BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Tomul LIX (LXIII), Fasc. 2, 2013
Secţia
CONSTRUCŢII. ARHITECTURĂ

# TRADITIONAL BUILDING MATERIALS AND FIBRE REINFORCED POLYMER COMPOSITES. A SUSTAINABILITY APPROACH IN CONSTRUCTION SECTOR

BY

**SEBASTIAN-GEORGE MAXINEASA* and NICOLAE ŢĂRANU**

“Gheorghe Asachi” Technical University of Iaşi
Faculty of Civil Engineering and Building Services

Received: February 5, 2013
Accepted for publication: February 22, 2013

**Abstract.** It is well-known that the construction industry is among the largest consumers of material, energy and a significant polluter. From the extraction of raw materials to disposal and recycling, the entire life cycle of a construction has a significant environmental impact. The manufacturing/ processing of materials represents an important phase in the life cycle of constructions which has a negative effect on the environment. Accordingly, the construction materials industry has made tremendous progress towards fulfilling some of the most important goals of the sustainability concept.

In order to reduce impact on the environment of new or existing constructions, the civil and structural engineers possess an important role. By using specific solutions and systems or other types of civil engineering applications, some objectives of sustainability can be achieved. Fibre reinforced polymeric (FRP) composite materials that are used for structural rehabilitation or are included in new structures, can be sustainable if the life span of the structures is highly increased with very low environmental impact and a minimum use of material resource.

*Corresponding author: *e-mail*: maxineasa_sebastian_george@yahoo.com

The main objective of this paper is to identify the specific challenges associated with both traditional civil engineering and FRP composite materials and their applicability in a sustainable environment.

**Key words:** sustainability development; life cycle of constructions; environment; fibre reinforced polymeric composite materials.

## 1. Introduction

Common knowledge says that construction industry is among the largest consumers of material, energy and a significant polluter. It is well-known that this sector is a key one for environmental protection and for a sustainable resource management. At the global scale we are currently consuming about 150% of the resource that the Earth can renew in one year. Thus, the existing patterns of production and consumption are unsustainable. The construction industry plays an important role, since it consumes more raw materials than any other economic activity, approximately 50% of the global consumption. Furthermore, it is expected that this industry will grow in the next years (Ewing *et al.*, 2008; Messari-Becker *et al.*, 2013; Pacheco-Torgal & Labrincha, 2013).

From the extraction of raw materials to recycling and disposal of waste material, the entire life-cycle of a construction has a significant environmental impact. An important phase which has a negative effect on the environment is the manufacturing/processing of materials. Thus, the traditional civil engineering materials industry has made tremendous progress towards fulfilling some of the most important goals of sustainability development. For example, substituting a volume of cement with fly ash in concrete, using recycled materials in steel production and sustainably harvested certified wood.

On the other hand, civil and structural engineers have an important role in sustainable construction development. The environmental impact of new or existing buildings is reduced using specific solutions and systems or other types of civil engineering applications. Therefore, some objectives of sustainability can be achieved (Ţăranu *et al.*, 2012).

## 2. Sustainable Development in Construction

In order to discuss about sustainable development in construction, we need to define the *sustainability* concept. According to ISO *15392*/2008, sustainability is a "state in which components of the ecosystem and their functions are maintained for the present and future generations" and "is a state that requires that humans carry out their activities in a way that protects the functions of the Earth's ecosystem as a whole". Sustainability is the global goal of sustainable development. We can say that the concept of sustainability represents an ideal state, a perfect equilibrium state between the requirements of the present generations, the level of resources used to fulfill the day by day human activities, and the actual level of Earth's resources including its capacity to renew the stock of resources for the next generations.

The world-wide accepted definition for sustainable development was included in the report that Bruntland Commission issued to the United Nations in 1987, which stated that "sustainable development is the one which meets the needs of the present without compromising the ability of future generations to meet their own needs" (World Commission on Environment and Development, 1987). This definition for sustainable development is actually present in the ISO *15392*/2008. The construction sector has an important role in the global sustainable development, being a key sector in every national economy and having an important environmental impact.

