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Security Requirements for earth construction: Comparative study of international codes

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Abstract
Earth construction offers outstanding architectural solutions to socio-economic contexts, climate and energy, it uses natural resources and respects the cultural dimension of territories. It preserves the bio diversity and the environment in practical dimensions of sustainability. Thus, Earth Construction needs to be technically designed and implemented, especially when facing natural hazards and other disasters such earthquake. In this paper, six international codes and regulations related to the security of earthen constructions in different countries are presented and discussed. A comparative study is conducted to assess the effectiveness of each of the security parameters provided as technical solution or security regulation of the earth-building. The major finding is that none of the codes or regulations covered all earth construction techniques. The second finding is that each code or regulation is influenced by the specific country's context, and finally there is still no harmony between different technical security requirements all over the world. Furthermore, the compressed earth blocks which is a recent and a modern technique is not covered by all the six codes.

Keywords: Earthen, regulations, seismic architecture, training, vulnerability, community, earthquake

1. Introduction
The training of architects and professional builders most of time gives no room for earthen architecture. It does not provide the wherewithal to establish a consistent study and specialization programs, despite the very rich heritage and an extensive use of this material in several countries such as Morocco, Yemen, Spain, Italy, Turkey, India and Peru.

Today about 30% of world population lives in clay houses. Two billion people are concerned, in all continents and under all climates [1]. About 140 World Heritage sites are built with this material [2]. They represent 15% of the listed sites by UNESCO. As an example, the built assets that Morocco counts on its list of World Heritage confirm the importance of natural resources in the creation of a decent living. Their recognition and registration mainly based on their remarkable construction techniques related to unbaked bricks. They show the know-how, engineering and construction practices as well as a deep expertise.

About 30 years ago, the 'Local Seismic Cultures' were demonstrated as intrinsic to the specific habitat in areas with frequent earthquakes, by the group of researchers and CSL Italian university, and defined as « the technical knowledge and behaviors consistent with these knowledge, to reduce the impact of local earthquakes » [6] [7] [8]. Thus, in seismic areas, the historical heritage's building resists to earthquakes, due to local constructions techniques or repair work that characterizes these buildings as well as their organization's logic. As such, several real illustrations testify, namely, earthquakes that hit the town of San Giuliano in Italy in 1999, the city of Izmit in Turkey in 1999, the Kachchh region of India in 2001, the city of Bam in Iran in 2003, and the city of Al Hoceima in 2004 [9].

While human settlements under the historic heritage built with adobe and rammed earth structures resist well to seismic hazards, more recent ones, that are the most common and widespread for housing in rural areas of developing countries, including Morocco, demonstrate their vulnerability when facing natural hazards, including

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earthquakes. Several examples of recent earthquakes attest this vulnerability and its poor performance in this regard: Izmit in Turkey in 1999, El Salvador in 2001, the Kachchh region of India in 2001, the city of Bam in Iran in 2003, the city of Al Hoceima in 2004 of Pisco in Peru in 2007 and Maule in Chile in 2010.
Several countries all over the world are as well affected by this disaster. The most disastrous consequences affect seriously the country's development paths. In 1976 over 500,000 people died as a result of seismic activity which occured in the Philippines, Indonesia, Turkey, Italy or China [3].
Nepal considered as an example, is one of the most exposed countries to high magnitude earthquakes. The last one was in April, 2015, with 7.8 in magnitude. It was by no means the worst of Nepal since the earthquake of 1934. In fact, 40% of the country was affected: nearly 5,500 dead and over 10,000 wounded. Economic and cultural consequences are added up to the collapse of heritage properties and housing stock. Beyond the power of this earthquake, other factors increase vulnerability to risk, namely, non-compliance with security standards in construction, lack of prevention at the institutional level and urban planning and poverty. The Nepalese government has accelerated the adoption of the law on disaster management, still awaiting consideration by Parliament, which is seeked to replace Regulation of 1982 [4].
The Maule earthquake in central Chile in February 2010 is one of the world's most powerful earthquakes, with 8.8 in magnitude. The number of victims stood at 521 and 800,000 homeless. The repetition of seismic events had forced the country to adopt very early (1935) a seismic building code, and has to change periodically to its most recent version in 2009. The origin of this code went back to earthquake regulations the year 1928. It has the advantage of being exhaustive and preventive. It is even more specific typologies and building materials with adobe bricks, specifying different architectural and structural characteristics. Its disadvantage is particularly the failure to address existing buildings that are most of adobe. The result is that almost all of this habitat has not resisted this latest earthquake [5].
In Morocco, the 2004 Al Hoceima's earthquake was a strong plash regulating the different types of building techniques using earth materials. It had also raised awareness of the importance of the traditional built heritage and, therefore, the material's intrinsic values it carries. The 'Earthen Constructions' Earthquake Regulations (RPCTerre 2011) on the use of natural material in buildings located in seismic areas, approved in May 2013, brings an unprecedented progress in Morocco regarding the consideration of this material and its structural rehabilitation in building techniques.

