FIBRE REINFORCED PLASTIC AS AN ENGINEERING MATERIAL

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Synopsis

Fibre-reinforced plastic, commonly known as FRP is a material which is today gaining more acceptance as an engineering material in all forms of mechanical and civil engineering applications.

While this presentation is not an indepth engineering study of FRP, it is written with a view to making you more aware of the progress of FRP over the years and its current place as an engineering material.

Introduction

Fibre-reinforced plastics, or FRP, is a general classification that refers to a wide group of composite materials in which high strength and stiffness characteristics of relatively fragile fibres are combined or allied to the robust durability of plastic resins. This variety of materials offers a tremendous range of physical properties, many of which are extremely attractive to engineers and designers.

The basic concept of fibre reinforcement is not new but over the past twenty years the application of FRP has grown dramatically; partly as the potential of these materials was recognised and demonstrated but probably mainly because of the greater availability of the principal reinforcing fibres on a commercial basis.

What is F.R.P ?

To understand what FRP is and why it is an excellent engineering material we need to look at its components more closely.

The Reinforcement

These can be made of virtually any materials depending on price and end use. Fibres range from Jute, which is a coconut husk derived fibre through to high tech fibres like Carbon or aramid fibre derived from oil. Aramid fibre is better known by its most common brand name - Kevlar. Jute is a reinforcement of very low mechanical properties (but cheap in certain countries)

Carbon and Kevlar are so called "high tech" fibres which are expensive but have excellent mechanical properties and are suitable for rigorous applications.

The Resin System

Again these can be of many different types dependant on price and engineering properties required. The basic resin types in common use are polyester, epoxy and vinylester. Polyester is the cheaper of the three and has properties suitable for most engineering uses. Vinylester and expoxies are used where higher performing resins are required.

To make an engineering material the fibre reinforcement is added to resin to produce a family of engineering materials with a wide range of cost performance advantages.

The reinforcing fibres provide strength, dimensional stability and heat resistance to the composite. Other properties - chemical, electrical, colour and finish for example - are determined by the selection of the resin material to be reinforced.

Many types of resin are available - over and above the three previously mentioned - to provide a wide range of mechanical, chemical, thermal and appearance properties in combination with the appropriate type of reinforcement.

There are two basic classes of resin systems :

1. Thermosets Heat is generally used to form and set the shape of the part permanently. The resin,once cured, cannot be re-formed; the process is irreversible.

2. Thermoplastics Heat is used to melt or soften the plastic during the forming operation. The shape is retained after the part is cooled. The shape is not permanent, since heating will soften the plastic and allow it to flow. The process is reversible.

Other components of the composite

Depending upon the application and the manufacturing process selected, a number of additives are employed to provide specific product or process properties. These include pigmentation (for moulded-in colour), flame retardants, inert fillers, compounds to enhance surface finish and reduce shrinkage in the mould, release agents, catalysts (to initiate the cure), viscosity control materials and weather resistance additives.

Choosing the right blend of reinforcement and resin

A primary choice for the designer working with FRP is the best combination of reinforcement and resin. Thousands of choices may be made and the composition controlled to meet virtually any desired combination of performance and cost objectives.

Choice of composition usually depends upon the property requirements of the finished product: mechanical, electrical, and chemical. The selected composition, the general shape considerations and production volume in turn indicate the manufacturing process to be employed.

Selecting the Optimum Process

Fibre-Reinforced Plastic technology encompasses a broad spectrum of manufacturing processes. These allow unlimited versatility, whether the end product is a 20m insulated body or a tiny precision gear.

Regardless of part size, complexity, production volume or property requirements, there is a process available to deliver a product with a favourable cost/performance ratio.

Contact moulding methods for large FRP parts

Typically, contact moulding is done with an open mould, either: a "male" configuration, which controls the internal shape and finish of the part, or a "female configuration" which controls external shape and finish. A laminate of fibre reinforcement and resin is built up by hand, or by use of a special chopper/spray gun which directs short fibers and catalyzed resin onto the mould surface. The part is usally cured at room temperature. Because of chemical catalysts and additives cure is achieved without added pressure.

Pressure is applied only to combine the glass and resin.

These basic contact moulding processes may be modified to improve the part surface away from the mould, to densify the laminate and to control the thickness or to accelerate curing of the part.

The contact moulding processes are ideally suited to the manufacture of large parts, such as boat hulls. Excellent mechanical properties are obtainable at moderate tooling cost.

