2° Seminário de ECONOMIA CIRCULAR

Maceió Inclusiva através de economia circular

PROYECTO BIOVALVO: Valorización de conchas de bivalvos gallegas en el sector de la construcción.

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ESPAÑA

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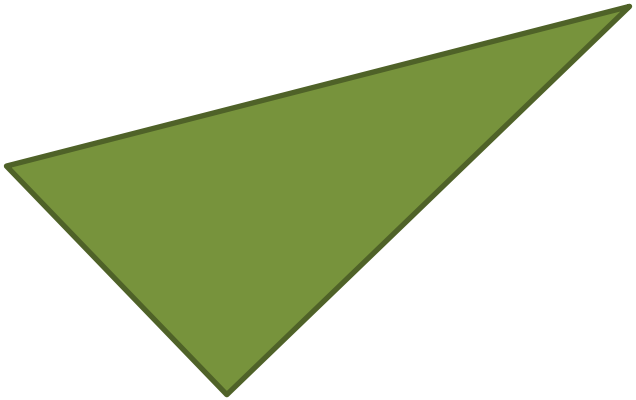
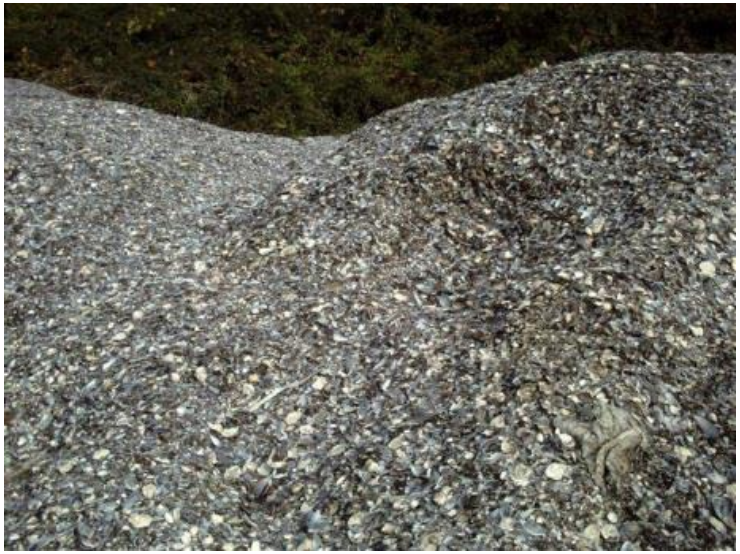


INTRODUCTION AND OBJETIVES

- **Aquaculture and cannery industry are really important economic sectors in Galicia**. They generate big profits and create thousands of employment. However, they **also produce loads of waste**, in which bivalve shells are remarkable because of their high volume. **Galicia generates around 25,000t of mussel shell residue every year** that usually are disposed in dump sites producing a great environmental impact.
- This project studies the possibility of reusing shells in construction sector.



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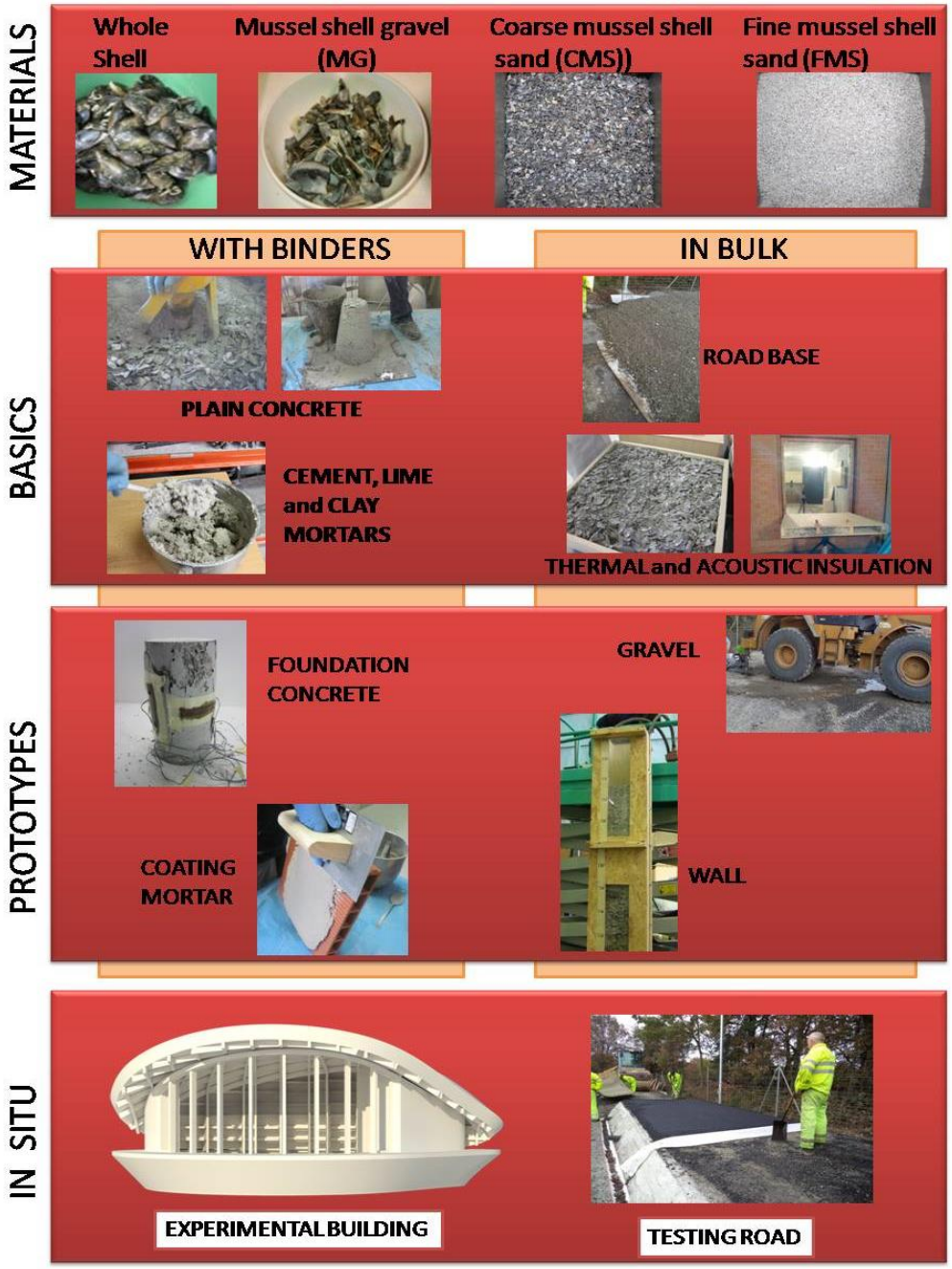
INTRODUCTION AND OBJETIVES

