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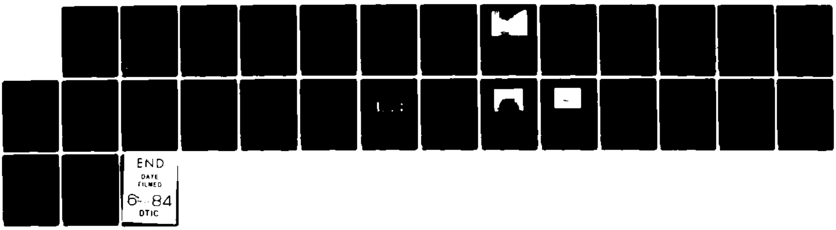

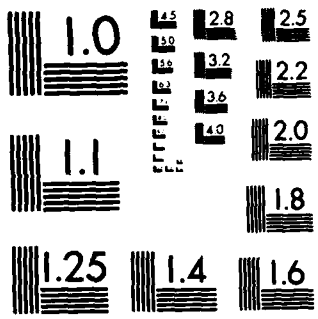

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DESIGN AND FABRICATION OF FRP TRUCK TRAILER SIDE RACKS

AD-A140 896

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COMPOSITES DEVELOPMENT DIVISION

August 1983

ARMY MATERIALS AND MECHANICS RESEARCH CENTER
Watertown, Massachusetts 02172

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ABSTRACT

This program was undertaken to determine and verify the technical and economic feasibility of replacing the standard plywood side racks for the Army M-871 semi-trailer with a lighter weight, lower cost, molded fibrous glass part.

Finite element modeling of the structure and service loads was conducted; prototype item mechanical testing verified the finite model analysis.

A trailer set (22) of prototype side racks was fabricated on contract for subsequent field testing.

CONTENTS

INTRODUCTION

Army cargo trailers, M-871 and M-872, currently use either plywood- or hardwood-planked side racks. Replacement of these materials has been considered by TACOM (U.S. Army Tank-Automotive Command). This project was undertaken by the Army Materials and Mechanics Research Center (AMMRC) and the strategy adopted for the evaluation and assessment of alternative options parallels the ten-step approach outlined below:

The Ten Stages of Design . . . from Concept to Production are:[1]

1. Determine function requirements
2. Determine product volume
3. Determine economic requirements
4. Determine the material and process
5. Create initial sketches
6. Detailed part drawings
7. Economic and feasibility analysis
8. Developing a prototype
9. Tool tryout
10. Preparing for production

Objectives

The goals of this TACOM project and the objectives of the AMMRC effort were to design and prototype a composite plastics replacement trailer side-rack that would offer reduced acquisition/maintenance costs and lower item weight for facilitated handling and increased cargo capacity. The program carried out at AMMRC included a feasibility study of substitute composite/plastics materials, design analysis, and optimization and verification of material/part configuration for weight, strength, and cost. Prototyping of the part, for initial field evaluation, was accomplished as a contractual effort.

Functional Requirements

In addition to the general mechanical requirements listed below, the in-service performance of the trailer panel demands durability, chemical resistance, environmental resistance, long-term rigidity and impact behavior, surface appearance, and maintenance freedom. Additionally, the ability to be repaired quickly in the field is important.

The redesign panels must retrofit the Army M-871 and M-872 trailers. The nominal 4 ft x 4 ft panels must be fabricated in three configurations of varying widths, i.e., bulkhead (50.25 in.), intermediate (46.50 in.), and end-gate (44.25 in.) panels to fit the existing stake layout. Figure 1 shows the standard side rack; Figure 2 shows installation on the M-872 trailer. Panel specifications include:

1. The panel must withstand a maximum load requirement of 50 pounds per square foot (psf) - 0.347 psi.

1. *Plastic Design Forum*, Volume 1, May/June 1976.

Figure 1. M-871 trailers (similar M-127 trailers shown in figure).

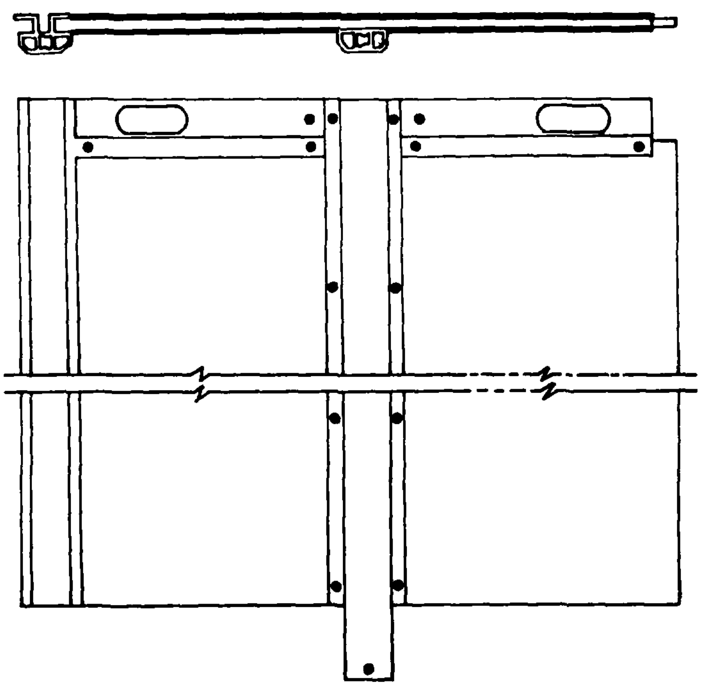

Figure 2. Intermediate panel.