Compression and injection moulding for complex high volume parts

High-volume techniques, notably compression moulding (usually of thermosetting resin systems) and injection moulding (usually of thermoplastic) have achieved widespread usage in the manufacture of highly refined FRP components at rapid production rates. Superior overall finish, excellent dimensional control and a high degree of complexity characterize such parts.

Compression and injection moulding offer considerable versatility in terms of the ways the fibre reinforcement, the resin system, and the additives can be tailored to end-use requirements and introduced to the moulds. In compression moulding, pre-combined reinforcement and resin are available in sheet (sheet moulding compound) or bulk form (bulk moulding compound). These compounds are placed in the mould and formed into thermoset parts by the application of heat and pressure.

For flat sheets and simple shapes, glass mats are placed into the mould, resin is poured over the mat, and the mould is closed under pressure to combine the resin and glass. Heat is applied to cure the resin.

For more complex parts, preformed fibrous glass and resin shapes (known as "preforms") can be placed in the mould. Fibreglass chopped strands can be blended with thermoplastic resin moulding powders or pellets for injection moulding.

In compression and injection moulding processes, the pressures and temperatures employed generally require large presses and fabricated steel moulds. However, because many complex parts can be moulded at high production rates, the tooling cost per part can often be quite low - as can the direct labour factor - for an advantageous cost / performance ratio.

Cold moulding methods

Cold moulding methods such as cold press moulding and comoforming represent recent process technology advances which offer production advantages for medium volume parts having excellent appearance, weatherability and finish properties. These methods fill the gap between contact moulding techniques (where tooling is simple and low in cost) and the more automated methods (where tooling costs are high)

Other important fabricating methods

There are other processes available for applications requiring special shapes, reinforcment orientation and resin systems. These include: Filament winding, a method which yields relatively high reinforcement, concentration and precise orientation, for the development of high strength hollow structures such as pipes, tanks, and pressure vessels; Continuous pultrusion, used to produce lengths of extremely strong FRP products having a constant cross section , such as rod stock channels and structual shapes and Rotational moulding, combining chopped fibreglass strands with selected moulding powders to produce large, complex, hollow shapes such as light globes.

Reinforced plastics shipments by markets (million lb)
Including: thermoset and thermoplastic resin composites, reinforcements and fillers

Markets	1976	1978	1980	1981	1982	1983	1984	1985	1986	1987 Forecast
Aircraft	22	22	25	28	22	25	29	33	37	40
Applicances/business equipment	98	123	104	117	82	106	123	133	136	141
Construction	248	323	287	317	312	400	430	444	456	464
Consumer products	102	116	103	115	84	128	143	144	149	152
Corrosion-resistant equipment	157	216	252	275	235	288	310	295	291	300
Electrical/electronic	123	170	162	178	140	170	189	190	201	208
Marine	365	430	275	290	230	276	309	330	340	351
Transportation/land	398	532	416	445	359	458	540	568	585	608
Other or specialities	66	74	70	75	64	72	80	79	83	85
TOTAL	**1,579**	**2,006**	**1,694**	**1,840**	**1,528**	**1,923**	**2,153**	**2,216**	**2,279**	**2,348**

Source: SPI Composites Institute

Many markets ... Many uses for Fibreglass-Reinforced Plastics

Here are some of the markets where Fibre-Reinforced Plastics and composites have made significant strides. Some of the more notable end-uses are listed.....but it only begins to tell the story of versatility in FRP.

Automotive

Where high-volume parts with fine finishes are coming into their own - and reducing costs.
Automobile body components /fender extenders/front ends/headlamp and taillamp housings/hoods/spoilers/ instrument panels/shift consoles/under the hood components/truck hoods/fenders/cab and body components/insulated tanks/engine covers/housings/fender liners.

Agricultural

Ruggedness and corrosion resistance are most desirable properties. Farm tractor hoods, grilles, instrument housings, seating, fenders/garden tractor and lawn mower bodies and housings/fertilizer and pesticide tanks and sprayers/feed troughs.

Appliances

Complex moulded parts replace die castings and sheet metal assemblies with many fasteners and welds.

Room air conditioner cases, base pans, bulkheads/ condenser and compressor fans.humidifier cases and blower wheels/dishwasher pump bodies/dryer ducts/home laundry tubs/water softener tanks, controls, and piping/ fan housings/gears/vacuum cleaner housings/iron handles/ soap dispensers/microwave oven cook trays/television swivel stands/sump pump bases.

