Sandwich Construction for Public Transportation

Troy, MI
September 12-13, 2002

Traditional Materials and Construction

Steel, Aluminum, Plywood,
and other traditional materials dominate.

History
Known Processes
Materials design data base and knowledge
Known costs
Consumer acceptance

Traditional Materials and Construction

Some major issues changing thought:

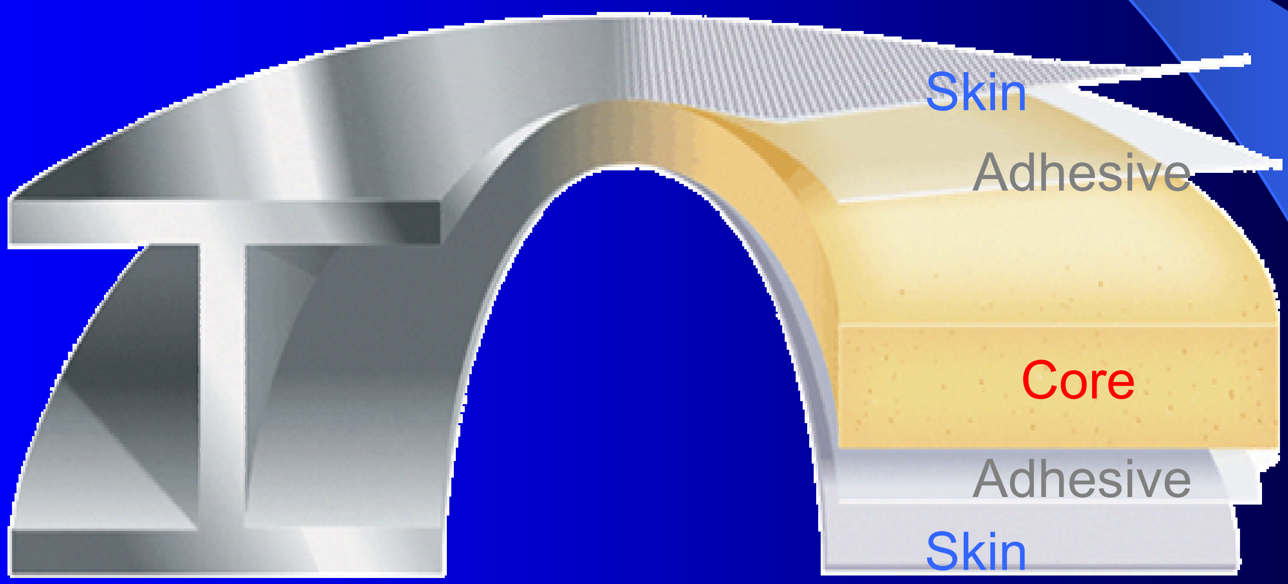
Clean Air Act and other government policies
Energy Costs
Need for more efficient public transport systems
New materials and processes improved

Six strong arguments for composite sandwich construction for transportation applications:

- **Optimized low weight**
- **Freedom of design**
- **Comfort**
- **Safety**
- **Maintenance**
- **Environmental Impact**

What is a Sandwich?

