

FFI RAPPORT

**TEST RIG DESIGN AND MANUFACTURE -
RTP103.014/FFI/6.2/WP/1/01**

SAGSVEEN Bendik

FFI/RAPPORT-2006/02427

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THESAURUS REFERENCE: 8) ABSTRACT <p>In the WEAO project Europa 103.014 "Lightweight low cost carbon fibre composite materials and structures for Armour Fighting Vehicle Platforms – CAFV", each nation will build an Application Case. The Norwegian Application case (NOAC) will add a new hull of carbon fibre sandwich panels, onto an existing BV-206 chassis. The NOAC will be equipped with add-on ballistic protection.</p> <p>It is necessary to run a test program on the NOAC to ensure that the structure will withstand the loads applied to it during operation. It is desirable not to perform destructive tests on the NOAC itself. Therefore some of the tests will be performed on separate structure panels mounted to a test rig. The test program includes shock and vibration test, repair test and testing of glued joints.</p> <p>The test rig is based on an aluminium frame welded together from extruded aluminium profiles. It has the shape of a side panel, and is mounted on a massive aluminium base plate, that is the interface to the shaker table.</p> <p>The design is verified through Finite Element analyses.</p>				
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1 INTRODUCTION

In the WEAO project Europa 103.014 “Lightweight low cost carbon fibre composite materials and structures for Armour Fighting Vehicle Platforms – CAFV”, each nation will build an Application Case. The NOAC (Norwegian application case) is based on modifying the Hägglunds BV 206 DN6, consisting of a front and rear vehicle joined together by a hydraulic steering/damping system. The original BV 206 DN6 is based on glass fibre reinforced polyester GRP sandwich and single skin laminates, not incorporating any ballistic protection. The NOAC is to be based on carbon fibre sandwich panels, with add-on ballistic protection. A new hull will be built, mounted to the original bottom plate.

It is necessary to run a test program on the NOAC to ensure that the structure will withstand the loads applied to it during operation. It is desirable not to perform destructive tests on the NOAC itself. Therefore some of the tests will be performed on separate structure panels mounted to a test rig.

This report gives details on the test rig design and manufacture.

2 TEST PROGRAM

The testing of the NOAC within WP6 will be divided into laboratory testing and field testing. The complete test plans for the NOAC is given in the document “RTP103.014/FFI/1.2.2/TR/103 – Overview of the Norwegian testing” (1). The tests that will need a test rig are as follows:

- Shock and vibration test:

One panel will be used for a shock and vibration test. A side wall, will be mounted onto a vibration table and exposed to shock and vibration loads corresponding to the toughest requirements for the vehicle. Vibration test spectrum from road and terrain will be used. The goal is to verify that the real panel behaviour corresponds to the design calculations, to test the integrity of the armour mounting, and to detect possible effects of damage after ballistic loading. This test will also be performed with a steel dummy add-on armour, to represent the added mass from the add-on armour.

- Repair test:

A repair test will be performed on a panel that has been locally damaged to evaluate the strength after the repair. A strength critical area, e.g. a fixing for an armour panel will be

damaged and then repaired. The panel will be mounted to the shaker table and compared with the results from the undamaged panel, to assess the effect of the repair.

- Testing of joints for assembly:

The joining methods chosen for the NOAC must be tested on actual NOAC joints. This will ensure that the selected methods and parameters are applicable for the NOAC. The interface between the side panel and the test rig will represent the actual glued connections to the adjacent panels. In this way the side panel will be glued to the test rig, and hence the connections will be tested according to the full shock and vibration spectrum.

General information on the vibration table is given in Appendix A.

3 TEST RIG DESIGN

All modelling is done with the Solid Works CAD program. The test rig is based on an aluminium frame welded together from extruded aluminium profiles. It has the shape of a side panel, and is mounted on a massive aluminium base plate, that is the interface to the shaker table. The frame is tilted 5 degrees from the base plate vertical, to give the same mounting angle as on the NOAC. The centre of gravity will differ slightly whether the dummy add-on armour is mounted to the side panel or not. The base plate is mounted in such way that the Cg on the test rig always will be within 50 mm from the centre of the shaker table.

The frame should be as stiff as possible, transferring the input from the shaker directly to the side panel interface. Analyses of the test rig mechanical structure are given in chapter 4. The test rig frame – side panel interface is made from aluminium profiles that represents the first 100 mm section of all panels adjacent to the side panel. These profiles will have the same stiffness as the actual NOAC sandwich panels / single skins. Gluing these profiles to the side panel to be tested, as described in chapter 2, will give very correct boundary conditions for the side panel.

To make the test scenario as realistic as possible, the shocks and vibrations from road- and terrain driving are measured at the same 100 mm distance from the side panel.

The complete test rig is shown in Figure 3.1 and Figure 3.2. The test rig – side panel interface principle is described in Figure 3.3. An actual NOAC glued connection is shown in Figure 3.4.

Production drawings of the test rig are shown in Appendix C. Some key dimensions are listed in Table 3.1.

