PANEL OF THERMOPLASTIC RECYCLED MATRIX REINFORCED COMPOSITES MODELIZATION FOR PILES WITH STEEL PIPES IN MARINE ENVIRONMENT APPLICATION

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Abstract: According to results from models of thermoplastic matrix materials design for marine environments, we have prepared thermocompression prototypes in order to analyze their behavior. The objectives of this study were to explore the possibilities of using standard elements (booster tubes) in combination with industrial plastic waste, generating new designs for a new application by combining CAD and FEM technology, build the prototypes to be tested under strictly controlled conditions using materials defined by their mechanical performance. We carried out an initial study to characterize the most appropriate matrix from recycled ABS computers and prepared a preliminary study of the metal reinforcement, cold formed and arc welded using a high frequency generator. After that we proceeded to calculate the size of the plates, bearing in mind the type of polymer matrix and the number and diameter of the tubes to be used in each case. The introduction of these tubes in polymer matrices causes stiffening of the panel and a decrease in weight in all polymers tested achieving lower densities of seawater. The results obtained in simulation models reveal that these new designs comply fully with the expectations raised initially by the collaborating company on whether these designs could bear loads and withstand unfavorable conditions.

1. INTRODUCTION.

The company sponsoring this research needed to investigate the possibilities of using its standard products, hollow steel construction tubes, in combination with plastic waste material produced by industry in the area (Ibi-Castalla industrial estates).

The finite element method was used in this case because of its possible application to whichever phase of the production process. As this is in reality the conceptual phase of possible new designs for new products, our objective was to determine which models to simulate in a predetermined prototype: hollow steel reinforcement tubes [5] and an ABS matrix, in order that once the manufactured units were tested and the results presented to the company, the same study could be carried out on the rest of the predesigned materials and geometries.

2. EXPERIMENTAL

Of the recycled compound materials analyzed [1,2] by the research group and the company, the study was initiated with materials that were of particular interest: standard d=63mm hollow steel reinforcement tubes DIN 2440, chosen for the possibility of continuous supply from the manufacturer, and an ABS matrix chosen because of its low water-absorption capacity.

As defined by studies on the most appropriate geometry, from the point of view of specific density, we will use the established dimensions obtained from research laboratory records to keep research costs as low as possible.

As this is initial research into new alternatives and applications for the products manufactured by the company, the basis of the mechanical experiments to be carried out on these prototypes would be two mechanical tests that are easy to reproduce in their laboratory. This would allow the company to verify the possibilities of this new line of research without incurring all the initial expenses involved.

The types of simulations to be carried out are:

a) Simple compression with uniform pressure applied to one of the faces with large section. This type was chosen to verify the behavior of the ABS matrix and the hollow steel reinforcement tubes (5) under load conditions which are normal on similar panels of other materials.

b) Uniform pressure on one of the faces with a greater section, with fixed anchors on three of the lateral faces with smaller section, leaving the rest of the faces free to observe the behavior of the compound material in normal situations. This simulation was chosen as it was considered that this type of prototype could form part of more complex flat structures, such as the interior decks of fish farm auxiliary boats (3,4).

The conditions for the load and working environment for the prototypes were fixed by the company sponsoring the research. The cases analyzed can be summarized as follows:

ABS thermoplastic matrix perforated and reinforced with 5 tubes of DIN 2440 steel with outside diameter de d=63 mm. Simulation type: simple compression with uniform pressure. Tests were carried out using two variations with static coefficients of friction (COF): CASE A: 0,15 (Broaching operation) and CASE B: 0,30 (melted) in such a way that we would be able to observe the behavior of the prototype when the coefficient of friction between faces was reduced.

ABS thermoplastic matrix perforated and reinforced with 5 tubes of DIN 2440 steel with an external diameter of d=63 mm. Simulation type: Three simulated lateral faces as fixed supports and the opposite face of the matrix with free movement. Two variations were modeled with different static rubbing: CASE A: 0,15 (broaching) and CASE B: 0,30 (melted) in order to observe their behavior.

ABS thermoplastic matrix perforated without reinforcement tubes. This test is carried out to analyze the influence of steel tubes (5) being present in the matrix. Two variations were modeled with different load conditions in order to compare Case1 with Case 2. In this model we analyzed the following scenarios: CASE A: Three lateral faces simulated as fixed supports and the other face with free movement. CASE B: Test type: simple compression with uniform pressure.

ABS thermoplastic matrix without perforation and without reinforcement tubes (solid panel). This test was carried out to analyze the influence of the steel tubes introduced inside the matrix from the point of view of tension. This test was carried out with three model variations with different loads in order to compare CASE 1 and CASE 2.