Sandwich Components



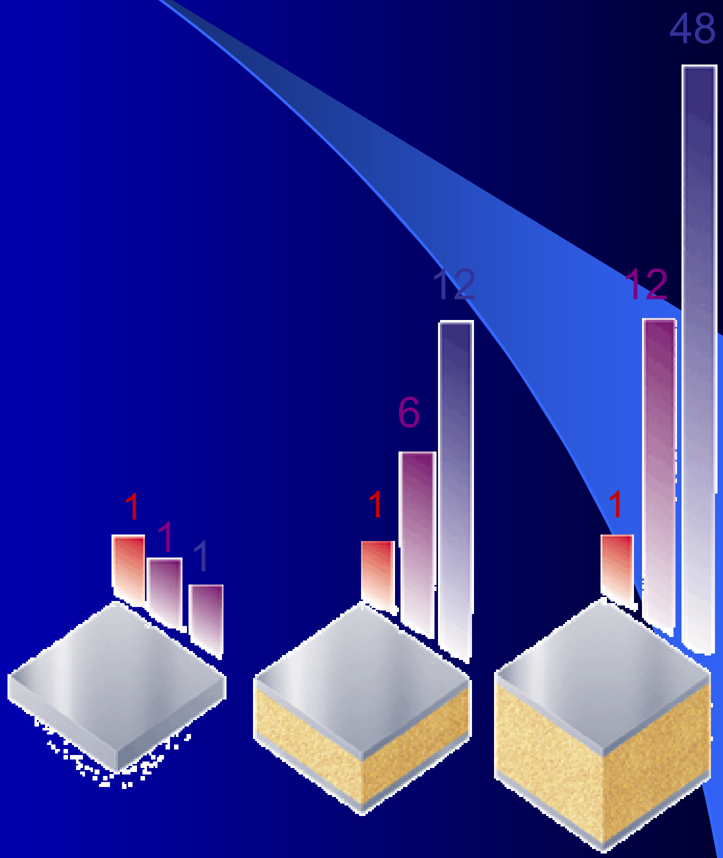
Definition of a TRUE Sandwich

- Thickness of core is much greater than the thickness of the skins

$$t_c >> t_s$$

Why Sandwich over Solid?

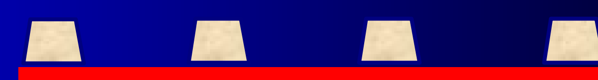
- Weight
- Strength
- Stiffness
- Labor
- Insulation



Labor Savings

- Less plies to laminate

- Less stiffeners or framework to install



Optimized low weight

Why is reduced weight so important?

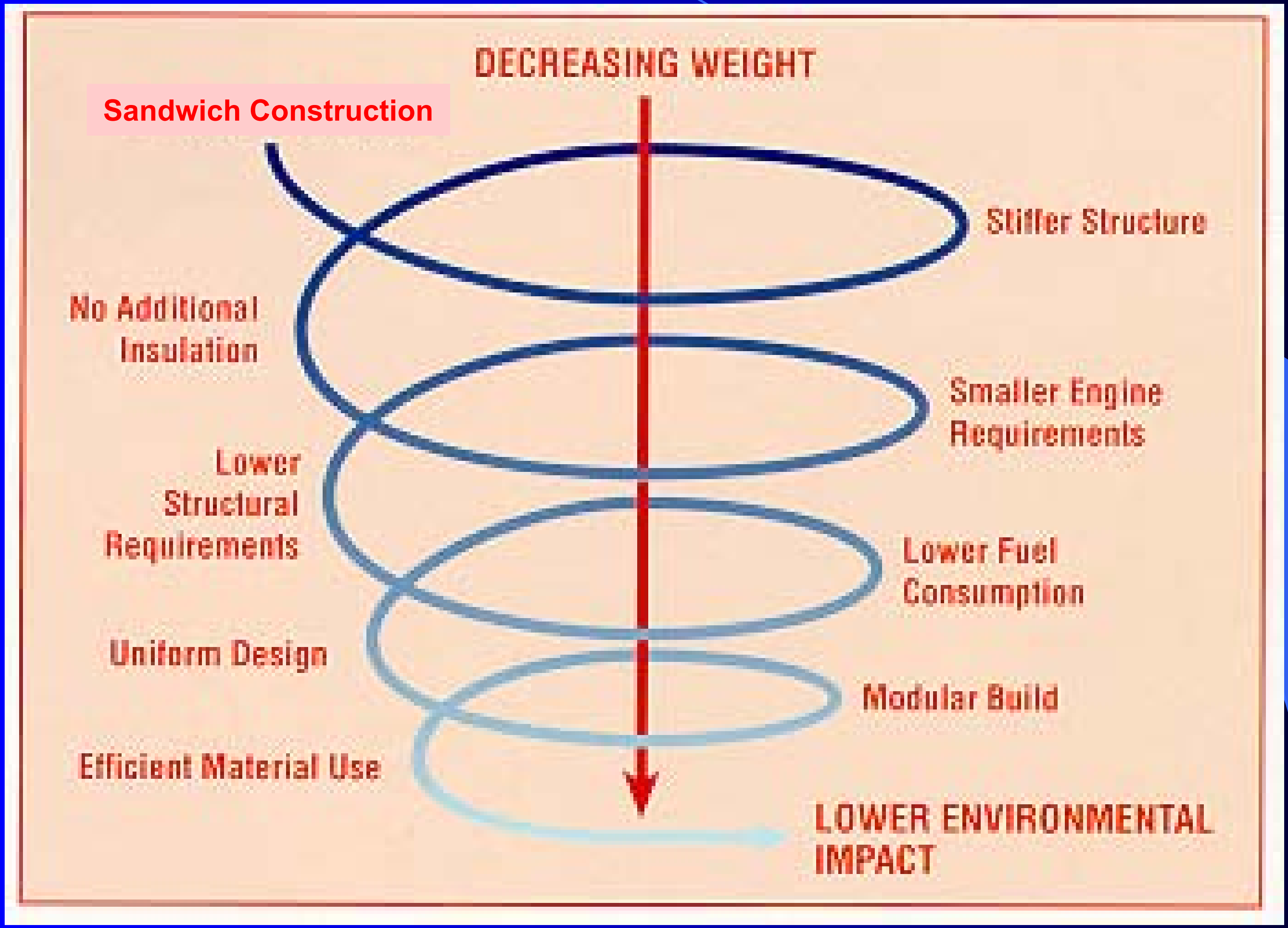
- ✓ **Increased payload**
- ✓ **Faster acceleration**
- ✓ **Lower energy consumption**
- ✓ **Lower noise**
- ✓ **Increased ease during fabrication**