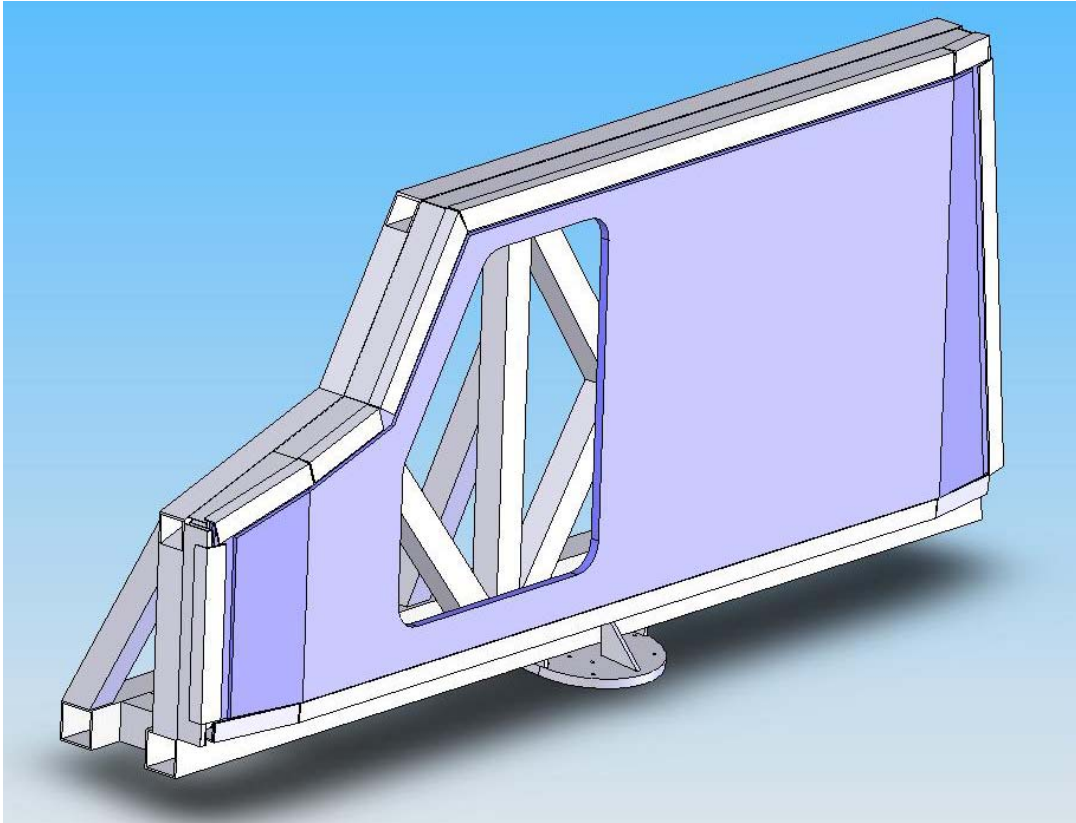


Figure 3.1. Test rig front side.

