization and the installation of adobe bricks type elements are not used heavy metals, radioactive materials, hazardous chemicals (biocides) and carcinogenic potentially substances to humans, as they are classified according to current legislation.

Once the building lifetime is established, and it has to be demolished, it results a considerable amount of waste. The obtained waste from a concrete building cannot easily reintegrate in nature, polluting the soil and the groundwater. The storing of remaining waste in the construction industry, after the demolition of

buildings whose life ended, was determined that it represents 25% of current landfills volume (Minke, 2005). In contrast, the demolition of buildings made of adobe bricks-type elements allow the reintegration in nature of most materials. Also, some of the used materials can be easily recycled or reused. The fact that the producing technology of adobe bricks type elements requires the use of some additive materials, does not bother their reintroduction in nature, these are mostly natural materials, but did not prevent nor recycling, which involves a new soaking with water, adjusting the composition and recast the elements. According to Morton reports (Morton, 2008), this construction type can reuse 24 million tons of soil waste annually, only in the UK.

3. Mechanical resistance and stability

There are now studies which attest the constructions durability achieved with local materials and indigenous techniques (Bui, 2009; Pushplata and Kumar, 2012; Moquin, 1994) in different geographical and climatic conditions. There are, also, some specific construction of adobe bricks-type elements problems, including the need for the development of larger thickness of the walls so as to achieve safety in terms of strength and exploration. However, the good behavior and the satisfactory durability of structures made of beaten soil elements and adobe bricks type masonry elements is documented still beginning in the nineteenth century. From Bibliographic Data analysis it has been established that the ideal soil for this purpose has to be at least 15-16% clay (Little and Morton, 2001; Minke, 2005; Revuelta-Acosta *et al.*, 2010; Kiroff and Roedel, 2010).

Many developed countries have proposed and implemented standards that regulate housing construction from soil. The first country, which has regulated the soil constructions, was Australia in 1952. In Germany, in 1944, it was established the first Earth Building Code which was the basis of DIN 18951, and New Zealand has the most regulated domain by the three acts: NZS 4297: 1998, NZS 4298:1998 and NZS 4299:1998 (Pacheco-Torgal and Jalali, 2012). In terms of mechanical strength, ASTM code D1 633-00 New Mexico indicates the material compressive strength, the minimum needed for the earth walls, of 2.07 N/mm^2. The Code regarding the walls of beaten earth, in Zimbabwe, requires a minimum compressive strength, for 400 mm thick walls, of 1.5 N/mm^2 for houses with one level and 2.0 N/mm^2 in the case of two-levels houses. The Australian Standard indicates a compressive strength of at least 1.15 N/mm^2 and ASTM International E2392/E2392M-10e1 (2010) indicates a value of 2,068 N/mm^2. ACI Material, Journal Committee indicates compressive strength values depending on the earth composition, as follows: 2.76 to 6.89 N/mm^2 in the case of sandy soil, and 1.72 to 4.14 N/mm^2 for clay soil (Bui *et al.*, 2009).

4. Fire safety

As discussed above, the main raw material which is used in the fabrication of adobe bricks is clay material with a reaction to fire - class A1, framed according to current regulations: EN 13501-1 "Fire classification of construction products and building elements - Part 1: Classification using data from reaction to fire tests" and Regulation Regarding the Classification and Grouping of

Construction Products According to the Fire Reaction Performance (MTCT and MAI, 2005). Therefore, it is a material with a high fire resistance.

In the adobe bricks masonry elements, the clay acts as a matrix that covers the other additives that can have various fire reaction classes, from A1 (sand, natural aggregates) to the F. On one hand, the fact that the clay is the majority material in composition and, on the other hand that it creates a shell for the materials with lower fire resistance class, leads finally, that the masonry elements have a high resistance to fire.

5. Hygiene and health

Still from Neolithic period, there are evidences of this type of construction in areas such as Mesopotamia, Anatolia and the Levant, this period beeing called, the Age of Clay, too (Deboucha and Hashim, 2011; Love, 2012; Moquin, 1994). In the seventh century BC, is certified a such construction, with impressives sizes, Babel (Moquin, 1994).

The use of clay soil in construction, it gives the opportunity of achievement a living environment pleasant, helpful, healthy, without toxic emissions, that adapts to users' needs; that ensures the indoor air relative humidity adjustment at 50 ± 5% and a permeability coefficient of water vapor with values between 156 ng/m²sPa and 479 ng/m²sPa, depending on the material density, throughout the year (Hall, 2007, 2009); resistant to insects attac, rodents, mold (Morton, 2008; Minke, 2005). A representative example of the ability to control the air humidity is the Hospital of Feldkirch, Australia, where it has been built a long gallery of 180 m and high up to 6 m of beaten earth, whose role was to control air humidity without need for additional conventional systems for this purpose (Pacheco-Torgal and Jalali, 2012).

6. Energy economy and thermal isolation

The European Union has set, as a goal for 2020, to reduce the primary energy consumption with 20% (WEC, 1995). According to Directive 2006/32/EC, it requires to Member States, that till to 2016 to adopte the national global indicative of 9% in terms to reduce the energy consumption through implementing energetic services and other measures to improve energy efficiency (Hall, 2007). According to data reported in the literature (Shukla *et al.*, 2009), it estimated that approximately an amount of energy of 370 GJ/year can be saved using adobe bricks type materials.