Conclusion:

Lower total Life Cycle Cost.

Increased Profits.

Optimized low weight



Optimized low weight

Life Cycle Cost

- ãPurchase price
- ãDocumentation
- ãOperational
- ãEnergy consumption
- ãSpare parts
- ãRepair
- ãMaintenance
- ãScrapping

Case:
$12,700/ton saved during the lifetime for a train (25 years) using sandwich construction.

Freedom of design

Skin Materials

Core Materials

Adhesives and Joining

Construction Processes

Key Properties of Skin Materials

- High Tensile Modulus
- High Compression Modulus
- Tensile Strength
- Compression Strength
- Interlaminar Shear Strength
- Bondability
- Adequate Toughness
- Temperature Resistant
- Moisture Resistance
- Adequate solvent resistance
- Adequate Peel Strength
- Adequate Fatigue Life

Typical Skin Materials

- Metallic
  - Aluminum
  - Steel
- Wood
  - Plywood
  - Veneer
- FRP
  - Carbon
  - Aramid
  - Glass
  - Hybrids

Key Properties of Sandwich Cores

- High Shear Modulus
- High Compression Modulus
- Shear Strength
- Compression Strength
- Tensile Strength
- Bondability
- Adequate Shear Strain
- Non-Friable
- Temperature Resistant
- Moisture Resistance
- Impact Resiliency
- Adequate solvent resistance
- Adequate Peel Strength
- Adequate Fatigue Life

Typical Sandwich Cores

- Honeycomb
  - Metallic
  - Plastic
- Wood
  - End-grain balsa
- Cellular Plastic
  - Polyvinyl Chloride (PVC) Foam
    - cross-linked (rigid)
    - Linear (semi-rigid)
  - Polyurethane (PUR) Foam
  - Styrene Acrilonitrile (SAN) Foam
  - PMI Foam

Key Properties of Adhesive Materials

- Tensile Strength Greater than Core
- Shear Strength
- Bondability
- Adequate Toughness
- Good Wet-Out of core and skin
- Temperature Resistance
- Moisture Resistance
- Adequate solvent resistance
- Adequate Peel Strength
- Adequate Fatigue Life

Typical Adhesive Materials

- Epoxy
- Urethane
- Urethane Acrylates
- Polyester
- Vinylester
- Phenolic

Construction Processes

- VARTM / Infusion / SCRIMP
- Pre-Impregnated Fibers (pre-preg)
- Wet lay-up
- Pultrusion
- Filament Winding
- RTM

Construction Processes

VARTM / Infusion / SCRIMP

- Large structures
- Reduced part count
- Consistent and good quality
- Controlled costs