2. Materials and method

Six codes and regulations for securing raw earthen constructions in different countries are presented and discussed. This sample includes three developed countries: New Zealand [12], Peru [13] and New Mexico [14], an emerging country: India [15] and two developing countries: Nepal [16] and Morocco [17]. A comparative approach is conducted under the following strategy :

- assessing the scope of each code and its coverage of different types of construction (major techniques);
- appreciate coefficients (limits) risk tolerance;
- compare different security parameters among these codes.

First of all, we found on the international level insufficient number of seismic codes and regulations on the earthen construction and rehabilitation. Often research interested in earth construction addressed more empirical knowledge than technical typologies and security fulfillment. The most relevant characteristics adopted in our analysis as criteria for the security requirement and for the comparison are:

- The density;
- The Granulometry;
- The limit tolerance in dimensions;
- The compressive resistance and the tensile strength (CraTerre);
- Shear resistance;
- The tolerance risk limits (coefficients).

These criteria are selected following a thorough analysis of the appropriate parameters and variables that govern the control of particular buildings toward stresses and seismic forces [10] [19].
These codes are chosen for their coverage but more for the construction capital (including the historical one) of the respective countries in terms of construction raw clay materials, especially for the current development that this sector knows in these countries.

Regarding granulometry and density, Table 1 shows that Nepal Code does not specify data relating to these two parameters. The guidelines are contained in a general regulation for all building materials. They are applicable only to cut stone structures with mortar cement and earth as well as adobe.

Table 1: Comparaison of the six codes in terms of granulometry and density

		Indian Code	Nepal Code	New Mexico Code		New Zealand Code	Peruvian standards	Moroccan Seismic Regulation
Density	Rammed earth			General and detailed conditions for the work of formwork and adobe.		Mixtures of soil and cement, which contain more than 15% by weight of cement, are outside the scope of this Standard field.		Earth compacted to 98% of its maximum dry density.
	Adobe	Sup. 1750 kg / m3 dry (stabilized brick)					1600Kg /m3	
	BTC							
Granulometry	Rammed earth	- Clay (<0.002 mm)>5-18% - Silt (0.002 – 0.075 mm)>10-40% - Sand (0.075 – 4.75 mm)>50-80% - Gravel (4.75 – 6 mm)>0-10 % - A natural sand is used for diluting the soil without organic matter: salt / chemical + Soil quality is suitable for the production of stabilized earth blocks. - The soil contains clay, minerals and inert particles (Silt and sand). For stabilized earth blocks, clay content and soil minerals are to control and adjust, diluting the ground sand.		- Maximum size rubble : 1,5 pouce (3,75 cm) - Maximum size of clay dough : 0,5 pouce (1,25 cm) - Prohibition of stabilizing asphalt. - Maximum size of earth to rubble compacted fine : 1 pouce (2,5cm).	- Limit of 2% over the blooms without organic matter. - Mortar: Same conditions as earth blocks, mortar or lime type M, N or S.			Clay 8 to 26% Stringers 8-16% Sable 32-58% Gravel 2 to 10%
	Adobe			- Adobe / Adobe press / Adobe stabilized: Limits warping or cracking.		Grains (Bricks): 7mm max. Grain size <2.5 cm.	Clay: 10-20% Limon: 15-25% Sand: 55-70% -No Organic soils -Can Contain straw -No More than 5mm rubble	- Clay 10 to 20% - Limon 15 to 25% - Sand 50 to 70% - The stones> 5mm in diameter eliminated
	BTC					Grains (Bricks): 7mm max.		