Aviation/aerospace

High strength with light weight are key characteristics of FRP, Aircraft interior components for passengers and cargo/wing tips/antenna components/radomes/wing fuel tanks.ducting/rocket motor cases/nozzles/nose cones/pressure vessels/instructment housing/launch tubes.

Business machines

FRP provides excellent surface finish and dimensional stability at elevated temperatures with high strength for housings and panels. Machine covers and housings/ access panels/keyboard caps/keys/printer heads/gears, cams and levers/frames/mounting panels/printed circuit boards/fans and blowers.

Chemical Processing

Corrosion resistance is the key to widespread applications in FRP. Chemical and fuel tanks, pipes and ducting/storage tanks and hoppers/process pump and valve bodies, casings, impellers/pressure vessels/filters/fume collection hoods and duct systems/scrubbing towers/electroplating racks and handling equipment/photographic processing equipment.

Construction

Ruggedness and moderate cost combined with good appearance. Structural shapes/paneling/siding/skylighting/curtain wall components/glazing panels/patio covers/concrete pouring forms.

Electrical/electronic

High dielectric strength with low moisture absorption. Electrical pole line hardware, crossarms, strain insulators, standoffs, brackets/shatterproof street lighting globes/switch control rods/hot sticks/electronic components/housings and backboards/utility line maintenance equipment.

House and home

FRP brings beauty and low maintenance for carefree living at low cost. Architectural components/appliance and equipment components/furniture;chairs,tables,lawn furnishings/sinks/bathroom tub/shower units/skylights.

Marine

FRP offers ease of repair, low maintenance, high performance. Pleasure, commercial, and military boat hulls and superstructures/barge covers/lighters/fuel tanks/water tanks/masts and spars/bulkheads/duct work/ventilation cowls/marker buoys/floating docks/outboard engine shrouds.

Materials handling

High strength and light weight produce durable, long life parts. Tote trays/bins/food processing and delivery trays,boxes,bins/tanks and pipes/conveyor system components/pallets and skids/cargo handling equipment.

Recreational

Low maintenance and good appearance produce better sporting goods and gear. Motor homes/travel trailers/truck campers/camping trailers/pick-up covers/water and snow skis/surfboards/golf clubs/hockey sticks/lacrosse sticks/archery bows/fishing rods/vaulting poles/recreational watercraft,canoes/snowmobile and all-terrain vehicle bodies/golf carts/protective helmets/swimming pools/diving boards/playground equipment.

Transportation

Toughness and lightness of FRP boost payloads with longer lasting equipment. Railway passenger and freight car components/transport seating/freight car roofs/hopper-car covers/refrigerator car liners/air cargo "igloos"/motor truck and bus components/rapid transit car ends/third rail covers, barges,truck trailer panels, refrigerated truck bodies.

Future Products

Future products to a great degree are only limited by the imagination of designers and in an industry such as road transport there is still plenty of room for imaginative design which can save cost and weight.

Components currently being looked at include steering wheel shafts, steering wheels, pistons, clutch plates, bearings,piston skirts and push rods along with road wheels and suspension components.

Why Engineer in FRP ?

Because benefits include :

Simplicity to form various shapes
Lightweight
High strength to weight
Good thermal insulation
Corrosion resistance
Non magnetic
Impact resistance
Easy to repair
Cost effective

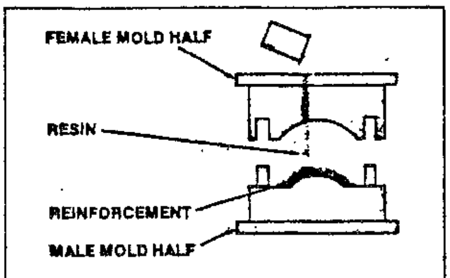
Conclusion

A good example of future engineering in fibre-reinforced plastic is an idea by a Swiss engineer Urs Meier of a plastic bridge to link across the Straights of Gibraltor. Concrete and steel are simply too heavy to be used for such a structure where the central span would be about 8500mm metres. The weight of this section if made from conventional building materials could not be supported by suspension cables. Making this section from carbon fibre-reinforced plastic (CFRP) however, would give the same strength but save 80 per cent of the weight. Furthermore, the cables themselves could also be made from CFRP. Indeed as carbon fibres have particularly good tensile strength this is an ideal application.

So why not design a truck with a gearbox housing, diff housing and chassis of FRP or a bus with a totally monocoque body similar to trailers, that would be taking full advantage of the inherant benefits offered by this state of the art material.

