public project summary

Proposal full title:

Advanced composite sandwich steel structures

Acronym:

SANDWICH

Date of preparation:

22-02-2000

Specific programme:

Promoting Competitive and Sustainable Growth

Title of Key Action:

Land Transport and Marine Technologies

Type of project:

RTD

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Abstract

Development & improvement of lightweight structures is a continuous challenge in particular for land & marine vehicles production. SANDWICH will enhance the features & capabilities of steel sandwiches by filling them with different low density cores. The aim is to develop panels for specific requirements defined by auto-, rail-, marine-industry. SANDWICH improvements compared to conventional structures: up to 50% lighter, 50% space saving, 20% noise reduction. Enhanced vibration properties, fire safety, crash worthiness & corrosion resistance. Erection time reduced by 30 %. 12 partners from 8 European countries, joined forces each of them an expert for one particular aspect & task. After a requirements analysis, design & production of the specimens & prototypes follows. A test phase delivers material behavioural data collected in a design tool which supports designers to develop tailor made SANDWICH products . A design guideline assures secure type approval and thus marketing success.

1 Summary

Aim of the Project: SANDWICH aims to develop novel steel-composite lightweight sandwich panels for primary load-carrying structures in ships and land transport by combining a laser welded steel structure with low-density foam cores. The excellent properties those modular sandwich panels will feature compared to conventional stiffened plates are as follows:

- *weight reduction up to 50%*
- *improved noise and vibration damping*
- *significantly improved crash resistance*
- *easy and fast assembly*
- *50% less space consumption*
- *enhanced fire safety and heat insulation*
- *reduction of manufacturing cost by accurate pre-manufacturing*
- *flexible use through modular solutions for panels and joints*

Technical and scientific objectives: A successful application of the new product, the advanced steel composite sandwich, requires however the solution of a variety of problems. Those are the definition of product properties, the development of design and application guidelines and tools, efficient and reliable production processes as well as the creation of proper structural joints and attachments. The integration of additional functions, like air conditioning, electrical power distribution, fire extinguishing systems and heat insulation into the load-carrying sandwich panels will make them more attractive for a wide range of industrial applications. The SANDWICH project is determined to solve these problems and make the advanced steel-sandwich panels available for industrial use.

Innovative Aspects: of the SANDWICH project are e.g.:

- *combining* low density materials with steel sandwiches *for both design and production*
- *development of design data and solutions for* all-steel laser welded sandwich panels with enhanced product properties *for a wide range of applications in the transport industry,*
- *development of* joints and attachments *to integrate the sandwich panels into land and marine vehicles,*
- *design of integrated* multi-functional units *based on the sandwich panels,* e.g. integrating cabling and ducting into the sandwich-panels
- *development of* production and assembly techniques *for sandwich panels,*
- *the creation of* design tools and guidelines *with pre-approved solutions accessible via the Internet, which can be used by industrial users to find the optimum sandwich solution for a specific application.*

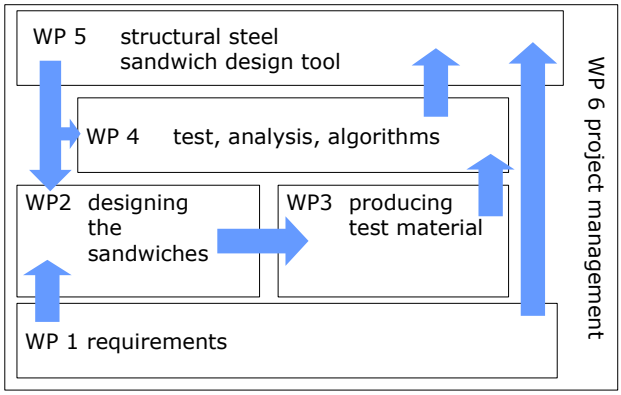
Scientific and technical work-plan

Requirements Definition: *Users from shipbuilding, ship equipment, railway and automotive describe their requirements towards the sandwich panels. A risk analysis will ensure, that no major aspects will be missing and that the view of approving bodies has been considered.*

