CIB W115 - Construction Material Stewardship

Book of Abstracts of the Conference:

Lifecycle Design of Buildings, Systems and Materials

Enschede, The Netherlands, 12-15 June 2009-06-08

Edited by
Elma Durmisevic
Conference Organization
Dr. Elma Durmisevic: Chair, University of Twente, the Netherlands
Dr. Robin de Graaf: Co-chair, University of Twente, the Netherlands
Mrs. Yolanda Bosch: University of Twente, the Netherlands
Mr. Mark Roelofsen: Student assistant, University of Twente, the Netherlands
Mr. Stefan Binnemars: Student assistant, University of Twente, the Netherlands

Steering Committee - tentative
Prof. Dr. Fred van Houten, University of Twente, the Netherlands
Prof. Dr. Abdol Chini, University of Florida, USA
Prof. Dr. Joop Halman, University of Twente, the Netherlands
Prof. Dr. Rikus Eising, Dean of the Faculty of Engineering Technology, University of Twente, the Netherlands
Dr. Wim Bakens, Secretary General of CIB, Rotterdam, the Netherlands
Prof. Dr. André Dorée, University of Twente, the Netherlands
Prof. Dr. John Story, Victoria University of Wellington, New Zealand
Prof. Dr. Frank Schultmann, University of Siegen, Germany
Prof. Dr. Jos Brouwers, University of Twente, the Netherlands

Scientific Board
Dr. Elma Durmisevic, University of Twente, the Netherlands
Prof. Dr. André Dorée: University of Twente, the Netherlands
Prof. Dr. Joop Halman, University of Twente, the Netherlands
Prof. Dr. Jos Brouwers, University of Twente, the Netherlands
Prof. Dr. Abdol Chini, University of Florida, USA
Prof. Dr. Frank Schultmann, University of Siegen, Germany
Prof. Dr. John Story, Victoria University of Wellington, New Zealand

Technical Committee - tentative
Prof. Dr. Jos Brouwers, University of Twente, the Netherlands
Prof. Dr. Abdol Chini, University of Florida, USA
Prof. Dr. John Story, Victoria University of Wellington, New Zealand
Prof. Dr. Frank Schultmann, University of Siegen, Germany
Prof. Dr. Joop Halman, University of Twente, the Netherlands
Dr. Elma Durmisevic, University of Twente, the Netherlands
Gilli Hobbs, BRE, UK
Catarina Thormark, TU, Sweden
Prof. Dr. Charles Kibert, University of Florida, USA
Dr. Shiro Nakajima, Japan
Prof. Dr. Chyime Anumba
Prof. Hendrik Hendrickx, University of Brussels, Belgium
Prof. Patric de Wilde, University of Brussels, Belgium
Prof. Dr. Andre Dorée, University of Twente, the Netherlands
Prof. Dr. Fred van Houten, University of Twente, the Netherlands
Wim Debacker, University Brussels, Belgium
Dr. Laura Itard OTB – Delft University of Technology, the Netherlands
Dr. Robin de Graaf, University of Twente, the Netherlands
Prof. A. Miller, University of Brighton, UK
Prof. Dr. Holger Wallbaum, ETH Zurich, Germany
TABLE OF CONTENTS

Preface

DESIGN FOR TRANSFORMATION AND REUSE OF BUILDINGS, SYSTEMS AND MATERIALS
Sustainable Construction Strategies: A Singapore Perspective.................................................................8
K. C. G. Ong, E Anggadjaja, S. L. Y Soh
National University of Singapore, Singapore

From Ugly Duckling to Swan - Transformation as an Alternative to Demolition........................................9
J.B. Storey
Victoria University of Wellington, New Zealand

Transforming Cities: Introducing Adaptability in Existing Residential Buildings through Reuse and Disassembly Strategies for Retrofitting..................................................................................................10
Vrije universiteit Brussel, Belgium

DESIGN OF SYSTEMS TO AVOID CONSTRUCTION MATERIAL WASTE
Requirements for Sustainable Construction Materials and Components..................................................11
N. Sunke, F. Schultmann
University of Siegen, Germany

Building green via design for deconstruction and adaptive reuse.............................................................12
T. Saleh, A. Chini
University of Florida, USA

Developing the Stavne Timber Block; Life cycle design in practice............................................................13
A.S. Nordby, K.S. Wigum, B. Berge
Norwegian University of Science and Technology, GAIA Trondheim, GAIA Lista, Norway

ADAPTABLE ARCHITECTURE
An Integrated and Flexible Approach for Post-Disaster Shelter Response..................................................14
C. Henrotay, W. Debacker, A. Paduart, N. De Temmerman, H. Hendrickx, M. Mollaert, P. De Wilde
Vrije universiteit Brussel, Belgium

A Deployable Mast for Adaptable Architecture.............................................................................................15
Vrije universiteit Brussel, Belgium
Adaptable Architecture with the Application of Dynamic Materials......................................................... 17
C.M.J.L. Lelieveld, A.I.M Voorbij
Delft University of Technology, the Netherlands

DECONSTRUCTION
Barriers for Deconstruction and Recycling of the Currently Built Single Detached Houses.......................... 18
S. Nakajima, J. Koga
Building research institute, Japan

A Neurofuzzy Knowledge Model for the Quantification of Structural Flexibility........................................... 19
R.W.J. Hoekman, R. Blok, F. van Herwijnen
Eindhoven University of Technology, the Netherlands

Construction Materials and C&D Waste in India......................................................................................... 20
Sandeep Shrivastava and Abdol Chini
University of Florida, USA

SUSTAINABLE MANAGEMENT OF BUILDINGS
Embodied and operational energy use of buildings.......................................................................................... 21
L.C.M. Itard
Delft University of Technology, the Netherlands

Research Framework for an Experimental Study on Phase Change Materials in Scaled Models of Dutch
Dwellings.................................................................................................................................................. 22
F. Muthing, A.G. Entrop, H.J.H. Brouwers
University of Twente, the Netherlands

The Jerusalem Eco-Housing Project - Applying Integrated Design Solutions.................................................. 23
Gil Peled
Eco challenges, Jerusalem

The influence of changes in the physical and technical design on social interactions in a cohousing
community.................................................................................................................................................. 24
J.T. Bouma, A.I.M Voorbij, W. A. Poelman
Hanze University Groningen, University of Twente, the Netherlands

DESIGN WITH REUSED MATERIALS AND COMPONENTS
The Process of Designing with Reused Building components.......................................................................... 25
Mark Gorgolewski, Lawrence Morettin
Ryerson University, The Fountainhead Design Group, Canada
Supply Driven Architecture (SDA) ........................................................................................................... 26
W. A. Poelman
University of Twente, the Netherlands