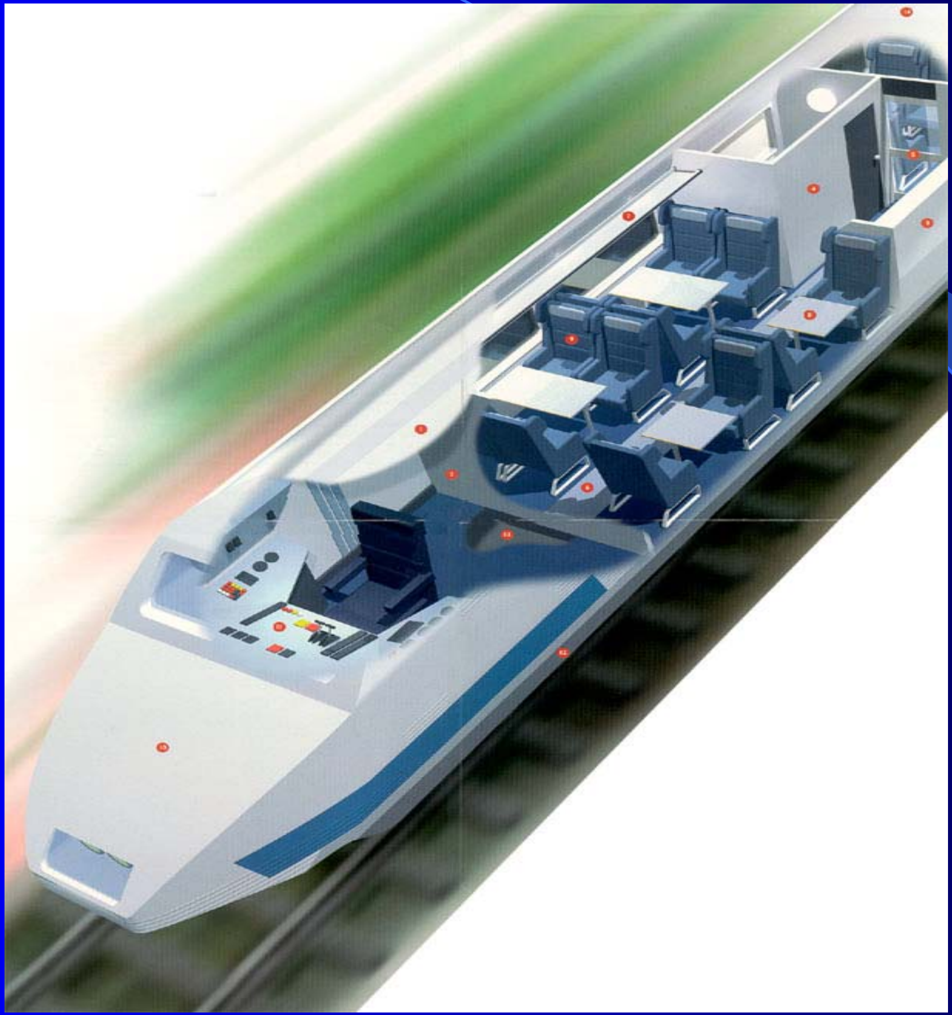
Core Processing Matrix

	Room Temp	Pre-Preg (Celsius)							
Core	Wet Lay-up	60	120	148+	Vacuum	Autoclave	VRTM	Thermoform	RTM
Rigid PVC	Yes	Yes	Yes**	No*	Yes	Yes*	Yes	Yes	Yes
Ductile PVC	Yes	No	No	No	Yes	No	Yes*	Yes	Yes*
SAN	Yes	Yes	Yes	No*	Yes	Yes*	Yes	Yes	Yes
PMI	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Polyurethane	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No**	Yes
Honeycomb	Yes	Yes	Yes	Yes	Yes	Yes	No	No	No
Balsa	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes

* Under controlled temperature, time, and pressure, using ramp-ups.