Design: *Sandwich panels, structural connections, attachments, integrated functional units and prototype solutions will be designed and optimised after the first production, test and calculation feedback is obtained. Multidisciplinary optimisation criteria as well as initial design and acceptance criteria will be defined.*

Production: *Test specimen and prototypes will be manufactured. Rules for Design for efficient production and assembly will be specified.*

Determination of Product Properties: S*pecimen will be tested to define the failure mechanisms and the product properties. Tests will be accompanied by parametric studies (calculations). First prototypes will be used to measure operational conditions in transport vehicles and ships. Design*



algorithms will be derived for the different properties of the advanced sandwich panels. Optimised prototypes will be tested under operational conditions.

Design Tools: *A design tool will be developed using the data, algorithms and experiences from the previous work-packages. The tool will be available via Internet to make it easily accessible for a wide range of users / customers.*

Figure 1-1 work-package interaction

Partnership: The entire SANDWICH team consists of 8 partners and 3 associated partners from eight European countries: Finland, Germany, Italy, the Netherlands, Norway, Poland and Sweden United Kingdom.

Main SANDWICH Output:	**Milestones**		
A new generation of lightweight products for both land and marine vehicles based on cored sandwich panels	M1	(pm 6)	requirements delivered,
	M2	(pm 9)	first design in place,
Design Tool to assist optimum design of sandwich panels, joints and functional units, utilising	M3	(pm 12)	first panels produced,
	M4	(pm 15)	first version of design tool available,
A sound material behaviour and operational properties database filled through intensive small and large scale testing of advanced sandwich panels	M5	(pm 21)	qualitative testing finished,
	M6	(pm 24)	design updated,
Design Catalogue including design guidelines for type approval of products after the project end	M7	(pm 27)	design tool updated
	M8	(pm 33)	quantitative testing finished,
Specimens and Prototypes.	M9	(pm 36)	design guidelines available, project finished.

2 Scientific / Technical objectives and Innovation

International state of the art

During the last years, European shipbuilders have developed a novel steel structural component for load carrying applications, the laser welded sandwich panel, which exhibits a number of very advantageous properties and which is so far unique in the world. While the panels have been developed and used in prototype applications for a specific product, a strong interest became obvious for a much wider range of applications throughout the transport industry. This requires the adoption of the sandwich design to the specific needs of new applications.

Composite and honeycomb sandwich panels have been widely used for less critical load cases, like in the outfitting sector, for smaller ships, aeroplanes and road vehicles. As the manufacturing and assembly requires specific know-how, the application of composites is often linked to high cost, which are justified in high-value products like naval ships and aeroplanes. Long term experience under operational conditions is often lacking.

Metallic foams are a new development, which show excellent energy consumption properties in crash situations and high residual strength in case of fire combined with low weight.

The combination of laser welded steel sandwich panels with a low-density core can significantly enhance product properties at reasonable cost. Choosing proper core material could increase local

impact strength of thin-core steel sandwich panels, make them more crash resistant and improve fire safety, heat insulation and corrosion resistance of the steel structure. The steel sandwich panel on the other hand shows excellent buckling and bending strength, high stiffness and high accuracy. Using laser welding technology it can be efficiently pre-manufactured in a modular way and at reasonable cost.

The demand for faster and lighter marine and land transports has increased the need for more efficient structures. Sandwich panels form one type of efficient structure enabling the application of steel, aluminium or composites in the construction. The present interest in steel sandwich structures has been awakened by the developments in laser welding technology enabling efficient production of these panels. The US Navy has studied the applications of laser welded corrugated core steel sandwich panels (LASCOR) since 1987. So far they have built five applications on Navy ships using stainless steel as material with plate thickness varying from 0.6 to 1.6 mm. These applications include bulkheads and decks in accommodation areas, deckhouses, deck edge elevator doors, and hangar bay division doors on conventional navy ships. In Japan panels for fast ship bottom

