ECCS/CIB Joint Committee on Sandwich Constructions: Recent European Recommendations on Design and Testing

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Abstract

Light-weight sandwich panels, made of two metal faces separated by an insulating core material, are modern pre-fabricated construction components. The design, manufacture and use of these composite structural elements have required continuous development of regulations and standards. The Joint Committee is the combination of two working groups; CIB W056 "Lightweight constructions" and ECCS TWG 7.9 "Sandwich panels and related structures". It therefore provides a powerful forum for the consideration of international research and development of the design, testing and end-use of sandwich panels. This paper introduces the Joint Committee and its work by outlining its history and its most important publication, "European Recommendation for sandwich panels". The significant influence of the Committee on the recently published European Product Standard EN 14509 is also described. Focus is then directed to the latest publications of the Joint Committee, namely the "Preliminary European Recommendations for Testing and Design of fastenings for sandwich panels" and the "State of the art report for Design of Sandwich Panels with Openings". The latter is still under preparation and will probably be published in 2010.

Keywords: sandwich panel, light-weight, fastening, opening, CIB, ECCS, recommendations

1. The joint committee on sandwich constructions

1.1 CIB steering group S56 and working commission W056

The first sign of the existence of the CIB Steering Group S56 was at the International Symposium on Low-Rise Lightweight Constructions held in Budapest in April, 1971. A significant product of this era was CIB Publication 59 "Recommendations for the Structural Design of Lightweight Sandwich Panels" which was published in 1978. This document gives principles for design with regard to static out-of-plane and in-plane actions, impact loads and dynamic loads. It also gives recommendations for design for environmental effects and fire. Finally, it discusses the properties of connections and construction systems including the principles of the quality control. The report was based on ISO standard 2394-1973 which introduces the principles of the modern limit state design. The report, which was far ahead of its time, was written as a framework for national regulations and it probably provided the first formalised recommendations for the design of sandwich panels. Nowadays, the emphasis in Europe has moved away from national guidelines and towards harmonized standards for the whole continent. However, historically, "Recommendations" produced by European-wide Committees of experts have led to a similar unified outcome.

The name of Steering Group S56 was changed to Working Commission W056 and the membership reconstituted. It held its first meeting in Espoo, Finland in May, 1984. Initially, developments in lightweight constructions were introduced and discussed without limitation as to materials or types of construction. Later, the subjects of W056 became focused more towards mineral wool cored sandwich panels because of the need for guidelines for this new sandwich panel product. The coordinators of W056 during this period were Professor J M Davies in 1986 - 89 and Lars Heselius in 1990 - 2006. Thus, W056 extended the Preliminary European Recommendations for Sandwich Panels written originally by ECCS TWG 7.4 (see 1.2) and the outcome was CIB Publication No 148 which was published in 1993 and reprinted in 1995.

1.2 ECCS technical working group TWG 7.4

The European Convention for Constructional Steelwork (ECCS) has a long and distinguished record of pre-standardisation work and its Technical Committee TC7 "Cold-formed thin-walled sheet steel in buildings" has been one of its most successful working committees and, since its inception in 1974, it has produced numerous significant documents. The workload of TC7 quickly increased to the point where a number of separate Working Groups were required and in 1983, noting the increasing interest of the market in light-weight metal sheet faced sandwich construction, it was decided to form a new technical working group TWG 7.4 "Sandwich Panels" to produce European Recommendations for design, testing and good practice in the use of sandwich panels. The work of TWG 7.4 started in 1983 under the chairmanship of Dieter Stemman taking full advantage of his experience with German "Zulassung" documents.

TWG 7.4 produced “Preliminary European Recommendations for Sandwich Panels” in two parts. Part I “Design” was published in 1991 and relates to the analysis, design and testing for the load-bearing capacity of the sandwich panels. This significant document has provided the basis for a number of subsequent Recommendations and Standards. Part II “Good Practice” was published in 1990 and introduces subjects such as building physics, fire, installation and erection work.

In the late nineties needs to update the European Recommendations became obvious and ECCS TC7 founded a new Technical Working Group TWG 7.9 “Sandwich Panels and related Subjects”. Because of the mutual interest, in 1998, ECCS TWG 7.9 and CIB W056 combined to form the Joint Committee on Sandwich Construction, which is still active today. The first two years of work resulted in the final manuscript of the “European Recommendations for Sandwich Panels, Part 1: Design”, which was published as CIB Publication No 257 in 2000 and ECCS Publication No 115 in 2001. The authors pay tribute to the work of Antti Helenius who acted as secretary of W056 and the Joint Committee for more than ten years.

