56. Alternative material for load-bearing wall with addition of walnut shell. Waste Reduction

Sánchez Mirón1, Beatriz Wendonly1 [1,*], Roux Gutiérrez2, Rubén Salvador2 [2] and Molar Orozco3, María Eugenia3[3]

(*) Facultad de Arquitectura Campus Arteaga Universidad Autónoma de Coahuila Unidad Saltillo wenzs.18@hotmail.com

(2) Facultad de Arquitectura Campus Arteaga Universidad Autónoma de Coahuila Unidad Saltillo roux33@hotmail.com teléfono móvil 52 833 1552438

(3) Facultad de Arquitectura Campus Arteaga Universidad Autónoma de Coahuila Unidad Saltillo bmolar60@hotmail.com teléfono móvil 52 811 9381379

Abstract Mexico and the United States are the two main producers of walnut in the world reaching the 98,2% of the total production, in Mexico 39.656 tons of walnut shell are thrown away annually, usually is one of the most commonly found waste in the Mexican markets, being a 5% used and the other 95% of the shell gets thrown away which cause a high volume of trash, if it is given a use it would reduce the volume of trash and it will propel the creation of new work sources.

Due to the scientific interest for recycling in order to reduce the quantity of waste it is pretend to give an alternative use for the shell in Compressed Earth Blocks (CEB). The goal is to determine the process in order to find the percentage of walnut shell that can be incorporated to CEB without damaging its properties, that while not being cooked allows to stock up heat and then liberate it avoiding changes in temperature inside the construction.

Keywords Alternative material, Walnut, Reduction, Waste.

1 Introduction

Since mid of the XX century, the construction with raw clay in Mexico started to decline and the use of more commercialized material raised, for example the concrete block, (Guerrero Baca, Roux Gutiérrez, & Soria López, 2010), for ideological and economical motives. This thanks to the industries, beneficiated by the savings that imply to standardize a product for many regions without making qualms about "the lack of linkage between the finished product, the user and its environment" (Espuna Mújica & Roux Gutiérrez, 2012) masquerading this generalization, offering "versatility" to the client (Ferrex, n.d.).

In view of the above, and the fact that the constructive systems employed in the place are made out of local and/or not renewable raw materials, brings as a consequence the following aspects:

- Inability to adapt to the weather of each locality (the block for example, according to Ferrex, is adequate for tropical or warm weathers) in other words means that they don´t react to the weather conditions of the localities where they are being comercialized.
- The growth in the construction cost, since they imply the extraction and transportation of the raw material, the fabrication of material and the commercialization.
- High energetic demand during the extraction of raw material process and the fabrication of material.
- The negative enviromental impact that the extration, frabrication and transporting of raw material process generates.

The 91% of the housing in the city of Saltillo, according to the INEGI, has walls made out of block, cement or concrete, being only the remaining 9% made from natural materials.

The CEB, are, as the name implies, prismatic elements emerged from applying pressure on a mold, either manual or mechanical, to the soil or raw clay, with a low percentage of a stabilizer, either lime, cement, gypsum and even other organic materials like vegetable fiber or extracts; that improves its original qualities.

The soil stabilization, consists in intercede over its characteristics (texture and structure) in order to improve some of its properties, beneath them the CEB is without doubt a construction material that offers us great benefits and satisfaction, and is within everyone reach.

Among the many advantages of using CEB, is the fact that the raw material, the adequate soil for the construction of these blocks, can be obtained at the construction place, since the 65% of the soil in the planet can be used (CATISMEXICO), and also it is an abundant material, renewable and reusable, being friendly with the environment.

In addition, it is a material that brings quality, durability, practicality, economy and thanks to its thermal mass improves the comfort inside the construction.

This lead us to the following question, what happens if walnut shell is added, that in theory has resistance to the compression and humidity?

The walnut shell is an organic waste that in general ends in a garbage dump. According to the experimental investigation NUEZISTENTE (LAS INGENIERAS), a reduced percentage, a 5% approximately, of this waste is presently being used by different industries, beneath them are the oil, the jewelry and the cosmetics, thanks to its properties.

