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THE EUROCODES AND THE CONSTRUCTION INDUSTRY

MEDIUM-TERM STRATEGY

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OBJECTIVE AND EXECUTIVE SUMMARY

Objective

The objective of this report is to describe the future work which has to be undertaken in the field of the structural/civil engineering Eurocodes as part of their natural evolution and to obtain:

- general agreement between the European Commission and the European Committee for Standardisation (CEN) on the Scope of the work that is needed,
- a framework mandate from the Commission to CEN concerning the execution of a standardisation programme on further development of the Eurocodes.

The framework mandate should be supplemented by individual mandates to be issued from the Commission to CEN to request the carrying out of drafting of further parts of the structural Eurocodes with a reasonable level of associated funding.

General

The development of The Eurocodes was originally to facilitate the application of the first European Public Procurement Directive (71/305 CEE) by providing design rules for buildings and civil engineering works. After 1990, the work was entrusted to CEN which formed TC 250 making it responsible for the development and completion of the Eurocodes which are a set of European Standards covering 10 main subjects in the field of structural and civil engineering, based on the requirements of the Council Directive 89/106/EEC relating to construction products(CPD). Each of the 10 subjects has several EN Parts, making a total of 58 Parts, the last of which was published by CEN in May 2007.

The World is changing and the evolution of Standards is a condition of their survival. The design and construction methods of buildings and civil engineering works are evolving to be economically more efficient and to take into account better the expectations of citizens: a higher level of protection, more comfort, increased durability and improved energetic performance.

The Eurocodes are not only the means to design for stability and resistance, including resistance in case of fire, but they are also an invitation to the development of mechanical and architectural innovation. They are a tool for advanced structural design for durable and robust structures.

The scene of construction activity is also changing. The population of our planet, which has passed 6,5 billion, is expected to reach nearly 9 billion by 2040, which means acceleration of the construction of buildings and transport infrastructure, acceleration of the production of traditional materials and development of new materials. Standards will be more and more a tool for helping stakeholders to obtain the desired levels of safety and quality.

At the European level, the scene is changing with the “Lead market initiative for Europe” highlighting, in particular, the evolution needed in the construction sector; the future publication of the Construction Product Regulation (CPR) adds a new basic requirement - sustainable use of natural resources. The concept adopted by TC 250 in delivering the Structural Eurocodes could be applied to all of the basic works requirements, through CEN.

Evolution of the Eurocodes

The evolution of the Eurocodes will follow four main strands:

- Maintenance - carried out by CEN/TC250 and its Sub-Committees with a remarkable intellectual precision, and many corrigenda and/or amendments have been, or will soon be, published by CEN. This activity involves a large amount of unglamorous work.

- Harmonization - a very heavy task. When information on the NDPs adopted in the Member-States has been collected by JRC, a technical report will be prepared to encourage a significant reduction in the number of NDPs. The preparation of such a report needs expertise from JRC and CEN/TC250 (Sub-committees, project-teams) and should be recognised in the general agreement.
- Further development - includes :
  - work on the evolution of the Eurocodes (simplification, clarification after feedback from designers, revision of serviceability criteria (imperfections and deflections) , incorporation of the latest results of research, re-consideration of the status of certain clauses or annexes, improvement of the liaison with other European standards, evaluation of interoperability and contents as regards all basic requirements of the future CPR, etc.),
  - development of new Eurocode Parts in the following fields :
    - assessment and retrofitting of existing structures,
    - deepening of the concept of robustness
    - new materials (for example, glass, FRP, very high performance concrete),
    - new types of structures (e.g. tensile surface structures),
    - incorporation of ISO Standards in the Eurocodes family (atmospheric icing of structures, actions from waves and currents on coastal structures).
- Promotion - in European and non European countries is mainly organised and supported by the Commission (JRC).

The following procedure to develop new Parts of the Eurocodes for Glass, FRP and Membrane Structures was agreed by CEN/TC250 recently:

1. Preparation of technical recommendations in 'Scientific and Technical Reports' prepared by JRC or by other recognised Scientific and Technical Organizations.
2. After acceptance of the 'Scientific and Technical Report' by TC250, adaptation of it into a CEN Technical Specification.
3. Upon the agreement of CEN/TC250, conversion of the CEN Technical Specification into a Eurocode Part.

The development of all matters dealing with structural aspects will be managed by CEN/TC250 which will need to form new Sub-committees.

Eurocodes and sustainability in construction

The building and construction sector plays an important role in sustainable development - it is a key sector in National economies. The perception of sustainability varies from person to person and a strategy needs to be defined, in the context of the built environment, social equity, cultural issues, traditions, heritage issues, human health and comfort, social infrastructure and safe and healthy environments, with special attention to the disparities in standards of living between developed and developing countries.

The present Eurocodes are also concerned with sustainability in construction (e.g. durability) but, even if some concepts are clear, their practical implementation needs to be defined more accurately to enable them to become really operational. It would be desirable to establish technical guidelines intended for experts in charge of standardisation as well as for designers of buildings and civil engineering works. These technical guidelines should be established by a working group of CEN in liaison with appropriate CEN/TCs, including TC 250, and this work should be included in the general mandate to CEN.

Time-table

This report describes a medium-term strategy, as a part of a long-term strategy, leading to a new generation of structural Eurocodes. The main efforts that may be envisaged in the future are:

- 2009: General agreement, general mandate and specific mandates by Commission to CEN;
- 2010 – 2015: Preparatory work on the revision/evolution of the Eurocodes, preparation of technical reports/specifications on assessment and retrofitting of existing structure, glass, FRP, tensile surface structures;
- 2015 – 2020: publication of the next generation of Eurocodes.

FOREWORD

All Eurocodes have been available since mid 2007 and the implementation in Member States of the EU and of EFTA is progressing well. The next step for CEN/TC 250 is to enter into maintenance, further harmonisation, further development and promotion of the Eurocodes.

Many documents have been prepared within CEN/TC250 in cooperation with JRC to define the most appropriate framework for the future development of the Eurocodes system. The present medium-term strategy is a synthesis of various exchanges of views since 2006, including the main decisions taken by the TC.

For the new work needed for the development of the Eurocodes, CEN/TC 250 needs the political backing by the Commission, expressed in terms of mandates with funding, where possible.

It is wished that the present strategic document will be useful to invite the Commission to bring a full support to CEN/TC250 in order to allow for full implementation and future expansion of the European set of design standards encompassing all essential/basic requirements for construction works.

CHAPTER 1
THE EUROPEAN SCENERY OF THE CONSTRUCTION ACTIVITY IN 2008

1.1 Introduction

The Eurocodes system was developed to facilitate the application of the first European Public Procurement Directive (1971) in the field of design rules for buildings and civil engineering works. In 1975, the Commission of the European Community decided on an action programme based on Article 95 of the Treaty of Rome. The objective of the programme was the elimination of technical obstacles to trade and the harmonisation of technical specifications for construction works. The documents, which were not really standards at the origin, were based on the works of international scientific associations and were intended to be used as a reference for the judgement of public tenders.

During 15 years, the Commission, assisted by a steering committee composed of experts from EU Member States, oversaw the development of the Eurocodes programme, which led to the publication of a first generation of European codes in the 1980s which were immediately submitted to international inquiries. After the adoption of the European Unique Act (1986) with the objective to modify and complete the Treaty of Rome, in particular to improve the decision procedures (vote at the qualified majority), new European directives were established, defining only essential requirements and the development of standards based on these requirements was transferred to appropriate standardisation bodies. One of these directives, published in 1989, dealt with construction products[1].

In 1989 the special agreement between the CEN and the European Commission transferred the preparation and publication of the Eurocodes to the CEN, thus providing the Eurocodes with a future status of European EN standards. The agreement specified that the Eurocodes were intended to serve as reference documents to be recognised by authorities of the Member States for the following purposes :

- as a means for enabling building and civil engineering works to comply with the "essential requirements" of the construction products directive (89/106/EEC), particularly the first two - mechanical resistance and stability, and safety in case of fire ;

- as a basis for specifying public construction and related engineering service contracts. At that time, this related to Council Directive 93/37/EEC of 14 June 1993 concerning the co-ordination of procedures for the award of public works contracts, and the services directive (92/50/EEC). Since the 31st of March 2004, these two directives have been replaced by a unique directive[2] (2004/18/CE) of the Parliament and of the Council on the coordination of procedures for the award of public works contracts, public supply contracts and public service contracts ;

- as a framework for drawing up harmonised technical specifications for construction products (ENs and European Technical Approvals).

The benefits and opportunities of adopting the Eurocodes can be summarised as follows:

- to provide a common understanding regarding the design of structures between owners, operators and users, designers, contractors and manufacturers of construction products ;

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[1] Council Directive 89/106/EEC of 21 December 1988 on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products, Official Journal of the European Union L 40, 11.2.1989.

[2] Directive 2004/18/EC of the European Parliament and of the Council of 31 March 2004 on the coordination of procedures for the award of public works contracts, public supply contracts and public service contracts, Official Journal of the European Union L 134, 30.4.2004.

- to facilitate the exchange of construction services between European Member States ;

- to facilitate the marketing and use of structural components and kits of parts in Member States ;

- to be a common basis for research and development in the construction sector ;

- to allow the preparation of common design aids and software ;

- to increase the competitiveness of the European civil engineering firms, contractors, designers and product manufacturers in their world-wide activities.

Finally, the Eurocodes are a set of common standards containing the European calculation methods to assess the mechanical resistance of structures or parts thereof and fire resistance as well. This set includes at present 58 documents (European standards) which were finalised and adopted through a formal vote before the end of 2006. All of them were published prior to June 2007.

The Eurocodes cover, at present, 10 design areas (Basis of Design, Actions, Steel, Concrete, Composite Steel and Concrete, Timber, Masonry and Aluminium, together with Geotechnical design and Seismic design).

The European Commission has formally recommended the 58 structural Eurocodes as "a suitable tool" for designing construction works, checking the mechanical resistance of components and checking the stability of structures. The Recommendation 2003/887/EC of 11 December 2003[3] says Member States should recognise that construction works designed using Eurocodes will conform with the essential requirements of mechanical resistance and stability, safety in use and safety in case of fire. Eurocodes are a state-of-the-art tool which will undoubtedly provide a higher level of safety than before for our citizens.

The Eurocodes constitute a coherent EU-wide framework of common calculation methods with facilities to adapt their functioning to national settings and priorities through a set of Nationally Determined Parameters (NDPs). When taking the Eurocodes on board, the Member states are expected to define the NDPs to be observed on their territory taking into account justified differences in climate, geographic conditions (e.g. seismic risk), levels of safety, or traditions regarding the way of life prevailing in their territory.

To secure the harmonization efforts, the Commission Recommendation includes a suggestion that Member-States, acting in coordination under the direction of the Commission, compare the NDPs implemented by each Member-State and assess their impact as regards the technical differences for works or parts of work. The Commission has developed and made available a structure, including appropriate databases, to collect and compare the defined NDPs, thus enabling further harmonization work.

The Recommendation 2003/887/EC underlines the necessity to support the implementation on the ground through fully integrating the Eurocodes into all relevant education and training activities on national and regional level and it indicates that continuous efforts to maintain the Eurocodes at the forefront of engineering knowledge and developments in structural design are needed, with further research on MS and EU level facilitating uptake of the latest scientific knowledge and the development of the construction market, including new materials, products and construction methods.

All EU Member States have now initiated the full adoption of the Eurocodes as national design codes including the definition of the Nationally Determined Parameters (NDPs). Due to different regulatory systems and setups the process and the time for full implementation vary depending on the Member States.

[3] Commission Recommendation of 11 December 2003 on the implementation and use of Eurocodes for construction works and structural construction products (2003/887/EC), Official Journal of the European Union, L 332/62, 19.12.2003.

According to the Public Procurement Directives (2004/17/EC and 2004/18/EC, adopted in 2004 and entered into force on 31 January 2006), the contracting authorities must during the transition period until 2010 allow the use of the Eurocodes in structural design aspects of tenders falling within the remit of these Directives. After 2010 the Eurocodes become the only possible design codes to use in publicly procured contracts.

1.2 Evolution of the design of buildings and civil engineering works

The design of buildings and engineering works is permanently evolving for several reasons.

- Constructors have to take into account the evolution of societal needs or requirements, generally expressed by political authorities (at the national or international level). These new societal needs are described in 1.4.
- Constructors have to take account of the evolution of the markets and in particular the increasing cost of raw materials to maintain as far as possible the requirement of economy of construction works. This point may have technical aspects if the manufacturing process of construction materials (in particular steel and concrete) is altered. The consequence of the more economic design is an evolution of the quality control of materials and structural components on site.

The competitiveness of construction companies depends on :

- the quality of the design,
- the quality of execution, including the quality of materials and manufactured components, and
- the ability to develop innovative solutions (innovative execution processes, use of new materials).

Of course, competitiveness implies, as well, relatively low cost.

The main developments in the construction sector in the last decades may be summarized as follows :

- implementation of computer-aided design which facilitates the use for refined structural models and advanced calculation methods ;
- development of architectural innovation (and complexity) in the field of high-rise and monumental buildings ;
- development of new execution methods, more simple, rational and industrialized, with, as a consequence, a decrease of the manpower volume ;
- development of transportation infrastructures (motorways, railways, airports, etc.), especially in urban and suburban areas (tram, metro, liaison between various transportation means) ;
- increase of the span length of footbridges and of very large bridges,
- development of the use of new materials like glass, FRP, or very high performance self-compacting concrete.

One major aspect of standardization is to establish a clear relationship between industry, clients, public authorities, etc. from both technical and contractual points of views.

1.3 The Eurocodes : a tool for advanced structural design

The Eurocodes highlight new or advanced concepts for the design of civil engineering works, the most important being :

- durability,

— robustness,

— use of new materials, and

— representation of actions.

These concepts are defined in EN 1990 : Basis of structural design, and developed in the other Eurocodes.

1.3.1 Structural durability

The concept of structural durability covers many aspects in the Eurocode system :

- definition of the design working life, i.e. the assumed period for which a structure is to be used for its intended purpose with anticipated maintenance but without major repair being necessary ;
- definition of exposure classes related to environmental conditions (for example as in Eurocode 2 "Design of concrete structures" in connection with EN 206 "Execution of concrete structures") ;
- reliability differentiation depending on the definition of consequences classes.

Durability is defined in EN 1990 by the requirement that deterioration over the design working life of the structure does not impair the performance of the structure below that intended, having due regard to its environment and the anticipated level of maintenance. In other words, the structure shall be designed to remain normally usable at the end of its design working life. This is very important : in terms of serviceability requirements, for the first time, an international design code states that irreversible serviceability limit states shall not be significantly exceeded when a structure reaches its design working life (e.g. 50 years for a common building).

1.3.2 Robustness

Our modern Societies have sometimes paradoxical, and maybe illogical, attitudes : they less and less accept risk in civil engineering, but are not ready to, or cannot, increase the amount of funds to ensure a higher safety level to people, or even increase the amount of funds devoted to maintenance and strengthening of existing construction works. But risk is a component of human life, and the cost of protection may be very high if, inspired by John Maynard Keynes, we say that "what finally happens is not what is unavoidable, but what is unforeseeable".