In order to achieve sustainability in the construction sector it is necessary to consider and interpret its aspects – economical, environmental, social and health & comfort, through sustainable development. At the same time, the technical and functional performance of construction works must be fulfilled (ISO *15392*/2008; Sustainable Smart ECO-Buildings in the EU, 2005). According to ISO *15392*/2008, the objectives for applying the concept of sustainability to constructions and, at the same time, promoting sustainable development, are: "improvement of the construction sector and the built environment, reduction of adverse impacts while improving value, stimulation of a pro-active approach, stimulation of innovation, decoupling of economic growth from increasing adverse impacts on the environment and/or society, reconciliation of contradictory interests or requirements arising from short-term and long-term planning or decision making"; and the principles that are applied to reach these objectives are: "continual improvement, equity, global thinking and local action, holistic approach, involvement of interested parties, long-term consideration, precaution and risk, responsibility, and transparency".

Life Cycle Assessment is the best tool to assess sustainability in the construction sector. According to ISO *14040*/2006 and ISO *14044*/2006, Life Cycle Assessment (LCA) is a "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle. LCA addresses the environmental aspects and potential environmental impacts (*e.g.* use of resources and the environmental consequences of releases) throughout a product's life cycle from raw material acquisition through production, use, end-of-life treatment, recycling and final disposal (*i.e.* cradle-to-grave)". To determine the sustainability of a material or of a construction, the following items must be considered: the initial, operating/maintenance and disposal cost, the life of the asset and its environmental impact through the whole life cycle. By applying LCA we can optimize the aspects of sustainability, from the extraction of raw materials to recycling and final disposal of waste (Ortiz *et al.*, 2009; Lee *et. al.*, 2012; Estes & Frangopol, 2005; Murphy, 2010).

## 3. Sustainability of Traditional Civil Engineering Materials

The construction materials industry has made tremendous progress to achieve sustainability in this sector through a sustainable development. For example, concrete, steel and brick production companies try to reduce the energy consumption in order to reduce $CO_2$ emissions and the embodied energy of their products. Recycling is another step to comply with the current environmental protection laws and to reduce the processing costs. In what follows some of the steps that are currently being undertaken are presented in order to promote the sustainability concept.

### 3.1. Concrete

Concrete is one of the most used building materials worldwide. During a year's time, a ton of concrete is produced for every human being. The main concrete ingredient, cement, had nearly doubled the carbon footprint between the years 1990 and 2005. In Fig. 1 it is represented the cement consumption rates from 1950 until 2010. With the current rate of cement consumption we can

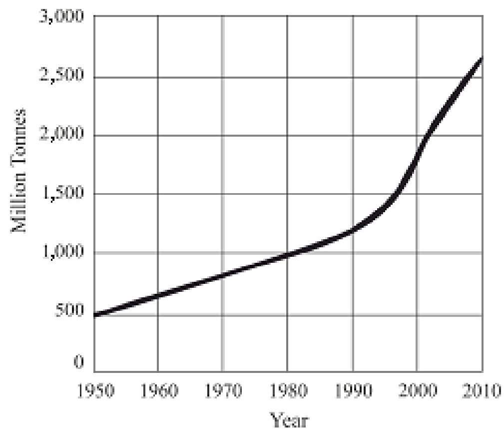


Fig. 1 – Historic and projected annual cement consumption rates (Mehta & Meryman, 2009).

expect the pollution levels from cement production to double about every 5 years. It is estimated that from the chemical reaction and the combustion of fossil fuels for generating heat necessary to manufacture a ton of cement is produced a ton of $CO_2$. Recent studies have shown that the cement production is responsible for 5%...7% of all $CO_2$ generated around the world. Therefore, in order to reduce the environmental impact of concrete, we must reduce the amount of cement used in concrete.

The cement producers chose to optimize the cement mixture by adding complementary cementing materials, like fly ash (a pozzolanic by-product of coal-fired electricity generation) and blast-furnace slag (a pozzolanic by-product of steel blast furnaces). There are two benefits for using this pozzolanic by-products: the environmental impact is reduced because of the replacement of cement with carbon-neutral by-products and these by-products are diverted from the landfills. The Portland Cement Association has developed some recommendations for the quantity of cement replacement with fly ash and blast-furnace by weight. Another environmental problem of the cement and concrete is the dust that is generated in the production stage. Thus, the Environmental Protection Agency has limited the quantity of dust that is released into the atmosphere. The concrete impact over the environment can be reduced by replacing the natural aggregates with recycled materials like: brick, glass, granulated plastics, waste fibreglass, and crushed blast furnace slag (Heede & Belie, 2012; Estrada *et al.*, 2012).