Not Covered

With the exception of New Zeland code which is very detailed for all the characteristics of materials and construction techniques and rehabilitation, all other regulations do not address the compressed earth bricks. They remain dependent on local building cultures in heritage vision. Tables 1, 2 and 3 show that the compressed earth blocks (CEB) technique is not covered in all the six studied codes. In the case of the Indian code, the latter technique is discussed in general, which does not differentiate the CEB technique over other techniques.
One can see that the CEB technique which has both the advantages of rammed earth and adobe, and proves high capacity for compressive and shear resistances, is surprisingly not covered by 5 out of the six codes.
The specificity of the Moroccan regulation is that it is dedicated exclusively to seismic earth building, which is not the case for other codes that are, in fact, only on the standardization of the earth construction.

Table 2: Comparative study of the international codes and regulations: Tolerance limits in dimensions

	Indian Code	Nepal Code	New Mexico Code		New Zealand Code	Peruvian standards	Moroccan Seismic Regulation	
Rammed earth		Standard rectangular bricks formed by hand or machine. Brick size: 240 × 115 × 57mm with 10mm thick horizontal and vertical mortar joints. Wall thickness: min. a half-brick (115mm) and max. a brick (240mm) required for non-load-bearing walls. Masonry mortar mud brick: - Thickness Min. Wall (mm): 350 - Height Max: between 3.0 and 3.2m - Max. short span of floor: 3.2m > Wall height <to eight times its thickness. > Openings: small enough and center. > Openings in a floor should preferably be at the same level. > The horizontal distance between two apertures> 1/4 of the height of the bottom opening. > The vertical distance between the apertures, one above the other> 600. > Anchor length of a header of each side of the opening> 300 mm. > Openings to locate away from the corners within a distance> 1/4 of the height of the opening, but not less than 600 mm. - Total length of the openings in a wall <50% of the length of the wall between consecutive transverse walls in building level, 42% in construction with 2 floors, and 33% in 3-storey buildings - Horizontal distance (width of the pier) between two openings> 1/2 of the height of the shorter opening, but not less than 600 mm. > Vertical distance between two openings directly above> 600 mm, and less than 1/2 of the width of the smallest opening. -If The wall vertical opening is> 50% of the wall height, vertical bars should be included in the amounts.	- Thickness of the exterior walls constructed of rammed earth: 18 inches (45 cm) min. - Thickness of the interior walls: 12 inches (30cm). - Installation of weather resistant barriers on all unstabilized adobe, is required.	- Wall thickness: 10-24 inches (25-60 cm). - Building 1 or 2 floors for all earthen wall systems covered. - In accordance with approved practices. - Definition of the dimensions of wood or concrete reinforcement. - Definition of anchor min. Roofing. - Max spacing. 24 feet (7.3 meters) between shear walls. - Definition of "bracing" and illustration of the connections to the outside wall. - Details pushed dimensions lintels depending on the scope and expense. - Close the openings of the limits of the angles is very detailed. - Openings must extend to within 06 inches (15cm) above the ground, with min. wall thickness, except for a restriction of 02 inches (05cm) for insulation borders. - Referral to other chapters of foundations in general for the depth, width, construction.	brick size : 30X14X10cm. The seismic zone safety factor 0.6: - A 600m2 area reserved for a ground floor, a 200m2 surface for 2 floors and a 300m2 area reserved for 2 floors whose only ground floor is earthen. - Maximum height: 06,5m Wall Thickness adobe: 28cm Variation in the thickness of adobes: 1.5cm. - The overlap of bricks between 25% and 75% of the length of the units. - The compressed brick walls must have a minimum thickness of 250 mm, except for the type CINVA BTC can be 130mm thick. - The tolerances in the dimensions are similar to those for reinforced concrete.		- Elancement: h / t <9. - Thickness Min. bearing walls 40 cm. - A total rammed Height: 0.8 to 1m.	- Minimum thickness of bearing walls: 0.4 m. - - Minimum thickness of walls: 20cm. - - Width of an opening <1.2m. - - Distance between an outer and an opening angle> 1.2m. - - Total sum of the widths of openings of a wall <40% of the total length of the wall in seismic areas "1". - - Length of support lintels (anchoring lintels) in each side of the opening> 50cm. - - The length of the wall between two successive walls that are orthogonal to it, must not exceed 10 times the thickness of the wall, and should not be greater than 64t2 / h, with "h" is the height, and "t "is the thickness of the wall.
Adobe	The maximum variation in the dimensions of the units should not be > of ± 2 mm. Length Width Height 305 143 100(mm) 230 190 100 230 105 75 230 105 100					Proportion between the length and height: 4/1 with h> = 8cm. a) sufficient length of walls in each direction, preferably they are all carriers. b) Have a floor which tends to be symmetric, preferably square. c) Openings are small beings and preferably centered. d) depending on the thickness of the walls, defining a reinforcement system which provides content for the corners and intersection parts.	- Slenderness h / and <9. - Rectangular Units: Length must be 2 times the width. - The height of adobe should be of the order of 1/4 of its length. - The minimum height of the adobe: 8 cm. - Maximum length of the wall (between shear walls) = 12 times the thickness. - In seismic zone 4 and 3, adobe structural walls must have minimum dimensions of 20x40x10cm. - Minimum load-bearing walls of adobe thickness of 40cm for seismic zones 1,2,3 and 4. - Adobe: 20x40x10cm.	
BTC	- Maximum change in units of dimensions < ± 2 mm (40*69*90) cm. - Faces flat and rectangular blocks with 90 ° angles. - Surface litter perpendicular to the block face. Length Width Height 290 90 90(mm) 290 140 90 240 240 90 190 90 90 190 90 40							