Based on the work of the CIB W056 Working Commission, a group of members combined together to write a book covering all aspects of sandwich panel design and construction. Although individual members took responsibility for individual chapters, this book is unique in that the authors took joint responsibility for the whole and each chapter was discussed in detail at a series of meetings. The contributions were edited by Professor J M Davies and the result was published in 2001 entitled “Lightweight Sandwich Construction”.

The above Recommendations have formed the basis of the European product standard for self-supporting double skin metal faced insulating panels, EN 14509, which was published in December 2006 and cited in the Journal of CEN in December 2008. Drafting of the product standard was in the hands of CEN Committee TC128/SC11, which includes most members of the Joint Committee. The product standard extends the European Recommendations to include all of the “Essential Requirements” of the Construction Product Directive in accordance with formal mandates.

Because it is a European “product” standard, EN 14509 defines the requirements and the methods of verification of the essential properties of the factory made sandwich panels. The standard does not and cannot specify requirements for operations carried out after manufacture such as cutting, fixing and installation. Consequently, in 2004, the reactivated Joint Committee identified a number of subjects in which further direction and harmonization is needed. The first items to be considered were the fastening and openings in sandwich panels.

2. The recent European recommendations

2.1 Testing and design of fastenings of sandwich panels

2.1.1 Background

The product Standard EN 14509 does not give any requirements regarding the joints and fastenings of the sandwich panels. In order to remedy this, the Joint Committee has produced preliminary recommendations which discuss the experimental determination of the load-bearing resistance of fastenings, the evaluation of the test results and the principles of the design of fastenings. These preliminary recommendations, now available as ECCS Publication No 127 and CIB publication No 320 in 2009, are based on the earlier versions of the European Recommendations for Sandwich Panels ECCS & CIB (2000) updated to accord with current knowledge and experience.

2.1.2 Fastening of sandwich panels

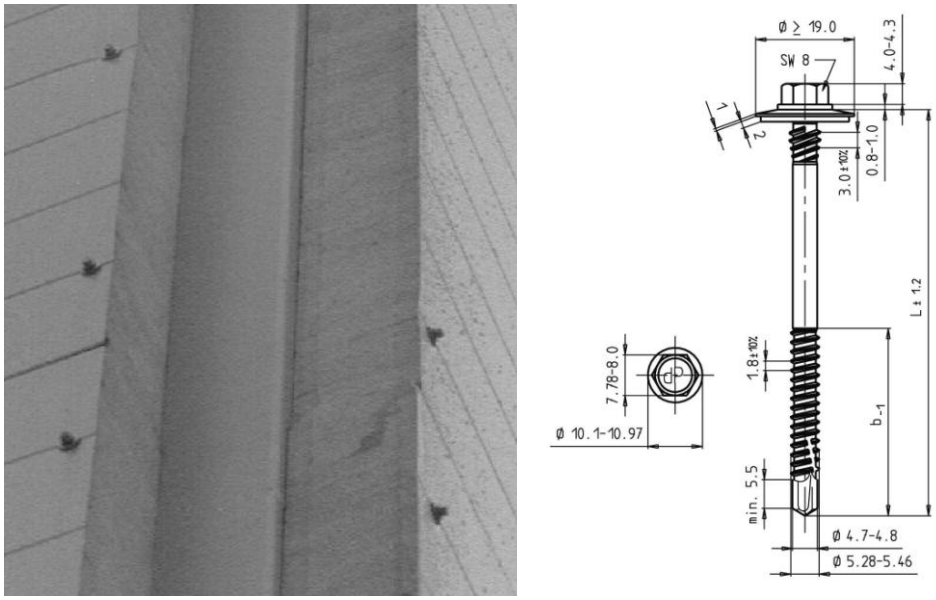

Figure 1: Fixings of sandwich panels: typical application and fastener (right hand Figure courtesy of Würth).

Because of the inherent rigidity of the sidelap, seam fasteners are not generally used in sandwich construction. Attention is therefore concentrated on the connections to the supporting structure. These may be concealed in the sidelap or may be visible and pass through the complete panel. Whichever solution is adopted, self-tapping or self-drilling screws are generally used. Both of these are able to cut their own threads into the substructure, however self-tapping screws require pre-drilling. The screws have a formed drilling bit that allows the screwing and drilling in a single

operation. In order to produce a rainproof joint, sealing washers with a vulcanised EPDM layer are used between the screw head and the face. The washers of the screws fixed to the upper flange of the trapezoidally profiled facing, may take the form of saddle washers to tighten and to support the profile.

