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URBISTICS PROJECT

LOCAL MATERIALS

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Introduction

The housing crisis is one of the most serious to hit nowadays more than half of the Tunisian population that are concentrated around new cities, in neighborhoods composed of indecent spontaneous habitats created from scratch since the existing way of building costs a lot.

This high cost of the building is mainly due to the share important building materials imported or using at some level of their production of significant energy. The prices of these materials therefore depend on the international market constantly destabilized by the recent energy crisis years. To produce housing at lower cost, it is important therefore to circumvent the influence of the cost of energy by upgrading local building materials.

Our study will be divided into five chapters.

The first, will present the local materials usable in the building, the difference between them, and their valorization. Chapter two will present the sizing calculations of various structures based on a standard SNHLM plan. chapter three, the economic calculation tables will be presenting the building costs, as for chapter 4 it will present the analyzes and comments on the results obtained. Finally the chapter 5 concludes and will propose subsequent studies to follow this project.

Chapter 1 : Bibliographic review

1.1. Introduction

Local materials are a various and large quantity of elements that existed with the earth's nature in this chapter we will detail the information about the used local materials in buildings.

1.2. Local materials

Local materials are the resources that can be found readily in large quantity at a particular location or area at a certain time. It could also be referred to as materials that can be used to fabricate a finished element. These materials however could be abundant in some area but not available in another. The availability may largely be dependent on geographical location of the area as well as the chemical and physical components of such materials. The paper critically appraises some local material available in south west Nigeria. The investigation revealed such materials as laterite, textile, bamboo, mosaic, mats stones, dye, timber, tusks, snail shell, cow dung, cowries'caneand mud.

The most common standard used (1), defines local materials in MR Credit 5 as "Building materials or products that have been extracted, harvested, or recovered, as well as manufactured, within 500 miles of the project site for a minimum of 10% or 20%, based on cost, of the total materials value."

1.2.1. Cork

Figure 1-1 Cork (1)

The gradual increase in the energy cost of certain construction and insulation materials, requires a return to the use of local materials. Known for its abundance, cork has a very important part among these materials and especially insulation materials.

To provide energy recovery from the cork material, several research programs have been launched to study the thermal behavior of this material. For this, a heat transfer modeling based on the principle of electrical analogy is developed, applied to a passive monolayer and multilayer system with different thermophysical properties and also to a granular sample limited by two metal plates assimilated to a metal material sandwich. granular metal. Cork is a natural product, obtained from the bark of the cork oak. It is a material resistant to compression, unreformable and hardly flammable. Cork is also a good sound insulator. It comes from the renewable bark of the cork oak tree which grows in various regions of the Mediterranean basin. Cork, a passive porous material, has important characteristics that make it both useful and necessary in several branches of industrial activity.

Benefit

The measurement results obtained give these conclusions:

- The analysis models are well approximated by the parametric identification method and the experimental results are comparable to those of the proposed models.

- The thermal properties of cork are representative of an insulating material with high thermal performance. In addition, this material behaves as a good insulator both in the compact state and in the granular state. It can thus be used to ensure incomparable interior comfort and overall high thermal inertia without resorting to a heating and air conditioning system which penalizes in terms of costs.

Origin

There are about 2,200,000 hectares of cork (2) forest worldwide; (2) 34% in Portugal and 27% in Spain. Annual production is about 200,000 tons (2); 49.6% from Portugal, 30.5% from Spain, 5.8% from Morocco, 4.9% from Algeria, 3.5% from Tunisia, 3.1% Italy, and 2.6% from France. Once the trees are about 25 years old (2) the cork is traditionally stripped from the trunks every nine years, with the first two harvests generally producing lower quality cork. The trees live for about 300 years (2).

The cork industry is generally regarded as environmentally friendly. Cork production is generally considered sustainable because the cork tree is not cut down to obtain cork; only the bark is stripped to harvest the cork. The tree continues to live and grow. The sustainability of production and the easy recycling of cork products and by-products are two of its most distinctive aspects. Cork oak forests also prevent desertification and are a particular habitat in the Iberian Peninsula and the refuge of various endangered species.

1.2.2. Laterite

Origin and Use

Figure 1-2 bricks laterite (3)

Laterite is both a soil and a rock type rich in iron and aluminum and is commonly considered to have formed in hot and wet tropical areas. Nearly all laterites are of rusty-red coloration, because of high iron oxide content. It is a very widespread material both in Africa and in the world, which gives it a tradition among the oldest known construction materials.

Historically, laterite was cut into brick-like shapes and used in monument-building. After 1000 CE, construction at Angkor Wat and other southeast Asian sites changed to rectangular temple enclosures made of laterite, brick, and stone. Since the mid-1970s, some trial sections of bituminous-surfaced, low-volume roads have used laterite in place of stone as a base course. Thick laterite layers are porous and slightly permeable, so the layers can function as aquifers in rural areas. Locally available laterites have been used in an acid solution, followed by precipitation to remove phosphorus and heavy metals at sewage-treatment facilities (4).

<u>Examples</u>

Some countries continue to use laterite such as India, Taiwan and many African countries. We can mention the temple of Angkor Wat (in Cambodia) as well as the Royal Palace of Abomey entirely in laterite. In Africa, rural areas use earth (mud clay, laterite) for the construction of dwellings while in urban areas laterite tends to disappear in favor of other "modern" materials.

Figure 1-3 Laterite used in india (5)

1.2.3. “Géobéton”

Figure 1-4Géobeton used in construction (6)

Geobeton is a material that has only been in use for a few years and is actually a material that requires very little cement with certain dyes and coarse sand or local earth or stabilized earth.

Geobeton is a material that has already proven itself in the area of impermeability, durability, reliability, aesthetics and cost efficiency.

Geobeton is particularly beneficial for certain countries, especially for developing countries, in particular Senegal, which do not have sufficient cement resources and even if cement exists, it remains very expensive (7).

Working principle

Added to a part of cement (+/- 5 to 10%) (6), the geo-concrete brick is generally lapped with small manual presses. It is a local and ecological building material. Traditional concrete construction, however, requires teams of careful masons because the bricks, once assembled, remain visible.

The geo-concrete technique is very widespread in Africa because it uses earth (laterite) as the main ingredient. Geobeton brick masonry is an ideal method of construction and perfectly suited to the African climate.

1.2.4. Sheep Wool

Figure 1-5 Shepp wool for construction use (4)

A study explores alternative usage of sheep wool as a construction material beyond its traditional application in the textile industry. Another goal of this research was to study the feasibility of replacement of commonly used thermal insulations with natural and renewable materials which have better environmental and primary energy values. Building physics, energy and environmental characteristics were evaluated and compared based on hygrothermal simulation and ecological balance methods. The observations demonstrate that sheep wool, compared with mineral wool and calcium silicate, provides comparable thermal insulation characteristics, and in some applications even reveals better performance.

Sheep wool is a natural, renewable, and sustainable material, and it is important to ensure that it is used in an environmentally friendly manner. This local materialprovides sustainable answers for all requirements of contemporary architecture as appropriate materials for insulation and energy saving in buildings. Based on the results of this study, it can be concluded that thermal insulation from sheep wool provides comparable characteristics with convectional materials, and in some applications, even performs better (1)

1.2.5. Bamboo

Due to a distinctive rhizome-dependent system, Bamboos are one of the fastest growing plants in the world and their growth is three times faster than most other. As a building material, it has high compressive strength and low weight has been one of the most used building materials as support for concrete, especially in those locations where it is found in abundance.

Bamboo as a building material is used for the construction of scaffolding, bridges and structures, houses.

Figure 1-6 Bamboo ysed in bridge constructon (8)

They are renewable and extremely versatile resource with multi-purpose usage. Among many uses of bamboo, Housing is one of the major areas' applications especially in the wake of residential shortages around the globe.

Bamboo as a building material is conventionally associated with the region of Southeast Asia and South America where climate is best suitable for its cultivation. In many of the nations, bamboo is used to hold up suspension bridges or simply make places of dwelling.

1.2.6. Other Materials

Recyclable materials

Recycled concrete aggregate (RCA) is one of the alternatives to virgin material that has engendered interest in recent years, especially as an alternative aggregate. There are limited available studies assessing the suitability of RCA as a base or subbase material in pavements. Therefore, the present research describes different laboratory experiments to determine the possibility of using RCA as alternative subbase material for road pavement in order to conserve natural resources and reduce geoenvironmental effects. Modified compaction tests, particle-size distribution, Los Angeles abrasion, Atterberg limits, specific gravity, California bearing ratio, and repeated load triaxial tests were carried out for that purpose. RCA was also reinforced with both biaxial and triaxial geogrids for material optimization. Shakedown analysis and parametric investigation using some constitutive models were conducted for further assessment. The physical and geotechnical properties showed that RCA is strong enough and fulfills the local road authority requirements to be used as a subbase material. The resilient modulus values of the reinforced RCA with geogrid was higher than the unreinforced RCA; in addition, the permanent deformation properties of reinforced RCA with geogrid was found to be smaller than that of the unreinforced RCA. The shakedown ranges varied from A to B, which indicates that RCA can be used as pavement subbase material when it is compacted with moisture content less than the optimum. The parametric investigation showed that some constitutive models are capable for assessing the behavior of both reinforced and unreinforced materials (1)

Timber

Timber is used in doors, windows, cabinet, cupboards, shelves, tables and railings etc. Timber is also popularly used in the form of plywood & raw wood. Products like ply blocks and ply boards. Heavy patterned doors and windows are made of solid wood/Timber to provide the strength, toughness and durability. Timber is, also, used for the construction of scaffolding, bridges and structures, houses.