Among the physicochemical properties (Copromex, 2013), are:

- Mohs hardness: 3,0
- Specific weight: 500 Kg/m^2
- Has a Mixed Sub angular shape,
- It is recyclable, biodegradable and non toxic,
- It doesn't generates dust
- It has a high resistance to ruptures and deformation
- It is biodegradable
- It is safety for health
- During combustion produces carbon dioxide.
- Color: brown
- It is non soluble in water
- It has a neutral pH
- Has no combustion at temperatures lower than 270°C

As reported by the Dirección General Adjunta de Planeación Estratégia, Análisis Sectorial y Tecnologías de la Información, or Adjunct General Direction of Strategic Planning, Sector Analysis and Information Technology, in English, the walnut production in Mexico increased close to an 80% during the last 13 years, reaching nowadays around 110 thousand tons. This is mainly due to the increase of plantings, which doubled, getting to the 104 thousand hectares in 2013.

The production in 2013 was above the 100,000 tons; but only less than 80,000 tons where harvested. Coahuila, in its southeast region is one of the main walnut producers in the country, and by consequence, of the waste that it generates. It ranks in third place national with the 14% of the production (2012) being this a total of 15 thousand tons.

When passing through the hull process, the walnut loose between a 40 and a 50% of its original weight (Nuez descascarada, n.d.), with which it is deduced that, from 15 thousand tons harvest in Coahuila, between 7.5 and 9 (thousand tons) represents the walnut and between 6 and 7.5 (thousand tons) the shell, which is wasted.

In accordance to the expressed, the objective is to establish the percentage of walnut shell that can be included in the CEB without affecting its properties negatively, achieving leverage of a waste and offering an alternative for the construction of load-bearing walls in Saltillo Coahuila, without making any damage to the ecosystem in the acquisition of the components and the fabrication o such alternative.

2 Methodology

Is quasi-experimental, tests were made to the raw material, both walnut shell and the land with a soil bank La Aurora, Coahuila.; as the final product, the CEB with and without addition of walnut shell (compression, absorption, etc.). Determining the walnut shell percentages, as the parameters of the final product must accomplish according to regulations, based on the following:

- Grain size by sieving (Regulation ASTM-D422-90)
- Plasticity (Regulation ASTM-D4318-93)
- Consistency limits: liquid limit (NMX-C-493-ONNCCE-2014) (M-MMP-1-07/07)
- Consistency limits: plastic limit (NMX-C-493-ONNCCE-2014) (M-MMP-1-07/07)
- Soil classification according to USCS (Sistema Unificado de Clasificación de suelos or Unified Soil Classification System in English)
- Identification of the percentage of lime for stabilization. Eades & Grimm Method.
- Analysis of the shell structure (done by the chemistry lab)

Analysis and verification of the CEB with and without the walnut shell addition:

- Resistance to simple compression (NMX – C – 404 – ONNCCE – 2005)
- Absorption (NMX – C – 404 – ONNCCE – 2005)

3 Development

After testing the raw material, we proceed to make the samples of each prototype, elaborating 10 CEB stocks, of 30 units each. For the preparation the stabilizers are added to the prepared soil, in the proportion that was previously established by the Eades & Grimm method. Also, the ground walnut shell is added in the specified percentage. In this case, the percentages where established by 5%, 10%, 15% and 20%.

After 6 hours of moldings and during the first 7 days, the blocks must be maintained humid by a successive watering way, which will bring a better re-

sistance to the material. This phase matches to the curing process. The CEB can be placed in pillars up to1,5 meters high.

The resistance to the compression test was made, this is calculate by dividing the maximum load by the original transversal area of a test tube in a compression trial.

To calculate the results it is necessary to take the compression resistance of a test tube as the maximum of N (kgf) divided by the transversal area of the test tube or rather the total area of a perpendicular section in the direction of the load.

$F = R$

(1)

Where:

R = Compression resistance in MPa (kgf/cm^2)

F = Maximum charge in N (kgf)

A = Transversal area (cm2)

The compression resistance is reported with an approximation of 100kPa (1,0 kgf/cm^2).