Conservation of Resources by Designing a Meccano for Temporary constructions ........................................... 27
Vrije universiteit Brussel, Belgium

INTELLIGENT AND ECO MATERIALS
Eco Concrete Stones with TiO2 for Atmospheric Decontamination ........................................................................ 28
M. M. Ballari, M. Hunger, G. Hüsken and H. J. H. Brouwers
University of Twente, the Netherlands

Construction Process Assessment or “Black Box Opener” .................................................................................. 29
L. Abarca, F.M. Scheublin, A.J.D. Lambert
Eindhoven University of Technology, the Netherlands

Constitutive modelling of viscoelastic behaviour of CNT/Polymer composites .................................................. 30
K. Yazdchi, M. Salehi
University of Twente, the Netherlands, Amirkabir University of Technology, Iran

The direct incorporation of micro-encapsulated Phase Change Materials in the concrete mixing process – A feasibility study .................................................................................................................................................. 31
University of Twente, the Netherlands, National Technical University of Athens, Greece
Preface

University of Twente in Enschede, the Netherlands, hosted the CIB W115 conference on Life Cycle Design of Buildings Systems and Materials from 12-15 June 2009. Unique feature of the conference was its attempt to bridge the gap between the theory and practice in the field of sustainable building construction by involving construction industry (region of Twente, The Netherlands) into the debate during the conference. Innovation in sustainable construction has been presented through number of case studies by the industry members of the Innovation Platform Twente (working Group IDF). The conference was organized by the University Twente, Innovation Platform Twente (Working group IDF) and CIB.

The emphasis of the conference was on innovative design and construction methods and assessment methods that will incorporate effective use of materials into the whole life cycle of buildings and building materials.

The conventional way of construction has become a burden to the dynamic and changing society of the 21st century. Developers and real estate managers warn that there is a miss-match between the existing building stock and the dynamic and changing demands with respect to the use of buildings and their systems.

A report by the World Resource Institute projects 300% rise in material use as world population and economic activity increases over the next 50 years. Steel price is rising. Raw materials are gradually diminishing and becoming expensive, landfill sites are filling up forcing disposal fees to increase and making the waste management exceptionally expensive.

The physical impact of increasing building mass in industrialised nations and developing world has become undeniable in 21st century. The appetite for raw materials and landfill sites, as well as acceleration of the changing demands by users clearly indicates that a fundamental change in the way buildings are designed and constructed is needed.

During the conference the state of the art papers have been presented with respect to life cycle design of buildings and materials.

This subject integrates issues from spatial adaptability and flexibility of building systems to material efficiency and energy saving (embodied energy).

Development of the research agenda with respect to this topic deal with issues such as, life cycle performance and strategies, design methodology, systems development, reuse, renewable materials, cad manufacturing, and development of performance measurement tools (transformation capacity-measurement tool, life cycle costing, life cycle assessments etc.).

Background on CIB W115

This CIB W115 Commission on Construction Material Stewardship aims to:

- Drastically reduce the deployment and consumption of new non-renewable construction materials, to replace non-renewable materials with renewable ones whenever possible, to achieve equilibrium in the demand and supply of renewable materials and ultimately to restore the renewable resource base
- Carry out these tasks in ways to maximize positive financial, social and environmental and ecological sustainability effects, impacts and outcomes.

Dr. Elma Durmisevic
Sustainable Construction Strategies: A Singapore Perspective

K. C. G. Ong, E Anggadjaja, S. L. Y Soh

National University of Singapore, Singapore

Abstract

This paper presents an overview of the Sustainable Construction Master Plan envisaged by the Building and Construction Authority (BCA), Singapore. Various initiatives that are currently being pursued to drive sustainable construction are discussed. To highlight strategic Thrust 3, one of the projects funded by the Ministry of Development’s Research Fund for the Built Environment is briefly described. The project utilizes microwave heating to increase the yield and quality of recycled concrete aggregates. The preliminary results obtained using the proposed system is briefly reported in this paper.

Keywords: Sustainable construction, Singapore, Waste to resource, Microwave heating, Recycled concrete aggregates
From Ugly Duckling to Swan,

Transformation as an Alternative to Demolition

J.B. Storey

Victoria University of Wellington, New Zealand

Abstract

In New Zealand the period 1960 to 1990 produced a whole crop of malformed office buildings. They were graceless, space and specification was minimalistic. They were built for developer/speculators who quickly sold them on to building owners before their shortcomings became obvious. They were bought and could be rented out because of the serious shortage of available office accommodation during this period.

Today these buildings are simply an embarrassment for everyone. The general feeling both in the building sector and the community at large is that they should be demolished. Yet they represent a huge investment of resources. So, is there a resource effective and financially beneficial way of dealing with these buildings? A progressive developer/owner and a skilled design team thought that there was, and transformed a 1960’s that was built down to the barest minimum standards allowed in the 1960’s NZ Building Code into a 5 star NZ Green Star (New Zealand Excellence), which is equivalent to a LEED Gold Standard, rated office building. It has been changed from a typical unlovely, unloved and unwanted Brutalist era concrete stub into a soaring crystalline tower that was essentially pre-let before any work started on site and will enhance the urban quality of the area. The scheme will transform the building from an ugly duckling into a swan, in the very best tradition of Hans Christian Anderson.

This paper tells the story of this transformation. It examines the technical processes involved, analyses the triple bottom line sustainability benefits and explains the lessons that have been learnt and their application to other buildings of a similar nature both nationally and internationally. It concludes that renovation is not only a sustainable option to the future use of these buildings but that and in most cases a better option than demolition or even deconstruction.

Keywords: Reconstruction, Resource Stewardship, Transformation, Existing Buildings, Offices
Transforming cities: Introducing adaptability in existing residential buildings through reuse and disassembly strategies for retrofitting


Vrije universiteit Brussel, Belgium

Abstract

Since the existing building stock will remain with us for decades, their importance as economic, social and cultural capital should not be wasted. In the framework of the current ecological and social issues, these buildings therefore need to be re-evaluated and re-designed based on their environmental impacts. In European countries, existing buildings account for over 40% of final energy consumption, of which residential use represents 63% of total energy consumption in the buildings sector. Consequently, there is an urgent need to increase the building thermal and energy performance of the existing residential buildings. On the other hand, building transformations are more and more required to answer variable factors of everyday life. However, the lack of flexibility in the conventional building design does not enable these crucial transformations, often causing demolition of building parts or even demolition of entire building structures in present renovation of buildings.

