RESEARCH ARTICLE (Open Access)

Concrete as "Green Building" Material

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Abstract

Concrete is the most widely used construction material. This is due to its low cost, general availability, and of course quite easy and wide applicability. But concrete also is characterized by great environmental cost. The natural materials mined and processed each year, by their sheer volume, are bound to leave a substantial mark on the environment. Most damaging are the enormous amounts of energy required to produce Portland cement as well as the large quantities of CO2 released into the atmosphere in the process.

All enlisted herein, is more than verified in Albania, especially in the territories where cement production factories operate. In order to have a future sustainable development, while in the same time trying to reduce the already noticed negative effects, measures need to be taken urgently.

Related to this issue ,a very successful measure is considered the use of suitable substitutes for Portland cement, especially with those that are byproducts of industrial processes, like fly ash, ground granulated blast furnace slag, and silica fume. Suitable recycled materials as substitutes for concrete aggregate are gaining in importance too, such as recycled concrete aggregate, post-consumer glass, tires, etc .This paper summarizes the various efforts underway worldwide, that should be undertaken in Albania also, to improve the environmental friendliness of concrete, to make it suitable as a "Green Building" material.

Keywords: sustainable development, green buildings, recycled concrete aggregate.

1. Introduction

1.1 The Concrete Industry in Albania

The concrete industry is related to many factors, and in general to the construction industry development. By this point of view, Albania during the previous century, because of the overall global geopolitics situation and later on its local issues, didn't really have a construction industry. This was emphasized during the communist regime, but as every other activity was centralized and controlled by the state. After the 90's and after the first shocking decade in many life and society aspects, during the years 2000 - 2010, Albania knew a very rapid growth - not balanced, asymmetrical, uncontrolled, chaotic, economically not feasible, that can be discussed critically in every possible aspect - especially regarding the civil constructions, due to the need for more and new apartments, and public works, due to the to the fact that in the previous decade the state care level for the infrastructure but not only, was quite not important. The situation resulted favorable for many investors and among them the ones of the cement industry. At the moment in Albania operate at least 10 cement factories, and the half of them with a high production rate, aiming not only the inner market but the regional one also. Some of them are local branches of bigger companies. It should be mentioned that their interest was and it is not based only on the inner development trend but on the fiscal policy on their behalf, low payments for the operators/ workers and the very good quality of the raw materials needed to produce the cement. On the other hand, the concrete aggregates (sand, gravel, crushed stone) were/ are procured from the local resources, most of the times with a tremendous environmental impact in time, not only in the landscapes, but what is more important in the flora and fauna, deforestation, erosion and floods [1]. Although the totalitarian regimen had many negative characteristics, its policy toward the environment was based on better principles compared

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(Accepted for publication on December 20, 2016)
***ISSN**: 2218-2020,*

to what followed and somehow it is still happening nowadays in Albania.

1.2 Sustainable Development – The Challenge for the Concrete Industry

Sustainable Development has become a household word, standing for a set of self-evident principles. Probably the first person who formulated the term was Hans Carl von Carlowitz (1645 – 1714), a forester in Saxony, Germany [2], [3], who called for sparing use of trees to give the forest a chance to regenerate and sustain itself. As logical as this general principle appears to be, it has often been violated with at times catastrophic consequences. Most of us are concerned about the world we will be leaving behind for future generations, that is, our children and their children. The old political conflict between supporters of "development" and those who wish to preserve the environment, obscures the fact that sustainability and development are not mutually exclusive. Rather, we are called upon to find the proper balance between economic development and environmental preservation. It is the purpose of this article to discuss various aspects of the concrete industry, because it has a much larger impact on sustainability than many of us may realize. Concrete is by far the most widely used construction material worldwide. In fact, it is more widely used than any other material, except water. Its huge popularity is the result of a number of well-known advantages, such as low cost, general availability, and adaptability to a wide spectrum of performance requirements. But this popularity of concrete also carries with it a great cost in terms of impact on the environment [3], [4],[5]:

1. Worldwide, over ten billion tons of concrete are being produced each year. Such volumes require vast amounts of natural resources for aggregate and cement production, meaning great environmental costs and consequences in time.