Not Covered

As seen before for the granulometry and the density characteristics, five out of the six codes do not provide any requirement for the CEB as an earth building technique (Tables 2 and 3).
Also, as show in Table 2, Moroccan regulation is the only one specifying the slenderness of specific walls in seismic zones. It’s limited however to the structures of rammed earth and adobe. Other codes give only the tolerance limits of the dimensions of the basic units of construction (Unit of rammed earth, adobe brick or brick CEB) . They are less demanding regarding the tolerances of construction systems and therefore, the architectural design [18].

According to the standard by CraTerre, The compressive resistance of the adobe masonry should be determined by tests on walls and test equipment *in-situ*. Also the shear resistance of the adobe masonry should be determined by compressive testing along the diagonal of the wall [3].

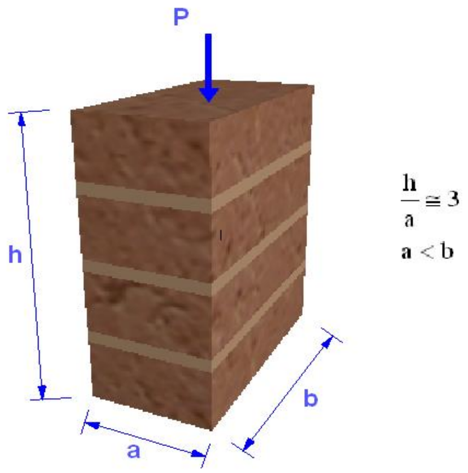

Figure 1: Muret for compressive crushing test.

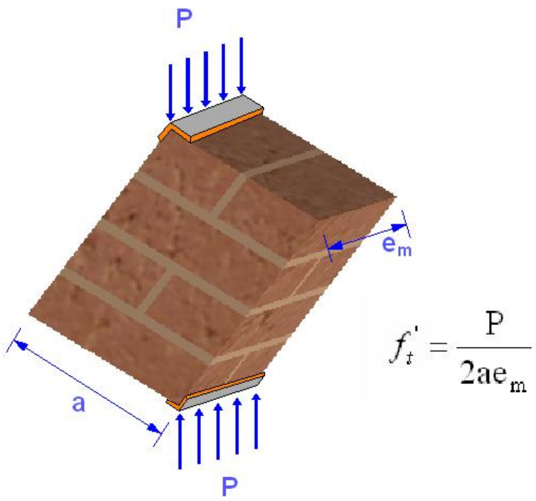

Figure 2: The shear resistance of masonry adobe.