- Residue used is heat treated at 135ºC for 32min (gravel) and crushed (sand)
- Two groups of applications are studied : with binders and in bulk:
  - With binders: mortars (cement, lime and clay), concrete (structural and non structural) and bitumen layers.
  - In bulk: thermal and acoustic insulation as filling material.
- Products (different scales):
  - Basic tests: preselection.
  - Prototypes.
  - In situ
- In situ application (viability)
  - An experimental modulus was built in the University of A Coruña gardens.
- Finally, a life cycle analysis of all the products was made.



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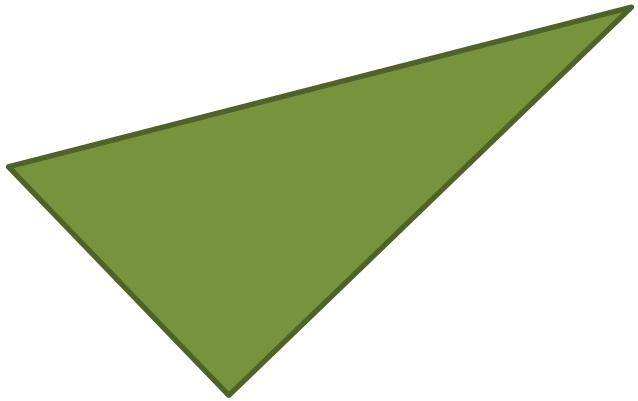


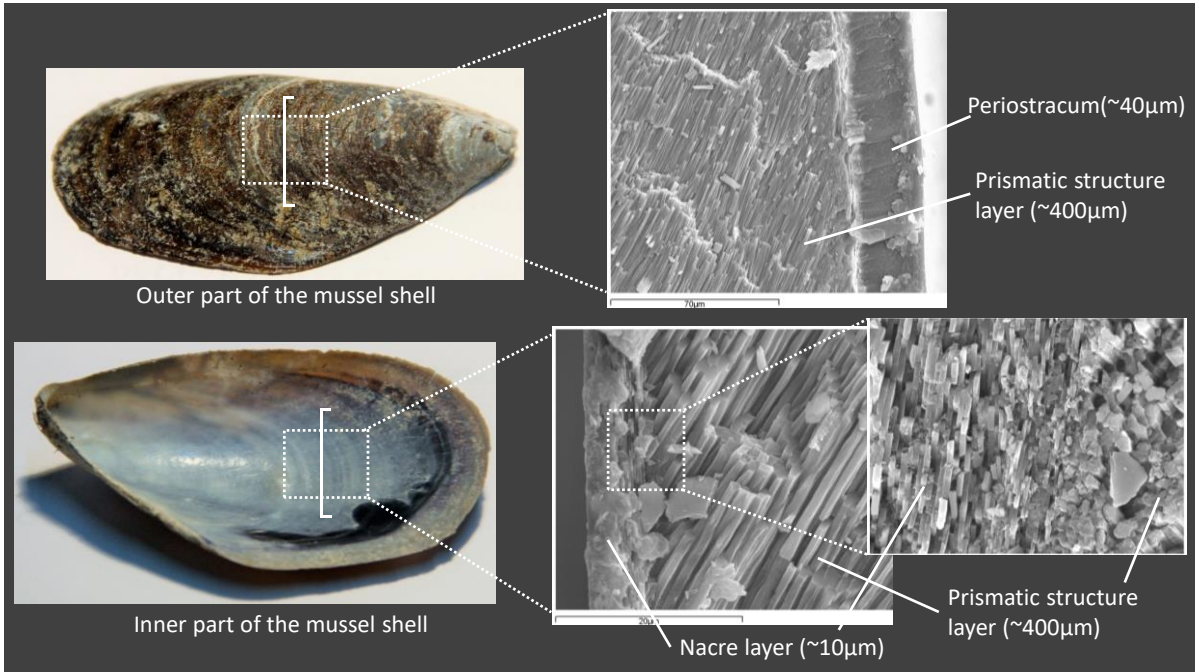
MATERIALS




- **Aggregate**:
  - Three different fractions of mussel shell aggregate, obtained from mussel shell waste were used: a mussel shell gravel (MG) and two mussel shell sands, one coarse sand obtained by crushing (CMS) and one fine sand obtained by grinding (FMS).
  - The most important properties of these are shown in the table.