The techniques used by the cement industry for reducing its carbon-footprint will result in a more durable concrete with a much longer service life and lower overall cost. This concrete will possess lower embodied energy, lower carbon emissions, lower environmental impact and an increased diversion of by-product materials from landfills.

### 3.2. Steel

Typically, the following two methods are used in the production of this material: electric-arc furnace (EAF) or basic oxygen furnace (BOF). Each of these methods uses a different amount of recycled materials; the steel produced by the EAF can have up to 100% recycled content and the one produced by the BOF method contains 10%...25% recycled content. Another difference between these two methods is the type of energy being used in the production process; EAF uses electricity and BOF uses coal or natural gas. Adding that the most structural steel used in construction is produced using the EAF process, we can say that EAF is the most friendly environmental method.

Steel has a unique property: it is 100% recyclable (a highly recyclable material), which means that steel can be recycled multiple times without any degradation of its mechanical properties. Increasing the use of recycled steel and changing the production process have led to a drastically decrease over the past 30 years of the $CO_2$ emissions and the amount of raw materials and energy used. The environmental thinking in steel industry took place in the 1970s and 1980s, when the manufacturers started to recycle steel and they switched from coal burning furnaces to electricity. Steel has a relatively small carbon-footprint, compared to concrete, approximately 0.70 t of $CO_2$ are produced to manufacture a ton of steel (Table 1). In future time, the steel industry can come to produce steel that has no carbon footprint, provided the EAF method will be used and the electricity needed in this process will be generated by only using renewable sources, such as solar and wind. Because the steel is highly recyclable, a large volume of deconstructed and scrap steel is diverted from the landfills and reused. In the last years the steel industry has contributed to the reduction of the amount of steel used in a construction project, by producing a high strength steel which has 40% higher strength compared to the steel used 30 years ago (Estrada *et al.*, 2012; AISC, 2011; Strezov *et al.*, 2013).

The steel industry has made tremendous progress in order to achieve the most important goals of the sustainability concept by applying solutions like development of high-strength steel, recycling and reusing steel, all of which will result in a sustainable cost effective material with a lower environmental impact.

### 3.3. Timber

Timber is the most available construction material derived from a renewable resource. Adding that trees are the most powerful and efficient tool of Earth for extracting the $CO_2$ from the atmosphere (Table 1), the using of timber in construction sector can have a significant impact over the environment.

One of the measures the timber industry has implemented in order to reduce the timber production negative effects such as soil erosion, habitat loss and increasing the level of $CO_2$, is to harvest the wood used in construction sector from certified forests. For example, because of reforestation practices, in the European Union, the forested area has increased with 2%, approximately 3.5 million ha, between 2000 and 2010 and in North America the forested area is the same size as 100 years ago (Eurostat, 2011; Ward, 2010). Another solution adopted by timber industry is to produce Engineering Wood (EW) products like plywood, oriented-strand board panels, glued-laminated lumber, laminated and parallel strand lumber, and laminated veneer lumber (Estrada *et al.*, 2012). These EW products are manufactured using trees with a smaller diameter from forests that are farmed using fertilizers and pesticides and are harvested relatively frequent. The EW products are difficult to recycle because in order to obtain these products, binders are required.

Considering that a tree sequesters $CO_2$ and releases $O_2$ in the atmosphere and the fact that the wood during processing requires low amount of energy, having as result a lower level of embodied energy, we can consider the timber used in construction sector as a carbon negative material. Also, a main benefit of wood is its biodegradability and the fact that its recycling is primarily used as bio-fuel. The main disadvantage is represented by the vulnerability of the wood to decay and to attacks from insects and thus, the wood must be protected using preservatives to ensure a long-term durability (Estrada *et al.*, 2012).

**Table 1**
*Net Carbon Emissions In Producing a Ton of Various Materials*
(Falk, 2010; Estrada *et al.,* 2012)

| Material | Net $CO_2$ emissions kg $CO_2/t^{a,b}$ | Near-term net carbon emissions including carbon storage within material kg $CO_2/t^{c,d}$ |
|---|---|---|
| Framing lumber | 33 | –457 |
| Medium-density fiberboard (virgin fiber) | 60 | –382 |
| Brick | 88 | 88 |
| Glass | 154 | 154 |
| Recycled steel (100% from scrap) | 220 | 220 |
| Concrete | 265 | 265 |
| Concrete[e] | 291 | 291 |
| Recycled aluminum (100% recycled content) | 309 | 309 |
| Steel (virgin) | 694 | 694 |
| Plastics | 2,502 | 2,502 |
| Aluminum (virgin) | 4,532 | 4,532 |