As this is an initial study for a new prototype, with the agreement of the company involved, it was necessary to determine the stress states (Von Misses) of the maximum deformations produced under previously defined different conditions. No other calculation to evaluate the economic viability of the new product has been carried out by the company. However, there remains the possibility of modifying the load and conditions at the company's discretion, once the possible commercial applications have been decided

The dimension characteristics of the pre-selected prototype are as follows:

Table 1. Dimension characteristics of the prototype to be simulated.

AC_5_d63_ABS_GP22_prototype	
Wide sheet (mm)	327.6
Length sheet (mm)	500.0
Thickness Sheet (mm)	75.6
Tubes number	5
Diam.x tube thickness (mm)	D63x2

The experimental test and simulation temperature is 23ºC, due to the marine exterior applications. Figur shows how we constructed a simulation graphic representation (in IGES format) of this prototype with the design program CATIA V5R19, formed of a matrix with five standard hollow steel tubes inserted (the most unfavorable case).

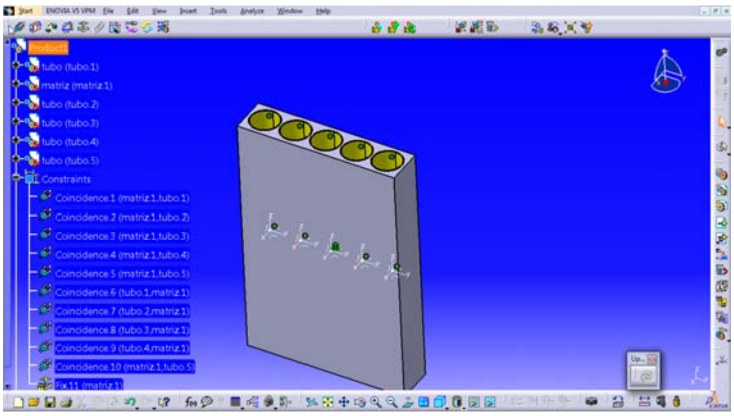

Figure 1. Representation of the prototype in CATIA V5 R19.

In this initial case, the optimum simple of the compound material is represented: ABS thermoplastic matrix and standard hollow steel construction tubes (DIN 2440 with approximate density of 1 g/cm3). In the absence of trustworthy data on recycled ABS, for our calculations and understanding of the behavior of this material we used the data provided by the German manufacturer BASF of their product "Terluran GP22" which is widely used for similar applications to ours (see

Tabl and Tabl).

Table 2. Mechanical characteristics of Terluran GP 22 (source: BASF)

Mechanical Properties			
Tensile modulus	ISO 527-1/-2	MPa	**2300**
Yield stress, 50 mm/min	ISO 527-1/-2	MPa	**45**
Yield strain, 50 mm/min	ISO 527-1/-2	%	**2.6**
Nominal strain at break, 50 mm/min	ISO 527-1/-2	%	**10**
Flexural strength	ISO 178	MPa	**65**
Charpy impact strength (23°C)	ISO 179/1eU	kJ/m²	**180**
Charpy impact strength (-30°C)	ISO 179/1eU	kJ/m²	**100**
Izod notched impact strength (23°C)	ISO 180/A	kJ/m²	**26**
Izod notched impact strength (-30°C)	ISO 180/A	kJ/m²	**8**
Charpy notched impact strength (23°C)	ISO 179/1eA	kJ/m²	**22**
Charpy notched impact strength (-30°C)	ISO 179/1eA	kJ/m²	**8**
Izod notched impact strength, method A (23°C)	ASTM D 256	J/m	**300**
Ball indentation hardness at 358 N/30 s	ISO 2039-1	MPa	**97**

Table 3. Other interesting characteristics of Terluran GP 22 (source: BASF).

Properties			
Polymer abbreviation	-	-	**ABS**
Density	ISO 1183	kg/m³	**1040**
Water absorption, equilibrium in water at 23°C	similar to ISO 62	%	**1**
Moisture absorption, equilibrium 23°C/50% r.h.	similar to ISO 62	%	**0.22**
Processing			
Processing: Injection moulding (M), Extrusion (E), Blow moulding (B)	-	-	**M**
Melt volume-flow rate MVR 220 °C/10 kg	ISO 1133	cm³/10min	**19**
Pre-drying: Temperature	-	°C	**80**
Pre-drying: Time	-	h	**2 - 4**
Melt temperature, injection moulding	-	°C	**220 - 260**
Mould temperature, injection moulding	-	°C	**30 - 60**
Moulding shrinkage, free, longitudinal	-	%	**0.4 - 0.7**