Concerning robustness, section 2.1 of EN 1990 includes the following Principle :

"A structure shall be designed and executed in such a way that it will not be damaged by events such as :

- *explosion,*
- *impact, and*
- *the consequences of human errors,*

to an extent disproportionate to the original cause."

And, in Section 3 of EN 1990, another Principle indirectly introduces the responsibility of the designer :

"The selected design situations shall be sufficiently severe and varied so as to encompass all conditions that can reasonably be foreseen to occur during the execution and use of the structure."

1.3.3 Treatment of new materials and actions

The rules (3) and (4) of EN 1990, clause 1.1 (Scope), allow for incorporation of additional rules, Parts, or even Eurocodes to the existing Eurocodes family, and to give this family the most extensive field of application.

(3) EN 1990 is applicable for the design of structures where other materials or other actions outside the scope of EN 1991 to EN 1999 are involved.

(4) EN 1990 is applicable for the structural appraisal of existing construction, in developing the design of repairs and alterations or in assessing changes of use.

NOTE Additional or amended provisions might be necessary where appropriate.

This confirms that the Eurocodes are really a tool for advanced design. However, there is a need to develop specific new Parts which require knowledge and resources.

1.4 Societal needs – The future Construction Product Regulation (RPC)

Societal needs influenced recently the views on the role of the construction industry : the maintenance of the heritage and the sustainable use of natural resources. In fact, these needs are not new, but they have become of vital importance.

The Council Directive 89/106/EEC of 21 December 1988 on the approximation of laws, regulations and administrative provisions of the Member States relating to construction products (CPD), which introduced the six fundamental requirements for construction works (mechanical resistance and stability, safety in case of fire, hygiene, health and the environment, safety in use, protection against noise, energy economy and heat retention) will be replaced by a European Regulation aiming to remove remaining regulatory and technical obstacles to the free circulation of construction products in the European Economic Area (EEA).

Annex 1 of the draft Regulation is devoted to basic works requirements and the first sentence is :

"Construction works as a whole and in their separate parts must be fit for their intended use.

Subject to normal maintenance, basic works requirements must be satisfied for an economically reasonable working life."

The basic works requirement are the six "fundamental requirements" of the CPD, but a new requirement has been added entitled <u>sustainable use of natural resources</u>, with the following explanation :

The construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and ensure the following :

- recyclability of the construction works, their materials and parts after demolition;

- durability of the construction works ;

- use of environmentally compatible raw and secondary materials in the construction works.

From a general point of view, sustainability may be defined as the capability to use national resources of the present without compromising their use by future generations.

The lead market initiative for Europe discussed in section 1.5 hereafter does not only address new buildings (as the Eurocodes so far do), but in particular existing buildings and engineering works which because of the important contribution of the building-stock (new structures form only 1% of the existing stock) would necessitate a substantial move of civil engineering activities to new promising areas.

Maintenance of the heritage means advanced methods for the assessment of existing structures and, in particular, original evolution models for structures. The need for rules and guidelines has been expressed several times during CEN/TC250 meetings. Advanced studies have been performed in many countries and in various fields : it is time to incorporate the results of these studies in documents (CEN Technical Specifications or Reports) intended to become additions to the existing Eurocode family.

Concerning the evolution of standards to take into account the sustainable use of natural resources, the question is widely open. Studies and research are necessary to incorporate in the existing standards advanced concepts like :

- the determination of life cycle costs including costs for energy (which leads to design and use for energy efficiency), and the emission of greenhouse gases (CO_2-equivalent) ;
- scales for the comparison of quality of buildings, especially the consumption of energy kWh_{EP}/m^2 and the emission of greenhouse gases in kg_{equ} CO_2/m^2, all calculated per year ;
- assessment of energy efficiency, i.e. rules for calculating the energy performance following the energy flow (for the energy certificate) in the light of the requirements (in terms of openings for national choices). This refers to the design of new buildings and the assessment of existing buildings and refers to existing European standards for :
  - Energy needs for heating, cooling and working (taking account of losses and gains),
  - Energy use for space heating, cooking, ventilation, domestic hot water and lightning, inclusive of system losses and auxiliary energy and definition of energy ratings.

1.5 The lead market initiative for Europe

The environment of the European standardization has been recently influenced by the “Lead market initiative for Europe”, and the work of TC250 cannot ignore this environment.

The construction market accounts for 10% of GDP and 7% of the workforce[4]. Buildings account for the largest share of the total EU final energy consumption (about 40%) and produce about 35% of all greenhouse emissions[5]. It has been considered that insufficiently coordinated regulations, coupled with the predominantly local business structure, lead to considerable administrative burden and to a high fragmentation of the sustainable construction market. There is a lack of knowledge on possibilities within the existing legal framework for public procurement that could facilitate demand for innovation-oriented solutions.

A different, more goal-oriented approach to construction in the form of a lead market on sustainable construction solutions is needed.

The “Lead Market Initiative for Europe”[6] , launched by the Commission in 2007, aims to unlock market potential for innovative goods and services by lifting obstacles hindering innovation. Six markets have been identified against a set of objective criteria and sustainable construction is one of them. The emergence of these markets will be fostered by :

- notably improving legislation,
- encouraging public procurement, and

[4] Source: EUROSTAT and FIEC.

[5] EU-Research project RELIEF, Work package 13: Purchasing Guidelines for Green Buildings Background Document, 2003.

[6] http://ec.europa.eu/enterprise/leadmarket/leadmarket.htm

- developing interoperable standards.

The latter item naturally calls for expansion of the Eurocodes interoperability in order to integrate innovation and sustainability aspects, such as the protection of environment, resources, energy saving, health protection, and security.

In the context of the Lead Market Initiative, the interaction and combined effects of two market drivers on innovation are of central importance:

- the rational use of natural resources (energy, water and materials),
- the user's convenience and welfare (accessibility, safety and security, indoor air quality, etc.).

For each lead market, a plan of actions for the next 3-5 years has been formulated. See the "Communication from de Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of the Regions" – 21/12/2007 – including its annexes 1 "List of actions" and 2 "Eplanatory Paper on the European Lead Market Approach, Methodology and Rationale".

Besides applying its better regulation policy, the EU may further render the regulatory framework more efficiently by accompanying measures and awareness campaigns. Standardisation measures can contribute significantly the Lead Market initiative for sustainable construction by creating regulatory basis for integrating innovation and sustainability aspects.

CHAPTER 2
EVOLUTION OF THE EUROCODES

Document CEN/TC250 N 630 , dated February 2006, was the final report defining the main evolution axes of the Eurocodes for the future. It gave proposals from CEN/TC 250 with regard to its role in the implementation, use and development of Eurocodes by providing on a European level :

- Maintenance,
- Harmonization (convergence of the technical content of National Annexes),
- Promotion of the Eurocodes,
- Further developments.

2.1 Maintenance

The internal policy concerning maintenance of the Eurocodes was prepared by the Chairman of CEN/TC250 in consultation with his Advisory Panel "Evolution" (doc. CEN/TC250/N707 Final – 16 January 2007).

This "internal policy" was needed to clarify :

- the procedure for providing comments and requests to the Commission, CEN/TC250 and its SCs,
- the procedure of dealing with comments in CEN/TC 250 and its SCs.
- the procedure for the publication of corrigenda and amendments.

The complexity of the maintenance of the Eurocodes is due to :

- the big number of standards (58 Parts, circa 5000 pages),
- the interrelationship between all these standards (several Eurocodes or Parts of Eurocodes may be concerned by a same amendment),
- the degree of progress in the processes of translation, implementation and development of National Annexes in the various Members States.

Maintenance cannot be reduced to simple corrections of mistakes and errors to be made available in accordance with the formal and rigid schedule defined in CEN internal rules and stated in document CEN/TC250/N778. Indeed, the maintenance activity includes :

- the "lessons" of "linguistic" misinterpretations revealed by translations in the various Member States,
- the analysis of "technical" misinterpretation or deviations highlighted in the National Annexes,
- the feedback from the first applications to real construction works,
- the analysis of internal inconsistencies and of inconsistencies with the relevant product, execution and test European standards.

Therefore, the maintenance of the Eurocodes appears to be more and more a new technical and transparent activity aiming at the improvement of the current versions.

For that reason, a big part of the maintenance activity should be considered as a component of what has been called "Further developments".

The situation concerning the publication of corrigenda and amendments by end of 2008 is shown in Table 2.1. This Table demonstrates the precision and the quality of the work carried on by SC members and SC Chairmen even if maintenance is not a glamorous activity.

Table 2.1 – Corrigenda and amendments : situation by end 2008

EUROCODE PART	STATE OF PROGRESS	PUBLICATION OF CORRIGENDA	PUBLICATION OF AMENDMENTS
EN 1990	With CMC	Sent to CMC in – Published Dec 08	
EN 1991-1-1	Rejected (await derogation from BT)	Sent to CMC in June 2008	
EN 1991-1-2	Rejected (await derogation from BT)	Sent to CMC in June 2008	
EN 1991-1-3	Rejected (await derogation from BT)	Sent to CMC in June 2008	
EN 1991-1-5	Rejected (await derogation from BT)	Sent to CMC in June 2008	
EN 1991-1-6	- Publication scheduled for 30/07/08	Sent to CMC in June 2008 - Published	
EN 1992-1-1		Published	
EN 1992-1-2	Publication scheduled for 30/07/08	With CMC since December 2007- Published	
EN 1992-2	Publication scheduled for 30/07/08	With CMC since December 2007 - Published	
EN 1993	All 20 parts being finalized by SC 3 Secretariat		
EN 1994-1-1	Rejected (await derogation from BT)	With CMC since April 2008	
EN 1994-1-2	Publication scheduled for 30/07/08	With CMC since April 2008 - published	
EN 1994-2	Publication scheduled for 30/07/08	With CMC since April 2008 - published	
EN 1995-1-1	With CMC for publication – May 08	Published	Amendment 1 including Corrigendum 2
EN 1995-1-2	Rejected (await derogation from BT)	Corrigendum 2 sent to CMC in June 2008	
EN 1996-1-1	With Secretary – questions back to SC 6 - Dec 08		Received 14/10/08 (Final final version)
EN 1996-1-2			
EN 1997-1			
EN 1997-2			
EN 1998-1	With Secretary –		Received 10/11/08

	questions back to SC 8 - Dec 08		
EN 1998-2	With CMC for translation and processing – June 08	Circulated for UAP	Amd 1
EN 1998-3			
EN 1998-4			
EN 1998-5			
EN 1998-6			
EN 1999-1-1	With CMC for translation and processing – June 08	Circulated for UAP	Amd 1
EN 1999-1-2			
EN 1999-1-3			
EN 1999-1-4			
EN 1999-1-5			

2.2 Harmonization[7]

Member States sometimes complain that the present versions of the Eurocodes require too much input from regulatory bodies that could be avoided by leaving out many possibilities of choice. For example, the open ranges of values for an open number of classes for imposed loads on building floors defined in EN 1991-1-1, could be substituted by specified classes with associated unified values, so that the regulatory choices are restricted to partial factors for actions only.

On the other hand, the Eurocodes and the European technical product specifications are not only intended to improve the competitiveness of the Construction industry in Europe but also outside the European Union. To this end the separation of design rules in the Eurocodes (which are the vehicle to disseminate the European product specifications) into "harmonized" rules and rules under national competence proves to be an enormous advantage, because it gives the desired flexibility to facilitate the acceptance in countries outside EU.

Following the Commission Recommendation (2003/887/EC) of 11/12/2003 on the implementation and use of the Eurocodes for construction works and structural construction products :

4. Member States should, acting in coordination under the direction of the Commission, compare the nationally determined parameters implemented by each Member State and assess their impact as regards the technical differences for works or parts of works. Member States should, at the request of the Commission, change their nationally determined parameters in order to reduce divergence from the recommended values provided by the Eurocodes.

The comparison of NDPs is essential for the evolution of the Eurocodes. CEN/TC250 needs :

- an overview of the approaches or procedures adopted in the National Annexes when alternative possibilities are left for national choice ;

[7] "Harmonization" is intended here as "Convergence of National Annexes developed and adopted in Member-States". "Harmonization" should also be understood between the Eurocodes and the hENs : in this case, Guidance Paper L shall be addressed to which degree CEN/TC250 will be involved.

- an assessment of the number of recommended values adopted by the big majority of Member States ;
- an analysis of the deviations in the choice of some NDPs (technical, economical, etc.) .
- an evaluation of Non-Conflicting Information in the National Annexes.

The preparation of the work for this comparison by JRC is in progress. In particular, a database has been developed to facilitate the analysis of the National Annexes.

The output of this work should be a proposal for a limited number of NDPs in each Eurocode Part. This proposal is the result of a detailed analysis and evaluation of the database of JRC, comparative studies and discussions among the members of the SCs – altogether a huge workload which must be mandated and funded.

2.3 Promotion

2.3.1 Promotion in the EU

The objective of promoting the Eurocodes is the dissemination of the European technical culture in civil engineering outside the EU to support globally the European construction industry.

Promotion cannot be disconnected from education, and many initiatives have been taken at national levels (evolution of teaching in universities, continuing education, workshops, etc.). Actions have been launched at the international level, generally with the participation of CEN/TC250 members and associated experts (visiting professors in foreign universities or lecturers in international conferences and workshops).

At the international level, the major events are :

- The IABSE international conference “Structural Eurocodes”, Davos, 1992; it was the first international conference devoted to a general presentation of the Eurocodes (ENVs).
- The IABSE international workshop « Basis of design and actions on structures » - Delft, 1996
- International Conference on « Safety, Risk and Reliability – Trends in Engineering » - Malta, 21-23 March 2001
- International conference "Eurocodes, building Codes for Europe" – Organised by the Commission - Brussels, 25 June 2002
- Workshop on the Adoption of the Eurocodes in the EU New Members, Accession and Candidate Countries, JRC, Ispra, November 7-9, 2005
- Workshop “Eurocodes: Background and Applications” - A “dissemination of information for training” event – JRC, Brussels, 18-20 February 2008.

To be mentioned, 18 years after the Davos international conference, the future IABSE-fib Conference “Codes in Structural Engineering, Developments and Needs for International Practice”, Dubrovnik, May 3-5, 2010.

2.3.2 Promotion in Third Countries

Many countries outside the EU are revising their construction codes. They are generally interested in the European experience. Some of them do not hesitate to use European standards as reference documents in their public tenders, others ask assistance from CEN and the Commission to assist them in the drafting of their future codes.