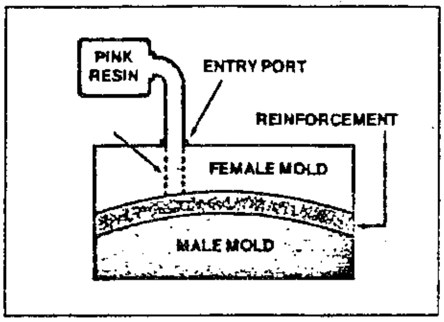
Cold molding methods:

Cold press molding:

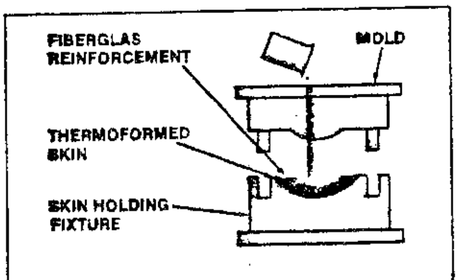


COLD PRESS MOLDING

Resin Injection Molding (or resin transfer molding):

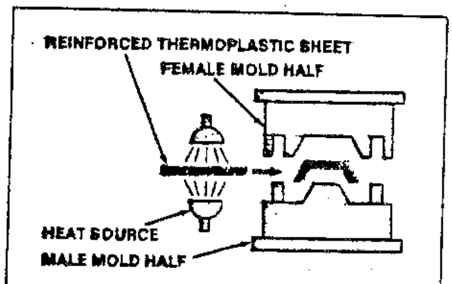


Comoforming:



COMOFORMING

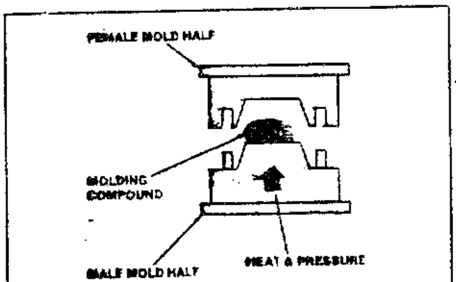
Cold stamping:



COLD STAMPING

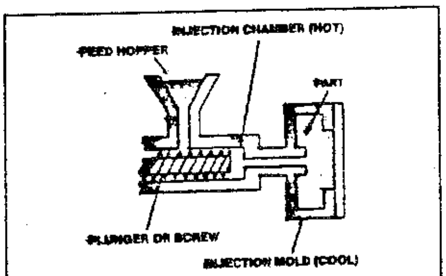
Matched mold methods:

Compression molding



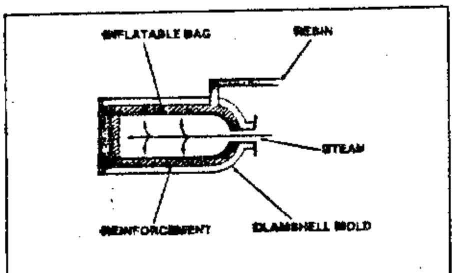
COMPRESSION MOLDING

Injection molding:



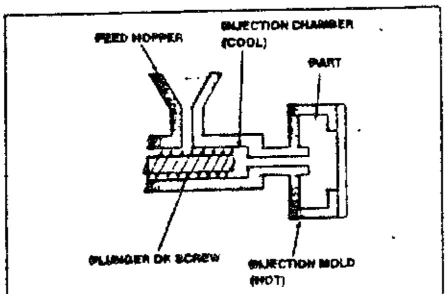
INJECTION MOLDING OF THERMOPLASTICS

Pressure bag molding:



PRESSURE BAG MOLDING

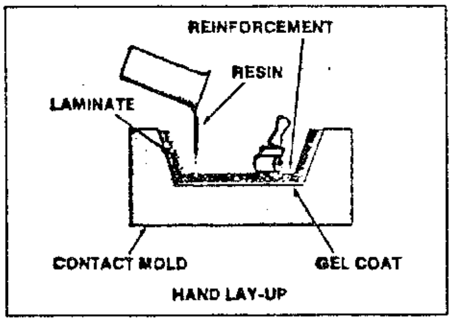
Injection molding of thermosets:



