SUSTAINABILITY TRENDS WHILE BUILDING WITH ECO-FRIENDLY MATERIALS

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Rezumat. *Substituirea parţială a cimentului Portland obişnuit cu adaosuri industriale este o modalitate recunoscută de a construi cu betoane cu impact redus asupra mediului. Identificarea criteriilor de bază ale unui produs ecologic este corelată cu procesul de fabricaţie a cimentului tradiţional pentru a obţine prin studii şi analize specifice ajustările necesare asupra unor noi categorii de ciment. Lucrarea prezintă cercetări recente privind cimenturi de generaţie nouă, numite cimenturi ecologice şi domeniile de utilizare în care să poată substitui total cimentul tradiţional, la parametri de produs finit superiori.*

Abstract. *Partial substitution of the Ordinary Portland Cement (OPC) with mineral admixtures is an acknowledged procedure to build with concrete of low environmental impact. The identification of the basic criteria for an ecological construction product is correlated with the fabrication process of the traditional cement to obtain the necessary technological adjustments for new cements based on specific study and analysis. The paper presents the recent research of a new generation of cements, the eco-friendly cements, and the domain of use where OPC can be totally replaced, at superior working parameters.*

Keywords: concrete, environment protection, eco-cements, sustainability

1. Sustainability by civil engineering applications

Deterioration of the environment by human activities has multiple consequences, out of which the ones related to the civil engineering domain are directly involved both in producing the necessary construction materials and in casting-in-place technologies. Thus, the following consequences are relevant: the CO_2 emissions, the consumption of non-regenerating resources, producing non-recycling waste, noise pollution and contributions of the continuing regress of bio-diversity by destructing the natural habitats.

Sustainability has on one hand an economical component, through companies that develops profitable activities and at the same time an environmental component, related to efficient and rational use of resources and protection of natural habitats. These components are mutually interacting based on regulations and laws.

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Sustainability is affected by the limitations of the materials used in civil engineering works and by the environmental impact when producing these materials. In Romania, the real estate development and transportation involves the intensive use of some construction materials, concrete and mortar, including also steel reinforcement to increase the structural performances. Building is an activity imposed by the dynamics of population and the increased of the life quality, and consequently there is a continuous interest to reduce the environmental impact of this activity. The life-cycle assessment for a construction material is performed based on indicators measuring its performance in all life stages: the acquisition of the starting materials, the fabrications, the transport, the cast-in-place, the service time, the maintenance, and potential reuse. A product, a construction material as well, is considered ecological fit when fulfilling a set of criteria, which are presented in figure 1 [1], [2].

