Digital Proceeding Of THE ICOEST'2013 - , Cappadocia
C.Ozdemir, S. Şahinkaya, E. Kalıpcı, M.K. Oden (editors)
Nevsehir, Turkey, June 18 – 21, 2013

No Waste in Nature: Using Nature as a Model for Construction Industry

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ABSTRACT

The dominant industrial development model of presentday, based on a linear output process. During this period that lots of energy and resources are consumed, the production of waste is so much and the most of these waste can not be recycled. As a result of that, there is a rising of the environmental problems. Unlike the linear (take-make-waste) consumer model, nature trying to create completely non-waste/zero waste systems and it depends on the understanding of holistic system. To minimize the negative effects that produced by the built environment beyond the construction industry in terms of creating positive outcomes experienced the need for a paradigm shift occurs.

In this context, the general aim of the study is trying to exhibit the understanding of the processes that occur in nature and how to take advantages from these process in construction industry. As a working method, natural environment and construction industries are analyzed comperatively in terms of use of materials and waste management. With a comparative study it is tried to understand that, how today's construction industry and natural processes have different points, and also what is necessaried by approach based on nature and how it is applied on building and building environment.

Keywords: Biomimicry, Building Environment, Closed-loop Material Cycle, Cradle-to-Cradle, Construction Industry, Construction Materials, Nature, Nature/Ecosystem's Laws, Paradigm Shift, Regenerative Approach, Sustainable Future, Zero Waste Management.

1. INTRODUCTION: TODAY'S CONSTRUCTION INDUSTRY

Construction industrial system today is primarily linear, with "take-make-waste" processes. The built environment today consumes 40% of energy, 25% of freshwater, and 30% of other natural resources, in addition to generating 40% of air emissions, 20% of freshwater effluents, and 25% of our solid wastes [1]. Construction waste which is within the group of solid waste, and consisted of construction materials and their components such as concrete, metal, wood, ceramics, plastic which come out as a result of restoration and destruction operations, and constitution and innovation of constructions, and manufacturing the construction material is modified as primary waste in many countries because of having large scale, their amount and

complexity. The percentage of construction waste in the total waste is stated as 44 % in Australia, 25-50% in Denmark, 38% in Hong Kong, 36% in Japan, 30% in Italy, 70% in Spain [2]. Because reuse, recylcling and recovery of most construction and demolition waste can not be properly provided, and because waste, which is not be able to be utilized, can not be stored, it causes this waste to be thrown away randomly to nature (Figure 1).

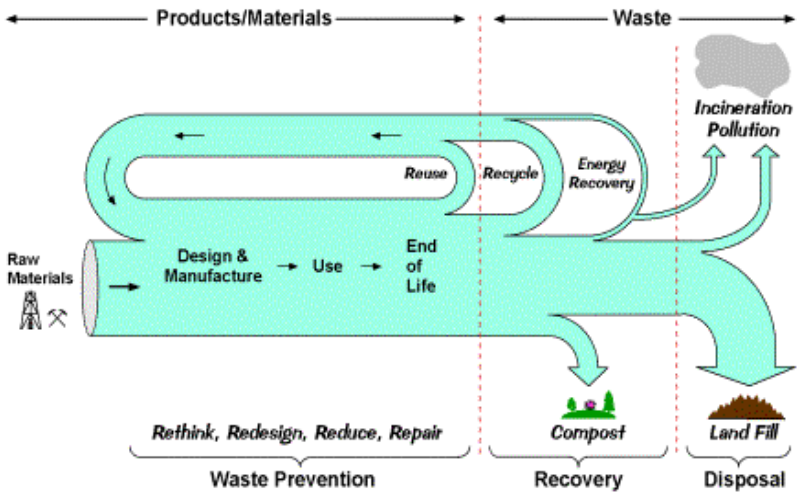

Figure 1. Material flows in today's construction industry [3]

As a result of that, there is a rising of the environmental problems such as the changes in climate, global warming, wasting of fresh water springs, erosion of ozonosphere, extinctions and loosing of characteristics of natural habitats. To eliminate these problems, several authors such as Reed [4] , Kellert [1], McDonough [5] suggest that current sustainability practice as applied to the built environment is insufficient to achieve a sustainable environment. The intended outcome of “green” or “high performance” design is to do “less harm”; a relative improvement to what exists now. Sustainable development or “achieving a steady state” is neutral or “100 per cent less bad”. This issue proves the “less bad” is not “good enough” idea briefly. In this context, according to these authors, in order to produce positive output, a “paradigm shift” is also required in thinking and practice. Paradigm shift which focus on to cradle-to-cradle, restorative and regenerative development [6] (Figure 2) is based on understanding of the biological or living systems and the laws of nature.

