SMALL VAULT MANUFACTURED WITH LIGHTWEIGHT CONCRETE WITH CONSTRUCTION AND DEMOLITION WASTE INCORPORATED IN THEIR MIXTURES

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ABSTRACT

In Argentina, small vaults were introduced by the Italians immigrants during the 19th Century to be used in roofs and floors for housing and public buildings. These vaults were built with bricks put on edge or in sharp ends, giving them the shape of small vaults which rested on iron rafters to cover the expanse of the room.
At present, in Argentina´s market we can find a variety of products, such as roof bricks made of different materials like ceramic, concrete and EPS[7]. These bricks are straight in their lower side and they need to be covered with a ceiling afterwards. The bricks or blocks are supported with thin concrete pre-tense beams; the system is completed with a compression layer of reinforced concrete in-situ.
In the construction areas, there is a big amount of arid waste in construction and demolition of buildings that exceed in quantity the circuit reuse. Also, there is discarded material from the packaging of EPS, both wastes are problems because of their volume and, the last one is an environmental contamination agent by drain obstruction. They do not have yet a formal circuit or rooted of reduction or commercialization that could be managed either by the Urban Collectors Cooperatives or by companies.
This research work, investigates the applications of concrete mixtures with the incorporations of recycled EPS and crushed rubble, which have been researched and developed at our Center in different small vaults designs in order to develop products that can compete economically with their equivalent in the national market. Thus, optimizing their characteristics in weight, vault's visible side endings, thermal insulation and safety at work, emulating the image of the traditional brick vaults and recovering memory constructive.
In this way, an efficient energetic constructive system is investigated and promoted, by developing an innovative product in technology and quality that represents an environmental improvement, which aims to reduce consumption of natural resources, trying to reduce carbon footprint and the possibility of creating green employment.

Keywords: sustainable, wastes, recycling, product, market.

[7]. Expanded Polystyrene

1.- The small vault, definition and history.

The small vault is a little vault that is used, between prefabricated small beams of concrete, in a mezzanine or in the roof of a room to cover the space. The system is complete with a concrete compression layer and iron mesh.

It was introduce in Argentina on the second half of the 19th century with the arrival of the Italian immigration, the work force increased, with which begins to change the appearance of Buenos Aires City. There are new techniques to build. The typical constructions for Italians dwellings were of bricks for the main structure of the walls, covers were of wooden structure and inside as mezzanines, small vaults with iron beams were used [1]. These floors were formed by a resistant structure (joists and beams of iron), insulating structure (small vaults), flooring and ceiling. The joints had a maximum length of 5 meters and the separations between them were from 0,60m to 0,70m. The small vault was the filling in the form of vault; they could be built of bricks with an isolation or resistance purpose and according to the flooring used in the top part. They could be simple, to be employed in mezzanine carrying wood flooring and which in turn could be flat or banked, high in the center, or double, which were composed by forged resistant, and they consisted of 2 simple rows, with bricks placed on edge [2].

With the emergence of new technologies, the common bricks were replaced by ceramic bricks for roof, of concrete or expanded polystyrene, and the iron joists were replaced, first by concrete joists made out in situ and then by pre-stressed concrete, prefabricated.

2.- Previous research on EPS and rubble in lightweight concrete.

Technology in building materials has advanced in recent years, non-traditional materials have been incorporated, such as waste or urban solid waste (USW) or recycled construction and demolition waste (CDW), replacing and combining with traditional aggregates in mortars and concretes.

The research conducted by María R. Sánchez de Colacelli and Ángel M. Costilla at the National University of Tucumán, Argentina, focused in recycling EPS to be used in buildings materials (blocks, bricks and panels) for walls in housing developed with cooperatives, also generating new jobs. The use of EPS as aggregate in mortars and concretes with different concentrations and particles sizes, replace the sand, obtaining in the mixtures an important weight reduction, better thermal insulation and economically viable costs [3].

The research conducted at the National Technological University, Regional Santa Fe, Argentina by M. Suarez, C. Degagot, M.F. Carrasco, A. Marcipar, R. y H. Saus Miretti, focused on the comparison of concrete made with waste debris (from demolition) and crushed bricks (from bricks factories) to assess the influence of materials with impurities on the behavior of concrete made with them. It concluded that these lightweight concretes cannot be regarded as structural lightweight concrete, and to be suitable for manufacturing of load bearing and non-bearing-block for slabs, and these blocks could be competitive in market [4].