Proceeded by the absorption test, the samples where weighed, and afterwards immersed 24 hours in water. Finished this period they were removed letting the surface water eliminate. After weighing the samples and determining the quantity of absorb water. The sampling was random, taking 5 samples randomly.

4 Results

Grain size

Table 1 Percentage retained in each mesh

#Mesh	Sieve opening (mm)	Weight soil retained	Retained percentage	Passing percentage
#4	101,6	10,2	2,04	97,96
#30	0,59	134,05	26,81	71,15
#100	0,149	82,9	16,58	54,57
#200	0,074	73,35	14,67	39,9
		199,5	39,9	0
Total		500	100%	

Plasticity

Table 2 Natural humidity, liquid and plastic limit

HumedadNatural

Test No.	Caps. No.	Caps. weigh gr	Caps. weight + hu-mid soil gr	Soil weight gr	Caps. Weigth + dry soil gr	Water weight gr	Dry soil weight gr	Water content (w%)
1	4	33,60	41,00	7,40	40,85	0,15	7,25	2,02
2	3	33,30	47,10	13,80	47,00	0,10	13,70	0,72

Liquid limit

Test No.	Caps. No.	Peso de Caps. gr	Hit number			Caps. weight + humid soil gr	Caps. weight + dry soil gr	Water weight gr	Dry soil weight gr	Water content (w%)
			1	2	3					
1	1	35,00	30			44,60	41,20	3,40	6,2	35,41
2	2	33,50		20		46,60	42,30	4,30	8,80	32,80
3	3	33,30			18	53,50	47,40	6,10	14,10	36,10

Ll%	**34%**
LP %	36%
IP%	2%

Classification of the soil according to the USCS

After the cleansing 12, 3 gr were left, passing 87, 7 gr which shows that the soil is fine since more of the 50% passes through the mesh #200.

Proctor test

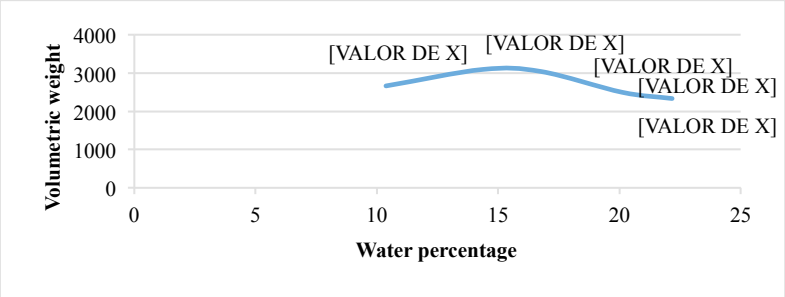

Fig. 1 Water content

Eades & Grimm Method

Table 3 Lime percentage

Container #	Weight	Container weight + 25g of soil	Lime % (g)	Total weight
R1	18,5	43,5	1%=0,33g	43,83

R2	18,4	43,4	2%=0,66g	44,06
R3	18	43	3%=0,99g	43,99
R4	17,8	42,8	4%=1,32g	44,12
R5	17,85	42,85	5%=1,65g	44,5
R6	18,1	43,1	6%=1,98g	45,08
R7	18,15	43,15	7%=2,31g	45,46
R8	17,8	42,8	8%=2,97g	45,77
R9	18,1	43,1	9%=3,3g	46,40
R10	17,85	42,85	10%=3,63g	46,48

Table 4 Shaking time

Container #	Start	At 10min	At 20min	At 30min	At 40min	At 50min	At 60min
R1	1:00 pm	1:10	1:20	1:30	1:40	1:50	2:00
R2	1:03	1:13	1:23	1:33	1:43	1:53	2:03
R3	1:23	1:33	1:43	1:53	2:03	2:13	2:23
R4	1:26	1:36	1:46	1:56	2:06	2:16	2:26
R5	1:27	1:37	1:47	1:57	2:07	2:17	2:27
R6	1:28	1:38	1:48	1:58	2:08	2:18	2:28
R7	1:29	1:39	1:49	1:59	2:09	2:19	2:29
R8	1:31	1:41	1:51	2:01	2:11	2:21	2:31
R9	10:48	10:58	11:08	11:18	11:28	11:38	11:48
R10	10:49	10:59	11:09	11:19	11:29	11:39	11:49