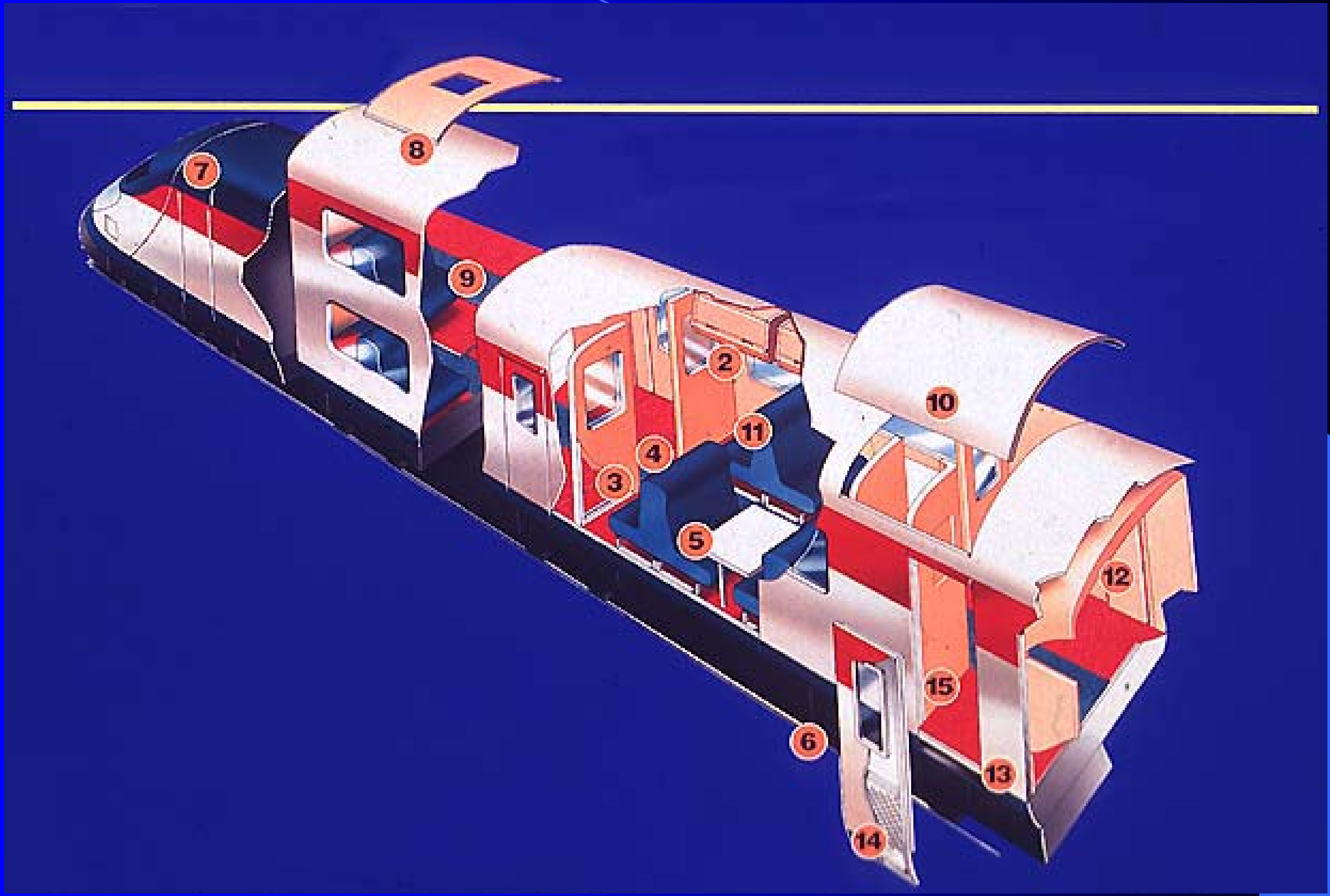
** Special Grades.

Freedom of design



Endless Possibilities!

Freedom of design



Courtesy of Hexcel Composites

Comfort

Multifunctional - Sandwich

Uniform design with seamless joints

- Integrated insulation
- Integrated sound dampening
- Optimal surface finish, easy maintenance
- No rot light panels
- Easy maintenance - moving and replacing panels.