[a]Values are based on life-cycle assessment and included gathering and processing of raw materials, primary and secondary processing, and transportation
[b]Source: EPA (2006)
[c]The carbom stored within wood will eventually be emitted back to the atmosphere and the end of the useful life of the wood product
[d]Derived based on EPA value for concrete and consideration of additional steps involved in making bloks

Timber industry has made progress in order to become an industry with low environmental impact which has the goal of manufacturing a carbon negative construction material. To achieve this goal, the timber industry must reduce their carbon footprint and become a carbon neutral industry by promoting the harvesting of certified forests, using non-toxic preservatives, development of new durable EW products, using locally available wood species, and recycling or using as bio-fuel of timber resulted from construction demolition.

### 3.4. Masonry

The environmental impact of masonry is highly influenced by the materials used for manufacturing bricks. For example, the level of embedded energy in fired clay bricks is almost three times higher than in concrete bricks (Table 2). Being a fired material, the process of manufacturing clay bricks requires a large amount of energy. Therefore, this material has a large amount of embodied energy and a significant carbon footprint. The environmental impact of concrete bricks is the same as the one of the regular concrete.

**Table 2**
*Embodied Energy in Masonry Materials*
(Volz & Stovner, 2010a; Estrada *et al.*, 2012)

| Material | Embodied energy, [MBtu/yd$^3$] |
|---|---|
| Concrete brick | 0.946 |
| Fired clay brick | 3.28 |
| Fly ash brick | 0.492 |

In order to reduce the level of the embedded energy and the carbon footprint of fired clay bricks, the masonry industry has developed the fly ash brick which has comparable mechanical properties with fired clay brick but the level of embedded energy in fly ash brick is much lower. For concrete brick, the manufactures have minimized the carbon footprint and the embedded energy by substituting cement with complementary cementing materials, like fly ash (Estrada *et al.*, 2012; Volz & Stovner, 2010b).

The masonry industries have made progress in order to reduce the carbon footprint and the level of embedded energy in fired clay and concrete bricks, which are two of the most used building materials worldwide. For the future, brick's manufacturers are expected to reduce more the environmental impact of their products by trying to minimizing the amount of cement used in concrete bricks, replacing fired clay bricks with fly ash bricks and trying to recycle and reuse the masonry construction waste.

## 4. Sustainability of Fibre Composites Polymeric (FRP) Composites Materials

"Fibre reinforced polymeric (FRP) composite materials are multiphase systems consisting of two or more chemically distinct constituents with properties superior to those provided by any constituent working individually" (Ţăranu *et al.*, 2012). In the first years of development the FRP composite materials were too expensive to utilize them in construction applications, but in time, the cost of this materials have decrease and the use of FRP composite materials in infrastructure applications has increased (Lee *et al.*, 2012).

The FRP composite materials used for structural applications are usually manufactured by combining a polymer matrix (epoxy, polyester or vinylester resin) with glass, carbon, or aramid fibres. The main advantages of FRP composite materials over the traditional civil engineering materials are:

high mechanical properties (high specific strength and high specific stiffness), lightweight, noncorrosive, durability and can be manufactured to satisfy specific performance requirements. FRP composites can be used for rehabilitation of existing structures, increasing the life span of the structures, or can be included in new constructions (Ţăranu *et al.*, 2012; Lee *et al.*, 2012; Estrada *et al.*, 2012).

The fabrication stage of the constituent materials for FRP composites have an important environmental impact. If we consider only the large amount of energy necessary for manufacturing the fibres and the primary resources used for obtaining the polymers, it appears that it is irrational to use FRP composite materials for a sustainable development in the construction sector. In the following sections there is presented an overview of the most used FRP composite constituent materials and their implications in a sustainable construction development.

### 4.1. Glass Fibres

This type of fibres are a very popular choice in construction applications of FRP composite materials. There are four types of glass fibres that are used in infrastructure applications, the *E*-glass, *S*-glass, *AR*-glass and *C*-glass. The main advantages of glass fibres are: low production costs, high strength and tolerance to high temperature and corrosive environments. Glass fibres are very sensitive to moisture, and if used in areas with high humidity the strength of glass fibres can be reduced by 35%. Compared with carbon fibres, the stiffness of glass fibres is relatively low. The manufacturing process requires a large amount of nonrenewable energy and consumption of large quantities of fossil fuels. In order to produce these fibres, it is necessary that all ingredients be melted into furnace at high temperatures, approximately 1,370ºC. Another disadvantage of the manufacturing stage is that the glass processing is dusty (Lee *et al.*, 2012; Hollaway, 2011).