2. Lateral panel deflection must not exceed 0.5 in.; greater deflections between stakes could result in panel/stake separations.

3. Target weight reductions for the redesigned panels were 25% to 30% over currently used plywood panels, weighing 40 lb, or the hardwood panels which weigh 92 lbs (excluding 8-lb panel stake).

4. Inside panel surfaces must be smoot. for removal of bulk cargo.

5. Military specifications (MIL-W-00391 \T) for environmental resistance and flammability were not considered essential for the scope of prototype/function studies.

Product Volumes

Volume requirements were determined for the side racks as shown in Table 1.

Table 1. TRUCK SIDE RACK PROCUREMENT*

Year	Trailer M-871		Trailer M-872
1979 through 1982	2961		3318
1983 Forecast	1100		1100
Spares		98	
Design Volume		2300 (combined units)	

Economic Requirements

Cost and weight reductions for each material's configuration were determined by the optimized structural design. Cost reduction was based on a 1982 average cost of $215.00 per rear panel and $225.00 for side panel.

Material Options

A series of composite constructions was considered for design, processing, and economic feasibility. Material options included:

1. Fibrous glass reinforced structural foam high density polyethylene (SF-HDPE).

2. Compression molded fibrous glass reinforced unsaturated polyester sheet molding compound (PY-SMC).

3. Resin transfer molded (RTM) fibrous glass reinforced unsaturated polyester composite.

4. Fibrous glass reinforced polyurethane reaction injection molding (RIM).

5. Plywood.

DESIGN AND COST ANALYSIS

Finite Element Stress Analysis

"In the past, for the most part, engineering design of SMC products has been empirical - "cut and try." If the product broke in testing or use, a rib was added or the thickness was increased locally. In this approach there was no way to know where overstrength and/or overweight existed.

However, ". . . advances in structural design techniques, particularly the use of finite element analysis (FEA), can result in highly efficient designs, but they do require more extensive mechanical properties characterization than has been generally available for SMC. The mechanical properties of a 50% random fiber SMC have now been fairly thoroughly determined."[2]

Several constraints imposed on the design of the truck panels included:

1. The border at each side of the panel had to be wide enough to accommodate the stakes that attached to the panel to the truck bed.

2. The depth of grillage had to be small enough to lie within the envelope produced by the stakes.

3. The draft angle of grillage stiffeners was selected as a 30° angle of repose to allow easy drainage of bulk cargo such as sand, and also to permit drape of the SMC in the fabrication mold as well as easy removal from the mold.

4. Ribbed panels require a flat or smooth inner surface. Early in the program it was determined that a flat monocoque panel would not suffice, due to either large deflections or excessive weight in sections thick enough to resist deflections. It was, therefore, decided to employ a stiffened panel to produce acceptable deflections and light weight.

Design in Structural Foam HDPE

A stress analysis of the proposed trailer side panel was conducted using the SAP-IV (The Structural Analysis Program for Static and Dynamic Response of a Linear System) finite element program. The panel was first modeled for the reinforced SF-HDPE using a series of flat plate elements with the rib stiffeners and stakes modeled as beam elements. Table 2 cites typical values used in the analysis. This model consisted of 64 plate elements and 96 beam elements. The HDPE was assumed to have a Young's modulus of 400,000 psi and a Poisson's ratio of 0.3. The plate element data are shown in Figure 3 and the beam element date are shown in Figure 4. The ribbed panel, flat inner surface concept was selected due to ease of fabrication with SF-HDPE and the ease of drainage of bulk cargo. The configuration is shown in Figure 5.

The panel was then subjected to a uniform pressure of 50 psf over the entire surface. The results of the analysis predicted the maximum bending stress in a plate element to be 400 psi and a maximum rib bending stress of 650 psi. These

2. LUBIN, G., Ed. *Handbook of Composites*, Van Nostrand Reinhold, Inc., New York, pp. 395-396, 1982.

stresses are well within the allowable for the material. In addition, the program predicted a maximum deflection of 0.3 in. at the top of the panel that also seems to be within satisfactory bounds.