The major events on promotion of the Eurocodes in third countries are:

- The workshop “Eurocodes: Building the future in the Euro-Mediterranean area”, organized by the Commission and NATO, Varese 27-29 November 2006;
- The EU-China Conference on Standards and Energy Efficiency in Building, jointly organised by the Chinese Ministry of Construction and the Commission, Beijing, 29-30 January 2008;
- The Workshop “EU-Russia cooperation on standardisation for construction: the Eurocodes, a tool for building safety and reliability enhancement” jointly organised by the Russian Federal Agency on Technical Regulation and Metrology and the Commission, Moscow, 9-10 October 2008;
- The Seminar “Towards The Eurocodes Era – Backgrounds and its Applicaqtions”, Bangkok, 1st-2nd December 2008.

In addition to these promotion activities, it appears necessary to strengthen the capacity of developing countries to participate in CEN. For example, in the development of efficient procedures and tools, CEN and the Commission should ensure the ability of developing countries to adopt and use the European standardization system which may generate confidence in the importing countries that they are implementing best practices in their own markets. This requires these countries to establish national mirror-committees, and link the activities of these mirror-committees with the development of national standards.

2.3.3 How to coordinate better the promotion

A Commission-CEN/TC250 action plan should be now established in order to :

- coordinate all individual actions aiming at the promotion of the Eurocodes,
- organise training workshops intermediate between the “information phase” and the detailed technical education with worked examples,
- envisage the possibility to bring some kind of assistance to non-EU countries to draft their own national building codes in direct line with the Eurocodes.

2.4 Further developments

Further developments correspond to needs expressed by CEN/TC250 members, national representatives (public authorities or consulting experts) and by the Commission itself.

2.4.1 Needs expressed by CEN/TC250 members, national representatives and Industry

From a general point of view, industry :

- is not in favour of quick and deep changes in the existing Eurocodes (their implementation and use is in a starting phase),

- is in favour of improvements with the objective to clarify the existing text and rules, to simplify them as far as possible, to shorten some Eurocodes to reach a better user-friendliness.

The development of new aspects is also very important : in the short term, the main subjects of interest have been identified :

- Guidelines on new materials, with a priority for structural glass, structural applications of FRP and very high performance concrete. These guidelines are intended to become additional rules to be incorporated to the existing Eurocodes, or additional standards to the family of Eurocodes. Review and development of existing rules in the context of the wider use of recycled or re-used materials and components.
- Guidelines for the assessment of existing structures, excluding, at present, historical monuments. No decision has been taken up to now concerning the final status of these guidelines due to the complexity of the problem : they may give rise to a

Eurocode, or to give rise to additional parts (normative or informative) to the existing Eurocodes, or to become a CEN Technical Specification.

- Deepening of the various aspects of the concept of structural robustness, achieving improved protection against earthquakes and fire, as well as further harmonising geotechnical design in Europe.
- Guidelines for the structural design of tensile surface structures, which will be prepared in a network of stakeholders coordinated by the TensiNet Association.

The Eurocodes are based on the semi-probabilistic approach of structural reliability, with the well-known concepts : limit states, designs situations, representative values of actions and resistances, combinations of actions and partial factors. For the long term, the conditions of an evolution of the Eurocodes to adopt a more performance-based style need to be examined, recognising that such performance based criteria need to utilise indicators that can be assessed before and during construction to avoid costly disputes and remediation work later in the life of structures.

But in any case, it is recognised that the Eurocodes need to taken into account the most advanced research results.

2.4.2 Needs expressed by the European Commission

The Eurocodes have been developed primarily to check the structural reliability of construction works, which covers, at the appropriate levels, safety (for permanent, transient and accidental situations), durability, serviceability and robustness. For that reason, the Eurocodes were attached to the fundamental requirements Nr. 1 and 2, and partly 4, of the CPD.

Viewing at the future European regulation (CPR), it is important that the interoperability and contents of the Eurocodes would be evaluated as regards all basic requirements, in particular the 7th basic requirement “sustainable use of natural resources”.

As a consequence, an analysis of the relationship between the design of buildings and civil engineering works and the concept of sustainable development or, more precisely, sustainable use of natural resources, should be developed in the short term. The output would be assessment of feasibility of a future expansion (new codes, new Parts and /or improvements) of the Eurocodes and associated EN standards for methods and products.

2.4.3 Incorporation of some ISO standards to the Eurocodes family

Since many years, a discussion took place regularly during CEN/TC250/SC1 meetings on the time lines to incorporate some ISO standards, after conversion, to the Eurocodes family. In a first step, the relevant standards, both established by ISO/TC98/SC3 are :

- ISO 12494 : Atmospheric icing of structures, and
- ISO 21650 : Actions from waves and currents on coastal structures

These standards are very useful for structural engineers. They need to be re-drafted in a Eurocode style. Other ISO standards may be useful to complement the Eurocodes family.

CHAPTER 3
RESEARCH, BASIC STUDIES AND COOPERATION FOR FURTHER HARMONISATION OF THE EUROCODES

3.1 Introduction

The Eurocodes have been developed on the basis of research and studies carried out by scientific and technical associations. For example, in the case of concrete structures, EN 1992 is mainly based on the work performed by CEB which produced the first "Recommendations" in 1964, then the Model codes 1978 and1990.

Institutionally CEN/TC250 has developed a direct liaison with UIC (Union Internationale des Chemins de Fer) for problems regarding the design of railway bridges (HGB - Horizontal Group for Bridges).

CEN/TC250 is not a research institution, but CEN/TC250 can express societal and technical needs and organise a standardisation activity on subjects where this standardisation activity appears to be useful to industry. Therefore cooperation with scientific and technical international associations is fundamental. Moreover, some research and studies may be directly performed by JRC for direct use of the results by CEN/TC250 in liaison with national research centres.

The major scientific and technical international associations cooperating, directly or through professional activity of CEN/TC250 experts, are :

- JCSS (Joint Committee on Structural Safety) : safety, reliability, risk analysis, probabilistic approach ;
- *fib* (Fédération internationale du béton) : reinforced and prestressed concrete structures (Prof. Walraven and Mancini are past presidents of this association, Prof. Fardis is the new president) ;
- ECCS (European Convention for Constructional Steelwork
- IABSE (International Association for Bridges and Structural Engineering)
- ISSMGE (International Society for Soil Mechanics and Geotechnical Engineering)

Liaisons have been established with European Technology Platforms, in particular :

- ESTEP (European Steel Technology Platform)
- ECTP (European Construction Technology Platform)
- ECP (European Concrete Platform – Resolution Nr. 249 was taken during the CEN/TC250 meeting held in Paris on 12 & 13 June 2008)
- Forestry (European Forest-Based Sector Technology Platform
- HFP (European Hydrogen and Fuel Cell Technology Platform)
- PV (European Photovoltaic Technology Platform)
- SusChem (European Technology Platform for Sustainable Chemistry)
- ESTTP (European Solar Thermal Technology Platform)

3.2 General basic studies and research needs concerning structural safety and robustness

In accordance with the Commission Recommendation (2003/887/EC) of 11/12/2003 on the implementation and use of the Eurocodes for construction works and structural construction products :

6. Member States should undertake research to facilitate the integration into the Eurocodes of the latest developments in scientific and technological knowledge. Member States should pool the national funding available for such research so that it can be used at Community level to contribute to the existing technical and scientific resources for research within the Commission, in cooperation with the Joint Research Centre, thus ensuring an ongoing increased level of protection of buildings and civil works, specifically as regards the resistance of structures to earthquakes and fire.

3.2.1 Research in earthquake engineering

Within the European Union, countries situated in the Mediterranean and Balkan regions experience high seismic activity, while most of the rest of the European countries face some degree of seismic risk. Indeed, a number of the most deadly earthquakes have occurred in Europe. Earthquakes cause human casualties, loss of homes and livelihood, damage in industrial installations and lifelines, resulting in huge economic losses. The economic damage caused by strong earthquakes has increased dramatically during the last decades in developed countries.

Globally, the future in earthquake engineering is mainly risk-based seismic assessment and retrofitting of buildings. European researchers in the field of earthquake engineering have a lasting practice of active collaboration, also with international partners, in the framework of research projects and large-scale experiments, many of which have contributed to the development of Eurocode 8. Compared to other existing codes, Eurocode 8 brings substantial progress by covering aspects not covered until now and by introducing recent analysis methods. Nevertheless, certain fairly important items, that were not sufficiently mature at the time of the finalisation of Eurocode 8, are not fully covered.

The European Commission, national authorities, the European Association for Earthquake Engineering and relevant professional associations have jointly organised a number of workshops with the specific objective to discuss research needs aiming at improved seismic protection in Europe. Such discussions are summarised in two background documents[8,9], where a set of research priorities is identified:

1. Harmonized European seismic hazard map
2. Design of irregular-in-plan buildings for torsion
3. Implications and re-evaluation of primary vs. secondary seismic elements
4. Seismic rules for flat slab systems
5. Seismic rules for prestressed concrete elements and systems
6. Design rules for masonry buildings
7. Seismic assessment and retrofitting of masonry-infilled frame buildings
8. Seismic design of the structure-foundation-soil system
9. Seismic protection of sensitive or valuable equipment and artefacts

New knowledge on these topics will allow Eurocode 8 to profit from recently achieved advances and innovation in the methods and technology of seismic protection and keep it at the forefront of international seismic codes.

The academic, research, design and consulting communities as well as industry have a role to play in different research areas. The required expertise from academia, researchers and practicing engineers includes:

[8] R. Spence, M. Lopes, P. Bisch, A. Plumier. Earthquake risk reduction in the European Union, unpublished report, 2005.

[9] M. Fardis. Pre- and co-normative research needs for Eurocode 8, unpublished report, 2007.

- engineering seismology;
- geotechnical earthquake engineering;
- earthquake engineering, in particular seismic design and codification; testing of materials, near to full-scale concrete systems, including prestressing, and masonry buildings; seismic retrofitting.

Considering industry, valuable contribution can be offered by manufacturers of prestressed components and systems, masonry units and systems, isolation and dissipation devices. It is highlighted that European manufacturers and consultants on seismic protection through isolation/dissipation are world leaders in innovation and field applications and will be very important partners.

Table 3.1 presents for each research topic, the number of years needed to complete the research (duration), an indication of the difficulty and amount of human/economical resources necessary for the successful completion of the research (effort) and the urgency of resolving the open issues (priority).

Table 3.1. Duration, effort and priority for each research item.

Topic	Duration	Effort	Priority
1	3-4 years	Medium	Medium – Low
2	3-4 years	Low	High
3	3-4 years	Low	High
4	3-4 years	Medium	Medium
5	3-4 years	Medium – High	Medium
6	3 years	Medium	High – Medium
7	3-4 years	Medium	High – Medium
8	2nd-3rd generation of ENs	High	Low
9	3 years	Medium	Medium

A more detailed treatment of the research topics described in this section can be found in the JRC report[10] that is based on the two aforementioned background documents.

3.2.2 Research in fire engineering

JRC established a report on the general needs for the Eurocodes fire design Parts[11]. The conclusions of this report are given hereafter :

The research needs […] address standardization needs arising from the state of-the–art of the Eurocodes fire design Parts. They can be divided into the following groups:

A. Further enhancement and/or expansion of the scope and of the basic approaches of fire safety design;

B. Upgrading of the design rules of the different Eurocodes fire design Parts.

In the same time the fundamental knowledge for the structural behaviour in different fire situations needs to be further extended and systemized viewing at the future development of the Eurocodes. In this aspect a third group of research needs should be considered, namely:

C. Expansion of fundamental knowledge on structural behaviour in fire.

With regard to the relevance to the timeline of development of the Eurocodes fire design Parts these three main groups of research needs might be classified as follows:

[10] Pre-normative research needs to achieve improved design guidelines for seismic protection in the EU, EUR 22858 EN, 2007 – **http://eurocodes.jrc.ec.europa.eu**.

[11] Needs to achieve improved fire protection as regards the implementation and development of the EN Eurocodes, EUR 235223 EN-2008 - **http://eurocodes.jrc.ec.europa.eu**.

• Groups A and C: pre-normative research needs;

• Group B: co-normative research needs.

The research priorities to carry out the research described in the various sections of this report are presented in Tables in terms of the necessary time span duration, effort and priority of including the results of the research into the EN Eurocodes. The time span duration is given in terms of the number of years to complete the research; the effort gives an indication of the difficulty, as well as the amount of human and financial resources necessary for the successful completion of the research; whereas the priority reflects the urgency of resolving standardization needs that would give a significant contribution towards improving the current versions of the Eurocodes.

In addition improvement in the consistency between assessment by calculation, through the use of Structural Eurocodes, and by test, through testing methods developed by TC 127 has to be made to avoid unnecessary competition with these two ways of assessing fire resistance performance.

3.2.3 Basic studies and research in the field of actions

EN 1991 : General actions is a key Eurocode, and probably one of the first Eurocodes already implemented and used in several European countries (in particular for the design of bridges). The practical application of several Parts of EN 1991 show that some refinements may be envisaged in view of future revisions, in particular :

- EN 1991-1-1 – imposed loads on building floors (effects of influence areas both for vertical and horizontal loads, simplified rules for chess board load arrangements, vertical loads due to moveable partition walls, etc.);
- EN 1991-1-2 – Fire actions (see 3.2.2) ;
- EN 1991-1-3 – Snow loads (refinement of existing snow maps, extension of the European snow map to cover all CEN countries, shape coefficients, etc.) ;
- EN 1991-1-4 – Wind actions (harmonization with EN 1993, extension of the European wind map, wind-snow, wind-ice and wind-rain interactions, etc.) ;
- EN 1991-1-7 – Accidental actions (liaison with EN 1990, robustness, risk oriented design rules, gas explosion rules and consequences, etc.);
- EN 1991-2 – Traffic loads on bridges (evolution of real traffic loads on road and railway bridges, vibrations of footbridges, etc.)

3.2.4 Basic studies and research in the field of building robustness

Many ideas are behind the concept of robustness. It is obvious that it covers the prevention of “disproportionate collapse” of building structures resulting from terrorist or malicious acts. Studies have been developed, mainly in universities, but only on particular aspects. Indeed, different approaches need to be developed depending on the type of structure and the type of basic constituent materials. But of course, robustness is not only a matter of resistance to malicious acts : seismic performance, resistance to exceptional actions, resistance to fire and to external blast wave loads are important aspects.

This topic needs to be correctly managed to establish, *in fine*, design rules. Of course, rather heavy and expensive research will probably be necessary.

3.3 Basic studies and research needs for the development of guidelines and rules for materials not yet covered by the Eurocodes

3.3.1 Structural glass

Recent architectural trends and technological developments have brought changes in the use of glass in buildings. Many glass products and configurations may be used by structural engineers and architects, to be selected depending on various parameters, in particular actions and loads that construction works have to sustain.

An important concern is the need for Europe to maintain a high level of technical proficiency, if it is to match the efforts of its potential competitors in the ever-increasing global market for glass products. Potential customers stipulate that projects are designed according to internationally recognised standards.

Demand growth for glass is driven not only by economic growth, but also by legislation concerning safety, including fire protection, security, noise attenuation and the response to the growing need for energy conservation.

Furthermore, the lack of standardisation leaves opportunities for deficient glass products and services to slip through the quality-assurance processes established in the construction sector. Standards are essential to limit the number of structural failures that arise from bad design or construction practice.

