International Journal of Architectural, Civil and Construction Sciences
ISSN: 2415-1734
Vol:6, No:7, 2012

Compressed Adobe Technology Analyses as Local Sustainable Materials for Retrofitting against Earthquake Approaching India Experiences

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***Abstract*—**Due to its geographical location, Iran is considered one of the earthquake-prone areas where the best way to decrease earthquake effects is supposed to be strengthening the buildings. Even though, one idea suggests that the use of adobe in constructing buildings be prohibited for its weak function especially in earthquake-prone areas, however, regarding ecological considerations, sustainability and other local skills, another idea pays special attention to adobe as one of the construction technologies which is popular among people. From the architectural and technological point of view, as strong sustainable building construction materials, compressed adobe construction materials make most of the construction in urban or rural areas ranging from small to big industrial buildings used to replace common earth blocks in traditional systems and strengthen traditional adobe buildings especially against earthquake. Mentioning efficient construction using compressed adobe system as a reliable replacement for traditional soil construction materials , this article focuses on the experiences of India in the fields of sustainable development of compressed adobe systems in the form of system in which the compressed soil is combined with cement, load bearing building with brick/solid concrete block system, brick system using rat trap bond, metal system with adobe infill and finally emphasizes on the use of these systems in the earthquake-struck city of Bam in Iran.

***Keywords*—**Local Materials, Compressed Earth Blocks, Sustainable Construction, Retrofitting

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I. INTRODUCTION

GENERALLY speaking, specialists' ideas about using adobe in the construction of houses are classified into two groups. According to the first group, adobe is extremely weak against earthquake and must not be used in earthquake-prone areas. It is believed that many people are buried and died under the earthquake debris. Therefore, it is evident that if one wants to have strong constructions and strengthen the walls of the buildings, use of Bamboo shoots or straw building shall be considered; like those done in Peru. The second idea is based on ecological considerations and use of local skills where special attention is paid to adobe as a construction technology and people's preferences. Another advantage of using adobe is creating job and income for low-income villagers.

II. MASONRY PRINCIPALS

A compressed earth block (C.E.B.) masonry structure consists of small building elements placed one on top of the other following a particular bonding pattern and bound together with mortar. The earth blocks therefore form a building system - whether it is a wall or a partition, a post or a pillar, an arch, a vault or a dome - which has compressive strength. This characteristic of compressive strength is indeed essential as, by contrast, masonry structures using small elements have very little tensile strength. The good strength and good stability of a masonry structure using small elements is dependent on the interaction of several factors: a) The quality of the block itself; b) The quality of the masonry (i.e. the interaction between the block, the bonding pattern and the mortar); c) The form of the building system, which should be suited to the compressive forces exerted; d) The quality of detailing of the building system, notably ensuring good protection against water and humidity and e) The quality of execution of the work [1].

A. Possible Uses of Compressed Earth Block Masonry

Compressed earth block masonry can be used for any kind of structure required by compressive forces (figure1). In compressed earth block construction, as in construction using other masonry elements (such as stones, fired bricks, sand-cement blocks), mortar plays a four roles: a) It bonds the masonry elements together in all directions (vertical and horizontal joints); b) It allows forces to be transmitted between the elements and notably vertical forces (i.e. the weight of the elements themselves, or applied forces); c) It enables these forces to be distributed across the whole surface of the masonry elements; d) It compensates for any defects in horizontality in the execution of the masonry work [2].

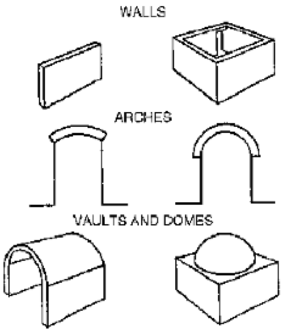

Fig. 1 Different building systems using C.E.B

B. Bonding Patterns

The term "bonding pattern" refers to the way in which compressed earth blocks are arranged, assembled and therefore bonded together in all directions of a masonry structure (horizontally and vertically, and in the thickness of the wall). The bonding pattern determines the position of each earth block from one course to another and notably prevents vertical joints occurring one immediately above the other, which would entail the risk of cracks spreading through the structure. Bonding patterns play an essential part in ensuring the cohesion, the stability and the strength of masonry structures built from small elements bonded together with mortar. Deciding which bonding pattern to use should be done before the masonry work begins will depend on five interrelated factors which should be considered together:

a) the type of structure (wall, partition, pillar, other);
b) the size of the structure;
c) the dimensions of the compressed earth blocks,
d) the skill of the masons (appropriate level of complexity);
e) the aesthetic effect required of the finished appearance of the external faces of the structure.