2. In addition, it has been estimated that the production of one ton of Portland cement causes release of one ton of CO_2 into the atmosphere. CO_2 is known to be a greenhouse gas that contributes to global warming, and the cement industry alone generates about 7% of it.

3. The production of Portland cement is also very energy-intensive. Although the plants have improved their energy-efficiency considerably in recent decades, it is technically impossible to increase that energy-efficiency much further below the current requirement of about 4 GJ per ton.

4. The demolition and disposal of concrete structures, pavements, etc., constitutes another environmental burden. Construction debris contributes a large fraction of our solid waste disposal problem, and concrete constitutes the largest single component.

5. Finally, the water requirements are enormous and particularly burdensome in those regions of the earth that are not blessed with an abundance of fresh water.

These points and numbers indicate that the concrete industry faces tremendous challenges. But the situation, because concrete as a final product is usually considered as an environmentally friendly material, as can be demonstrated readily with a life-cycle analysis [6], is not as bad as it might seem. The challenge therefore is simplified in primarily reducing Portland cement's impact and on the environment (concrete aggregate procurement impact can be drastically reduced by laws enforcement and their correct applicability). In other words, we can, if it is necessary, use as much concrete, but with as little Portland cement as possible.

1.3. Feasible measures and Strategies

The concrete industry can easily fulfill the sustainable development requirement implementing a number of feasible measures like [3]:

1. Increased use of supplementary cement material - since the production of Portland cement (known as Ordinary Portland Cement OPC) is energy intensive and responsible for much of the CO_2 generation, the substitution of other materials, especially those that are byproducts of industrial processes, such as fly ash and slag, is bound to have a major positive impact (production parts of what is known as Geo polymer concrete - see below).

2. Increased reliance on recycled materials - since aggregate constitutes the bulk of concrete, an effective recycling strategy will lessen the demand for virgin materials.

3. Improved durability - by doubling the service life of our structures, we can cut in half the amount of material needed for their replacement.

4. Improved mechanical properties - an increase in mechanical strength and similar properties leads to a reduction of materials needed.

5. Reuse of wash water - the recycling of wash water is readily achieved in practice and already required by law in some countries.

There are large differences between the degrees to which various countries have already implemented

these strategies. In particular, there is a noticeable difference between Albania and many European countries in this regard (and not only). Albanians, due to their bigger daily problems and the lack of state care, didn’t pay the needed attention to the development costs in local or global terms, while many of them being a part or the cause of these costs. However, the self-evident principles of sustainable development are now being accepted also by a growing part of the Albanian public. As a result, Albanians are increasingly willing to contribute their share to the preservation of their environment, which includes a reasoned approach towards sustainable development. Much of what follows is generally well known and already implemented in many European countries, Japan and somehow in United States. A systematic adoption of the strategies outlined above will go a long way towards improving the industry’s record. Implementing effective strategies to lessen the environmental impact of the concrete industry by prudent use of those tools requires a concerted effort of the industry, starting with well-focus and research and development (considerable body of literature exists on methods to improve the mechanical properties and durability of concrete).Even more important for success, are economic incentives and political developments to convince industry leaders that increased incorporation of sustainable development principles is possible without adversely impacting the industry’s profitability. The emphasis here will be on how to make concrete a “green building material” by use of cement substitutes and recycled materials.

2. Materials and Methods

2.1 Concrete and Cement Substitutes

2.1.a Geopolymer Concrete

An interesting new innovation in concrete is the use of a variety of Geopolymers (a geopolymer is a synthesized inorganic material that has been used in a wide range of diverse applications such as heat-resistant ceramics, waste encapsulation and construction products over the past 40 years). These materials can be combined with materials such as ground granulated slag, fly ash, and natural pozzolans, to produce concretes without the need to use ordinary Portland cement. This concrete is strong, durable, and with better thermal insulation properties. Geo polymer has been found to be having high resistance to acid attack. Further concrete exhibits zero alkali aggregate expansion which is an important property in areas with potentially reactive aggregates. However a major advantage of some types of geo polymer concrete is their greatly improved fire resistance in comparison with traditional (ordinary) Portland cement concretes. Geo polymer concretes produce only about 7% of the carbon dioxide generated in the production of traditional OPC concretes, giving the material the potential to earn valued carbon credits [7].