Therefore, it is time to establish, in a first step, unified guidelines, then a CEN Technical Report/Specification, and finally a Eurocode which would give information on the structural performance of glass, requirements to ensure the appropriate reliability of structures, and design rules. CEN/TC250 and the JRC have prepared a report that describes the rationale and justification for a European code for the design of glass structures[12].

A layout similar to that of the Eurocodes is proposed: a generic Part 1 for the design of glass components independent of any application field and Parts 2 to 9 which are related to specific glass applications and give supplementary rules. An example of detailed table of contents is given in Annex B of this document.

The layout of the guideline is also an indicator of the sequence of works. The first working package should include Part 1 and Part 2 that could be based on EN 13474. The other working packages would follow. The works will profit from existing national and international standards, technical regulations and codes of practice, as well as from new research, where necessary.

3.3.2 Fibre reinforced polymers (FRP)

Fibre reinforced polymers (FRP) have been used in the construction sector since the mid-1980s, mostly for the strengthening of existing buildings and bridges, and increasingly since the mid-1990s as pilot projects for new structures.

The FRP sector in the EU market is estimated to be worth around €7 billion and this value is expected to grow by 3,8% per annum. However, recent data show that the European market share for the worldwide export of plastics reduced, while the Asian (particularly Chinese) share increased. At the same time, the use of FRPs in the transportation and construction markets in the USA has grown substantially. The leadership of the USA market is demonstrated by the fact that it comprises approximately 80% of the vehicular bridges and 50% of the pedestrian bridges.

The safe implementation of FRP composites and the need to promote the competitiveness of this emerging industrial sector are the main drivers quoted by representatives from the European construction associations.

New structural products and kits made from FRP are being developed, patented and applied without any certification. The longer the FRP construction is allowed to go ahead using non-standardised technical solutions, the greater the risk of failures. The only means to reduce this risk is the implementation of standards explicitly geared to FRPs.

[12] Purpose and justification for new design standards regarding the use of glass products in civil engineering works, EUR 22856 EN, 2007 – **http://eurocodes.jrc.ec.europa.eu**.

The current situation results in obstacles to the free circulation of FRP products and related services within the European Union, due to the multitude of products, design manuals and recommendations that are not immediately comparable and which make the selection process for the users more difficult.

In the absence of European standards, it is possible that USA producers will use their proven expertise and consolidated standardisation status to compete in the European market. Just as notable though, is the potential for expansion in the Asian, and, particularly, the Chinese market. The lack of codes could prove to be a stumbling block for the successful bid by a European company in the currently largest construction market in the world.

CEN/TC250 and the JRC have prepared a justification document for the development of standards for the design of FRP products in civil engineering[13]. It is proposed that the European Commission should endeavour to expand the current series of Eurocodes with the final addition (after Technical Guideline and CEN Technical Report/Specification) of a new Eurocode to provide a method for calculating the mechanical strength of structural elements consisting entirely, or in part, of FRP composites.

On the basis of a go-ahead for a new code, the planning and consultation stage will be conducted by the key stakeholders. This will concern on one hand the key EU-wide organisations representing the industrial parties and on the other, the regulatory authorities from Member States as well as CEN, EOTA and research institutions. The knowledge-base for the development of the new Eurocode will be compiled from available national, European (EN) and international standards, e.g. ISO, as well as results of pre-normative basic research.

Through numerous letters of interest, European industries have clearly demonstrated a keen interest in economically supporting the activities related to the development of a new code.

An example of table of contents for pultruded members and further details on the standardisation needs regarding FRPs in construction are given in Annex C.

3.3.3 Ultra-high and self-compacting concrete

High Strength/High Performance Concrete (HSC/HPC) is the object of particular interest and extensive research. Its use in construction is increasing, but clients and designers often express the wish of an introduction of models, rules and requirements in EN 1992 for this material, with an extension to ultra-high performance fibre reinforced concrete (UHPFRC) and to self-compacting concrete. Many studies and research has been performed by laboratories, universities and constructors. Recommendations have been already published by scientific and technical organizations, concerning mechanical properties, time effects, fatigue, temperature effects and contact with water. The information is rich and it should not be too difficult to define harmonized design rules and requirements.

3.4 Research needs in structural behaviour

3.4.1 Evolution models for existing structures

Having in view assessment and retrofitting of existing structures, many studies have been performed at national levels as well as at the international level by technical and scientific associations[14].

To estimate the evolution of existing structures, specific models of behaviour are needed. As an example, for reinforced or prestressed concrete structures, material properties evolve : for concrete, the evolution of its compressive and tensile strength is influenced by the carbonation depth and the chloride content and penetration. For prestressing and

[13] Purpose and justification for new design standards regarding the use of fibre-reinforced polymer composites in civil engineering, EUR 22864 EN, 2007 – **http://eurocodes.jrc.ec.europa.eu**.

[14] To be mentioned the JRC Scientific and Technical Report "Assessment of Existing Steel Structures : Recommendations for estimation of Remaining Fatigue Life" – EUR 23252 EN – 2008.

reinforcement, the mechanical properties evolve due to corrosion or poor quality of the grouting of tendons. This has consequences on the yield stress and tensile strength, and on the ultimate elongation.

Finally, specific models for the structural behaviour of reinforced concrete structures subjected to corrosion are needed, taking into account the loss of bar section and modification of material characteristics, cracking of concrete, strength reduction for concrete in compression and in tension, bond loss.

These specific models, for all relevant construction materials, need to be incorporated in the existing Eurocodes, based on the work of experts in national or international associations, under the responsibility of CEN/TC250 Sub-Committee chairmen.

3.4.2 Membrane structures

Following a proposal from Prof. Marijke MOLLAERT, professor at the Flemish Free University of Brussels (VUB), technical guidance for the structural design of tensile surface structures will be prepared in a network of stakeholders coordinated by the TensiNet Association, an international association already very active in this field (**www.tensinet.com**), under the responsibility of CEN/TC250. The network will include technical textiles producers, tensile surface structures manufacturers, contractors, architects, engineers and designers, research institutes and universities.

An example of table of contents is given in Annex E.

3.5 Basic studies and research needs for further harmonization of geotechnical design in Europe

A document, dated 29 June 2007, was established by the Maintenance Group and members of CEN/TC250/SC7 Geotechnical Design.

It gives at the mentioned date the status of harmonization in Eurocode 7 and describes the various fields for research, including questions of sustainability and economy.

Hereafter, the summary of the study is recalled.

The report describes the actual state of standardization in geotechnical design in the European countries and shows where it is rudimentary and further efforts for harmonization are urgently needed. Concepts and items are presented showing how, by research, the potential for further harmonization of geotechnical design in Europe can be investigated and decisions for further standardization in Subcommittee 7 can be supported.

For typical geotechnical structures and/or limit state of EC 7-1 and for the recommended procedures of EC 7-2 research should be done in the following steps :

– Collection of detailed information on the application of EC 7-1 (i.e. design approach, partial factors and calculation model) in the Member States for the verification of the geo-technical structure and/or limit state ;

– Comparative calculations and studies on the different applications of the EC 7-1 with respect to the resulting design ;

– Evaluation of the results with respect to the harmonization potential ;

– Recommendations for the adaptation of EC 7-1 and/or National Determined Parameter specially in view of improving the sustainability and economy of geotechnical design.

To put this research programme into action about 450.000 € are needed. The detailed items for research are listed in an annex.

3.6 Bridges

3.6.1 General

Bridges belong to those structures for which quality management in view of sustainability has a long tradition.

Fig. 3.1 demonstrates the life cycle of a bridge, its design, construction, its use with inspections and maintenance and at the end of service life its demolition and recycling or reuse.

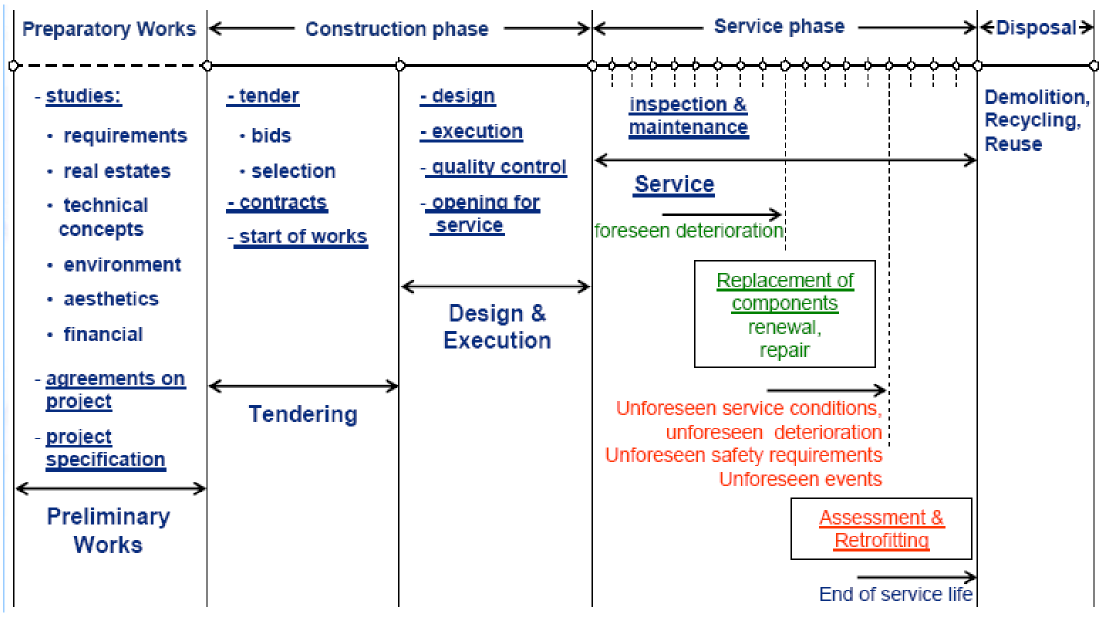

Fig. 3.1 – Life cycle of a bridge

Maintenance as foreseen in the design includes the renewal or repair of components the life of which is smaller than that of the main structure of the bridge, as e.g. of stayed cables, expansion joints, structural bearings, etc.

If however during service unforeseen events occur, as e.g. the service requirements change or unforeseen deterioration takes place, then a new assessment of safety, serviceability and remaining fatigue life is necessary to decide on measures for retrofitting or if that is not possible or uneconomical on substitution.

In order to facilitate the assessment and retrofitting of existing bridges the Joint Research Centre has published jointly with the European Convention for Construction Steelwork several technical reports that may be source documents for the further works on new Eurocodes:

3.6.2 Railway bridges

An international inquiry, which geographically covered most of Europe and its major climate zones, was launched and its results were analysed during 2004/2005 in the project "Sustainable Bridges – Assessment for Future Traffic Demands and Longer Lives", an Integrated Research Project within the Sixth Framework Programme of the European Commission (see www.sustainablebridges.net).

The European railway bridge stock is generally quite old and contains a mix of bridge types. The predominant type of bridge is the arch, mostly having brick construction, with lesser, but almost equal, quantities of metallic and concrete bridges. The stock also contains a smaller number of composite bridges. The majority of European railway bridges are small span (below 10m), with spans over 40m only accounting for 5% of the bridges in the survey. Most long span bridges are of metallic construction.

The five priority research topics turned out to be:

- assessment (main priority, to reach better assessment rules and confirmation of dynamic factors);
- structural behaviour and monitoring;
- repair and strengthening;
- dynamic effects and vibration;
- life cycle analysis.

The global purpose of sustainability for railway bridges is to assess their readiness to meet the demands of the 2020 scenario which requires increased capacities with heavier loads to be carried and bigger forces to be absorbed due to longer faster trains and mixed traffic.

CHAPTER 4
SUSTAINABILITY IN CONSTRUCTION

4.1 General - Definitions

The most often quoted definition of sustainability is “meeting the needs of the present without compromising the ability of future generations to meet their own needs”. It was first introduced in 1987 in the Report of the World Commission on Environment and Development, known by the name of its Chair as “Brundtland Commission”.

Sustainable development is therefore development that meets the needs of the present without compromising the ability of future generations to meet their own needs. In other words, sustainability is the “capacity to use natural resources of the present without compromising their use by future generations”.

Figure 4.1 shows the key international events related to political strategies and decisions for sustainability, the evolution of concepts and ideas and the gradual involvement of stakeholders.

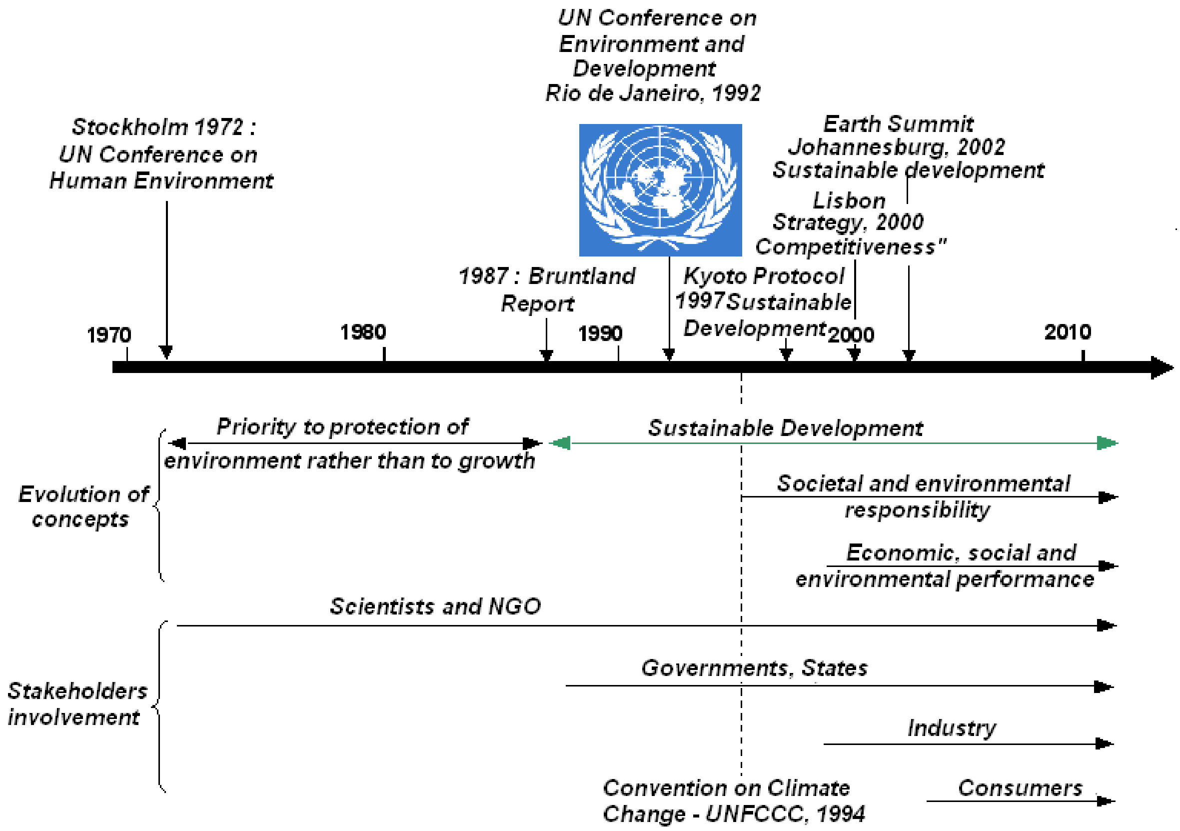

Figure 4.1 – Development of the “Sustainability attitude”

The following two events are of special importance for the construction sector:

- The adoption in 1997 of the Kyoto protocol aiming at stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system The actions needed for reduction of greenhouse gas emissions relate to sustainable development, e.g. energy efficiency, use of renewable energy sources, environment friendly technologies, etc..
- The launching at the European Council in Lisbon in 2000 of the so-called Lisbon strategy aimed at making the EU the most competitive economy in the world by 2010

with emphasis on the transition to a competitive, dynamic, knowledge-based economy and on decoupling the economic growth from the use of natural resources. A stronger European economy is vital for the sustainable development; it will help generate the means to invest, for example in a cleaner environment, in better education and health care and in social protection. In turn, more sustainable use of natural resources and increased social justice are critical to the economic success.