Mud

In the construction industry, mud is a semi-fluid material that can be used to coat, seal, or adhere materials. Depending on the composition of the mud, it can be referred by many different names, including slurry, mortar, plaster, stucco, and concrete.

Design Guidance and Development of Construction Stormwater Technologies

As one of the biggest sources of non-point pollution, soil erosion has become an increasingly important topic on US construction sites. Erosion and Sediment Control (ESC) practices are commonly used on construction sites to reduce soil erosion and sediment release (9)

1.3. Valorization

The choice of building materials is an essential step for the smooth running of construction, building or renovation work. However, it is essential to study certain factors beforehand in order to choose the right material.

For this reason, local building materials are currently more popular.

Local materials are increasingly valued in home construction. Indeed, these materials have many advantages from both economic and environmental point of view as well as esthetic.

Faced with environmental issues, the use of local materials remains the best solution to reduce the carbon footprint resulting from transport. Indeed, the construction sector is responsible for more than 50% of a building's greenhouse gas emissions over its entire life cycle. (3)

As for the economic problems; by reducing transport; construction companies ensure great reductions in the total costs of the works. Moreover, some studied shows that building materials or products that have been extracted, harvested, or recovered, as well as manufactured within 500 miles of the project site results to a minimum of 10% and 20% reduction of the total materials value (10)

On the other side, local materials are sought because they match the local design aesthetic andgivethe building more integration with the local culture.

Also, in various green building certifications, the use of local materials increases the constructions' sustainable. (1)

However, despite all the obvious benefits, the use of local materials in construction has been limited. High-tech materials and advanced technologies; like 3D printing, Double skinned walls …; seem to be more dominating.

Nowadays, it is important to upgrade these resources by combining them with new technologies in order to comply with time, cost and quality requirements. Each geographical area offers resources in materials that it is important so it's the engineer role to know the possibilities of exploitation.

- **Co-valorization of Local Materials Tuffs and Dune Sands in Construction of Roads**

In the developing countries, the road remains the vector of economic development in the sense that it allows the opening up of whole regions and the integration of the whole territory in the economic development of a country. So, due to the distribution of population density and the vastness of the territory, the density of the road network is increasingly important in the Saharan countries.

Among the materials available in the Saharan regions are limestone encrusted tuffs. According to the studies carried out on the tuffs, one realizes that they have geotechnical characteristics which can be variable. The latter, according to the proportion of fine elements and LA values are more or less accepted for use in roadworks especially in roads subject to dense and heavy traffic. To enhance the performances of this local materials, the strategy used is to combine the beneficial effects of mixing different materials and the treatment using different binders.

Figure 1-7 Dune sand (1)

1.4. Comparison between the performance of local materials

Local materials are internationally valued since they reduce the environmental impact of the construction. Local materials such as earth, stones, wood etc ... have served faithfully in the construction of the social habitat since Millenia. it is estimated that between a third and a half of the world population lives today in earthen habitats. Often assimilated to "poor man's material", denigrated by people and authorities, the land is one of the finest building materials available. it is far from having served, as some think, only for construction of rural or simple dwellings: entire towns (Jericho (Israel), Chanchan (Peru), etc.), great monuments, aqueducts and many palaces were built using earth. The pyramids of Saqqhara (Egypt) attest to the confidence that the pharaohs rightly placed in the durability of earthen constructions. Like any other building material, earth must be optimized thanks to the wealth of knowledge currently acquired in geotechnics and the science of materials. Natural stones are, like earth, widely used in construction for their remarkable hardness.granite, basalt and even products of their deformation are used for the aesthetic aspect that they present. Wood is also an expanded resistant material known in the world but whose use in construction is strongly discouraged nowadays because of the ecological imbalance created by desertification in Sahelian countries. Those three materials compared to the other ones are the strongest and most used worldwide but the difference between them shows up in the cost,aesthetic and quantity settings, **aesthetically** wood and stone are the best materials to be used,earth is the best in terms of **cost effectiveness** since it is distributed in large quantities and in many places around the world.building with woods can be done in many places since It is found in most habitable places on earth, and has proved to be a **sound building** material for thousands of years also It is relatively **inexpensive**, unless you import a rare species for a specially designed home .Wood is **easy to build** with, and doesn't require much **in the way of heavymachinery** or tools. It can be worked into just about **any shape** that a builder may require.However, contrary to earth it is **weak** in terms of **durability** since it can Be flammable and susceptible to rot and decay, wood is one of the least durable building materials for exterior building. Insects such as termites and carpenter bees can also cause great damage. Moreover, in terms of **maintenance** Homes with wood exteriors need to be painted or sealed on a fairly regular basis.Contrariwise Stone is **long lasting** in terms of **durability** since it is able to withstand fire, water damage, and most natural disasters with very little destruction. This is the reason stone monuments of many ancient civilizations still survive today. Stone is also **very strong**, and for this reason is often used to create the foundations of buildings.Like wood, stone can be found in most places on earth.Stone can often be procured at a fairly **low price**, though building with it may be another matter. However, building with stone can also be **expensive**, since the material is **heavy** and **more difficult** to work with.it is also **Non-malleable:** Where wood could be shaped to suit most situations, stone is more difficult to work with. It can be cut and shaped, but the tools and time required are extensive. Added to that, it is **Heavy**: Working with large pieces of stone usually requires heavy machinery.

Figure 1-8 different loacal materials used in building (1)

1.5. Conclusion

With the advancement of technologies and rapid improvement in building materials to keep up with the pace of urbanization, the construction methods and technologies has been facing challenges due to unsustainable aspects of some building materials. This has put stress on the environment and has also increased consumption of energy and other degradable resources. On the hindsight, this has also created opportunities for innovative and unconventional resources to emerge by reinventing the traditional building materials and using it in an intelligent way!

Chapter 2 : Study of structural variants for the construction of low-cost housing

2.1. Introduction

The perfect way to show the value of the local materials in construction is to provide an example based on detailed calculations that prove the efficiency of its use. In this chapter we will study two forms of roofing combined with the different cases of possible masonry, it will be about showing that the various variants of the examples structures hold both from the point of view of resistance and stability. Our approach, in each case, will be by carrying out a structural analysis, sizing and determination of the quantities of materials required.

2.2. The used case

It is a project in Senegal « Dakar » designed by the national society of moderate rental housing S.N.H.L.M (société nationale des habitations à loyer modéré).

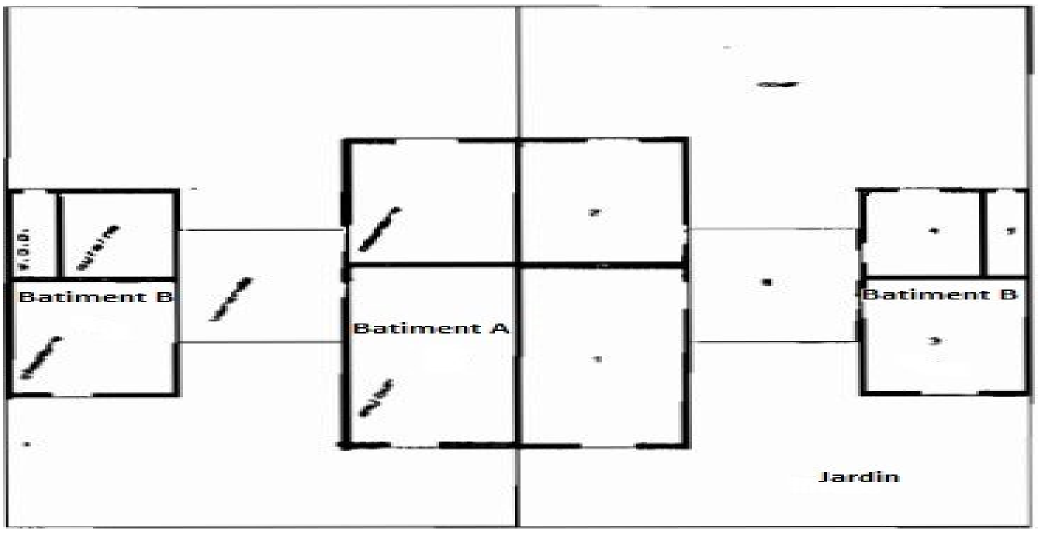

Figure 2-1 Basic plan (4)

2.3. Roof shape analysis

2.3.1. Roof covering made from Geobeton bricks (situation1)

It is necessary to rest the roof on a vertical support in stone, wood or brick. The roof preferably follows a chain curve or a parabola to avoid the occurrence of tensile forces. This form is respected throughout construction and checked using tension wires which help in positioning the bricks and which must be light enough to be able to hold adhesion simply to the mortar which must be drying fast and good adhesion to the earth.

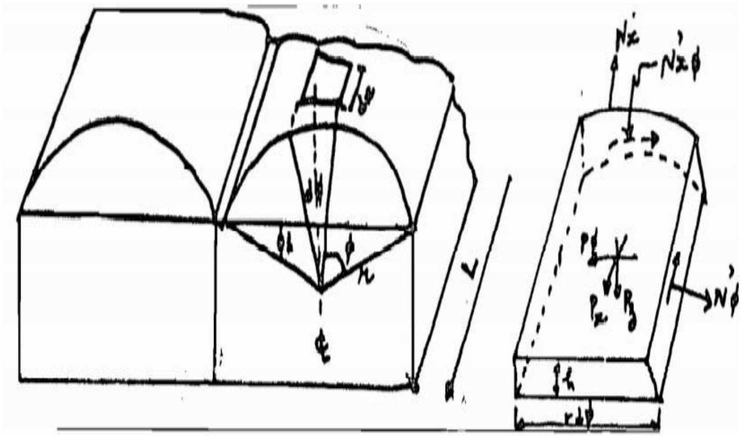

Figure 2-2 Studied case of the roof (4)

2.3.1.1. Structural analysis

Reference (11) gives the general stress equations.

a) Load calculations according to the DTU (11)

Due to the lack of analysis rules specific to the structures in Geobeton, it was used those relating to concrete blocks cement, in particular the French standardization DTU Unified Technical Directives.