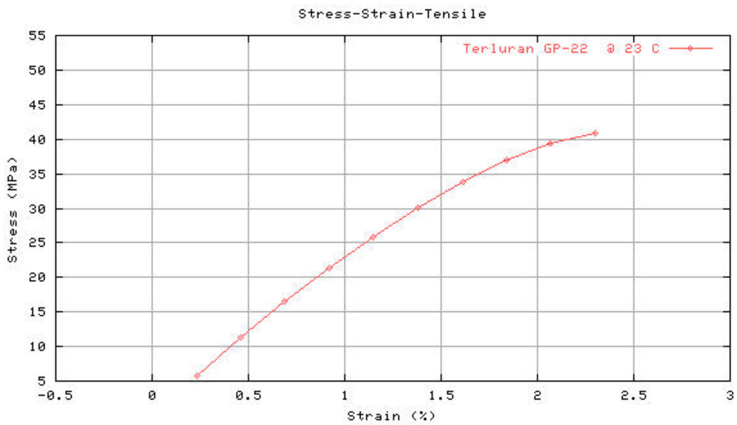

Figure 2. Stress-deformation curve of Terluran GP-22 (source: BASF) a 23ºC.

In hollow tubes materials, steel was chosen and it was necessary to define a new material GP22 to define the ABS from the BASF brand used (Terluran GP 22). We have introduced manually the mechanical characteristics of Tables 2 and 3. Similarly, we introduced the strain-stress curve points of the pre-selected ABS at an environmental temperature of 23ºC, obtained from Figure 2. The aim of that is to analyze with the ANSYS program the plastic behavior of the Terluran GP 22 material.

Figur3 and 4 shows the exported model (CAD) and the simulation model (CAE).

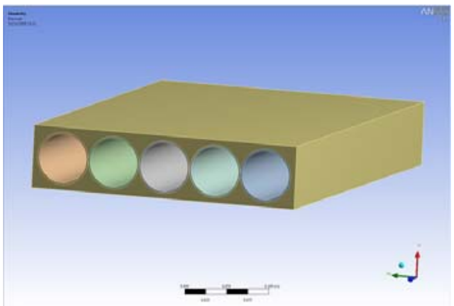

Figure 3. Geometry of the model.

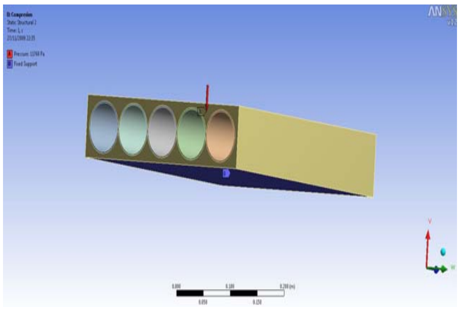

Figure 4. Example of simulated model.

3. RESULTS AND DISCUSION.

We can compare the results obtained in the simulation series by fem program (Ansys™).

Table 3. Summary results of all simulated cases

CASE	1	1	3	4		2	2	3	4
subcase	A compression 0,15	B compression 0,30	B compression	B compression		A 3 fix 0,15	B 3 fix 0,30	A 3 fix	A 3 fix
Von Misses eq. Stress, max	**1,89 Mpa**	**0,855 Mpa**	**4,769 Mpa**	**0,023 Mpa**		**10,202 Mpa**	**4,676 Mpa**	**18,89 Mpa**	**0,119 Mpa**
Von Misses eq. Stress, min	**269,3 Pa**	**978,47 Pa**	**415,79 Pa**	**6194,3 Pa**		**3,1937e-9 Pa**	**11,119 Pa**	**5,6179e-9 Pa**	**989,08 Pa**
Máx. Displacement shape	**0,003mm**	**0,001 mm**	**0,018 mm**	**0,0006 mm**		**0,06 mm**	**0,034 mm**	**0,6 mm**	**0,009 mm**
Node numbers	**113.958**	**24.404**	**115.728**	**13.478**		**113.958**	**24.404**	**115.728**	**13.478**
Elements number	**44.161**	**13.519**	**58.591**	**6.607**		**44.161**	**13.519**	**58.591**	**6.607**

In comparison with its yield strength, we see that this combination of materials more than fulfills the expectations of the patron company.

This series of models will allow us to later apply the rest of the applicable materials to the matrix along with the rest of the geometric alternatives, allowing us in a later phase to compare these simulated models with the experimental tests for each type of prototype constructed.

In Table 4, we can see the use of the tool included in ANSYS called “Contact Tool”, which allows us to analyze the type of contact existing between the outer face of each of the reinforcement tubes and interior housing of each of them in the ABS matrix. We obtained data before and after simulating the model in cases 1 and 2. In both cases, there are no situations of abnormal inactive.