### 4.2. Carbon Fibres

The advantages of carbon fibres are: high tensile strength, high modulus of elasticity, and high tolerance to high temperatures and corrosive environments. Due to their tolerance to corrosive environments, the carbon fibres can be used for applications in marine environments. They are petroleum-based and in the manufacturing stage there are reached temperatures above 1,600ºC. This type of fibres has a big environmental impact because, like in the case of glass fibres, a large amount of nonrenewable energy is required in the manufacturing stage. The environmental impact of carbon fibres can be reduced due to their mechanical properties. Thus, in a construction application it can be used a lower quantity of carbon fibres to achieve the same performance given by a larger quantity of glass or aramid fibres (Lee *et al.*, 2012; Hollaway, 2011).

### 4.3. Aramid Fibres

Aramid fibres are often used for applications which require a high impact resistance. Because this fibres have a low axial compression strength, poor transverse properties and low shear modulus, they are usually used in construction applications as a composite hybrid material which is obtained by combining the aramid fibres with other fibres, such as carbon fibres. Unlike the glass and carbon fibres, the maximum value of temperature for manufacturing aramid fibres is around 200ºC. The main advantageous properties of aramid fibres are: a very low density, high tensile strength and stiffness (Hollaway, 2011; Stoian *et al.*, 2004).

### 4.4. Epoxy Resins

Compared with other polymers, epoxy resins are more expensive, but are used in many construction applications due to their advantageous properties, like high mechanical strength, low viscosity, low shrinkage rates and durability. In order to initiate and accomplish the crosslinking, almost all epoxies used in composite applications require an increased and well controlled temperature and the use of curing agents (hardeners) and accelerators. Most hardeners used in epoxy systems are highly toxic and cause severe irritation if are touched or inhaled. Additionally, it is known that some of them are carcinogens and can cause damage to the liver and kidneys (Lee *et al.*, 2012; Strong, 2008).

### 4.5. Polyester Resins

Polyester resins are the most widely used thermosetting resins. Their main advantages are: high corrosion resistance, uncomplicated manufacturing process and low cost. The price of unsaturated polyesters is about 33%...50% less than epoxies and about 25% less than vinylesters. Like in the case of epoxy resins, the crosslinking agents and the catalysts used for the polymerization reaction of polyester resins have high levels of toxicity and can create serious health problems. For example, styrene is a crosslinking agent used in polyester resins, which easily evaporates and has an important negative impact over the human's health in the mixing and applications stage. Other disadvantages of polyester resins are low temperature tolerance and shrinkage from crosslinking (Lee *et al.*, 2012; Strong, 2008).

### 4.6. Vinylester Resins

Like epoxy and polyester resin, the vinylester is a thermosetting material. The vinylester resins are cheaper than epoxies but slightly more expensive than polyesters. Compared with polyesters, the vinylester resins have superior toughness and corrosion resistance to water and organic solvents. Still the vinylester resins have weaker properties than the epoxy resins. The vinylesters have another advantage with respect to the polyesters, namely the lower quantity of styrene used for vinylesters manufacturing. Therefore, the impact of the styrene emissions over the human's health is reduced (Lee *et al.*, 2012; Strong, 2008).

### 4.7. Sustainable Construction Development Using FRP Composite Materials

The manufacturing processes of FRP composite materials has an important impact over the environment because it requires the use of raw materials, energy and water. Adding that during the manufacturing stage different types of emissions are released in air, land, and water, it may appear that we can not use FRP composite materials for a sustainable construction development.

Usually, the FRP composite materials are used for rehabilitation or strengthening existing constructions and for retrofitting structural elements. All of these applications have the scope of increasing constructions' life span. The construction of a new structure requires large amounts of energy and a significant initial investment. If this structure is demolished before or even after the end of expected service life, all the embodied energy and the initial and during life costs are wasted. Therefore, we can say that it is more sustainable to rehabilitate and reuse an old building than to demolish this building and construct a new one.

As stated before, through the usage of FRP composite materials we increase the life span of an existing structure and thus, we reuse this structure after the end of initial expected service life. Increasing the service life of an old structure is the biggest advantage of FRP composite materials in a sustainable development of constructions' sector. In consequence, by using FRP composites in construction applications, we can promote all aspects of the sustainability.

