DEVELOPMENT OF A STRUCTURAL RPV SECTION SERVING AS AN INTEGRAL FUEL TANK MADE OF SANDWICH CFRP

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ABSTRACT

This paper presents the results of a development work conducted at I.A.I under M.O.D support. A composite structural element representing a RPV wing box or fuselage section, and serving as an integral fuel tank was developed.

Several structural concepts applicable to RPVs have been evaluated. The chosen concept is based on an all composite structure, consisting of thin graphite fabric facings and a H/C sandwich core for the shear carrying skins, and highly loaded beams to carry the bending moments. The main beams have thick Graphite caps either consisting of thick laminates or reinforced by roving. Riveted solid laminate stiffened panels serve as access panels.

Special sealing methods were implemented to prevent fuel leakage. Innovative design concepts have been applied in this structure, while using low cost manufacturing and assembly methods.

Extensive coupon testing was performed:

- To develop the attachments details between the different structural elements.
- To develop a sealing technology and attachment details capable of preventing fuel seepage through laminated panels.
- To develop innovative 3-D thick beam caps.

Full scale static and fatigue tests were performed to prove the following:

- The capability of the structural wing/body element to sustain the combined aerodynamic and fuel loading.
- The effectivity of the sealing concept against fuel leakage under loading for long time durations.

This technology was successfully implemented in the HERON, a medium altitude long endurance RPV recently developed at I.A.I.

INTRODUCTION

Israel Aircraft Industries (IAI) has been engaged in the development of Remotely Piloted Vehicles (RPVs) for several years. In typical High Altitude Long Endurance RPVs (HALE), the structural weight has to be reduced substantially relatively to conventional aircraft, to provide the required performance. As a result, an unconventional, very light weight structure should be designed. Innovative integral fuel tanks for such RPVs, which do not include any separate internal fuel container, and might be located either in the wings or in the fuselage, may lead to considerable weight and cost savings.

This paper presents the results of a design and experimental work conducted at I.A.I under M.O.D support. A composite structural element representing a RPV wing box or fuselage section, and serving as an integral fuel tank was developed.

One of the main concerns was to obtain appropriate attachment details between the different structural elements comprised in the fuel tank, which will ensure structural integrity while preventing fuel seepage through the structure. Extensive coupon testing was performed for this purpose, the results of which were implemented in the final design and production.

A design to cost approach was applied, leading to low cost manufacturing and assembly methods.

Such innovative fuel tanks were successfully implemented in the IAI HERON, a medium altitude (30,000 ft), long endurance (20 to 50 hours) RPV, which marks IAI entry into the HALE development era.

STRUCTURAL RPV ELEMENT SERVING AS AN INTEGRAL FUEL TANK

An Integral fuel tank was designed and produced using a concurrent engineering and design to cost approach. A building block approach was applied, starting with extensive coupon testing, the results of which were implemented in the final design. This lead to an all composite structural element, 1300x800x450mm, consisting of two main carrying beams, upper and lower sandwich skins, and two side closing ribs serving as access panels, as presented in Figure 1.

The main beam Graphite caps consist of thick lay-ups of tape prepreg, capable of sustaining the high bending loads acting in a typical RPV wing or fuselage section.
The caps were manufactured at 350°F and 7 ATM. One problem encountered for large stack-ups, such as $\{[(\pm 45^\circ),(0^\circ{}_3)]_{12}, (0^\circ{}_{60})\}_S$, was that cracking occurred through the thickness, parallel to the fibers direction. This is due to the fact that there is a significant difference in the coefficient of thermal expansion between the groups of 0° fibers and those of 45°. This problem was partly solved by minimizing the amount of layers having the same orientation in each group of layers, for example $[\pm 45^\circ, (0^\circ)_8]_{24}$, and will be eliminated with the reduction of the curing temperature.

The other beam has thick caps reinforced by Graphite roving and produced using a wet lay-up process.

The upper and lower panels of the box have thin Graphite/Epoxy fabric facings and non-metallic honeycomb sandwich cores. Riveted solid laminate stiffened panels serve as side access panels.

Assembly of the different structural elements was performed using special assembly methods, to ensure structural strength, while preventing fuel seepage through the sandwich panels.