Figure 1. Ordinary concrete and Geopolymer concrete

2.2 Use of Cement Substitutes

The reduction in the use of Ordinary Portland Cement (OPC) can be achieved with its partial replacement by various cement materials, such as: fly ash (pulverized fly ash (PFA), ground granulated blast furnace slag (GGBS), metakaoilin, wood ash and limestone powder. The high-strength concrete which was known in the late 1970's is now referred to as High-Performance Concrete (HPC) because it has been found to be much more than simply strong. Use of this cement material has resulted in an improvement of the properties of concrete.

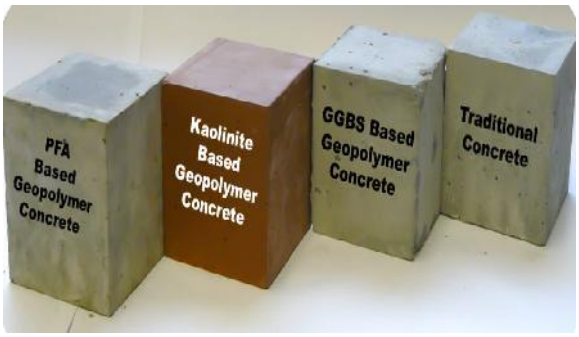

Figure 2. Geopolymer Based Concrete

These include:

- a lower heat of hydration, which minimizes the risk of thermal contraction cracking, providing the concrete is insulated in order to minimize temperature differentials between the core and surface temperature at early ages

- increased resistance to chemical attack, including that from sulphates and salt water

- increased resistance and often elimination of alkali - aggregate reaction

- the resistance to chloride induced corrosion of reinforcing steel is improved, which is especially important in structures, in or adjacent to the marine environment [7].

2.2.a Fly ash (pulverized fly ash)

Fly ash is the residue that is left from burning coal, and this is formed when the gaseous releases of the coal is efficiently cooled. It is somewhat like a glass powder that is fine in nature. However, the chemical constituents of this residue might vary from one other. Fly ash has several industrial applications and is widely found in power plant chimneys. The material is also used as substitute cement by mixing it with lime and water. The material is embedded with myriad beneficial features and so is being utilized as a significant building material for the construction purposes. This type of concrete is much dense and smooth. Below listed are few of the advantages and disadvantages of fly ash concrete. The advantages of using fly ash in concrete includes the followings [7], [8].

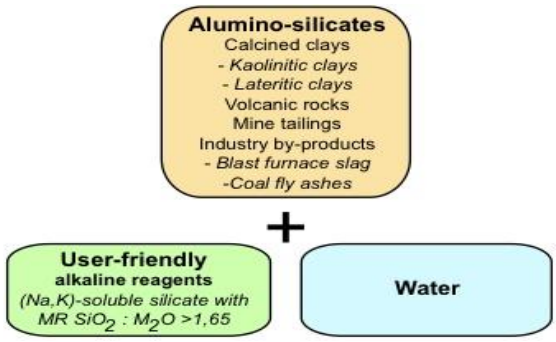

Figure 3. Geopolymer

- it is theoretically possible to replace 100% of Portland cement by fly ash, but replacement levels above 80% generally require a chemical activator (optimum 30%)
- fly ash in the concrete mix efficiently replaces Portland cement that in turn can aid in making big savings in concrete material prices
- it is also an environmentally-friendly solution, which meets the performance specifications
- it improves the strength over time and thus, it offers greater strength to the building
- increased density and also the long-term strengthening action of flash that ties up with free
- lime and thus, results in lower bleed channels and also decreases the permeability
- the reduced permeability of concrete by using fly ash, also aids to keep aggressive composites on the surface where the damaging action is reduced - it is also highly resistant to attack by mild acid, water and sulfate;
- it effectively combines with alkalis from cement, which thereby prevents the destructive expansion
- it is also helpful in reducing the heat of hydration - the pozzolanic reaction in between lime and fly ash will significantly generate less heat and thus, prevents thermal cracking
- it chemically and effectively binds salts and free lime, which can create efflorescence - the lower permeability of fly ash concrete can efficiently reduce the effects of efflorescence.