Table 5 Optical lime percentage and pH

Container (R#)	Lime % (g)	PH
R1	1%=0,33g	11,07
R2	2%=0,66g	11,11
R3	3%=0,99g	11,09
R4	4%=1,32g	11,28
R5	5%=1,65g	11,37
R6	6%=1,98g	11,41
R7	7%=2,31g	11,76
R8	8%=2,97g	11,69
R9	9%=3,3g	11,62
R10	10%=3,63g	11,55

In this case, the pH began to 11.07 gradually increasing to 11.76 with 7% (2,31g) lime, then fell. This occurs because the greater the amount of calcium hydroxide, the pH increases, however, at some point, an ion exchange occurs and the pH tends to drop.

Table 6 Populations stabilized with cement 10%

No. Population	% - kg Walnut shell	Ground (kg)	Cement (kg)	Water (L)
		Population base		

1a	without shell.	44,5 kg	4,450 kg	6,5 L
Populations with walnut shell				
2a	5% - 2,225 kg	42,275 kg	4,450 kg	6,5 L
3a	10% - 4,450 kg	40,050 kg	4,450 kg	6,5 L
4a	15% - 6,675 kg	37,825 kg	4,450 kg	6,5 L
5a	20% - 8,900 kg	35,600kg	4,450 kg	6,5 L

Tabla 7 Populations stabilized with lime 7% and cast 3%

No. Poulation	**% - kg Walnut shell**	**Ground (kg)**	**Lime (kg)**	**Cast (kg)**	**water (L)**
Population base					
1b	Sin cascara.	44,5 kg	3,115 kg	1,335 kg	7,5 L
Populations with walnut shell					
2b	5% - 2,225 kg	42,275 kg	3,115 kg	1,335 kg	7,5 L
3b	10% - 4,450 kg	40,050 kg	3,115 kg	1,335 kg	7,5 L
4b	15% - 6,675 kg	37,825 kg	1,115 kg	1,335 kg	7,5 L
5b	20% - 8,900 kg	35,600kg	3,115 kg	1,335 kg	7,5 L

Simple compression tests

To select randomly the 10 sample of each stock to test, they where enumerated from 1 to 30, after, a Web site was used (No SetUp, 2016).

In the manufacture of the samples, a manual press was used, in which the CEB where obtained on a standard measure 10x20x5 cm.

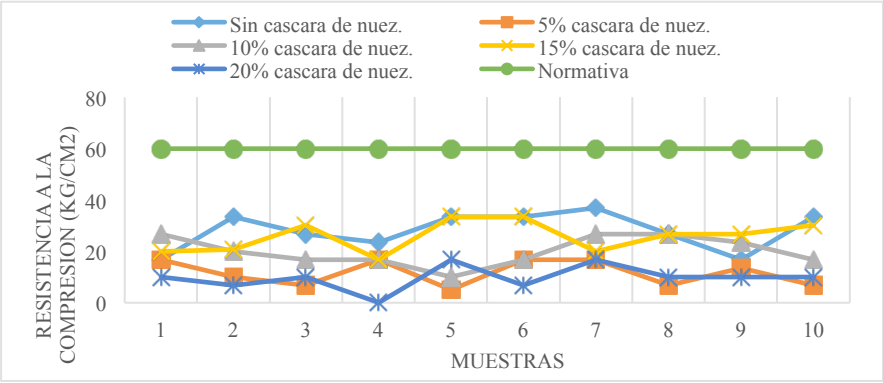

Fig. 2 Comparison of the CEB stabilized with cement to 10% results

It can be observed, that only the first stock is over the indicated by the regulation 60 kg/cm^2. The others are below the regulation NMX – C – 404 – ONNCCE – 2005.