Sustainable development is a long term goal of the European Union, which is set out in article 2 of the EU Treaty. The strategy for sustainable development, adopted in 2001[15] and amended in 2005[16] provides an EU-wide policy framework to deliver sustainable development. It rests on four pillars - economic, social, environmental and international - which need to reinforce one another. The strategy identifies seven unsustainable trends on which action needs to be taken: social exclusion and an ageing society (already covered by the Lisbon Strategy), climate change and energy, transport, production and consumption, natural resources, health, and promotion of sustainable development globally. This strategy lists a whole range of operational and numerical targets and specific measures at EU level to attain these objectives.

4.2 Sustainable development in the construction sector

The building and construction sector plays an important role in sustainable development, because

- it is a key sector in national economies,
- the built environment represents a large share of the economic assets of individuals, organizations and nations,
- it is one of the single largest industrial sectors, with all the consequential aspects of employment, economic importance and environmental impact,
- proper housing and infrastructures are key elements in determining the quality of life, and
- it has a significant interface with poverty reduction through the provision of basic services and the potential opportunities to engage the poor in construction, operation and maintenance activities.

The building sector in Europe uses[17] about 40% of total energy consumption. Space heating is by far the largest energy end-use of households in Member States (57%), followed by water heating (25%). Electrical appliances and lighting make up 11% of the sector’s total energy consumption. Moreover construction activities consume more raw materials by weight (about 50%) than any other industrial sector and consequently construction and demolition activities cause also the largest waste streams (between 40 and 50%), although most of it is recyclable.

Sustainable construction can be defined as a dynamic of developers of new solutions, investors, the construction industry, professional services, industry suppliers and other relevant parties towards achieving sustainable development, taking into consideration

[15] Commission Communication of 15 May 2001 'A Sustainable Europe for a Better World: A European Union Strategy for Sustainable Development' (Commission proposal to the Gothenburg European Council) [COM(2001) 264 final - not published in the Official Journal].

[16] Commission Communication of 13 December 2005 on the review of the Sustainable Development Strategy - A platform for action (COM(2005) 658 final - not published in the Official Journal).

[17] EU-Research project RELIEF, Work package 13: Purchasing Guidelines for Green Buildings Background Document, 2003

environmental, socio-economic and cultural issues[18]. It embraces a number of aspects such as:

- design and management of buildings and constructed assets,
- choice of materials,
- building performance, as well as
- interaction with urban and economic development and management.

Different approaches may be followed according to the local socio-economic context; in some countries, priority is given to resource use (energy, materials, water, and land use), while in others social inclusion and economic cohesion are the more determining factors.

Sustainable construction is an integral part of the European policy on sustainable consumption and production, which builds on the following elements:

- Integrated Product Policy (IPP)
- Thematic Strategy on the Sustainable Use of Natural Resources
- Thematic Strategy on Waste Prevention and Recycling
- Eco-Management and Audit Scheme (EMAS)
- Ecolabel Scheme
- Environmental Technologies Action Plan (ETAP)
- Green Public Procurement (GPP)
- Eco-design of Energy Using Products Directive (EuP)
- European Compliance Assistance Programme - Environment & SMEs

A key element of sustainability is related to the energy issue. As the building sector is at present responsible for more than 40% of the EU energy consumption, the requirement to reduce CO2-emission and EU-energy dependence results in:

- the reduction of energy demand,
- intelligent use of renewable energies.

4.3 Standardisation for sustainable construction

In the case of European standards, and because all Member States have their own personality, the strategy of sustainability needs to be defined, taking into account the context in the built environment, the social environment, which includes social equity, cultural issues, traditions, heritage issues, human health and comfort, social infrastructure and safe and healthy environments. Special attention should be brought to the disparities in standards of living between developed and developing countries.

Considering all aspects of sustainability leads to an integrated design of structures that does not meet only the traditional requirements for:

- mechanical resistance and stability, and
- safety in case of fire

but that meets all seven “Basic Works Requirements” of the future “Construction Product

[18] Accelerating the development of the sustainable construction market in Europe. Report of the Taskforce on sustainable construction for preparation of COM(2007) 860 « A lead market initiative for Europe »

Regulation” (CPR), i.e.:

1 Mechanical resistance and stability

2 Safety in case of fire

3 Hygiene, health and the environment

4 Safety in use

5 Protection against noise

6 Energy economy and heat retention

7 Sustainable use of natural resources.

As various requirements may lead to conflicting directions for design, a first conclusion is that a concerted action is necessary to develop a consistent European Standard Family that is suitable for structural optimisation.

Basic works requirements	1	2	3	4	5	6	7
	mechanical resistance and stability	resistance to fire	hygiene, health, environment	safety in use	protection against noise	energy economy heat retension	sustainable use of natural resources
CEN/TC250 + CEN/TC´s	Eurocodes Product Standards			EC's PS			
CEN/TC89 CEN/TC228 CEN/TC156 CEN/TC88 CEN/TC113						Design methods, Products	
CENTC350 CEN/TC351							Sustainability

Figure 4.2 – The basic works requirements and CEN/TCs

4.4 Eurocodes and sustainable construction

To uphold the Eurocodes as the most advanced codes for design of buildings and civil engineering constructions, they should become a tool that is as comprehensive as possible to the designers/users.

The need of a consistent approach to tackle the different dimensions of sustainable development in construction, such as effective protection of the environment, prudent use of natural resources, maintenance of high and stable levels of economic growth and employment, naturally calls for examining the possibilities for making the Eurocodes as comprehensive as possible tool for the designers/users. This activity should concentrate on assessing the feasibility of integration of additional aspects of sustainability (e.g. durability, robustness to natural and man-made hazards, health, environment, energy efficiency) and of incorporation of new and emerging technologies in the Eurocodes. In the same time the interoperability of the Eurocodes with the other standards involved in the assessment of sustainability should be checked and improved if necessary.

Focus should be made on the analysis of the extent and mode of incorporation of the energy efficiency/performance of buildings, and health and environment policy requirements in the existing and new design standards. On this basis the scope of the extension and/or amendment of the Eurocodes should be assessed and delineated.

It appears to be desirable to establish guidelines, dealing with analysis and optimisation of civil engineering works in connection with sustainable development, for experts who will be in charge of the first deep revision of the Eurocodes and of further developments of the

Eurocodes. These guidelines should include developments on the following topics:

- Respect of Environment and sustainable use of natural resources;
- Preserve human health and enhance the hygiene of life in the built environment;
- Ensure the required (or desirable) durability.

In the same time the capacity of the Eurocodes to support the methods used in assessment of the sustainability needs to be examined and if necessary, enhanced. In this connection the following methods should be considered:

- Assess and reduce the environmental impact through a Life Cycle Analysis;
- Assess and optimise the overall cost through a Life Cycle Cost calculation;
- Taking into account maintenance and management, anticipate future needs;
- Risk analysis.

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ANNEXES

ANNEX A
ASSESSMENT AND RETROFITTING OF EXISTING STRUCTURES

This draft Annex was prepared by the CEN/TC250 Chairman's Advisory Panel (CAP) "Assessment". It should be understood that its content is presented as an illustrative proposal – but not wholly fixed at this stage – and that some flexibility will be retained when the work will be undertaken.

1. Objectives

(1) This proposal aims at developing European technical rules for the assessment and retrofitting of existing structures complementing the CEN EN Structural Eurocodes and the associated CEN standards for products, prefabricated components and execution.

(2) This proposal is motivated, and considered necessary, by the expanding and extensive construction activities in retrofitting buildings and engineering works that aligns with the new strategy for sustainable construction in Europe. This strategy recognises the importance of extending the life of existing assets thereby delivering environmental, economic and socio-political benefits. There is a lack of an applicable set of harmonised European wide assessment and design rules, that gives rise to a concerted European effort.

(3) The new rules arising from the proposal will establish a communication platform for architects and engineers and provide the technical basis for the construction industry to change to new markets and activities.

(4) The new rules also aim at matching the efforts of Europe's main competitors from America and Asia and at strengthening existing and finding new markets outside Europe.

2. Sustainable development

(1) A sustainable development for construction will not simply respond to new needs by adding new buildings to the existing building stock or demolish old buildings and simply substitute them by new ones: It will analyse existing buildings to identify their possibilities for meeting sustainability goals.

(2) An assessment of existing structures may be necessary in case of:

- rehabilitation of an existing constructed facility during which new structural members are added to the existing load carrying system,
- adequacy checking in order to establish whether the existing structure can resist loads associated with the anticipated change in use of the facility, operational changes or extension of its design working life,
- repair of an existing structure, which has deteriorated due to time dependent environmental effects or which has suffered damage from accidental actions for example due to impact, explosion, fire or earthquake,
- doubts concerning the actual reliability of the structure,
- requirements from authorities, insurance companies or owners or from a maintenance plan.

(3) General principles of sustainable development regularly lead to case 2 (defined above) in majority of practical cases in conjunction with severe economic constraints.

(4) Hence the approach for the assessment of an existing structure is in many aspects different from that for designing the structures of new buildings. However the EN Eurocodes still apply for new products and prefabricated components used in existing structures.

(5) The application of design-orientated methods to the assessment of existing structures often leads to a high degree of conservatism. This conservatism has severe economic, environmental and socio-political consequences when it results in satisfactory structures being condemned as unsafe, thereby leading to an unnecessary investment of resources in replacement or retrofitting, with its associated disruption.

3. Main growth drivers

(1) The main growth drivers are as listed below:

Structure	Demand	Growth drivers
Building	Sustainable development	Re-use of buildings in urban development
	Energy saving (heating)	Energy saving legislation and building regulations, reducing of energy loss of building, activation of structure for heat retention
	Energy saving (cooling)	Energy saving legislation, reduction of air-conditioning load in buildings. Preventing non air-conditioned buildings from overheating.
	Fire safety	Legislation in view of safety evacuation of occupants, safety of fire-fighters and protection of neighbours.
	Safety for other accidental situations	Adaptation to new occupancies and uses, accounting for accidental loads or seismic loads. Requirements for robustness
	Serviceability and security	Improving of vibration behaviour, use of daylight, elevators
	Acoustic	Legislation against noise from outdoor of from the building
Bridges	Sustainable development	Using existing lines and crossings
	Security of use	Operational requirements for dimensions of bridges, clearances, etc., no disruption of traffic by maintenance and repair
	Safety	Load carrying capacity, resistance to accidental situations, seismic resistance and, in some circumstances, fire safety.
	Durability	Reduction of maintenance costs, enhancement of residual life

4. Main topics

(1) A common approach for the assessment should be based on the following principles:

- currently valid EN Eurocodes for the verification of structural reliability should be applied; historic National Codes valid in the period when the structure was designed may be used as guidance documents to identify possible critical problem areas.
- actual characteristics of structural materials, actions, geometric data and structural behaviour should be considered using the original design documentation including drawings.

(2) The main topics to be covered by the new harmonised European document on assessment will be:

- methodology of collecting, evaluating and updating data,
- recommendations for the verification applying the partial factor method and/or using directly the probabilistic methods consistent with EN 1990
- target reliability level of existing structures taking into account residual life time, consequences and costs of safety measures,
- assessment based on satisfactory past performance,
- recommendation concerning intervention and report.

(3) Basic principles for retrofitting equal to any type of material and way of construction are:

- compatibility of structural components and materials of the old structure and the new structure in view of structural behaviour and durability, which leads to optimisation with synergic action,
- as far as historic structures under protection of monuments are concerned: Reversibility of the structural intervention so that future generations can modify the technology without any damage to the features of the historic construction.

(4) Specific assessment and retrofitting methods that are linked with regional peculiarities (e.g. from shortcomings in old National design or execution standards or the use of particular materials or building techniques) are intended to be included in National Annexes.

5. Source Documents

(1) There are International and National Standards and Guidelines either emerging or available, which can be used as base documents or supporting documents for the new European document on the assessment and retrofitting of existing structures.

(2) International Standards and Reports are:

- ISO 13822: 2001 — Basis for design of structures – Assessment of existing structures
- fib bulletin 17 (technical report): — Management, maintenance and strengthening of concrete structures
- JRC-ECCS-Joint report: — Assessment of existing steel structures
- EN 1504-1ff (CEN/TC 104/SC 8) — Products and systems for the protection and repair of concrete structures
- FP7-Report: — Sustainable steel bridges for railways.
- RILEM Publication S.A.R.L. — Probabilistic Assessment of existing Structures

(3) There are also National Standards for the assessment and retrofitting of bridges in use, e.g. in UK (Highways Agency requirements), Germany (DS805 and Leitfaden für den Sicherheitsnachweis vorhandener Straßenbrücken), the Czech Republic and Austria.

(4) A more general National approach are "Swisscodes for existing structures" which are currently being developed using existing codes SIA 469, SIA 462, SIA 162/5. The national Code SIA 269 (Basis for conservation of existing structures) was recently released for public inquiry.

(5) Also background documents to the existing EN Eurocodes that may be consulted for applying more sophisticated methods may be used.

6. Organization of Work

(1) The new European technical rules for the assessment and retrofitting of existing structures will be worked out using the existing organization of CEN/TC250.

(2) The works are initiated, supervised, and coordinated by a Horizontal Group (HG) for "Assessment and retrofitting for existing structures".

(3) The contributions of the subcommittees SC1 to SC9 could be developed in Working Groups (WG) of the relevant SC's and of CEN/TC250 Basis of structural Design.

7. Work Programme

(1) The works shall be performed in several steps:

Step 0: Preparation of a "European guidance" giving a unified European approach and published as "JRC-Scientific and Technical Report".

Step 1: Agreement of CEN/TC250 to apply for a CEN-Working item for preparing a CEN-document on the basis of the "JRC-Scientific and technical report" and final preparation of the appropriate CEN-document.