The aim of this paper is to specify a systemic design approach to adapt residential buildings, extending their initial material and energy consumption while providing additional value to the buildings in environmental terms. Features are being incorporated into the retrofitting of residential buildings, which enable future transformability and which introduce reuse of building products providing answers for the increasing construction and demolition (C&D) waste in the current built environment. Through a case study for retrofitting of a high-rise residential building, a systemic approach introducing disassembly and reuse strategies is being explored. New opportunities are being created, by stripping the building to its bearing structure and adding a new adaptable infill, composed of reconfigurable and reusable building components. This will allow similar buildings to easily (re)transform their spatial configuration to answer changing living conditions in the future and to keep the building physics performances up to date without taking part in the increasing C&D waste streams and the current environmental degradation.

Keywords: 4 Dimensional Design, design for disassembly, material and component recovery, reuse of existing buildings, transformation
Requirements for Sustainable Construction Materials
N. Sunke, F. Schultmann
University of Siegen, Germany

Abstract
Under the focus of construction material stewardship, the construction industry is characterised by a high material intensity due to the heterogeneous mix of construction materials and components inherent in buildings and the related construction and demolition waste streams.

The tremendous impact of the construction industry becomes obvious considering aspects like resource deterioration as well as congestion of landfills. Additionally, negative environmental impacts arise due to various construction waste streams. With this respect, efforts are undertaken to foster the development of new construction materials, paying respect to the requirements set by the need for a sustainable development. In the paper, the focus is drawn to the ecological as well as economic dimension of sustainability. Thereby, ecologic aspects attached to construction materials stewardship comprise required characteristics of materials in order to avoid negative ecological impact. In contrast, economic factors focus on cost but also quality issues and associated terms like eco balancing and life cycle costing. Thereby, the whole life cycle of a construction material has to be taken into consideration. In the paper, requirements for construction materials will be elaborated and initiatives and examples to approach these requirements are discussed.

Keywords: Construction materials, life-cycle, sustainability, requirements
Building green via design for adaptation and deconstruction

T. Saleh, A. Chini

University of Florida, USA

Abstract

According to the United States Environmental Protection Agency (EPA), only 8% of the construction and demolition (C&D) waste is generated during the construction phase. However, 48% of C & D waste is generated during the building demolition at the end of its life cycle and 44% is generated during the renovation of the building structure. EPA has also estimated that the C & D comprise 25 to 30% of all waste produced in the US each year. The preceding data suggests that it is imperative to design a building for adaptive reuse as well design for deconstruction (DfD) and material reuse. The overall goal of DfD is to reduce pollution impacts and increase resources and economic efficiency in the adaptation and the eventual disassembly of buildings. Ultimately, when a building is designed for deconstruction, the design aims at salvaging the building’s components and materials for reuse, remanufacturing and recycling. This paper will discuss the imperative need in today’s construction industry to create a design for deconstruction category in United States Green Building Council’s LEED point system that allows projects that are designed for adaptability and deconstruction to earn points towards the green building certification. The growing customer interest in greener buildings as well as the state and local initiatives to downsize the construction and demolition debris add an additional value that the owner or developer can not easily put a dollar value on, but contributes greatly to the achievement of the rising green sustainability objectives. Earning LEED points can be a substantial incentive for owners and architects to think about designing new buildings for adaptation and deconstruction.

Key words: deconstruction, adaptability, recycle, reuse, LEED
Developing the Stavne timber block;

Mitigation and adaptation in practice
A.S. Nordby, K.S. Wigum, B. Berge

Norwegian University of Science and Technology, GAIA Trondheim, GAIA Lista, Norway

Abstract

A prototype building block in massive wood designed and described by Bjørn Berge (Berge 2006) is being developed for full scale production in Trondheim. The project aims at an optimization of both climate mitigation and long term resource efficiency. At the Salvage yard of Stavne Gård, reclaimed wood from deconstructed buildings are planned for use in the new blocks which are, in every sense, carbon neutral. By utilizing waste material, new wood resources are saved. At the same time, as all growing biomass transforms CO$_2$ from the air to glucose, the effect of carbon storage may help reduce the threat of climate change.

The issue of adaptability is strongly focused. This regards flexibility of construction, as the building blocks can be incorporated into various types of walls and thus enable climate adaptation for different regions. Also, changing functional demands in the user phase are met. Finally, through limited material selection, durable design, high generality, flexible connections and accessible information, the salvageability of the blocks is optimized (Nordby 2007). The components thereby facilitate future reuse in new buildings, and after the last service-life they may be burned for heat recovery in standard wooden stoves.

Further development aim at improving the connection methods as well as the generality of the blocks. The joints should be easily accessible and enable parallel deconstruction. For the purpose of architectural flexibility, standard dimensions and a smaller scale than the original prototype are preferred. Besides, lightweight components will increase the possibilities for self-building. However, the demands of structural stability and thermal insulation must be satisfied. This is tested through model-making and in full scale.

Keywords: Building components, Massive wood, Salvageability, Closing the loop, Carbon neutral
An integrated and flexible approach for post-disaster shelter relief

C. Henrotay, W. Debacker, A. Paduart, N. De Temmerman, H. Hendrickx, M. Mollaert, P. De Wilde

Vrije universiteit Brussel, Belgium

Abstract

Disasters – natural as well as man-made – and the resulting need for shelter may occur all over the world. As a result, relief agencies have to manage a diversity of preconditions with regard to the local context and the nature of the disaster. In addition, even within one specific post-disaster situation, the different phases of relief (emergency – transit – reconstruction) are characterized by very different shelter needs. Therefore along each post-disaster recovery process a variety of specific shelter solutions are required that suits the logistical, socio-cultural and economic needs, the local climate, the family size, the livelihoods, etc. Taking into account the complexity of post-disaster shelter support in which relief workers have to manage quick interventions, a great amount of varying parameters and the unknown course of the situation, research has indicated that the static, end-state design of current shelter solutions lacks adaptability; as a result of what they difficultly meet the variety of specific shelter needs and can difficultly support the shelter process.

In order to increase the effectiveness and adequacy of post-disaster shelter response a novel and integrated design approach has been developed at the Vrije Universiteit Brussel that aims to support the various shelter and settlement options and to sustain the process from aid to sustainable development. The suggested approach relies on the design of adaptable, versatile and compatible construction systems and shelter kits. Based on a holistic research method, the feasibility of the presented concept and the construction systems has been investigated by means of field investigation, design-based research, structural analysis calculations and experimental investigation – comprising laboratory tests and prototype field testing. Current research concentrates on the improvement and elaboration of the presented design approach. Attention is given to the integration of diverse local materials and the interchangeability with different (local) construction systems and techniques.