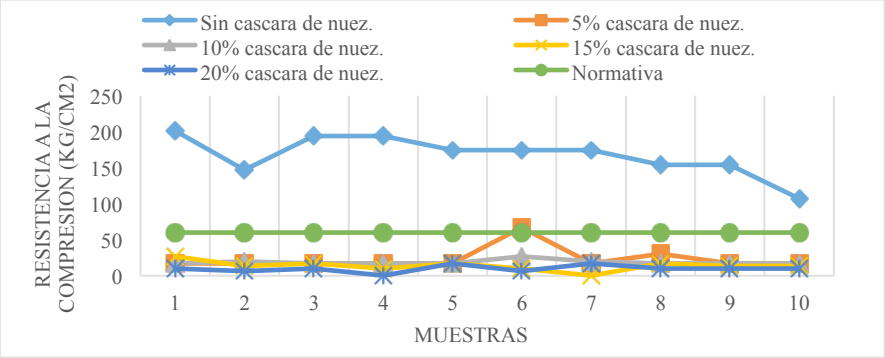

Fig. 3 Comparison of the CEB stabilized with lime to 7% and to gypsum 3% results

To improve the water resistance, workability, and mechanical properties of this earth, it can be stabilized with 3% gypsum (Kafescioglu R, 1980).

It can be seen that none of the stock passes the 35 kg/cm^2

Absorption tests

To select randomly the 5 samples of each stock, they where enumerated from 1 to 30.

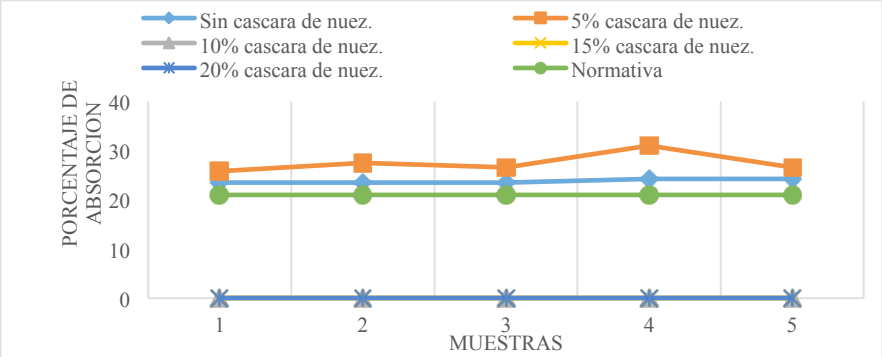

Fig. 4 Comparison of the results of CEB stabilized with cement at 10% absorption

The 3 stocks are over the 21% allowed in the absorption point by the regulation NMX-C-404-ONNCCE-2005.

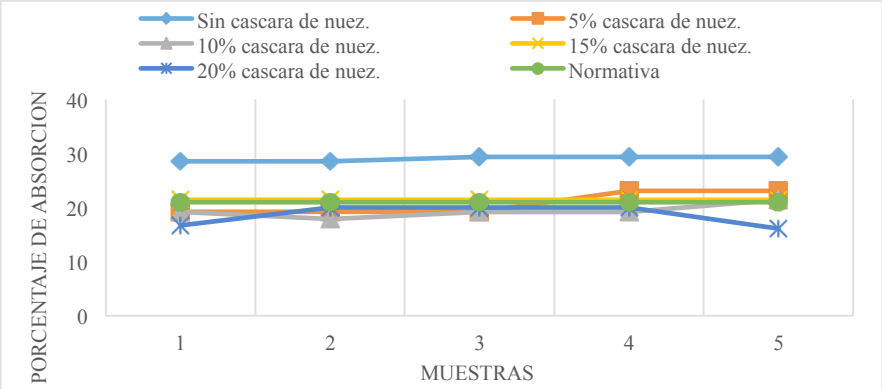

Fig. 5 Comparison of the results of the stabilized with lime to 7% and gypsum to 3% absorption tests

The one that doesn't contains walnut shell exceed the 21% absorption allowed by the regulation. The stock in addition with 15% of walnut shell, is above the established limit only by a 0,42%. The rest of the stocks are under the limit allowed by a little bit.