Compressed square-shaped earth block is adopted from both traditional adobe bricks and those significantly used in construction works of Latin America which have roots in the history of countries like Colombia, Peru, Ecuador and Bolivia [3]. Such a shape is very effective in the systems of equipped buildings and was used in construction of strong houses against earthquake in Peru and the Philippines. It also strengthens the vertical elements of wood and steel structures.

Buildings which use small construction materials benefit from more flexibility due to employing modular construction materials method. This modulation is combined with dimension and size of building systems; therefore, it can be described as functional sizes in building elements including compressed earth blocks. It can also be described as functional principles of connection patterns, used in developing building systems [4]. A good construction work depends on the knowledge and skills of its designer; otherwise, some problems will occur. Some cases of construction problems are shown here (Fig.2)

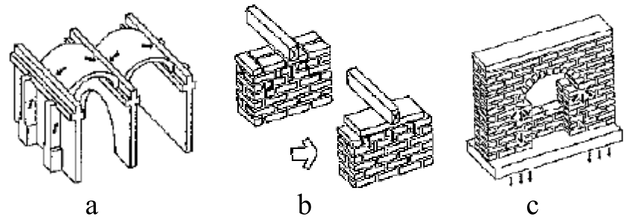

Fig. 2 from left to right: a) Absorbing the forces exerted vaults; b) Spreading the load of the forces exerted by floors on the wall; c) Absorbing the arches

Compressed earth block masonry enables one to build either load bearing walls, both thick and thin, or non-load bearing walls such as partitions which divide up the space within a building. This simple classification offers great architectural flexibility. Although there are some main problems to achieve this objective, there are some other methods to solve them (fig.3).

C. Roofs with Compressed Earth Blocks

These roofs are the inheritor of traditional adobe roofs which have expanded in hot and dry areas such as Mesopotamia, Egypt and Iran, where wood is rarely found. By constructing arches and domes, the constructors implement the potential capability of these construction materials when working in high pressures. Such roofs create aesthetic aspects regarding architectural forms and interior spaces to satisfy the attraction-seeking architects and employers. Thanks to scientific experiments, researches and architectural achievements and experiences which are the result of expanded technical trainings and university degrees, C.E.B. technology is significantly progressed, and great efforts are taken in basic and technical subjects these days. This will help achieve ultimate techniques in the future [5].

III. Bam Earthquake and Crisis Management in Cultural Heritage

When Bam earthquake happened in December 2003 in the south-east of Iran, the population of this city was estimated to be 200000 people and most of the houses were made of mud and adobe with the average life of more than 30 years. More than 80% of Bam citadel, which was the biggest mud and adobe complex in the world and aged more than 2000 years old, was crushed. In fact, 86% of rural and urban facilities were destroyed and around 62000 buildings were damaged. 12 thousand babies, nine thousand students and two thousand teachers died in this disaster. Undoubtedly, if the disaster that happened in Bam would have happened in any other cities of Iran, it could have had the same consequences and destruction.