	(S)	(MG)	(CMS)	(FMS)
Heat treatment	No	30min - 135ºC	30min - 135ºC	30min - 135ºC
Crushing process	No	No	Crushed	Ground
Fineness modulus	-	5.38	1,9	4,64
Particle density (kg/l)	-	2.62	2.65	2.73
Water absorption (%)	-	2.17	2.56	4.12
Sand equivalent (%) UNE-EN 933-8	-	-	99.3	68.2
Flakiness index (%) UNE-EN 933-3	-	99.24	-	-
Los Ángeles Coefficient (%) UNE-EN 1097-2	-	20	-	-
Chlorides (1%) UNE-EN 1744-1	-	0.46	0.28	0.51
Soluble sulphates (%) UNE-EN 1744-1	-	0.4	0.63	0.59
Total sulphates (%) UNE-EN 1744-1	-	1.5	1.6	1.3
Organic matter (visual) UNE-EN 1744-1	-	Darker	Darker	Darker
Light particles (%) UNE-EN 1744-1	-	0	0.1	
Organic matter (%) UNE 103204:93	**-**	**0.27**	**1.49**	**2.15**

- Materials conclusions:
  - The mussel shells have a composition of **calcite** $CaCO_3$ with a lower quantity of aragonite, traces of vaterite, **and different matrix proteins** and chitin, which **embed in three different layers**. The outer layer is the periostracum, which is mainly composed of a protein called chitin. The middle layer is composed of parallel calcite prisms, and the inner layer, known as nacre, is composed of laminar aragonite with a brick-and-mortar like structure. Furthermore, mussel shell nacre is also high in chitin.
- Final conclusion:
  - The main mussel shell characteristics that can affect concrete and mortar properties, when they are used as aggregates, are their **flat and flaky shape** and especially the presence of **organic matter** (matrix proteins).



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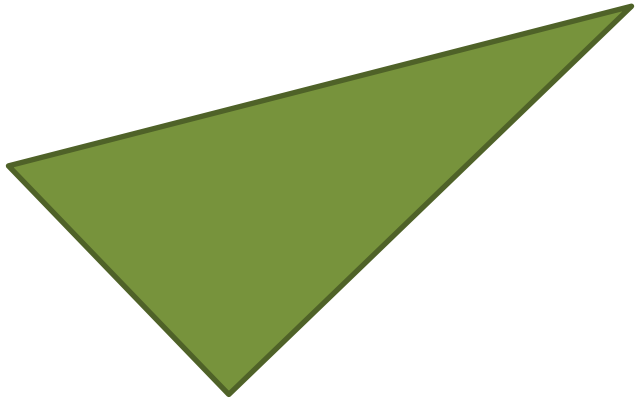

MORTARS

- **Mixes**:
  - For every binder (cement, clay and lime), three substitution rates of natural sand with mussel shell sand by volume were used**: 25%, 50%, 75% and 100%.**



CeM	LM	CM
Cement:sand bulk volume rate = **1:4**	Lime:sand bulk volume rate = **1:2**	Mass of clay over whole solid matter = **2%**
Water/cement mass rate = 1	Water/(dry lime paste) mass rate = 1.7	Water/binder (2µm smaller particles) mass rate = 10


