



TOPIC 3 - (Material characterization)

Architecture, Bioclimatic and New Materials in Housing Solutions in Colombia

Feasibility to produce hybrid materials

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Abstract

Our time is distinguished from the major periods of architectural history mainly for the concurrent existence of many partially conflicting trends. It is not easy, either for the expert well-informed way through this seeming chaos. The situation is even more difficult for the student or the hobbyist interested in this topic. [1]

The proposed research aims to contribute elements that characterize some new materials (composite materials) [2] in order to generate constructive elements using an appropriate cost-effective, enabling to provide solutions to problems in bioclimatic housing in Colombia whose construction (of the elements), from non-conventional systems, reduce the difficulties that currently generate traditional construction processes.

Characterized materials and components of the system limiting the design to a panel system for leather finishing in a model of basic shelter located in intermediate seismic hazard zone, according to the classification of the NSR-98 [3], with emphasis on Bogotá, Colombia.

Communication text

Just like the man, by means of the culture, the clearing, the channels, the ways, modifies the Earth face and creates an own geography, the architect generates new conditions for the historical life, social, moral. The architecture is creative of unforeseeable surroundings. It satisfies certain necessities and it propagates others. The Architecture is the inventor of a world.

Henri Focillon, *La vie des formes*, Flammarion, Paris, 1934 (trad. it. *La vita delle forme*, Einaudi, Turin, 1987).



In the world in which it is lived, the risk plays a fundamental role. And it is that, in essence, the life is pure risk; the constant effort to maintain it is, in fact, a fight against all those factors that induce the permanent possibility to lose it.

The complexity of the vital experience in our civilization produces a confrontation continued, that is assumed of collective or individual form, as much plus whichever greater is the sophistication degree that marks the human relations. In many cases, the scale and the complexity of the risks make a long term prediction difficult, and anyway the mitigation of its consequences is a difficult and expensive task.

Since with the present state of the knowledge an effective prediction is not feasible from any type of phenomenon, natural or it is caused, the effort of the competent authorities would be due to concentrate in prevention tasks, which they include an ample fan that goes from the investment in investigation and development until elements that generate worthy house in extreme cases, and the adoption of special measures in the matter of territorial ordering.

The fact of the architectonic innovation and the renovation of the way of life in the present century is provoking a deep malaise, because that one can be perceived how around the question of the new thing, the postulates of a thought very generalized are outlined, that leans in the opposition between the old thing, given back the past, and the modern thing, installed on the facts of the future, and the rejection to the previous models, in fact surpassed, in benefit of another proposal that is estimated necessarily more good. The reflection on the space of the innovation takes to define two levels of reading: first, the structure, the essential, the lasting thing; second, the secondary thing, the weather.

Although the question of the house continues being one of most complex and fundamental, this one is only determining in the social evolution in as much is related to the urban context, the landscape, the nature of the cities and its evolution in the time.

When having as departure point the previous thing is arrived more at a level of defined analysis than it touches to the essential, the lasting thing: the collective space that stays, nobodies are the new programs of house, like the place of the movement and the relation between the members of that group, the structural frame that must contain in perfect coherence, the complexities of an architectonic and urban heterogeneity, but also, the socio-cultural determinant. The true tools of the renovation of the habitat locate less in the necessity of new expositions for the districts that we denominated subnormal, that in the search of new urban strategies, founded on a first of all contextual approach, for the elaboration of fragments of a city in transformation. The great delay that lives the construction in our country must, to a great extent, to the rejection and the fear to confront new constructive technologies.



Thus, as the problem of the land in Colombia is exemplified by the monoculture, the problem of the construction is characterized by the concentration of efforts, practices, qualification and investigation around conventional materials for our constructions as he is it the concrete one, followed by the rubblework and in some cases by the steel to complement and to close his structures.

The present investigation on the use of new materials, in the development of solutions of house in Colombia, goes not as much to the search of new expositions to generate a house worthy, like a the search of a strategy founded on the critical apprehension of the own reality of our country, a reality that is accompanied by a glance able to reveal the potential force of each site, to affirm its essence, to restitute that poetry of the evident thing, the ordinary.

We got to dwell, apparently, only by means of the construction. This last one, the construction, has to the first - dwelling as its goal (...) Of this form serious dwelling in any case the aim that presides over all construction. To dwell and to construct are related like aim and means. Nevertheless, while it is this whole which we have in mind, we will take to dwell and to construct like two separated activities: an idea that in if it has something of correct. Still, at the same time, by the scheme mean-aim we obstructed our vision of the essential relations. Because to construct it is not only means and a route towards dwelling: to construct is, in itself, to dwell.

Martin Heidegger, 5 of August of 1951, Symposium on "Man and celebrated space" in Darmstadt, Germany. Called conference Bauen Wohnten Denken, To construct To dwell To think.

The necessity of shelter and formation of habitat in the different zones that compose the Colombian territory, in both types of scale, rural and urban, is determined by natural, social and cultural factors; this, in principle sustains the development of the present project of investigation, limiting that the exercise was limited urban zone basically.

This problem requires of industrialized and self-sufficient solutions, which must generate respect and conscience of certain the natural and cultural surroundings, trying not to alter nor to force these conditions to obtain an optimal operation of the given answer.

The problem of the house for the sectors of low income in Colombia has been understood generally in quantitative terms, considering tangentially the deficit, situation qualitative that repels in deterioration of the quality of life of the population.

In Bogotá, city which the present investigation is limited, between 1972 and 1985 the rate of diminution of the dimension of parcel for houses had been reduced 3,56%. In this sense, the batch size has been reduced to a 60% from its initial dimension [4]. In fact, at this moment the minimum house is constructed in a parcel of 36 m² (3 meters wide and 12 meters in length).