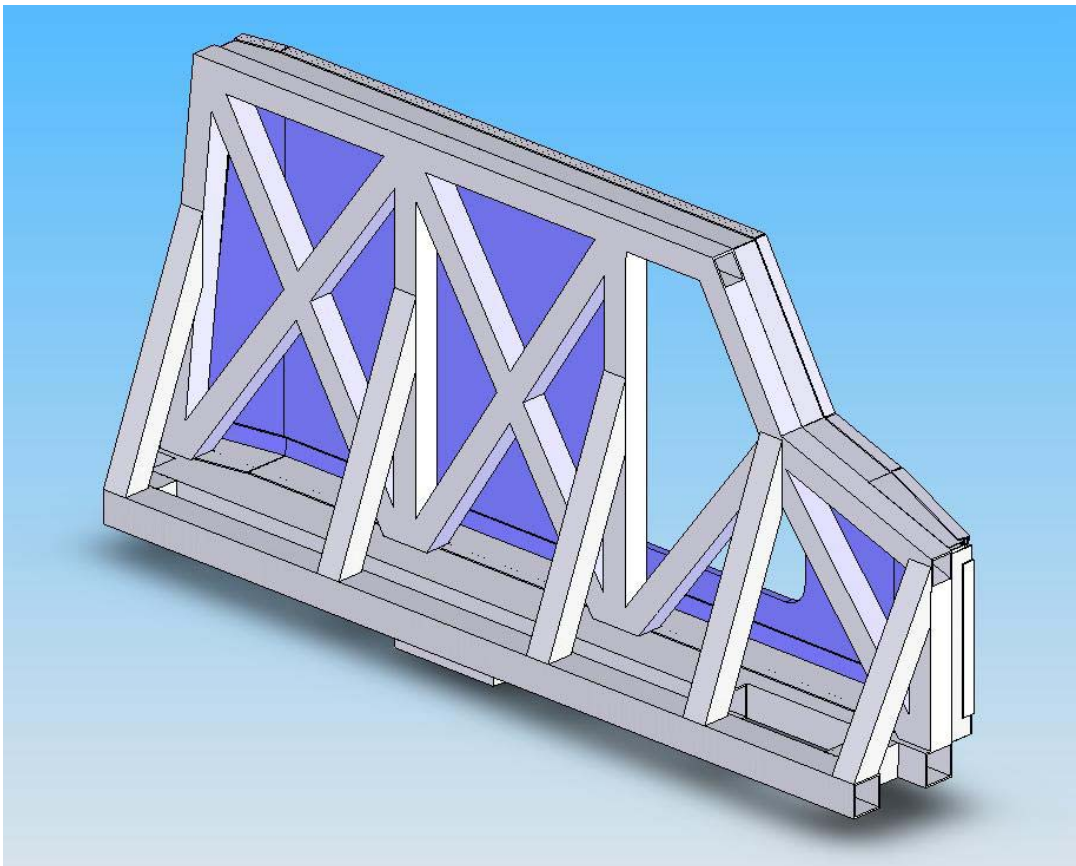


Figure 3.2. Test rig reverse side.

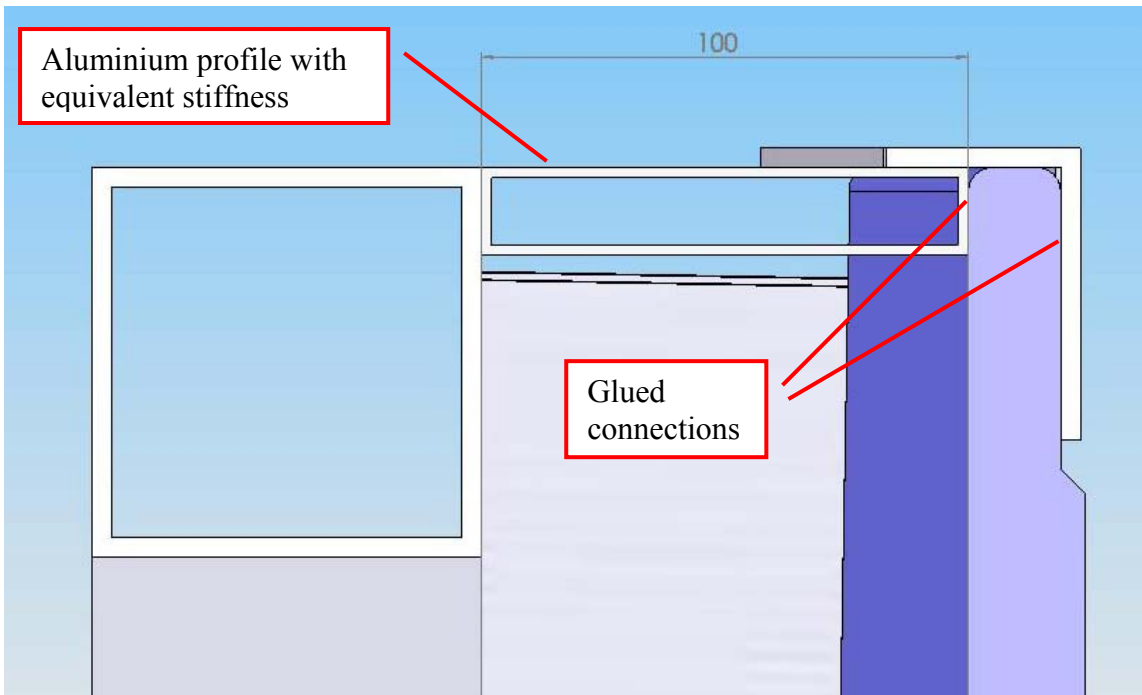


Figure 3.3. Upper test rig - side panel interface.