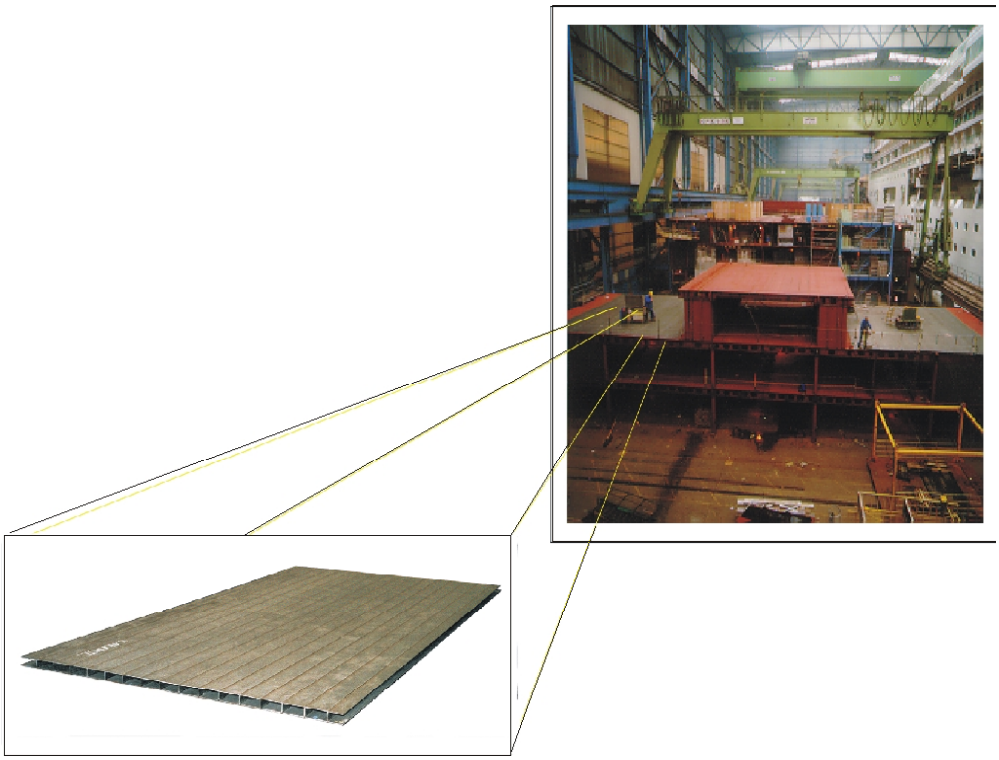


Figure 2-1 Example of installation of all steel sandwich on a cruising ship deck structure.

structures have been developed using stainless steel as a material. US shipyards as well as shipyards in Asia are showing growing interest on the steel sandwich panel solutions.

MEYER WERFT has studied since 1993 applications of laser welded steel sandwich panels onboard cruising ships and also installed a number of test panels as bulkheads and staircase landings for passenger ships . MEYER WERFT has also conducted a number of tests to get approval for these panels as strength carrying elements on a cruising ship . In total about 12 000 m^2 of sandwich structures have been so far installed on cruising ships, an example of these installations is shown in Fig. 2-1.

The studies related to the all steel sandwich panels at Helsinki Technical University / Ship Laboratory were initiated in 1987. The studies have included development of design methods, weight optimisation, ultimate strength testing under hydrostatic loading, fatigue testing, fire and noise testing of the panels. In addition local strength of sandwich panels was analysed. In 1997, the first all steel sandwich test panels used as longitudinal and transverse bulkheads were installed on a cruising ship in Finland .

Technological approach

An all-steel sandwich panel welded by laser is a new solution to obtain light and efficient ship structures. It has high potential for weight savings as shown in Fig 4-3, but also require new approaches e.g. for detail design of the joints for attachment of these panels to each other and to surrounding structures Fig.2-2. No recognised acceptance criteria or design methods are at present available for these type of structures, which complicates the practical applications foreseen.