- Self-weight of Lateroc blocks =$10 \times 14 \times 29\ kg/m^2$
- total weighted load =$1.35 \times 632 \times 0.00981 = 8.37\ kN/m^2$

b) Verification of the resistance and stability of the roof

Lateral compression (11):

$$N_\phi = p_d \times r \times \cos(\phi\kappa - \phi) \quad (1)$$

- Nϕ : Lateral load compression;
- r : radius of the arch generating the roof ;
- ϕκ : half of the tight angle of the arc ;
- ϕ: the angle at the calculation point of N1 ;

A.N: r = 7.7m , ϕκ = 30°, ϕ = 30° Nϕ = 64.4 KN/m

For a thickness of 12 cm we have a load stress of: $\sigma = \frac{64.4}{120} = 0.53$MPa

The average resistance of the bricks on the edge published in the reference [3] is of the order of 5 MPa. Therefore, the safety factor is:

$$C = \frac{R_C}{\sigma} = \frac{5}{0.53} = 9.43 \quad (2)$$

Shear Stress (11):

It is the shear in concrete that is most to be feared. The straining effort is given by:

$$Nx_{\phi} = p_d \times L \times \left(1 - \frac{2x}{L}\right) \times \sin\left(\emptyset_k - \emptyset\right) \quad (3)$$

L: is the length of the building;

- ⇨ Nx_{ϕ}= 8.37 × 7.7 × (30) = 32.2KN/m
- ⇨ $\sigma = \frac{32.2}{120}$= 0.26MPa

The shear strength in the mortar is given by the formula :

$$Rc = 0.2 \times 1 \times 0.6 \times v_{f'c} \quad (4)$$

f'c is the motar resistance, than Rc=0.2*0.6*v30=0.66MPa and the security coefficient becomes C= 0.66/0.26 =2.53.

Longitudinal compression (11)

The compression effort is :

$$N_x = \frac{p_d \times L \times x \times \left(1 - \frac{x}{L}\right) \times \cos\left(\emptyset_k - \emptyset\right)}{r} \quad (5)$$

A.N: N'x=[8.37*7.7*(1-0.5)]/2 = 16.1 KN/m

The loaded stress then becomes σ = 16.1 / 120 = 0.13 MPa, the safety coefficient becomes:

$$c = \frac{5}{0.13} = 38$$

The safety coefficients vary from 2.53 for shear to 38 for compressions

- ⇨ We can conclude that the material is adequate from a strength point of view. The overall stability of the roof is ensured, especially as the vault shape allows the elements to self-lock.

2.3.1.2. Estimation of the quantity of the required materials

a) Lateroc Geoconcrete bricks 10 × 14 × 29

Building A: S1 =2*(2*r*ϕk *k*L)=2*(2*7.7*30*3.14*7.7)/180 =124 m^2

Building B: S2 =2*(2*7.7*30*3.14*5.2)/180= 84 m^2

Side covers of buildings:

$$S_3 = \frac{8\times(r^2\times(2\times\emptyset_k - \sin(2\times\emptyset_2))}{2} \tag{6}$$

S3 = 42m^2;

S = S1 + S2 +S3 = 124.1 + 84 + 42 = 250$m^{2;}$

The total number of bricks for a consumption of 25 bricks of m^2 is 6250.

b) Water proofing and bonding plaster for bricks

Quantity estimation of mortars for exterior and interior plaster : the composition of this mortar must be such as to ensure the waterproofing of the roof. Reference (12) used with success, on a dome built at the E.P.T. a volume of cement for four volumes of sea sand.The volume of mortar required for a thickness of 1cm is V = 2 * 0.01 * 250 = 5 m^3 Either 1m^3 of cement for 4m^3 of sand Brick bonding mortar, SENAC technical documents recommend a quantity of 9.5 liters / m^2. Therefore, the total mortar volume becomes V = 0.0095 * 250 = 2.375m3.

The composition of this mortar according to reference (12) is:1 volume of lateritic sand (σ 50 = 2 mm} for 2 volumes of sand of sea and 0.67 volume of cement for a joint thickness of 3 cm.

We therefore have:

- 0.65 m^3 of lateritic sand ;
- 1.3 m^3 of sand sea ;
- 0.43 m^3 of cement ;

2.3.2. Fiber cement roofing on a frame made by wood(situation 2)

The frame of building A has a double slope at the hips with an area to be covered of 72 m^2 and that of buildings B in lean-to with an area of 54 m2. We will present the results of buildings B and A in the following tables.the concluded results are based on detailed calculations obtained from reference (13).

Used materials:

- Fiber cement type OGL 2.00 / 0.92 m, thickness: 4mm;
- weight per m2 of coverage = 9 kg;
- useful surface covered by panels = 1.57 m^2;
- Red wood: density T = 700 kg / m^3;
- resistance to bending:σb = 60.82 MPa;
- compressive strength perpendicular to fibers:σc = 6.0 MPa;
- 2 * 1 m hardboard false ceiling;

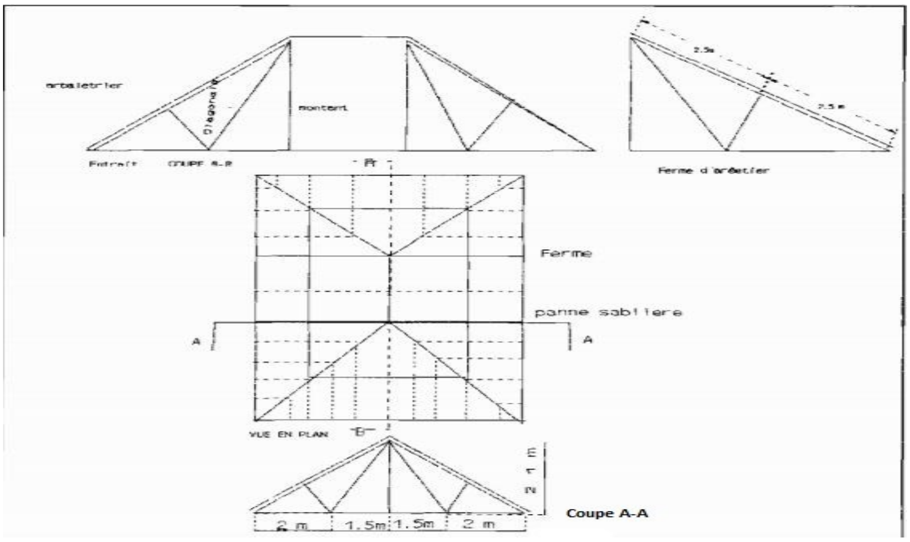

Figure 2-3 Frame (4)

The stresses in the frames were determined using the CREMONA graphic method[].

The results are in tables below:

N° des Barres	efforts dûs aux charges verticales*	efforts dûs aux vents*	Efforts Maxima*	
			−	+
ENTRAITS				
A-4	25.4	4.1		29.5
4-5	16.8	2.3		19.1
5-6	16.8	2.3		19.1
6-B	25.4	-2.8	-2.8	25.4
ARBALE-TRIERS				
A-1	-29.4	2.7	-29.4	2.7
1-2	-27.2	2.1	-27.2	2.1
2-3	-26.4	5.5	-26.4	5.6
3-B	-29.4	4.8	-29.4	4.8
DIAGONA-LES				
1-4	-8.4	-2.0	-10.4	
4-2	11.2	2.3		13.5
2-5	0.97	0.0		0.97
2-6	10.2	-5.7	-5.7	10.2
3-6	-7.8	4.9	-7.8	4.9

Figure 2-4 Results of the trusse's structural analysis (4)

n°des Barres	Charge F(kN)	F/fc x10³*	section commerciales(mm²)	portées (m)	nombres requis
ENTRAIT					
A-4	29.5	4.85		2	2
4-5	19.1	3.18		1.5	2
5-6	19.1	3.18	40x60	1.5	2
6-B	25.4	4.23		2	2
ARBALE-TRIERS					
A-1	29.4	4.9		2	2
1-2	27.2	4.53		2	2
2-3	26.4	4.4	40x60	2	2
3-B	29.4	4.9		2	2
DIACO-NALES					
1-4	10.4	1.73		1	2
4-2	13.5	2.25		2.6	2
2-5	0.97	0.16	40x60	2.1	2
2-6	10.2	1.7		2.6	2
3-6	7.8	1.3		1	2
POUR LES DEMI-FERMES D'ARETIER					
A-1				2.5	4
1-2	40 x 60			2.5	4
A-4				2.5	4
1-4				1.0	4
4-2				3.0	4
4-3				1.5	4

Figure 2-5 Dimensionning result of building A (4)

ELEMENTS	Equarrissage mmxmm	portée (m)	nombres par bâtiment	nombres totaux
Entraits	40x60	3.0	3	6
Arbalétriers	40x60	4.3	3	6
pannes	80x80	3.0	4	8
chevrons	40x60	4.5	13	26
contre fiches	40x60	2.2	3	6

Figure 2-6 Dimensionning result of building B (4)