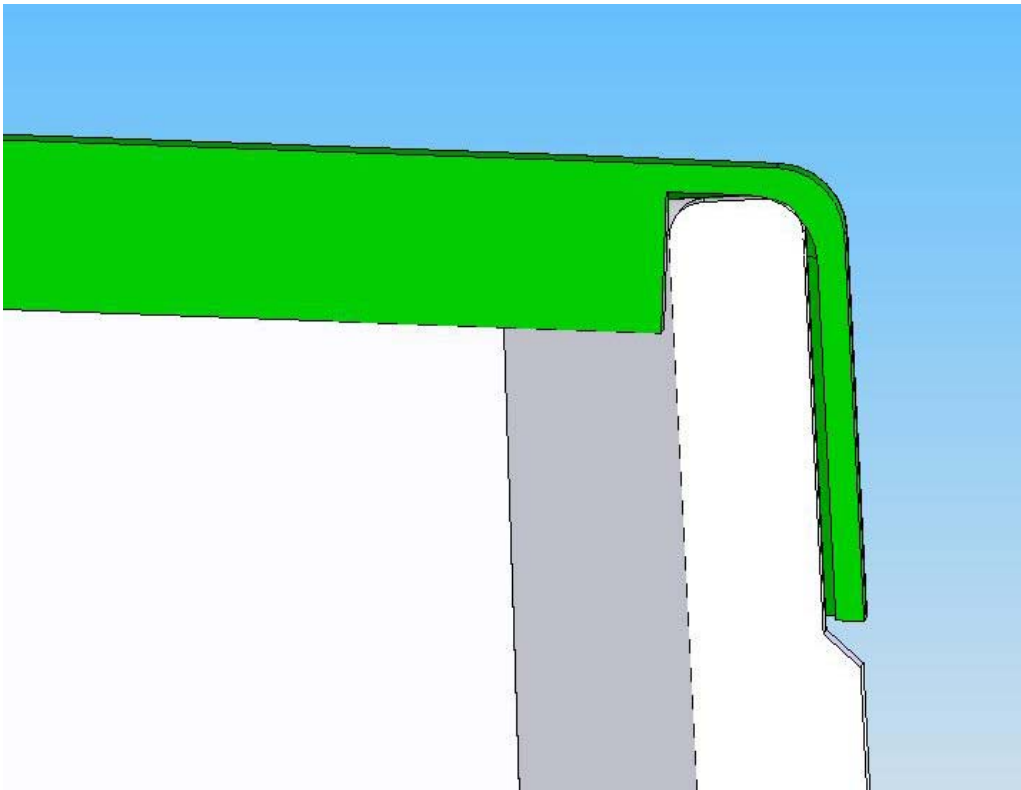


Figure 3.4. NOAC actual upper glued connection.

Table 3.1. Test rig key dimensions.

Total length	2819 mm
Total height	1344 mm
Total depth	527 mm
Weight with dummy add-on armour mounted	238 kg
Weight without dummy add-on armour mounted	147 kg

4 TEST RIG CALCULATIONS

The test rig frame itself has to be as rigid as possible within certain weight and cost limitations. It is designed with use of the Finite Element Method (FEM). The analyses are performed in COSMOS Works, an integrated FEM module in Solid Works, and in MSC.Nastran.

The frame-part of the rig must transfer the shaker loads as directly as possible to the section to be tested. This frame has a first modal frequency of about 38 Hz. The mode is shown in Figure 4.1. The frame is considered to be rigid enough to sufficiently transfer the loads.

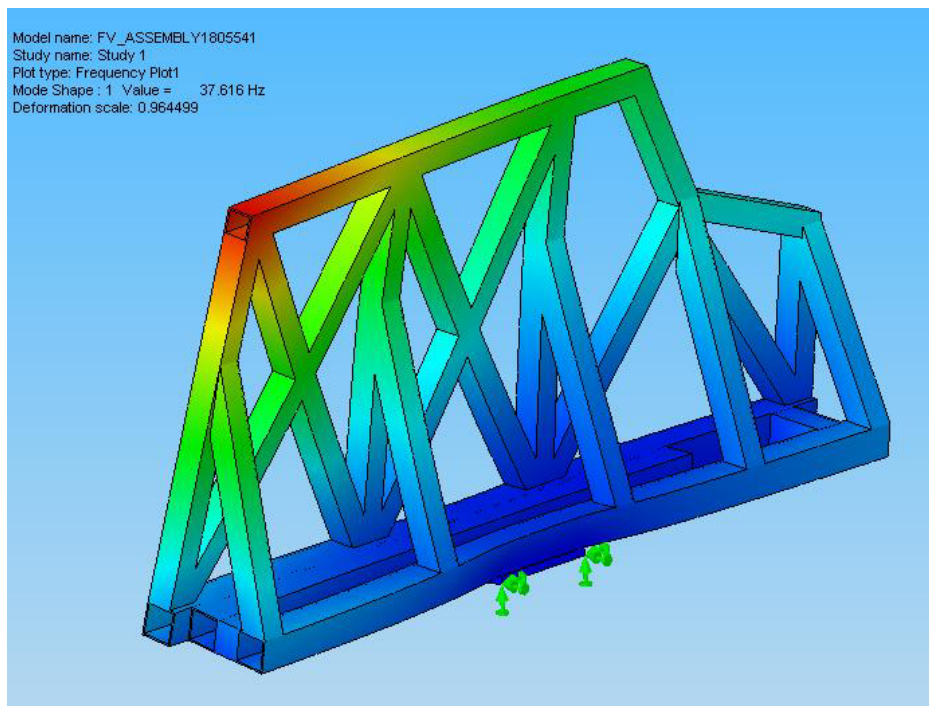


Figure 4.1. Test rig frame first mode, 38 Hz.

A modal analysis of the sandwich side panel is performed in the FE program MSC.Nastran. In this case the side panel is modelled, using a detailed laminate material. The perimeter of the panel is fixed. The results are given in Table 4.1. With the added mass from the dummy add-on armour, the result indicates a first modal frequency of about 50 Hz. The side panel without

the added mass is estimated to have its first normal mode at about 118 Hz. These frequencies are clearly above the first modal frequency of the test rig frame. As the sandwich is very light and stiff, it will be difficult to design a test rig where the first modal frequency is above the frequencies of interest in the side panel. The test rig frame will therefore be equipped with accelerometers to verify and isolate its own modal frequencies.