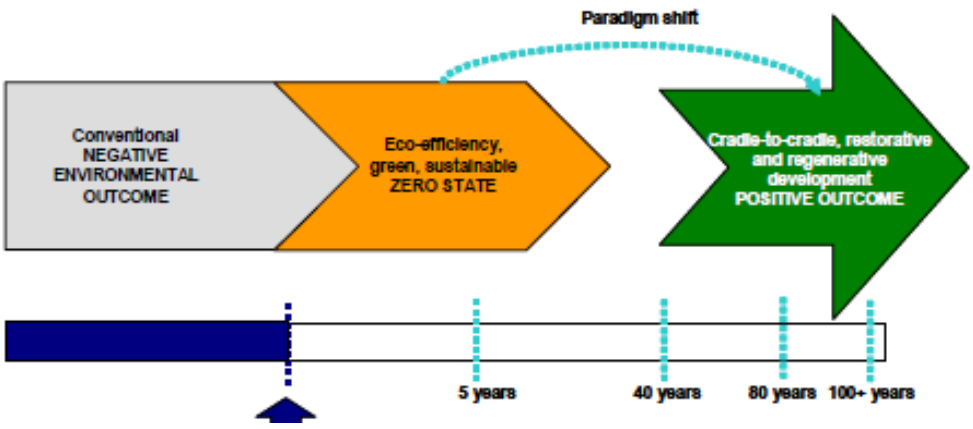

Figure 2. Achieiving positive environmental outcomes [6]

2. NATURE'S MATERIALS AND THE CYCLICAL CHARACTERISTIC OF NATURAL PROCESSES

Nature uses very few materials in itself. Ekmekçi [7] indicates that there are only four polymer fibers including silk in spiders' web, chitin in insects and crustacean, collagen in animals and cellulose in herbs. Also, Rao [8] Liu and Jiang [9] state that the materials of natural world has some peerless features such as self-generation, hierarchical structuring, multi-functional behavior, adaptation of the structure and form that depends on the function, adaptation to changing environmental conditions, self-repairing, self-replicating, re-adjust, establishing of chemical equilibrium, non-linearity, compositeness, lightness, durability and biodegradable. The materials that the animals use to build their nests skilfully are also natural materials which have entirely recyclable features such as soil, mud, clay, straw, grass, leaf, creeper, branch, pieces of tree, wax, feather, spider webs, snakeskin and slaver [10]. Bontha "et al." [11] explain that the sequence of events in building a nest-site selection, site preparation, collection of materials, carrying that material to the site and the actual construction of the nest are very similar to man's building activities. But organisms generally reside and manufacture in the same location. They don't pollute in this region because it would directly impact adversely on their quality of life; namely, food supply, sleeping and breathing [12]. Further efficiency and sophistication are clearly the goals of the evolutionary processes of animal architecture. Pallasma [13] state tahat animal buildings even fulfill strict criteria for economy and efficiency through minimizing the use of material and labour. Certain animals, such as spiders and some wasp species, eat their structures in order to reuse their building material.

Also, the cyclical qualities of natural systems are brilliant. All natural ecosystems involve elements, nutrients and metabolisms in which everything is used and reused in a continuous cycle. Waste virtually does not exist in nature because each organism's processes contribute to the health of the whole ecosystem. One organism's waste is food for another, and nutrients and energy flow perpetually in closed-loop cycles of growth, decay and rebirth. In other words, waste equals food [14]. Thompson [12] state tahat this process represents a constantly changing and a renewed cycle of material flow. Also, solar energy powers ecosystems directly or indirectly. It is primarily collected by photosynthesizers before being transformed throughout the food chain. Living and natural systems are not merely closed loop systems, but continually evolving open systems [15].

3. USING "NATURE'S ZERO WASTE MANEGAMENT" AS A MODEL FOR CONSTRUCTION INDUSTRY

When the features of materials in nature, their use by organisms and circular processes are taken into consideration, it is realized that materials are naturally produced without any necessity to serious processes in the body of organism, and they do not pollute their environment while they are forming their living areas, and the different kinds of organisms provide the sustainability of ecosystem within the cooperation, and the biological waste is recycled completely to nature by parting as a result of various reactions, and so there are "zero waste" in nature. In this sense, today's construction industry held responsible for many problems in global dimension must predicate nature as a model on finding solution to the problems, idea and practice. Also much more acquisitions of nature which can not be uttered within the context of work, and mentioned above combine the different disciplines at this point. Many authors feature some approaches such as construction ecology, industrial

ecology, industrial metabolism [16], building ecology [17], ecosystem biomimicry [18] or ecosystem based biomimetic theory [19] which propose to be taken lessons by observing ecosystem behaviours in construction industry. The simulations between nature/ecosystem and construction industry have become higly important especially in today's conditions with regard to its creation of new insights. Construction industry which has also appreciated laws of nature/ecosystems correctly must primarily accomplish "zero waste management system" of nature.