The research conducted at the University of Cuenca, Ecuador, by Carlos E. Contreras Cojano, focused on the development of concrete with aggregate from construction waste with the aim of achieving a 210 kg/cm2 compression strength, developing different dosages by replacing the natural aggregate by recycled aggregate from concrete pavements. By the results obtained in tests of compression and bending, it is concluded that with the replacement of the natural arid in 40 %, they will reach high levels of resistance, [5].

As for the replacement of arid virgins for recycling, both in case of the Universities of Tucumán and Santa Fe of Argentina, and in the Cuenca, Ecuador, It was proved the

feasibility of its incorporation in concretes, that it can manufacture products for construction.
The Association Argentina of Expanded Polystyrene (AAPE), the technical consultant arch. Pablo Azqueta conducted a report on the utilization of lightweight concrete with pre-expanded beads of polystyrene or ground styrofoam. The report mentioned the properties that make a lightweight concrete material, very low specific gravity, good thermal insulation, low thermal conductivity; low moisture absorption and good working strength are mentioned. According to the investigation, the pre-expanded polystyrene can be replaced by ground expanded polystyrene for fillers, counterweights, and insulation that do not require special specification for working strength. In order to improve their adhesion to concrete, it is suggested to use an acrylic or vinyl coating or vinyl glue [6]. Arch. Azqueta advised arch. Yajnes, for her investigation on the SI TPR 19 project [7], about the use of EPS.

3.- Definition of materials and features.
In this project proposes the recycling and reuse of rubble characterized by come from small residential demolitions carried out by the owners and the complete or partial demolitions of buildings by specialized companies, for the manufacture of the products.
The archs. Silvana Sutelman, Marta Yajnes and team, did an investigation of the rubble circuit in Buenos Aires, Argentina, since its demolition work, up to their reuse, where it was observed that the generated waste exceeds in quantity to its reused, [8]. This material is characterized by a density in sieving state between 900 and 1000 kg/m3.
With respect to EPS intends to reuse and come from medical supplies, foodstuff, electrical consumer goods, furnishing and insulation panel buildings, etc. of variable densities between 20 and 50 kg/m3. In Buenos Aires, Argentina, this waste does not have a formal of circuit reduction or marketing.

4.- Hypothesis
It is possible to keep the constructive local traditions through the use of construction products as the small vault with lightweight concrete of low density mixtures, incorporating recycle materials, rubble from demolition and EPS, contributing in the application of an efficient energetic constructive system. It is considered that the resulting small vault compared with ceramics bricks of roof found in the market will be more economical and lightweight, with endings included in the product, easy transport without break, to be used in construction mezzanines.
With the incorporation of MSW and CDW as part of their mixtures, it is reduced the volume and environmental pollution generated by them, which contributes to reduce de ecological footprint.

5.- Objetives
- To design a product that keeps the local constructive traditions, emulating the image of the traditional small vault made of bricks.
- To respect the width measures between pre-stressed concrete joists as indicate the market in order to allow them a suitable replacement and to obtain an optimum coupling and simple with these joists.
- To design a product to be easily replicated by the vulnerable social sectors.
- To design a product that will compete with its equivalent in the national market, optimizing its characteristics, in terms of price and weight.
- To incorporate demolition rubble waste and EPS in the concrete mixtures. EPS lowers its density and to improves its thermal insulation.

- To generate a product that ensures a mezzanine system suitable to be stepped on by the staff's workers, at the time of assembly.
- To obtain endings that do not requires ceiling application, reducing the time and the materials costs and labor, in the mezzanine construction and at the same time not submit pores that allow the nesting of insects or accumulation of dirt.
- To reduce production times, adapting the existing moulds and using multiple moulds for the serial production of the product.

6.- Features

The small vault investigated in the CEP Centre is characterize by three layers: a lower and an upper of cement mortar, a concrete mixture in the middle that was chosen according to bases of cement, lime and recycled materials: rubble crushed from demolition constructions (CDW), ground EPS packaging (USW) and additives. The rubble into the concrete, contributes to its hardness and the EPS to improve thermal insulation and a lower weight, being lower than the ceramic elements and concrete of the market, [9]. Its lower face has a sight termination, eliminating work task. It offers a greater security during the assembly work by the easy transport of the product without that break and by its form (Fig 1).