Keywords: sustainable post-disaster shelter process; design for deconstruction; transformable shelters
A deployable mast for adaptable architecture
Vrije universiteit Brussel, Belgium

Abstract
An innovative concept for a deployable mast for architectural applications is proposed (Fig. 1). Its purpose is two-fold: serving as a supporting mast for an architectural tensile surface structure while acting as an active element during the erection process.

Fig. 1. Concept of the deployable mast supporting tensioned membranes

The mast consists of scissor-like elements (SLE’s) which are comprised of bar elements connected by an intermediate pivot joint, allowing a single rotational degree of freedom perpendicular to the common plane of the bar elements. Using scissor units is an effective way of introducing a single D.O.F. mechanism into a structure, providing it with the necessary kinematic properties for the deployment, during which the mechanism transforms from a compact state to a larger, expanded state (Fig. 2).

Fig. 2. Deployment sequence of the mast
A special kind of scissor unit is used for the structure, consisting of ‘angulated elements’ [1], which have been extensively investigated and this has yielded a wide range of concepts and applications in the field of deployable scissor structures [2]. Although primarily intended for radially deployable closed loop structures, it is shown in this paper that angulated elements can also prove valuable for use in a linear three-dimensional scissor geometry. It is explained how angulated elements offer, for the proposed application, an advantage over polar units in terms of deployment behaviour and a reduction of the number of connections. As the deployment is an integral part of the design, an insight in the relationship between the geometry of the structure and its subsequent kinematic behaviour is offered. The mobility of the system is assessed through the use of an equivalent hinged-plate model [3]. A purpose-built joint is proposed, allowing all necessary rotations between subsequent elements.

Also, a 1:2 scale proof-of-concept model has been built to investigate the deployment behaviour (Fig. 3). Finally, the mast is structurally analysed under wind and snow action and conclusions are drawn on the structural feasibility of the proposed design.

REFERENCES


Keywords: Deployable structures, transformable structures, adaptable architecture, scissor structures, kinetic architecture.
Adaptable architecture with the application of dynamic materials
C.M.J.L. Lelieveld, A.I.M Voorbij

Delft University of Technology, the Netherlands

Abstract

With fast developments on technological and electronic level, our perception of the world and the pace of our life have changed. Generally, electronic devices are designed for customization and are highly innovative. In the architectural environment customization of homes is only possible with relatively large effort, e.g.; by demolition, refurbishment or renovation. This leads to the impression that our homes do not fit our expectations on easy personification.

This research examines the possibility of an architecture, which can instantly adapt components to the requirements of the users or situation. An example of adaptable component is the immediate change of the colour of a room. This adaptability could be realized with the use of dynamic materials, which can change their physical appearance under the influence of a changed input. The molecular reconfiguration can be modified, which leads to the change of, for example; transparency, strength or color. In this research dynamic materials form the basis for the realization of an adaptable architecture.

An analysis of dynamic materials has been executed to get an overview of the current technology. An overview is made of dynamic materials and their characteristics and possible application in architectural environments. Dynamic materials are mostly applied on micro scale. For architectural purposes the dynamic materials need to be applied on macro scale, which will be a focal for the research. This required change in application, also results in a request for different characteristics of those dynamic materials. As neither theories nor practical knowledge on this matter is available, this study is largely based on practical experiments.

The aim is to generate a prototype of a composite of shape changing materials which can be applied in an adaptable design of an architectural scale. The focus lays on the interior elements of the building; such as non-bearing walls, ceilings or floors.

Keywords: adaptable architecture, dynamic materials
Barriers for deconstruction and recycle of the currently built single detached houses

S. Nakajima, J. Koga

Building research institute, Japan

Abstract

The currently built single detached houses are significantly difficult to deconstruct and the materials discharged during the dismantling process have low potential to be recycled as raw materials to reproduce building materials or other products. To make effective feedback loops of the building materials it is quite necessary to design houses that can be easily deconstructed. And we should precisely know what is ongoing on the deconstruction or dismantle sites to get useful design ideas.

The whole deconstruction processes of 17 single detached houses were recorded in detail. The 17 houses included timber post and beam houses, two by four houses, steel framed houses and a prefabricated steel unit house. Most of them were dismantled and two of them, the timber post and beam house and the prefabricated steel unit house, were deconstructed. The amount of the workers, the types and amount of the waste and the logistics of the waste were recorded to create a database. And all undesirable design for deconstruction were also recorded and included in the database.

The CO2 emission caused by the dismantle works and the transportation process was also calculated and included in the database. And the material recovery ratio was analyzed and included in the database.

Based on the data included in the database the influence of the construction methods and the dismantling methods on the CO2 emission and the material recovery ratio was analyzed. And the barriers for deconstruction and recycle of the currently built single detached houses were discussed. The detail of the database and the results of the studies are reported in the paper.

Keywords: Deconstruction, Recycle, Single Detached House, CO2 emission, Material recovery ratio
A Neurofuzzy Knowledge Model For The Quantification Of Structural Flexibility
R.W.J. Hoekman, R. Blok, F. van Herwijnen
Eindhoven University of Technology, the Netherlands

Abstract
As lifecycles of buildings tend to shorten, an increase in discrepancies between functional, technical and economical service lives can be identified, causing an unwanted degeneration of the quality of the built environment and putting a heavy burden on the environment. It is presumed that buildings designed to foster a prolonged service life, are able to address these issues, provided they possess certain capacities to accommodate substantial change in the future: flexibility or adaptability. In the pursuit of adaptability as a design criterion, qualities regarding the building structure are of critical importance. Structural flexibility, the ability to facilitate changes within the use of a building or its configuration without compromising structural performance, is considered to be a key precondition. In order to actively implement such features however, their suitability should be measured and quantified. Therefore, the current development of an assessment tool is introduced, intended to quantitatively express the performance of building structures in relation to the suitability of a building regarding its adaptability. This assessment tool is structured as a knowledge model, incorporating design knowledge through the systematic evaluation of fundamental interdependencies in the properties of a buildings’ configuration. Serving as a taxonomy, an abstract building model is specified, derived from a buildings’ typical functions, classifying the relationships between the main structural elements and critical elements in other building layers. The topology of this knowledge model is considered to be a feed forward neural tree, to which input variables are fed as performance indicators of a certain configuration. Their classification is based on functional, technical and physical relationships in regard to a certain level of flexibility. To address the highly diffuse nature of design information, fuzzy logic is applied to enable computation. It is expected that this assessment tool can be a valuable asset in the evaluation of configuration alternatives, as well as providing insights in the potential of existing structures in regard to conversion or renovation.