Table 2. DESIGN PROPERTIES OF HDPE FOAM WITH 20% CHOPPED GLASS FIBERS

Flexural Strength	4×10^3 psi
Flexural Modulus	4×10^5 psi
Tensile Strength	5×10^3 psi
Density (solid)	1.1 g/cc
Density (foamed)	0.8 g/cc
Material Cost	$0.92/round

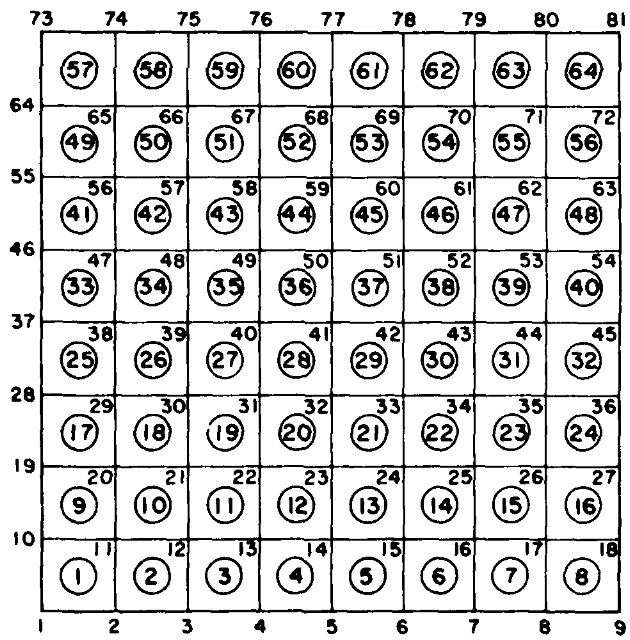

Figure 3. Plate analysis.

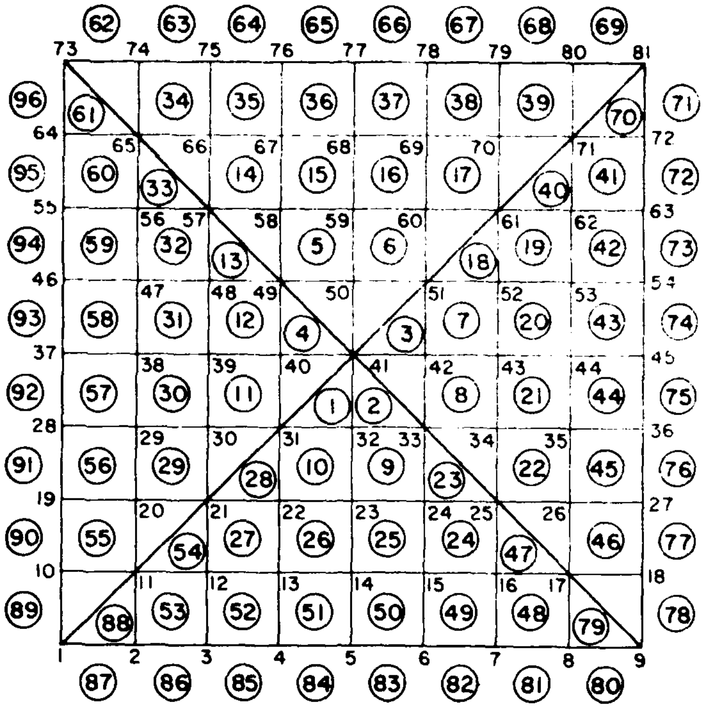

Figure 4. Beam analysis.

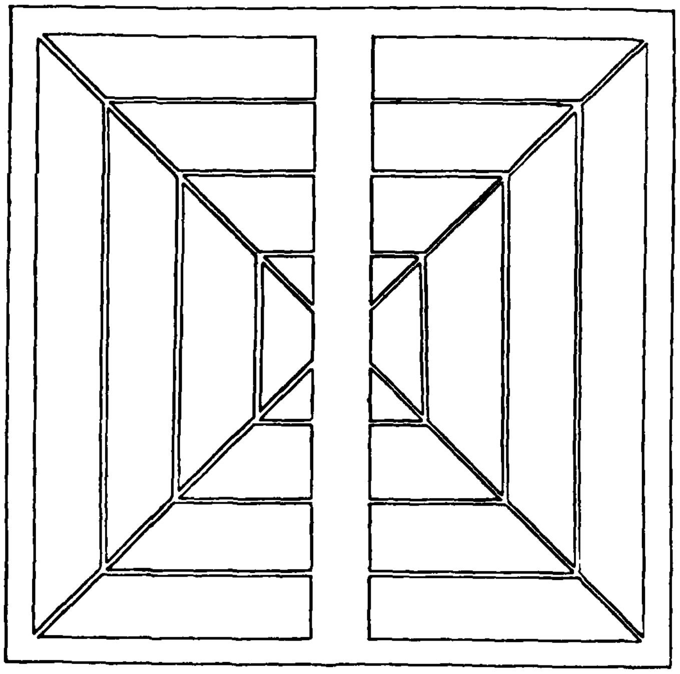

Figure 5. Structural foam design.

Manufacturing Cost Analysis for Structural Foam Panels

Aluminum tooling can be used for injection molding of structural foam. The tooling lead time is estimated as 14 to 16 weeks. The tool would use a simple center-gated sprue with a maximum flow path of fewer than 34 in. A chemical blowing agent (CBA) can be used in the process to cause foaming and the desired density reduction. The cavity and the integral rib structure can be machined via a numerical control tape machine. The estimated cost for an aluminum production mold is $25,000. Over the lifetime of the mold, more than 25,000 parts could be made, and the tooling can be amortized at $1.00 per panel.