Table 4.1. Normal mode frequencies – side panel (MSC.Nastran).

Normal mode appearance	Frequency
Side panel (1 st mode)	118
Side panel (2 nd mode)	152
Side panel with added mass from armour (1 st mode)	50
Side panel with added mass from armour (2 nd mode)	64

An analysis of the complete test rig with the side panel installed, including the added mass from the add-on armour, shows that there are three normal modes in the test rig itself before the first panel modes. Then two panel modes follows. The frequencies are listed in Table 4.2.

The first two side panel modes are shown in Figure 4.2 and Figure 4.3. As we can see from the table, it should not be a problem to isolate these frequencies from the frequencies of the complete test rig assembly. The modes found in the Cosmos Works analyses for the complete assembly show higher frequencies for the pure panel modes, than what we find in MSC.Nastran (Table 4.1). This is probably due to the simpler material model in the Cosmos Works analyses, only using equivalent material parameters for the sandwich panel. Most likely the shear stiffness of this equivalent material is too high. Also, for simplicity, it is used a rather coarse solid mesh in the Cosmos Works FE model. It can be argued that a more refined shell mesh would give more accurate results, and that the coarse solid elements are too stiff. However the results clearly give us an indication of what to expect during testing, and if we substitute the panel modes from Table 4.1 into Table 4.2, the total overview will be quite good.

Table 4.2. Normal mode frequencies in test rig - side panel assembly (Cosmos Works).

Normal mode appearance	Frequency
Complete test rig - side panel assembly	22
Complete test rig - side panel assembly	32
Complete test rig - side panel assembly	40
Side panel (1 st mode)	55
Side panel (2 nd mode)	75
Combined mode, test rig – side panel	83

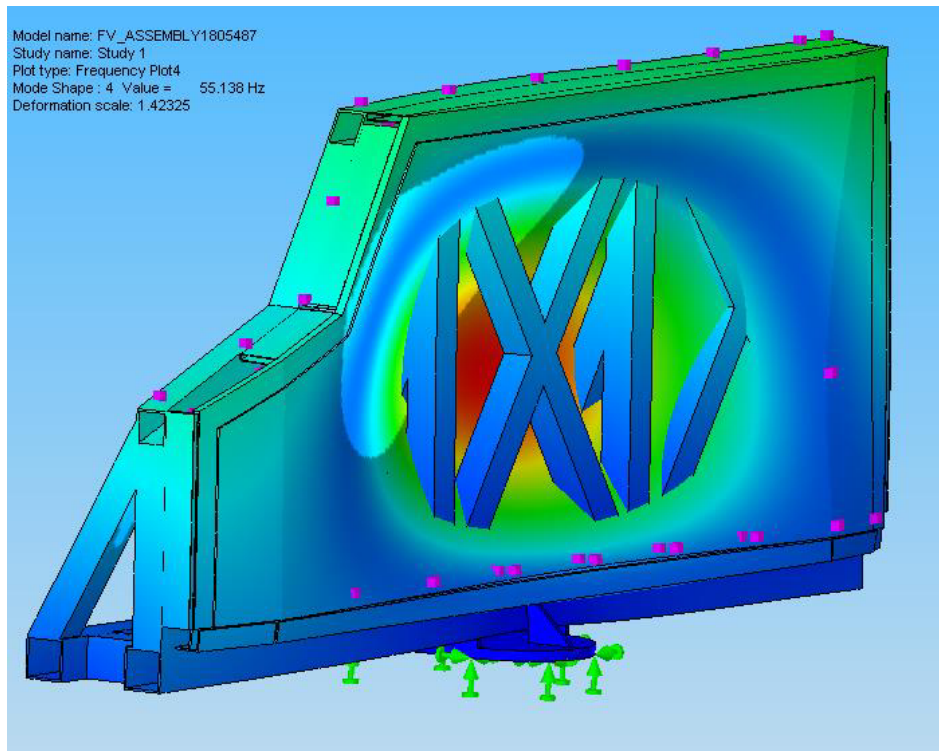


Figure 4.2. Side panel first mode.