Traditional Design - Metal

Many different parts, bolted or welded together

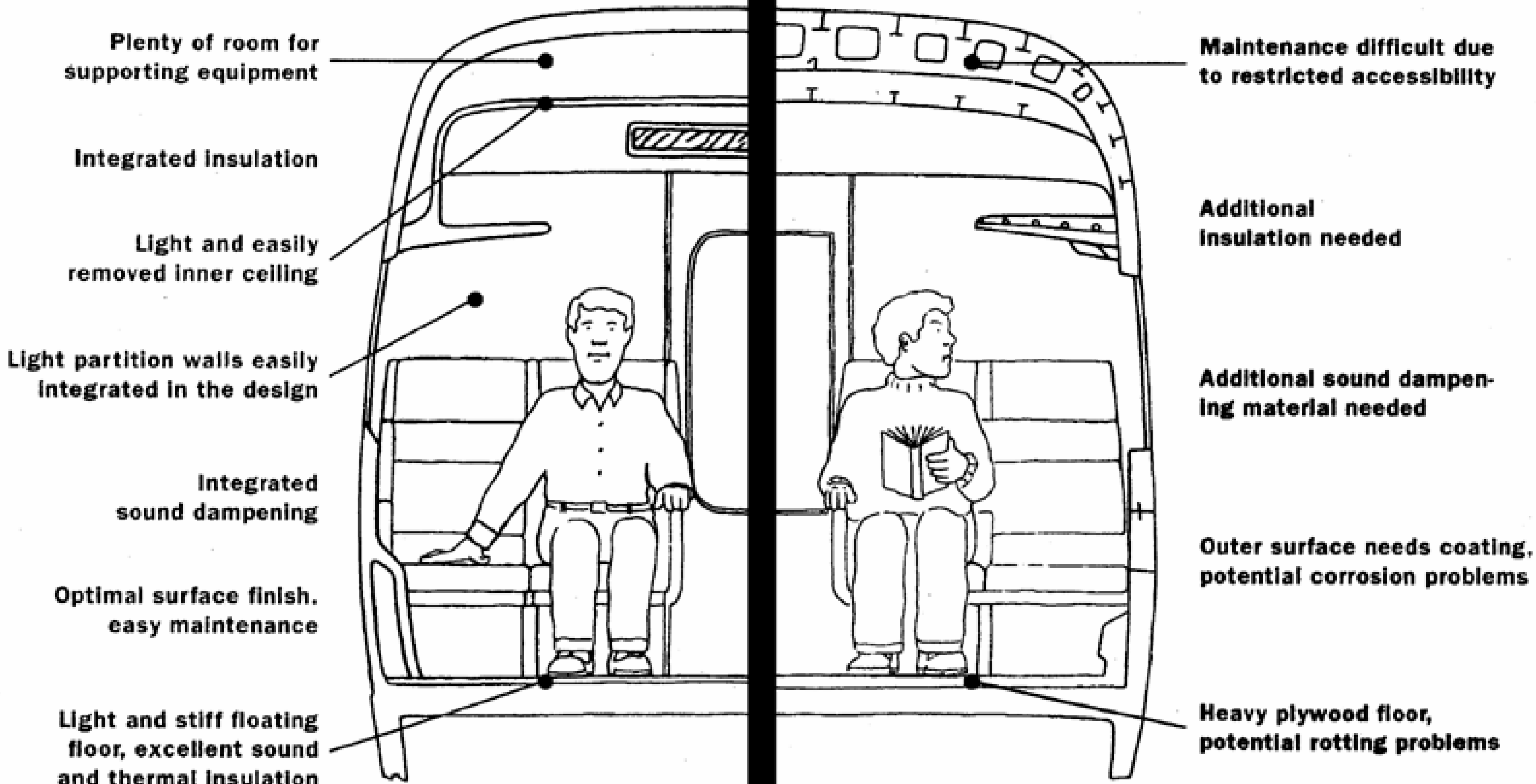
- Additional insulation needed
- Additional sound dampening material needed
- Outer surface needs coating, potential corrosion problems
- Potential rotting on heavy plywood floors.

Multifunctional, *sandwich*

Uniform design with seamless joints

Traditional design, *metal*

Many different parts, bolted or welded together



Safety

- Fire, Smoke, and Toxicity Properties.
- Crash / Energy Absorption Properties.

Safety

Oxygen Index

Oxygen index is the minimum percentage of oxygen required in the surrounding air to sustain a fire. Normally, there is 21% oxygen in air. Materials that have an oxygen index greater than 21 are said to be self-extinguishing.

Heat Release and Heat Release Rate

Heat Release (HR) is a measure of the energy released from a material when it is burned. The Heat Release Rate (HRR) is the rate at which energy is released during the test – of particular interest is the Peak Rate. The HR and HRR can be measured using equipment such as an OSU test chamber, developed by Ohio State University.

Safety

Smoke Generation

There are various pieces of equipment to measure smoke generation from burning materials. Two examples are the NBS (National Bureau of Standards) and the OSU (Ohio State University) smoke chambers.

Toxicity

Burning and combustion not only release heat, they also produce residual products such as char and smoke. Standards have been established to dictate the types and quantities of combustion products allowed for certain materials.

Safety

NF F 16-101

NF F 16-101 is a French standard for railway rolling stock, fire behavior and choice of materials. The materials are classified with respect to fire behavior and smoke index. Fire behavior has five classes, M0 – M4, were M0 is the highest. Smoke index is a combination of smoke density and toxicity. It also has five classes, F0 – F5, were F0 is the highest.

DIN 5510, Part 2

DIN 5510, Part 2 is a German standard for preventive fire protection in railway vehicles. The materials are tested and classified with respect to flammability, smoke development and dripping. Flammability includes burn length and burn time after test and is classified S1-S5, were S5 is the highest. There are two classes for smoke development and dripping, SR1/SR2 and ST1/ST2, were SR2 and ST2 are the highest.

Safety

NFPA (National Fire Protection Association)

NFPA 130 Standard for Fixed Guideway Transit Systems is an American set of rules for Trains, and Subway used in the USA using ASTM E162 and ASTM E662 for Flammability and Smoke Emissions.