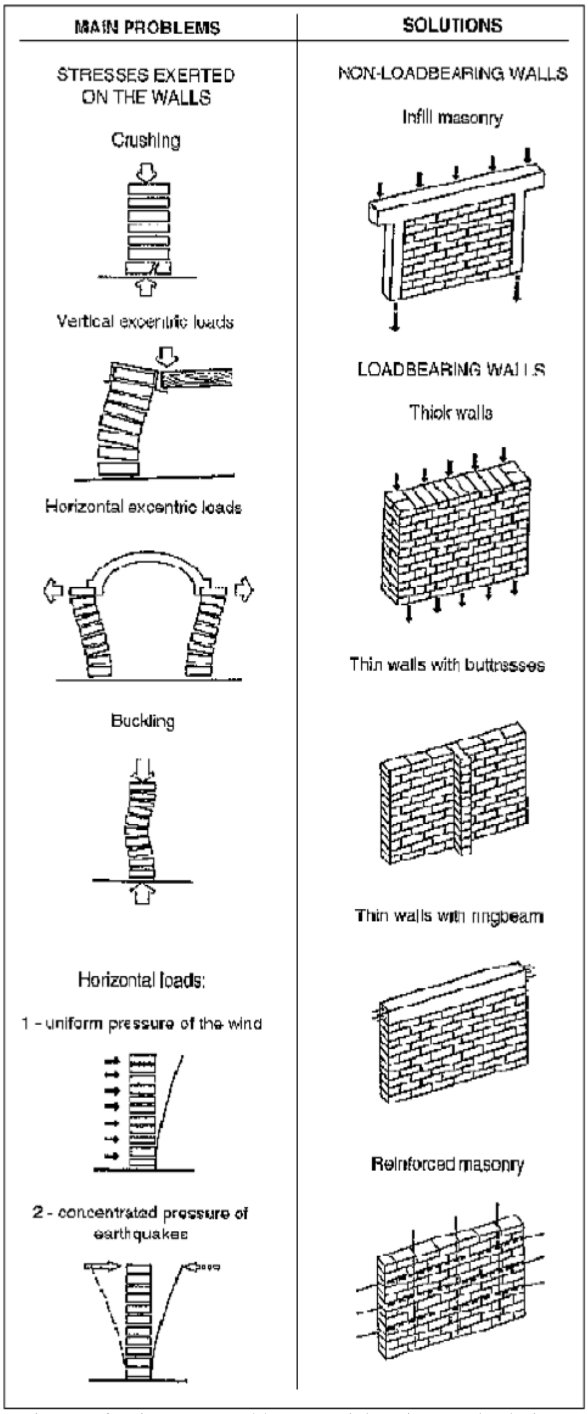

Fig. 3 Left: Five great problems & Right: Five good solutions

During the last years, Iran has experienced different ways to resist against natural forces and has suffered a great loss to manage the cities efficiently. However, safeguarding cities against natural forces is more observed recently, and the existing management and technological methods especially about safeguarding services, institutions and urban buildings are improved. To achieve better results, the experiences of India in the field of strengthening buildings are studied here.

IV. India and Strengthening Systems of Compressed Soil Construction Materials

A. Making Sustainable Compressed Soil with Cement

This method is considered as a developed technology by Auroville building center in India. It was used in earthquake-struck villages and suburbs to renovate thousands of houses in Cachche region. This technology takes advantage of two options: As first option, rectangle-shaped blocks with minimum pressure resistance of 5 N/mm2 are used in construction where cement mortar is used between each row.

The second option is to use the mixture of clay and cement in metal shapes and compress layers in the region. Again, this mixing and compressing is applied in a way to achieve the minimum pressure resistance 5 N/mm2. Both of these methods are employed in Cachche region in India. However, the second system is faster and more economical. It should be mentioned that, in the systems mentioned above, all the measurements and standard earthquake resistant calculations in particular adobe buildings are considered. These systems are completely resistant against different earthquake magnitude as well. The expense of constructing such houses is around 60% that of the houses constructed by brick or solid concrete blocks [6].

B. Load-Bearing Construction using Brick/Solid Concrete Block

This kind of construction is used traditionally in India and other earthquake-prone areas. Suitable strength and the implementation of earthquake-resistant material is one of the typical characteristics of it. After this method was adopted, later earthquakes showed that the buildings constructed according to the standards of this method were suitable and desirable; despite the fact that they were only 10 kilo meters away from earthquake fault. Different standards are specified for different methods to make adobe building resistant in Iran.

The main difference between Iran and India's standards is that in Iran connecting concrete columns in brick or stone architecture are placed where vertical loads apply. According to the consultants, the problem of establishing limits in brick blocks of the walls originates from lack of positive shear connection in them. The experts continued to explain both the reasons by which they could make Iran's standard more efficient and the methods to improve them by making suitable shear connection and finally by producing much better adobe in order to improve concrete products.