The formula to calculate these resistances are giver by CraTerre as :

The ultimate stress from tests on walls : $f_t' = \frac{P}{2ae_m}$

The allowable shear stress : $V_m = 0.4 f_t'$

The design shear stress : $V_m = 0.25\, kg/cm^2$

Table 3: Comparative study of compressive and shear resistances (Figures 3 and 4)

		Indian Code	Nepal Code	New Mexico Code	New Zealand Code	Peruvian standards	Moroccan Seismic Regulation
Compressive strength	Rammed earth			Minimum compressive strength : 300 psi.	Walls: of> 1.3 MPa. Brick BTC vertical: 2 MPa. Brick BTC horizontally: 3,6 MPa. Adobe and rammed = uc Pressed brick = 0.5 x f'uc For bricks: the compressive strength is calculated from the flexural strength as follows: fe > 3,2 MPa (compressive strength of earth wall construction) fe = 3,5 fet (flexural tensile strength of earth)		The minimum characteristic resistance is fc = 0.5N/mm^2
	Adobe	3,5MPa compressive moy. min.	A crush strength of at least 3.5 MPa.	- The compressive strength is not given. - Qualified soil means any soil, or mixture of soils, that attains 300 psi compression strength and attains 50 psi. modulus of rupture.		Minimum compressive strength 2 Kg / cm². =	The size of the specimen is the smallest dimension of the adobe units (10x10x10cm) Minimum ultimate compressive strength is f0 = 12 kg / cm^2 Constraint calculation compressing a wall adobe (fm) is obtainable by expression fm = 0.25 fm ' Minimum value calculation stress to compressing a wall adobe is 2kg / cm^2
	BTC		A crush strength of at least 3.5 MPa				
Resistance to shear stresses	Rammed earth			Without clarification, apart from the requirements for the strength of materials.	f_n : 0,09 MPa f_n with a formal seismic guard : 0,08 MPa f_{es} : 0,07 x f_e or (70+5h)KPa (h : the height of the earthen wall in meters)		In the absence of test results of the bending tensile strength, the flexural tensile strength is taken as ftf = 0.1 fc, where fc is determined from the compressive strength test MPa Shear strength is equal to f_{es} = 0.07 f_c. In the absence of the test results, the shear strength is taken equal to f_{es} = 0.08MPa
	Adobe					V_m : 0,025 MPa	The Shear Stress admissible in masonry : $V_m = 0{,}4\ f_t'$ where the ultimate stress obtained from the test on walls $f_t' = P/2ae_m$ where the design shear stress : V_m = 0,25 *kg*/cm^2 (See Figure 3)
	BTC						

Not Covered (shaded cells)

1 Psi = 0,006894 MPa

1 N/mm^2 = 1 MPa

1Kg/cm^2 = 0,0981 MPa

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Table 4: Comparative study of the limit risk tolerance (Coefficients)