The possibility for this investigation occurs to design no conventional fixed or transportable houses "in its constructive system", where the flexibility and congruency between the design and the function provide variety of spaces.

Of equal way, one considers to today present/display new possibilities - in day somehow sub valued to restrain monotony and the absence of innovation in the development of new material constructive processes using different from conventional (concrete, wood and steel) in the structures, finished and the closings of the created architectonic projects until now.

Nowadays in the world the investigation and proposal on new materials are very outpost. Still we do not have the formation and the culture of the development, when materials like the plaster-cardboard panels appear to us, fibrocement, synthetic materials and others, we followed convinced that that material that do not have high a specific weight does not have the suitable structural characteristics to generate constructions with high specifications of earthquake-resistance and durability.

The use of light materials and constructive systems that facilitate the transport, the adjustment and the solution of houses of great quality in the different zones that compose the Colombian territory, must be high-priority in a country like ours that refuses to accept that we are in a great zone of seismic threat, with unfavorable climatologic conditions, permanent state military and that not yet implements suitable constructive systems for the use of new materials.

The new materials - material composed of high behavior such as the reinforced polymeric materials with fibers, not yet have reached their maturity in calculation and use after civil structures. Reliable procedures have not arisen from analysis of prediction of fault.

As far as plate and shells they have been developed to a great extent from isotropic methods, without taking into account the sharp effect very from the interlaminar one or doing suppositions simplified. It is possible to be said that they are in a point of evolution similar to which the steel had in century XIX.

In order to be brief the normal period of time that would perhaps require the development of the necessary technologies, the FHWA [5] is investing several million dollars to consider it an area of investigation of high priority of which great opportunities for the construction of tightened bridges are expected. Other awaited applications are bars of reinforcement, grids, slabs, systems beam-column and anchorages of pre-effort.



From the previous premises, the present investigation does not try to generate norms, on the contrary it projects to characterize new materials (material compound), its processes of obtaining and application to no conventional constructive systems, supported in Law 400 of 1997 [6].

Traget Horizon: To foment the use of new materials (fibers, matrices and materials for nuclei), through handling of a promotion and suitable diffusion of the benefits and possibilities that present/display these for the design of nontraditional constructive systems of houses in Colombia.

In Colombia, for the development of constructive systems of house, the knowledge does not exist and the uses of new materials and for cultural reasons systems different from the traditional ones are ignored (conventional). It is continued thinking that the camping carps are complex membrane systems, when the reality is another one.

The planning of the cities and the incapacity of the official beings to face extreme situations, that unfortunately have become daily as much for displaced emergencies as for or natural catastrophes, create a critical character, by this, is here where greater obligation in the treatment of all the necessities of the human being exists.

The New Materials. The sector of the construction is specially promising for the new structural materials from the point of view of the high amounts that of them could be used, since the concepts of security and reliability in this sector are fundamental.

The new materials, and in special those reinforced by textile armors, allow to generate elements that can respond to the exigencies of resistance, rigidity, stability and balance, multiproperties (thermal and acoustic) and of aptitude to the integration of functions (Smart Home). The search of the human comfort and the economy of energy - as much in the plane of generation like of use, and the necessity to industrialize the construction (to evaluate the real costs and to diminish the wrecks) is aspects that favor the development of the new materials in the construction.

Architecture and Sustainability. The architecture necessarily is implied in all program of sustainable development, an inescapable question without a doubt in the century that begins. The buildings have an impact in their surroundings on different scales, from the region to the city, the sector and the district. This impact is derived from the elements and the systems that constitute them, of the used materials, and are pronounced of diverse forms throughout the complete cycle of life of the building. The selection of materials that implies all project brings with himself inevitable consequences: the impact of its extraction,



processing and fabrication; the energy necessary to carry out these processes; the emissions associated with the later product use certain, as well as its maintenance, demolition, recycling and spill.

Also, in the strategies to future that affect the fuel use, the great environmental impact of the possible polluting emissions to the atmosphere, of the consumption of energy in its extraction, its processing and its distribution must consider.

It is possible to consider, in addition from the global impact to scale, the impact on the smaller scale of the spaces inhabited like the interiors of the houses and the places of work, in relation to aspects like the quality of the air, the ventilation, the good thermal conditions, the space quality and the illumination, the developed activity or the pleasure and the security.

The constructed surroundings constitute basic and relatively stable means. The fact that the buildings have, generally, a life of several decades, and some even gets to conserve itself during centuries, turns them one of the main patrimonies of the society. To valorize implies it to consider the service life of the buildings in its totality and to avoid those pretensions of short reach that are justified in the mere minimization of the initial investments.

A strategy based in the sustainable development will try to prolong the life of the existing structures, as well as to reuse the materials of its construction it originated. The adaptation of the existing thing is, generally, preferable to the construction of a new building; the update of its operation constitutes an effective unfolding of the resources.

Used materials

For the present investigation two models set out which are analyzed first mathematically from Methods of Finite Elements - MEF- using program ANSYS [7], followed becomes he himself analysis in program DAC [8] and finally with the support of SIKA ANDINA of COLOMBIA and ANDERCOL S. A., that facilitated the material for the laboratory tests, the Extension Institute and Investigation - IEI - of the Faculty of Engineering of the National University of Colombia are made pertinent tests to the laminates in the laboratory.

The laminates: For the laminates two combinations set out, first, was used a CARBON FIBER + EPOXY, the second sample is made from the FIBER GLASS + POLYESTER.