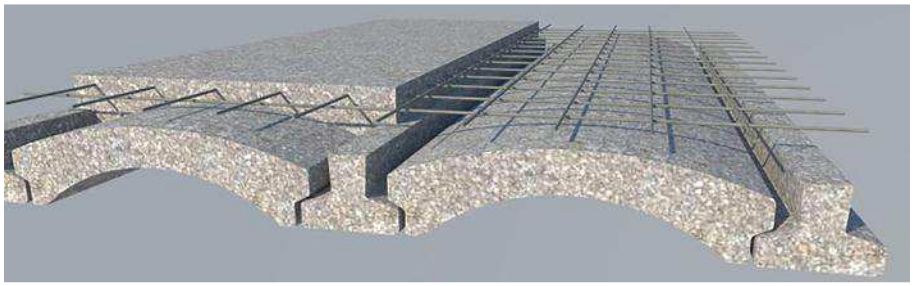

Fig. 1"Details of the construction system"

7. - Small vault proposals

At the beginning we worked with 2 similar design proposals, subsequently we added a 3rd one. The proposals 1 (Fig. 2) and 2 (Fig. 3) have a double curvature in its lower and upper faces. In both cases, the width measurement is 0.41m for them to be placed between the axes on the joist, and they respect the 0.50m width which is used in the market. The 3rd proposal (Fig. 4), it changes the shape in the upper layer replacing the curve by straight lines. Its width varied to 0.42m to optimize the support between the joists. In the 3 proposals the lengths used are 0.50m, twice of the market and 0.25m as an alternative to avoid cuts in the construction.

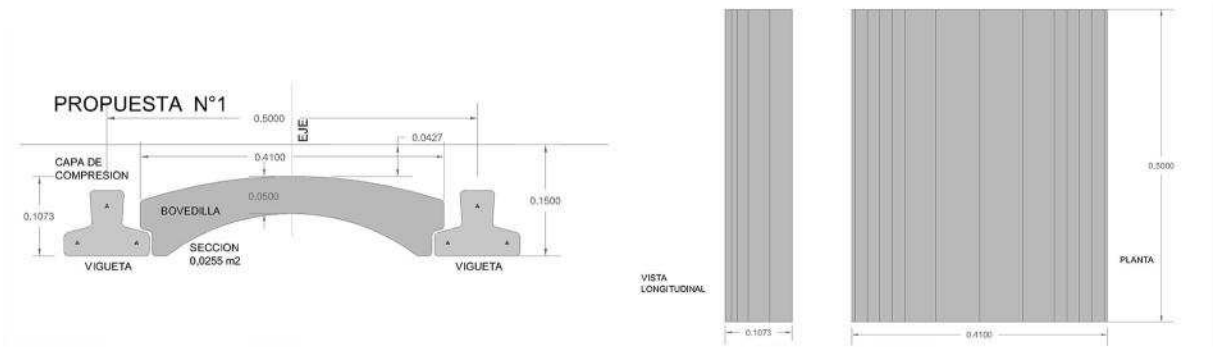

Fig. 2 "Plant, longitudinal view and section of the proposal Nº1"

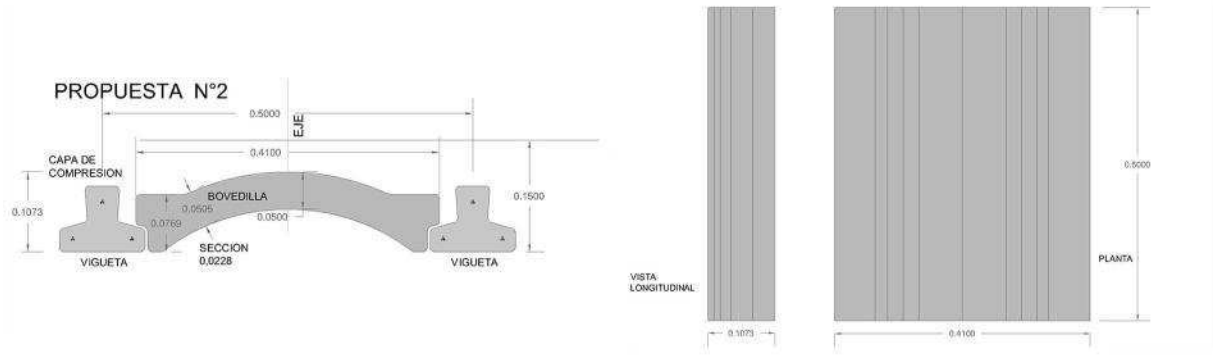

Fig. 3 “Plant, longitudinal view and section of the proposal Nº2”