Safety

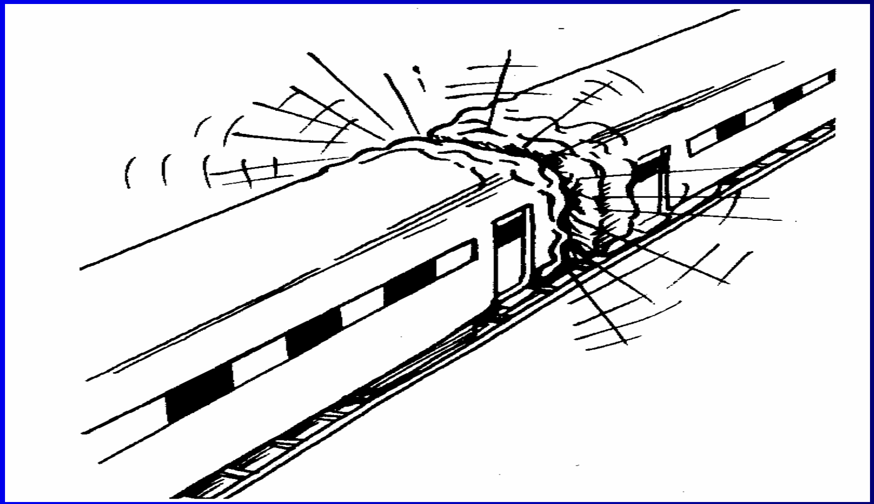
Incorrect Energy Absorption

Conventional vehicles from steel have too low energy absorption.

Safety

Correct Energy Absorption

Vehicles made with sandwich construction technology using crash zones result in better deceleration rates.



Safety

Impact/Damage Resistance

- Increased puncture resistance
- Core dissipates impact energy reducing damage to inner skin
- Larger panel size dissipates impact energy

Maintenance

- Easy repair
- No corrosion (metal free parts)
- No rotting (wood free parts)
- Long lifetime (structural parts)

Environmental Impact

LCA - Life Cycle Assessment

- Sandwich design offering weight savings and a stiffer structure are the keys to a favorable LCA.

- Easier and faster building (reduced labor).

- A multifunctional sandwich decreases the need for other construction materials.

Environmental Impact

Reduced Emissions:

Vehicles are 30% of world’s emissions

↓

Need to reduce emissions

↓

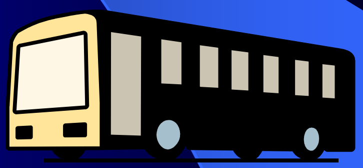
Need to reduce weight

↓

Use new solutions

↓

Sandwich Technology



Track Record

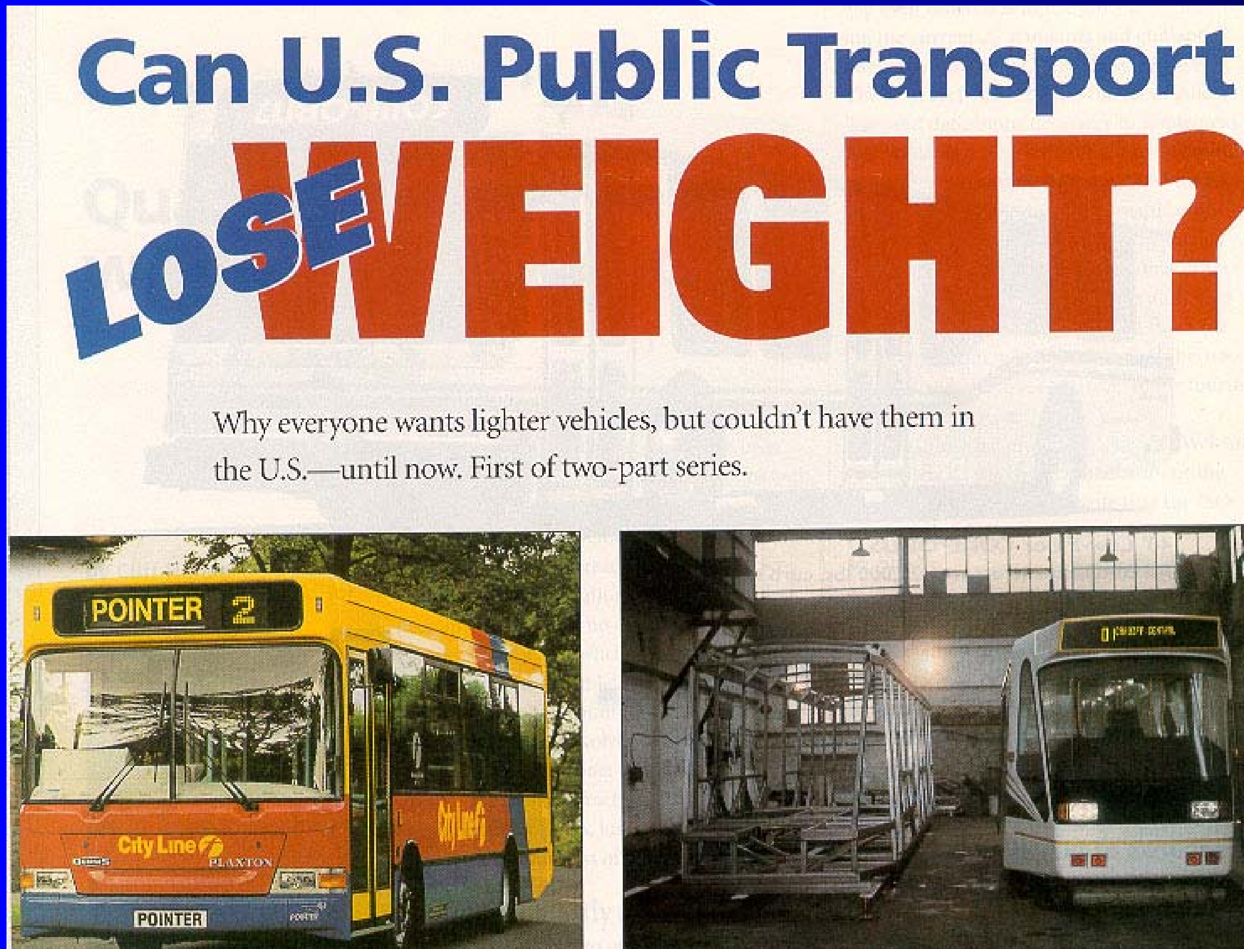
- Sandwich Technology is well proven all over the world.