The fibers: In the case of skeletal composites of high behavior (like he is the proposed one in this paper), usually they are reinforced with continuous fiber, which is the spine of the material that determines the rigidity and reinforcement in the direction of the same one and the local efforts are transferred from a fiber to another one.

Carbon fiber: For the model a commercial fiber made by Excel is used, dependent company of General Electric and whose characteristics described in the Table 1 and provided by the manufacturers, were the employees for the mathematical model.

Table 1. Carbon fiber + Epoxy, Ref. EXCEL AS4/3502

AS4/3502	CARBONO	EPOXI	UNIDIREC	70%VF
RIGIDITY		RESISTANCE		
Ex(GPa)	146	X(MPa)	1650	
Ey(GPa)	9,7	X'(MPa)	1350	
Ez(GPa)	9,7			
		Y(MPa)	59	
vxy	0,31	Y'(MPa)	200	
vxz	0,3			
vyz	0,52	Z(MPa)	55	
		Z'(MPa)	250	
Gxy(GPa)	5,2			
Gxz(GPa)	5	Sxy(MPa)	70	
Gyz(GPa)	3	Sxz(MPa)	75	
		Syz(MPa)	100	

For the physical model is used SikaWrap Hex 103C (Table 2), which is a fabric of unidirectional carbon fibers, high strength and high modulus, structural reinforcement used in bending, shear, confinement of structural elements such as beams, columns, slabs, and walls. The material is saturated in work using the epoxy system SikaDur 300 Hex or SikaDur Hex 306 to conform to Carbon Fiber Reinforced Polymer system to (CFRP), used for the reinforcing of structural elements.

Table 2. Carbon Fiber SikaWrap Ref HEX 103C

Typical Data	
Storage Conditions	Store dry at 40°-95°F (4°-35°C)
Color	Black
Primary Fiber Direction	0° (unidirectional)
Weight Per Square Yard	18 oz. (618 g/m ²)
Fiber Properties	
Tensile Strength	5.5 x 10 ⁵ psi (3,793 MPa)
Tensile Modulus	34 x 10 ⁶ psi (234,500 MPa)
Elongation	1.5%
Density	0.065 lbs./in. ³ (1.8 g/cc)



Fiberglass: For the proposed model uses a commercial fiber manufactured by Sika Corporation, and whose characteristics described in Table 3 below and provided by the manufacturers, were used for the mathematical model.

Table 3. Fiber glass + Polyester, Ref. HEX 100G

MATERIAL	ELASTIC CONSTANTS						MAXIMUM RESISTANCE				
	R gr/cm ³	Vf %	Ex GPa	Ey GPa	n _{xy}	ES GPa	X MPa	X' MPa	Y MPa	Y' MPa	S MPa
Glass fiber /polyester	1.93	50	38	10	0.26	4.5	750	850	22	110	55

For the physical model is used SikaWrap Hex 100G (Table 4), which is a fabric of unidirectional glass fibers. The material is saturated polyester resin work using CRISTALAN 809 (Table 6), to form a polymer glass fiber reinforced (GFRP), used for strengthening structural elements.

Table 4. Fiberglass SikaWrap Ref HEX 100G

Typical Data	
Storage Conditions	Store dry at 40°-95°F (4°-35°C)
Color	White
Primary Fiber Direction	0° (unidirectional)
Weight Per Square Yard	27 oz. (913 g/m ²)
Fiber Properties	
Tensile Strength	3.3 x 10 ⁵ psi (2,276 MPa)
Tensile Modulus	10.5 x 10 ⁶ psi (72,413 MPa)
Elongation	4%
Density	0.092 lbs./in. ³ (2.54 g/cc)
Nominal Thickness	0.014 in. (0.359 mm)

Resins: In a composite, the matrix is much more than just glue that holds together the fibers. It is also a barrier that protects the fibers are not damaged, making them resistant to moisture, chemical attack and / or high temperatures. It also maintains the fibers as they are buckle and give in easily when compressed.

Epoxy Resin: Sikadur 330 (Table 5), impregnating resin used in the models of this research is a system of two component epoxy impregnation, thixotropic, solvent free.



Table 5. Typical Properties of SIKADUR 330 (not reinforced)

Typical Data (Material and curing conditions @ 73°F (23°C) and 50% R.H.)				
Shelf Life	2 years in original, unopened container.			
Storage Conditions	Store dry at 40°-95°F (4°-35°C). Condition material to 65°-75°F (18°-24°C) before using.			
Color	Light gray.			
Mixing Ratio	Component 'A' : Component 'B' = 4 : 1 by weight			
Consistency	Non-sag paste.			
Pot Life	57 minutes (325 ml)			
Tack Free Time	4-5 hours			
Heat Deflection Temperature (ASTM D-648)	7 day [fiber stress loading=264 psi (1.8 MPa) 120°F (50°C)			
Mechanical Properties				
Compressive Properties (ASTM D-695), psi (MPa)				
	40°F (4°C)	60°F (16°C)	73°F (23°C)	90°F (32°C)
8 hour	-	-	-	8,000 (55.2)
1 day	-	8,100 (55.8)	10,700 (73.7)	10,600 (73.1)
3 day	8,100 (55.8)	11,200 (77.2)	11,100 (76.5)	11,000 (75.8)
7 day	11,200 (77.2)	11,600 (80.0)	11,200 (77.2)	11,800 (81.3)
14 day	12,500 (86.2)	12,400 (85.5)	11,800 (81.3)	11,900 (82.0)
Tensile Strength (ASTM D-638)	7 day 4,900 psi (33.8 MPa)			
Elongation @ Break (ASTM D-638)	7 day 1.2%			
Flexural Strength (ASTM D-790)	7 day 8,800 psi (60.6 MPa)			
Flexural Modulus (ASTM D-790)	7 day 5.06 x 10 ⁵ psi (3,489 MPa)			