Keywords: adaptability, structural flexibility, knowledge model, assessment tool
Construction Materials and C&D Waste in India
Sandeep Shrivastava and Abdol Chini

University of Florida, USA

Abstract
With the advent of sustainable practices in the construction industry, construction and demolition (C&D) waste generation and handling issues have been in focus to achieve the sustainable goals for our common future. It is estimated that around 2 to 3 billion tons per year building waste is produced globally. C&D waste issues are important for the developing countries, which are entering or already entered in construction boom era. Owing to growth in construction in India, it is appropriate to link generation of C&D waste with the growth. If measures to minimize and handle the C&D waste are not developed and efficiently adopted it may threat the environment as well as sustainable movement of Indian construction industry. C&D waste in India in 2008 may be estimated as 15.7 million tonnes. Other than new construction, renovation or repair of buildings and demolition of an existing building are the main causes of waste generation from the construction industry. In India, services of demolition contractors are taken when an old building is to be demolished due to deterioration of the building or to make way for construction of a new building. C&D waste minimization and handling is necessary in view of limited landfill space and increasing quantum of demolition waste. Some major decisions like- reforming government policies & laws to make C&D waste management mandatory for all type of construction activities; use of Reduce, Reuse, Recycle (3Rs) policies; development of detailed database for Indian construction industry are needed to face C&D waste challenges more efficiently and to take an active part in sustainable construction movement. This paper provides an overview of the construction industry in India, gives some statistics about the current volume of C&D waste, and makes recommendations on how to minimize generation of C&D waste in the future.

Keywords: Construction and Demolition Waste, Recycling, sustainable construction, demolition
Embodied and operational energy use of buildings
L.C.M. Itard

Delft University of Technology, the Netherlands

Abstract

Up to now energy savings in the built environment have been approached from the side of operational energy use, e.g. the energy that is used by and in buildings during their operational service life. However, when the operational energy use for heating, cooling and lighting is reduced, the embodied energy use (i.e. the energy embodied in the manufacture and transport of building components) could become an important item. In this paper we present the results of an energy flow investigation - based on LCA considerations - on the relative values of embodied and operational energy of dwellings. Several building methods (among other things concrete and timber frame skeleton) and renovation measures (e.g. insulation and HVAC equipment) are compared. Next to this the specific cases of passive housing and zero-energy dwellings are studied more in detail. Based on this energy flow analysis, recommendations are made on possible improvements of low energy dwelling design.

Keywords: Life cycle assessment, embodied energy, materials, operational energy use, passive houses
Research Framework for an Experimental Study on Phase Change Materials in Scaled Models of Dutch Dwellings

F. Muthing, A.G. Entrop, H.J.H. Brouwers

University of Twente, the Netherlands

Abstract

In modern Dutch dwellings, about 10% of the annual use of primary energy is used to cool the dwelling, whereas about 50% of the primary energy is used for heating. With the technology of Phase Change Materials (PCM’s) exergy savings can be made in both areas. Exergy is a property used to determine the useful work potential of a given amount of energy at a specified state. In contrast to energy, exergy can be destroyed; therefore it is more appropriate to use this property.

PCM’s are materials with a high latent heat capacity which are, by melting and solidifying at a certain temperature, capable of storing and releasing a certain amount of energy. At hot days the PCM’s can store (part of) the excessive heat to form a (temporarily) buffer. The heat is released again when the temperature drops below the melting temperature of the PCM. As a result, people inside a building incorporating PCM’s can experience more comfort than in conventional buildings.

To measure the possible energy and exergy savings, an experimental research facility was set up. In this field set-up, modern Dutch dwellings are simulated by using scaled models with and without PCM in concrete floors. These models are provided with sensors measuring the inside temperature and the incoming solar irradiation. As a reference, a weather station collects data on the outside temperature, humidity, solar irradiation and wind speed. By comparing these data, the influence of the PCM’s becomes apparent.

In this proposition paper, a research framework to analyse the influence of PCM will be presented. To provide models, software packages will be assessed. The software package, which must be able to calculate the thermodynamic differential equations dynamically, will visualize the incoming and outgoing energy flows. The results, regarding the effectiveness of PCM, will also be implemented in the computation methodology of the Energy Performance Coefficient (EPC).

Keywords: Phase Change Materials, Built Environment, Solar energy, Exergy Savings, Experimental Research
The Jerusalem Eco-Housing Project - Applying Integrated Design Solutions

Gil Peled

Eco challenges, Jerusalem

Abstract

The existing housing stock in Israel consists of some 2 million dwellings in multi-storey residential buildings. Nearly half of them were constructed 50 years ago or more, and require extensive refurbishing to current standards and reduction in their harmful emissions. The Jerusalem Eco-Housing Pilot Project, the first of its kind in Israel, consists of the renewal of a typical apartment building focusing on sustainable and affordable improvements to the building's structure with occupants' participation in the process. The purpose of the project is to demonstrate best practice including specifications and procedures which can be widely implemented to improve the environmental performance of the existing building stock. For this, an integrated design strategy has been developed, addressing energy efficiency, water conservation, use of materials, waste reduction, transport, occupants' wellbeing, health and safety, urban ecology, and disaster control. The following paper describes the current status of the project and the applied integrated design solutions.

Keywords: sustainable, housing, integrated design, Jerusalem
The influence of changes in the physical and technical design on social interactions in a cohousing community

J.T. Bouma, A.I.M Voorbij, W. A. Poelman

Hanze University Groningen, University of Twente, the Netherlands

Abstract

Cohousing has gained renewed interest in the Netherlands, especially for populations of over 50 years of age and as an alternative for professional and family care. This in combination with living independently. In a cohousing community people have the possibility to share daily life activities in a specially developed facility. This paper presents the relation between changes in technical and physical characteristics and social interaction in a cohousing community. Based on literature and case studies gathered by students changes in social interaction through changes in the design of the cohousing community and home technology have been observed. Based on the results it was concluded that the relation between changes in the physical and technical context and social interaction occur in expected and unexpected ways. Changing interactions can be related to the script or to the change itself.

Keywords: Social interactions, cohousing community, home technology, physical design
The Process of Designing with reused building components

Mark Gorgolewski, Lawrence Morettin

*Ryerson University, The Fountainhead Design Group, Canada*

Abstract

It is generally recognized that the use of recycled materials and the reuse of components in buildings can lead to lower environmental impacts. However, at present, in North America the perceived difficulties inherent in the incorporation of reclaimed materials into new buildings often discourage clients and designers from embracing reuse unless it is for principled rather than financial reasons. Although materials costs can be lower through reuse, it must be recognized that these may be offset by higher labor costs and increased design time, and fees, resulting from more research required by the design team. In addition, there is likely to be greater uncertainty over costs and program as delays can occur if key components cannot be readily sourced or there are delays in the demolition process. Thus, using reclaimed components has significant implications on the “process” of how to design a building as well as its construction. Traditional relationships and design procedures may not be best suited to maximize material reuse and appropriate construction contracts are needed to accommodate component dismantling and reuse. These issues need to be understood by the design team and client so that appropriate strategies are put into place.