The fasteners between the sandwich panel and the substructure may be loaded by tensile and shear forces as well as by bending moments (head deflection) due to the thermal movements of the faces.

2.1.3 Tensile and shear resistance of fastenings

The load-bearing performance of fastenings is mainly determined experimentally. Therefore, tensile, shear and bending tests have to be performed. Attention is generally concentrated on the strength (capacity) of the connection. However, it is important to appreciate that stiffness and ductility are also important. In particular, sandwich panel assemblies are generally extremely rigid with regard to in-plane displacements so that any such movements (due, for example, to thermal elongation or parasitic stressed skin action) must be accommodated primarily by ductility in the fastening system.

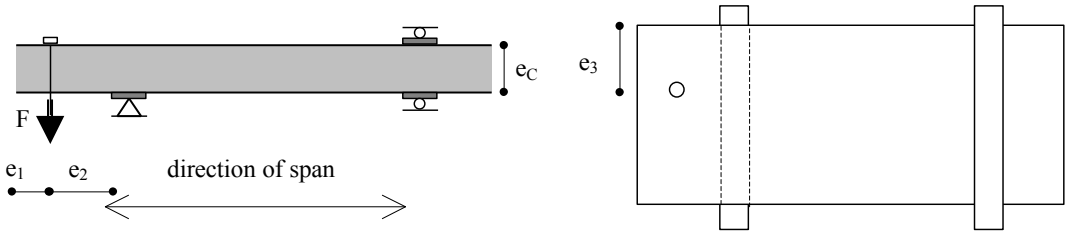

Figure 2: Test arrangement for pull-through resistance based on small-scale specimens at an end support (ECCS & CIB, 2009).

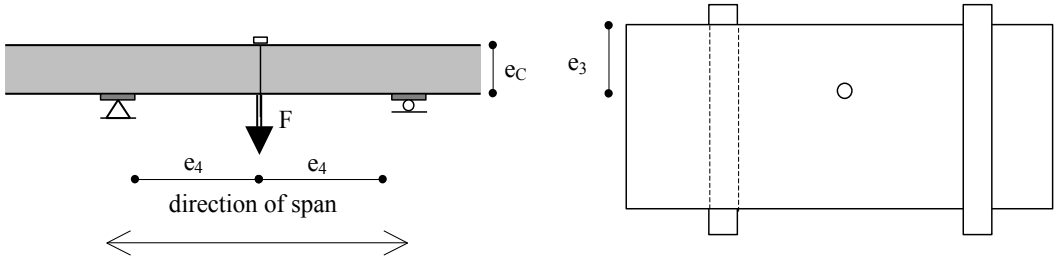

Figure 3: Test arrangements for pull-through resistance with small-scale specimens at an intermediate support (ECCS & CIB, 2009).

The tensile resistance of a fastening represents the minimum value of the pull-through resistance and the pull-out resistance. The load-bearing capacity of the screw itself does normally not play an important role in the resistance of the fastenings of sandwich panels. The Recommendations ECCS & CIB (2009) deal with the pull-through resistance only. For determining the pull-out resistance reference is made to ECCS (2008).

The distance between the end of the panel and the fastener has an influence on the tensile resistance of the fastening. Therefore, two separate test arrangements have been developed to take into account the different nature of the fastening at an end support and at an intermediate support as shown in Figs 2 and 3. ***Figure 4*** shows the principal set-up of a test for the determination of the shear resistance of a screw fastening. Since the influence of the external face decreases with the increasing thickness e_C of the core layer, the tests are to be performed with the largest envisaged panel thickness. As an alternative, the sole direct load transmission between the internal face and the substructure may be investigated.

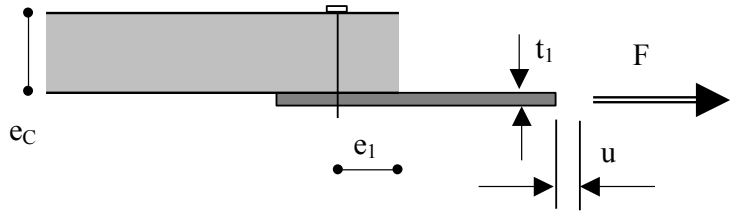

Figure 4: Shear test assembly for screws passing through the panel (ECCS & CIB, 2009).