Polyester resin: CRISTALAN 809 is a polyester resin orthophthalic, hixotropic, and pre-accelerated. CRISTALAN 809 characteristics of rapid impregnation by contact molding processes that minimize labor requirements and optimize the costs of the lamination process. CRISTALAN 809 distributed by Andercol S.A. in Colombia, is manufactured under license and advice from Scott Bader Limited (England) and is approved by the British company Lloyds Register of Shipping for the construction of vessels under their supervision

Table 6. Typical Properties CRISTALAN 809 cured (not reinforced)

Barcol hardness (Model GYZJ -934-1)	46
Water Absorption (24 hours at 23 ° C)	15 mg
Deflection temperature under load (1.80MPa)	66° C
Specific gravity, 25 ° C	1.20
Elongation at break (2)	2.9%
Tensile strength	64 MPa
Tensile Module	3.4 GPa
Shrinkage Stress	10%



Planning

The architectonic exposition for the proposed module of house is based on the norm that at the moment exists in Colombia and which is protected under Decree 2060 [9] of the 24 of June of 2004.

Considering these parameters, design a basic module for a house with the possibility that can be expanding in the time, this expansion is sustained in all the theory of development of Progressive House, theory and conditions that are not necessary to treat in the present investigation but which nevertheless they are well documented in different books and articles dedicated specially from this subject.

The work tries to provide a house model (Fig. 1) that can be growing through time, but that continues conserving its resistant characteristics earthquake. By this, to confront the problem of the growth of the house, through figures that are formally stable, a strategy is required. This strategy must fulfill two aspects mainly:

1. To occupy the space available totally.
2. To allow to a control on the form and the structure of the future stages of the house.

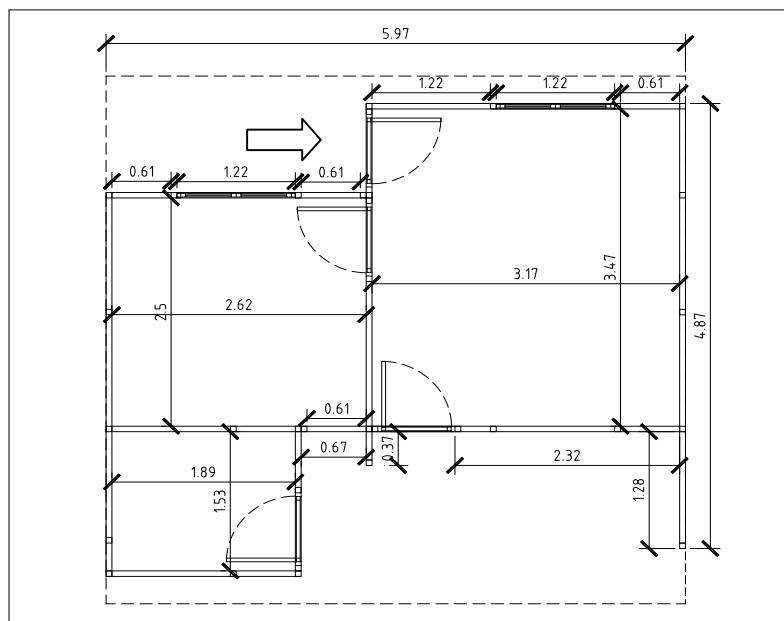


Figure 1. Architectonic plant of proposed model house



Constituent elements. Panel: The panel has been elaborated with a unidirectional laminate of thickness equivalent to 2,5 mm and a nucleus of 60,0 mm, for a total of 65,0 mm. of thickness; a modular length of 61 cm. or 122 cm. and a height of 230 cm.

Connectors: The vertical connector is a closed element whose dimensions are 90,0 mm. x 65,0 mm. and a length of 230 cm., equal way sets out a horizontal connector in form of "U" as it ends superior for the panels whom at the same time mooring tape works as to strictness the system and whose dimensions are 90,0 mm x 90,0 mm.

Exposition of the analysis

Analysis DAC: DAC (Designing Advanced Composites). Program developed by the University of Zaragoza in the Department of Mechanical Engineering and specifically in the laboratory of composites materials. This program is based on the method of finite element analysis (FEA) that solve the deviation (arrow) and the force of a symmetrical laminate rectangular type plate or sandwich that has conditions of system simply supported or embedding in two opposite sides. The load can be a load precise located or a uniform pressure on the whole plate, the laminate and the nucleus of the sandwich can be any type of material.

Comparative analysis

Models 1 and 3 (Table 7): For the present model a condition of support of joint-joint in the ends of the panel according to the conditions demanded by the program in the panel of access of data is considered.



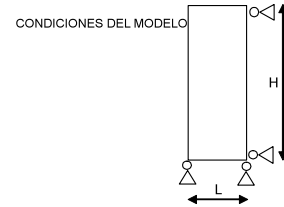
Table 7. Comparative analysis Models 1 y 3 DAC

ANÁLISIS COMPARATIVO
 MODELO DAC

PANELES FRONTALES

MODELO 1	LAMINA EN FIBRA DE CARBONO + EPOXI TEJIDO UNIDIRECCIONAL
AS4/3502 + PUR_40	

DESPLAZAMIENTO	FPF	1,93E-03	DESPLAZAMIENTO ADMISIBLE	X	4,88E-03	mt
	LPF	1,96E-03		Y	4,88E-03	
	PROMEDIO	1,95E-03		TOTAL	6,90E-03	
COEFICIENTE SEGURIDAD	FPF	1,851E+01	CARGA TOTAL	X	1,85E+05	Pa
	LPF	1,850E+01		Y	1,85E+05	
ESFUERZOS EN EL PLANO	SIGMA 1	-1,010E+07	ESFUERZO ADMISIBLE EN EL PLANO	M	7,93E+04	Pa
		1,010E+07				
	SIGMA 2	-3,100E+06				
		3,100E+06				
	SIGMA 6	-2,850E+06				
		2,850E+06				
ESFUERZOS INTERLAMINARES	SIGMA 4	0,000E+00	Pa			
		4,470E+02				
	SIGMA 5	0,000E+00				
		1,610E+03				