## 5. Conclusions

Fulfilling the sustainability aspects in constructions sector through sustainable development has become a global problem. Worldwide, efforts are made in order to reduce the significant environmental impact of constructions.

Knowing that constructions industry is among the largest consumers of raw materials, nonrenewable energy and a significant polluter, the construction materials manufacturers have tried among the years to reduce their negative impact over the environment. For example, the manufacturers are trying to use complementary cementing materials in concrete, more recycled materials in steel production, only wood harvested from certified forests and replacing the fired clay bricks with fly ash bricks. All the steps already taken and the ones planned for the future have the declared scope of reducing the carbon-footprint.

Even if the production stage of FRP composite materials has negative impacts over the environment, the aspects of sustainability can be achieved in constructions sector by using the previously mentioned. The main advantage is that the life span of an existing structure is extended through FRP composite applications. Thus, we can avoid all the environmental implications of demolishing and constructing a new building.

## REFERENCES


Bowyer J., Bratkovich S., Lindberg A., Fernholz K., *Wood Products and Carbon Protocols: Carbon Storage and Low Energy Intensity Should be Considered*. Dovetail Partners, Inc., Minneapolis, 2008.

Brundtland G.H. and World Commission on Environment and Development, *Report of the World Commission on Environment and Development: „Our Common Future"*. Oxford Univ. Press, New York, 1987.

Estes A.C., Frangopol D.M., *Life Cycle Evaluation and Condition Assessment of Structures*. In: Chen W.F., Lui E.M. (Eds.), *Handbook of Structural Engineering*. 2nd Ed., CRC Press, New York, 2005.

Estrada H., Borja D.H., Lee L., *Sustainability in Infrastructure Design*. In: Jain R., Lee L. (Eds), *Fiber Reinforced Polymer (FRP) Composites for Infrastructure Applications*. Springer, Dordrecht, Netherlands, 2012.

Ewing B., Goldfinger S., Wackernagel M., Stechbart M., Rizk S.M., Reed A., Kitzes J., *The Ecological Foot Print Atlas 2008*. Global Footprint Network, Res. a. Standards Dept., Oakland, 2008.

Falk R.H., *Wood as a Sustainable Building Material*. In: *Wood Handbook: Wood as an Engineering Material*. Chapter **1**. Gen. Techn. Report FPL-GTR-190, US Dept. of Agric., Forest Serv., Forest Prod. Labor., Washington D.C., 2010.

Hollaway L.C., *Key Issues in the Use of Fibre Reinforced Polymer (FRP) Composites in the Rehabilitation and Retrofitting of Concrete Structures*. In: Karbhari V.M., Lee L.S. (Eds.), *Service Life Estimation and Extension of Civil Engineering Structures*. Woodhead Publ., Oxford, 2011.

Lee L., Jain R., Stephenson L., Ramirez C., *Introduction*. In: Jain R., Lee L. (Eds), *Fiber Reinforced Polymer (FRP) Composites for Infrastructure Applications*. Springer, Dordrecht, Netherlands, 2012.

Mehta P.K., Meryman H., *Tools for Reducing Carbon Emissions to Cement Consumption*. Struct. Mag., **16**, *1*, 11-15 (2009).

Messari-Becker L., Bollinger K., Grohmann M., *Life-Cycle Assessment as a Planning Tool for Sustainable Buildings*. In: Strauss A., Frangopol D.M., Bergmeister K. (Eds.), *Life-Cycle and Sustainability of Civil Infrastructure Systems.* Proc. of the Third Internat. Symp. on Life-Cycle Civil Engng. (IALCCE 2012), Taipei, Taiwan, 2012, 1558-1562.

Murphy R., *Life Cycle Assessment*. In: Baillie C. (Ed.), *Green Composites. Polymer Composites and the Environment*, Woodhead Publ. Ltd., Cambridge, 2010.

Ortiz O., Castells F., Sonnemann G., *Sustainability in the Construction Industry: A Review of Recent Developments Based on LCA*. Constr. a. Build. Mater., **23**, 28-39 (2009).

Pacheco-Torgal F., Labrincha J.A., *The Future of Construction Materials Research and the Seventh UN Millennium. Development Goal: A few Insights*. Constr. a. Build. Mater., **40**, 729-737 (2012).