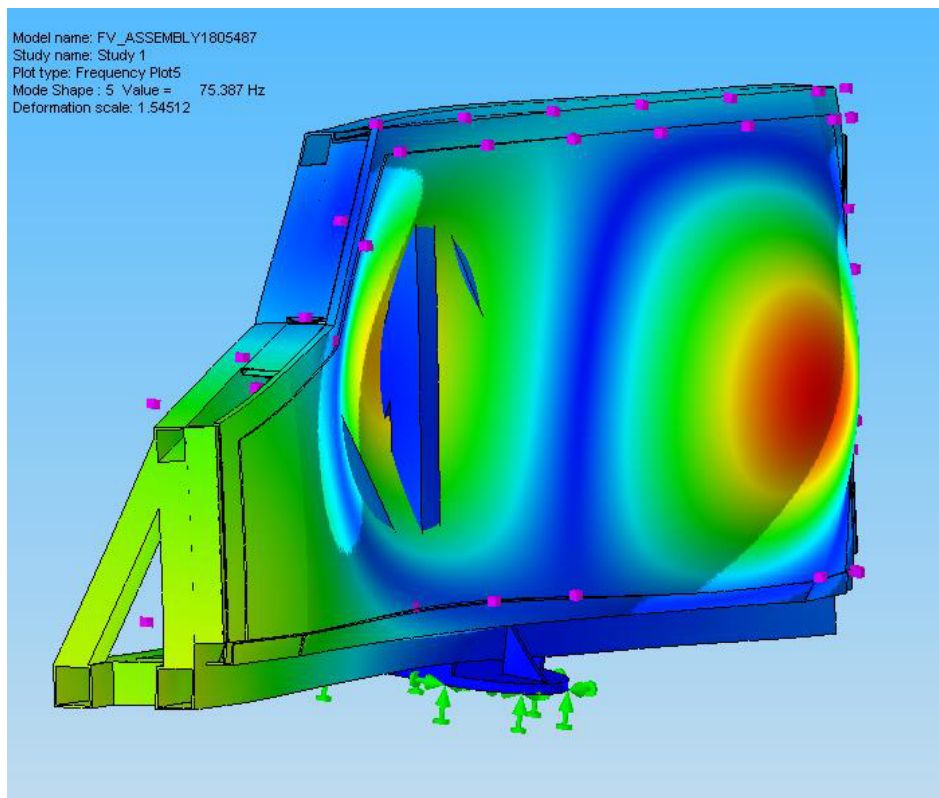


Figure 4.3. Side panel second mode.

5 CONCLUSION

The test rig design provides a realistic interface for the sandwich side panel to be tested. It is a rigid design, that will transfer the shaker loads directly to the test section. The frequencies of the first three normal modes of the test rig itself (with the test panel mounted), are lower than the first normal mode frequency of the side panel to be tested (with the added weight from the armour). This is not easy to avoid in this case. However the modes are clearly separated in the frequency domain, and it should not be a problem to isolate the modes of interest. In addition the use of accelerometers will help us separate the test rig modes from the panel modes.