2.4. Masonry shape analysis

2.4.1. Reinforced concrete frame with filling agglomerates of cement and sea sand (Situation 3).

1.2.4.1. Framework

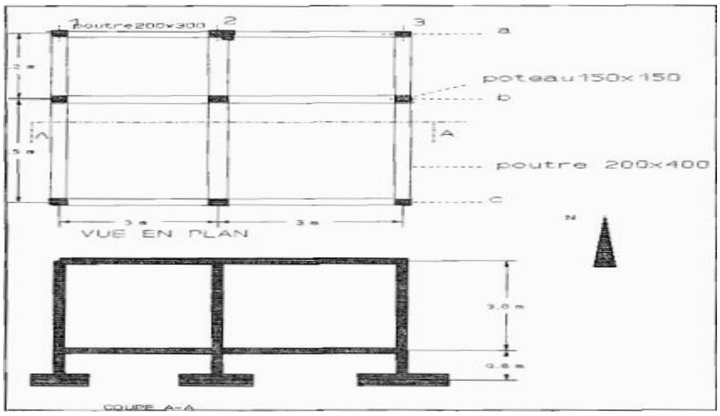

Figure 2-7 Framework result in armed concrete (4)

a- Upper chaining beam

- Beams at axes 1,2 and 3:

Based on the predimensionning of the structure: 200*400mm, the loads calculations and the moments and the shear forces calculated using the hardy cross method we have this diagram :

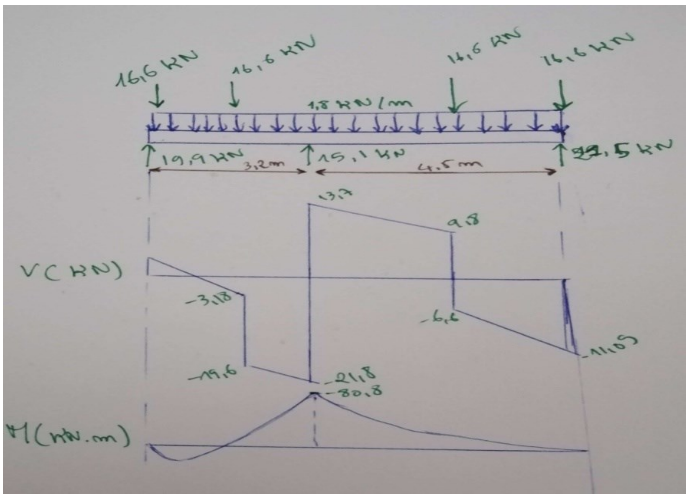

Figure 2-8 : diagram

The concluded reinforcement using BAEL is described below:

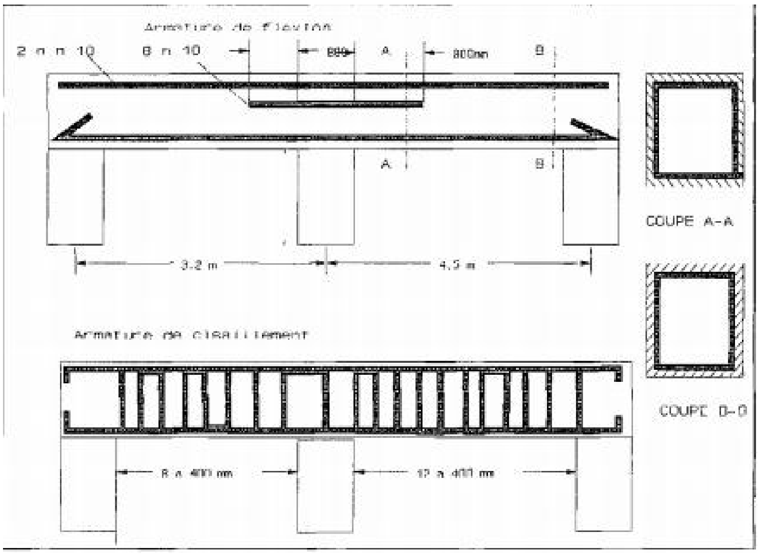

Figure 2-9 work frame (4)

<u>Calculation of the quantity of concrete required materials</u>:
formwork volume V = 3 * (7.7 * 0.2 * 0.4) = 1.848 m3
Reinforcement:
10mm bar : 3 * 4 = 12 bars of 12 m ;
8mm bar : 2 * 3 = 6 bars of 12 m ;

- Beams at axes a, b and c

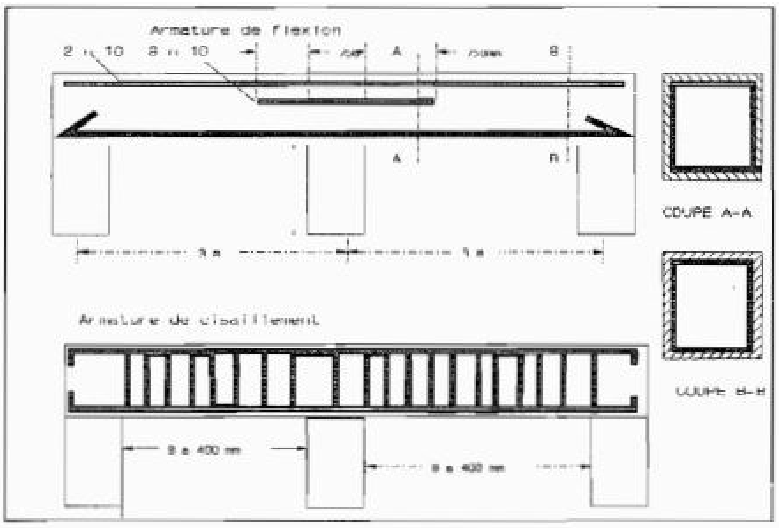

Figure 2-10 Framework (4)

<u>Calculation of the quantity of materials required concrete:</u>
formwork volume: V = 3 * (6 * 0.2 * 0.4) = 1.44 m3)
Reinforcement:
3mm bar: 3 * 4 = 12 bars of 12 m ;
8 mm bar: 2 * 3 = 6 bars of 12 m ;

a. Poles

- Loading

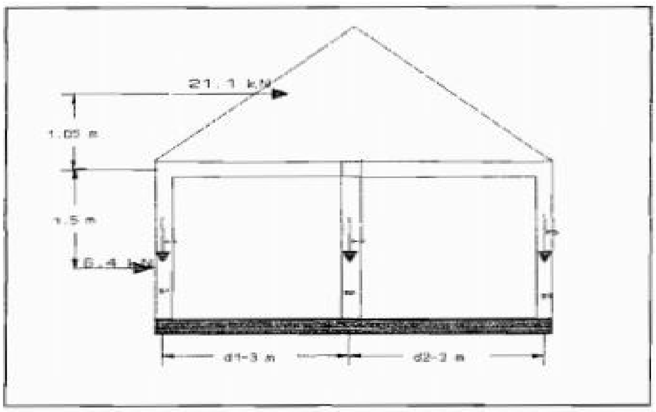

Figure 2-11 Loading (4)

- Dimensioning using BAEL

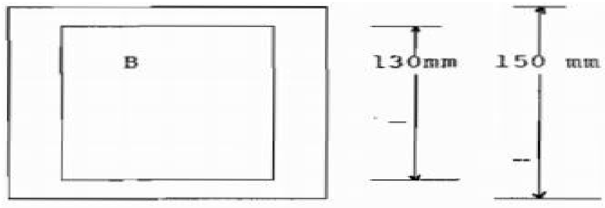

Figure 2-12 poles's section (4)

The detailed calculations gave Amin = 2.4 cm^2 so we can choose:
Longitudinal bars : 4 bars n°10 ;
Transverse bars : 30 bar frames n°8 with a 120 mm space between them ;
<u>calculation of the quantities of materials required:</u>
concrete : formwork volume = 9 * (3.6 * 0.15 * 0.15) = 0.729 m^3
Reinforcement
Bars n°10 : 9 * 16 = 144 m or 12 bars of 12 m ;
Bars n°8 : 9 *18 = 162 m or 14 bars of 12 m ;

b- Lower chain beams

- Beams at axes 1, 2 and 3

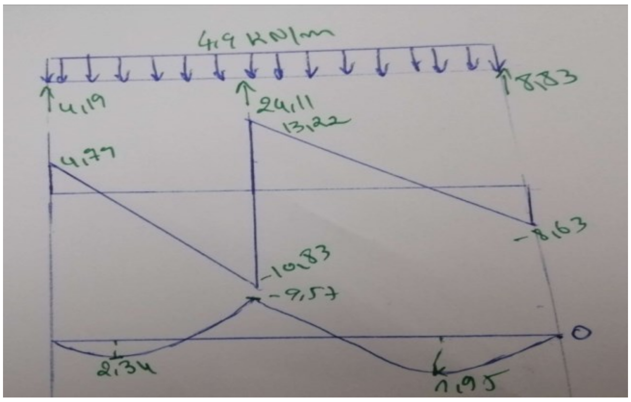

Figure 2-13 Loading

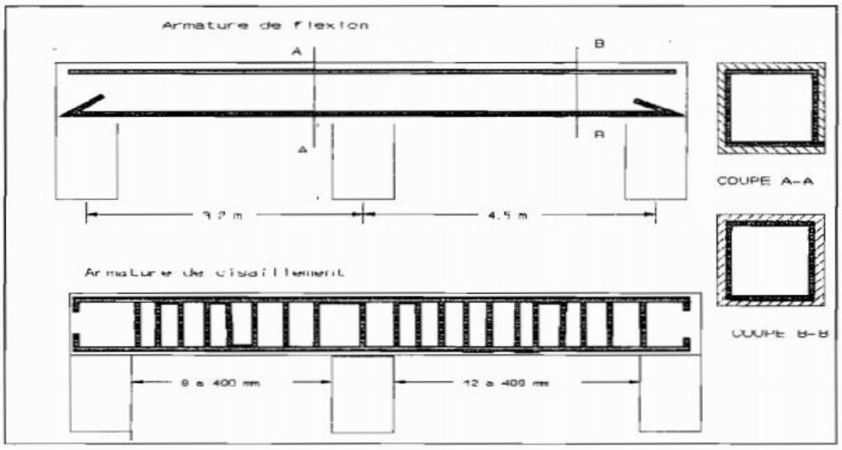

Figure 2-14 workframe (4)