For the determination of the resistance of a screw to the deflection of the screw head, the shaft of the fastener is subjected to a repeated deflection of „u", where u is the maximum lateral displacement of the head. The deflection spectrum is as follows: 20.000 cycles with a deflection of 4/7 u, 2.000 cycles with a deflection of 6/7 u and 100 cycles with a deflection of u. This load spectrum is based on the assumption of a service life of 50 years in a location in central Europe. During the test, the screw shall not fail and, after cyclic loading, the screw has to achieve at least 80 % of the mean value of the pull-out resistance without the repeated load.

2.2 Openings in sandwich panels

2.2.1 Background

In the majority of buildings, functional requirements necessitate openings in the wall and roof cladding. The current state of the art with regard to openings within the sandwich panel wall and roof construction generally requires the addition of reinforcement in the form of additional framing to replace the load-bearing capacity which has been removed by the opening (Fig 5). Recent research results indicate that this additional framing is not always needed. The state of the art report of the Joint Committee will introduce the possibility of designing panels with openings without the need for any additional strengthening.

2.2.2 Remaining resistance of panels with openings

The cross-section of the panel which remains after cutting an opening may be able to carry the applied loads. In this case, the opening is classified as „small". The evaluation of the remaining

resistance is evidently the primary design task and this includes verification of the resistance of the net section to the design bending moments and shear forces at the critical points in the vicinity of the opening taking account of any stress concentrations.

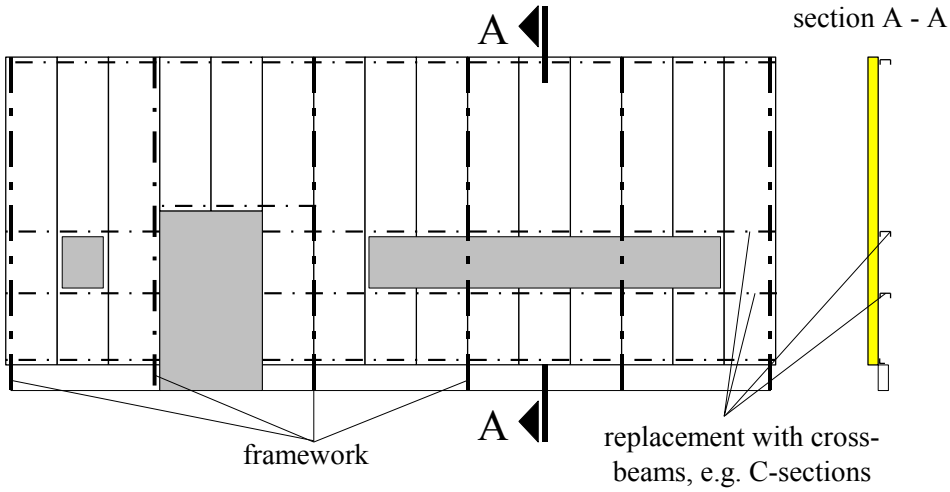

Figure 5: Openings requiring additional supporting members (ECCS & CIB, 2010).

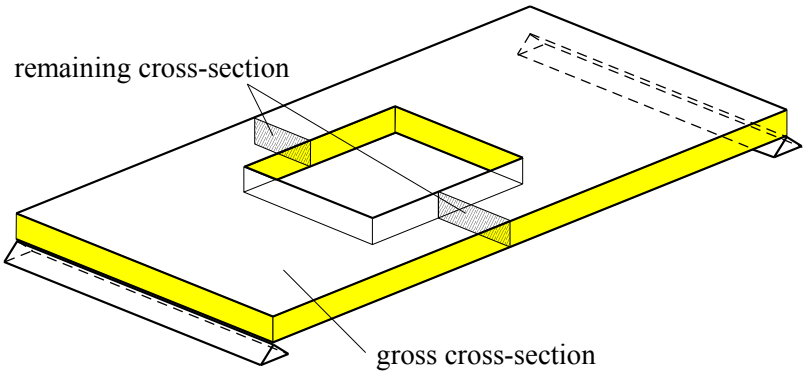

Figure 6: Remaining cross-section in the vicinity of an opening (ECCS & CIB, 2010).

The ECCS & CIB report (2010) gives design formulas to calculate the remaining resistance of a panel with openings (Fig 6).