CONSIDERATION OF FUEL INFLUENCE

The influence of the fuel on the mechanical properties of the composite materials was checked. For this purpose, coupons were manufactured, from solid laminate and sandwich panels. Three manufacturing processes were compared:

- Wet lay-up
- Prepreg at vacuum
- Prepreg at 3 ATM.

In each of the manufacturing processes, the influence of several parameters was checked (see Figure 2):

- Minimal thickness required for prevention of fuel leakage
- Addition of high fiber density fabric
- Contribution of adhesive layer between facing and core in a sandwich
- Application of nylon coating
- Introduction of plastic film in the fuel side

It was found that in a structure consisting of 2-3 layers, it is recommended to add one layer of high fiber density fabric, a plastic film, and an external nylon coating, in order to improve the capability of preventing fuel leakage or seepage.

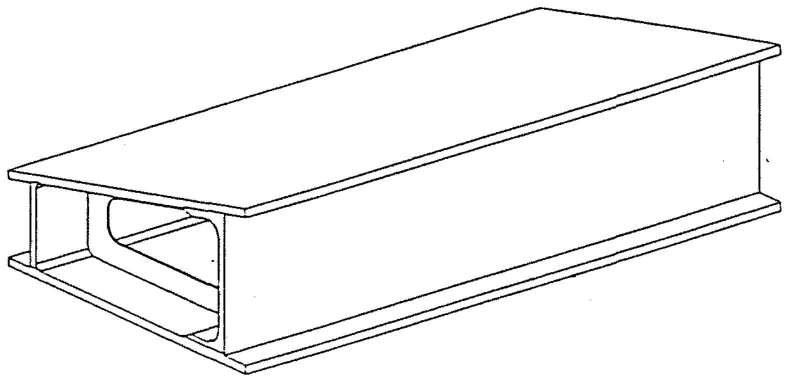
The coupon mechanical testing consisted of 4 point bending of beams, as well as in plane shear and interlaminar shear tests. Identical coupons were then soaked in fuel for six months, and tested as described above.

No changes in the mechanical properties were noticed.

ATTACHMENT DETAILS

The design of the integral pressurized fuel tank was accompanied by coupon testing of various types of attachments, to check their capability of sustaining the required opening bending moments.

Sandwich panels were manufactured of non-metallic honeycomb or foam core with Graphite/Epoxy or Kevlar/Epoxy facings, cocured at 250°F/vacuum.