To achieve a good thermal insulation respectively a good thermal inertia, allowing heat storage on warm period and release it in the cold one, the clay mixture density, used in the fabrication of adobe bricks type masonry elements, has to fit in within 1800 - 2000 kg/m³ (Burroughs, 2008; Minke, 2005). Another important element for achieving a satisfactory thermal comfort is the thickness of the walls. Reports of literature (Goodhew and Griffiths, 2005; Minke, 2005; Pacheco-Torgal and Jalali, 2012; Parra-Saldivar and Batty, 2006; Revuelta-Acosta *et al.*, 2010) indicated a minimum thickness of 30 cm to obtain a satisfactory heat transfer coefficient.

According to reports in the literature (Goodhew and Griffiths, 2005; Parra-Saldivar and Batty, 2006; Rees *et al.*,

2001), the thermal conductivity of adobe bricks type elements is influenced by the content of their moisture and by air relative humidity. Also, the presence or absence of partitions inside the building influences the internal temperature in the room and the behavior in terms of heat transfer (Parra-Saldivar and Batty, 2006).

Based on experimental research reported in the literature (Goodhew and Griffiths, 2005; Viviancos *et al.*, 2009) and on experimental research conducted by the authors, it can be appreciated that the addition of vegetable fibrous material and other additive materials used in the composition of clay mixture influence the thermal conductivity coefficient, this varying between 0.24 and 0.34 W/mK. One possible explanation is the material porosity variation, which influences directly the thermal conductivity. The additions, especially the vegetable ones, grow the clay mixture porosity and, consequently, grow the thermal isolation capacity of adobe type bricks elements.

7. Costs and sustainability

A construction products analysis, from the harvesting of raw materials to final disposal, provides a better understanding of long-term material costs. From this point of view, the costs of achievement, operation, maintenance and disposal of such buildings are small. Typically, the raw material is exploited in areas close to the construction site, with simple means. Making the building elements requires a simple technology, accessible even low-skilled personnel, consisting primarily of components mixing, casting in molds and the natural drying. The building work, also, requires a simple, accessible and inexpensive technologie respectively the simple brick building with a similar clay paste compositions that have been shaped the building elements, but with an increased workability and plasticity. The maintenance and repairs are easily made, using the same clay compositions. After completing the building life time, it can be demolished, the materials will integrate mostly in nature, without involving high costs for waste treatment.

Studies of literature and historical data have indicated a durability that can meet the needs of a generation, under normal operating conditions and performing the maintenance and repairs required by this type of material (Pacheco-Torgal and Jalali, 2012). The main disadvantages, in terms of durability and construction costs, are a lower durability of materials; a low resistance and the risk of erosion of the walls in contact with rainwater or other water streams; the need for frequent repairs. The walls resistance to the erosive action of rainwater is still a controversial subject, some researchers claiming that the rain has a negligible erosive effect if its intensity does not exceed a rate of 25 mm/m (Ogunye and Boussabaine, 2002). However, the most researchers in the field agree that the sustainability depends substantially on how the maintenance and repairs are performed (Little and Morton, 2001).

8. Impact on other activity fields - the tourism

The Eco-tourism is one of the most affordable and tendering travel options, both for suppliers and consumers. In Romania, this branch of

tourism, becames increasingly important due to some local advantages that can be realized: the areas where "time seems to be stopped"; the protected natural areas due to biodiversity, parks and natural areas in UNESCO patrimony, etc.

The National Strategy for Ecotourism Development in Romania, 2009 (INCDT, 2009), indicates that the International Ecotourism Society (TIES) identified a 20-34% annual growth of this type of tourism, since 1990. Also, it said that, at global, since 2004 the eco-tourism grew three times more than the global tourism industry. It is estimated that 87% of British travelers believe that their holidays should not harm the environment; 53% of American tourists consider their tourist experience is richer when they learn as much as possible about local customs and culture; 95% of Swiss tourists consider that respect for local culture is very important, when it is chosen a holiday location.

The constructions of adobe bricks type masonry elements contribute to the development of eco-tourism by several features: they allow a better integration in nature, keeping unchanged the surroundings features and a great respect for the landscape integrity, utilizing local materials and having generally a traditional design; reduce significantly the waste and pollution that result routinely in the building achievement; allow placement in areas which are not included in the urban environment; allow to obtain living conditions / accommodation comfortable, healthy, with low cost.

Therefore, the development of this type of construction helps to maintain and increase the possibilities of eco-tourism development, which will increase the number of jobs and stimulate the economy, especially in rural areas.

9. Conclusions

As a result of the discussions in the context of sustainability, it can be said that construction of adobe-bricks type elements meet successfully the sustainable development principles, namely:

- to respect the principle of equal opportunities for current and future generations, through conscious and judicious use of natural resources and existence of the possibility recycling and reuse of materials.
- to respect the right to be insured, both, for the current generation and for future generations, the possibility of a healthy and safe life, in a welcoming environment.
- ensuring the possibility, but the obligation, too, for the next generations, to manage the use of natural resources.

The construction of adobe bricks-type elements allow the preservation of local cultural identity because they are based on traditional constructions, specific for the place. This type of construction provides a healthy and comfortable living environment, they have a small impact on the landscape; they are available for many categories of users because they are relatively inexpensive to build and maintain and they are efficient in terms of energy. These buildings can contribute to increase the tourism, especially the eco-tourism, beeing accesible for the tourism providers and attractive to consumers. At the end of life service, these buildings can be easily demolished, the most part of materials can be reused,

recycled or re-integrated into the natural environment.

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Received: 22 December 2015 • **Revised**: 5 February 2016 • **Accepted**: 20 February 2016