The current waste managament activities mostly focus on decreasing the waste, and the precautions for this purpose economically bring an additional burden. However, waste must be prevented rather than decreasing and recycling them in order that construction environment can produce positive inputs. C. Kibert, editor of Construction Ecology. Nature as the Basis for Green Building [16]; who suggests: the primary lesson construction industry can learn from nature is to cycle its materials in a closed-loop manner, the goal being a "zero waste" system [20]. Zero waste approach aims to provide zero waste in product life cycle, zero waste in production and management activities, zero emission, zero harmful waste, zero solid waste, 100% effective use in energy, raw materials and human resources. As in natural cycle, waste of a production activity must be a source of another production activity [21] (Figure 3). When considering global problems lived, to achieve zero waste managament is not only a vision, but also a necessity.

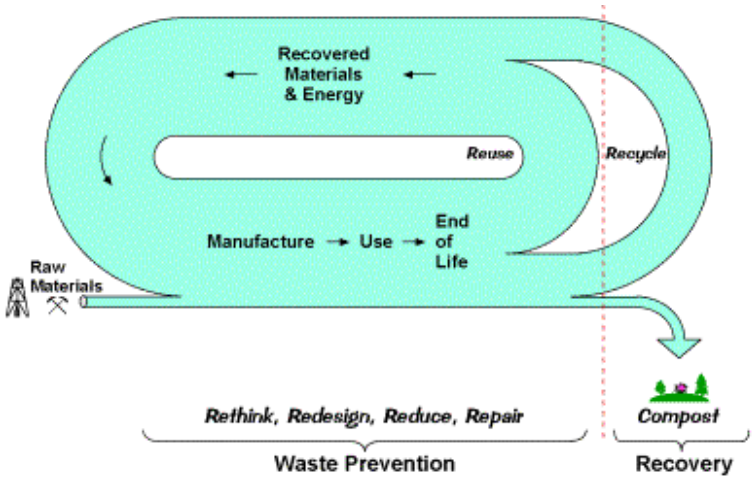

Figure 3. Ideal, improved material flows [3]

3.1. Design concepts

During the process of creating a sustainable construction environment, wastes can be prevented through designs based on full life-cycle thinking. Energy, source consumption and waste production increased by wrong decisions in the design process feature innovative design aproaches such as "biomimicry, cradle to cradle, restorative and regenerative based on nature in architecture discipline. McDonough and Braungart [14] state that, by clearly understanding the chemistry of natural processes and their interactions with human purpose, architects can create buildings that are delightful, productive and regenerative by design.

Biomimicry is the study and application of natural solutions to design challenges. "Nature is imaginative by necessity, and has already solved many of the problems we are grappling with today," says Janine Benyus [22] founder and president of the Biomimicry Institute. Cradle to

cradle, restorative and regenerative concepts of meaningfully mimicking and understanding ecosystems and biology are developed in the research areas of biomimicry and ecological design. These design stratagies aim for positive environmental impact. And are likely to contribute to achieving a truly sustainable built environment. The key differences between these concepts lie in the perceived role of humans. The restorative and cradle-tocradle approaches seek to improve ecosystem health through active human management. Regenerative design and development acknowledges humans as an integral part of ecosystems and aims for a mutually beneficial relationship. It seeks to repair the capacity of ecosystems to function at optimum levels without ongoing human intervention [6].

In a **cradle-to-cradle approach**, waste can equal food. Products and building components should be % 100 biodegradable or % 100 recyclable. A cradle-to-cradle system powered by renewable energy in which materials flow in safe, regenerative, closed-loop cycles [23]. Process-integrated technology, as advocated by the cradle-to-cradle approach, includes the cascading use of resources in which high-grade flows are used in high-grade processes and residual waste flows are used in lower-grade processes, thus utilizing the initial value of a resource in the most efficient way [24]. In cradle-to-cradle design, the materials of building elements which return to industry at the end of their life can be used to produce equally valuable new elements. Consequently the construction industry can reduce costs by recovering valuable materials from buildings at the-end-of-their-life [25].

Restorative design understands buildings as existing within a wider environmental context and buildings respond to environment like living systems. Cradle-to-cradle design shares some elements with restorative approach [6].