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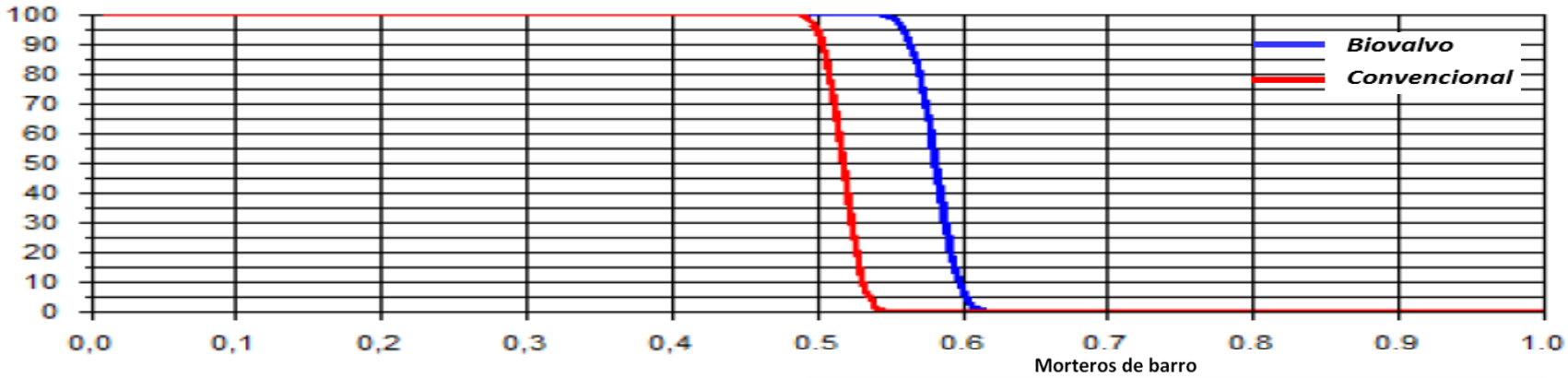
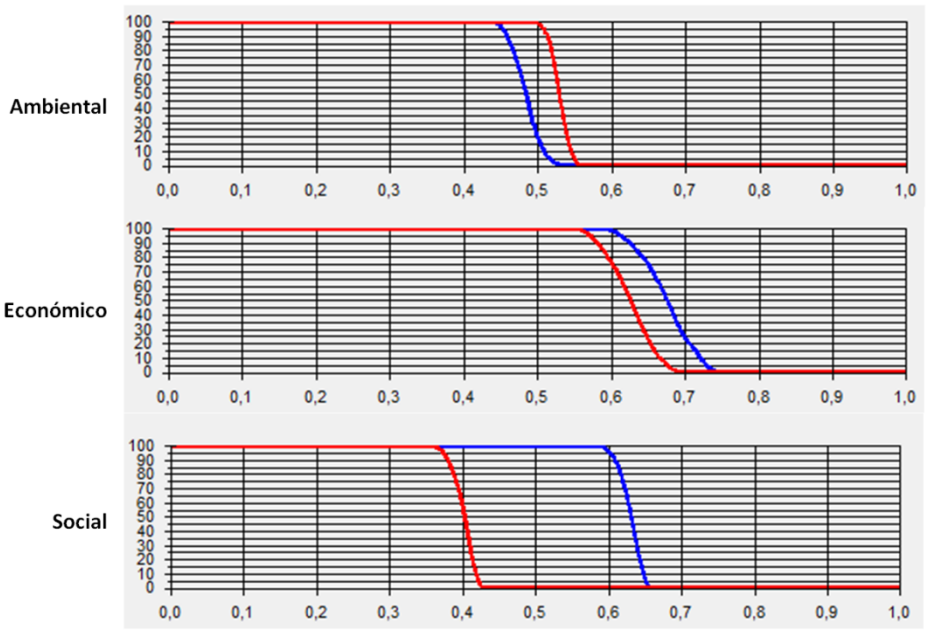
- Sustainability Indexes
  - These indexes were analysed. In all cases they were better when mussel sand was used.





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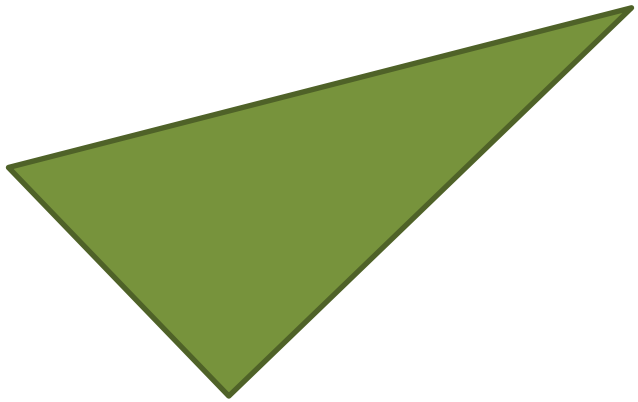


CONCRETES

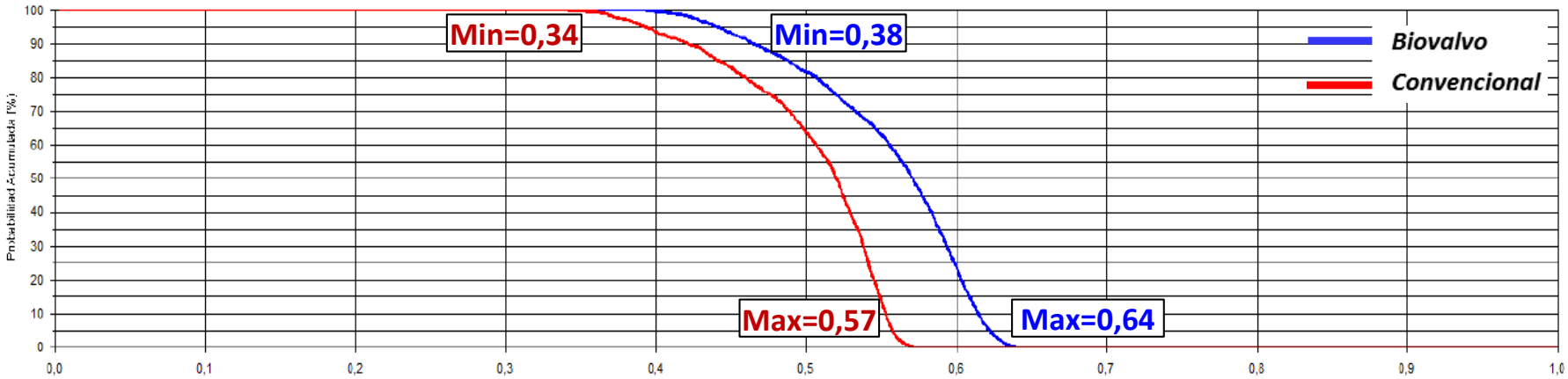
- **Mixes**:
  - A non-structural concrete (NSC) with a w/c ratio of 0.75 and with 225 kg of cement was designed as reference.
  - A reference structural concrete (SC30) was adjusted to fulfill the requirements for marine environment. It was designed with a w/c ratio of 0.50 and with a cement content of 260 kg.