MODELO 3	LAMINA EN FIBRA DE VIDRIO + POLIESTER TEJIDO EQUILIBRADO
HEX 100G + PUR_40	

DESPLAZAMIENTO	FPF	2,90E-03	DESPLAZAMIENTO ADMISIBLE	X	4,88E-03	mt
	LPF	3,44E-03		Y	4,88E-03	
	PROMEDIO	3,17E-03		TOTAL	6,90E-03	
COEFICIENTE SEGURIDAD	FPF	8,024E+00	CARGA TOTAL	X	1,94E+05	Pa
	LPF	1,790E+01		Y	1,94E+05	
ESFUERZOS EN EL PLANO	SIGMA 1	-1,000E+07	ESFUERZO ADMISIBLE EN EL PLANO	M	6,80E+04	Pa
		1,000E+07				
	SIGMA 2	-3,280E+06				
		3,280E+06				
	SIGMA 6	-2,240E+06				
		2,240E+06				
ESFUERZOS INTERLAMINARES	SIGMA 4	0,000E+00	Pa			
		4,560E+02				
	SIGMA 5	0,000E+00				
		1,660E+03				

VALORES CONSTANTES L panel (mt) = 1,220
 H panel (mt) = 2,300
 e panel (mt) = 0,065



Models 2 and 4 (Table 8): The handled conditions of support for the present model are of embedding and joint considering that the mooring tape serves like continuous support for being and to be supported on the connectors.

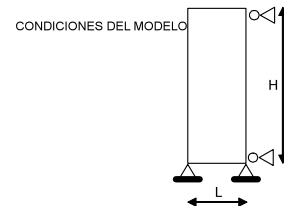
Table 8. Comparative analysis Models 2 y 4 DAC

ANÁLISIS COMPARATIVO
 MODELO DAC

PANELES FRONTALES

MODELO 2	LAMINA EN FIBRA DE CARBONO + EPOXI TEJIDO UNIDIRECCIONAL
AS4/3502 + PUR_40	

DESPLAZAMIENTO	FPF	1,91E-03	DESPLAZAMIENTO ADMISIBLE	X	4,88E-03	mt
	LPF	1,94E-03		Y	4,88E-03	
	PROMEDIO	1,92E-03		TOTAL	6,90E-03	
COEFICIENTE SEGURIDAD	FPF	1,891E+01	CARGA TOTAL	X	1,85E+05	Pa
	LPF	1,894E+01		Y	1,85E+05	
ESFUERZOS EN EL PLANO	SIGMA 1	-8,190E+06	ESFUERZO ADMISIBLE EN EL PLANO	M	7,93E+04	Pa
		8,190E+06				
	SIGMA 2	-2,930E+06				
		2,930E+06				
	SIGMA 6	-2,580E+06				
		2,580E+06				
ESFUERZOS INTERLAMINARES	SIGMA 4	0,000E+00				
		5,420E+02				
		0,000E+00				
	SIGMA 5	1,560E+03				



MODELO 4	LAMINA EN FIBRA DE VIDRIO + POLIESTER TEJIDO EQUILIBRADO
HEX 100G + PUR_40	

DESPLAZAMIENTO	FPF	2,77E-03	DESPLAZAMIENTO ADMISIBLE	X	4,88E-03	mt
	LPF	3,26E-03		Y	4,88E-03	
	PROMEDIO	3,01E-03		TOTAL	6,90E-03	
COEFICIENTE SEGURIDAD	FPF	7,057E+00	CARGA TOTAL	X	1,94E+05	Pa
	LPF	1,893E+01		Y	1,94E+05	
ESFUERZOS EN EL PLANO	SIGMA 1	-8,170E+06	ESFUERZO ADMISIBLE EN EL PLANO	M	6,80E+04	Pa
		8,170E+06				
	SIGMA 2	-3,270E+06				
		3,270E+06				
	SIGMA 6	-2,030E+06				
		2,030E+06				
ESFUERZOS INTERLAMINARES	SIGMA 4	0,000E+00				
		6,670E+02				
		0,000E+00				
	SIGMA 5	1,550E+03				

VALORES CONSTANTES L panel (mt) = 1,220
 H panel (mt) = 2,300
 e panel (mt) = 0,065

Analysis ANSYS (Bidimensional): For a Modeling in Finite Elements more precise, program ANSYS has been used in second instance version 9.0 lawyer to the Faculty of Engineering in the Masters of Materials and Processes. Ansys is a modeled tool for of complex problems of different types from structures in finite elements. Ansys can exhibit the results of the analysis in a series of hi-res graphs that can be collated with the results of the proposed model.