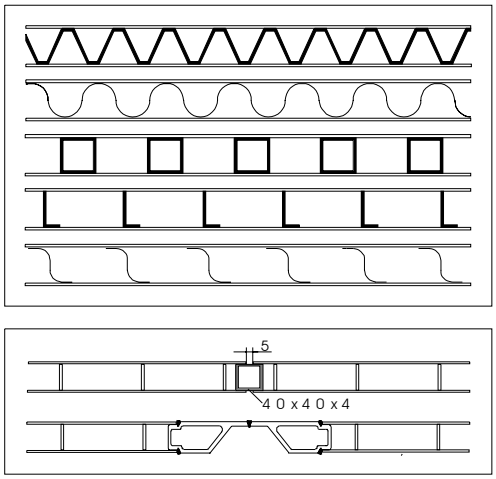


Figure 2-2 Examples of possible core and joint solutions for steel sandwich panels

Innovations

The innovative idea of the project is to develop laser welded sandwich panels further and fill them with core material according to the particular requirements. By filling of these newly developed steel sandwich with a low density core, several possible advantages can be gained. These fillings require, however, also a new approach to design methods, production and joint developments, which has to be carefully studied before used in practical applications. Also novel optimisation algorithms are needed to integrate the steel sheets with other type of core material. The great variety of possible core profiles as illustrated in Fig. 3 complicates the further the design procedures needed together with the number of studied materials such as normal strength steel, high strength steel and stainless steel. The studied low density core materials include e.g. polymeric foams, metallic foams, light concrete and balsa wood.

One of the main innovation in this project is the integration of functions. The functions to be integrated are e.g. insulation, piping (air-conditioning, ventilation) and the finishing off the walls. This increase the efficiency of building ships, trains and trucks significantly.
An innovative spin off from this project is the design tool for sandwich structures. The required structural design for sandwich structures with integrated functionality can be obtained easily.

Scientific and technological goals

The scientific and technical goals of the project are: reduce weight by 30% -50% and enhance at the same time fire and insulation properties, noise and vibration properties and crash behaviour, while keeping the strength equal to conventional structures. The side effect anticipated from this innovative development work are: fuel consumption decrease, payload increase, increase of production efficiency (load carrying structure integrated systems), no need for surfacing the panels through increase of accuracy, high potential for modular pre-fabrication, less spacious and therefore increase of pay volume. Achieving these goals enable European shipbuilding and land transport together with railway industry to keep the technological advantages against US and Asia achieved by earlier innovative applications of steel sandwich panels.

The application of sandwiches is advantageous, because it replaces conventional structures. The material steel is known the sectors involved in this project. It is weldable and very well suited to have other function integrated, like ventilation, air-conditioning, electricity lines, etc.

The approach in this project is chosen, so strong interaction is achieved between the design, production and testing. This interaction provides the solutions for a practical and optimal design. Finally a design tool is developed, so for future application, the most adequate sandwich can be designed in short time. Three transport branches are involved (automotive, railway and sea), ensuring a wide applicability of sandwich structures.