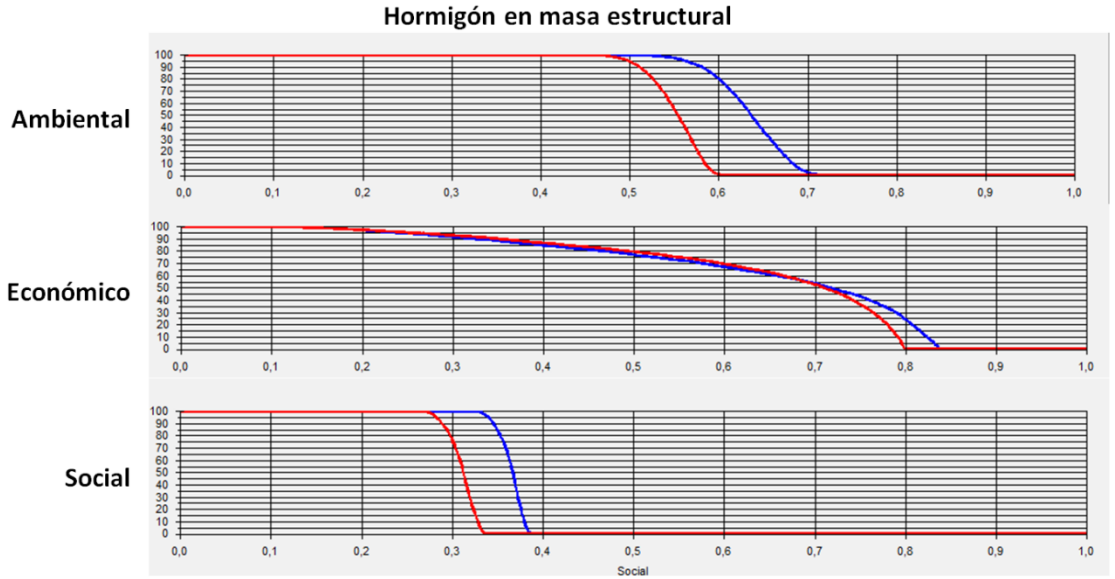
	Concrete	%NS (natural sand)	%MS (mussel sand)	%(NG/Coarse) – %(NG/Gravel)	%(MG/Coarse) – %(MG/Gravel)
SC 30	SC30 reference	100	0	100-100	0-0
	SC30 MS 25%	75	25	100-100	0-0
	SC30 MS 50%	50	50	100-100	0-0
	SC30 MS 65%	35	65	100-100	0-0
	SC30 MG 25%	100	0	75-65.4	25-34.6
	SC30 MG 50%	100	0	50-30.7	50-69.3
	SC30 MG 65%	100	0	35-9.9	65-90.1
	SC30 MS+MG 5%	95	5	95-93.1	5-6.9
	SC30 MS+MG 12.5%	87.5	12.5	87.5-82.7	12.5-17.3
NSC	NSC reference	100	0	100-100	0-0
	NSC MS 25%	75	25	100-100	0-0
	NSC MS 50%	50	50	100-100	0-0
	NSC MS 75%	25	75	100-100	0-0
	NSC MS 100%	0	100	100-100	0-0
	NSCMG 25%	100	0	75-62.5	25-37.5
	NSCMG 50%	100	0	50-25.1	50-74.9
	NSCMG 67%	100	0	33.3-0	66.7-100
	NSC MS+MG 5%	95	5	95-92.5	5-7.5
	NSC MS+MG 12.5%	87.5	12,5	87.5-81.3	12.5-18.7

- Then **three series** of mussel concretes were made: **one** series with **only sand** replacements (NSC MS), other series with **only coarse replacements** (NSC MG), and the **last series** with **both coarse and fine** replacements (NSC MS+MG).

	Non-structural concrete		Structural concrete	
Material	Volume (dm^3)	Weight (kg)	Volume (dm^3)	Weight (kg)
Water	168.75	168.75	180.00	180.00
Cement	72.58	225.00	116.13	360.00
NS(0-4)	495.30	1322.46	435.08	1161.66
NG(4-16)	192.45	502.30	216.04	563.86
NG(10-20)	95.92	255.14	77.76	206.83
Total	1025.00	2473.64	1025.00	2472.35

- Sustainability Indexes
  - These indexes were analysed. In all cases they were better when mussel sand or gravel were used.