<u>Calculation of the quantities of required materials:</u>

concrete: formwork volume V = 3 * (0.2 * 0.3 * 7.7) = 1.386 m^3 ;

Reinforcement: bars of 10 : 3 * (4 * 8) = 96 m or 8 bars of 12 m ;

of 8 : 3 * (1 * 20) = 60 m or 5 bars of 12 m ;

- Beams at axes a, b and c

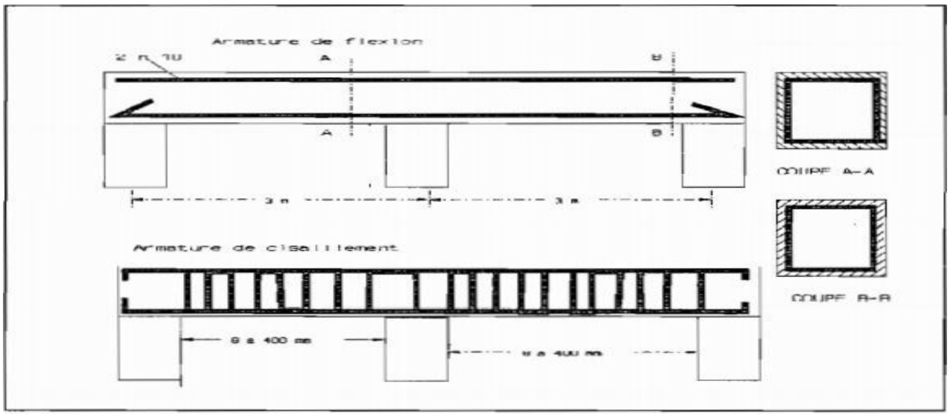

Figure 2-15 Workframe (4)

<u>Calculation of the quantities of materials required</u>

Concrete: formwork volume v = 3 * (0.3 * 0.2 * 6) = 1.08 m3 ;
reinforcement bars of 10 : 3 * (4 * 6) = 72 m or 6 bars of 12 m ;
bars of 8 : 3 * (1 * 17) = 51 m or 5 bars of 12 m ;

c- Foundation

The adapted shape is square soles homothetic to poles

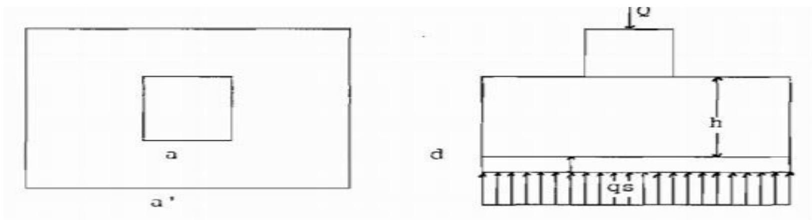

Figure 2-16 Soles shape (4)

The concluded results of dimensioning using BAEL are:

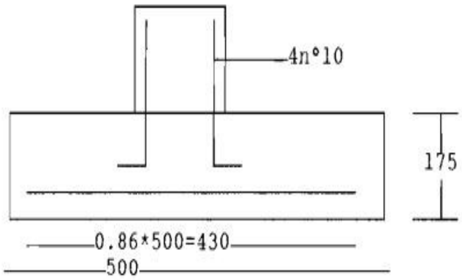

Figure 2-17 Workframe of the sole (4)

<u>Calculation of required quantities of materials</u>

Concrete : formwork volume v = 9 * (0.5 * 0.5 * 0.175) = 0.396 m3 ;

Reinforcement : bars of 10 : 9 * (4 * 0.5 + 4 * 0.5) = 36 m or 3 bars of 12 m ;

d- The lintels

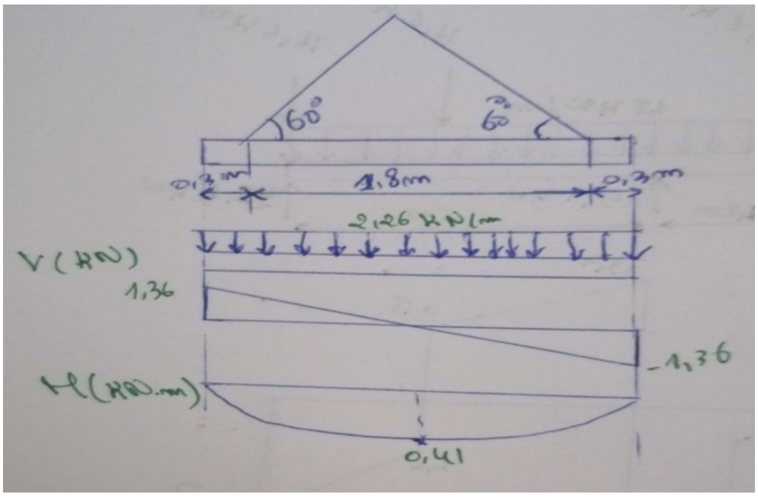

Figure 2-18 Loads

The stresses being low, we will provide 2 bars n°10 to take up the bending of lintels of section 150x150

Calculation of the quantities of materials required

Concrete: formwork volume v = 8 * (1.8 * 0.15 * 0.15) = 0.32 ml ;

Reinforcement: 10 bar: 8 * (1.8 * 2) = 29 m or 3 bars of 12 m ;

2.2.4.1. Masonry

The masonry is made up of 15x20x40 hollow agglomerates for the elevation and solid agglomerates of 15x20x40 for the base, they are dosed at 6,250 kg / m^3

a- Calculation of the quantities of bricks required
- Basement wall

S = 3 * (4.2 * 0.6) + 3 * (2.9 * 0.6) + 3 * (5.7 * 0.6) = 29.04 m2 with a number of 13 bricks per square meter of wall we have for everything 377 solid bricks.

- Wall in elevation

- East West facade (18% opening): S1 = 2 * [(7.7-0.3) * (3-0.35) (1-0.18) = 32.2 m2;
- North South facade (16% opening) : S2= 2*[(6-0.31' (3-0.35) (1- 0.16)]= 25.4 m2;
- Sitting walls (in both directions): S3= (3-0.5)*[(7.7-0.3)+(6-0.3)]= 34.7 m2

⇨ Then : S = SI + S2 + S3 =32.2+25.4+34.7 = 92.3 m2

calculation of the number of bricks

With 13 bricks per square meter, we have a total numberof 1196 of hollow bricks.

3.2.4.1. FLOOR PAVING

the paving form is made of 8 cm of concrete dosed at 250kg / m^3 which rests on a clean concrete dosed at 150 kg / m3 of 5 cm even resting on a backfill of lateritic sand of 15cm (4).

Calculation of the quantities of required materials

- concrete dosed at 250 kg/m^3 : volume v = 0.08*[(6 - 0 . 3)* (7 . 7- 0 . 3)] = 3. 374 m^3
- concrete dosed at 150 kg/m^3 : volume v=0.05*[(6-0.3)*(7.7-0.3)]=2.11m^3
- lateritic filler sand : volume v= 0.15*[(6-0.3)*(7.7-0.3)]=6.33 m^3

4.2.4.1. Coating and overlap joint

a- Coating

The use of cement and sand agglomerates requires mortar finish dosed at 350 kg / m^3 (4)to a thickness of 1 cm on every wall.

Quantity of mortars required : v = 2 * 92.3 * 0.01 = 1.846m3 ;

b- lap joint

The seat and upright joints have a thickness of 1.2 cm. That is to say for 13 liters Per square meter of coverage, we have : v = 0.013 * (92.3 + 29.04) = 1.58 m^3.

2.4. GEOBETON WALL ELEVATION

2.4.1. arch roof case (situation 1)

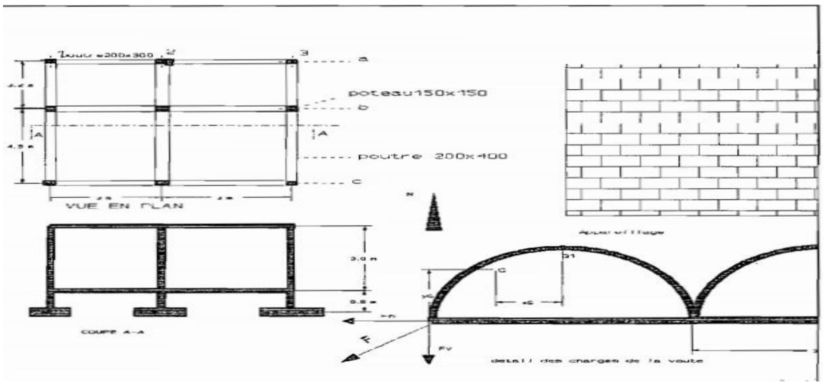

Figure 2-19 geoconcrete frame (4)

a- Chaining

Based on DTU, calculations are made in order to determine the chaining dimensioning.