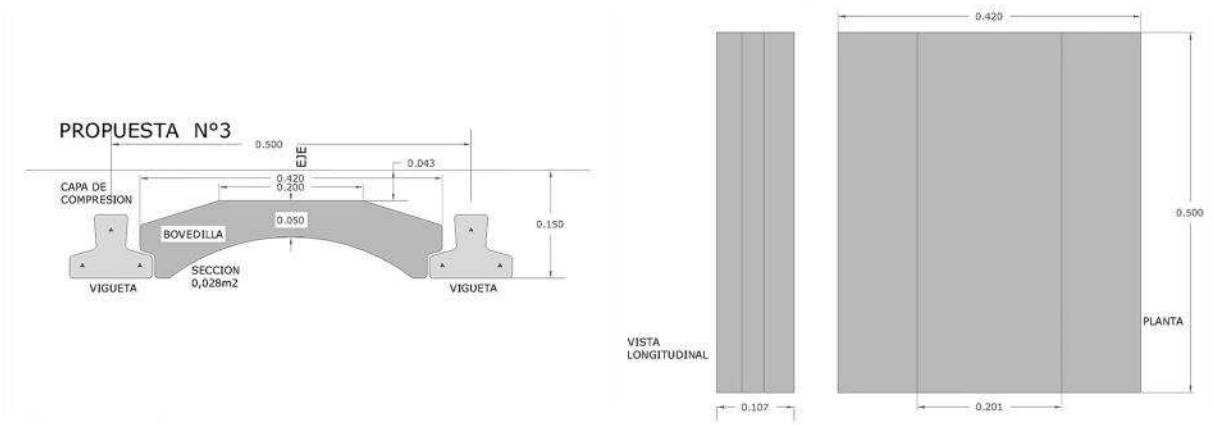

Fig. 4 “Plant, view longitudinal and section of the proposal N°3”

8.- Methodology

The methodology adopted is an experimental nature with preliminary tests practice made at the CEP prior to the finals to be held at the National Institute of Industrial Technology INTI [10]. Work Plan:

- Human resources selection: working with the CEP team teachers and grade of the architecture career students either interns with advanced academic credits or from the subject of ITC (Introduction of constructive types) of the first year of the career.
- Tests and mixtures choice on existence moulds: to test mode with the employment of the small vault iron existing mould. The mixtures used were developed in the CEP TRP 19 project.
- Redesign of the product.
- Moulds assembly.
- Collection of recycle of materials and its treatment or processing.
- Collection of virgin materials donated or purchased.
- Preparation of mixtures and filling the moulds.
- Curing and drying of the concrete, weighing, control and preliminary tests of the small vault.
- Redesign of the product, mould adaptation and filling moulds with mixtures.
- Product selection and commercial feasibility study: By their satisfactory results in their blends and weights, the selection of the product is made and subsequently the calculation costs and compared it with market.

9.- Development of the investigation

9.1.- Assembly of moulds

As a test, we used a small vault iron mould existing in the CEP, which despite not complying with the design that had been stipulated; it was adapted to give the curve shape of the 2 first proposals (Fig. 5). Its length is 0.50m.
What was intended with this test; was to have a first approach to the investigation to analyze the results of the resulting small vaults to evaluate the advantages and disadvantages of the mould and the mixtures.

Fig. 5 “CEP existing vault mould”

Later we worked with the proposals 1 and 2 (Fig. 6 photo 1 y 2). We used low costs materials for the development of the moulds, to be able to modify them as it progressed in the study of the dismount mould.
For the base, we first used foam board (a layer of EPS, covered on both sides per cardboard) and then we changed for wood. We use EPS on the sides and we covered with an adhesive film and vinyl so the mixture material will not stick and to cover the lower curvature we used a plastic of high impact.

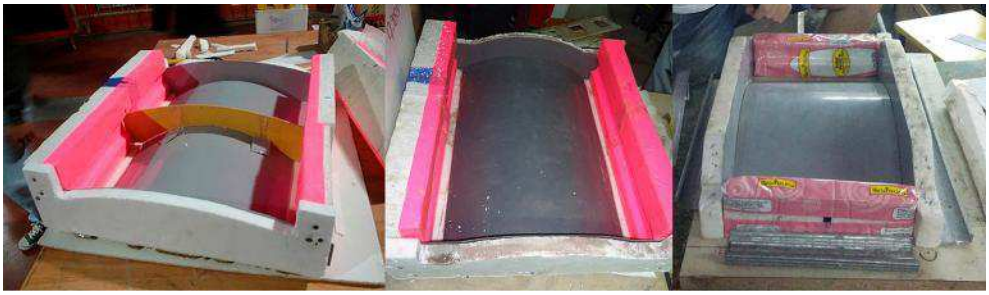

Fig. 6 “Moulds of proposals 1, 2 and 3”

We took the decision to make multiple moulds to optimize the series production of the small vaults. In our case we had in mind the sizes of the shaking table and our economic resources; we could only make the moulds of 2 small vaults for each proposal. Taking into account the studies of mould released with the used mixtures, that we will explain later, it was decided to make a 3er proposal (Fig. 6 photo 3). In this case an existing mould was adapted to the new design, but with a 0.25m length so that its manipulation is easier.