The SF mold design produces a foamed part 0.312 in. thick. The reinforcing ribs would be 0.25 in. by 0.313 in. A 1 in. draft and 0.060 in. radius are recommended for the ribs. This radius was selected because a larger radius increases the notch sensitivity. The design was selected for the following reasons:

1. The box rib design for SF eliminates warpage of the part due to uneven shrinkage. The part, conceptually shown in Figure 5, would be center-gated.

2. The part weight can be reduced significantly by adding ribs since additional stiffening would be achieved.

3. Bosses could be molded into the panel; inserts would be ultrasonically welded into the bosses. The panel would be attached to the stake via a nut and bolt passing through the boss insert.

The molding cost is based on a machine rate of $100/hour. Also, a part with a thickness of 0.312 in. has a cycle time of approximately 2 minutes. Hence, the estimated hourly production rate is 30 parts and the molding cost is $3.33/panel. For this wall thickness at a density of 0.8 g/cc, including reinforcing ribs, the weight is 21 lb. The total manufacturing cost of the structural foam panel is shown below:

Resin costs (0.92/lb) (21-lb panel)	$19.32
Molding Cost	3.33
Mold amortization	1.00
Total cost/panel	$23.65

Design in SMC

The concept selected was a grillage-stiffened panel for FRP construction. The grillage provides ease of fabrication and drainage of bulk cargo. The FEA model consisted of 10 grillages/panel; each stiffener was 0.5 in. deep with a draft angle of 30^{o} (Figure 6).

A second finite element model of the panel was formulated and analyzed using the SAP IV finite element analysis program. The model consisted of 265 nodal points, 244 plate elements, and 28 beam elements to represent the stakes (see Figure 7). The beam elements were restrained at their point of attachment to the truck bed. The SMC layup was assumed to be isotropic with an elastic modulus of 1.65×10^{6} psi. The assumed SMC properties are shown in Table 3.

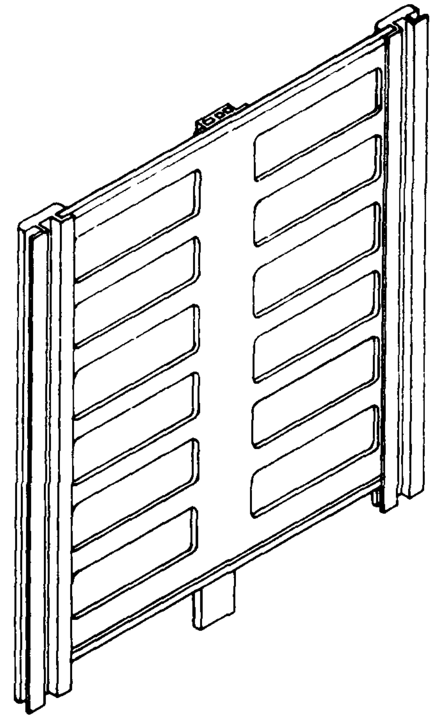

Figure 6. Fiber reinforced plastic panel conceptual design.

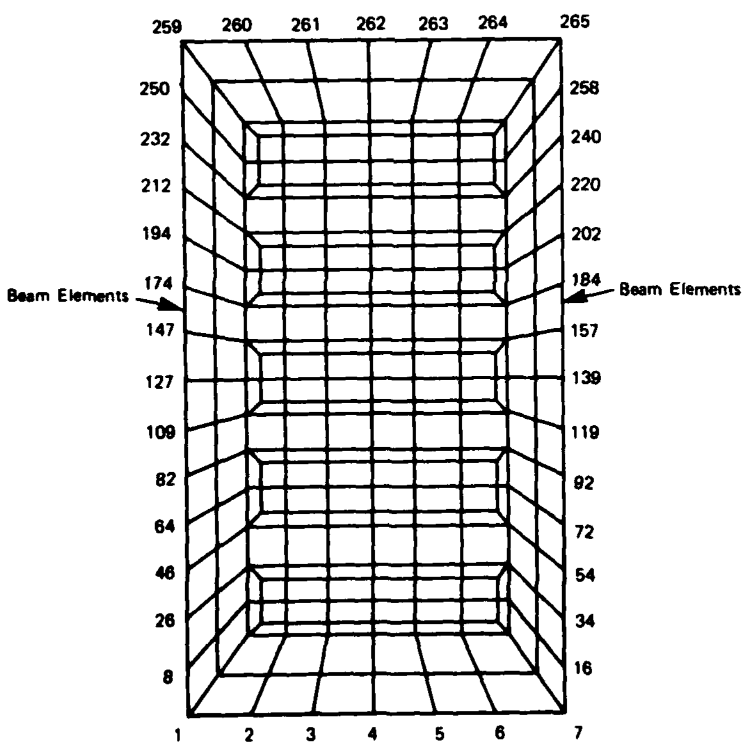

Figure 7. Finite element model grillage stiffened panel.