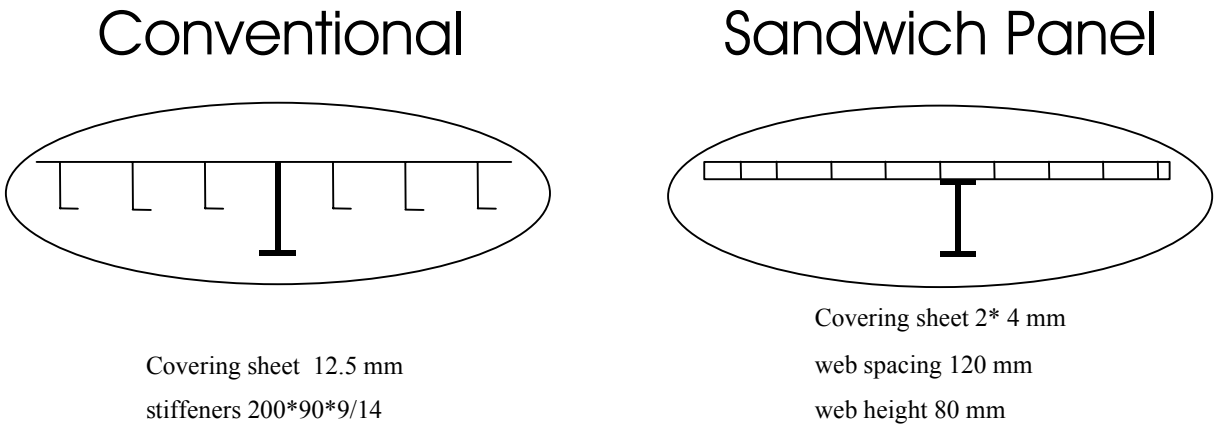


Figure 2-3 Example of a RO-RO deck design using conventional panels and sandwich achieving 34 % weight saving and 50 % cost savings. Also remarkable space saving of 120 mm for outfitting has been achieved.

Research objectives

The research goals for the project include development of reliable design formulations and verification of the developed design approaches by laboratory testing including strength, fatigue, noise, fire, corrosion and crash testing. Also the development work to build the optimisation procedures for steel sandwich panels filled with low density composite or metal foam solutions is a demanding research task requiring contribution of highly qualified research personnel. The main technical achievements anticipated are related to the gathering of experience how to produce these type of panels and to the developing of design guidelines and software tools for practical design of these panels.

3 Project workplan

The participation of industries with exceptional requirements profile, matching both potential future markets and most extreme usage scenarios allow to define complete requirement set. This defines a solid basis for the all-round capabilities of the sandwich panels.

Transportation industry certainly provides such extreme operational conditions acting at the same time as a potential market for the future product.

The requirements definition will be performed from the perspective of:

- MEYER WERFT *a shipyard specialised on Passenger ships,*
- MACOR *an equipment manufacturer specialised on structural ship equipment like hatch covers, hoistable decks moveable bulkheads doors etc.,*
- CETEC *a design office with special expertise in fast ships and lightweight structures,*
- TRANSTECH *a railway wagon design and manufacturing company and*
- JÜNGER *an automotive supplier company with focus an heavy duty trailer production.*