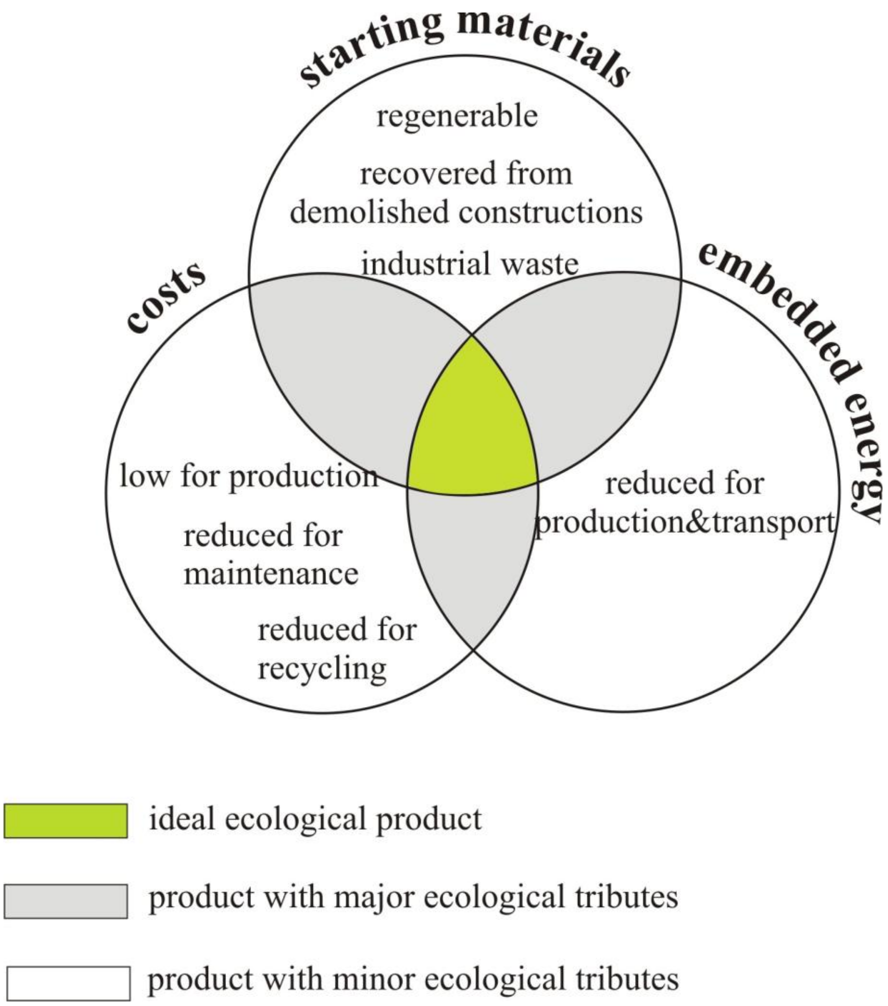


Fig. 1. The concept of the ecological product.

Cement and by it, concrete and mortar, is the construction material the most frequently used in structures for civil engineering and it has the most significant impact on the environment, mainly by the fabrication process supplemented by the accumulation of large quantities of cement dust generated by the demolition of concrete structures [3].

The main issues to address by adequate research resulted from the correlation of the life stages: fabrication, transport, cast-in-place technology, service, maintenance, demolition, and recycling, all presented in figure 2 [4].

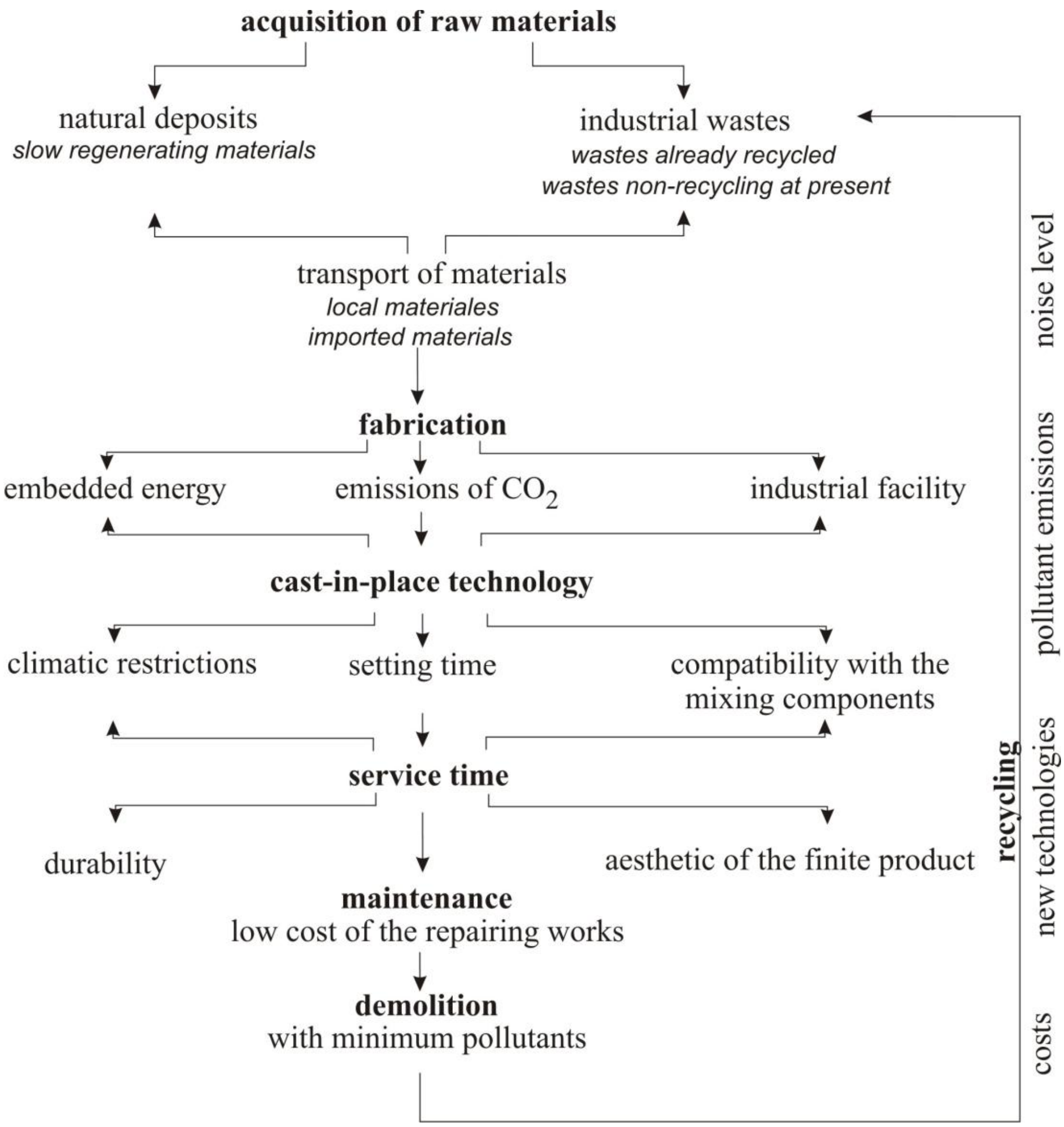


Fig. 2. Ecological issues during the life-cycle of the construction materials.