APPENDIX

A SHAKER INFORMATION

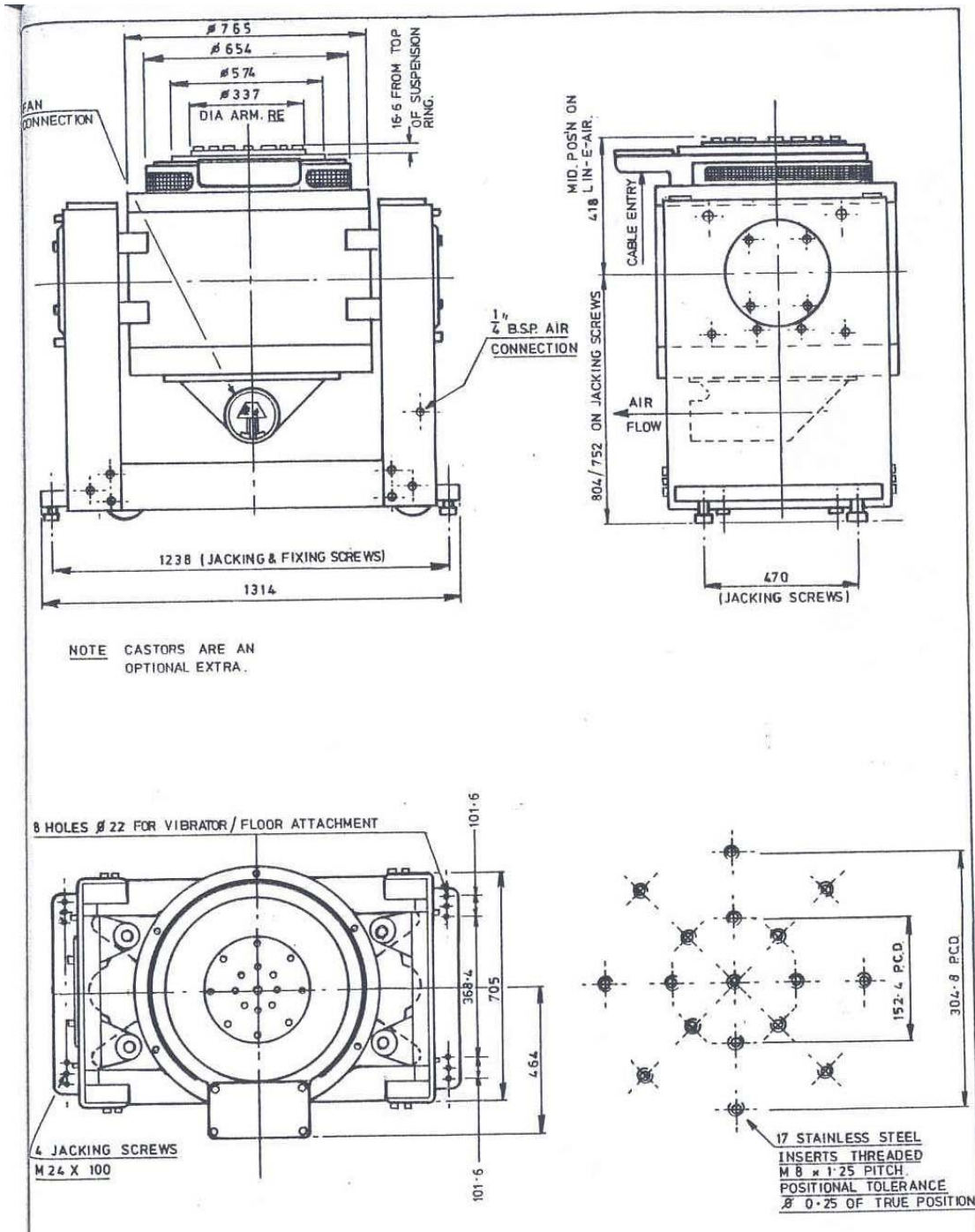


Figure A.1. Shaker table dimensions.

SHAKER: LDS – 824.

Max. displacement : 1" (2,54cm)

Max. velocity: 1,78 m/s

Max. acceleration: 100 G.

Useful frequency range: 5 –3000 Hz.

Max. weight on armature: 45 kg. (At maximum acceleration)

B MATERIAL PROPERTIES**Aluminium:**

- $E = 69 \text{ GPa}$
- $\nu = 0.3$
- $\rho = 2700 \text{ kg/m}^3$

Sandwich:

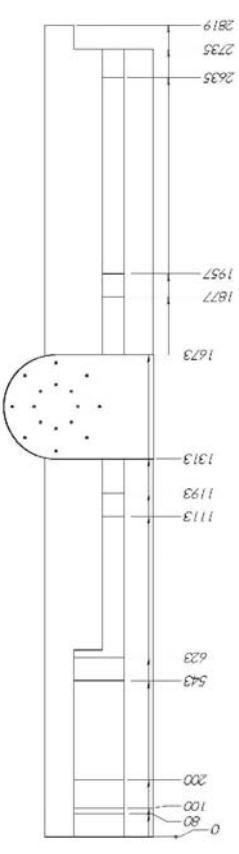
- $E = 20 \text{ GPa}^*$
- $\nu = 0.3$
- $\rho = 1730 \text{ kg/m}^3$ (included 34 kg/m^3 added mass from add-on armour)

* Equivalent stiffness for a sandwich with 1.8 mm carbon skins and 20 mm H80 PVC core.

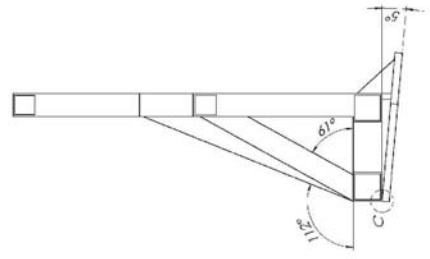
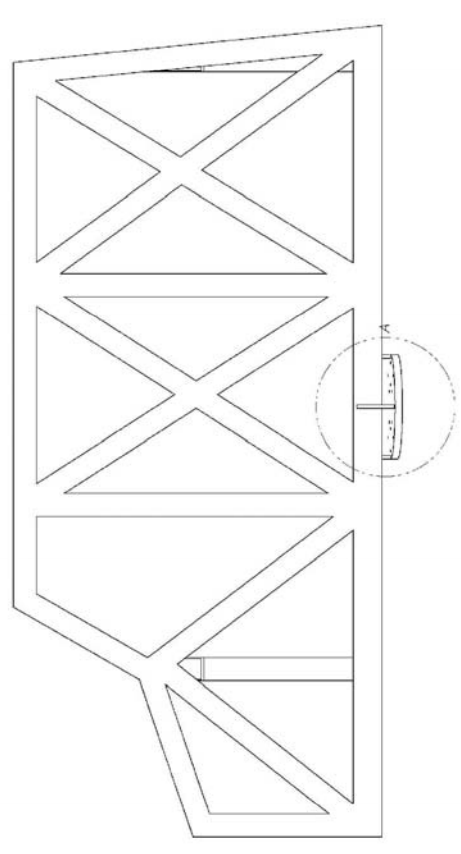
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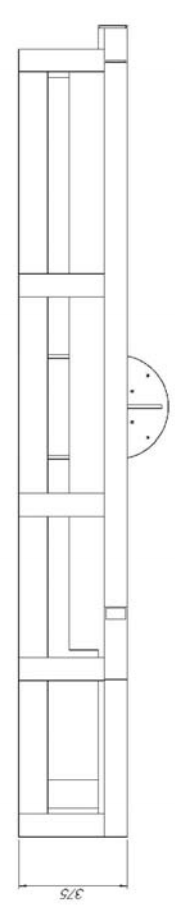
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All parts are to be welded together.
See sheet 2 for bill of materials.