5 Conclusions

In the compression test the stocks stabilized with 10% cement, show:

- The stock that presents higher resistance to compression is the one that doesn't contains walnut shell.
- The stocks in addition of 5%, 10%, 15% and 20% decreased its resistance by a 86%, 92% and up to a 94% respectively.
- The samples used to present porosity and disintegration.

In the compression test the stocks stabilized with 7% of lime and 3% of gypsum, show:

- The stock that presents the higher resistance to compression is the one without walnut shell.
- The stocks in addition of 5%, 10% and 20% decreased only a 59%, 28%, 8% and 65% respectively.
- The samples looked more firm and solid.

In the absorption test the stocks stabilized with 7% of lime and 3% of gypsum, show:

- The stock that presents the less absorption percentage is the one without walnut shell. Against the one that contains 5% of walnut shell, which absorbed 23.8%, this means, that only a 4% more.
- From the stocks added with 10%, 15% and 20% a record couldn't be made because deformations where present at the moment of removing them from the water.

In the absorption test of the stocks stabilized with 7% of lime and 3% of gypsum, show:

- The stock that presents the lower percentage of absorption is the one that contains a 20% and 10% of the walnut shell, with 18,55% and 19,39% respectively.
- The stock without walnut shell, showed a 30% of absorption, this means 9% above the official regulation.

At the end, it was established that the physicochemical properties of the CEB, in varying degrees looked negatively affected. Also, they don't present the re-

sistance to compression characteristics pointed by the official regulation for structural walls, they could only be employed as divisor walls.

It is intended to perform tests with other soils and other nut type and add them with elements that contain the same fiber that can help to improve their resistance qualities.

8 References

CATISMEXICO (n.d.) Bloques de tierra Comprimida. Retrieved in nov 2015 from https://catismexicoesp.wordpress.com/2011/06/01/compressed-earth-blocks-cebs/

Copromex (Enero de 2013) Copromex. Retrieved in nov 2015 from Sand-Blast: sistemas abrasivos y protec-tivos de alta tecnología: www.copromex.com.mx

Dirección General Adjunta de Planeación Estratégica, Análisis Sectorial y Tecnologías de la Información (Julio de 2014) Financiera nacional de desarrollo agropecuario, rural,forestal y pes-quero. Retrieved in nov 2015 from http://www.financierarural.gob.mx/informacionsectorrural/Panoramas/Panorama%20Nuez%20(jul%202014).pdf

Espuna J A & Roux R S (2012) Bloques de tierra comprimida adicionados con fibras natura-les. Plaza y Valdés S.A. de C.V.

Ferrex (n.d.) Ferrex. Retrieved in 2015 from www.materialesdeconstruccion.com.mx/materiales-block.php

Guerrero L F, Roux R S, & Soria F J (2010) Ventajas constructivas del uso de tierra comprimida y estabilizada con cal en México. Palapa. Revista de investigación científica en arquitectura., Colima, México

INEGI (2000) DISCO COMPACTO DE SISTEMA DE CONSULTA DE INFORMACION CENSAL 2000 "SCINCE POR COLONIAS 2000". México

Kafescioglu R, Toydemir N, O¨ zu¨ ekren B, Gu¨ rdal E. (1980). Yapı malzemesi olarak kerpic -'in alc -ı ile stabilizasyonu (Stabilizing earth with gypsum as a construction material), Istanbul, TUBITAK MAG505.

LAS INGENIERAS (n.d.) NUEZISTENTE. MEXICO

Nuez descascarada (n.d.) Retrieved in nov 2015 from http://catarina.udlap.mx/u_dl_a/tales/documentos/lmnf/chow_d_m/capitulo2.pdf

Núñez A (2007) La cadena de producción en el cultivo del nogal pecanero en México y Esta-dos Unidos. Retrieved in nov 2015 from http://www.comenuez.org/xoo/uploads/Eventos/8_Nogalero/

SIAP (2013) Atlas Agroalimentario "Nuez". Retrieved in nov 2015 from http//www.siap.gob.mx/atlas2013/index-html

Mora J A (2004) El Problema de la Basura en México. Fundación de Estudios Urbanos y Metropolitanos, D.F. México