9.2.- Development of the small vault

During the process of the investigation of the small vault, the mixtures used of lightweight concrete, were developed in the CEP TRP19. These mixtures were tested in test tubes before and during the process of investigation, within that project.
Due to lack of economic resources were not made test in the INTI of thermal conductivity of concrete used in this product, so the information that we had was used.
To determine the concrete mixtures, the values of the tables for concretes of the IRAM 11601 standards of Insulation for buildings [11] was used to determine

concrete mixtures, where a concrete with EPS of 500 kg/m3 density has a thermal of 0,15 W/m·K and for a 1000 kg/m3 its thermal conductivity is 0.26 W/m·K.
On the other hand was a test of thermal conductivity of the 09/04/2012 by the CEP at INTI, with an EPS concrete recycle and a density of 632kg/m3, its value of apparent conductivity was of 0,17 W/m·K ± 3% (fig. 7).
This proved that the values obtained for mixtures of concrete with aggregates of EPS recycled; they correspond to the virgin aggregates of EPS and have a better thermal insulation, lowering its density, with respect to traditional concrete mixtures.


INTI Construcciones

Externo Nº 0011-12

A: CEP – FADU - UBA Fecha: 09 de abril de 2012
Atte.: Arq. Ricardo Tartaglia Correo electrónico:

De: INTI Construcciones Página: 2 de 3
U.T. Habitabilidad

ENSAYO DE CONDUCTIVIDAD TÉRMICA

Condiciones De Ensayo:
Las mediciones fueron efectuadas a intervalos sucesivos, luego de haberse establecido el régimen permanente de temperaturas hasta lograr un pico promedio de la conductividad térmica menor al 0,1%.
Superficie sobre la que se efectuó la medición : 0.09 m².
Orientación de la probeta : Horizontal.
Dirección de la transferencia de calor : Vertical, Descendente

Material : M1: compuesto por 8.0 litros de poliestireno expandido, 2.3 litros de cemento, 1.15 litros de agua y 0.1 litros de aditivo "TACURU". IL: CT2101-11. (Figuras Nº1a y 1b)

Figura Nº1a Figura Nº1b

Densidad aparente de la muestra: 632 kg/m³
Temperatura de la Placa Caliente (T1): 37.1°C ±0.1 °C
Temperatura de la Placa Fría (T2): 13.2 °C ±0.1 °C
Diferencia de temperatura entre placas: 23.9°C ±0.1 °C
Espesor promedio de la muestra en la medición (*): 0.020 m ± 0.001 m
Caudal Térmico (Q): 195,9 W/m² ±13,3W/m²
Temperatura media de la muestra: 25.2°C ±0.1 °C
CONDUCTIVIDAD TÉRMICA APARENTE (λ): 0.17 W/m K ±3%
Temperatura Ambiente: 24°C Humedad Relativa: 57% Presión Atmosférica: 100.4kPa

INTI

Fig .7 “Thermal conductivity test”

As they are laboratory studies all the consumption for the materials used were indicated in kilos to difference of the EPS that by their characteristics would not viable, and is indicated in liters on the value of the cement.
The proportion of the water that is used in these mixtures is 50% in relation to the cement, if the sand is dry, but if it is wet this proportion must be changed.
When using a crushed EPS, should be added to the mixture an adhesive vinyl, for what EPS will not fly and accede to the cement.
In the first instance, to the small vault developed to test mode with the plate mould, existing in the CEP, we used a mixture of concrete with two different dosages, test 1 and 2, detail dosage table 1. The materials used were: cement, hydraulic lime, sand, and coarse aggregates rubble and EPS from recycling.