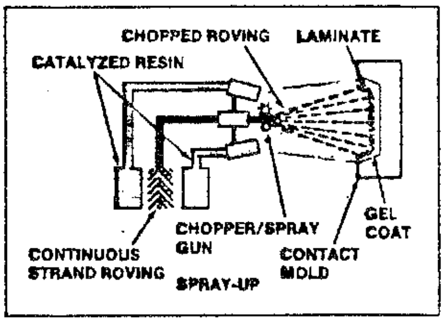
INJECTION MOLDING OF THERMOSETS

Contact molding methods:

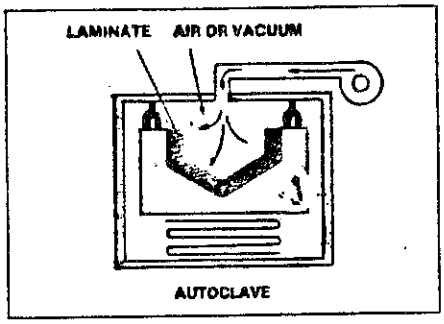
Hand lay-up:



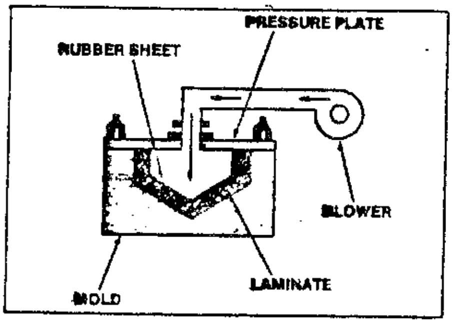
Spray-up:



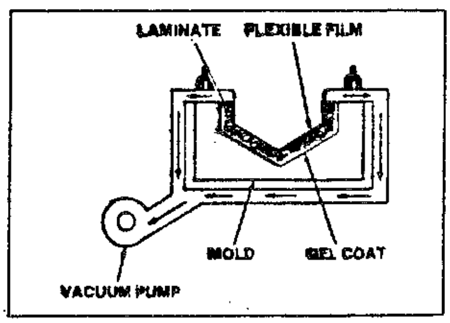
Autoclave:



Pressure bag:

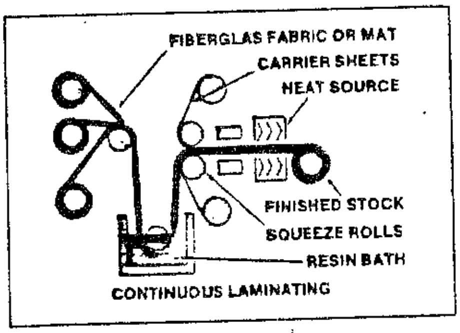


Vacuum bag:

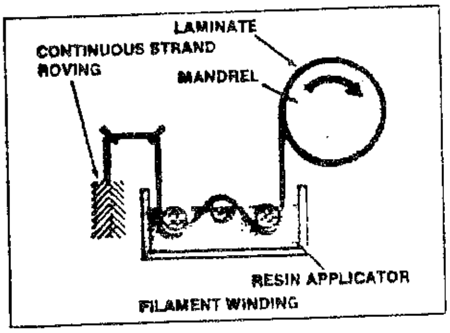


Other Important Molding Methods:

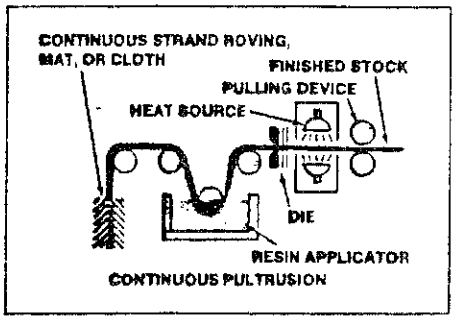
Continuous laminating:



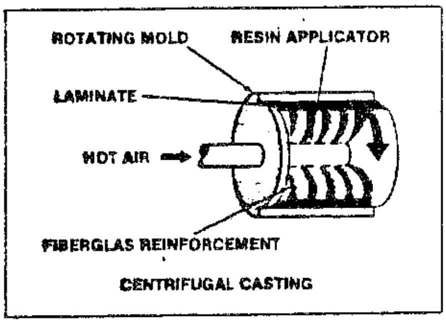
Filament winding:

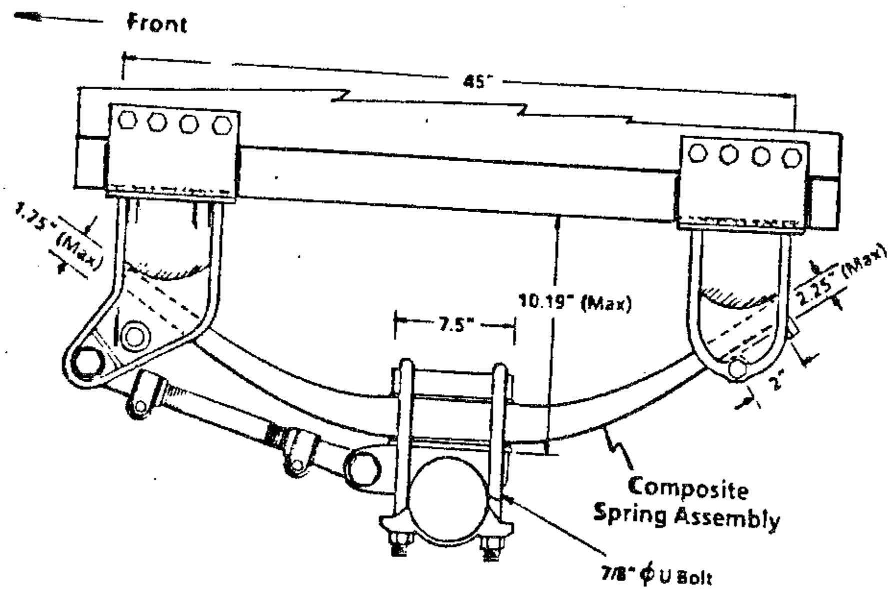


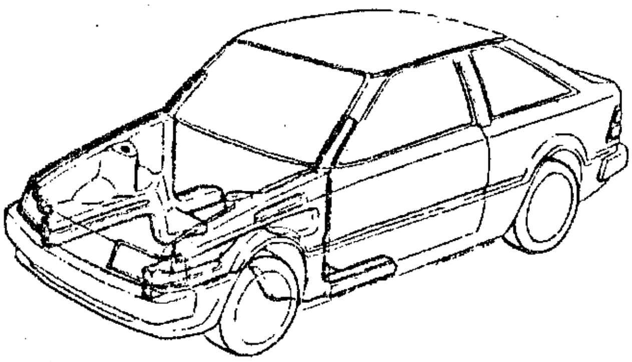
Continuous pultrusion:



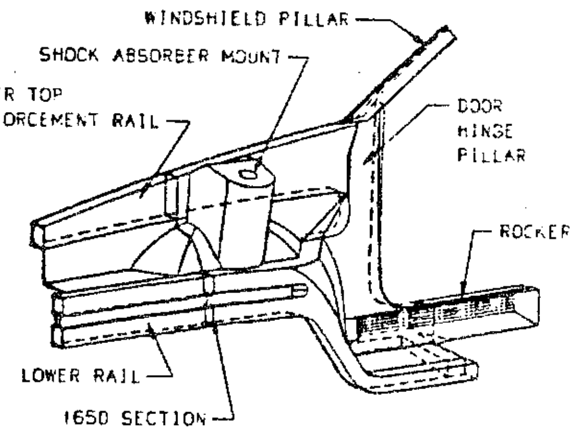
Centrifugal casting:



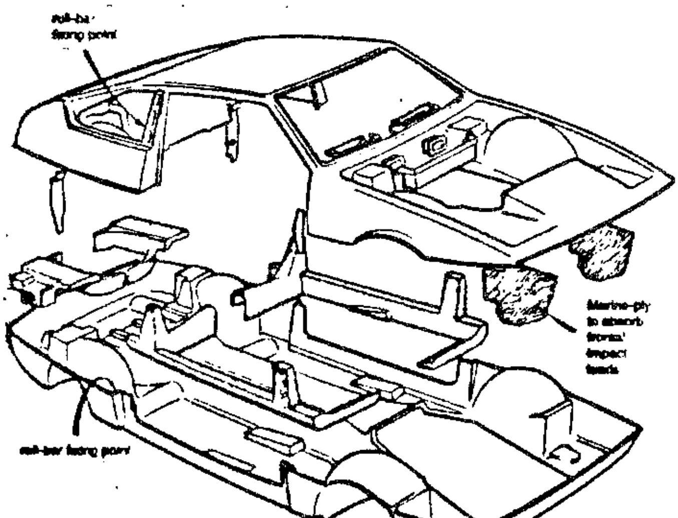




Composite front structure.



Composite apron structure.



Composite body panels
of the 1987 Lotus Esprit.