2. Eco-friendly cements as construction materials

Ordinary Portland Cement (OPC) uses raw materials (1,6 tons of limestone, clay, and gypsum / 1 ton of OPC and consumes fossil fuels to obtain the necessary processing energy at 1400°C) with emissions of CO_2 (1 ton de of OPC / 940kg CO_2). This cement is on one hand non-recycling products, with high consumption of raw and non-regenerating materials, also responsible for 7% of the global warming due to human activity, and on the other hand, with limited mechanical, non-corrosive, frost sensitive, pervious, and durable related performances, at high production costs.

There is a constant interest to identify eco-friendly alternatives that can substitute OPC and develop high performances in terms of strength and durability for civil engineering works. Partial substitution of OPC begun by industrial processing of the ground granulated blast furnace slag (GGBFS), later by fly ash products, and continued by intensive research for the last 20 years with results as several cement alternatives with low environmental impact during fabrication. Partial replacement of OPC – CEM I with mineral admixtures such as GGBFS, natural or artificial pozzolanic products etc. resulted in obtaining Composite Portland Cements - CEM II and CEM III, used in concretes for various structures in civil engineering applications [5]. Thus, the main research issues of the investigation programs are synthetically presented in figure 3 [6].

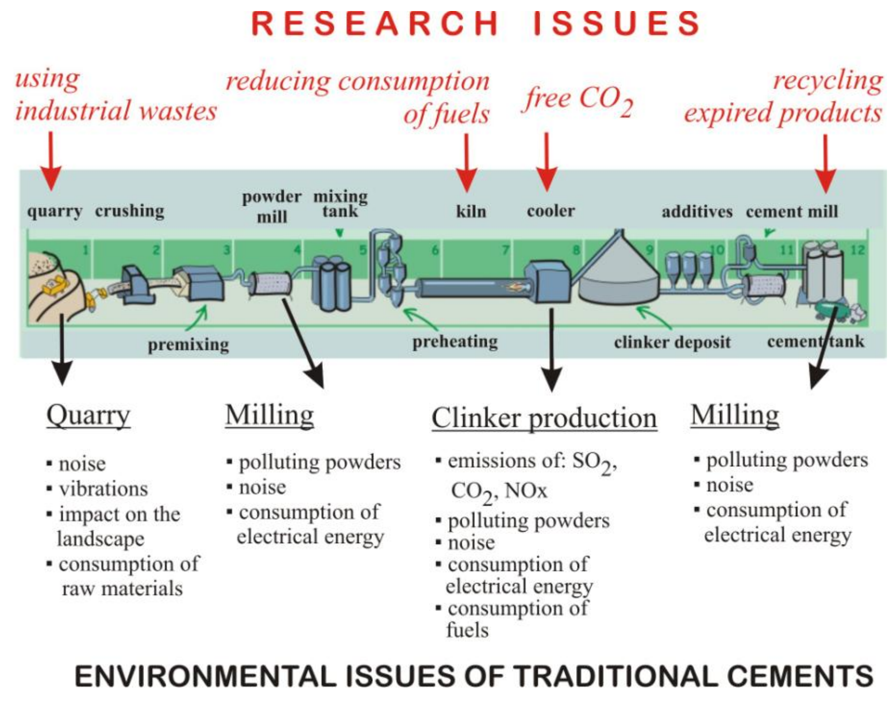


Fig. 3. Issues of the research for eco-friendly cements.

The following cements address the category of eco-friendly or green cements:

1) CKD-FA (cement kiln dust and class F fly ash) – a well graded mixture of two industrial wastes the alkalis from CKD may activate hydration of FA, and thus it may create a cementitious material in which the waste material deficiencies will be converted into benefits [7];

2) geopolymer – an amorphous alumino-silicate product synthesized simply by mixing alumino-silicate reactive materials and strongly alkaline solutions, then curing at room temperature, with low emissions of CO_2 and less energy consumption [8];

3) magnesium phosphate cement (MPC) – obtained by properly mixing MgO particles, fly ash, and phosphate [9];

4) anhydrous calcium sulphate in the β - anhydrite III' form, known as a super-suphatic cement (under the trademark of kerysten) [10].