Test	Cement Mixtures CEP TRP19	Dosage				
		Cement	Lime	Sand	Rubble	EPS
Test 1	N°1	1	-----	1	1	3.75
Test 2	N°20	1/2	1/2	1	1	3.75
Test 3	N°2	1	1/4	3/4	-----	3.75
Test 4	N°2b	1	1/4	3/4	-----	5

Table1 “Dosage used for the test Small Vault 1, 2, 3 and 4”

Fig. 8 “Small vault test with an existing mould Test 1 and 2”

The weights of both small vaults are 9.850 kg (11/02/2014) with a long of 0.50m.
As shown in tables 1, the only difference between both test are the dosages, where was replaced part cement for hydraulic lime. In this first test, the problems that were detected, were with respect to their section. The small vault was very weak in thickness, because it is a lightweight concrete and a low density, so we had to use a thicker one that has the mould, since cracks and breaks are possible. With respect to the width of the mould, the resulting small vault generated one greater distance between pre-stressed concrete joists than the commercial 0.50m, so it would have to reduce its width. Also the concrete was hardening it dissolves easily, (Fig. 8). It tested 2 types of mixtures in 3 samples, with crushed EPS lightweight concrete. It used the Proposals 1 and 2 of small vault. For the test 3 with mix N° 2, with a length of mould of 0,50m and for the test 4 it used mix N°2b with a length of mould of 0,25m, (fig. 9). Detail dosage table 1.

Fig. 9 “Small vault, Proposal 1 and 2”

The results obtained in the 2 proposals with the mixture N°2 were very good, still the same homogeneous and with an easy transport of the product without breaking, with a weight-for-proposal 1 of 9.48 Kg (01/10/ 2013) and 8.60 kg (01/10/ 2013) to Proposal 2, with a density in both cases of 660 kg/m3.
For the 3rd sample was taken the proposal 1 mould, with 0.25m long and with the mixture N°2b, the amount of EPS added to this mixture was excessive and the small vault dissolves easily. Its weight was 3.35 kg (08/10/2013), when compare with the 0.50m long its weight would be 6.70 kg.
In all 3 cases we could dismount the sides of the mould after 20 minutes but not its base, having to wait 6 hours until mixture hardens, as their form of double curvature it was not allowing to recover it. It therefore had to consider several bases if you wish to make a serial production of the small vault.
It was also observed, that if the small vault was only made of lightweight concrete, or of low density, being porous his constitution, could nesting insects, accumulate dirt and there is a risk of it dissolves on the way from the factory to the construction. For this reason it was thought to make a layer of mortar cement on the bottom and on the top by way of protection taking into account that they added extra weight to mixtures. It was also thought to add color to the bottom face for its view termination and delete tasks of termination on the construction. This aggregate of color is a powder called

Ferrite. In these tests the rubble was also incorporated into concrete mixture, this time filtered dust from the rubble so not disarm, (Fig. 10). Detail dosage table 2.

Mixtures	Mixture CEP TRP19	Prop	Dosage					
			Cement	Lime	Cement Adhesive	Sand	Rubble	EPS
Layer top - bottom	-----	-----	1	-----	-----	3	-----	-----
Concrete	N°2	1 - 2	1	1/4	-----	3/4	-----	3.75
Concrete	N°7	1	1	-----	1/2	1	1	5
Concrete	N°1	3	1	-----	-----	1	1	3.75
Concrete	N°12	3	1	-----	-----	1/2	1/2	3.75

Table 2 “Dosage for small vault three layers Proposal 1, 2 and 3”

Fig. 10 “Small Vault three layers, Proposal 1 and 2”

Always the same dosages were used for mixtures of upper and lower layers. Only thing that changes between them is the addition of the dye type Ferrite in the mortar to give color in the bottom layer and greater ratio water-cement on the top layer, since it is lightweight mortar.

The results obtained in both proposals from a three-layer composition and mixture N°2 were very good in terms the easy transport of the product without breaking, termination to the view and protection of the layer of concrete. The weight of the proposal 1 was 11.88 kg (10/10/2013) and proposal 2 was 10.72 kg (29/10/2013). Their density is 660 kg/m3.

With the mix N°7, we used the mould of proposal 1. This mixture contains a cement adhesive that is widely used in construction to paste all kinds of tiling on floor. This adhesive is used to replace the vinyl adhesive and also contains cement replaces part of it in the mixture.

The results obtained of the small vault with the mixture N°7 were very good in terms of the easy transport of the product without breaking, and terminations. The weight is 13.035 kg (18/02/14) and a density of 830 kg/m3.

To resolve the recovery of the base of the mould in less time, we modified the design of the small vault in the upper face and prepared for a long of 0.25 m. The idea was to recover the full mould, investing it to support it on a flat surface when the cement mortar will harden, (fig. 11). 2 concrete mixtures have been tested, N°1 y la N°12. Detail dosage table 2.