Fly ash also has some disadvantages.

Figure 4. Ordinary Portland Cement Vs. Fly Ash

- the quality of fly ash to be utilized is very vital - poor quality often has a negative impact on the concrete
- the poor quality can increase the permeability and thus damaging the building
- some fly ash produced in power plants is usually compatible with concrete, while some other needs to be beneficiated, and few other types cannot actually be improved for using in concrete - thus, it is very much vital to use only high quality fly ash to prevent negative effects on the structure.

In Albania, this material cannot be procured in great quantities because of the small number of active Thermal Power Plants fueled by coal - at the moment only one in Vlora and in the near future this one will be fueled by gas right after the realization of TAP project). Another alternative is to import it from Kosovo and the other neighbor countries.

Figure 5 Ground Granulated Blast-Furnace Slag

2.2.b Ground Granulated Blast-Furnace Slag

Ground Granulated Blast Furnace Slag (GGBFS) is another excellent cement material. It is obtained by quenching molten iron slag (a by-product of iron and steel making) from a blast furnace in water or steam, to produce a glassy, granular Ground Granulated Blast-Furnace Slag is considered an excellent cement product that is then dried and grounded into a fine powder. Here the optimum cement replacement level is somewhere between 70 and 80%. Like fly ash, also GGBFS can improve many mechanical and durability properties of concrete and it generates less heat of hydration. The use of GGBFS in concrete has increased considerably in recent years, and this trend is expected to continue. The worldwide production of granulated blast-furnace slag, however, is only about 25 million tones per year. Yet, slag is not as widely available as fly ash. Generally, the comparison of ground granulated blast furnace slag (GGBFS) with Portland cement concrete can be summarized as follows [7]:

- concrete with Type IS cement (Portland-Slag Cement)or with higher dosages of GGBFS added at the mixer usually will have lower heat of hydration
- concretes containing slag may show somewhat longer time of setting than straight Portland cement mixtures, particularly for moderate and higher dosages and at lower ambient temperatures.
- concrete with Type IS cement (Portland-Slag Cement) gains strength more slowly, tending to have lower strength at early ages and equal or higher strength at later ages increasing slag dosage is associated with lower permeability in concrete
- concrete containing GGBFS dosages greater than 35% by mass of cement material, have demonstrated an improvement in the resistance to sulfate attack, as well assupression of alkali-aggregate expansion.

Figure 6 . Ordinary Portland Cement Vs. Fly Ash Vs. Silica Fume

As mentioned, this material is not so easily available, and in Albania can be a byproduct of the only steel factory in Elbasan, for the moment under a Turkish management and that lately stopped its production due to financial problems. So, again, the other alternative is to import these material, a solution that might result in elevated costs.

2.2.c Silica Fume (SF)

Silica fume, also known as microsilica, is an amorphous (noncrystalline) polymorph of silicon dioxide, silica. It is an ultrafine powder collected as a by-product of the silicon and ferrosilicon alloy production and consists of spherical particles with an average particle diameter of 150 nm. This finely divided, glassy powder results from the condensation of silicon oxide gas. Silica fume is composed primarily of silicon dioxide (SiO2).Particles are about 100 times smaller than the typical particles of Portland cement. Silica fume is typically used in quantities ranging from (7÷12)%of the mass of the cement material. Perhaps the most important use of this material is as a mineral admixture in concrete. Because of its fine particles, large surface area, and the high SiO_2 content, silica fume is a very reactive pozzolan when used in concrete. Worldwide production is estimated to be about 2 million tones. It is generally specified for specialized applications, such as structures exposed to aggressive chemicals. Its primary use is to enhance the durability of concrete by making it less permeable. Silica fume addition benefits concrete in two ways. First, the minute particles physically decrease the void space in the cement matrix this phenomenon is known as packing. Silica fume is added to concrete to increase compressive strength or to improve durability. Properly proportioned silica fume concrete can achieve very high early and ultimate compressive strengths. Today, using silica fume, concrete with compressive strength in excess of 100MPacan be readily produced [7].