Full scale test element

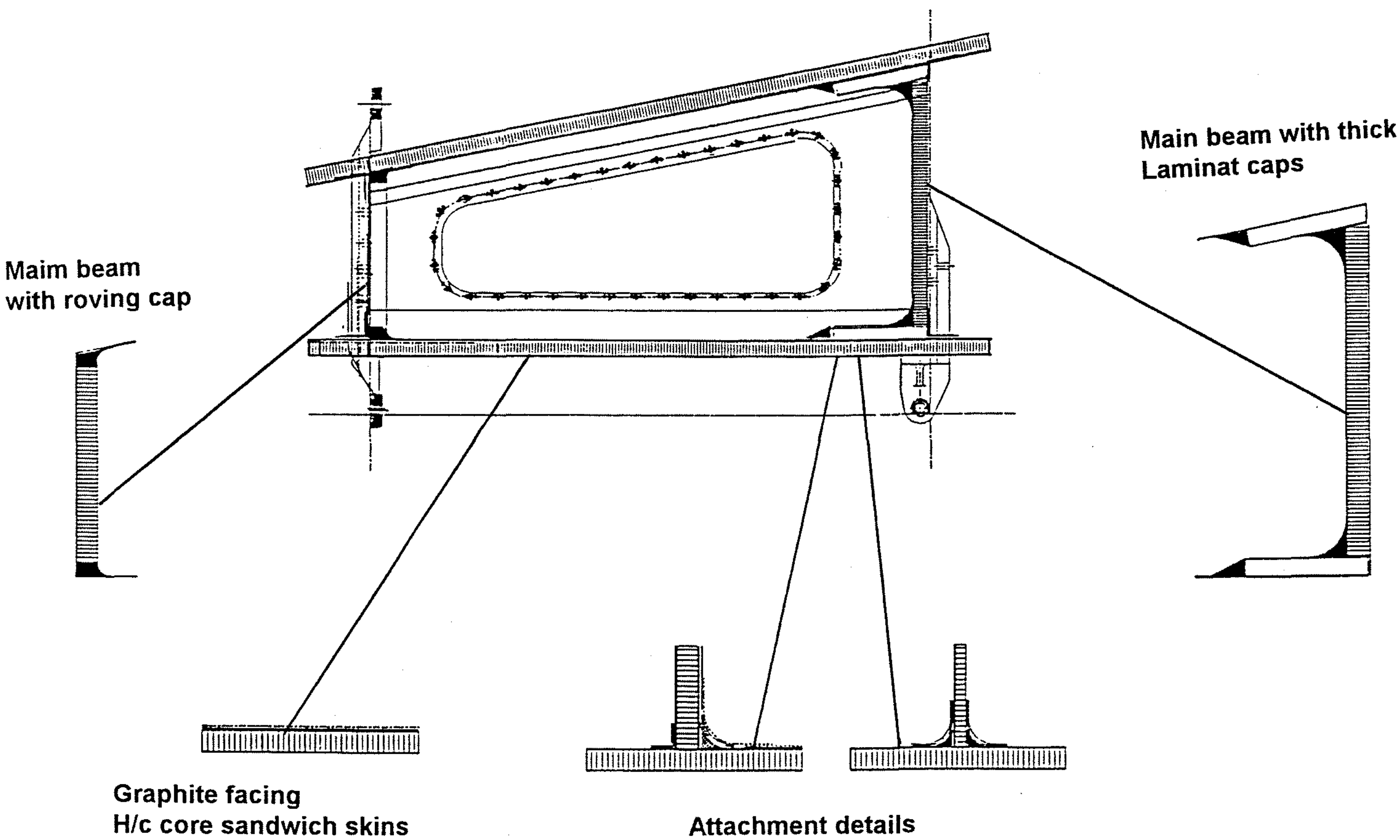