This paper is based on a survey and other data collection that was undertaken as part of a study at Ryerson University. It will consider the practical implications of component reuse strategies on the process of designing and constructing buildings. How does the design team have to adapt its working methods to maximize the potential for reusing components? What are the contractual and liability issues? What are the implications for the client? The paper will highlight the lessons learned from reusing salvaged and reclaimed materials in Canadian construction projects. Using the experience from these projects the paper will outline the differences in process that design teams need to embrace, and some key procedural points that need to be integrated into architectural handbooks of practice.

*Keywords: reuse, recycling, reclaimed materials, design process*
Supply driven architecture

W. A. Poelman

University of Twente, the Netherlands

Abstract

Problem Statement

Waste problems in building industry are subject for discussions in politics as well as in architecture and science. Solutions are searched for in the field of sustainable materials and in reuse of buildings and/or building elements. In this context “design for disassembly” (Durmisevic 2007) is an important issue. The disadvantage of the reuse of building elements at this moment is that the elements, generally spoken, are connected with building systems and the architecture of those systems. It would be interesting to disconnect reuse of building components from building systems and make them available for ‘free’ architecture. This could be enabled by building databases of available building components equipped with all necessary information for the architect, visual as well as technical. For the profession of architecture this so-called supply driven design would be a challenge. At this moment architects have a lot of freedom to use materials and components and this freedom will degrease when they have to take the supply side of reusable materials in account.

Objectives

The objective of the project is to build a body of knowledge about the feasibility and consequences of “supply driven design”, as well as finding out what methodological aspects it could have for the profession of architecture.

Questions to be answered are:

Could the supply side be able to offer enough options for the architect to be interesting? What are the experiences with existing databases like the : Grondstoffenbeurs)?

Could software help, in what way, to offer opportunities from the database to find the optimal components for the architects assignment?

Could the database inspire the architect for new architecture or will supply driven design decrease the creativity?

Is the quality control problem solvable, as it is in automotive where databases for re-usable components are widely accepted?

Expected outcome:

This project aims at finding out the feasibility of supply driven design, so one of the results would be an estimation of the importance in the future. Furthermore the project will provide an overview of what is happening in this field and related fields. Finally the project will lead to suggestions with respect to further research to be done and with respect to the development of an infrastructure to enable supply driven design.

Keywords: reuse, building components, databases, sustainability, methodology
Conservation of resources by designing a Meccano for temporary constructions


Vrije universiteit Brussel, Belgium

Abstract

As a part of material culture, buildings have to support human needs. But because of their static nature, obtained through design, most contemporary buildings and their components have a negative impact on their surroundings. The huge quantities of waste produced during demolition and the still rising emission of greenhouse gases created during use of the building, manufacture and waste treatment of its components are environmental indicators of an inefficient and unhealthy design.

Reusing building components is an effective way of conserving embodied resources, materials as well as energy, in a life cycle perspective. However this will require innovative design strategies, which anticipate an eventual demolition and provide versatile and adaptable constructions.

This paper shows how the Hendrickx-Vanwalleghem (H-V) design approach provides constructions and their components with the necessary reuse qualities. These are different from most existing building solutions, since they are not designed to deliver an end-product. On the contrary, a multitude of adaptable configurations is realised, using a minimum number of different components. Like in a Meccano building set, the components can be reused in other configurations, as a result of the formulation of geometrical standardisation rules.

To monitor the environmental load of such Meccano-like designs, an assessment method that focuses on the conservation of natural resources and energy, in a life cycle perspective, is detailed in this paper. The technical constraints and environmental benefits of the H-V design approach are discussed through a case study, i.e. a temporary construction.

Keywords: reuse; building components, life cycle, environmental load assessment, Meccano
Eco concrete stones with TiO\textsubscript{2} for atmospheric decontamination

M. M. Ballari, M. Hunger, G. Hüskens and H. J. H. Brouwers

University of Twente, the Netherlands

Abstract

Nitrogen oxides (NO\textsubscript{x}) is the generic term for a group of highly reactive gases, most of them emitted in air in the form of nitric oxide (NO) and nitrogen dioxide (NO\textsubscript{2}). NO\textsubscript{x} causes a wide variety of health and environmental impacts, like the formation of tropospheric ozone, urban smog and acid rain. The European Union (EU) has taken important steps over the past decade leading to a decrease in the emissions to air and water of a number of contaminant. Some of the pollutant emissions have since become more or less manageable, although particulates, NO\textsubscript{x} and smog are still problematic.

Heterogeneous photocatalysis represents an emerging environmental control option for the efficient removal of chemical pollutants. This process involves a solid semiconductor catalyst, regularly titanium dioxide (TiO\textsubscript{2}), which is activated with ultraviolet light of the appropriate wavelength. The development of innovative materials that can be easily applied on structures, with both de-soiling and de-polluting properties, is a significant step towards improvements of air quality. The use of TiO\textsubscript{2} photocatalyst in combination with cementitious and other construction materials has shown a favorable effect in the removal of nitrogen oxides.

In the present work the degradation of NO\textsubscript{x} compounds employing concrete paving stones with TiO\textsubscript{2} to be applied in road construction is studied. The experiments were carried out in a photoreactor designed according to the standard ISO 22197-1 (2007) to assess these kind of photocatalytic materials. A kinetic model is proposed to describe the photocatalytic reaction of NO and NO\textsubscript{2} and the influence of several parameters that can affect the performance of these stones.

Keywords: heterogeneous photocatalysis, air purification, concrete roads, nitrogen oxides, kinetic model.
Construction process or “black box” opener
L. Abarca, F.M. Scheublin, A.J.D. Lambert

Eindhoven University of Technology, the Netherlands

Abstract

The construction industry and related ones are considered the world’s largest industrial employer and natural resources consumer. 50% of all materials extracted from the earth are transformed into construction materials and products. When these materials enter the waste stream, they account for some 50% of all waste generated prior to recycling, recovery or final disposal, showing that the metabolism (processing) of those products in the construction sector is not efficient. In spite of these alarming conditions, very little detailed knowledge currently exists about the origins and distributions of construction wastes, and those losses arise very often from inadequate management or poor housekeeping.