Table 3. MECHANICAL PROPERTIES OF PY-SMC

Percent Fibrous Glass (FG)	15 - 30	%
Flexural Strength	$18 - 30 \times 10^3$	psi
Flexural Modulus	$14 - 20 \times 10^5$	psi
Tensile Strength	$8 - 20 \times 10^3$	psi
Tensile Modulus	$16 - 25 \times 10^5$	psi
Ultimate Tensile Elongation	0.3 - 1.5	%
Compressive Strength	$15 - 30 \times 10^3$	psi
Notched Izod Impact Strength	8 - 22	ft-lb/in.

The panel was loaded to a uniform pressure of 0.349 psi, which represents the maximum operational load. Table 4 presents the deflection and weight of the selected design. For comparative purposes, the deflections and weights of two thicknesses of monocoque design are included.

Table 4. DESIGN RESULTS

Panel Type	Thickness (in.)	Deflection (in.)	Weight/Half-Panel (lb)
Monocoque	0.15	0.70	7.7
Monocoque	0.20	0.30	10.27
Grillage	0.15	0.18	8.58

Economic Review and Comparisons

The bulk density of 30% random fiber SMC is estimated to be 1.35 g/cc and costs $1.84/lb for discontinuous oriented mat. The thickness of the redesigned composite panel was reduced by 50% for SMC, and a density of 1.83 g/cc was used in calculating the economic comparisons. The 30% SMC panel weighs 2.34 lb/ft^2 for a 0.25 in. thickness. For a 0.163-in. thick panel, the scaled total weight is 17.2 lb/panel.

The estimated cost for a production SMC steel mold is $300,000. It can be assumed that the mold life will exceed 100,000 parts. Based on this number, the amortized mold cost is $3.00/panel. If the press/operator rate were $100/hour and the estimated cycle time were 1.6 minutes (based on 1 minute per 0.100 in. of thickness), then the production rate is 37/hour at a molding cost of $2.70/panel. The total cost for the production of a SMC panel is:

Material cost (17.2 lb @ $1.35/lb)	$23.22
Molding cost	2.70
Mold amortization	3.00
Total	$28.92

Based on the Morrison SPI paper,[3] a matched die molded part offers favorable economics compared to other molding techniques, including RTM. Based on a price index of 100 for the compression molded part, and assuming only 20/hour over a mold tooling life of 100,000 units, the index of mold cost per part was 0.030, while RTM was calculated to be 0.167. As can be seen from Table 4, the grillage design of 0.15-in. thickness exhibits 40% less deflection and weighs 16% less than a monocoque design that is 33% thicker. The maximum bending stress in the panel is only 1400 psi, occurring near the support stakes, and the maximum membrane stress is 500 psi, occurring in the grillage. All of the stresses in the panel are well below the allowable limit for the SMC material.

For comparative purposes, using the present material, plywood (1.7 MM psi flexural modulus), a 0.250 in. thickness was required to realize an 0.18 in. deflection under load. However, to meet the Federal Specifications for puncture resistance, the plywood had to be 0.625 in. thick (2.5 x the necessary thickness).

Based on SMC mat weighing 1 oz/ft^2. Thus, a 5-ply, 150-mil structure (0/90/random/90/0) would weigh 1 lb/ft^2. The composition will exhibit a flexural modulus of 1.65×10^6 psi (refer to Table 6). A half panel will weigh 7.7 lb (7.42 ft^2) and the grillage will weigh 0.88 lb. The standard double panel shall weigh 17.2 lb.

Thus, matched die molding was the least expensive technique, offered 5 fold productivity compared to the RTM process, enjoyed the longest mold life, and its mold amortization rate was the most favorable for reinforced plastics/composites.

A recent concept for manufacturing a large number of structural components is the "birdcage" principle of construction that separates the structural function from the surface or closure functions of exterior panels. This independent structural skeleton provides rigidity, strength, and functional performance.[4]

In the comparison noted below, Table 5, a one-piece thermosetting composition is less expensive than aluminum and engineering thermoplastic. These panels can be cost effective with steel.

Table 5. RELATIVE PRICE INDEX - PANEL CONSTRUCTION

	1982	1987	1992
Steel	100	100	100
1-Piece TS	200	180	90

Design in Fibrous Glass Resin Transfer Molding (RTM)

A third analysis was conducted to determine material requirements for fabrication by fibrous glass RTM. Literature cited properties used in the initial calculation are shown in Table 6.

3. MORRISSON, R. S. *Resin Transfer Molding of Fiber Glass Preform Reinforced Polyester Resin*, SPI Paper No. 15-D.
4. *Plastics World Magazine*, Volume 40, pp. 52-53, November 1982.