- Wide acceptance in assorted transportation applications - high speed trains, city buses, trams, etc.

- Applications range from roof to skirts, from nose cover to whole coach bodies.

Disadvantages

- Material Cost
  - potentially offset by labor savings
- Learning Curve
  - Employees/Teams must be trained to properly construct and repair sandwich structures
  - Materials and process knowledge and confidence
  - Life Cycle Assessment implementation



Can U.S. Public Transport LOSE WEIGHT?

Why everyone wants lighter vehicles, but couldn't have them in the U.S.—until now. First of two-part series.

METRO Magazine

April 2000

Mode	Factors Driving Lighter Weight	Key Strategies	Key Barriers
Motorcoach	• Operating Costs • Styling	• **Composites**, aluminum in bodies, components • Multiplexing Wiring	• High Capital Costs • Price Competition • Cheap Used Coaches
Transit Bus	• Operating Costs • FHWA Weight Limits	• **Composites**, aluminum in bodies, components • Multiplexing wiring • Future: total redesigns	• Higher initial purchase price • Slow market acceptance of life-cycle costing
Passenger rail	• Operating costs • Infrastructure costs • Styling	• **Composites**, aluminum in bodies • Modular vehicle platforms	• Buff strength requirements (though changing) • Slow market acceptance of new technology

One Common Motive w/Composites: Reduce Operating Costs

ATTB – Foam Core Sandwich Composite

Amtrak Acela – Honeycomb and Balsa Sandwich Composites

NABI Compobus – Balsa Sandwich Composite

By OmniNova
MaxiRider
OmniNova
JZN 410

Adtranz Regina – Balsa Sandwich Composite

Bombardier Talent
Foam and Hoenycomb Sandwich Composite

Alstom Hanover Tram – Foam Sandwich Composite

Adtranz Itino – Foam and Honeycomb Sandwich Composite

Alstom Citadis –
Foam Sandwich Composite

Alstom Lirex
Foam and Honeycomb Sandwich Composite

Alstom S-Train – Foam Sandwich Composite front and floors


BOB
DEG


4501


650 100-1
DB


L200
Evolution


fonte: www.webventure.com.br

The ThermaCore floor is completely level and constructed of durable yet lightweight, material that insulates against sound and heat loss for a more comfortable living environment.


2B
1B
9B
10B
3B
7B

Courtesy of Hexcel Composites

Closing Comments

- Concept of sandwich construction for public transportation applications proven successful.

- Large opportunity for the growth of sandwich composites in public transportation, but it will take time.

- Understand the application and needs → Select the appropriate sandwich solution.

- Consult experts in both materials and processing.

Thank you!

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