Regenerative development or design implies that built environments can be designed to produce more energy and resource than they consume, and to transform and filter waste into healthgiving resources [19]. Environmentally, this means more efficient and effective use of resources and prevention of waste. This may also support conservation of non-renewable resources. Regenerative desing uses advanced building techniques that emphasise the simplest solutions and buildings are responsive to the local environment ve sources. Also, whole systems-based and living system-based approaches are crucial to regenerative design and development. Buildings are not considered as individual objects, but instead are designed as parts of larger systems allowing complex and mutually beneficial interactions between the built environment, the living world and human inhabitants. This ensures that a constantly dynamic and responsive built environment evolves over time. So, the project becomes more flexible and adaptable in the future [6]. Open space applications allowed to different configurations for the space flexibility must have the demountable capabilities in order that construction components can be used in a different project. With the design, standard and modular uses which enable to the constant use of construction materials and their components, zero waste is produced, and economical benefit is provided by increasing the longevity of the construction.

Some of the key potential benefits the three approaches could deliver are an emphasis on the long-term consequences of material and energy source selection, greater understanding of local traditions and indigenous knowledge.

3.2. Construction materials and techniques

Approaches about waste production and material use in design concepts handled, also increase the potantials of new material uses to be integrated with the design. Also research in

this field, the cyclical processes and material features have been analysing, and new material and construction techniques have been improving in the direction of those inspirations.

Biodegradable materials are part of a naturally occurring closed loop cycle. While biodegradability is often associated with natural materials, man-made materials can also be made to biodegrade. Sassi [26] states that biodegradable materials can be grouped in four categories: natural materials that can be used following minimal processing (e.g. timber, bamboo); natural materials bonded with a resin or mesh (e.g. sisal carpet, soy boards); natural compounds used in manufacturing products including adhesives and other polymers (e.g. natural protein to manufacture biodegradable plastics); and biodegradable synthetic materials (biodegradable plastics). Plant-based natural biodegrable materials such as timber, bamboo having used since from the very old periods have been using in construction structure, and in ground, wall and roof claddings with their similar and new uses today. While straw was being used as a binder within the material before, nowadays the use of straw bales which are manufactured by compressing the straws has been increasing as the wall material. In addition, different cladding types can also be obtained from straws compressed with more advanced techniques. Plant-based and also earth-based materials such as adobe, cob, rammed earth in which soil are used naturally, as local sources are utilized, and they are produced in the place as close as possible to the construction area, and they are recycable and economical, and they can be brought to nature without producing waste, and be recycled [27, 28], they are evaluated as the ecological material today. Also in composite applications, if a material is synthetic, this complicates the material to be degraded by microorganisms in nature. The use of expanded starch packaging is already relatively widespread and could be introduced to building industry. Building products made with synthetic biodegradable plastics are unlikely to be developed for the time being, due to the higher manufacturing costs, but could be developed in future [26].

Biomimetic or bioinspired materials are developed using inspiration from nature. Bioinspired materials design has gained considerable interest during the past decade, mainly due to the growth of interdisciplinary interactions between biologists, chemists, physicists, materials scientists and the remarkable physical and mechanical properties that biological materials exhibit. What seems to be effortless in a biological system that produces complex, multifunctional materials can, indeed, be translated to processing of synthetic (alloys, polymers, ceramics, and composites) materials [29]. Selfrepair and self-healing are interesting features in the design of materials for architectural application. Thomas Speck has investigated the self-healing characteristics of climbing plants, and developed a self-healing membrane material for use in pneumatic structures [30]. Also, the biological mechanism of self-healing in bone has been developed for bone-inspired self-healing composites. In the new material, the repair process begins as soon as a crack forms. When the material cracks, the micro-capsules rupture and release the heating agent into demaged region through capillary action [31]. Also Rachel Armstrong and his friends have been studying the potantials of new material use of that kind in architectural design by trying to increase their interaction abilities with nature, and environment in which materials are placed, and with materials such as protosel called as living technology or metabolic, and have some unique characteristics of living systems [32]. With the use of those materials obtained by nanotechnological operations, construction components can be more long-lasting, and economical use of material can be provided, and thus waste is not produced as well. The subject matter to be taken attention at this point is whether evaluations are made or not with regard to the effects of such kind of materials on environment and human health, and on the intensiveness use of energy and source during the life cycle process.

