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Toward bio-based geo- & civil engineering for a sustainable society

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Abstract

The since 2010 running research program 'Bio-Based Geo & Civil Engineering for a Sustainable Society (BioGeoCivil)', funded by the Dutch technology foundation STW, aims to develop novel bio-based construction materials that can be used in Civil- and Geo-engineering constructions to enhance the sustainability performance of the sector. Rationale is that the sector produces still today excess amounts of waste in all life cycle phases of a construction, from building to use phase as well as end-of-life phase. Aim of the program is to mimic nature as 'building' processes in nature do not produce any waste as all elements, also residual material. is considered a high grade resource. In order to substantially improve the sustainability profile of the sector, upgrading of secondary- or byproducts must be achieved to allow functional performance similar to primary materials and resources. The challenge of the six currently running projects within the BioGeoCivil program is therefore not only to mimic nature but also to include bio-based materials or processes in civil- or geo-engineering applications which result, in comparison to traditional building products, in drastically improved performance both on sustainability and durability level. The six projects comprise: 1. Fungal biofilms (coating) for wood protection, 2. Bacteria-based repair and performance improvements of aged concrete structures, 3. Bacteria-based ground stabilization to mitigate liquefaction and piping of granular sediments, 4. Engineering of bacterial biofilms on buildings and infrastructure as a basis for natural protection, 5. Lift up Lowlands: upgrading of natural materials (bio-remediation of sludge) for sustainable lift up of low lying polder areas, and 6. Towards the development of carbon dioxide neutral renewable cement.

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1. Introduction

Traditionally the disciplines of Civil- and Geo engineering sciences focus on building structures that are durable, i.e. last long. In recent decades sustainability practices are becoming more and more important and minimizing production of waste, emission of harmful components, saving of energy and recycling of elements and materials have become standard practices. However, in order to further and substantially improve both durability and sustainability performances of construction materials, technological innovations are required. Eminent requirement for these novel materials is that for their production and subsequent lifetime phases use of energy and dependence on use of finite resources, and emission of harmful substances for humans and environment are minimal. Use and implementation of bio-based materials and processes could make an important contribution to this aim as these are renewable by nature. The projects currently running in the BioGeoCivil program build further on concepts that have been are still being developed. One example is the development of self-healing materials in which limestone production by specific bacteria result in self-healing of cracks in concrete [1]. The ability to self-heal is widespread in nature and the used building concept here is based on damage management rather than damage prevention as in current man-made constructions [2]. The damage management concept used in nature generally requires much less resources in comparison to damage prevention as constructions built according to latter concept are usually over-dimensioned with respect to their required functional performance.

Main objectives of the BioGeoCivil program are therefore the development of biology-based materials as well as processes which can help to solve engineering challenges addressing sustainability performance while at the same time safeguarding required durability aspects such as sufficient strength are functional service lifetime performance. Figure 1 shows a schematic drawing of the main aim of the program, i.e. mimicking in trying to establish a fully circular resource and material approach in which no waste or other emissions are produced as all residual materials provide useful resources for other products or life cycle stages of the construction.

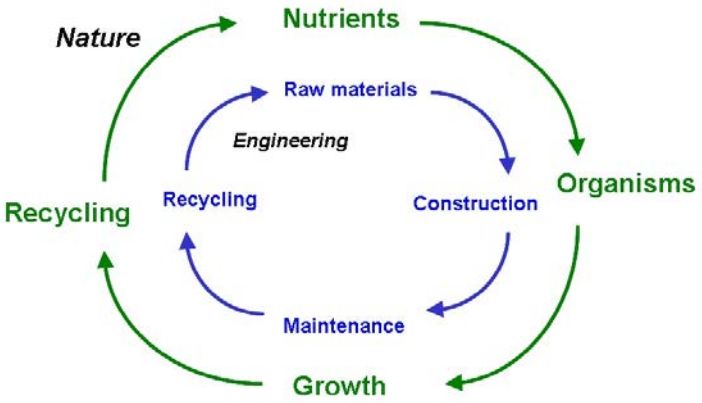

Figure 1: Resources and materials cycle in nature taken as inspiration for establishing fully circular material use in the civil- and geo-engineering building cycle.

In order to increase the chance of success, requirement for all six projects currently running in the BioGeoCivil program was that scientists from the different scientific disciplines biology and civil- and geo-engineering work closely together within each individual project.

The following main objectives were defined in the program [3] to achieve this goal:

1. Increase our fundamental knowledge of mechanisms nature uses to solve construction and functionality challenges we face in the field of geo and civil engineering
2. Develop robust biology-based technology, methods and processes that enable improved functionality and reduced environmental burden in geo and civil engineering applications