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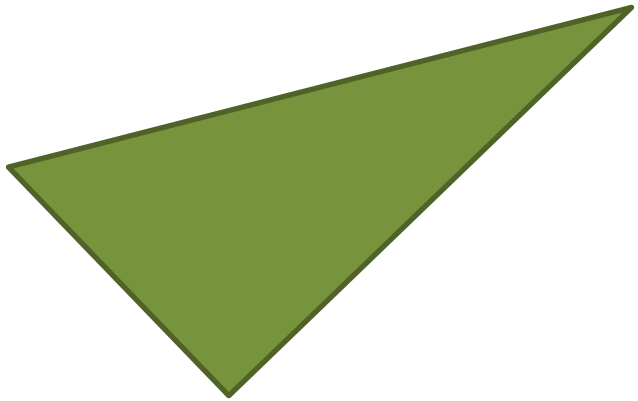


MUSSEL SHELL AS INSULATING FILLING MATERIAL

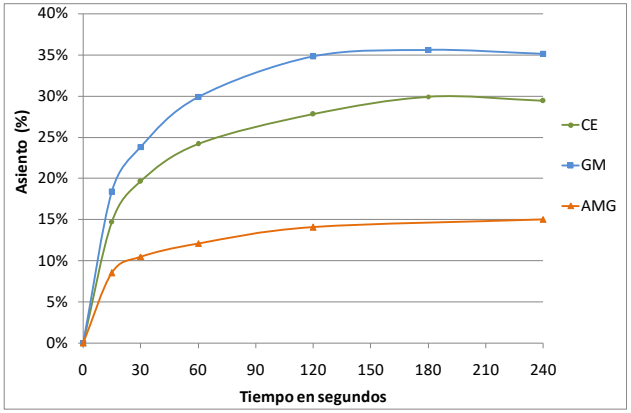
- **Results:**
  - Thermal conductivity (UNE EN 12667:2002)
    - It was selected the coarse size materia, gravel and whole shells.
    - The termal conductivity was measured with the material in a wooden box. This reproduces the insulation layer of a wall.
    - Results showed that both, the gravel and the whole Shell exhibited good behaviour as insulation material. So, this could be considered a good solution in any building Wall.

Materiales	Valor λ (W/mK)
Panel de corcho	0,045 - 0,038
Lana mineral	0,05 - 0,031
Arcilla expandida	0,148 - 0,095
Concha mejillón (entera, triturada)	*0,13 - 0,10*
Madera conífera ligera	0,13 - 0,23
Bloque cerámico aligerado	0,28
Ladrillo hueco	0,32
Bloque de hormigón hueco	0,45

Muestra	Densidad media ensayada (Kg/m^3)	% Aumento densidad	Conductividad térmica (W/m.K)
Concha entera CM	249	-	0,120
Concha triturada GM	492	97%	0,110
Arena gruesa AMG	1070	330%	0,150

MUSSEL SHELL AS INSULATING FILLING MATERIAL

- **Prototypes**
  - In order to confirm the results obtained with the standard test and to define the best compacting procedure different prototypes were developed.
- Compacting cylinder
- Wall section protype

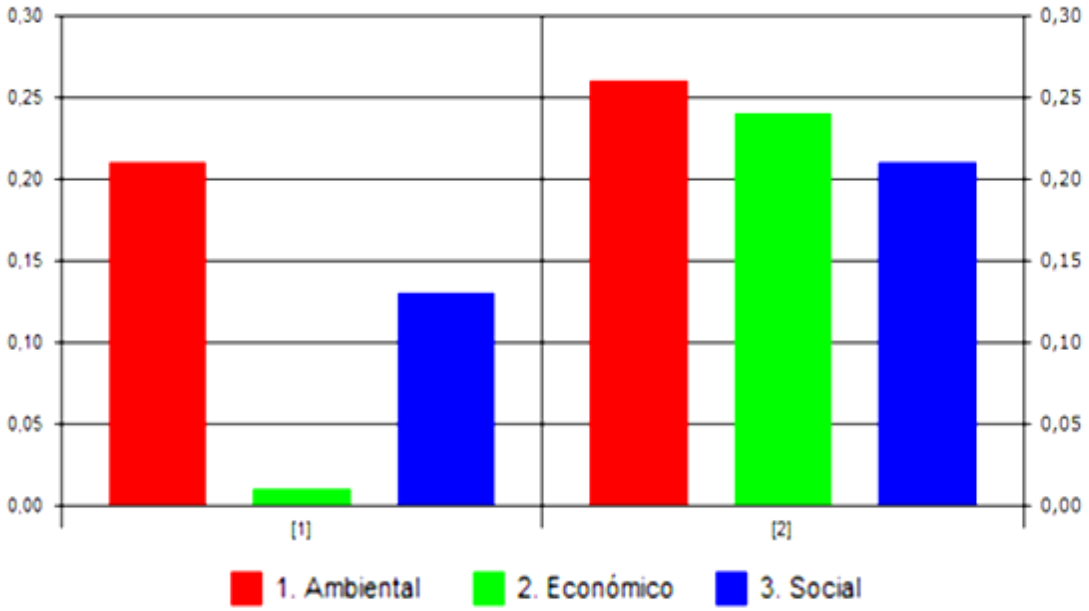


MUSSEL SHELL AS INSULATING FILLING MATERIAL

- **Sustainability**
  - The global evaluation is always positive for biovlavo products, however, they are not always the best products with partial indexes are examinated (environmental, social or economics).