Fig.11 “Small Vault three layers, Proposal 3”

The mixture N°1 with a density of 660 kg/m3 had already been used in the test mould, at the beginning of the research and it dissolves easily, but with adjustments are made with the sifting of the rubble, were obtained very good results in tests, mixture is not disarmed to the touch, and could to retrieve full mold approximately at one hour. A weight of 8.705 kg (02/12/14) was obtained. To obtain a lighter-weight piece, it was tested mixture N°12 with 620 kg/m3 of density and it was obtained a piece with a weight of 5.785 kg (09/12/14).
To test the small vault with the students in the CEP, it was placed 2 pre-stressed concrete joists in the floor at a distance of 0.50 m between their axes with 2 small vaults and a wood on top of these, to which a student climbed. The small vault resisted the weight of a person and they had a good coupling between the small vaults and pre-stressed concrete joists (Fig 12). We are expected in the future to be able to realize tests in the INTI.

Fig.12 "Tests made with students in the CEP"

10.- Product selection and commercial feasibility study

10.1.- Product selection

They were making the costs of proposal 3 with mixtures, N° 2, N° 7 and N° 12. The data were provided by materials market and Construction Company. Homemade. (fig.13).

COSTOS DE BOVEDILLA Prop 3	actualizada 18/01/15	BOVEDILLA 50
MEZCLA 1 CON TACURÚ	DENSIDAD 660 kg/m3	PRECIO FINAL
MATERIALES		$ 14,17
MANO DE OBRA 4 PERSONAS		$ 7,00
AMORTIZACION MAQUINAS Y GASTOS VARIOS		$ 2,48
GASTOS DE MANTENIMIENTO Y ADMINISTRACION Y BENEFICIO		$ 3,54
		$ 27,19

COSTOS DE BOVEDILLA Prop 3	actualizada 18/01/15	BOVEDILLA 50
MEZCLA 7 CON WEBER	DENSIDAD 830 kg/m3	PRECIO FINAL
MATERIALES		$ 11,83
MANO DE OBRA 4 PERSONAS		$ 7,00
AMORTIZACION MAQUINAS Y GASTOS VARIOS		$ 2,48
GASTOS DE MANTENIMIENTO Y ADMINISTRACION Y BENEFICIO		$ 3,20
		$ 24,51

COSTOS DE BOVEDILLA Prop 3	actualizada 18/01/15	BOVEDILLA 50
MEZCLA 12 CON TACURU	DENSIDAD 620 kg/m3	PRECIO FINAL
MATERIALES		$ 11,11
MANO DE OBRA 4 PERSONAS		$ 7,00
AMORTIZACION MAQUINAS Y GASTOS VARIOS		$ 2,48
GASTOS DE MANTENIMIENTO Y ADMINISTRACION Y BENEFICIO		$ 3,09
		$ 23,68

	$/u	u	a igual sup
LADRILLON DE TECHOS CERAMICOS	$11,94	2,000	$ 23,88
revoque materiales cielorraso	$29,00	0,500	$ 14,50
mano de obra revoque	$30,00	0,500	$ 15,00
TOTAL			$ 53,38
Mercado Libre consultado 18/01/2015	http://articulo.mercadolibre.com.ar/MLA-511063827-ladrillo-para-techo-ceramico-11x25x42-cm-ladrillo-sapo-_JM		

Fig.13 “Summary of costs of Mixtures N° 1, 7 y 12 and ceramic brick for roof”

It was a comparison of the 3 mixtures, taking into account their weight, density, and cost. Detail table 4.

Proposal 3 long 0.50m	Weight Kg	Density kg/m3	Cost $ AR
Mixture N°1	17.41	660	27,19
Mixture N°7	13.035	830	24,1
Mixture N°12	11.57	620	23,68

Table 4 “Proposal 3 - Mixture N°1, N°7 y N°12”

The variation between the 3 mixtures taking the highest and the lowest value in weight, density and price, was 5.81 kg in weight, 2.10 kg/m3 density in and $ AR 3,51 in price. The mixture N°12 obtained the lowest values in weight, density, and price.
The proposal 3 with the mixture N°12 was the selected, as the most appropriate for using in a production system, by the incorporation of rubble and EPS in its mix of concrete, for the results obtained with the dismount of the mould, the ease transport of the product, a lower weight, density and cost.