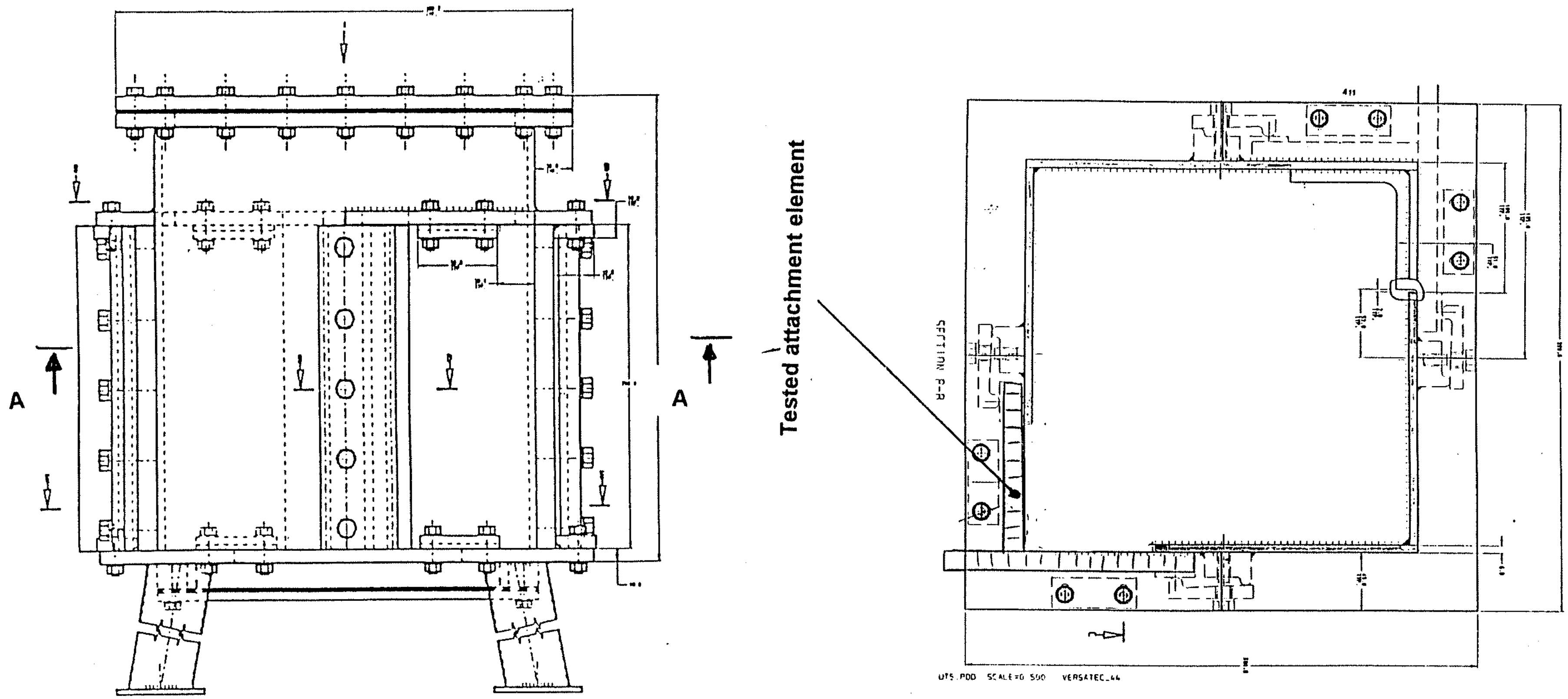