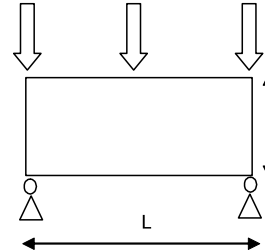


Table 9. Comparative analysis Models 1 y 3 ANSYS

**ANÁLISIS COMPARATIVO
 MODELO ANSYS**

CONDICIONES DEL MODELO

MODELO 1	LAMINA EN FIBRA DE CARBONO + EPOXI TEJIDO UNIDIRECCIONAL
AS4/3502 + PUR_40	



DESPLAZAMIENTO	X	6,47E-07	DESPLAZAMIENTO ADMISIBLE	X	4,88E-03
	Y	3,10E-09		Y	4,88E-03
	TOTAL	5,90E-06		TOTAL	6,90E-03
ESFUERZO	X	2,06E+05	ESFUERZO ADMISIBLE	X	1,85E+05
	Y	4,93E+04		Y	1,85E+05

MODELO 3	LAMINA EN FIBRA DE VIDRIO + POLIESTER TEJIDO EQUILIBRADO
HEX 100G + PUR_40	

DESPLAZAMIENTO	X	9,55E-07	DESPLAZAMIENTO ADMISIBLE	X	4,88E-03
	Y	3,21E-09		Y	4,88E-03
	TOTAL	1,09E-04		TOTAL	6,90E-03
ESFUERZO	X	4,22E+04	ESFUERZO ADMISIBLE	X	1,94E+05
	Y	4,56E+04		Y	1,94E+05

Analysis ANSYS (Laminates): For the modeled one of you laminate use I modulate SHELL63. The SHELL elements find great application in the modeling of structures done from laminate or in elements of thin wall. Some variations of this element (SHELL91) can be used to model several layers of thin elements, as it happens in the modeling of compound materials.

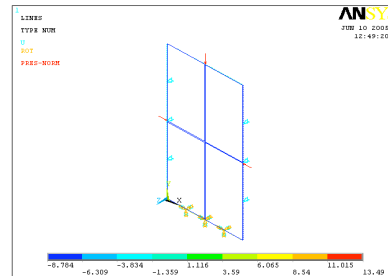


Table 10. Comparative analysis Panels 1 y 2 ANSYS

**ANÁLISIS COMPARATIVO
 MODELO ANSYS**

CONDICIONES DEL MODELO

PANEL 1	LAMINA EN FIBRA DE CARBONO + EPOXI TEJIDO UNIDIRECCIONAL
AS4/3502 + PUR_40	



DESPLAZAMIENTO	X	0,00E+00	DESPLAZAMIENTO ADMISIBLE	X	4,88E-03
	Y	0,00E+00		Y	4,88E-03
	Z	5,59E-04		TOTAL	6,90E-03
ESFUERZO	X	1,01E+03	ESFUERZO ADMISIBLE	X	1,01E+03
	Y	1,01E+03		Y	1,01E+03

PANEL 2	LAMINA EN FIBRA DE VIDRIO + POLIESTER TEJIDO EQUILIBRADO
HEX 100G + PUR_40	

DESPLAZAMIENTO	X	0,00E+00	DESPLAZAMIENTO ADMISIBLE	X	4,88E-03
	Y	0,00E+00		Y	4,88E-03
	Z	1,35E-03		TOTAL	6,90E-03
ESFUERZO	X	1,11E+03	ESFUERZO ADMISIBLE	X	1,11E+03
	Y	1,11E+03		Y	1,11E+03

Economic viability

¿Which to choose?: That is a question that habitually the client does. For it will be necessary to analyze certain circumstances that surround to the work in construction. In the first place we would have to analyze the run time of the work, the constructive system, the technology to install, the design of the house, the place chosen for its erection, the personnel whom the work will execute, etc. and by on all the things the cost of the same one. It is understood that at this time the costs between a system and another one do not defer too much in our country, because until the industrialized systems do not make in series and in amount, their costs will not diminish. It corresponds then to dedicate us to the other circumstances.



Table 11. Cost-Benefit relation

ALTERNATIVA 1		LAMINA EN FIBRA DE CARBONO + EPOXI TEJIDO UNIDIRECCIONAL		DATOS GENERALES DE LA LAMINA POR PANEL					
AS4/3502	PANELES	BASE	ALTURA	ANGULO	FLECHA ADMISIBLE	AREA POR LAMINA	VOLUMEN POR LAMINA	PESO POR LAMINA	
DENSIDAD - KG/M3	1600	P1	0,6100	2,30	90,00	0,00244	1,4030	0,0018	2,8060
ESPOSOR ELEMENTO	0,00125	P2	1,2200	2,30	90,00	0,00488	2,8060	0,0035	5,6120
		P3	0,6100	2,70	90,00	0,00244	1,6470	0,0021	3,2940
COSTO ELEMENTO \$K	40.000,00	P4	1,2200	2,70	90,00	0,00488	3,2940	0,0033	6,5880
PROMEDIOS TOTALES P1+P2+P3+P4							2,2875	0,0029	4,5750

ALTERNATIVA 1		MATERIAL DEL NUCLEO EN ESPUMA POLIURETANO DENSIDAD 40 KG/M3		DATOS GENERALES DEL NUCLEO POR PANEL					
pur_40	PANELES	BASE	ALTURA			AREA DE ESPUMA	VOLUMEN DE 1 mm	PESO DE 1 mm	
DENSIDAD - KG/M3	40	P1	0,6100	2,30			1,4030	0,0014	0,0561
ESPOSOR ELEMENTO	0,0600	P2	1,2200	2,30			2,8060	0,0028	0,1122
		P3	0,6100	2,70			1,6470	0,0016	0,0659
COSTO ELEMENTO \$K	5.000,00	P4	1,2200	2,70			3,2940	0,0033	0,1318
PROMEDIOS TOTALES P1+P2+P3+P4							2,2875	0,0023	0,0915