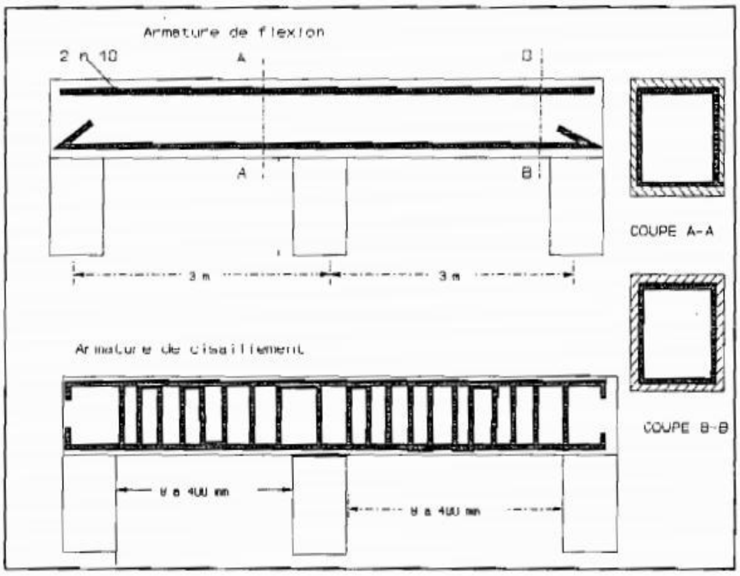

Figure 2-20 frame (4)

<u>Calculation of the quantity of required materials :</u>

Beams on the North South concrete facade:

- Formwork volume: $V = 2*(0.2*0.2*6) = 0.48\ m^3$;
- reinforcement bars of 10 : 2*(4*7)= 56 m so 5 bars of 12 m ;
- reinforcement bars of 8 : 2* [2*16(0.3+0.4)] = 44,8 m so 4 bars of 12 m ;

Beams on the East West concrete facade:

- Formwork volume = $2*(7.7*0.2*0.2) = 0.616\ m^3$
- Reinforcement bars of 10 : 2*(4*8)=64 m so 6 bars of 12 m ;
- bars of 8 : 2*(1.4*20)=56m so 5 barres of 12 m ;

b- Masonry

It is carried out as a load-bearing wall of geo-concrete laid out in pIat Chaining vertical to the right angles is executed as indicated on the figure 3-22 to avoid the occurrence of damaging cracks to the stability of the structure.The required safety factor relates to the breaking stress measured on a block he the stress under nominal c hage. We usually adopt a varying ratio between 9 and 11 for geo-concrete. The reference (14) published following compression tests on LATEROC bricks from stabilized at 6% cement an average value of the resistance of 10.6 MPa (4).

e- Calculation of the stress pressure on the most loaded brick
The load transmitted to the wall if we neglect the effect of the roof
in the east wall is Fv = 23.6 kN / m ;
A brick placed above the strip footing takes up the efforts of the roof and the self-weight of the wall.

- P = Fv + h * Pp where h is the height of the wall and Pp the weight at square meter of wall $Pp = 3.37\ Kg / dm^3$;
- P = 23.6+ (3.6 * 3.31) = 35.52kN;
- The nominal stress is therefore $\sigma = \frac{P}{l}$ where l is the width of a brick.

  σ = 35.52/0.14 = 0.25 Mpa ;
  The coefficient is therefore Fs = 10.6 / 0.25 = 42.4 ;
  ⇨ The bricks are therefore quite resistant!

Calculation of the quantities of materials required

Calculation of the total area to be covered S

- North South facade: SI = 2 [(3.6 * 6) (1-0.16)] = 36.3 m^2 ;
- east west facade : S2 = 2 '[(3.6 * 7.7) (1-0.18)] = 45.5 m^2 ;
- mitoyen wall: S3 = 3.6 * (7.7 + 6) = 49.3 m^2 ;
- Total area S = Sl + S2 + S3 = 36.3 + 45.5 + 49.3 = 131.1 m^2

➔ the number of bricks with an estimate of 35 bricks per square meter, we have a total of 4589 bricks.

c- Foundation

It is executed as a running sole under the wall. The calculation is done for one meter of wall and according to BAEL rules.

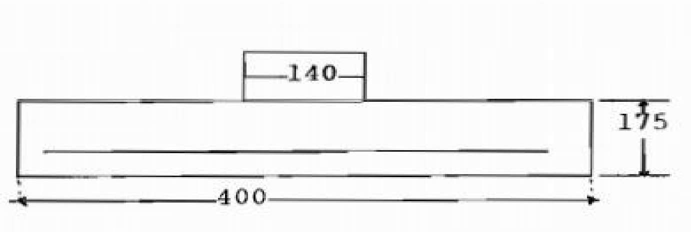

Figure 2-21 framework of the foundation (4)

Calculation of the quantities of materials required

- Concrete : framework volume = perimeter * section = [(6 * 3 + 7.7 * 3) (0.4 * 0.175)] = 2.88m3 ;
- Reinforcement : bars of 10 = 41.1 * 0.5 = 20.6 m or 2 bars of 12 m ;

d- Brick plaster and mortar
- Plaster

Plastering of geo-concrete bricks is not a systematic option. The latter mainly depends on the rain conditions and the desired aesthetic appearance. In the case where the bricks are highly compressed (use of Duplex terrablock for example) and stabilized, a simple varnishing gives a very aesthetic appearance to the wall.

- Brick bonding mortar

The quantity of laying mortar is according to the technical document SENAC (4) of 19 liters per square meter of installation. For a surface of 131.1 m^3 a volume of 2.5 m^3.This mortar can have the following composition:

- 2 volumes of sea sands;
- 1 volume of lateritic sands;
- 2/3 volume of cement.

2.4.2. Case where the roof is a wooden frame

The dimensioning of the structural work in this case is identical to case of the vaulted roof. We therefore renew the same quantities of materials.

2.5. MIXED MASONRY ELEVATION (situation 4 and 5)

Mixed masonry consists of filling the framework with reinforced concrete by geo-concrete bricks placed on the edge. The configuration practice is shown in figure below.

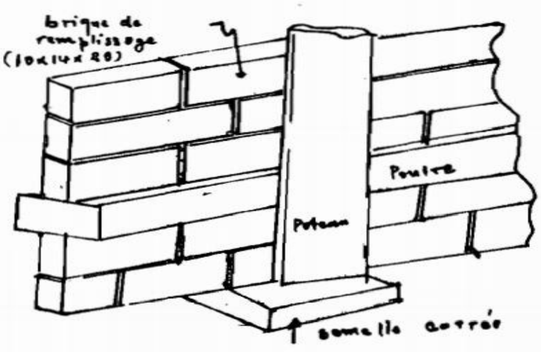

Figure 2-22 mixt case of facade (4)

The dimensions of the framework are identical to those of armed concrete performed in the part. As for the number of bricks for the filling it is equal to (22 bricks per square meter of cover) than 22 * 131.1 = 2882 bricks.

The laying mortar is estimated at 9.5 liters per square meter of pose. The total volume is therefore equal to V = 0.0095 * 131.1 = 1.245 m3.

2.6. Conclusion

All in all, the structural calculations carried out made it possible to prove the resistance and security that one can hope for designed structures. Due to the lack of standardized rules for Calculation of earthen structures we have sometimes used those applicable to mortar blocks. The quantities of mortars thus obtained will make it possible to calculate the relative cost of each solution through chapter 3.

Chapter 3 : Comparative economic study of designed housing variants

3.1. Introduction

This chapter is an accomplishment of the technical phase studied in chapter 2 by an economic study of the project.

Then, we will determine the costs of buildings A and B using the quantities of materials calculated beforehand.

The materials used are decomposed into simple elements that we can easily get them considering the unit prices we have. So, the concrete will be decomposed into cement, sand, gravel and water, the reinforcement into 12-meter bars, the wood into volumes.

3.2. Calculation of elementary materials quantities in concrete

We supposed a concrete of class Al dosed at 350 kg / m (4),

- The ratio Water/cement is 0.6
- The particle size fraction is 3
- The quantity of cement in 1 ml of concrete is 350 kg with a density of 1.162
  ➔ A volume of $\frac{350}{1162} = 0.301\ ml,$
- The volume of water required is: $0.301 \times 0.6 = 0.181\ ml$

Therefore, the quantity of aggregate is: $1 - (0.301 + 0.181) = 0.519\ ml$

The use of 1 volume of sand with 3 volume of grit, summarize the following quantities of materials composing a cubic meter of concrete:

- Cement: 350 kg
- Water: 0.181 m^3
- Sand: 0.130 m^3
- Gravel: 0.389 m^3

Note: these calculated quantities are those required without consider losses. For example, water is the material which generates the most loss, this is why the calculation of materials costs increases with the quantity of water up to 100%.

The tables from Table-annex 1 to Table-annex 10 from the annex show the quantities needed for each material for the two buildings A and B in the five following solutions:

1) timber frame roof over classic chipboard masonry
2) vaulted roof on the masonry supporting geobeton
3) wooden frame roof on the masonry supporting geo-concrete
4) timber frame roof on mixed masonry
5) vaulted roof on mixed masonry

3.3. Calculation of solutions costs

Due to the lack of a detailed database, calculations are made, only, for material costs knowing that (4):

- Unit prices are taken from other projects
- Total price of each material = unit price of material x quantity of material
- Total price = sum (total price of each material) + labor.