Expanded clay (0,14-0,09W/mK)

Mussell shell granular insulation (0,11W/m.K)



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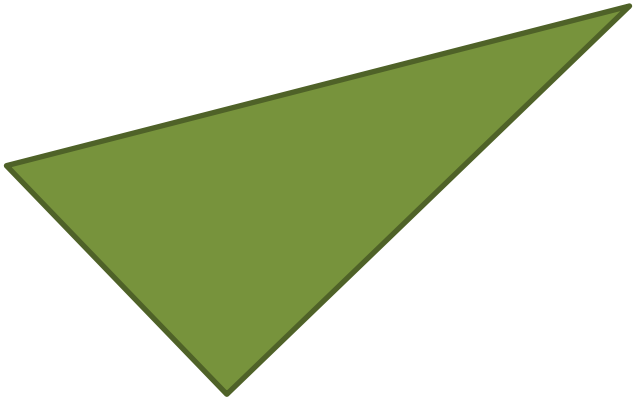

- **Experimental road section**
  - Description
    - The test section is divided into two subsections of 5 m in length and 3 meters wide and separated by a plastic geotextile sheet. One of the sections is made with conventional materials and other using mussel materials in the maximum amount possible.
    - The section corresponds to a section 4221 (low traffic roads and paths) with the following layers:
      - ZA20 conventional graded gravel and gravel including a 20% of gravel mussel
      - 5 cm layer of AC16 SURF 50/70 D with 100% of mussel shell fines as filler

In conclusion, it should be noted that the use of products mussel has not produced significant problems or reductions of productivity , effects on the work equipment or construction defects . Finally , control processes have established that the layers with mussels meet the physical, chemical and mechanical requirements set forth in PG -3 (Road Regulation limits).

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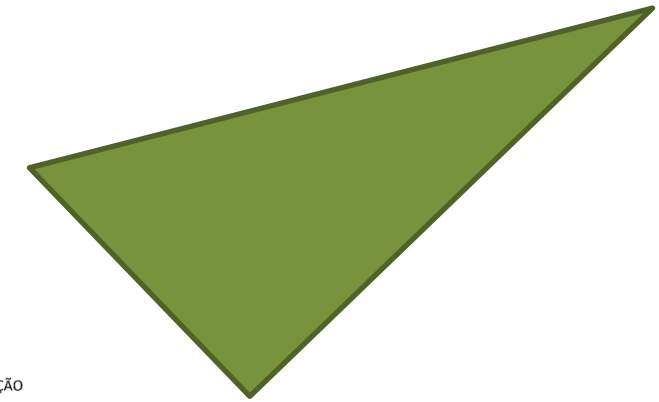
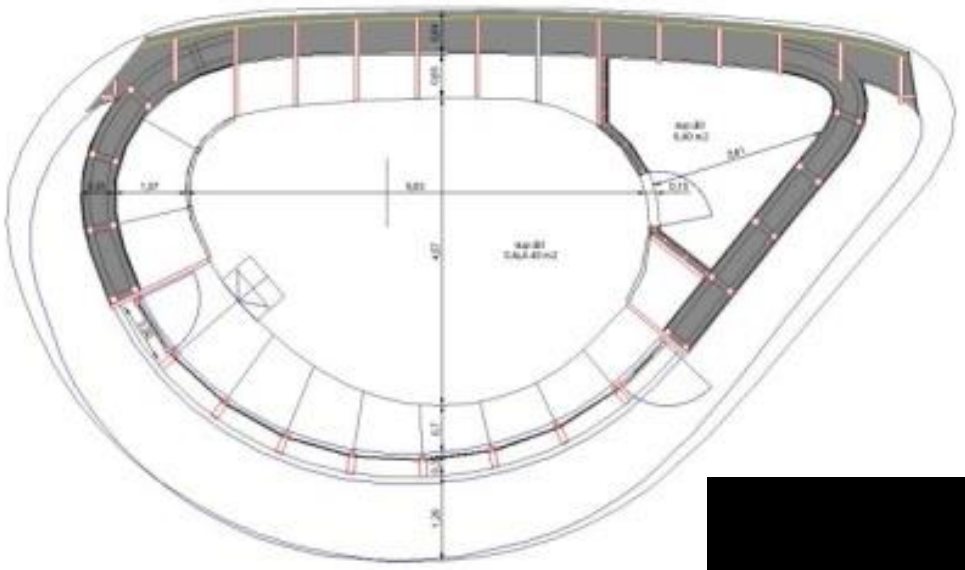
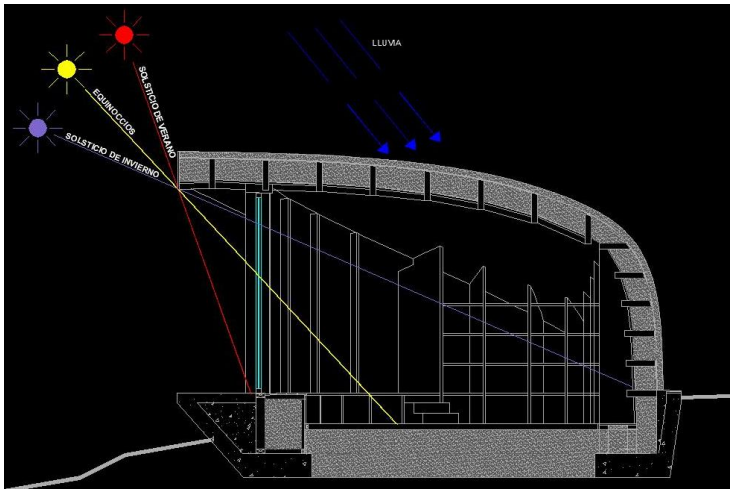