Such a CEN-document could be a CEN-TR (Technical Report) or CEN-TS (Technical Specification) or an amendment and supplement of the existing EN Eurocodes.

Step 2: Decision of CEN/TC250 whether to start a process converting the CEN TR or CEN TS into EN Eurocodes or parts added to the existing EN Eurocodes.

(2) The work for steps 0 and 1 shall be performed in the period 2008 to 2013. The schedule for the work programme of step 2 should follow the review and revision process of the Eurocodes.

ANNEX B
TECHNICAL GUIDANCE FOR THE DESIGN OF GLASS STRUCTURES

As for Annex A, it should be understood that its content is presented as an illustrative proposal – but not finalised at this stage – and that some flexibility will be retained when the work will be undertaken.

1. Objectives

This section describes the rationale and justification for a European code for the design of glass structures, its parts or kits for use in civil engineering works, outlining the specific aims and reasons for standardisation in this area.

Whereas glass components were used as infill elements in the past, modern architectural concepts include glass components as load-bearing elements. The expanding use of glass products in the construction sector is accompanied by the lack of a set of European design rules for the safe implementation of glass products.

No less important is the need for Europe to maintain a high level of technical proficiency, if it is to match the efforts of its potential competitors in the ever-increasing global market for glass products. Leading European industries are strengthening the existing and finding new markets outside of Europe. Nevertheless, their potential customers stipulate the need to back up their designs with internationally recognised standards.

CEN/TC250 and the JRC have prepared a justification document for the development of standards for the design of glass products in civil engineering[19]. It is proposed to prepare pre-normative technical guidance for the design of structural glass, as:

- glass consumption in the building sector has increased;
- there is a large global demand;
- European design and product standards are needed to make the European glass industry more competitive.

2. Market situation and trends

Today's architects are using larger glass surfaces in their designs, with increasing added functionality and complexity. The global market for float glass in 2004 was approximately 38 million tons (~5 billion m^2). Figure B.1 shows that most of the world's float glass (90%) goes into buildings, while automotive applications account for around 10%. Europe, China and North America account for 75% of the total demand for glass. The four leading glass companies in the world together produce 62% of the world's high-quality float glass.

Over the past 20 years, glass demand has grown more quickly than Gross Domestic Product, as shown in Figure B.2. Over the long term, glass demand is still growing at around 3.9% per annum. However, the lack of design standards for use of glass in civil engineering works can, in the long term, decrease the growth of glass consumption in structural applications. This is an important issue, because in the next decade there is expected to be a quick growth of flat glass consumption in developing markets. Appropriate standards for building practice are more needed in these markets than in developed ones, where the growth will be slower in the future.

[19] Purpose and justification for new design standards regarding the use of glass products in civil engineering works, EUR 22856 EN, 2007 – **http://eurocodes.jrc.ec.europa.eu**.

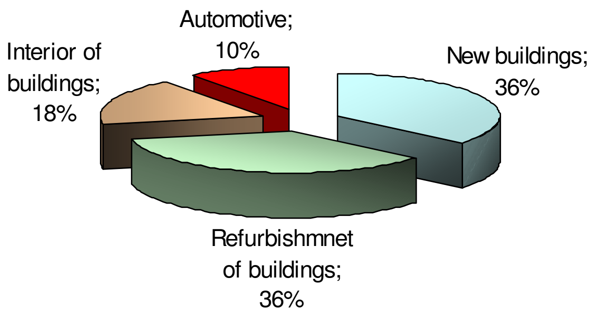

Figure B.1. Float glass consumptions for various applications.

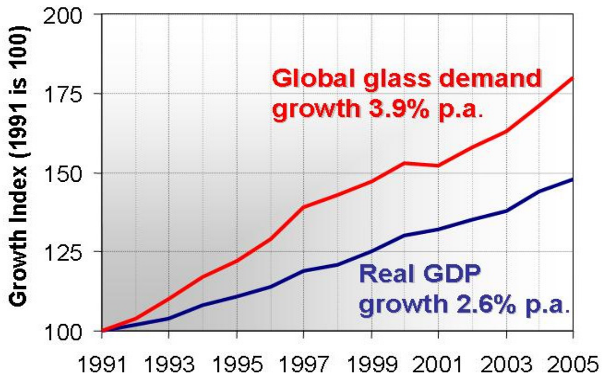

Figure B.2. Comparison of the growth indices of glass demands and GDP.

3. Main growth drivers

Demand growth for glass is driven not only by economic growth, but also by legislation and regulations concerning safety, noise attenuation and the response to the growing need for energy conservation. Table B.1 lists a number of growth drivers for flat glass consumption and the corresponding performance requirements for glass products.

Table B.1. Growth drivers for flat glass consumption.

Demand	Growth drivers
Energy saving (heating)	Energy saving legislation and building regulations, reduction of energy loss from buildings and energy labelling of windows.
Energy saving (cooling)	Energy saving legislation, reduction of air-conditioning load in buildings. Preventing non air-conditioned buildings from overheating.
Safety	Increasing legislative requirement for safety glass.
Security	Requirement for transparency combined with security/safety features.
Fire protection	Compliance with fire regulations combined with requirements for good light transmission.
Acoustics	Increasing noise levels caused by traffic, aircrafts etc progressively covered by legislation.
Self-cleaning	Reduce use of detergents and improve safety of cleaning works on high-rise buildings. Product range now extended to incorporate self-cleaning features.

Regarding safety, the lack of standardisation leaves opportunities for deficient glass products and services to slip through the quality-assurance processes established in the construction sector. It is possible that an unregulated market, currently characterised by the potential to deliver wide profit margins, could result in the implementation of sub-standard applications that one day may result in failures. Standards are essential to limit the number of structural failures that arise from bad design or construction practice.

4. Purpose and contents of the technical guideline

The preparation of the guideline for the design of glass components in buildings and civil engineering works is aimed at laying the ground for a future Eurocode and/or ETA Guideline. Therefore, this guideline will be prepared by a network of stakeholders coordinated by the JRC. The network should include glass producers and fabricators; design offices; representatives from CEN/TC250, CEN/TC129 (Glass in building) and EOTA; research institutes and universities.

A layout similar to that of the Eurocodes is adopted, see Figure B.3. The guideline consists of:

- a generic Part 1 for the design of glass components independent on any application field;
- application Parts 2 to 9 which are related to specific glass applications and give supplementary rules to Part 1.

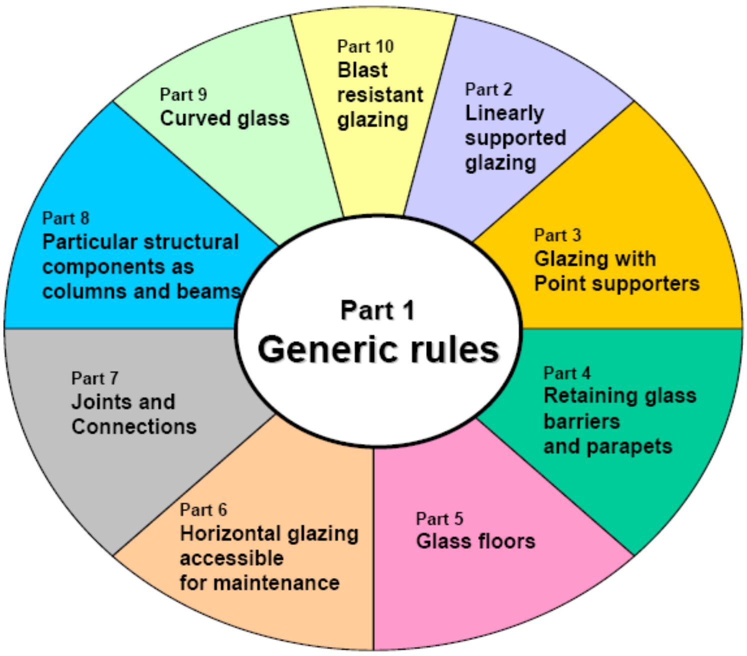

Figure B.3. General layout of the guideline for the design of structural glass.

The list of contents for each part is shown in Tables B.2 to B.10 that present also items which will be the subject of research and international agreement.

Part 1 can, as far as possible, be based on EN 13474. However, various items as the risk table, particular testing procedures, the consistence with existing product and test standards, ψ values, γ_M values, approaches, residual strength and requirements for execution need further works.

Part 2 can, as far as possible, be based on EN 13474. A particular task is to adjust the safety approach to the experience with glasses that have well proved their safety in practice.

Particular tasks in Part 3 are to agree on the way how FEM modelling can give reliable results and to link the input for FEM modelling to the results of test procedures.

A particular task of agreement in Parts 4 and 5 is to clarify testing scenarios (loading condition and loading time) and procedures.

5. Existing standards and source documents

European countries are leading both on the level of national and European standards. These standards are related to use of glass in buildings, in particular:

- classification of different types of flat glass;
- test methods for the determination of mechanical properties of glass sheets;
- performance and blast resistance (USA);
- tolerances;
- fixings;
- conformity evaluation (EN);
- sealants and sealing of glass panels (EN, ISO);
- durability and appearance of glass panels (ISO);
- energy efficiency issues.

Other useful source documents are:

- codes of practice for the design and installation of glass panels issued as British Standards;
- technical regulations related to structural use of flat glass in Germany;
- the working document "Ouvrages particuliers en verre" that is under development by the Belgian Building Research Institute.

The brief overview of standards related to use of glass in buildings clearly shows that there are no standards that would in general cover the design of structural elements and structures made of glass products. Therefore, a concerted attempt towards the development of such standards is required.

6. Work programme

The works shall be carried out by a group of experts (Project Group with 5 – 7 persons) probably under the authority of a CEN/TC250 Sub-Committee in close contact with EOTA and with other non-European organisations that also work on glass codes, e.g. the American Society of Civil Engineers (ASCE).

The construction sector organisations will be expected to identify the types of construction works and structural elements for which industry sees the most pressing need, so as to orient the work of the Core Group.

The layout of the guideline is also an indicator of the sequence of works. The first working package should include Part 1 and Part 2 that could be based on EN 13474. The other working packages would follow.

The deliverables will be:

- the guideline in the form of a report;
- a background document including the technical justification based on experimental and analytical research, parametric studies and bibliography.

The technical report and background document will be submitted to CEN/TC250 in support of the development of a new standard.

Table B.2. Contents and research items for Part 1: General rules for the design of glass components

Contents	Research items
1. General 1.1 Scope 1.2 Normative reference 1.3 Assumptions 1.4 Terms and definitions 1.5 Symbols 1.6 Conventions for axes	
2. Basis of design 2.1 Basic requirements, Risk-oriented design 2.2 Classification of components to use and failure consequences 2.3 Detailing for residual resistance 2.4 Reliability requirements 2.5 Design assisted by testing	Risk table
3. Materials 3.1 Glass 3.2 Interlayers 3.3 Support devices	Testing procedure Product-standards
4. Actions 4.1 Characteristic values 4.2 Temperature differences 4.3 Differences of air pressure and temperature	ψ-values
5. Action effects 5.1 General 5.2 Sandwich action in laminated glass 5.3 Complying effects in insulating glass	 G-modulus of foil
6. Calculative verifications 6.1 Reference to EN 1990 6.2 Design values 6.3 Ultimate Limit States 6.4 Serviceability Limit States	 γ_M values
7. Verification of residual strength 7.1 General 7.2 Testing and calculations	Approach
8. Structural detailing 8.1 Glass thicknesses 8.2 Holes and cut outs 8.3 Supports	
9. Requirements for execution 9.1 Tolerances 9.2 Surface qualities	Tolerances for flatness and alignment, scratching

Table B.3. Contents and research items for Part 2: Linearly supported glazing

Contents	Research items
1. General 1.1 Scope 1.2 Normative reference 1.3 Symbols 2. Materials and Products 3. Conditions for application 4. Supplementary conditions for horizontal glazing 5. Supplementary conditions for vertical glazing 6. Actions and verifications Annex A Approximate procedure to determine climatic effects in plane rectangular two-pane insulating glasses	Adjustment of design results to practice; residual strength

Table B.4. Contents and research items for Part 3: Glazing with point supports

Contents	Research items
1. General 1.1 Scope 1.2 Normative reference 1.3 Symbols 2. Materials and Products 3. Conditions for application 4. Verification for the Ultimate Limit States 4.1 Modelling for FEM-analysis 4.2 Validation of FEM-meshes, contact zones and product properties 5. Verification for serviceability Limit States 6. Structural Detailing Annex A Validation of FEM-mesh Annex B Validation of contact zones and product properties Annex C Specification of testing of point-supports	Rules for FE-modelling, testing, bench marks

Table B.5. Contents and research items for Part 4: Retaining glass barriers and glass parapets

Contents	Research Items
1. General 1.1 Categorisation 1.2 Normative reference 2. Conditions for application 2.1 Selection of materials and products 2.2 Protection of edges 3. Verification of ULS and SLS 4. Resistance to impact loads 4.1 Experimental verification 4.2 Configurations approved by experimental tests 4.3 Transfer of impact loads to the substructure Annex A Verification of impact loads by testing Annex B Configurations for which impact resistance has been proved by tests Annex C Configurations where calculative verifications for impact may be performed	Scenarios for testing

Table B.6. Contents and research items for Part 5: Glass floors

Contents	Research items
1. General 1.1 Scope 1.2 Normative reference 1.3 Symbols 2. Materials and Products 3. Conditions for application 4. Support conditions 5. Numerical verification under static loading 6. Experimental verifications for impact loads and residual resistance	Testing procedures

Table B.7. Contents and research items for Part 6: Horizontal glazing accessible for maintenance

Contents	Research Items
1. General 1.1 Scope 2. Materials and Products 3. Requirements for ULS, SLS and residual resistance 4. Testing for impact and residual resistance	Damage scenarios and testing

Table B.8. Contents and research items for Part 7: Joints and connections

Contents	Research items
1. General 1.1 Scope 1.2 Normative reference 1.3 Symbols 2. Basis of design 3. Type of connections 4. Materials and products 4.1 Contact pieces 4.2 Bolted connections 4.3 Friction grip connections 4.4 Glued connections 4.5 Hybrid connections 5. Design assisted by testing	Determination of resistances, long term behaviour

Table B.9. Contents and research items for Part 8: Particular structural components

Contents	Research items
1. General 1.1 Scope 1.2 Normative reference 1.3 Symbols 2. Basis of design 3. Materials and products 4. Design of members for ULS 4.1 Glass components and structure 4.2 Beams 4.3 Columns 4.4 Beam-columns 4.5 Plates 4.6 Shear walls 4.7 Plate-shear walls 5. Design for SLS 6. Design assisted by testing	Determination of design rules for short term and long term loading

Table B.10. Contents and research items for Part 9: Curved glass

Contents	Research items
1. General 1.1 Scope 1.2 Normative references 1.3 Symbols 2. Basis of Design 3. Materials and Products 4. Design for ULS, SLS and residual resistance 5. Design assisted by testing	Distribution of prestress, Design rules

ANNEX C
TECHNICAL GUIDANCE FOR THE DESIGN OF PULTRUDED FRP STRUCTURES

1. Objectives

Fibre reinforced polymers (FRP) have been used in the construction sector since the mid-1980s, mostly for the strengthening of existing buildings and bridges, and increasingly since the mid-1990s as pilot projects for new structures. In the case of new structures, three basic types of applications can be distinguished: concrete reinforcement, new hybrid structures in combination with traditional construction materials and all-composite applications.