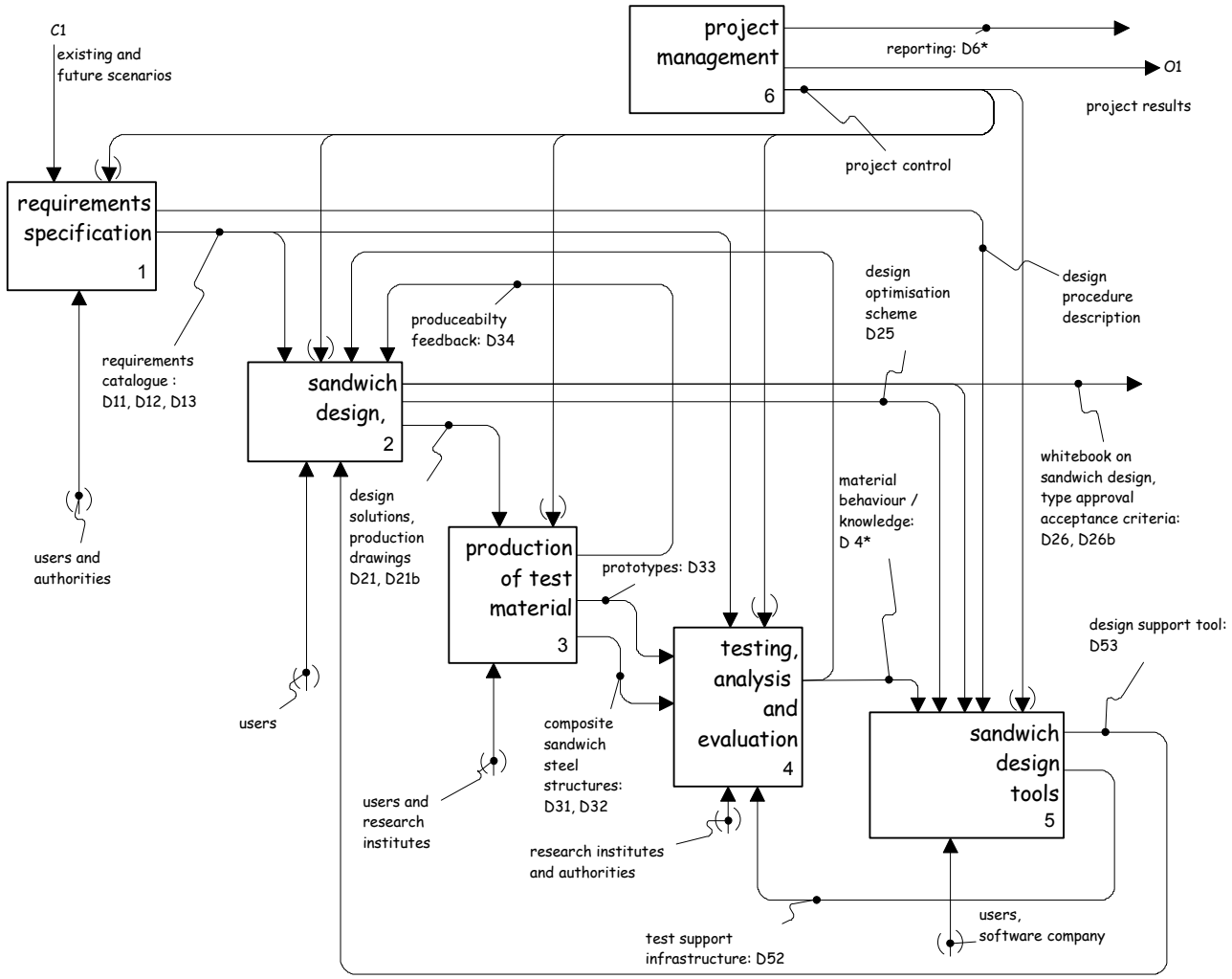
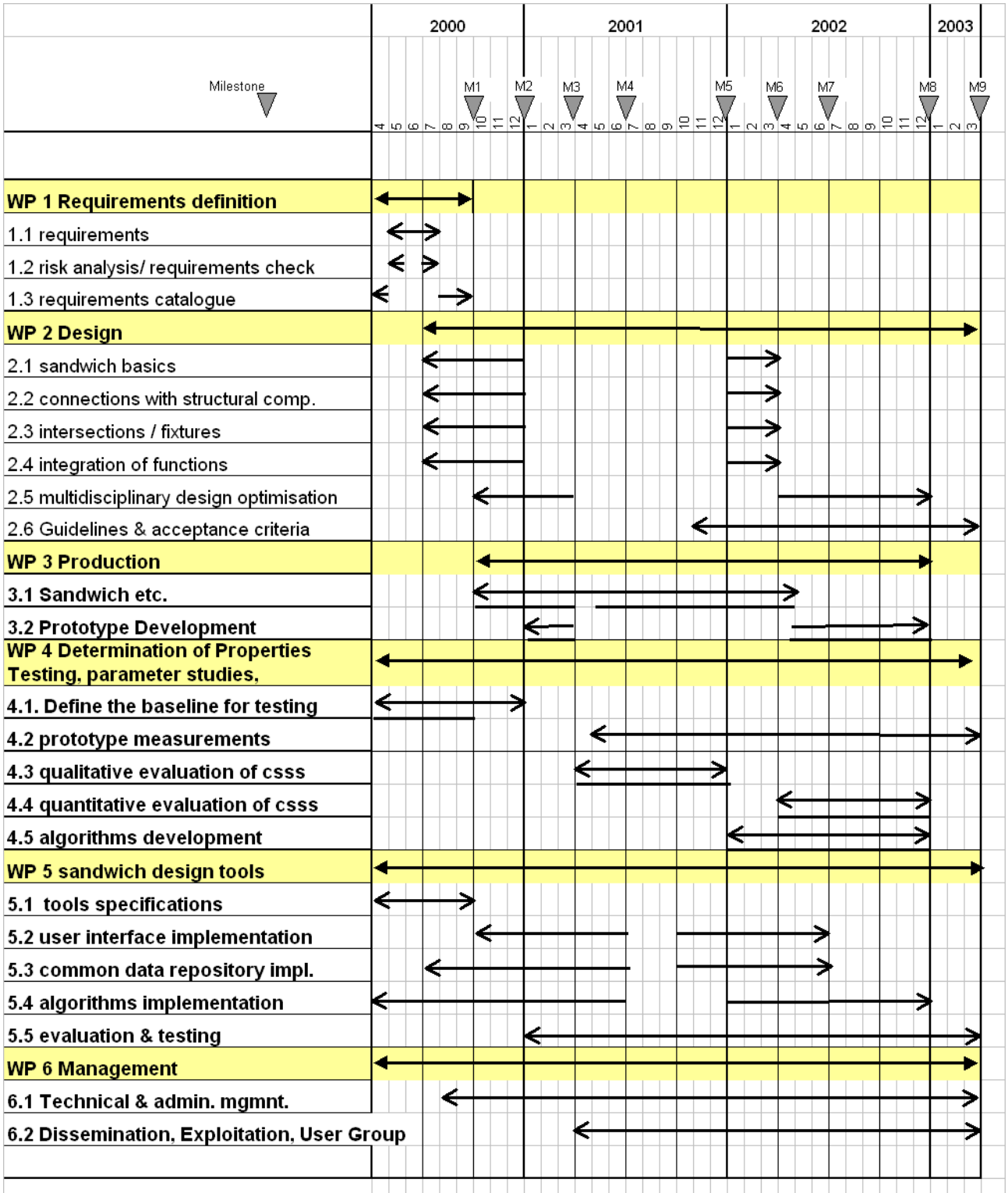


