Environmentally compatible structures (ECS) - Introduction into the theory of ECS

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Abstract

The growth of population, industry, megacities, car traffic, intensity of building industry, etc. with consequent health threatening environmental pollution, became a most urgent global problem number one of the development and survival of the mankind.

¨To ensure protection and restoration of clean environment for future generations, a scientifically based internationally accepted unified environmental strategy is necessary.

No doubt, this calls for introducing university subjects, scientific research and corresponding university text books in the field of environmentally compatible design and technology of buildings. Scientists, university staff members together with outstanding specialists in this field have to find and suggest the best acceptable means to unify the fundamentals on how to ensure environmental protection in structural engineering and architecture and identify the role of university education in this attempt.

The concept of the text book on ECS, is meant as a contribution to this strategy.

Keywords: ECS, theory of ECS, design characteristics, EC form, physical geometry, disjoint covering, indoor environment.

1. Concept and focus of the text book

1.1. Introduction

The first edition of the text book on the „Environmentally Compatible Structures and Structural Materials (ECS) - Introduction into the theory of ECS" is part of the programme of the IASS WG 18 since its foundation. It is considered one of the key tasks of the international working group.

The first edition of the text book on ECS is also an outcome of a series of preceding international seminars, focused to the same topic. Actually, Prague, is the venue of the seminars, as well as of the WG 18 Secretariat. The seminars, dealing with environmentally compatible structures and structural materials reflect also more than ten years of experience in this field.

The idea to set up and publish a university text book on the concept of the „theory of environmentally compatible structures and structural materials", was, at the time of foundation of the IASS WG in 1999, part of the initial motivation of the WG. However, the idea to prepare the book with the above topic, could be accomplished only after several international seminars on ECS and simultaneous selection of a team of top international experts from various countries, predominantly members of IASS or of the WG 18.

The text book dealing with the concept of the theory of ECS, is focused on the fundamentals of the design of ECS, motivated predominantly by genera intensifying of environmental pollution, caused by rapid and uncontrolled industrial development and traffic.

The text book is meant for final year and PhD students in the field of civil engineering and architecture and also as an incentive for PhD topics and further development of ECS and research. The book may be also useful to designers and researchers interested in the topic and wishing to contribute to its further development.

The first edition of the university text book is likely to be published in the second half of 2009.

The editors as well as over fifteen co-authors, specialists in the relevant fields from various universities, institutions and companies, are recruited from countries in Europe and overseas. The list of the editors and co-authors will be attached in the book.

1.2. General comments

Structures contribute to environmental pollution during all phases of their life cycle, i.e. in the phases of execution, performance and use until final demolition. All phases contribute to environmental pollution to a large extent predominantly by consuming energy, producing waste, harmful emissions, etc They are responsible for about one third of the total environmental pollution. To minimise these effects in design, technology and performance of structures, is one of the reasons, why the editors took up the decision to initiate publishing a university text book on ECS within the IASS WG 18, as a timely and relatively urgent need.

The theory of ECS is an applied subject of environmental sciences in the field of civil engineering and architecture, the focus of which is to restore clean environment and minimise any environmental pollution effect in the phases of design, technology and use of buildings and structures.

2. The primary aim of the theory of ECS

The primary aim of the text book and of the theory involved is to suggest a scientific concept of the theory of environmentally compatible structures and structural materials (ECS), aiming at maximum possible protection of the environment from harmful environmental effects of civil engineering objects throughout its life cycle.

The aim of this textbook is to *supplement the existing two basic classical design conditions with a new third environmental condition.*

The two classical requirements of any design have to ensure:

a) *safe resistance* of the designed structure against all external loads or effects, to which it may be subjected over the whole life span and

b) responsibility, that the structure will *serve the purpose* for which it was designed or redesigned, throughout the expected life cycle, while the new, ***third supplementary environmental condition***, has to ensure, that

c) during all phases of the life cycle of the structure, its *environmental pollution effect is reduced to minimum*. The last design condition is meant to protect the local, regional and global clean environment.

The structural and architectural design of ECS, satisfying the three conditions, is designated as *„design of environmentally compatible structure (ECS)."*

However, it should be stressed that *ECS is expressing a one way environmental effect only,* i.e. the effect of the building on the environment and not vice versa. The reverse effect, i.e. the effect of the environment on the structure, is already taken care of by the classical design codes and text books.