	Indian Code	Nepal Code	New Mexico Code	New Zealand Code	Peruvian standards	Moroccan Seismic Regulation
Rammed earth		- Tolerances of -10 mm in length, -5 mm width and ± 3 mm thickness The seismic areas are classified according to the risk of damage: - Zone A: Risk of collapse and widespread heavy damage - Zone B: moderate injury risk - Zone C: Risk of minor damage. The buildings are to be built on hard floors (0.2 MPa), medium (between 0.15 and 0.2 MPa) and low (0.1 to 0.15MPa). It is dangerous to build on weak soils (0.1 to 0.05MPa).	- Without clarification, apart from the requirements for the strength of materials and form of reports relevant to the walls, as in the degree of seismic risk sector - Some precautions to follow: the steel reinforcement bars and steel fasteners between earth walls and other elements, such as wooden frames and sandpits. - Limits the number of shrinkage cracks. - Requires sampling tests of compressive strength for the adobe and adobe, and sampling for testing MOR adobe and adobe pressed. - Authoritative heights indicated in a very detailed table as a function of seismic risk.	- Seismic coefficients based on zoning: between 0.4 and 1.2. - Seismic Zone safety factor <0.6: Wall Elancement = 10, the slenderness of the wall = 12. - Seismic Zone safety factor> 0.6: Wall Elancement = 6, the slenderness of the wall = 8 - Wall opening <33% of the width of the brick, Or, 11cm diameter brick, or 0.95 cm2. - Estimation of the lower 5% value determined with 75% confidence. - A wall meets the performance criteria if it does not reduce its thickness of more than 5%, nor more than 30 mm at any time during its life. - Holes in walls <200 mm. - Supply systems not to insert in the central third of the wall and the thickness is <10% of the thickness of the wall. - Horizontal position of a building ± 30 mm of the specified element or specified in the plan at its base or at the floors. - Deviation from vertical to total height of construction (of the base) ± 25 mm. - Type in a stage of a vertical line through the base of the organ: ± 25 mm 3 m high or ± 0.1 times. - Relative movement between the supporting walls of adjacent stages which are intended to be in vertical alignment: ± 30 mm. - Deviation (arc) of the line in the plane, in all lengths up to 10 m: single curvature ± 30 mm. - Deviation from the specified thickness of the joint of the bed: ± average of 30 mm, while length of 3 m. - Deviation from wall Thickness : -20 mm et+40 mm.		
Adobe	Each block can be reinforced with 10 mm deep. The reinforcement zone should be limited to 25% of the surface area, and it is preferable to have at least one reinforcement per side. The compressive strength of the block does not fall below the minimum average of the compressive strength of more than 15%.				- Schools, hospitals, local and municipal government - Utilization factor: 1.2. - Dwelling houses and public constructions: Factor: 1.0. - The seismic action is represented by a lateral force: H = S x U x C x P where, C represents the percentage of weight to be applied laterally as seismic load. C is dependent on the seismic zone in which the property is situated. In the highest seismic zones, C is equal to 0.20. The soil factor, S, is 1.00 if the soil is good (rock or very dense soil) and 1.20 when the ground is soft or intermediary. The use factor, U, is 1.00 for houses and 1.20 for buildings such as schools or medical facilities. The weight must include 50% of the live load). P is the total weight of the construction. Reinforcing materials: sticks, adobe with wooden slats, steel in concrete collar beams and columns.	- 0,25 : Coefficient to be applied to the compressive strength. - 0,4 : Coefficient to be applied to the resistance to shear stresses.
BTC						

3. Analysis and discussion

Few studies addressed technical structures and analyzed in depth the materials and their implementation to specific dimensions anti-disastrous. The best known and advanced codes are those identi[illegible]nd discussed previously. When these codes and regulations exist, they all share the basic conditions of [illegible] development. Indeed, they all started as immediate response to an earthquake disaster that required in emergency a regulatory framework that secures the constructions.

Table 5 defines the type and importance of strengthening, according to the geometrical wall dimensions used as a basis in the Moroccan Regulation:

$$\left(\lambda = \frac{t}{h} \right)$$

Where ‘t’ is the thickness of the wall, and ‘h’ is wall height.

The Moroccan regulation does not bring innovative requirements that combine modern and contemporary technological inventions to the cultures specifically to earth and local knowledge holders of solutions adapted to the human and his environment, the concept of sustainable development.

The Nepal, Peruvian and Moroccan Regulations are technical and regulatory documents rather than a development of the earthen’s potential, and its promotion in the construction sector in rural and urban areas, as its stated in 'Foreword' section. Indeed, these Regulations which are likely influenced by the historical heritage deal with the traditional construction techniques, mainly the rammed earth, adobe and cob. None of these codes deals with compressed earth block (CEB) and stabilized compressed earth block (SCEB) as modern technique with both advantages of adobe and rammed earth, recognized and proven by numerous research studies.