Figure 1. Representative wing box/fuselage section serving as an Integral fuel tank



Section A-A

Figure 2. Test rig for attachment details sealing

The attachments consisted of a wet lay-up of Gr/Epoxy plies with or without corner fillers. When corner fillers were used, they consisted of either epoxy mixed with microballoons or foam. Typical details are presented below, for attachments between:

- sandwich panels (Figures 3,4)
- sandwich panel to moderately thick solid laminate (Figure 4)
- sandwich panel to very thick solid laminate (Figure 5)

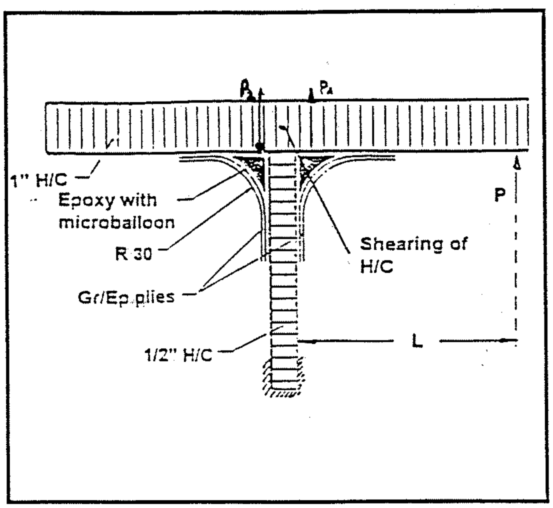


Figure 3
Sandwich/Sandwich Attachment

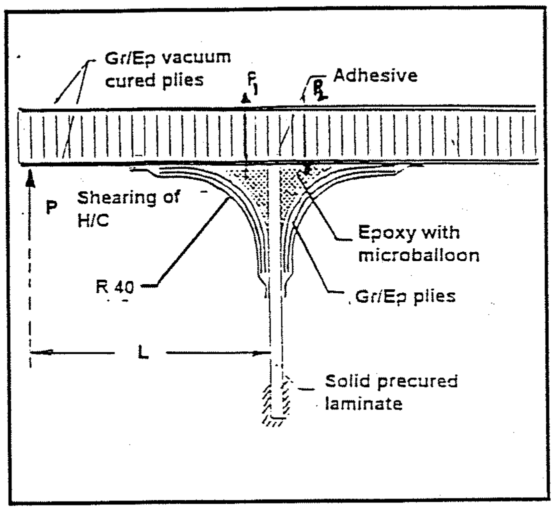


Figure 5
Sandwich/Solid Laminate Attachment

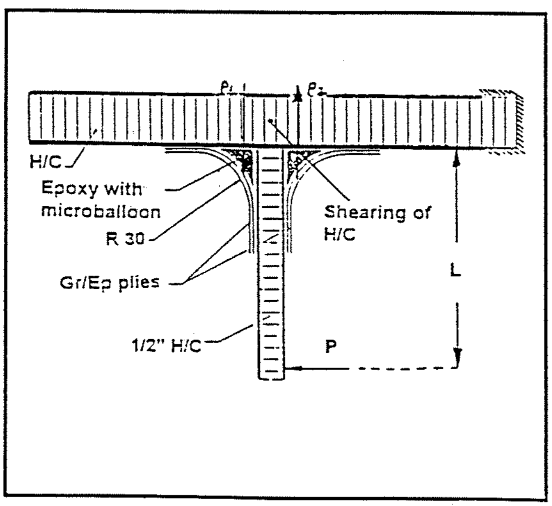


Figure 4
Sandwich/Sandwich Attachment

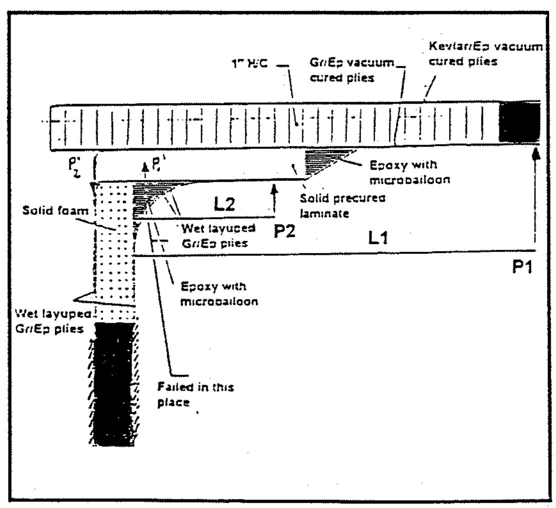


Figure 6
Sandwich/Solid Laminate Attachment

The configurations shown in figures 3,4 and 5 failed in shear of the H/C, while the one shown in figure 6 failed in wrinkling of the sandwich skin for the load denoted by P_1, and in shear of the filler for the load denoted by P_2 . The maximum bending moment was transferred by the configuration presented in figure 5. The coupon testing showed that a preferred detail of connection is one which has a bonded filler, with a radius equal the sandwich panel thickness. The corner filler should consist of a tough and strong material, in order to obtain an in-place, efficient, low-cost attachment.

FULL SCALE TESTING

A special test rig was designed for testing the representative integral fuel tank, under static and fatigue loading, as shown in Figure 7.

Testing consisted of the following main steps:

- Static loading by combination of bending and torsion of the box
- Same static loading, adding internal pressurization
- Fatigue testing under constant internal pressure and cyclic bending and torsion loading for two life times

NDT inspections were performed prior, during and after testing to ensure that no fuel leakage occurs.

The design of the fuel tank was accompanied by a structural finite element analysis. The finite element model was loaded by a constant distributed internal pressure of 5 psi and by a concentrated load of 6000 kg at one of the tank corners.

The results which have been obtained from the F.E. analysis are in good agreement with those obtained from the test. Strain levels of 4000$\mu\xi$ in tension and in compression were reached. Figure 8 gives the strain levels on the center of the upper panel obtained from the test, compared to those obtained from the F.E. analysis, at the same location. Figure 9 presents deflection contours for the case which combined the inside pressure with the concentrated load. The maximum deflection obtained during testing is 24 mm, while the calculated one is 21mm.

CONCLUSION

A composite structural element representing a RPV wing box or fuselage section, and serving as an integral fuel tank was developed. Innovative design concepts have been implemented in this structure, while using low cost manufacturing and assembly methods. Specifically, the following capabilities were developed:

- Structural attachments details capable of sustaining fuel loads as well as aerodynamic loads.
- Sealing technology and attachment details capable of preventing fuel seepage through sandwich panels having thin laminated facings.
- Innovative beams having thick caps, with a large fiber ratio in the load direction.

Full scale static and fatigue testing has proved the structural integrity and performance under loading for long time durations.

This technology was successfully implemented in the HERON, a medium altitude long endurance RPV recently developed at I.A.I.