No. LAMINADOS CARAS	VARIACION DE ESPESORES DE LOS PANELES EN mm (PANEL = 1,22 mt)												VR M2
	A 60 mm			B 57,5 mm			C 55 mm			D 52,5 mm			
	FLECHA RESULTANTE	PESO KG	COSTO \$	FLECHA RESULTANTE	PESO KG	COSTO \$	FLECHA RESULTANTE	PESO KG	COSTO \$	FLECHA RESULTANTE	PESO KG	COSTO \$	
4	0,00222750	23,79	987.285,00	0,00235614	23,56	985.798,13	0,00249935	23,33	984.311,25	0,00265963	23,10	982.824,38	
6	0,00197515	32,94	1.463.085,00	0,00208184	32,71	1.461.598,13	0,00220010	32,48	1.460.111,25	0,00233183	32,25	1.458.624,38	
8	0,00184331	42,09	1.938.885,00	0,00193857	41,86	1.937.398,13	0,00204383	41,63	1.935.911,25	0,0021607	41,40	1.934.424,38	
10	0,00176068	51,24	2.414.685,00	0,00184879	51,01	2.413.198,13	0,00194591	50,78	2.411.711,25	0,00205348	50,55	2.410.224,38	351.847,83

PANEL CON LA FLECHA ADMISIBLE MAS DESFAVORABLE. ■
 ALTERNATIVA MAS FAVORABLE EN FUNCION DE LA FLECHA Y EL No. DE SUBLAMINADOS. ■
 ALTERNATIVA MAS FAVORABLE EN FUNCION DE LA FLECHA, EL PESO, EL COSTO, EL No. DE SUBLAMINADOS Y EL ESPESOR DEL PANEL. ■

ALTERNATIVA 2		LAMINA EN FIBRA DE VIDRIO + POLIESTER		DATOS GENERALES DE LA LAMINA POR PANEL					
AS4/3502	PANELES	BASE	ALTURA	ANGULO	FLECHA ADMISIBLE	AREA POR LAMINA	VOLUMEN POR LAMINA	PESO POR LAMINA	
DENSIDAD - KG/M3	1930	P1	0,6100	2,30	90,00	0,00244	1,4030	0,0014	2,7078
ESPOSOR ELEMENTO	0,00100	P2	1,2200	2,30	90,00	0,00488	2,8060	0,0028	5,4156
		P3	0,6100	2,70	90,00	0,00244	1,6470	0,0016	3,1787
COSTO ELEMENTO \$K	4.000,00	P4	1,2200	2,70	90,00	0,00488	3,2940	0,0033	6,3574
PROMEDIOS TOTALES P1+P2+P3+P4							2,2875	0,0023	4,4149

ALTERNATIVA 2		MATERIAL DEL NUCLEO EN ESPUMA POLIURETANO DENSIDAD 40 KG/M3		DATOS GENERALES DEL NUCLEO POR PANEL					
pur_40	PANELES	BASE	ALTURA			AREA DE ESPUMA	VOLUMEN DE 1 mm	PESO DE 1 mm	
DENSIDAD - KG/M3	40	P1	0,6100	2,30			1,4030	0,0014	0,0561
ESPOSOR ELEMENTO	0,0610	P2	1,2200	2,30			2,8060	0,0028	0,1122
		P3	0,6100	2,70			1,6470	0,0016	0,0659
COSTO ELEMENTO \$K	5.000,00	P4	1,2200	2,70			3,2940	0,0033	0,1318
PROMEDIOS TOTALES P1+P2+P3+P4							2,2875	0,0023	0,0915

No. LAMINADOS CARAS	VARIACION DE ESPESORES DE LOS PANELES EN mm (PANEL = 1,22 mt)												VR M2
	A 61 mm			B 59 mm			C 57 mm			D 55 mm			
	FLECHA RESULTANTE	PESO KG	COSTO \$	FLECHA RESULTANTE	PESO KG	COSTO \$	FLECHA RESULTANTE	PESO KG	COSTO \$	FLECHA RESULTANTE	PESO KG	COSTO \$	
4	0,00398486	23,24	128.109,15	0,00420467	23,06	126.919,65	0,00444588	22,88	125.730,15	0,00471147	22,69	124.540,65	
6	0,00317182	32,07	174.023,85	0,00333534	31,89	172.834,35	0,00351427	31,70	171.644,85	0,00371072	31,52	170.455,35	
8	0,00275557	40,90	219.938,55	0,00289038	40,72	218.749,05	0,00303753	40,53	217.559,55	0,00319869	40,35	216.370,05	
10	0,00250127	49,73	265.853,25	0,00261858	49,55	264.663,75	0,00274637	49,36	263.474,25	0,00288603	49,18	262.284,75	45.655,43

PANEL CON LA FLECHA ADMISIBLE MAS DESFAVORABLE. ■
 ALTERNATIVA MAS FAVORABLE EN FUNCION DE LA FLECHA Y EL No. DE SUBLAMINADOS. ■
 ALTERNATIVA MAS FAVORABLE EN FUNCION DE LA FLECHA, EL PESO, EL COSTO, EL No. DE SUBLAMINADOS Y EL ESPESOR DEL PANEL. ■



Table 12. Economic Analysis and comparison with other systems

COMBINACIONES DE MATERIALES			No. LAMINADOS DOS CARAS	ESPESOR RELLENO mm	ESPESOR TOTAL PANEL mm	FLECHA RESULTANTE	PESO KG	COSTO \$ PANEL (1,22*2,3)	COSTO \$ M2 PANEL	FACTOR DE SEGURIDAD
ALTERNATIVA 1	LAMINA EN FIBRA DE CARBONO + EPOXI TEJIDO UNIDIRECCIONAL Y MATERIAL DE RELLENO EN ESPUMA POLIURETANO DENSIDAD 40 KG/M3	AS4/3502 y PUR_40	4	60	65	0,00222750	23,79	987.285,00	351.847,83	18,5
ALTERNATIVA 2	LAMINA EN FIBRA DE VIDRIO + POLIESTER TEJIDO EQUILBRADO Y MATERIAL DE RELLENO EN ESPUMA POLIURETANO DENSIDAD 40 KG/M3	ve_uni100g y PUR_40	4	61	65	0,0039849	23,24	128.109,15	45.655,43	17,9