2.2.3 Activation of the load-bearing resistance of neighbouring panels

If the remaining cross-section of an individual panel is not able to carry the applied loads, the load-bearing resistance of the neighbouring panels can be activated. Due to the difference of the stiffness between the panels with and without openings, the whole or a part of the loads applied directly to the panel with openings will be transferred via the longitudinal joints to the adjacent panels (opening „A“ in ***Figure*** 7). The most severe case is the load transfer from a completely cut sandwich panel

(opening „B" in ***Figure*** 7). While in case A the panel might have sufficient capacity to withstand the load, case B relies entirely on the load transfer. In both cases, the neighbouring panels will receive additional loads which can be calculated on the basis of the compatibility of the deflections in the longitudinal joints (Figure 8). These loads are transferred by these joints and therefore, the assessment of the strength and stiffness of the joints is essential. Furthermore, the load transfer will result in an eccentric line load applied to the adjacent panel without an opening thus activating its torsional rigidity and causing additional shear stresses due to the torsional moment.

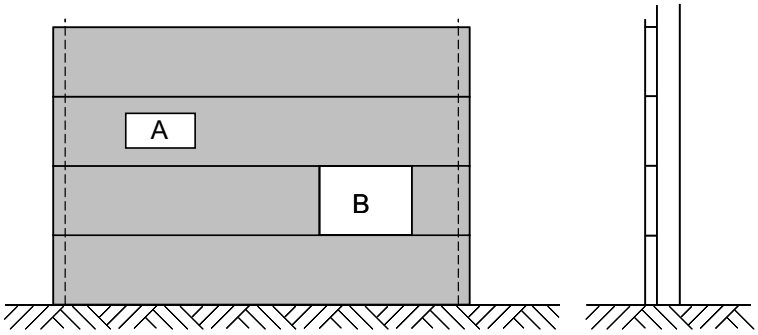

Figure 7: Small and full-width openings in sandwich panel walls (ECCS & CIB, 2010).

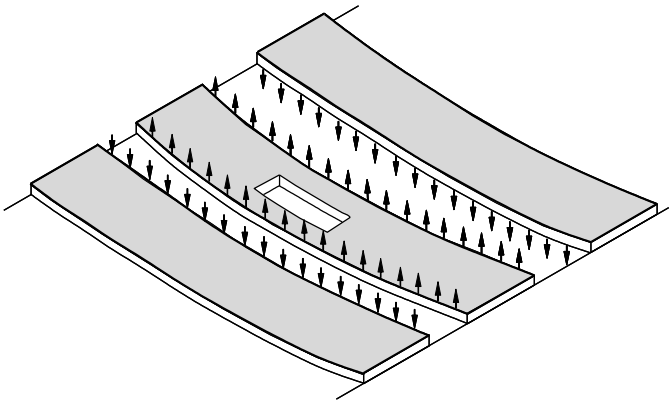

Figure 8: Line loads on the longitudinal joint between neighbouring sandwich panels with different bending and shear stiffness (ECCS & CIB, 2010).

The intensity of the load, which can be transferred through the longitudinal joints to adjacent panels, depends on the bending, shear and torsional rigidity of the complete panels and, in addition, on the shear rigidity and shear resistance of the longitudinal joint. Simple framework-software can be used to compute the internal forces and deflections. ECCS & CIB (2010) presents the basic principles of the design procedure. A test set-up for the determination of the stiffness and resistance of the longitudinal joints is presented as well as formulas to determine the required bending and torsional stiffnesses of the panels.

2.2.4 Large-sized openings

In some cases load transfer from the panel with openings is not possible due to the limited shear resistance of the longitudinal joint or the limited load-bearing resistance of the neighbouring sandwich panels. An additional frame has then to be designed to carry the whole load of the sandwich panel with openings. This frame may be placed within the longitudinal joints of the panel (Figure 9).