Figure 3-1 work-package breakdown structure

These partners will contribute in a streamlined manner to a document collecting all the load cases and its combinations with particular requirements regarding strength, fire and heat insulation, corrosion, noise and vibration and crash behaviour. A second result from this group is a functional description of the design tool to be developed in WP5. With this requirement catalogue and unfortunately still without the design tool a first set of sandwich designs need to be developed (WP2), detailed enough to allow a subsequent production of the test panels and prototypes (WP3). These panels and prototypes will be tested against strength, fire, heat and insulation, noise and vibration and crash worthiness (WP4). Within the testing work-package accompanying calculations as well as the development of descriptive algorithms (engineering formulas) are performed. This will be done in parallel by the material experts and the authority/class society to double check. The results gained from this work-package are the major input for both the sandwich design tool (WP5) and the design guidelines. Once the algorithms are embedded in the design tool first tests will be made with both aspects usability and engineering capabilities. The knowledge gained on the composite sandwich steel panels will be utilised also by WP 2 (sandwich design) for improved design solutions and will thus trigger an update of design and production of test material and the subsequent tests. The cyclic improvement of the design, the next generation of test material and tests will of course also improve the algorithms and thus the design tool. We plan for two of these “iteration loops”. Figure 3.1 shows the work-package breakdown structure and iteration / feedback loops.