The theory of ECS has to comply with all existing and valid natural principles and laws, such as

a) preservation of energy and mass,

b) principle of minimum potential energy and

c) the principle of limits.

Accordingly, the theory of ECS must be compatible with the development of applied environmental sciences , engineering experience in the field of environmentally compatible structures and with all corresponding social and economical aspects.

3. Theory of ECS – the core of the text book

It is generally accepted, that no scientific field or subject can exist, or be established, unless its concept is based or supported by a generally valid theoretical background. The theory of ECS is meant to constitute the theoretical background and the fundamentals of environmentally compatible structures..

The above statement calls for establishing a unified scientific field, which will represent the basic concept of the theory of ECS and its fundamentals with acceptable methodology of practical application. The theory of ECS is meant to formulate such principles, which

would enable and ensure sustainable and environmentally compatible development in building industry and preserve lasting clean global environment.

The concept of the theory of ECS presented in the text book, has two fundamental partes, i.e. part A and part B.

Theory of ECS – part A

Part A is primarily dealing with the principles and procedures of the design of ECS Part A has four fundamental components:

1. the three globally valid basic principles,
2. the design characteristics of specific types of structures,
3. the optimisation methods compatible with the resultant environmental impact assessment of the structure,
4. case studies of similar EC structures.

With new practical and theoretical experience gained in the future, the theory of ECS is likely to undergo positive development   in all fields of design, technology of execution and use, performance and maintenance,   reconstruction and   renovation phases and lastly the phase of final demolition, recycling of the demolished structural waste and recultivation of the land.

Validity	Universal validity	Social aspects	Global validity
Focus	**Principle 1** is an *axiom* of global equilibrium	**Principle 2** is a *statement* ensuring sustainable development	**Principle 3** is a *theorem* of "limits to growth and to resources"
Definition	Global lasting dynamic EQUILIBRIUM in nature must be preserved.	By H. BRUNDTLAND: SUSTAINABLE DEVELOPMENT is such, which satisfies the present needs without harming the needs of future generations.	In a CLOSED SYSTEM of limited resources a lasting unlimited quantitative growth is not possible.
Tools	Ensure implementation of ECS – Environmentally Compatible Structures.Tab.1: A brief survey of the principles of the theory of ECS	Introduce limits to greenhouse gas emissions (CO_2, NO_x, SO_2, NH_4, freon, etc.) and reduce environmental pollution.	Protect non-renewable resources Introduce new technologies with alternative power resources: solar, wind, hydro, bio-gas, nuclear, etc

Tab.1: A brief survey of the principles of the theory of ECS

The theoretical field dealing with the above topics, has been designated: „the theory of ECS". As described above, the fundamentals of ECS are based on the *three principles,*

which constitute the first component of the theory of ECS, formulated in para 3.1 of the book. The three principles are briefly demonstrated in the Table 1.

The first and the third principles are based on globally valid natural laws, which are independent on time and the locality, while the second principle is reflecting the general interhuman moral and social attitude of lasting sustainable development.

The three principles, described in para 3.1 of the book, represent the theoretical background as the most important <u>first component</u> of the theory of ECS.

4. Comments to the four components of the theory of ECS-part A

a) *The first component of part A, as quoted above,* deals with the three basic natural and social principles. However, one can hardly expect, that the designer of any EC structure should be able to practically apply and quantify the effect of the three principles in the design of ECS. Therefore, for practical design purposes, the t*hree fundamental principles*, which form the first component of the theory of ECS, *must be transformed* into a practically acceptable and applicable version. Such transformed versions of the three principles are designated as *„design characteristics (DCH)"*. The DCH form the second component of the theory of ECS.

To ensure maximum possible protection of the environment in the design of ECS, the DCH must be optimised (generally minimised). With such understanding, the optimised values of the DCH become a key characteristic in the design of the environmentally compatible structure.

It should be noted that for different types of structures the design characteristics will probably be   different. It is evident, that e.g. the DCH for residential buildings cannot be identical with the DCH of a dam, or of a bridge, as the environmental pollution effect of specific structures may be entirely different.