Table 5: Type of reinforcement of a wall according to its elancement (slenderness)[17]

Elancement wall λ	Reinforcements required
$\lambda \leq 6$	Chainings
$6< \lambda <8$	Chainings + horizontal and vertical reinforcing elements at the junctions of walls
$8< \lambda <9$	Chainings + horizontal and vertical reinforcing elements throughout the wall

The codes can be classified whithin three categories depending on their coverage of the construction techniques:

- The New Zealand Code provides three documents that deal with almost all the techniques including the main three which are the rammed earth, adobe and compressed earth block.
- The Moroccan Regulation, the Indian standard code and Nepal code are in an intermediate class. The first consisting of two documents, covering the traditional techniques of the country: rammed earth, adobe and cob. It does not, however, cover new techniques such as compressed earthen block CEB. The Indian standard is interested in stabilized bricks (adobe bricks), but does not cover neither the cob nor the compressed earth blocs. The Nepal code regulates traditional masonry raw earthen-based without differentiating between these three types of construction.
- The Peruvian standard in class 3 is exclusively dedicated to the adobe brick.

Codes are strongly inspired by the local constructive specificities and cultures. Their nature, scope and perspective, reflect the living context. This vision plays a lot in the standardization of techniques and proposed solutions. The examples of India and Morocco are significant. They both represent countries with two different perspectives: the first one projected towards the industrialization of the material through the CEB (modern technology and efficient), while the second one has a more conservative vision of the material (rammed earth and adobe).
In the codes analysis, there is a divergence in the techniques, materials, and regulated construction systems. Furthermore, the requirements of the Moroccan regulation indeed have some similarities with the other codes, only on the progress of the element and strengthening and improving the tolerance limits and security factors. The same goes for the Peruvian code and also with CRA Terre references [3].
The Moroccan regulation is the only one of these six codes that specifically studies the seismic hazards in buildings on earth thanks to the earthquake of El Hoceima in 2004 that triggered the development of this regulation.
The Peruvian code tries to find technical solutions by combining homogeneous reinforcing materials and additives for stabilization, being more natural, as maximum to be bio resourced whereas the Moroccan regulation prefers the reinforced concrete and modern engineering in the improvements.
The Indian Code also brings proactive solutions in line with the socio-economic context, and by encouraging stabilized compressed earthen blocks. The country has decides to promote an economic and environmental material in the production of habitat. The industry of this material as well as presses and equipments has invested, among others, with the establishment of specialized laboratories which have enabled the scientific and experimental research progress (Laboratory Earth Euroville - Serge Maini).
The commitment of Morocco in the construction techniques with rammed earth and adobe, traditionally used in the several places of the Moroccan architecture and construction, is among the reasons that prevented the prospective vision and development of other earthen material techniques such as the compressed earth block (CEB). This option consequently makes the regulation more conservative.
Furthermore, some codes are likely a balance between mandatory safety requirements to ensure, and the duty of protecting heritage and remarkable sites. It's the case of the Indian and the Peruvian standards.

4. Concluding remarks

The security of environmental building as defined in regulations proves to be one of the main obstacles to the use of earth bricks in the construction sector. It crystallizes, as explained in this article, the intelligence required for a sustainable and environment-friendly habitat, as well as for a better guarantee to perpetuate cultures and earth architectural tradition. The few studies and specific scientific researches in Morocco, showed that the architectural heritage is by nature seismic-proof. But these assets have not been incorporated into that regulation.
Indeed, human foundations within the architectural heritage, namely, monuments, groups of buildings and sites [12], are living testimonies of cultural forms and smart groups. They capitalize complex and constructive organizational skills adapted to different conditions, circumstances and conjunctures companies, sites and territories. The recognition of the value of these entities driven by international bodies such as UNESCO, unequivocally demonstrates their degree of importance.

Security parameters are apparently not standardized aver all codes or at least being uniform. The compressed earth block (CEB) does it considered by specialized scientists is not covered by five out of the six codes. Also, except the Moroccan regulation, other codes give only the tolerance limits of the dimensions of the basic units of construction. They are less demanding regarding the tolerances of construction systems

While ensuring the safety of property and human lives, and the minimum technical conditions to be observed for an earthen habitat, the seismic code thereon should :

- Be financially accessible ;
- Capitalize all the existent know-how ;
- Consider the seismic local cultures ;
- Not be limited to the engineering of the earthquake ;
- Integrate the urban environment as well as the environmental context and climate ;
- Consider the materials as innovative development tools.

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