The Material Flow Analysis approach (MFA) can help to analyse the efficiency of construction processes by means of investigating the physical flows. Through balancing inputs and outputs, the flows of wastes and environmental loadings become visible, and their sources can be identified. This approach presents the limitation that by measuring just flows is insufficient to understand the processes that takes place. Therefore, the description of the flows is important as well as the comprehension of the processes behind them. In order to understand them the “Aggregated Process Model” has been proposed in order to open the “black box” or subsystems present in the construction activity.

The goals of the study are: (1) to gain insights into the traditional and industrialised construction processes in order to analyse the performance of the production systems, (2) to develop a documented example of the practical use of MFA approach and (3) to develop MFA Framework for the Construction Sector.

Keywords: Construction industry, material management, material flows, aggregated process model, industrial metabolism.
Constitutive modelling of viscoelastic behaviour of CNT/polymer composites

K. Yazdchi, M. Salehi

University of Twente, the Netherlands, Amirkabir University of Technology, Iran

Abstract

Nanotubes are recognized as a highly promising material in wide range applications. There is increasing interest from aerospace, consumer goods and industrial product markets to use nanotubes to impart enhanced thermal, mechanical and electrical properties in composite systems. Both experimental and theoretical studies have shown that carbon nanotubes (CNTs) have extraordinary mechanical, electrical and thermal properties. The high strength and elastic modulus, fibrous shape and very large aspect ratios of these NTs make them a very promising candidate as the ideal reinforcing fibers for advanced composites with high strength and low density. The nanocomposites exhibit high electrical conductivity, significant third order non-linear optical behavior and electroluminescence, while having substantially improved mechanical strength relative to the neat polymer. However, very limited attention has been paid to the viscoelastic behavior of nanotube reinforced polymer composites (NTRPC). Since the experimental techniques are so expensive, there is a need to develop analytical models that are capable of predicting the time-dependent viscoelastic behavior of such nanocomposites.

In this paper, the constitutive relation and linear viscoelastic behaviour of NTRPC are studied using methods of micromechanics and nanomechanics. First, the effects of volume fraction, shape, aspect ratio and mechanical properties of carbon nanotubes (CNTs), on the overall elastic properties of NTRPC are obtained through a variety of micromechanical techniques based on Eshelby's Equivalent Inclusion. Secondly, by incorporating the Dynamic Correspondence Principle (DCP), the elastic solution is extended to solve the related linear viscoelastic problem. The results are in good agreements when compared with previous analytical and experimental data.

Keywords: Nanocomposites; Carbon nanotubes; Mechanical properties; Viscoelastic
The direct incorporation of micro-encapsulated Phase Change Materials in the concrete mixing process – A feasibility study


University of Twente, the Netherlands, National Technical University of Athens, Greece

Abstract

Thermal storage is an important aspect of energy conservation. During the past years a growing demand for thermal comfort in combination with low energy consumption could be observed in the built environment. Following this trend thermal mass activation of massive structural elements came into the focus of research. Owing to its high heat storage capacity, concrete is a suitable material for thermal activation. In this respect the application of the various phase change materials (PCM) appears to be a very promising solution. This, however, raises the question of the incorporation of PCM into the concrete.

The present study refers to a set of tests using different amounts of micro-encapsulated PCM in self-compacting concrete mixes. This study furthermore focuses on the direct mixing of micro-encapsulated PCM into concrete and its influence on the material properties. Therefore, the fresh concrete properties and the hardened properties are investigated. The hardened properties comprise strength tests as well as a thorough assessment of the thermal properties. It will be shown that increasing PCM amounts lead to lower thermal conductivity and increased heat capacity, which both significantly improve the thermal performance of concrete structures and therefore save energy. On the other hand, a significant loss in strength and a conducted micro-structural analysis both indicate that a large part of the capsules cannot withstand the shear loads during mixing. This is due to the insufficient mechanical as well as chemical resilience of the encapsulating material. However, the compressive strength of the specimens still satisfies the demands of most structural applications.

Keywords: PCM, self-compacting concrete, latent heat capacity, hydration heat, energy saving
CIB’s mission is to serve its members through encouraging and facilitating international cooperation and information exchange in building and construction research and innovation. CIB is engaged in the scientific, technical, economic and social domains related to building and construction, supporting improvements in the building process and the performance of the built environment.

**CIB Membership offers:**
- international networking between academia, R&D organisations and industry
- participation in local and international CIB conferences, symposia and seminars
- CIB special publications and conference proceedings
- R&D collaboration

**Membership:** CIB currently numbers over 400 members originating in some 70 countries, with very different backgrounds: major public or semi-public organisations, research institutes, universities and technical schools, documentation centres, firms, contractors, etc. CIB members include most of the major national laboratories and leading universities around the world in building and construction.

**Working Commissions and Task Groups:** CIB Members participate in over 50 Working Commissions and Task Groups, undertaking collaborative R&D activities organised around:
- construction materials and technologies
- indoor environment
- design of buildings and of the built environment
- organisation, management and economics
- legal and procurement practices

**Networking:** The CIB provides a platform for academia, R&D organisations and industry to network together, as well as a network to decision makers, government institutions and other building and construction institutions and organisations. The CIB network is respected for its thought-leadership, information and knowledge.

The CIB has formal and informal relationships with, amongst others: the United Nations Environmental Programme (UNEP); the European Commission; the European Network of Building Research Institutes (ENBRI); the International Initiative for Sustainable Built Environment (iiSBE), the International Organization for Standardization (ISO); the International Labour Organization (ILO), International Energy Agency (IEA); International Associations of Civil Engineering, including ECCS, fib, IABSE, IASS and RILEM.

**Conferences, Symposia and Seminars:** CIB conferences and co-sponsored conferences cover a wide range of areas of interest to its Members, and attract more than 5000 participants worldwide per year.