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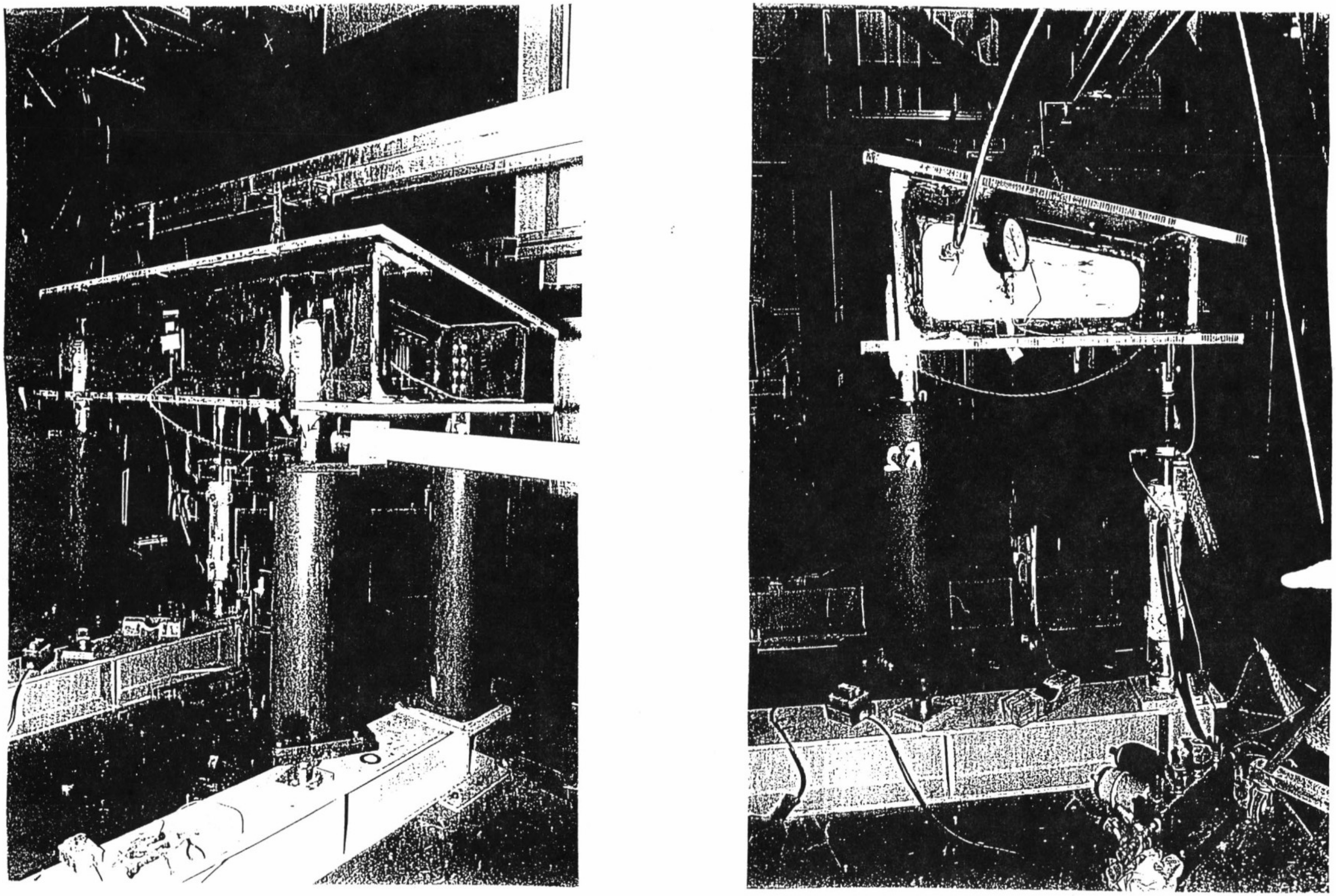