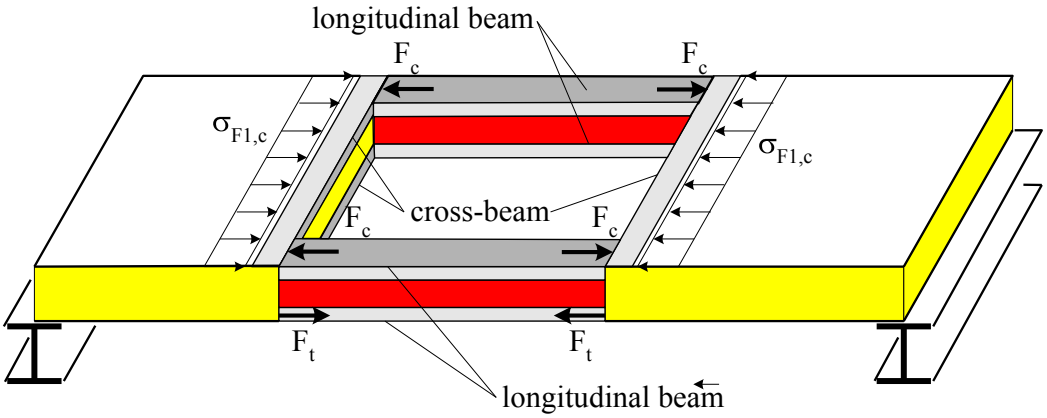

Figure 9: Frame-construction within the panel using special aluminium profiles with web parts made of plastic sections (ECCS & CIB, 2010).

3. The EASIE project

The Joint Committee is the birthplace of the European research Project "Ensuring Advancement in Sandwich Construction through Innovation and Exploitation" (EASIE). The „EASIE" project commenced in October 2008 and is funded to approximately 4 million Euro with financial support from the European Community's Seventh Framework Programme FP7/ NMP2-SE-2008 under grant agreement No 213302.

EASIE provides support to small and medium sized enterprises to develop the design, manufacturing and use of products related to sandwich constructions. The Joint Committee first defined subjects and tasks of the project reflecting the needs and interests of the industries were collected. In addition, EASIE will also study subjects relevant to the updating of the product standard EN 14509. It includes a number of innovative subjects such as the performance of sandwich panels subject to in-plane shear and axial resistance.

The second goal of EASIE is to disseminate existing and new information for use in practice. This will be carried out through seminars and the production of practical guidelines and e-learning modules. The subject areas include the principles of the design and use of sandwich panels, fastening and fixing, properties in extreme situations and the information given by the research results of EASIE. Practical guidelines and seminars will help and broaden the correct and safe use of sandwich panels in Europe and ICPC.

4. Future tasks of the Joint Committee

The earlier work of the Joint Committee has produced independent technical harmonised guidelines and relevant background documents for the European product standard. The technology of sandwich panels is still evolving and the Committee seems still to have a useful role as author of technical guidelines based on new and reliable information without pressure from commercial or other interests. Because of this continuous development, keeping the available documents up to date is an important task of the Committee. Future tasks are likely to include the preparation of new guidelines on the basis of the technical information emerging from projects such as EASIE. Finally, questions arising from environmental issues in buildings and building products may open new technical tasks requiring a measure of European collaboration.

References

CIB (1978) *Recommendations for the structural design of lightweight sandwich panels*. Rotterdam: CIB - International Council for Research and Innovation in Building Construction, S56 Lightweight Constructions.

International Organization for Standardization (1973) *General principles for the verification of the safety of structures*. ISO 2394.

Davies J M et al. (2001) *Lightweight sandwich construction*, Oxford, Blackwell Science.

ECCS & CIB (2000) *European Recommendations for Sandwich Panels – Part 1: Design*. Brussels/Rotterdam: ECCS - European Convention for constructional steelwork, TWG 7.9 Sandwich panels and related structures & CIB - International Council for Research and Innovation in Building Construction, W056 Lightweight Constructions. ECCS Publication No 115 and CIB Publication No. 257.

ECCS (2008) *The Testing of Connections with Mechanical Fasteners in Steel Sheeting and Sections*. Brussels: ECCS - European Convention for constructional steelwork, TWG 7.10 Connections in Cold-formed Steel Structures. ECCS Publication No 124.

ECCS & CIB (2009) *Preliminary European Recommendations for Testing and Design of Fastenings of Sandwich Panels*. Brussels/Rotterdam: ECCS - European Convention for constructional steelwork, TWG 7.9 Sandwich panels and related structures & CIB - International Council for Research and Innovation in Building Construction, W056 Lightweight Constructions. ECCS Publication No 127 and CIB Publication No. 320.

ECCS & CIB (2010) *State of the art report for Design of Sandwich Panels with Openings*. Brussels/Rotterdam: ECCS - European Convention for constructional steelwork, TWG 7.9 Sandwich panels and related structures & CIB - International Council for Research and Innovation in Building Construction, W056 Lightweight Constructions. (will be published in 2010?)

EN 14509 (2006). Self-supporting double skin metal faced insulating panels - Factory made products - Specification. Brussels: CEN - Comité Européen de Normalisation.

Ensuring Advancement in Sandwich Construction through Innovation and Exploitation: www.easie.eu