Table 6. TYPICAL FRP PHYSICAL DATA (RTM CONSTRUCTION)[5]

Material	1-oz Cont. Strand Mat (CSM)	18-oz Woven Roving (WR)	5-ply CSM/WR Candidate No. 1	5-ply CSM System No. 2
Dry Weight (lb/ft^2)	0.062	0.125	0.436	0.310
% Glass/Resin	30/70	50/50	40/60	30/70
Total Weight (lb/ft^2)	0.207	0.250	1.121	1.035
Nominal Thickness per Ply (in.)	0.030	0.029	0.148	0.150
Density (g/cc)	1.5	1.6	1.56	1.5
Tensile Strength (psi)	10,400	31,000	22,700	10,400
Flexural Strength (psi)	16,000	31,500	22,200	16,000
Flexural Modulus ($x10^6$ psi)	0.63	1.5	0.98	0.63

Candidate No. 1 = CSM/SR/CSM/WR/CSM
Candidate No. 2 = 5-ply CSM

A 5-ply, isotropic material configuration (CSM/WR/CSM/WR/CSM) was selected as a "first cut" analysis. Alternating continuous strand mat with woven roving plies generally produces better "fill-in" of weave in thin lay-ups than use of woven rovings alone, as well as providing better ply-to-ply bonding with woven roving. The lay-ups (as with SMC) was assumed to be isotropic, but with an elastic modulus of 980,000 psi. A second configuration of 5-ply (1-oz) CSM assumed an elastic modulus of 630,000 psi.

In each analytical case the grillage-stiffened panel configuration and a flat panel were assumed and subsequently loaded to the required uniform pressure of 0.349 psi. Results are shown in Table 7.

Table 7. RTM DESIGN RESULTS

Panel Type	Thickness (in.)	Deflection (in.)	Weight/Half-Panel (lb)
Grillage CSM/WR	0.150	0.303	9.3
CSM/CSM	0.150	0.471	8.56
Monocoque CSM/CSM	0.150	1.18	7.68
	0.200	0.505	10.78
CSM/WR	0.150	1.83	8.32
	0.200	0.786	11.22

5. HAWKINSON, K. *Fiber Glass Boat Building for Amateurs*, pp. 74-78, 1982.

Manufacturing Cost Analysis for RTM Panels

RTM tooling requirements can be met either by gel-coated plastics or metal tooling. Costs are estimated at $10,000 for plastics tooling to produce the side rack and would have a production life of 3000 units. A metal mold for the same component would cost $20,000 and would be expected to service a production run of 6000 parts. Cycle time for production of the part is estimated to be 10 to 15 minutes. Thus, for optimum efficient production, two molds should be utilized. Over the lifetime of the plastics tooling cost can be amortized at $3.33/panel. Molding cost is estimated to be $100/hour (2 man-hours and equipment); estimated production cost, at 4/hour, is $25.00/panel.

Current materials cost for RTM were determined to be $0.90 to $1.00/lb for fibrous glass mat or woven roving and $1.10/lb for MEK-P initiated/promoted polyester resin. A total FRP material cost of $1.00/lb was assumed for this study. The total manufacturing costs for the RTM panel is noted below:

Resin/glass costs ($1.00/lb) (17.66 lb/panel)	$18.00
Molding cost	25.00
Mold amortization	3.00
Total	$46.00

The specific economic highlights are compared in Table 9.

Design in Fibrous Glass Reinforced Reaction Injection Molding (R-RIM)

A 30% glass reinforced polyurethane RIM system has a density of 1.17 g/cc and a Flexural Modulus of 345,000 psi. A 30% hybrid composition of fibrous glass and mica offers a flexural modulus of 448,000 psi. Recent developments in epoxy-RIM compositions offer modulus values exceeding 300,000 psi, but are too expensive ($2.65/lb). Monsanto's NYRIM nylon block copolymer RIM system, exhibits a 650,000-psi flexural modulus (with 33% glass reinforcement) but costs more than $4.00/lb. For 30% glass reinforced PU-RIM, the FEA determined thickness of 0.250 in. with grillage will meet the necessary demands and will weigh 9.14 lb vs 8.58 lb for the SMC construction. Noted below (Table 8) is a listing of relative weights required for equivalent stiffness.

Table 8. EQUIVALENT WEIGHT/STIFFNESS FACTORS[5]

Polyurethane - Structural Foam	$1.00
Aluminum	1.48
Steel	2.88

R/RIM Economics

Based on a polyurethane RIM system containing 30% fibrous glass reinforcement and selling for only $1.00/lb, the following data indicate the very favorable economics of another manufacturing alternative. Table 9 indicates relative economic consideration for four alternative manufacturing technologies.