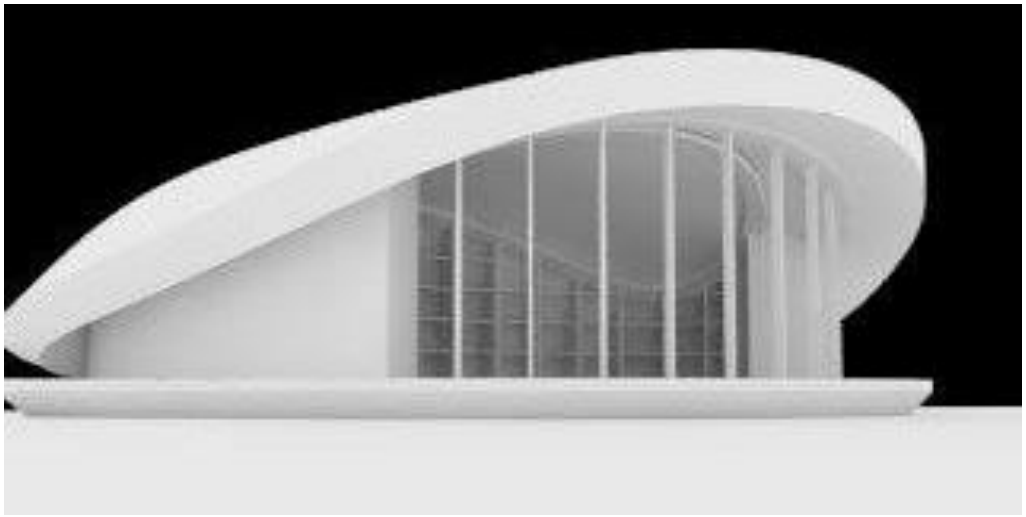
EXPERIMENTAL BUILDING (MÓDULO BIOVALVO)

Experimental building “BIOVALVO”. 40m^2 designed accoring to **standard Passivhaus** and under **bioconstruction criteria**. In this work we will prove the viability of every mussel shell products.



Horizontal section





3D view

EXPERIMENTAL BUILDING (MÓDULO BIOVALVO)

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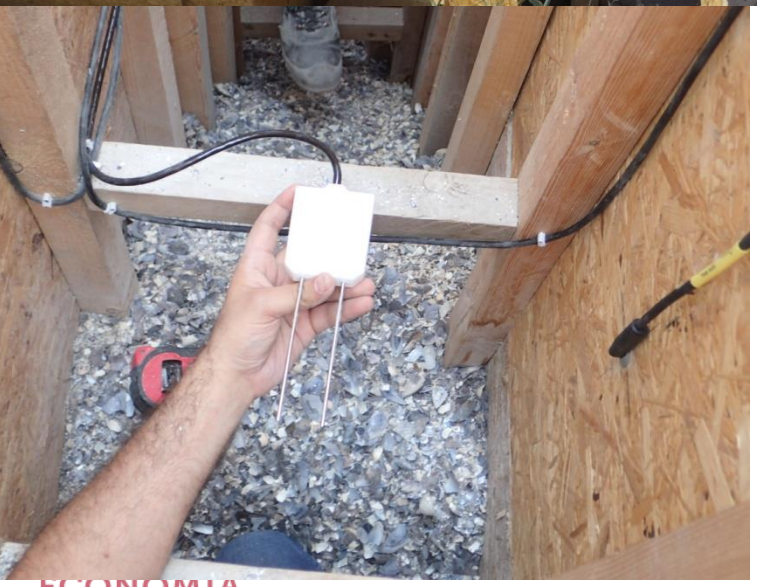
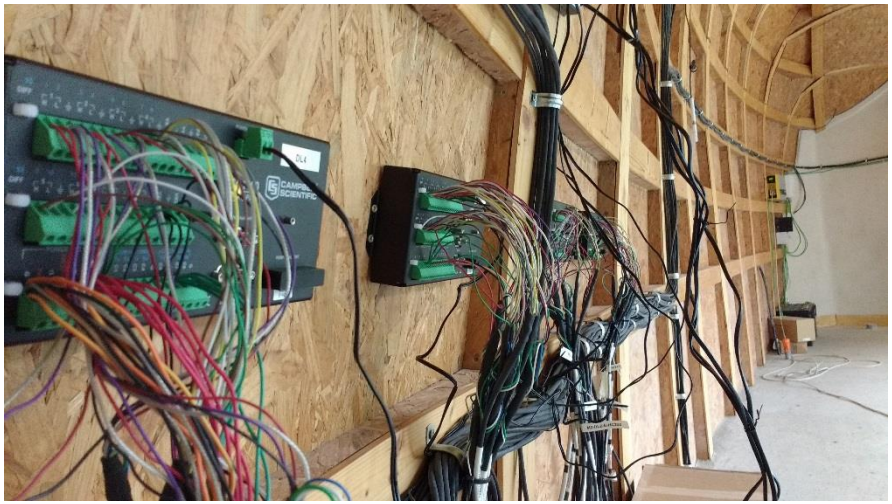


Muros de estructura ligera de madera rellenos con concha de mejillón aislante.

EXPERIMENTAL BUILDING (MÓDULO BIOVALVO)

Revestimiento con morteros de arcilla, cal y cemento, con 50% de árido de mejillón.

EXPERIMENTAL BUILDING (MÓDULO BIOVALVO)



Obrigado pela sua atenção

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