COMBINACIONES DE MATERIALES			No. LAMINADOS DOS CARAS	ESPESOR RELLENO mm	ESPESOR TOTAL PANEL mm	FLECHA RESULTANTE	PESO KG/M2	COSTO \$ PANEL	COSTO \$ M2	COSTO \$ M2 ADICIONALES	COSTO \$ M2 CONSTRUIDO	COSTO (promedio) MÓDULO VIVIENDA	FACTOR DE SEGURIDAD
ALTERNATIVA 1	LAMINA EN FIBRA DE CARBONO + EPOXI TEJIDO UNIDIRECCIONAL Y MATERIAL DE RELLENO EN ESPUMA POLIURETANO DENSIDAD 40 KG/M3	AS4/3502 y PUR_40	4	60	65	0,00222750	23,79	987.285,00	351.847,83	220.000,00	571.847,83	21.707.915,33	18,5
ALTERNATIVA 2	LAMINA EN FIBRA DE VIDRIO + POLIESTER TEJIDO EQUILBRADO Y MATERIAL DE RELLENO EN ESPUMA POLIURETANO DENSIDAD 40 KG/M3	ve_uni100g y PUR_40	4	61	65	0,0039849	23,24	128.109,15	45.655,43	220.000,00	265.655,43	10.084.545,96	17,9
ROYALCO	LAMINA EN PVC Y MATERIAL DE RELLENO EN CONCRETO O MORTERO	Panel ROYALCO_6 4 mm	2	60	64	0,002	8,5	120.653,40	52.458,00	306.120,00	358.578,00	13.611.979,46	7
SPEEDCO	LAMINA EN FIBROCEMENTO Y MATERIAL DE RELLENO EN ESPUMA POLIURETANO DENSIDAD 40 KG/M3	Panel THERMO WALL_64 mm	2	60	65	0,0024	160,00	250.000,00	65.000,00	220.000,00	285.000,00	10.818.885,00	4
METECNO	LAMINA EN ACERO Y MATERIAL DE RELLENO EN ESPUMA POLIURETANO DENSIDAD 38 KG/M3	Panel MONOWALL 1000/B	2	50	60	0,0015	37,23	261.464,00	113.680,00	220.000,00	333.680,00	12.666.826,48	4
VIVIENDA CONVENCIONAL	MÓDULO BÁSICO DE VIVIENDA (VIS) MAMPOSTERÍA ESTRUCTURAL	Unidades de Mampostería en arcilla	NO APLICA	NO APLICA	140	0,5%hp	128,57	552.000,00	230.000,00	220.000,00	450.000,00	17.082.450,00	1,28



CONCLUSIONS

The obtained effective structural properties in the proposed structural material are finally summation of contributions of their different components and their configuration. So that the mechanical properties of the final compound material depend partly as much on the individual properties of the components like of the geometric disposition of these.

The proposed models fulfill the imposed conditions of load in the present investigation, although they were not exposed to the maximum limits, the dispositions of characterization of the material are the suitable ones.

After evaluated the models economically, the difference in the final values by square meter is clear, although the relation is 1:7 having like first proposal in smaller value alternative 2 (Fiber glass + Polyester and nucleus in PUR_40), is evident that as important aspects as the security is sacrificed by the price.

Is conclusive that if it is possible to make structural systems using new materials, although in spite of the qualities of smaller weights and design of the properties of he himself, the unit cost of these I continued being the main disadvantage for a greater use. Nevertheless, One of the most important advantages of the compound materials is, that the high cost of the raw materials is compensated with the low cost of the equipment and manual labor in the preparation process, assembled, and application of the compound materials directly in the proposed structural elements (panels for this case).

REFERENCES

- [1] CEJKA Jan. *Tendenzen zeitgenössischer Architektur*, 1ª ed., Stuttgart: W. Kohlhammer GMBH, 1993, pág. 7. (Versión castellana: *Tendencias de la arquitectura contemporánea*, 2ª ed., Barcelona: Editorial Gustavo Gili, S.A., 1995, Pág. 7.)
- [2] The composites materials consist of a heat set resin mixture like the polyester or epóxy and of a reinforcement with fiber glass, carbon fiber, fabric or other matters. For this case, reference to materials composed of polimérica matrix is done since they exist material compound that can be formed by phases different from the given ones in the present definition (ceramic steel, materials, etc.). The main advantages of this type of materials are their lightness (approx 25% less than the steel), great mechanical resistance, resistance to the corrosion, low thermal conductivity, etc.
- [3] AIS, Asociación Colombiana de Ingeniería Sísmica. NSR-98, *Normas colombianas de diseño y construcción sismo resistente*, Ley 400 de 1997, Decreto 33 de 1998, 2ª ed., Bogotá: [s.e], 1998, Pág. A21.



- [4] Parcela para vivienda en las décadas de los 70 y 80, dimensiones promedio 12.00 m x 24.00 m.
- [5] FHWA, Federal Highway Administration, U.S. Department of Transportation, Washington D.C.
- [6] AIS, Asociación Colombiana de Ingeniería Sísmica, NSR-98, *Normas colombianas de diseño y construcción Sismo Resistente*, Ley 400 de 1997, Decreto 33 de 1998.
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