The costs are presented in the tables below:

Tableau 3-1 : cost of solution 1

Solution 1 : timber frame roof over classic chipboard masonry			
Material	**Quantity**	**Unit price FCFA**	**Total price FGFA**
Cement (sac de 50 kg)	180	1760	316 800
Seasand (m^3)	9	2125	19 125
Laotericsand (m^3)	11	1440	15 840
Large aggregate (m^3)	9	11250	101 250
Hollow bricks	2346	130	304 980
Solid bricks	681	115	78 315
Water (m^3)	10	200	2 044
X bars of 10	106	1500	159 000
Y bars of 8	68	1000	68 000
Wood (m^3)	2.239	120000	268 680
N Fiber cement	126	2432	306 432
M false ceiling (m^2)	77.20	750	57 900
Nails (kg)	20	600	12 000
Wire (kg)	4	700	2 800
	Total materialscost		1 713 166
	Workforce		0
	Total		1 713 166

Tableau 3-2 : cost of solution 2

Solution 2:vaulted roof on the masonry supporting geobeton			
Material	**Quantity**	**Unit price FCFA**	**Total price FGFA**
Cement (kg)	139	1760	244 640.000
Seasand (m^3)	10	2125	21 250.000
Laotericsand (m^3)	13	1440	18 720.000
Large aggregate (m^3)	5	11250	56 250.000
Lateroc brick	15489	45	697 005.000
Water (m^3)	8	200	1 664.400
X bars of 10	26	1500	39 000.000
Y bars of 8	21	1000	21 000.000
Wire (kg)	4	700	2 800.000
	Total materialscost		1 102 329.400
	Workforce		0
	Total		1 102 329.400

Tableau 3-3 : cost of solution 3

Solution 3 : wooden frame roof on the masonry supporting geo-concrete			
Material	**Quantity**	**Unit price FCFA**	**Total price FGFA**
Cement (sac de 50 kg)	107	1760	188 320
Seasand (m^3)	8	2125	17 000
Laotericsand (m^3)	12	1440	17 280
Large aggregate (m^3)	5	11250	56 250
Lateroc brick	9279	45	417 555
Water (m^3)	6	200	1 256
X bars of 10	26	1500	39 000
Y bars of 8	21	1000	21 000
Wood (m^3)	2.239	120000	268 680
N fiber cement	126	2432	306 432
M false ceiling (m^2)	77.20	750	57 900
Nails (kg)	20	600	12 000
Wire (kg)	4	700	2 800
	Total materials cost		1 405 473
	Workforce		0
	Total		1 405 473

Tableau 3-4 : cost of solution 4

Solution 4 : timber frame roof on mixed masonry			
Material	**Quantity**	**Unit price FCFA**	**Total price FGFA**
Cement (sac de 50 kg)	145	1760	255 200.000
Seasand (m^3)	7	2125	14 875.000
Laotericsand (m^3)	11	1440	15 840.000
Large aggregate (m^3)	9	11250	101 250.000
Lateroc brick	5538	45	249 210.000
Water (m^3)	8	200	1 687.200
X bars of 10	106	1500	159 000.000
Y bars of 8	68	1000	68 000.000
Wood (m^3)	2.239	120000	268 680.000
N fiber cement	126	2432	306 432.000
M false ceiling (m^2)	77.2	750	57 900.000
Nails (kg)	20	600	12 000.000
Wire (kg)	4	700	2 800.000
	Total materialscost		1 512 874.200
	Workforce		0
	Total		1 512 874.200

Tableau 3-5 : cost of solution 5

Solution 5: vaulted roof on mixed masonry			
Material	**Quantity**	**Unit price FCFA**	**Total price FGFA**
Cement (kg)	176	1760	309 760.000
Seasand (m^3)	10	2125	21 250.000
Laotericsand (m^3)	12	1440	17 280.000
Large aggregate (m^3)	9	11250	101 250.000
Lateroc brick	11748	45	528 660.000
Water (m^3)	10	200	2 095.200
X bars of 10	106	1500	159 000.000
Y bars of 8	68	1000	68 000.000
Wire (kg)	4	700	2 800.000
	Total materials cost		1 210 095.200
	Workforce		0
	Total		1 210 095.200

3.4. Cost comparison

Often, tender documents and consumers require the use of solution (1) formulation which consists of wood frame roofs covered with fiber cement on infill masonry in a reinforced concrete frame. This is why our comparison is based on this model.

Indeed, authorizing the use of "earth" or "geobeton " for a certain part of the construction results in a variable saving according to the rate of earth used.

The following table gives the percentages of achievable savings.

Tableau 3-6 : cost solutions comparison

Solution	Cost (FCFA)	Economy realized value (FCFA)	Economy realized percentage
1	1 713 166	--	--
2	1 102 329.400	610 836.600	36%
3	1 405 473.000	307 693.000	18%
4	1 512 874.200	200 291.800	12%
5	1 210 095.200	503 070.800	29%

3.5. Conclusion

The comparison of the costs of the different solutions proposed shows that the use of local materials leads to a reduction in the materials cost and that the greatest reduction is the solution 2 which is the use ofvaulted roof on the masonry supporting geobeton.

Chapter 4 : Analysis and commentary

4.1. Introduction

In recent years, the technical community (contracting authorities, project managers, design offices, companies) has become aware of the need for rational and economical management of materials resources. This naturally leads to the question of whether it is appropriate to use unusual sources of materials, including co-products and by-products of industry, recycling materials, but also certain natural materials.

The substitution of normal granulates (hard, clean and well graded, or well-known and used for a long time) by other materials for the realization of road infrastructures is an often-mentioned poTableau 7ssibility. However, such an act must not harm the quality or durability of the road built, must be carried out at controlled cost, and must not lead to pollution at the site of use.

It therefore requires substantial preliminary studies which, in turn, must be carried out according to a methodical approach.

Ensuring the non-polluting nature of the material and the existence of regulations on the subject is nevertheless a prerequisite before undertaking any technical valorization process.

As far as the economic aspect is concerned, it is important to be aware that the overall cost of using such materials may be higher than that of traditional solutions, and the acceptance of additional costs is therefore a matter for the client to decide. The evaluation of the cost of technical solutions will therefore represent an essential step between the study and operational use phases.

4.2. Satisfaction degree of each situation in the studied case

The organism of every individual is constituted in such a way that it can face exceptional climatic agents: high winds. Full sun. High or low temperature; the noise. The consumer will therefore only accept the product if he offers the necessary security and the assurance that there is a compromise between the **resistance-comfort-cost** trilogies.

Tableau 4-1 : efficiency of each situation

	Situation 1	Situation 2	Situation 3	Situation 4	Situation 5
Materials resistance	Good$^-$ if precautions	Good$^-$ if precautions	very resistant	resistant	resistant
resistance & stability	Good if precautions	Good if precautions	stable and durable	stable and durable	stable and durable
resistance to tempreture	Good	Good	Good	Good$^-$	Good$^-$
Protection from moisture	Good	Good	Good	Good	Good
accoustic pretoection	Good$^-$	Good$^-$	Good$^-$	Good$^-$	Good$^-$
protection from fire	very good	Good	Good	Good	very good

4.3. Identification of the risk factor

This identification of the risk factor is the result of research:

- Of the properties of the composite material concerned by the insufficiency of the characteristic of the local material, which is the object of the approach,
- Of the possible resulting defects of this properties.

The possible defect related to the limiting characteristic of the aggregate for the use in question is the risk factor whose influence on the overall properties of the mixture must be investigated.

The main factor limiting the valorization of a material is often its heterogeneity. Road techniques can accommodate deficiencies in the geometric, physical or chemical characteristics of the materials, but cannot manage too much heterogeneity.

Many attempts had failed to upgrade local materials have often been due to this heterogeneous rather than to the defect of a characteristic.

So, the application of the valorization approach to a local material will therefore require making sure beforehand that this material is sufficiently homogeneous in relation to the envisaged uses, or that it is technically and financially possible to homogenize it.

Among these possibilities, it should be noted that a classic method of homogenization is that of "deposit - recovery", which allows, in one or more phases, a mixing of the stored materials. Further upstream in the case of a natural material deposit, the management of the exploitation can partly solve this problem, either by the targeted extraction of homogeneous zones of a deposit, or, on the contrary, by the simultaneous extraction of zones with different characteristics, and a mixing taking place from the very first stages of elaboration. In any case, the effect of homogenization by blending remains difficult to define and requires numerous identifications, or even semi-sized tests.[8]

4.4. Risk assessment

Risk assessment requires:

- a good knowledge of the characteristics of the aggregate or by-product;
- a laboratory study of the properties characterizing the composite material comprising the aggregate / by-product in question;
- a test site to observe the behavior of the composite material on site (during installation and over time).[8]

4.5. Implementation of the derogation

The approach followed must make it possible to examine the consequences of the defectiveness of a characteristic of the material on the properties and behavior of the mix and the structure, and to check that it does not call into question the rules of the art of pavement construction, its quality of use or its durability, etc...

At the end of the process, it should be clearly formulated:

- The production conditions and the associated quality approach to ensure the conformity of the materials to those studied;
- The nature and extent of the derogation, with all other characteristics of the aggregate remaining in conformity with the specifications;
- The possible field of use in the technique under consideration;
- Possible adjustments to the composition of the mixture, production, compaction, ... (7)

4.6. Conclusion

All the five solutions examined in this project make it possible to respond to the concerns of the user in the valuation of construction in geo-concrete. They give as wide a choice as possible to promoters on the one hand and consumers on the other. However, precautions must be taken into account in each case of study since the efficiency of this local material can change depending on the building circumstances.

Conclusion and recommendations

The objective of housing the most population today in cities in developing countries cannot be reached without revaluation of local building materials.