Consequently, for each type of structure or building, such as residential, linear, industrial, office buildings, large span structures, shells, hydrostatic structures, etc., the list of corresponding   design characteristics, will be entirely different. Therefore, from pollution point of view, the lists of the DCH of different types of structures, must be set up separately. It is evident, that with transformation of the three principles from the first component of the theory of ECS/A   into the second component, i.e. into the design characteristics of the selected type of structure, the lists of the DCH is becoming one of the most important part of the theory of ECS.

b) Consequently, the second component of the theory of ECS covers the specific lists of the „Design characteristics (in short DCH) of various types of structures". .By optimising (minimising) the DCH, the designer would simultaneously minimise the environmental pollution effect of the designed EC structure and achieve, that the structure will be environmentally compatible.

Under the term „type of structure", groups of structures for similar or identical purposes, as quoted above, (e.g. residential or industrial buildings,, roads, hydrostatic structures, bridges, skyscrapers, etc.) are understood. The list of the DCH for various types of structures, is

likely to undergo development, amendments and improvements. The lists of the DCH may also slightly defer from region to region.

c) *The third component* of the theory of ECS is dealing with methods of mathematical or with so called „engineering, optimisation", explained in the text book. (This method may include also optimisation by experience, or by comparison with similar EC structures), the application of which should expectedly result into minimised or optimised values of the corresponding DCH and consequently into minimised environmental pollution.

d) The last component of the theory of ECS - part A, (denoted as case studies) demonstrate a brief overview, of accomplished ECS, structural systems, technologies and methods. The chapter with case studies of ECS, is of fundamental importance in view of the development of the theory of ECS. The experience, gained from realised low-energy, passive-energy or other types of EC structures, play a fundamental role in the development of the theory of ECS.

5. Commentary to the theory of ECS

It is legitimate to ask: „why do the three principles, representing the first component of the theory of ECS, constitute the core of the theory of ECS?" The first and third principles express the dynamic global equilibrium of the diversity of all living and non living components of nature existing within given natural limits, in accordance with the principle of preservation of mass and energy. Clean atmospheric environment, similarly as all geotechnical resources, are actually part of the global equilibrium system. Excessive smog and traffic exhalations in some megacities and other man-induced atmospheric pollution phenomena and atmospheric changes prove that the equilibrium can be violated. It is imperative, that the global, natural equilibrium system is respected by men regardless of the population changes or of rapid industrial development.

Man must be aware of and respect his key role in preservation of the lasting global equilibrium of the Earth..

The second principle, the s.c. Brundtland´s statement, is the social and moral reflection of the need to maintain sustainable development with due regard to the diversity of economic activities and social power of men.

To conclude, it is justified to state that the three principles represent the key part of the theory of ECS.

It has been explained, that the DCH, as the second component of the theory of ECS, represent a transformed version of the three theoretical principles, so as to make it suitable for practical design of ECS and that the lists of DCH should be set up for each type of structures, separately.

Apart from the optimisation of the DCH in the design, the application of the DCH´s is, to some extent, also a matter of experience of the designer in the fiekd of ECS. This follows also from the fact that the list of DCH may be influenced by local conditions, local technologies and by economical and social conditions.

6. Theory of ECS – part B

New ideas, which may influence the new trends in theory of ECS.

Apart from part A of the theory of ECS, which is dealing with the theoretical background of the design of ECS, chapters 3.6-3.12 of the theory of ECS-part B are devoted to specific new ideas in structural engineering and architecture, as well as to some critical comments to classical design approaches. They may considerably influence the development of the theory of ECS.

An overview of some new ideas in the design philosophy of environmental compatibility of structures, particularly with due regard to the "experience of structures generated by nature", which are automatically environmentally compatible, is discussed in this part of the theory of ECS. Application of the experience of "natural structures" may be of considerable importance in the development of ECS.

It should be recalled that the *classical geometry* of structural forms in the design is generally concentrating on idealised geometrical linear, planar or space forms corresponding more or less to analytical equations of n-th order. Similarly, the application of *orthogonal multicell systems* are in classical design often understood as „the only possible design systems", in spite of the fact that it may not always suit the design requirement of environmentally compatible solutions. They may not even be compatible with the principle of minimum potential energy, which corresponds to minimum energy requirement.

Structures created by nature, where the orthogonal system is almost non-existent, prove the above fact. Therefore, in the theory of ECS, the application of those ideas, which are respecting the natural principle of minimum potential energy, which simultaneously satisfy the requirement of environmental compatibility of ECS, is becoming more and more essential. This is why the text book is attempting to introduce and apply these aspects in the design of ECS. The experience of structures generated by nature, appears as an important source of environmentally compatible forms and structures.