Unconventional materials, different from the others, offer different alternatives as recycable materials such as old car tires, glass and plastic bottles, aluminium cans, paper, etc. existed as

waste in nature are used as a construction material. Architect Michael Reynolds, creator of radically sustainable living options through a process called "Earthship Biotecture." Reynolds' solar homes are created from natural and recycled materials, including old tires, aluminum cans, plastic bottles. The primary retaining walls are constructed with used tires, filled with earth and stacked up like bricks [33]. Eco-Tec is environmental waste mamagement company that specializes in construction plastic bottles. The Eco-Tec building system utilizes pet bottles filled with rubble, soil and plastic debris. In addition, the system utulizes synthetic rope, wire and natural materials found near the project site [34]. The other example that using plastic bottles is EcoARK, was constructed by Taiwan-based engineer Arthur Huang, using a whopping 1.5 million PET bottles to raise awareness about the importance of recycling [35]. Shigeru Ban is well known for his paper architecture. With the building materials he uses, which are wood pulp or paper, he builts artistic, durable and renewable structures. He determined that recycled cardboard can be shaped and rolled into sturdy beams and strong trusses, all of which are fire resistant and water-proof, and uses these materials to build some of the most impressive edifices on the planet [36].

5.3. A new role of designer

Osmani "et al." [37] states that 33% of waste occurred in the construction area arises from the failures of the designer in his management of waste decrease precautions. Authors emphasize that constructional waste increases during and after the construction by the reasons such as insufficient communication and coordination, inadequate knowledge of the designer, indefinite specifications, last minute design changes, the ground conditions not predicted, making mistakes in the choice of material, the detail deficiencies and complications, insufficient design data, design mistakes in the design stage. At this point, as Mang and Reed [38] also remark that the ecological worldview and the regenerative paradigm have significant implications for the role of the designer as well as the process and definition of design. A focus on development or design that seeks to reduce environmental impact is more difficult than a conventional approach to design. This may increase the creativity of design teams, and the innovation of solutions to meet these increased challenges.

In order to accomplish zero waste management through an regenerative approach, the viewpoint of the architect and his team whom they are the head of design team must be as the following: They must rebuild the thought system performing a working process between the disciplines during the planning and design process. They must be capable of commenting cleverly laws of nature in the whole life cycle process of construction. They must not only focus on the formation of building, but also through taking natural processes as a model mentioned within the context of work they must fulfill the right decisions related to the choice of construction material and construction technology, and the usability of the space and building for a long time which is quite effective in waste production. They must be able to refresh themselves all the time by getting beyond the habits and education given deficiently, and integrate the new approaches which will prevent waste occurrence with their design by empowering the technical and technological background. They must be able to evaluate the energy and source possibilities of the "place", and disseminate an apprehension which can offer different solutions according to each "place". They must be able to handle the matter with an integrated approach in the urban dimension beyond the only construction scale. In order that the architect can have those qualifications as soon as he starts his professional life, during his education period as well, it is proceeded that there will be a necessity for a fundamental change towards education understanding which is resulted by a right source transformation and is corporated with the innovative systems of nature from education perception which can not manage the limited use of energy and source and accelerates the

environmental corruption. Especially, the subjects concerning waste management which is not much given a place in today's architecture education must be included to curriculum.

6. RESULT AND DISCUSSION

Construction industry, which owns a great interest with waste production in the rise of global problems lived, must realize laws of nature in finding solutions stage, and especially must implement zero waste managament of nature is what is emphasized within the context of work. However, it is not possible that zero waste management would be properly achieved in a short time through the methods offered within the context of work. The issue of waste management must be multi dimensional and have many disciplines, and must be handled in an integral frame. What is certainly expected is waste would be prevented during the design stage in order not to be occured waste. Nevertheless, the change and consciousness must happen not only in architecture and disciplines concerned, but also in each sector of the society from the users to municipalities, and even the process must be stepped up by new policies developed in national and global dimensions. Today many countries realize that the expected situation must require a long period because of conventional and actual approaches about zero waste. Zero waste management has been become difficult to be put into practice because producers and consumers have short-term ideas, and there is a harmony deficiency in laws on the face of the situations, and less money is expected to spend in constructing the building process, and because the society is also unconscious and reluctant in the choice of correct construction material and technique. To limit or prevent material use which is inconvenient to closed-loop process, and to make evaluations of life cycle in the choice of construction techniques and right material, and to practise the economic encouragement for the consumer that he can choose those materials and techniques are all the necessary things to be done. Despite the global and political pressures, and actual wishes and manipulations of the users and the sector, the fulfillment of all the disciplines related to the construction for their actions has a significant role to accomplish by considering the conveying capacity of natural environment, and aiming at harmony with laws of nature, and keeping the requirements rather than demands in the foreground.

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