Table 9. COMPARATIVE MANUFACTURING COSTS[6]

	SF-HDPE	SMC	RTM	R/RIM
Parts/hour	30	37	4	30
lb/part	21	17.2	18.10	18.28
Cost/part				
*Material ($/lb)	0.92	1.35	1.00	1.00
**Mold Tooling ($) per part	1.00	3.00	3.00	0.85
*Molding ($) per part	3.33	2.70	25.00	3.33
Total cost/part ($)	23.65	28.92	46.60	22.48

*Fibrous glass combined with resin

**Assumes amortization over the useful life of the tool

Thus, RIM systems compare very favorably to the more established compression molded SMC panels since RIM requires:

1. Less energy for large production runs, R/RIM has a Production Economic Index of 430 vs 590.6 for SMC (P.E.I. = Mold Cost x Energy x Cycle Time)

2. Inexpensive material

3. Reduced tooling and mold equipment cost

4. Lower cost per part for amortization of tooling and equipment

5. The total manufacturing cost (material, tooling, and molding) for the RIM panel ($22.48) is comparable to the structural foam PE panel ($23.65) and is more competitive than SMC ($28.92) and RTM ($46.00).

In all cases, however, these four systems offer significant advantages over the conventional plywood panels that cost $220.00 each, plus $10.00 for the mounting stakes. Figure 8 compares tooling and production cost components for each composite option to current panel production. A break-even analysis, shown in Figure 9, shows that FRP panels manufactured by RTM have the lowest tooling cost; hence, the lowest break-even quantity.

6. SPEIRS, III, R. G. *R/RIM Technology: A Status Review*, Master's thesis, The University of Lowell in Massachusetts, Tables V, VI, and XV, 1982.

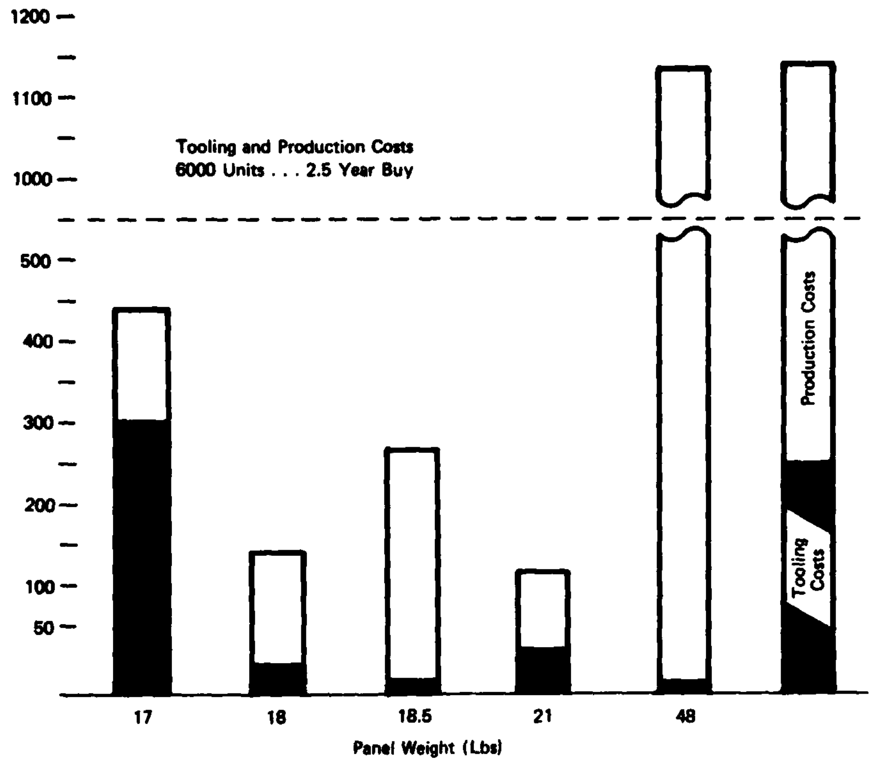

Figure 8. Tooling/production cost comparisons.

Units Required to Equal Current Side Rack Cost	Fixed Cost (Tooling) / Replacement Panel Cost – Variable Costs
RTM . . . . 64 Panels	\$10,000 / (\$200 – \$43.66)
RIM . . . . 115 Panels	\$20,000 / (\$200 – \$21.63)
S. FOAM . . . 139 Panels	\$25,000 / (\$200 – \$20.66)
SMC . . . . . 1,724 Panels	\$300,000 / (\$200 – \$25.92)

Figure 9. Break-even cost analysis.

PROCESSING AND PROTOTYPING

Several fibrous glass/polyester systems were cured to measure the mechanical properties, especially the modulus, so that the test values could be compared with the theoretical values assumed in the calculations. Table 10 notes the results for a white polyester SMC D 30-R20. This material was molded between caul plates at 300°F and 100 psi for 15 minutes. The results show a mean flexural strength of 67,000 psi and a flexural modulus of 3.4 x 10^6 psi. Similarly, CSM, WR, and CSM/WR (Owens Corning Fiberglass) test configurations were impregnated and hand laid-up). The isophthalic polyester laminating resin was cured with MEK-P and a cobalt naphthenate promoter at room temperature using a contact mold with an air-barrier cover sheet. Table 10 shows the results for the mechanical testing. The mean flexural strength of all mat configuration was 27,500 psi and the flexural modulus was 0.8 x 10^6 psi, which is only half of the assumed model value. A composite burnout confirmed that the molded plate was resin rich, resulting in the reduced modulus.