FRP elements can be either fabricated on site from their constituents or delivered as semi-finished products (protruded profiles) to be incorporated in the structure. Examples of semi-finished products and structural components are flexible tension elements, profiles stiff in bending and sandwich panels. Some applications are shown in Figure C.1. Tension elements comprise strips and sheets, used mainly for strengthening of existing structures, as well as bars for concrete reinforcement and internal or external prestressing. Protruded profiles are used as beams and columns, while sandwich panels are employed mainly in bridge decks.

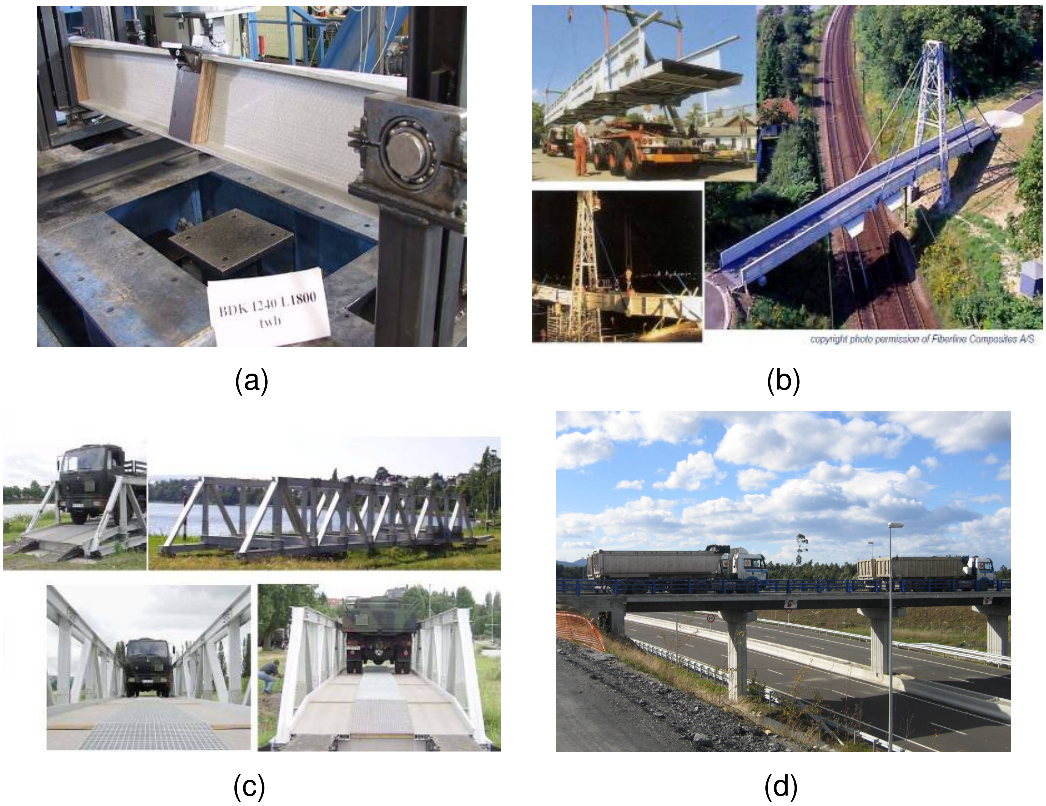

Figure C.1. Protruded GFRP beam in test rig (a), footbridge (b), military bridge with bolted connections (c) and highway overpass with composite girders (d)

CEN/TC250 and the JRC have prepared a justification document for the development of standards for the design of FRP products in civil engineering[20]. It is proposed that the European Commission should endeavour to expand the current series of Eurocodes with the addition of a new Eurocode to provide a method for calculating the mechanical strength of structural elements consisting entirely, or in part, of FRP composites. This proposal is motivated by the expanding use of FRP composite materials in the construction sector and the lack of a set of European-wide design rules.

2. Market situation and trends

In a survey by the French Ministerial organisation Service des Études et des Statistiques Industrielles (SESSI)[21], based on EUROSTAT data, it is estimated that the FRP sector represents 5% (equivalent to €7 billion) of the total EU plastics market, which is estimated to be worth €140 billion. These figures match those in a study by the UK's Department of Trade and Industry (DTI)[22]. Based on figures for 1998, the DTI estimated that the overall revenue for the FRP sector in the EU 15 was €5 billion, and that this value was expected to grow by 3.8% per annum.

In view of the fact that, in Europe the building trade represents 30% of the FRP composite line (including plastics and other reinforcement substances), it is believed that FRPs will have an increasing use in the building industry, particularly when used as main structural components that will enable new architectural shapes.

The SESSI report highlights the finding that, between 1990 and 2001, the European market share for the worldwide export of plastics reduced from 62% to 48%, and over the same time period the Asian (particularly China) share of the same market had increased from 12% to 21%.

At world level, a study of the evolution of the number of pedestrian and vehicular bridges shows that the growth rate has been exponential. The N. American sector dominates both the total number and cumulative length of bridges built in both the vehicular and pedestrian cases. The leadership of North-America in the FRP sector is clearly demonstrated by the fact that the N. American region (essentially USA), comprises over 80% of the vehicular bridge market and nearly 50% of the pedestrian bridge sector.

The evolution of the FRP market in the USA can be seen in Figure C.2, where it is shown that the use of FRPs in the transportation and construction markets has grown substantially over the past four decades. The most significant difference vis-à-vis Europe, has been the R&D resources that have been pooled by Federal and State authorities into finding the best technical solutions for the uptake of FRPs in the construction sector. Most of these programmes have been tagged also to pre-normative and normative guidelines for application of FRPs in construction.

[20] Purpose and justification for new design standards regarding the use of fibre-reinforced polymer composites in civil engineering, EUR 22864 EN, 2007 – **http://eurocodes.jrc.ec.europa.eu**.

[21] **http://www.industrie.gouv.fr/sessi/4pages/pdf/4p189-anglais.pdf**

[22] Department of Trade and Industry, UK polymer composites sector: Foresight study and competitive analysis, October 2001 – **http://www.dti.gov.uk**.

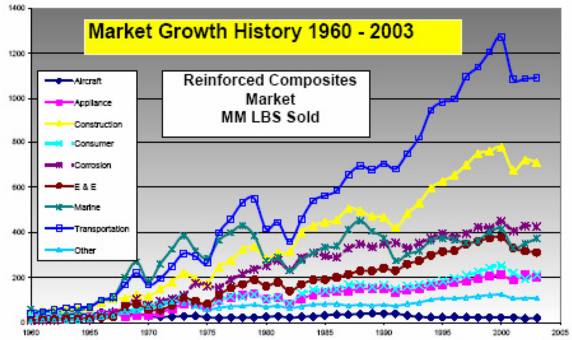

Figure C.2. Evolution of FRP market in the USA (source: ACMA[23])

A report by the National Cooperative Highway Research Program[24], funded by the Transportation Research Board, discusses the findings of a study to develop a strategic plan for FRPs in the highway infrastructure. The report concludes that, apart from certain key technical aspects that still have to be evaluated (such as environmental and durability aspects), the main barrier preventing FRPs from becoming competitive are related to manufacturing costs, proper technical knowledge by practising civil engineers, and the lack of appropriate codes and standards.

3. Growth drivers

The safe implementation of FRP composites and the need to promote the competitiveness of this emerging industrial sector are the main drivers quoted by representatives from the European construction associations.

Over the past decade, there has been a shift from demonstration projects towards market-driven applications, particularly in the area of repair and retrofit of RC structures. New structural systems made from FRP are being developed, patented and applied without any control over their correctness and appropriateness. Quite often the end-users are given no assurances – other than in-house design procedures, usually purporting to be based on proprietary technology – as to the certification of products and kits sold to them. Clearly, the longer the FRP construction is allowed to go ahead using non-standardised technical solutions, the greater the risk of catastrophic failures occurring. The only means to reduce this risk is the implementation of harmonised standards explicitly geared to FRPs.

The current situation is characterised by a multitude of design manuals, practical recommendations and FRP products that are not immediately comparable and which make the selection process for the users all the more difficult. This constitutes an obstacle to the free circulation of FRP products and related services within the European Union.

In the absence of European norms, it is possible that USA producers will use their proven expertise and consolidated standardisation status to compete in the European market. Just as notable though, is the potential for expansion in the Asian, and, particularly, the Chinese market, which accounts for the single largest growth rate in the world. It is important to point out here that the clients stress the importance of backing up the designs with appropriate construction codes. In this sense, the lack of codes could prove to be a stumbling block for the successful bid by a European company in the currently largest construction market in the world.

[23] American Composites Manufacturing Association – **http://www.acmanet.org**.

[24] National Cooperative Highway Research Program, Transportation Research Board of the National Academies, Report 503, Application of fiber reinforced polymer composites to the highway infrastructure, Washington DC, 2003 – **http://www.trb.org**.

4. Organisation of works

On the basis of a go-ahead for a new code, the planning and consultation stage will be conducted by the key stakeholders. This will concern on one hand the key EU-wide organisations representing the industrial parties and on the other, the regulatory authorities from Member States as well as CEN, EOTA and research institutions.

The main aspects of the strategic plan will be as follows:

- Define the legal and economic basis (remunerated public bids and private-public partnerships) that will motivate participation in the strategic plan.
- Approve strategic plan, responsibility lines and management structure.
- Frame the new code within the strategic plans of CEN and EOTA, i.e. define the setting of the new code within the context of the current Eurocode set and existing ETAGS.
- Define the scope of the code (structures, materials and processes).
- Define the schedule and resource requirements for conducting planning and feasibility studies.
- Disseminate activity (including knowledge-base of FRP applications in civil engineering) to individual members of professional, commercial and academic organisations.
- Perform techno-economic analysis (including construction and manufacturing methodologies, life-cycle cost analysis, repair and rehabilitation techniques) to be presented to DG ENTR.
- Organise specific training programmes for both practising and future civil engineers.

The knowledge-base for the development of the new Eurocode will be compiled from available EN product standards (e.g. protruded profiles), results of pre-normative basic research in structural elements, as well as international material, testing and product standards, such as ISO, that are acceptable directly by the Eurocodes family.

In the initial stage, the preparation of the code could benefit from the experience and the work carried out by *fib* Task Group 9.3, which has developed the twice-reprinted Bulletin 14[25]. Furthermore, many universities and research centres have performed research which led to guidelines (e.g. the “Guides for the design and construction of externally bonded FRP systems for strengthening existing structures” produced by the National Research Council of Italy[26]).

Through numerous letters of interest, European industries have clearly demonstrated a keen interest in economically supporting the activities related to the development of a new code.

5. Example of content for the technical guidance on pultruded structures

[25] Externally bonded FRP reinforcement for RC structures, *fib* Bulletin No. 14, 2001.

[26] **http://www.cnr.it/sitocnr/Englishversion/CNR/Activities/RegulationCertification.html**

Chapter-1: General Provisions **1.1 Scope** **1.2 Materials** **1.3 Basis of Design** **1.4 Actions and combinations of actions**	**Chapter-1: General Provisions** **1.1 Scope** - Field of application **1.2 Materials** - FRP constituent materials - Physical and mechanical properties for pultruded FRP products - Effects of fire - Durability and environmental effects - Resistance to impact **1.3 Basis of Design** **1.4 Actions and combinations of actions**
Chapter-2: Limit State Design **2.1 Scope** **2.2 Properties of Sections** **2.3 Design values of material properties** **2.5 Stability of Frames and Members** **2.6 Serviceability limit states** **2.7 Design for Ponding** **2.8 Fatigue** **2.9 Design of Connections** **2.10 Gross and Net Area**	**Chapter-2: Limit State Design** **2.1 Scope** **2.2 Properties of Sections** **2.3 Design values of material properties** - Strength - Stiffness **2.5 Stability of Frames and Members** - General resistance requirements - Stability of frames - Stability of members - Bracing of members and frames **2.6 Serviceability limit states** - Deformations - Vibrations - Connection Slip - Expansion and Contraction **2.7 Design for Ponding** **2.8 Fatigue** **2.9 Design of Connections** **2.10 Gross and Net Area**
Chapter-3: Members in Tension	**Chapter-3: Members in Tension** - Resistance requirements - Design value of the tensile strength - Built-up members - Members with holes - Slenderness limitations

Chapter-4: Members in Compression **4.1 Scope** **4.2 General Provisions** **4.3 Slenderness and Effective Length Considerations** **4.4 Critical Stress in Compression for Common Sections** **4.5 Compression Strength for Members with Other Cross Sections** **4.6 Compression Strength for Built-up Members**	**Chapter-4: Members in Compression** **4.1 Scope** **4.2 General Provisions** **4.3 Slenderness and Effective Length Considerations** - Effective member length - Effective length factor - Compression member effective length - Compression member effective slenderness ratio **4.4 Critical Stress in Compression for Common Sections** - Geometrically symmetric I-shaped sections - T-shaped sections - Single angle sections with equal legs - Single angle section with unequal legs - Square and rectangular tube sections - Circular tube sections - Square, rectangular, and circular solid sections **4.5 Compression Strength for Members with Other Cross Sections** **4.6 Compression Strength for Built-up Members**
Chapter-5: Members in Bending & Shear **5.1 Scope** **5.2 Design of Members for Flexure** **5.3 Design of Members for Shear** **5.4 Design of Web and Flanges for Concentrated Forces** **5.5 Design for Copes, Notches, Holes, and Openings** **5.6 Design of Flexural Members for Serviceability**	**Chapter-5: Members in Bending & Shear** **5.1 Scope** **5.2 Design of Members for Flexure** - Design resistance of sections in tension or compression - Design resistance of sections to local instability - Design resistance of sections to lateral-torsional buckling **5.3 Design of Members for Shear** - Design resistance of sections in shear - Design resistance of sections to web shear buckling **5.4 Design of Web and Flanges for Concentrated Forces** - Design resistance of webs in tension or compression - Design resistance of sections to web crippling - Design resistance of sections to web compression buckling **5.5 Design for Copes, Notches, Holes, and Openings** - Copes and notches in the flange - Holes and web openings - Doubler plate requirements **5.6 Design of Flexural Members for Serviceability** - Deflections