10.2- Comparative with the market

In the comparison one with the products that exist on the market, the design of the proposals 3 for being selected with the N°12 mixture. It will compare this proposal with its equivalent in the market, the ceramic brick of roof to be the most used, which is also being joined the terminations in the construction. In both cases are considered to be the 0.50 m long, taking 2 units in the case of the ceramic brick for roof. (fig.14).

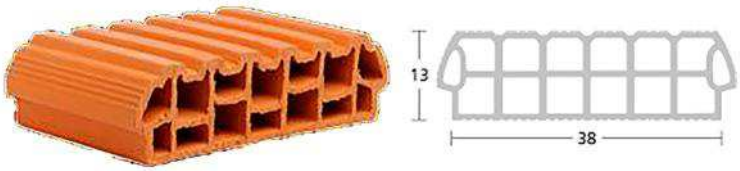

Fig.14 “Picture of ceramic brick for roof”

Comparative with the market	Mixture Nº 12 Proposal Nº 3	Ceramic Brick for Roof- we are considered 2 units
Measures (m)	0.42x0.50	0.11x0.38x0.25 (units)
Weight (Kg)	11.570	13.20
Total Cost ($AR)	23,68	53,38

Table 5 “Comparative between the proposal 3 and the equivalent market”

From the comparison seen in table 5, proposal 3 is lighter in weight and its cost is lower compared to the ceramic brick for roof. The difference in favor of the small vault is 1.63 kg and 29,70$AR.
If we take a m2, the difference price between both products is 118,8$AR, being the cost approximate per m2 of the small vault of 94,72 $AR and the cost approximate per m2 of the ceramic brick for roof of 213,52 $AR. Therefore, it is concluded that the small vault of the Proposal 3 with the mixture N°12 is a viable material for serial production and marketing. Detail table 5.

11.- Achievements

- There achieved a product that respects the measures of width of placement between and pre-stressed concrete joists as it indicates the market.
- There achieved a product easily replicated by vulnerable social sectors.
- There achieved a product that competes with the Ceramic Brick for Roof that exist in the market, in terms of weight and price.

- With the addition of rubble as a coarse aggregates, even if isn't resistance tests done at INTI, if they are used correctly in position, they resist the weight of a person stop over. They do not break, being safe to the management work of the staff, at the moment of installation. With the addition of EPS as a coarse aggregates and the choice of the mixture of concrete N°1, N°7 and N°12, managed to get a thermal conductivity that is appropriate within the values of the test of the CEP and the Norms IRAM 11601, cited in paragraph 9.2.
- There achieved to incorporate a termination on the bottom side of the small vault, in its side in sight. This means that you do not need applied ceilings, reducing the time and costs of materials and labor, in the construction of a mezzanine and in turn who not have pores that allow the nesting of insects or accumulation of dirt.
- There achieved to perform multiple molds to optimize series production, but by the size of the shake table that is in the CEP, it could only be of small vault.
- By 2015 is expected to materialize the series production of the small vaults and build a module for an eco-efficient housing. There is a signed agreement of transfer by the Cep and the “Cooperative Nuevamente” of beneficiary. On the other hand side the CEP has won “Ingeniero Enrique Mosconi” project [12], where this cooperative is included in the eco-efficient construction, where will be incorporated into a module, the small vaults, among other developments of the Center.

12.- Difficulties

- Due to lack of financial resources, were not performed trials of resistance and thermal conductivity at INTI, nor a mould of sheet metal, what would imply a better study of the same one to facilitate its mould release. They could not, purchasing machinery and tools, for the discharge and weights of materials control, since they are made manually.
- The high cost of vinyl products used in the mixture with EPS and the lack of information in alternative materials.

13.- Conclusions

The small vault is a tangible product and innovative of technologically and quality, using concretes with added recycled rubble and EPS, promoting the application of an efficient energetic constructive system, minimizing the consumption of natural resources and transforming waste into resources, with the goal of reducing the ecological footprint and ability to create green jobs.

To build a house, considering the proposal 3 with the mix 12, per m2 of new housing, recycled waste used as a coarse aggregates are 6.12 kg for the rubble and 45.90 liter for the EPS. If the house had a surface of 60m2, it use 275kg of rubble and 2065.5 liter of EPS, therefore with the incorporation of these residues in the concrete of the small vault, it reduces the volume they produce on the environment.

The small vault is a product that can replicate easily, by time and simplicity of its manufacture, and taking into account that the residue of EPS does not have a collection circuit formed in Argentina, you can create a new source of employment for the sector of the marginalized in our society, where inclusion of a collection circuit of such waste for subsequent use in the manufacture of the product.

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