Figure 7. Full scale test rig

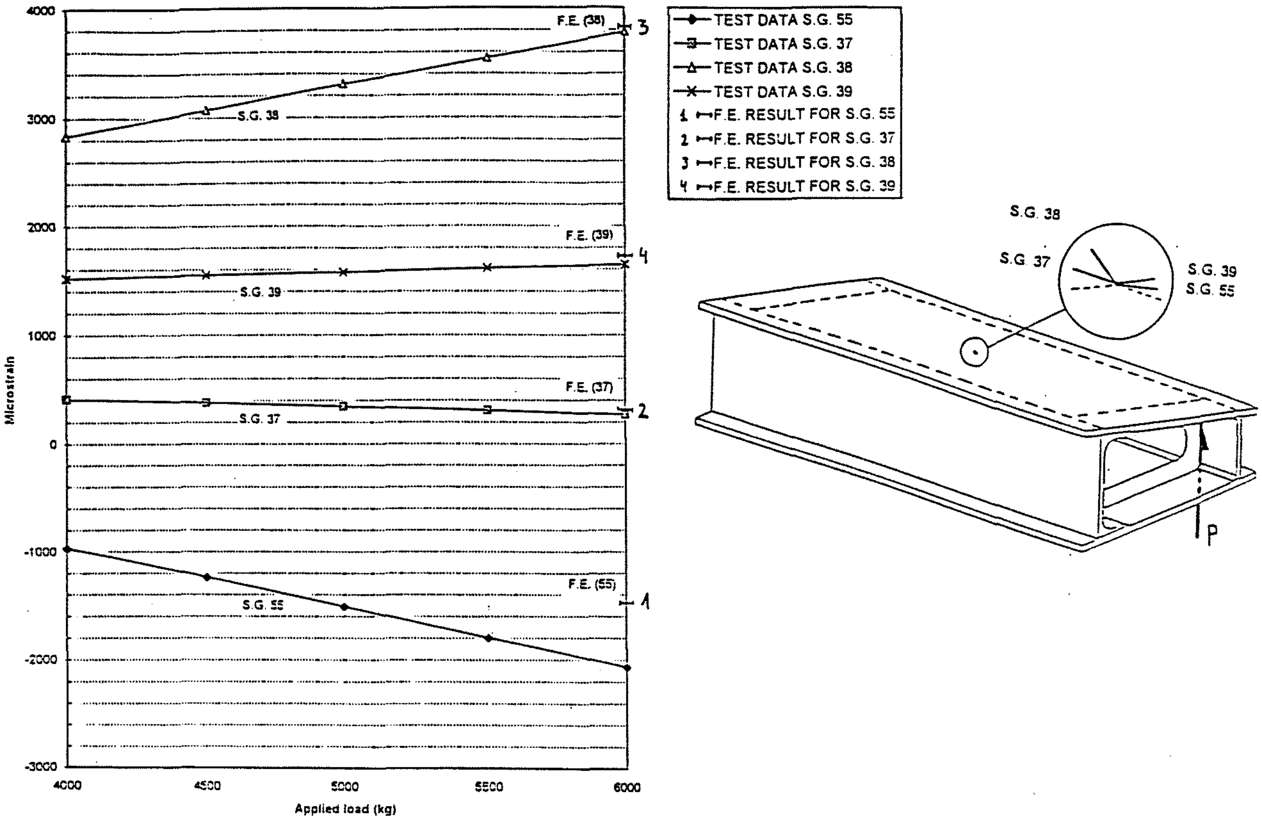

Figure 8 - Comparison of strains: Test versus Finite Element Analysis

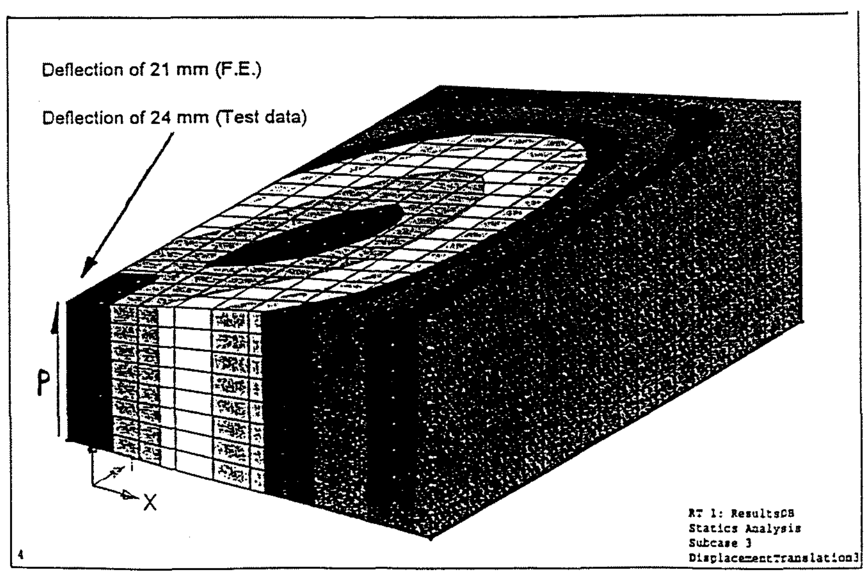

Figure 9 - Comparison of deflections: Test versus Finite Element Analysis