Indeed, the use of these local materials reduces construction costs.

Thus, the technical and economic studies that we have carried out through this project have shown that it is possible to achieve when we choose to use these materials.

During this project, we recalled the types of local materials that can be encountered very frequently and the uses that can be made of it. On the other hand, we made an economic study and the necessary calculations to compare between housing variants. Finally, we ended with an analysis of the valuation method.

As a conclusion, the aim of this project is to define the avenues for the use of local materials. But this cannot be reached if there will not be a number of campaigns to promote the use of these materials.

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Annex

Annex 1. Quantity of materials

Annex 1 represents the tables of the materials quantity used in the 5 solutions proposed in chapter 3 of this document for buildings A and B.

Table-annex 1 : Quantity of materials - Building A - Solution 1

Element Materials	Roof	Masonry	Paving	Beams	Poles	Foundation	Lintels	Total
Cement (kg)	0	933	1160	2014	255	139	112	4613
Seasand (m^3)	0	1.26	2.153	0.745	0.094	0.051	0.0414	4.3444
Laotericsand (m^3)	0	0	6.33	0	0	0	0	6.33
Large aggregate (m^3)	0	0	1.58	2.236	0.283	0.154	0.124	4.377
Hollow bricks	0	1154	0	0	0	0	0	1154
Solid bricks	0	363	0	0	0	0	0	363
Water (m^3)	0	0.602	0.748	1.04	0.132	0.071	0.06	2.653
X bars of 10	0	0	0	38	12	3	3	56
Y bars of 8	0	0	0	22	14	0	0	36
Wood (m^3)	1.668	0	0	0	0	0	0	1.668
N fibercement	72	0	0	0	0	0	0	72
M false ceiling (m^2)	46	0	0	0	0	0	0	46
Nails (kg)	10	0	0	0	0	0	0	10

Table-annex 2 : Quantity of materials - Building B - Solution 1

Element Materials	Roof	Masonry	Paving	Beams	Poles	Foundation	Lintels	Total
Cement (kg)	0	952	727	2195.2	227	139	112	4352.2
Seasand (m^3)	0	1.29	1.42	0.812	0.084	0.045	0.0414	3.6924
Laotericsand (m^3)	0	0	4	0	0	0	0	4
Large aggregate (m^3)	0	0	1	2.436	0.252	0.136	0.124	3.948
Hollow bricks	0	1192	0	0	0	0	0	1192
Solid bricks	0	318	0	0	0	0	0	318
Water (m^3)	0	0.614	0.469	1.134	0.117	0.063	0.06	2.457
X bars of 10	0	0	0	32	12	3	3	50
Y bars of 8	0	0	0	20	12	0	0	32
Wood (m^3)	0.571	0	0	0	0	0	0	0.571
N fibercement	54	0	0	0	0	0	0	54
M false ceiling (m^2)	46	0	0	0	0	0	0	46
Nails (kg)	10	0	0	0	0	0	0	10

Table-annex 3 : Quantity of materials - Building A - Solution 2

Element Materials	Roof	Masonry	Poles	Foundation	Chainage	Total
cement (kg)	930	523	1160	1008	387	4008

seasand (m^3)	1.44	1.36	2.153	0.18	0.141	5.274
laotericsand (m^3)	0.381	0.68	6.33	0	0	7.391
largeaggregate (m^3)	0	0	1.58	0.56	0.423	2.563
lateroc brick	3622	4589	0	0	0	8211
water (m^3)	0.6	0.34	0.748	0.52	0.198	2.406
x bars of 10	0	0	0	2	11	13
y bars of 8	0	0	0	0	10	10

Table-annex 4 : Quantity of materials - Building B - Solution 2

Element Materials	Roof	Masonry	Poles	Foundation	Chainage	Total
cement (kg)	651	535	727	549.5	460.00	2922.5
seasand (m^3)	1.02	1.39	1.42	0.203	0.17	4.203
laotericsand (m^3)	0.273	0.69	4	0	0	4.963
largeaggregate (m^3)	0	0	1	0.609	0.511	2.12
lateroc brick	2 588	4690	0	0	0	7278
water (m^3)	0.42	0.345	0.468	0.284	0.238	1.755
x bars of 10	0	0	0	1	12	13
y bars of 8	0	0	0	0	11	11

Table-annex 5 : Quantity of materials - Building A - Solution 3

Element Materials	Roof	Masonry	Poles	Foundation	Chainage	Total
cement (kg)	0	523	1160	1008	387	3078
seasand (m^3)	0	1.36	2.153	0.18	0.141	3.834
laotericsand (m^3)	0	0.68	6.33	0	0	7.01
largeaggregate (m^3)	0	0	1.58	0.56	0.423	2.563
lateroc brick	0	4589	0	0	0	4589
water (m^3)	0	0.34	0.748	0.52	0.198	1.806
x bars of 10	0	0	0	2	11	13
y bars of 8	0	0	0	0	10	10
wood (m^3)	1.668	0	0	0	0	1.668
nFibercement	72	0	0	0	0	72
m false ceiling	46	0	0	0	0	46
nails (kg)	10	0	0	0	0	10

Table-annex 6 : Quantity of materials - Building B - Solution 3

Element Materials	Roof	Masonry	Poles	Foundation	Chainage	Total
cement (kg)	0	535	727	549.5	460.00	2271.5
seasand (m^3)	0	1.39	1.42	0.203	0.17	3.183
laotericsand (m^3)	0	0.69	4	0	0	4.69
largeaggregate (m^3)	0	0	1	0.609	0.511	2.12
lateroc brick	0	4690	0	0	0	4690
water (m^3)	0	0.345	0.468	0.284	0.238	1.335
x bars of 10	0	0	0	1	12	13
y bars of 8	0	0	0	0	11	11

wood (m^3)	0.571	0	0	0	0	0.571
nFibercement	54	0	0	0	0	54
m false ceiling	31.2	0	0	0	0	31.2
nails (kg)	10	0	0	0	0	10

Table-annex 7 : Quantity of materials - Building A - Solution 4

Element Materials	Roof	Masonry	Paving	Beams	Poles	Foundation	Lintels	Total
cement (kg)	0	79.1	1160	2014	255	139	112	3759.1
seasand (m^3)	0	0.34	2.153	0.745	0.094	0.051	0.414	3.797
laotericsand (m^3)	0	0.34	6.33	0	0	0	0	6.67
largeaggregate (m^3)	0	0	1.53	2.236	0.283	0.154	0.124	4.327
lateroc brick	0	2882	0	0	0	0	0	2882
water (m^3)	0	0.169	0.748	1.04	0.132	0.071	0.06	2.22
x bars of 10	0	0	0	38	12	3	3	56
y bars of 8	0	0	0	22	14	0	0	36
wood (m^3)	1.668	0	0	0	0	0	0	1.668
nFibercement	72	0	0	0	0	0	0	72
m false ceiling (m^2)	46	0	0	0	0	0	0	46
nails (kg)	10	0	0	0	0	0	0	10

Table-annex 8 : Quantity of materials - Building B - Solution 4

Element Materials	Roof	Masonry	Paving	Beams	Poles	Foundation	Lintels	Total
cement (kg)	0	72.8	727	2196	227	123	112	3457.8
seasand (m^3)	0	0.625	1.42	0.812	0.084	0.045	0.0414	3.0274
laotericsand (m^3)	0	0.312	4	0	0	0	0	4.312
largeaggregate (m^3)	0	0	1	2.436	0.252	0.136	0.124	3.948
lateroc brick	0	2656	0	0	0	0	0	2656
water (m^3)	0	0.156	0.468	1.134	0.117	0.063	0.06	1.998
x bars of 10	0	0	0	32	12	3	3	50
y bars of 8	0	0	0	20	12	0	0	32
wood (m^3)	0.571	0	0	0	0	0	0	0.571
nFibercement	54	0	0	0	0	0	0	54
m false ceiling (m^2)	31.2	0	0	0	0	0	0	31.2
nails (kg)	10	0	0	0	0	0	0	10

Table-annex 9 : Quantity of materials - Building A - Solution 5

Element Materials	Roof	Masonry	Paving	Beams	Poles	Foundation	Lintels	Total
cement (kg)	930	79.1	1160	2014	255	139	112	4689.1
seasand (m^3)	1.44	0.68	2.153	0.745	0.094	0.051	0.414	5.577
laotericsand (m^3)	0.381	0.34	6.33	0	0	0	0	7.051
largeaggregate (m^3)	0	0	1.53	2.236	0.283	0.154	0.124	4.327
lateroc brick	3622	2882	0	0	0	0	0	6504
water (m^3)	0.6	0.169	0.748	1.04	0.132	0.071	0.06	2.82
x bars of 10	0	0	0	38	12	3	3	56
y bars of 8	0	0	0	22	14	0	0	36

Table-annex 10 : Quantity of materials - Building B - Solution 5

Element Materials	Roof	Masonry	Paving	Beams	Poles	Foundation	Lintels	Total
cement (kg)	651	72.8	727	2196	227	123	112	4108.8
seasand (m^3)	1.02	0.625	1.42	0.812	0.084	0.045	0.0414	4.0474
laotericsand (m^3)	0.273	0.312	4	0	0	0	0	4.585
largeaggregate (m^3)	0	0	1	2.436	0.252	0.136	0.124	3.948
lateroc brick	2 588	2656	0	0	0	0	0	5244
water (m^3)	0.42	0.156	0.468	1.134	0.117	0.063	0.06	2.418
x bars of 10	0	0	0	32	12	3	3	50
y bars of 8	0	0	0	20	12	0	0	32