Stoian V., Nagy-Gyorgy T., Dan D., Gergely J., Daescu C., *Materiale composite pentru construcţii*. Edit. Politehnica, Timişoara, 2004.

Strezov V., Evans A., Evans T., *Defining Sustainability Indicators of Iron and Steel Production*. J. of Cleaner Prod., doi: 10.1016/j.clepro.2013.01.016 (2013).

Strong A.B., *Fundamentals of Composites Manufacturing. Materials, Methods, and Applications*. 2nd Ed., Soc. of Manuf. Eng., Dearborn, 2008.

Ţăranu N., Oprişan G., Enţuc I., Budescu M., Munteanu V., Ţăranu G., *Composite and Hybrid Solutions for Sustainable Development in Civil Engineering*. Environ. Eng. a. Manag. J., **11**, *4*, 783-793 (2012).

Van den Heede P., De Belie N., *Environmental Impact and Life Cycle Assessment (LCA) of Traditional and 'Green' Concretes: Literature Review and Theoretical Calculations*. Cem. & Concr. Compos., **34**, 431-442 (2012).

Volz V., Stovner E., *Reducing Embodied Energy in Masonry Construction*. Part 1: *Understanding Embodied Energy in Mansonry*. Struct. Mag., **17**, *5*, 8-10 (2010a).

Volz V., Stovner E., *Reducing Embodied Energy in Masonry Construction*. Part 2: *Evaluating New Masonry Materials*. Struct. Mag., **17**, *9*, 42-45 (2010b).

Ward R., *Can Using More Wood Reduce Your Environmental Footprint?*. Struct. Mag., **17**, *2*, 16-18 (2010).

* * * *Environmental Management–Life Cycle Assessment–Principles and Framework*. ISO 14040:2006(E).

* * * *Environmental Management–Life Cycle Assessment–Requirements and Guidelines*. ISO 14040:2006(E).

* * * *Forestry in the EU and the World. A Statistical Portrait*. Eurostat Statistical Books, Publ. Office of the Europ. Union, Luxembourg, 2011.

* * * *Sustainability in Building Construction – General Principles*. ISO 15392:2008(E).

* * * *The Sustainable Aspects of Structural Steel.* American Inst. of Steel Constr. (AISC), On line at: http://www.aisc.org/uploadedFiles/Steel_Solutions_Center/Conceptual/My_Project/Files/Talking%20Points%20-%2010.2009.pdf, 2011

* * * *Towards Sustainable and Smart-Eco Buildings*. Summary report on the EU-Funded project smart-eco, Contract number FP6-2005-TREN4-038699.

## MATERIALE DE CONSTRUCŢII TRADIŢIONALE ŞI COMPOZITE POLIMERICE ARMATE CU FIBRE. O ABORDARE REFERITOARE LA SUSTENABILITATE ÎN DOMENIUL CONSTRUCŢIILOR

(Rezumat)

Este deja cunoscut faptul că domeniul construcţiilor reprezintă unul dintre cele mai poluante activităţi economice, folosindu-se cantităţi semnificative de materiale şi

energie. Începând cu extragerea materiei prime şi finalizând cu demolarea clădirii şi depozitarea deşeurilor, întreg ciclul de viaţă al unei construcţii are un impact semnificativ asupra mediului. O fază importantă care influenţează negativ mediul înconjurător este reprezentată de fabricarea materialelor de construcţii. Astfel, producătorii materialelor de construcţii tradiţionale au făcut eforturi însemnate în a atinge aspectele conceptului de sustenabilitate.

În încercarea de a reduce impactul asupra mediului a structurilor noi sau existente, inginerii constructori au un rol important. Aşadar, anumite aspecte ale sustenabilităţii pot fi evidenţiate prin folosirea unor soluţii sau a altor tipuri de aplicaţii specifice ingineriei civile. Materialele compozite polimerice armate cu fibre (CPAF), care sunt folosite pentru reabilitarea structurilor existente sau pentru realizarea structurilor noi, pot reprezenta o alegere sustenabilă dacă perioada de viaţă a structurii este mărită semnificativ, cu un impact scăzut asupra mediului şi cu o minimă utilizare de materiale.

Prezenta lucrare îşi propune să identifice şi să analizeze provocările asociate atât cu materialele tradiţionale, cât şi cu cele compozite polimerice armate cu fibre şi aplicabilitatea acestora în cadrul unei dezvoltări sustenabile.