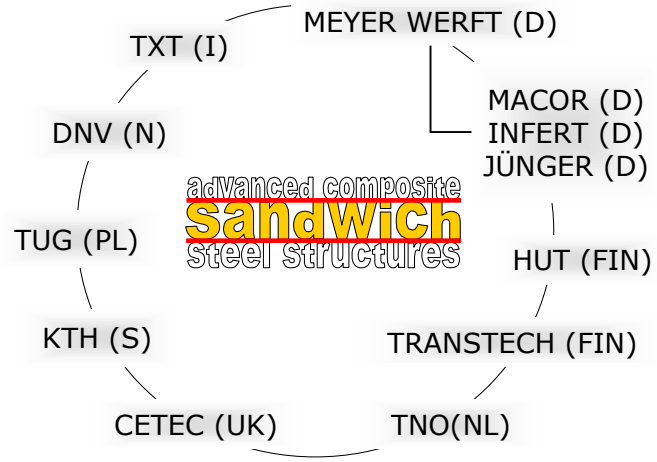
4 Project schedule



M1	**requirements delivered**
M2	**first design in place**
M3	**first panels produced**
M4	**first version of design tool available**
M5	**qualitative testing finished**
M6	**design updated**
M7	**design tool updated**
M8	**quantitative testing finished**
M9	**design guidelines available, project finished**

5 The consortium

Users from the transport industry define their requirements and work together to develop a modular sandwich design (one shipyard MEYER WERFT, a ship equipment supplier MACOR, a trailer manufacturer JÜNGER, a producer of railway vehicles TRANSTECH). Experts from research institutes (HUT, KTH, TUG and TNO) and commercial engineering consultants (CETEC and INFERT) will evaluate the properties of the proposed solutions and derive design algorithms. Each research partner has a specific expertise for a group of properties or materials.. MEYER WERFT experienced in laser welding will produce test specimen and prototypes and give feedback on produceability. A classification society (DNV) assures, that no relevant aspect is missing in the design and testing and that the derived solutions will be approved. A software company (TXT)will put the results into a computer programme. The tasks within the project are thus clearly distributed among the partners, making use of the leading European experts.



MEYER WERFT initiator and co-ordinating partner of SANDWICH is developing sandwich structures since 1996. In this effort MEYER was supported by INFERT and HUT. Also RAUTARUUKKI was involved in the development effort providing there know how on special steel qualities and profile shapes. Since than TNO was small scale testing while INFERT was supporting with FEM calculations. This core team had during their initial studies contact to the experts from TUG, and KTH so that the forging of the right team was a logical step.
Especially the good co-operation reported from INFFERT between themselves and the University of Gdansk (TUG) convinced the consortium to invite Prof. Rosochowicz to strengthen the project with his expertise. The successful production possible through utilising laser welding encouraged the team to further enhance this idea to make it a product beyond marine markets. After the first publications on sandwich panels many trailer manufacturers approached MEYER to express their interest among those JÜNGER and TRANSTECH were selected to strengthen this consortium.
Since large scale testing for strength and fatigue but also crash tests are a major work task within SANDWICH, it was essential to forge a powerful testing team with both large capacity and a huge variety of skills and testing equipment TNO, TUG, KTH and HUT provide a complementary set of skills and equipment. TNO is the expert on large scale crash testing world wide, while TUG has the corresponding equipment for large scale fatigue an strength tests. HUT is specialised on small and medium scale vibration testing while KTH is known for their expertise in noise tests. The expertise for the low density foam will be also provided by the different institutes, KTH for PMI, PUR and balsa, TNO for light concrete, metallic foams expertise will be bought in from IFAM which is planned to be subcontractor to MEYER.
The mix of engineering consultants and direct users of the sandwich panels features the idea of multiplying the know how and thus usage of the sandwich panels in variant branches and application fields throughout Europe.

Among others RAUTARUKKI, SCANIA and ADTRANZ has expressed their interest in participating in a SANDWICH user group which will be initiated during the life of the project. This user group will reflect on the requirements document as well as on the design guidelines and will be the first ‘non project partner tester’ of the internet interface of the SANDWICH design tool. This will be beneficial for both project partners and user group members, and we therefor expect to expand the user group fast.