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The emerging trends in sustainable construction materials

Karol S. Sikora

In order to achieve sustainable constructions, locally sourced materials are needed to be utilized that will reduce transportation distances and hence greenhouse gas emissions, and support the local economy.

Nowadays, the most common construction material in the world is concrete. Over 20 billion tons of concrete are produced annually, which requires 5 billion tons of sand for concrete construction[1]. Furthermore, global cement production is expected to increase from about 4 billion tons in 2018 to 5 billion tons in 2030[2]. A similar trend for sand is expected. The amount of sand used worldwide in the production of concrete is calculated as between 15 and 40 billion tons per year[3,4]. Due to high energy involved in the production processes of cement, it accounts for 5 % of global carbon dioxide emissions. The possible ways of changing these trends, and providing sustainable solutions will be discussed in this presentation.

It may be addressed by partly substituting energy consuming Portland cement with supplementary cementitious materials (SCM), like fly ash (FA) or ground-granulated blast-furnace slag (GGBS). Their disposal can be harmful, because they contain small amounts of toxic metals. Therefore, SCM utilization as a cementitious material is beneficial in two ways. It reduces the amount of SCM for disposal and limits the demand for clinker production. However, SCM in concrete affect the hydration process in early stages that results self desiccation and consequently autogenous shrinkage and crack propagation. These processes may be mitigated by the introduction of internal curing. The concept is to provide internal water reservoirs, evenly distributed in matrix, which maintain saturation within the cement paste capillaries and gradually provide water for cement hydration. It is mainly implemented by the application of pre-soaked aggregates or Superabsorbent polymers (SAP). In cementitious matrix of fresh composite, SAPs form a system of evenly distributed pores filled with water which can be gradually released during hydration process.

The use of sea sand and seawater in concrete can be immensely beneficial for the economy and environmental sustainability. Concrete made with sea sand and sea water has no severe effect on concrete workability, setting times, and most importantly on strength[5]. Nevertheless, usage of sea components is limited due to the corrosive effects of salts on steel bars, which are used as reinforcement with concrete structures. Thus, steel-reinforced concrete derived from salty, sea components has low durability. Hence, production of concrete increases the demand on fresh water supplies and more distant low-salt sand resources in coastal areas that are otherwise rich in water and sand albeit salty. An alternative to steel reinforcement bars is an artificial form of basalt called basalt fibers (BF). These have the advantage of being resistant to severe salt corrosion.

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[1] https://www.statista.com/statistics/376665/industrial-sand-and-gravel-production-by-top-countries/

[2] https://www.statista.com/statistics/267364/world-cement-production-by-country

[3] Neumann, F., & Curbach, M. (2018). Thermal treatment of desert sand to produce construction material. In MATEC Web of Conferences (Vol. 149, p. 01030). EDP Sciences.

[4] Peduzzi, P. (2014). Sand, rarer than one thinks. United Nations Environment Programme.

[5] Xiao, J., Qiang, C., Nanni, A. and Zhang, K. (2017), Use of sea-sand and seawater in concrete construction: Current status and future opportunities, Construction and Building Materials, 155, 1101-11.

Due to its abundance, desert sand could provide a very attractive alternative for other materials in terms of costing, perfectly addressing sand shortage for construction. The main obstacles for desert sand utilization for construction are: uniform sizing, regular shape with smooth surface, and chemical composition negatively affecting concrete hardening. In the past, numerous methods were known for sintering sand in order to make fireclay bricks for furnaces. However, all these methods require a binder. In recent years, some technical solutions were developed to modify or reshape desert grains. These technical approaches are mainly based on a melting process followed by a crushing process[6,7] or on pre-shaping the aggregate with a high voltage electrostatic field[8].

Wood through the photosynthesis process can store the carbon dioxide from the atmosphere providing renewable material of 'mother nature', when sourced from sustainably managed plantations. However, due to limitations in cross sectional sizes, lengths, and mechanical properties of cheaper and common softwood species, sawn timber does not satisfy requirements of high performance multi-storey constructions. To address these constrains, the capacity of lower grade timber can be enhanced by its utilization in novel engineered wood products. Studies confirm that there is potential in using low quality timber for cross-laminated timber (CLT) manufacture and this presents new opportunities. CLT is a prefabricated multi-layer engineered wood product made of at least three orthogonally bonded layers of timber. In order to increase rigidity and stability, successive layers of boards are placed cross-wise to form a solid timber panel. Load-bearing CLT wall and floor panels are easily assembled on site to form multi-storey buildings. This improves construction and project delivery time, reduces costs, and maximizes efficiency on all levels.

Another one of the most promising materials meeting sustainability requirements is timber-concrete composite (TCC). TCC is made by connecting a concrete topping with timber joists or beams to selectively utilize advantages of their structural properties. The first attempts of the introduction of TCC in bridges started in the 1920s[9], but only recently TCC has been used for newly-designed multi-storey buildings.

Furthermore, there is potential for bamboo utilization in construction, mainly in Latin America and Southeast Asia due to its abundance[10]. Taking similar engineering approach as with timber, glued laminated bamboo and bamboo based panel are two types that can be used in modern bamboo structures[11]. Their strength and stiffness promote the bamboo to be the material for multi-storey and large-span construction. Due to its mechanical properties similar to timber and much higher growth and recycle rate, bamboo provides number of advantages as a structural material[12]. Bamboo has greater strength-to-weight ratio than vast majority of wood species, cast iron, aluminum alloy and steel[13]. In recent years, several typical engineered bamboo products such as bamboo ply, strand woven bamboo and glued laminated bamboo have been researched and produced. These products are made from

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[7] D. Behnisch, J. Ikic (2015). Method and device for producing artificial crushed sand by means of a thermal treatment using sand in the form of fine sand (fs/fsa) and/or round sand as the starting material. Patent WO 2015/172765 A1.

[8] E. Rabe. (1984). Formkörper auf der Basis von Quarzsand, ihre Herstellung und Verwendung sowie Vorrichtung zur Durchführung des Verfahrens. Patent DE 3248537 A1.

[9] Muller, P. (1922). Decke aus hochkantig stehenden Holzbohlen oder Holzbrettern und Betondeckschicht." Patentschau aus dem Betonbau und den damit verwandten Gebieten, Auszuge aus den Patentschriften, Beton und Eisen, H. XVII, S. 244 (in German).

[10] Ju TW. (2013). Research and application of modern bamboo construction system. Hunan University, 2013.

[11] Xiao Y, Li J. (2015). The state of the art of modern bamboo structures. Industrial Construction. 2015: 45(4): 1-6.

[12] Sharma B, Gatóo A, Bock M, Ramage M. (2015). Engineered bamboo for structural applications. Construction and Building Materials;81:66-73.

[13] Li HT, Zhang QS, Huang DS, Deeks AJ. (2013). Compressive performance of laminated bamboo. Composites Part B: Engineering.;54:319-28.

veneers, strands and sliced piece of bamboo, which are combined into a specific structure and then bonded together with adhesives by high-pressure and/or high-temperature. This process improves significantly parameters when comparing to natural product allowing utilization of species of lower properties that were not considered before for high performance usage.

The presentation will cover the aforementioned technologies, and discuss emerging trends in construction materials leading to sustainable future.