**Leading conference series include:**
- International Symposium on Water Supply and Drainage for Buildings (W062)
- Organisation and Management of Construction (W065)
- Durability of Building Materials and Components (W080, RILEM & ISO)
- Quality and Safety on Construction Sites (W099)
- Construction in Developing Countries (W107)
- Sustainable Buildings regional and global triennial conference series (CIB, iiSBE & UNEP)
- Revaluing Construction
- International Construction Client’s Forum

**CIB Commissions (May 2009)**
- TG53 Postgraduate Research Training in Building and Construction
- TG57 Industrialisation in Construction
- TG58 Clients and Construction Innovation
- TG59 People in Construction
- TG62 Built Environment Complexity
- TG63 Disasters and the Built Environment
- TG64 Leadership in Construction
- TG65 Small Firms in Construction
- TG66 Energy and the Built Environment
- TG67 Statutory Adjudication in Construction
- TG68 Construction Mediation
- TG69 Green Buildings and the Law
- TG71 Research and Innovation Transfer
- TG72 Public Private Partnership
- TG73 R&D Programs in Construction
- TG74 New Production and Business Models in Construction
- TG75 Engineering Studies on Traditional Constructions
- W014 Fire
- W018 Timber Structures
- W023 Wall Structures
- W040 Heat and Moisture Transfer in Buildings
- W051 Acoustics
- W055 Building Economics
- W056 Sandwich Panels
- W062 Water Supply and Drainage
- W065 Organisation and Management of Construction
- W069 Housing Sociology
- W070 Facilities Management and Maintenance
- W077 Indoor Climate
- W078 Information Technology for Construction
- W080 Prediction of Service Life of Building Materials and Components
- W083 Roofing Materials and Systems
- W084 Building Comfortable Environments for All
- W086 Building Pathology
- W089 Building Research and Education
- W092 Procurement Systems
- W096 Architectural Management
- W098 Intelligent & Responsive Buildings
- W099 Safety and Health on Construction Sites
- W101 Spatial Planning and Infrastructure Development
- W102 Information and Knowledge Management in Building
- W104 Open Building Implementation
- W107 Construction in Developing Countries
- W108 Climate Change and the Built Environment
- W110 Informal Settlements and Affordable Housing
- W111 Usability of Workplaces
- W112 Culture in Construction
- W113 Law and Dispute Resolution
- W114 Earthquake Engineering and Buildings
- W115 Construction Materials Stewardship
- W116 Smart and Sustainable Built Environments
- W117 Performance Measurement in Construction
Publications: The CIB produces a wide range of special publications, conference proceedings, etc., most of which are available to CIB Members via the CIB home pages. The CIB network also provides access to the publications of its more than 400 Members.

Recent CIB publications include:
- Guide and Bibliography to Service Life and Durability Research for Buildings and Components (CIB 295)
- Performance Based Methods for Service Life Prediction (CIB 294)
- Performance Criteria of Buildings for Health and Comfort (CIB 292)
- Performance Based Building 1st International State-of-the-Art Report (CIB 291)
- Proceedings of the CIB-CTBUH Conference on Tall Buildings: Strategies for Performance in the Aftermath of the World Trade Centre (CIB 290)
- Condition Assessment of Roofs (CIB 289)
- Proceedings from the 3rd International Postgraduate Research Conference in the Built and Human Environment
- Proceedings of the 5th International Conference on Performance-Based Codes and Fire Safety Design Methods
- Proceedings of the 29th International Symposium on Water Supply and Drainage for Buildings
- Agenda 21 for Sustainable Development in Developing Countries

R&D Collaboration: The CIB provides an active platform for international collaborative R&D between academia, R&D organisations and industry.

Publications arising from recent collaborative R&D activities include:
- Agenda 21 for Sustainable Construction
- Agenda 21 for Sustainable Construction in Developing Countries
- The Construction Sector System Approach: An International Framework (CIB 293)
- Red Man, Green Man: A Review of the Use of Performance Indicators for Urban Sustainability (CIB 286a)
- Benchmarking of Labour-Intensive Construction Activities: Lean Construction and Fundamental Principles of Working Management (CIB 276)
- Guide and Bibliography to Service Life and Durability Research for Buildings and Components (CIB 295)
- Performance-Based Building Regulatory Systems (CIB 299)
- Design for Deconstruction and Materials Reuse (CIB 272)
- Value Through Design (CIB 280)

An example of a recent major CIB collaborative activity is the Thematic Network PeBBu - Performance Based Building: a four-year programme that included 50 member organisations, that was co-ordinated by CIB and that was funded through the European Commission Fifth Framework Programme.

Themes: The main thrust of CIB activities takes place through a network of around 50 Working Commissions and Task Groups, organised around four CIB Priority Themes:
- Sustainable Construction
- Clients and Users
- Revaluing Construction
- Integrated Design Solutions

CIB Annual Membership Fee 2007 – 2010

<table>
<thead>
<tr>
<th>Fee Category</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>FM1</td>
<td>Fee level</td>
<td>10526</td>
<td>11052</td>
<td>11605</td>
</tr>
<tr>
<td>FM2</td>
<td>Fee level</td>
<td>7018</td>
<td>7369</td>
<td>7738</td>
</tr>
<tr>
<td>FM3</td>
<td>Fee level</td>
<td>2413</td>
<td>2534</td>
<td>2661</td>
</tr>
<tr>
<td>AM1</td>
<td>Fee level</td>
<td>1213</td>
<td>1274</td>
<td>1338</td>
</tr>
<tr>
<td>AM2</td>
<td>Fee level</td>
<td>851</td>
<td>936</td>
<td>1030</td>
</tr>
<tr>
<td>IM</td>
<td>Fee level</td>
<td>241</td>
<td>253</td>
<td>266</td>
</tr>
</tbody>
</table>

All amounts in EURO

The lowest Fee Category an organisation can be in depends on the organisation’s profile:

- **FM1** Full Member Fee Category 1 | Multi disciplinary building research institutes of national standing having a broad field of research
- **FM2** Full Member Fee Category 2 | Medium size research Institutes; Public agencies with major research interest; Companies with major research interest
- **FM3** Full Member Fee Category 3 | Information centres of national standing; Organisations normally in Category 4 or 5 which prefer to be a Full Member
- **AM1** Associate Member Fee Category 4 | Sectoral research & documentation institutes; Institutes for standardisation; Companies, consultants, contractors etc.; Professional associations
- **AM2** Associate Member Fee Category 5 | Departments, faculties, schools or colleges of universities or technical Institutes of higher education (Universities only)
- **IM** Individual Member Fee Category 6 | Individuals having an interest in the activities of CIB (not representing an organisation)

Fee Reduction:
A reduction is offered to all fee levels in the magnitude of 25% for Members in countries with a GNIpc less than USD 1000 and a reduction to all fee levels in the magnitude of 25% for Members in countries with a GNIpc between USD 1000 – 7000, as defined by the Worldbank. (see http://siteresources.worldbank.org/DATASTATISTICS/Resources/GNIPC.pdf)

Reward for Prompt Payment:
All above indicated fee amounts will be increased by 10%. Members will subsequently be rewarded a 10% reduction in case of actual payment received within 3 months after the invoice date.

For more information contact
CIB General Secretariat:
e-mail: secretariat@cibworld.nl
PO Box 1837, 3000 BV Rotterdam, The Netherlands
Phone +31-10-4110240; Fax +31-10-4334372
Http://www.cibworld.nl