To visualise the new „engineering and creative ideas", an overview of some of these, is listed in the next. They are demonstrated in the text book more in detail.

- Interconnection between emissions and fuel-based power generation demonstrate that between harmful emissions and the resources of fuel-based power generation there is a mutual interconnection.
- Environmentally compatible forms represent a specific new chapter in the theory of ECS.
- The new concept of „physical, or physically defined geometry", is not attempting to base the search for EC forms on idealised forms only, as in classical geometry. The concept of physical geometry represents a new approach in the design of EC forms. An example of a drop of water, or the experimental shells designed by H. Isler, are excellent examples.
- New trends in search for alternative sources of energy are shown by prof. Schlaich alt. from Germany.
- A critical review of the classical orthogonal systems in the design of structures, is demonstrated by applying hexagonal coverings in many structural systems.. It is known,

that the hexagonal disjoint coverings are optimised in terms of energy and material consumption.
- A critical review of the concept of indoor environment as well as of the interior arrangements in the design of housings and offices reflect the changing relation between men and nature.
- The differences between the design practice, applied by man and nature in the design of structures, should be critically assessed.
- Man should be aware that our understanding of environmental compatibility is limited by global dimensions, as man is living in a closed space of the globe. Beyond this space: the global units are no more valid.

Each of the above specified ideas are discussed in the text book with regard to various engineering structures structural materials and experience of nature. The aim of the theory of ECS is also to initiate and build up incentives for research in the field of ECS in accordance with the fundamental principles of the theory of ECS.

7. An example from physical geometry demonstrates the relationship between the form, external effects and environmental compatibility.

"Structures" generated by nature in accordance with   the principle of minimum potential energy, satisfy automatically the principles of environmental compatibility. Consequently all structures generated by nature, consumes minimum energy and minimum volume of structural material. It is evident that they are automatically environmentally compatible.
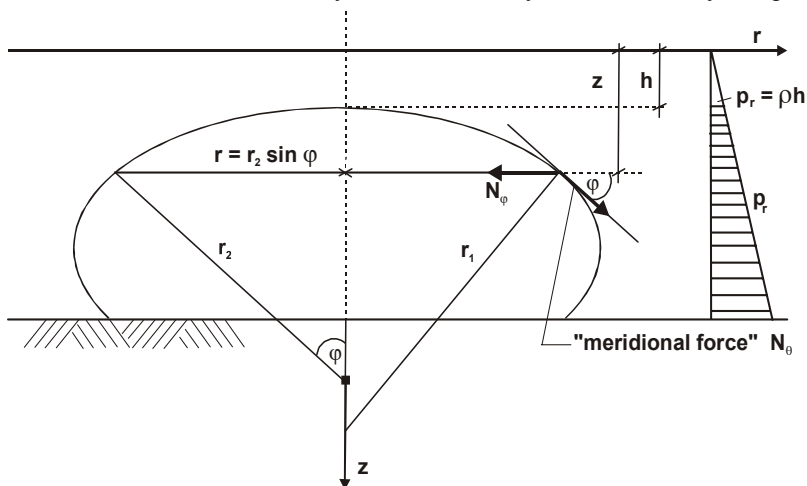

Figure 1: A drop of liquid resting on a horizontal plane.

The statical conditions of a drop of water (Fig. 1), supported by a horizontal plate, with uniform stress distribution in the cross sections, demonstrated below by Equ. (1) is a good example of ECS in structures generated by nature.

The cross section of the drop, its constant wall thickness **(t)**, the hydrostatic pressure of the liquid, the internal membrane forces and the curvatures are demonstrated in Figure 1. The internal membrane forces of the drop are: the hoop forces N_φ and the meridian forces N_θ are given by Equ. 1.

$$N_\varphi = N_\theta = t \cdot \sigma \qquad \text{and} \qquad T_{\varphi,\theta} = 0 \qquad (1)$$

8. Conclusion

The focus and intention of this paper is just to give a brief insight in the concept and understanding of the theory of ECS. It is not the intention of the authors to present a complete overview of the chapters written by a number of university professors and specialists from countries from Europe and overseas.

However, the authors would like to take this opportunity to express their thanks and gratitude for any comments of those colleagues who might wish and have an opportunity to peruse the book, aiming at any improvement or possible reeditions of the book in the future.

Information will be available on the IASS web site, as soon as the book will be published.

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