Table 10. EXPERIMENTALLY DETERMINED FIBROUS GLASS REINFORCED POLYESTER MATERIAL PROPERTIES

Material	SMC (C30-R20)	CSM (3 oz) 3 Ply	WR (18 oz) 2 Ply	WR (18 oz) 2-ply and CSM (1 oz) 2 Ply
Thickness (in.)	0.211	0.175	0.060	0.120
%Glass*	55	30	62	40
Flexural Strength (psi)	64,216	27,503	52,216	32,563
Flexural Modulus** (x10^6 psi)	3.489	0.798	1.575	1.219

*Samples were burned-out at 500°F for 2 hours

**Tested according to ASTM D 790

DESIGN VERIFICATION

Ideally, finite element analysis of the various panel concepts has permitted the evaluation of materials and design options, and selection of structural configurations requiring a minimal "cut and try" refinement.

For convenience in fabrication, the grillage-stiffened FRP construction was selected for prototyping, testing, and design verification. A full-size panel contact mold was constructed from plywood; the grillage draft angle was cut to 30° and all mold surface corner radii were cut to 0.100 in. All contact surfaces in the mold were sealed with white shellac and finished with five coats of carnauba wax. The completed mold is shown in Figure 10.

Figure 10. FRP prototype mold.

FRP molding procedures were duplicated for each part produced. In general, the waxed mold was coated with a release agent prior to lay-up. Isophthalic polyester laminating resin was brushed onto the mold, fibrous glass was then placed in the mold, "wetted-out," and rolled free of air. This step was repeated until the laminate schedule was completed.

After completing the laminate lay-up, the surface was covered with a flexible polyvinyl alcohol (PVA) sheet, edge-sealed, and evacuated. The sheet formed an air barrier while providing some laminating pressure. Cure time for each part was approximately 2 hours.

The purpose of this study was to determine the effectiveness of FEA for structural design and reduction of "cut and try" fabrication. The most meaningful evaluation of the FRP prototypes was the verification of the FEA predictions, duplicating test conditions on an experimental basis and generating data for comparison. The test fixture devised for the flexural testing program is shown in Figure 11. Individual panels were placed on the fixture, pre-measured, and loaded with canvas until a weight equalled a pressure of 50 psf or a deflection of 0.5 in. Deflections were noted and compared to the theoretical predictions (Figure 12).

Figure 11. Test fixture.

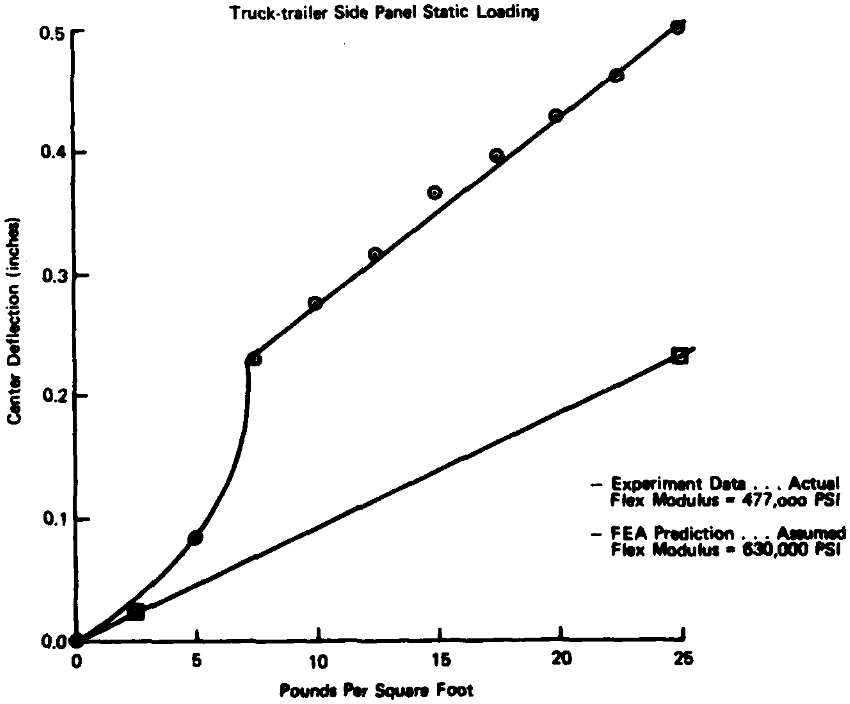

Figure 12. Test results.

DISCUSSION

Based on fewer than 3,000/year projected near-term buys of the M-871 and M-872 trailer side-racks, RTM manufacturing technology was identified as providing the most cost-effective (total program cost) means for producing a limited number of parts for field evaluation under actual service conditions.

SMC production would require a ten-fold increase in annual part quantity to be cost-effective. Reinforced RIM has been shown to be potentially economical manufacturing method.

Laboratory prototyping and testing showed good correlation with experimentally developed FEA models. This illustrates the applicability of the FEA concept as a timesaving step in designing composite structural parts of simple geometries.

Trailer sets of similar FRP composite panels are now being fabricated on contract for service evaluation.

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