Table 4. Contact information

Initial Information

For additional options, please visit the context menu for this table (right mouse button)

Name	Contact Side	Type	Status	Number Contacting	Penetration (m)	Gap (m)	Geometric Penetration (m)	Geometric Gap (m)	Resulting Pinball (m)	Real Constant
Frictional - Part 6 To Part 4	Contact	Frictional	Closed	2003,	9,3567e-017	0,	4,1592e-004	0,	6,9229e-003	7,
Frictional - Part 6 To Part 4	Target	Frictional	Closed	1196,	2,414e-015	0,	4,749e-004	0,	3,5418e-003	8,
Frictional - Part 6 To Part 3	Contact	Frictional	Closed	1986,	4,2001e-017	0,	4,4267e-004	0,	6,3595e-003	9,
Frictional - Part 6 To Part 3	Target	Frictional	Closed	1199,	2,4706e-015	0,	5,3983e-004	0,	3,5418e-003	10,
Frictional - Part 6 To Part 1	Contact	Frictional	Closed	2063,	1,7745e-017	0,	4,1871e-004	0,	6,2937e-003	11,
Frictional - Part 6 To Part 1	Target	Frictional	Closed	1192,	1,9803e-015	0,	5,2201e-004	0,	3,5418e-003	12,
Frictional - Part 6 To Part 5	Contact	Frictional	Closed	2012,	6,146e-017	0,	4,165e-004	0,	6,3385e-003	13,
Frictional - Part 6 To Part 5	Target	Frictional	Closed	1191,	1,1882e-015	0,	5,1125e-004	0,	3,5418e-003	14,
Frictional - Part 6 To Part 2	Contact	Frictional	Closed	1966,	9,9864e-017	0,	3,818e-004	0,	6,8506e-003	15,
Frictional - Part 6 To Part 2	Target	Frictional	Closed	1194,	1,9426e-015	0,	4,2961e-004	0,	3,5418e-003	16,

Color Legend

Red	The contact status is open but the type of contact is meant to be closed. This applies to bonded and no separation contact types.
Yellow	The contact status is open. This may be acceptable.
Orange	The contact status is closed but has a large amount of gap or penetration. Check penetration and gap compared to pinball and depth.
Gray	Contact is inactive. This can occur for MPC and Normal Lagrange formulations. It can also occur for auto asymmetric behavior.

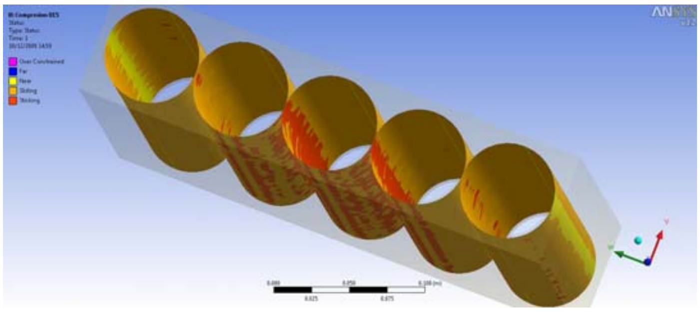

Figure 5. Example of the "contact tool". Simple compression.

Once the plastic has been poured into the mold, the mold is closed and introduced into the hot plate machine (Figure 6) which is set at a determined temperature depending on the fusion temperature of the plastic to be used in the prototype matrix. When the mold is introduced into the machine, a certain pressure is applied so that the plastic takes the shape of the mold. After a determined period of time, the mold is extracted from the hot plate machine and allowed to cool, so that the plastic may then be extracted from the mold and the supports removed, thus obtaining the final prototype.

Figure 6. Hot plate press used.

To produce the various prototypes, figure 7, different types of polymer were used: computer ABS and PP1B and PVC, and the results can be seen in the following figures.

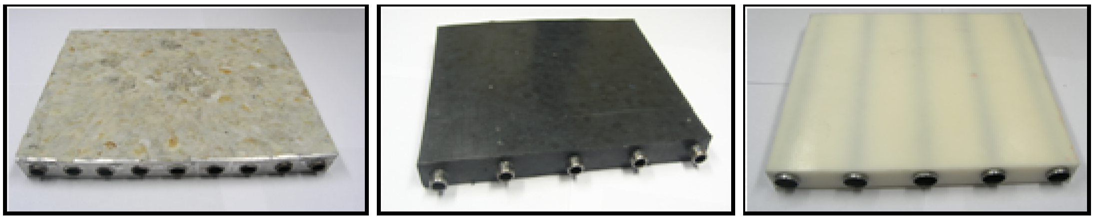

Figure 7. Prototypes manufactured with COMPUTER ABS, PP1B and PVC respectively

6. CONCLUSIONS.

The tests carried out on the different recycled polymer materials show that the COMPUTER ABS is the material with the lowest resistance and lengthening of the materials and coming from carcasses of electrical elements, it contains fire-resistant material. However, as it is the material with the lowest commercial possibilities, using this material could be economically interesting. On the other hand, the materials that showed the best results were ALARM ABS and PP1B.

Calculations on the density show that depending on the density of the matrix, the diameter of the tubes used is different, but 5 tubes are always used with whichever material so that density stays at a minimum.

In the laboratory, the prototypes were constructed correctly and their reproduction is not at all complex.

7. REFERENCES

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