The super-sulphatic eco-friendly cement (kerysten) is the only one patented as a material and industrial process, in France (January 14, 2010 - WO 2010/003827 A1[11]) and applied already in a specific industrial facility.

The starting material can be exclusively industrial gypsum wastes from chemical fertilizers, detergent and tinned food production, mostly non-recycling materials and lying abusively on the Earth surface: phosphogypsum 800 mil.tons and over 130 mil.tona are produced annually; lactogypsum 7 mil.tons and 20 mil.tons are expected to be produced annually by 2020; citrogypsum 100 mil.tons and 2 mil.tons are further produced annually; Flue Gas Desulfurization gypsum 350 mil.tons and over 50 mil.tons are further produced annually [10].

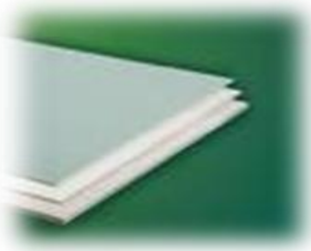
The production process runs at low temperatures and only releases water vapors in the atmosphere which means that the process is CO_2 emissions free. The resulted binder is entirely recyclable when the storage time expires, without generation of any waste products.

There is already an industrial producing company of this material (since 2008), that expands their interest by research and development of various products (mortar and concrete included) based on reactive anhydrous calcium sulphates that partially substitutes OPC and also by defining new technical solutions related to the civil engineering domain.

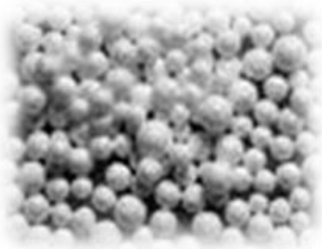
Civil engineering applications verified on works performed by the producing company are of the following categories: precast light and self-compacting concrete elements with partial substitution of OPC – dividing and insulating walls – self-leveling floor screeds, finishing products for buildings; as base material for ordinary road repair works; in self-compacting plain concrete used in severe service conditions, by direct contact with the sea-water or animal (pig) manure 4 [10].

Both in the tested prototypes in laboratory conditions and the performed works built on site this super-sulphatic cement has been proved a high quality material, with significant economical, technical and ecological advantages as well.

Thus this cement is the base material for new research projects to identify new applications in civil engineering and consequently to optimize various compositions for eco-friendly construction materials (injecting fluids, mortar and concrete), and also to create new structural elements using plain or fiber reinforced materials for constructions of large volume, involved in providing sustainability in Romanian infrastructure development. Intensive research programs have been started at the Faculty of Civil Engineering and Building Equipment, Technical University „Gheorghe Asachi” from Iaşi, with intermediate results that certify this cement to be adequate in further construction in line with the base concept of sustainability.



Boards



Insulating layers

Renderings

Hemp blocks

Flooring screeds

Light weight dividing walls

Soil stabilization

Fig. 4. Applications at present for the super-sulphatic cement – *photos presented by the company KanduCo – France [10]*

The main advantages when using this super-sulphatic cement are the followings:

- the initial setting time is very reduced but can be controlled for the necessary casting-in-place duration for large volumes of mortar/concrete;
- heat release during the hardening process that develops a significant bonding with the contact elements, without damaging contractions, in this respect a proper material for rehabilitation projects;
- tension strength during bending 10 times higher than with concrete made with OPC and consequently the necessary cross-section of the structural elements can be significantly reduced;
- a good material compatibility with glass reinforced fiber polymer composite, developing structural performances of reinforced elements with low self-weight.

3. Concluding remarks

Green cements are the research products of numerous laboratory investigation projects that built the certitude that construction future will remain true to the basic concept of sustainability.

The identified green cement as a super-sulphatic cement under the trademark of kerysten is the one binder that responds satisfactorily to all basic criteria to select cement with low environment impact:

- it can be produced in large amount due to the fact that the producing technology is currently patented and functional in the first industrial facility (in France), another one being under development (in Belgium);
- the starting material is abundant and accessible, as non-recyclable wastes from the detergent and fertilizer industry, that continues to increase the annual production for the next 10 years;
- the production costs are low and as long as the fabrication units are built next to the waste producing facilities that thus become the starting material of this new cement;
- the time depending performances are at least comparable with the ones of the traditional cements;
- this cement is entirely recyclable, with free CO_2 emissions.

The intermediate research results developed both in laboratory and on site conditions are satisfactorily to justify furthering the use of this material for civil engineering applications and also to initiate the necessary actions to build a production facility in Romania as well.

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