C. Brick Construction using Rat Trap Bond

This system is used in the walls bearing side and vertical loads. By placing the adobe in the edges, the walls are shaped as Flemish bond. Therefore, it is necessary to make calculation after every bond in the plan due to the existence of hallow inner space (75mm*230mm). This system is more economical if using of brick is decreased by 25%; as a result, heat production will be more desirable for replacing air in the walls. The houses should be strengthened by similar horizontal quake bond and vertical steel placed in important and vital architectural points of the buildings; as shown in the sample solid adobe blocks. At the same time, compared to works with less bricks and with horizontal joints, the speed is more and vertical steel can be employed easily in vital points and hallow spaces of the adobe works.

D.Metal Frame Building with Brick Infill

After adobe, this kind of construction is common in Bam. In spite of using metal structures, most of the destructions and collapses happened in these structures. Therefore, it was necessary in new construction to replace them with more resistant structures. Based on the observations, it seems necessary that the following points be mentioned:

a) Lack of diametric bracing;

b) Weak welding connections between metal columns, main bars and metal bracing;

c) Lack of shear transfer between infill walls and metal elements;

d) Non-girthed brick architecture with any column or other parts [7].

E. Proposed Earthquake-Proof Building Technology for Bam

a) Adobe construction materials using wood, bamboo or straw to make building resistant against earthquake (as in Mexico or Peru);

b) Making sustainable compressed soil with cement; used in renovated construction of Gujarat in India with earthquake-proof characteristics;

c) Making earthquake-proof load-bearing brick walls based on Iran and India standards;

d) Making brick using rat trap bond with load-bearing walls;

e) Metal frame buildings with adobe infill

V.Conclusion

In fact, protecting people's life and their properties, the knowledge and skills, production and industrial instruments, institutions and urban services against natural forces, shall always be inseparable part of country plans and urban management. With regard to risk management and safety in planning for cities, the knowledge, intelligence and realization shall be taken into account and its responsibility should be divided among different organizations of society.

The C.E.B. technique has several advantages which deserve mention:

a) The production of the material, using mechanical presses varying in design and operation, marks a real improvement over traditional methods of producing earth blocks, whether adobe or hand-compacted, particularly in the consistency of quality of the products obtained. This quality furthers the social acceptance of a renewal of building with earth.

b) Compressed earth block production is generally linked to the setting up of quality control procedures which can meet requirements for building products standards, or even norms, notably for use in urban contexts.

c) In contexts where the building tradition already relies heavily on the use of small masonry elements (fired bricks, stone' sand-cement blocks), the compressed earth block is very easily assimilated and forms an additional technological resource serving the socio-economic development of the building sector.

d) Policy-makers, investors and entrepreneurs find the flexibility of mode of production of the compressed earth block, whether in the rural or the urban context, small-scale or industrial, a convincing argument.

e) Architects and the inhabitants of buildings erected in this material are drawn to the architectural quality of well-designed and well-executed compressed earth block buildings.

C.E.B. technology has made great progress thanks to scientific research, to experimentation, and to sustainable architectural achievements which form the basis of a wide range of technical documents and academic and professional courses. A major effort is now being devoted to the question of norms, continuing ecological and sustainability issues and this should help to confer ultimate legitimacy upon the technique in the coming years.

References

[1] J. Norton, *Building with Earth, a Handbook.*. New York, NY: IT Publications, 1986, pp. 113–121.
[2] H. Zomorshidi, *Vault and Arch in Iranian Architecture*, Tehran, TEH: Keyhan, 1988. pp. 97-104.
[3] P. Moory, *Materials and Manufacture in Ancient Mesopotamia: The Evidence of Archaeology and Art: Metal and Metalwork, Glazed Materials and Glass*, Oxford, OX: Oxford University, 1985. pp. 76-83.
[4] G. Memariyan, *Structures in Iranian Islamic Architecture*, Tehran, TEH: Iranian University of Science & Technology, 1989. pp. 65-71.
[5] G. Mcnally, *Soil and Rock construction Material*, London, E & F.N. Espon, pp. 45-56, 1998.
[6] H. Zomorshidi, *Iran Architecture-Understanding of Iranian Masonry Construction Materials*, Tehran, TEH: Azadeh, 2006. 121-134.
[7] A. Moradi, A., *Twelve Lessons on Restoration*, Tehran, TEH: Center for Architecture & Urban Studies and Restoration, pp. 83-89, 2008.

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