Chapter-6: Members under Combined Loads **6.1 Doubly and Singly Symmetric Members Subject to Flexure and Axial Force** **6.2 Doubly Symmetric Members Under Torsion and Combined Torsion, Flexure, Shear, and/or Axial Force**	**Chapter-6: Members under Combined Loads** **6.1 Doubly and Singly Symmetric Members Subject to Flexure and Axial Force** - Doubly symmetric members subject to flexure and compression - Doubly symmetric members subject to flexure and tension - Singly symmetric members subject to only strong axis flexure and compression - Singly symmetric members subject to only strong axis flexure and tension **6.2 Doubly Symmetric Members Under Torsion and Combined Torsion, Flexure, Shear, and/or Axial Force** - Torsional strength of circular and rectangular hollow tubes - Rectangular hollow tubes subject to combined torsion, flexure, shear, and axial force - Design resistance of open doubly symmetric shapes subject to torsion and combined forces
Chapter-7: Plates **7.1 General Provisions** **7.2 Design of Plates of In-Plane Loading** **7.3 Design of Plates for Out-of-Plane Loading** **7.4 Design of Plate Girders** **7.5 Design of Plates in Connections**	**Chapter-7: Plates** **7.1 General Provisions** **7.2 Design of Plates of In-Plane Loading** - Resistance of plates to loading in tension - Resistance of plates to loading in compression - Resistance of plates to in-plane shear loading **7.3 Design of Plates for Out-of-Plane Loading** - Resistance of flexural plates and panels to bending (two-way bending action) - Resistance of flexural plates and panels to bending (one-way bending action) - Resistance of stiffened plates to bending - Resistance of plates and panels to punching shear **7.4 Design of Plate Girders** - Limitations - Design of members for flexure - Design of members for shear - Design of members for local stiffening **7.5 Design of Plates in Connections** - Design of gusset plates - Design of haunch type moment connections - Design of diaphragms

Chapter-8: Joints and Connections **8.1 General Provisions** **8.2 Requirements for Bolted Connections** **8.3 Connections Design**	**Chapter-8: Joints and Connections** **8.1 General Provisions** - Axially-loaded connection types - Limitations on bolted connections - Framing connections **8.2 Requirements for Bolted Connections** - Bolts - Size and use of bolt holes - Washers - Connection geometry requirements **8.3 Connections Design** -Design value of strength of single row bolted connections - Design value of strength of bolted connections with two or three rows

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- Guidelines for the Design and Construction of Externally Bonded FRP Systems for Strengthening Existing Structures – Timber structures – Preliminary study - CNR-DT 201.2005 - June 2007

- Guidelines for the Design and Construction of Externally Bonded FRP Systems for Strengthening Existing Structures – Metallic structures, preliminary study - CNR-DT 202.2005 – June 2007

- Guide for the Design of Fibre-Reinforced Concrete Structures –CNR-DT 204.2006 – November 2007

(2) Fiberline: Design Manual, www.fiberline.com (producer of profiles for structural use)

(3) Björn Täljsten: FRP Strengthening of Existing Concrete structure, Design Guideline, Luleå University of Technology (text book)

(4) B. C. Jensen et. all. Glass-fibre-reinforced Plastic Columns. Danish Society for Structural Science and Engineering, no.3, Sept. 2005. (research paper)

ANNEX D
TECHNICAL GUIDANCE FOR THE STRUCTURAL DESIGN OF TENSILE SURFACE STRUCTURES

1. General layout of the guideline

The guideline may consist of

- a general Part 1 : General introduction and scope
- Parts 2 to 6 which are related to specific aspects of the structural analysis and erected construction.

The layout of the guideline is also an indicator for the sequence of works to be performed.

2. Preparation of the guideline

The guideline may be prepared by the TensiNet Association (www.tensinet.com) in close contact with the European Organisation for Technical Approvals (EOTA) born out of the Construction Products Directive 89/106/EC (CPD). The guideline and *research items* will be based on :

- The TensiNet Design Guide and TensiNet working documents
- Existing and draft national codes and guidelines
- Research results, like from the IP Contex-T (www.contex-t.eu)

3. Contents of the various Parts

The following general information needs to be specified

- Scope
- Normative references (Compatibility with existing Eurocodes has to be guaranteed. See http://eurocodes.jrc.ec.europa.eu/showpage.php?id=332)
- Symbols
- Specific terms

3.1 Part 1 – General introduction and scope

The content of Part 1 is listed below as a preliminary information :

1. Form, Behaviour and Qualities of Fabric Structures
2. Applications and classification (Structure categories according to the function of the structure, Structure categories according to the design working life)
3. Design Sequence
4. Equilibrium Surfaces
5. Wealth of Forms (Anticlastic Tensioned Membrane Structures, Synclastic Tensioned Membrane Structures)
6. Specific Actions
7. Membrane Support Structures (Steel Ref. EN 1993, Timber Ref EN 1995, Aluminium Ref EN 1999)
8. Analysis (Ultimate and Serviceability Limit States)
9. Design Development and Detailing

10. Requirements for erection and tensioning

3.2 Part 2 - First structural design

1. Formfinding
2. Simulation models
3. Methods for Design (Geometric formfinding, force density, dynamic relaxation, finite element method)
4. Weave direction on surface (Isotropic materials, anisotropic materials)
5. Pre-tension
6. Supporting structure
7. Load bearing behaviour (Force density, dynamic relaxation, finite element method)
8. Patterning
9. Verification
10. Advanced methods

3.3 Part 3 - Materials

1. Materials (Base fabrics, coatings, coated fabrics, films)
2. Material behaviour
3. Technical membrane materials (PTFE-coated glass fabric, PVC-coated polyester fabric, Silicone-coated glass fabric, ETFE film)
4. New and emerging materials (This paragraph needs input for *material behaviour* and *material strength*).

3.4 Part 4 Design loading conditions and analysis

1. Selfweight
2. Prestress
3. Snow on *doubly curved surfaces* (*Wind tunnel testing,* CFD)
4. Wind on *doubly curved surfaces* (*Wind tunnel testing,* CFD)
5. Temperature
6. Seismic actions
7. Construction tolerances
8. Partial factors and combinations of actions
9. Robustness

3.5 Part 5 Detailing

1. Detailing Principles
2. Patterning
3. Types of connections (Seams, edges, field supports, corners, base plates, anchorage)

Scenarios for testing have to be established

3.6 Part 6 Structural design and safety criteria

1. Membrane: partial factors
2. Cables, Ropes and Webbing Belts: partial factors

3. Supporting Steelwork, Wooden or Aluminium Elements: partial factors
4. Ultimate Limit States (Struts, columns, beams, arches, cables)
5. Serviceability Limit States (Deformations, ‘Ponding’, ‘Flutter’)
6. *Fully Integrated Stability Analyses*
7. Damage scenarios and testing
8. *Partial factors*

ANNEX E
WHY STANDARDS ARE SO IMPORTANT

Standards yesterday, today and tomorrow

Since several millenniums, the art of construction was the science of architects and engineers. Imhotep (2650 – 2600 BC) is considered to be the first engineer, architect and physician in history known by name. He designed the Pyramid of Djoser at Saqqara. The ancient Egyptians credited him with many inventions, but his science of civil engineering has never been written.

The most outstanding engineers and architects of Antiquity never wrote books to transmit their knowledge. Only building codes, expressing requirements, have been discovered by historians. The earliest known building code is that of Hammurabi (about 1780 BC), the sixth king of Babylon. The Hammurabi Code dealt with two basic building issues, namely the fee a builder was paid to complete a house, and the recourse an owner had in the event that a builder did not properly construct a house.

The Hammurabi Code (Louvre Museum)

One of the first and most famous books on construction and architecture was written by Marcus Vitruvius Pollio (80-70 BC, 15 BC). He was a Roman writer, architect and engineer. He is the author of “De Architectura”, known today as “The Ten Books on Architecture”, a treatise written in Latin and Greek on architecture, dedicated to the emperor Augustus. Vitruvius is famous for asserting in his book that a structure must exhibit the three qualities: “firmitas, utilitas, venustas”, that is it must be resistant, useful and beautiful.

Up to the 18th century, building design was mainly empirical (no calculations), but rules of good practice were known. Nevertheless many bridges and buildings collapsed during building. During the 19th century, the use of a new material, iron, as a building material was a real revolution. Scientists and engineers developed a quite new science, strength of materials and structural analysis, and defined a first approach about structural safety.

The good practice was fixed by outstanding engineers and architects through papers, research and examples of remarkable construction works.

This is always the case, but, today, things have changed. The population of our planet, which has passed 6,5 billion, is expected to reach nearly 9 billion by 2040. The problem is clear: how to accelerate the construction of buildings and transport infrastructure, and how to organise the production of building materials, fitting them together in buildings and civil engineering structures, so to help break down the barriers between nations, rich and poor. It is no more only a matter of outstanding engineers and architects: it is a matter of organisation of our society at the level of the planet where all citizens will have both rights and obligations. And the major rights are health and safety, security, education, a clean environment, as well as information and representation.

It is possible to help citizens to exercise these rights, and some correlated obligations, by providing consumers with information and protection, by ensuring the quality and safety of products and services, and by defining requirements or giving guidance related to the environment and other important issues including societal equity, health, security and fair trade. All these objectives may be reached thanks to standardization.

In short, standards:

— are tools for establishing project specifications. They use a language which is known and agreed, ensuring the legitimate transparency of the building process of construction works ;

— contribute to harmonize the practice for individual contracts, and to organize the market (in a global sense) within an industrial sector, complementing the specific national regulations ;

— reflect the current state of technology, and allow a more rational public purchase.

Benefits for the European Union

The European Union (EU) is the largest group of independent countries in the world, which has continually made efforts to abolish technical barriers to trade and to facilitate global markets via implementation of common standards, since the standards:

- are a key strategic element for the global economy, enabling it to facilitate access to new supply and export markets. In fact, harmonized international standards make it possible to reduce costs, to facilitate the conclusion of contracts and to reduce technical barriers to trade. Moreover, standardization helps provide higher quality at lower costs by ensuring that competition exists between vendors. It makes it easier for consumers to make an informed choice about equipment or services that they buy.
- serve as a bridge between an invention and its practical application on an industrial basis. Therefore, standards serve as a positive stimulus for innovation. The spread of innovation through the application of standards takes on particular importance in the information society and standards make it possible to support technology transfers.
- have the potential to play a leading part in promoting sustainable development across all its three spheres: economic growth, environmental integrity and societal equity.

ANNEX F
LIST OF EUROCODES

Eurocode – Basis of Structural Design

Title			Reference
Basis of Structural Design			EN 1990
	A	Annex A2 : Application for Bridges	EN 1990/A1

Eurocode 1 - Actions on Structures

Title	Reference
Part 1-1: General Actions - Densities, self-weight, imposed loads for buildings	EN 1991-1-1
Part 1-2: General Actions – Actions on structures exposed to fire	EN 1991-1-2
Part 1-3: General actions - Snow loads	EN 1991-1-3
Part 1-4: General actions - Wind actions	EN 1991-1-4
Part 1-5: General actions - Thermal actions	EN 1991-1-5
Part 1-6: General actions - Actions during execution	EN 1991-1-6
Part 1-7: General Actions - Accidental actions	EN 1991-1-7
Part 1-8 : General actions - Atmospheric icing of structures	**EN 1991-1-8**
Part 1-9 : General actions - Actions from waves and currents on coastal structures	**EN 1991-1-9**
Part 2: Traffic loads on bridges	EN 1991-2
Part 3: Actions induced by cranes and machinery	EN 1991-3
Part 4: Silos and tanks	EN 1991-4

Eurocode 2 – Design of Concrete Structures

Title	Reference
Part 1-1: General – Common rules for building and civil engineering structures	EN 1992-1-1
Part 1-2: General - Structural fire design	EN 1992-1-2
Part 2: Concrete bridges	EN 1992-2
Part 3: Liquid retaining and containment structures	EN 1992-3

Eurocode 3 – Design of Steel Structures

Title	Reference
Part 1-1: General rules and rules for buildings	EN 1993-1-1
Part 1-2: General - Structural fire design	EN 1993-1-2
Part 1-3: Cold-formed thin gauge members and sheeting	EN 1993-1-3
Part 1-4: Structures in stainless steel	EN 1993-1-4
Part 1-5: Plated structural elements	EN 1993-1-5
Part 1-6: Strength and stability of shell structures	EN 1993-1-6
Part 1-7: Design values for plated structures subjected to out of plane loading	EN 1993-1-7
Part 1-8: Design of joints	EN 1993-1-8

Part 1-9: Fatigue strength	EN 1993-1-9
Part 1-10: Material toughness and through thickness assessment	EN 1993-1-10
Part 1-11: Design of structures with tension components	EN 1993-1-11
Part 1-12: Supplementary rules for high strength steels	EN 1993-1-12
Part 2: Bridges	EN 1993-2
Part 3-1: Towers and masts	EN 1993-3-1
Part 3-2: Chimneys	EN 1993-3-2
Part 4-1: Silos	EN 1993-4-1
Part 4-2: Tanks	EN 1993-4-2
Partie 4-3: Pipelines	EN 1993-4-3
Part 5 : Piling	EN 1993-5
Part 6: Crane supporting structures	EN 1993-6

Eurocode 4 - Design of composite steel and concrete structures

Title	Reference
Part 1-1: General rules and rules for buildings	EN 1994-1-1
Part 1-2: General - Structural fire design	EN 1994-1-2
Part 2: Bridges	EN 1994-2

Eurocode 5 – Design of timber structures

Title	Reference
Part 1-1 : General – Common rules and rules for buildings	EN 1995-1-1
Part 1-2 : General – Structural Fire Design	EN 1995-1-2
Part 2 : Bridges	EN 1995-2

Eurocode 6 – Design of Masonry Structures

Title	Reference
Part 1-1: General - Rules for reinforced and unreinforced masonry, including lateral loading	EN 1996-1-1
Part 1-2: General - Structural fire design.	EN 1996-1-2
Part 2: Selection and execution of masonry.	EN 1996-2
Part 3: Simplified calculation methods for masonry structures.	EN 1996-3

Eurocode 7 – Geotechnical Design

Title	Reference
Part 1: General Rules	EN 1997-1
Part 2: Ground investigation and testing	EN 1997-2

Eurocode 8 – Design of structures for earthquake resistance

Title	Reference
Part 1: General rules, seismic actions and rules for buildings	EN 1998-1
Part 2: Bridges	EN 1998-2
Part 3: Strengthening and repair of buildings	EN 1998-3
Part 4: Silos, tanks and pipelines	EN 1998-4
Part 5: Foundations, retaining structures and geotechnical aspects	EN 1998-5
Part 6: Towers, masts and chimneys	EN 1998-6

Eurocode 9 - Design of aluminium structures

Title	Reference
Part 1-1: General - Common Rules	EN 1999-1-1
Part 1-2: General - Structural Fire Design	EN 1999-1-2
Part 1-3: Additional rules for structures susceptible to fatigue	EN 1999-1-3
Part 1-4: Supplementary rules for trapezoïdal sheeting	EN 1999-1-4
Part 1-5: Supplementary rules for shell structures	EN 1999-1-5

ANNEX G
GENERAL BIBLIOGRAPHY

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3) Purpose and justification for new design standards regarding the use of fibre-reinforced polymer composites in civil engineering – JRC report – EUR 22864 EN – 2007