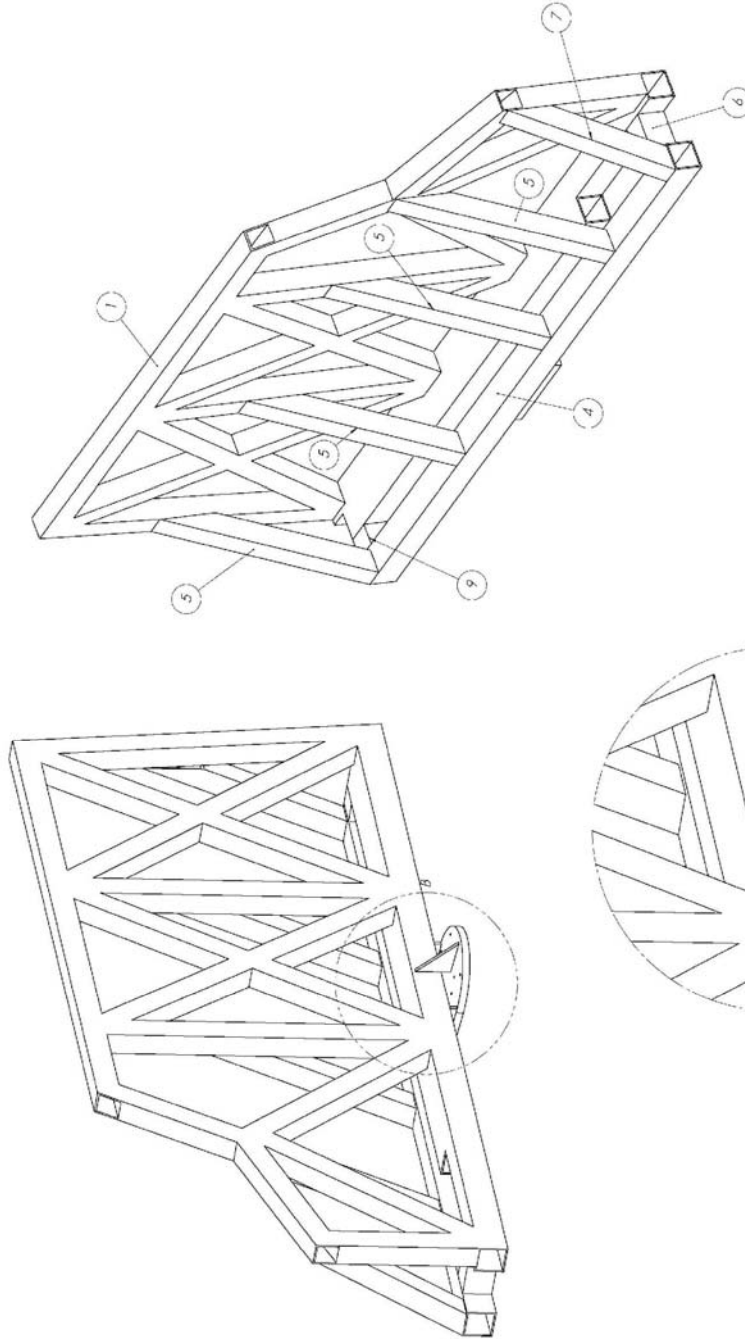
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101:201-NOAC			Rev. nr.		
2-1805541			Rev. nr.		

FFI
FELLESVERKSTEDET
Målestok 1:10
2-1805541

ITEM NO.	PART NUMBER	DESCRIPTION	QUANTITY
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2	FV_PART1805536	Base plate, test rig	1
3	FV_PART1805540	stabilizing rib, test rig	1
4	FV_PART1805537	100x100x5 stabilizing bar, test rig	1
5	FV_PART1805538	upper stabilizer bar, test rig	4
6	FV_PART1805546	80x80x4 short stabilizing bar, test rig	1
7	FV_PART1805542	Front stabilizer bar, test rig	1
8	FV_PART1805550	5-deg rib, test rig	2
9	FV_PART1805558	80x80x4 spacer, test rig	1



Rev: 02-2006	Rev: 02-2006	Rev: 02-2006	Rev: 02-2006
Date: 24.10.2006	Date: 24.10.2006	Date: 24.10.2006	Date: 24.10.2006
Author: M. M. M.	Author: M. M. M.	Author: M. M. M.	Author: M. M. M.
Checker: M. M. M.	Checker: M. M. M.	Checker: M. M. M.	Checker: M. M. M.
Designer: M. M. M.	Designer: M. M. M.	Designer: M. M. M.	Designer: M. M. M.
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Checker: M. M. M.	Checker: M. M. M.	Checker: M. M. M.	Checker: M. M. M.
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References

- (1) ELVEBAKKEN Dag, ANTONSEN Gard, LILLEBORGE Jørn, DULLUM Ove, FJELDLY Tor Alexander, SAGSVEEN Bendik (2006): RTP103.014/FFI/1.2.2/TR/103/ - Overview of the Norwegian testing, 00980