This type of material, as it can be understood, serves to improve concrete characteristics, while very easily reducing the Portland cement ratio, meaning that it is not an alternative to be considered in fulfillment of the focus of these paper “Concrete as a Green Material”. Due to Albanian industrial development this material can only be imported, meaning not such a feasible choice.

2.2.d Silpozz

Silpozz is a very good super-pozzolan. Silpozz more exactly is an organic micro-silica/ amorphous silica, with silica content of above 90%, having particle size of 25 microns mostly. Finer size of particles helps in filling up the interstices between the cement and the aggregate i.e where the strength and density comes from.

And that is why it can reduce the amount of cement in the concrete mix [7].

- the use of silpozz in concrete can increase the compressive strength by (10÷20)% and high resistance towards the chemical attack, abrasion and reinforcement corrosion
- silpozz has a huge potential to be used as replacement of silica fumes at cheaper cost without affecting the quality
- the use of silpozz helps in reducing the heat of hydration as much as by 30%which helps in preventing the cracks during the casting and

also it reduces the water penetration by 60% proving to be excellent water resistance [9].

Quite the same comments can be made and are valid for Albania as for the Silica Fume.

2.3. Concrete and recycled materials

2.3.a Concrete debris

Concrete debris is probably the most important candidate for reuse as aggregate in new concrete. On one hand, vast amounts of material are needed for aggregate and on the other, construction debris often constitutes the largest single component of solid waste, and probably the largest fraction of this is concrete. Using such debris to produce new concrete conserves natural resources and reduces valuable landfill capacity at the same time. In Europe and Japan, such recycling is already widely practiced [10], [11], whereas in Albania there is still nothing organized planned even for the near future.

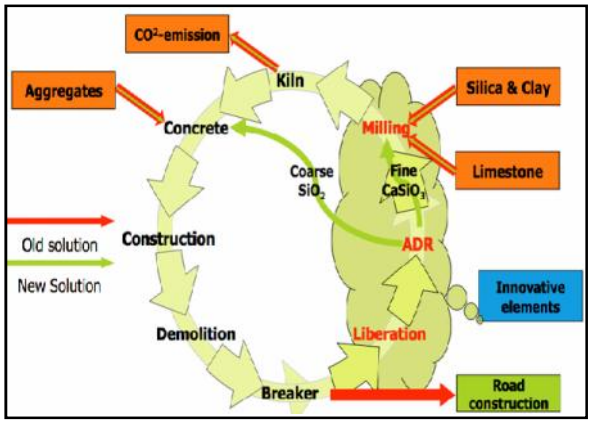

Figure 7 . C2CA Project of European Commission: Recycling Concept Scheme

The disposal of demolished concrete involves costs, which are likely to go up. Available sources of suitable virgin aggregate are being depleted, such as gravel pits, and opening new sources of virgin material is getting increasingly difficult because of environmental concerns. Since the cost of transportation is the main component of the cost of bulk material like sand and gravel, it may not take much of a shift to turn the economics in favor of recycling and re-use. Turning recycled concrete into useful or even high-quality aggregate poses well-known technical challenges [10]. There are contaminants to be dealt with, high porosity, grading requirements, as well as the large fluctuations in quality. Not all applications require high-strength concrete, though. Recycled concrete aggregate is likely to be quite adequate for some projects, while for others, a blend of new and recycled aggregate may make most economic and technical sense. For the Albania conditions, especially based on the mentioned fact that the available aggregate resources like rivers were and still are (although not very clearly accepted by the state) very badly consumed, resulting in an increase of floods, in number and consequences, the implementation of this alternative would be very important. The implementation process of course should be studied and based even on other countries successful experience. As a guide, the results of the European Commission Project with title “Advanced Technologies for the Production of Cement and Clean Aggregates from Construction and Demolition Waste” - C2CA, closed on April 2015 after 4 years of scientific activity.

2.3.b Post-consumer glass

Post-consumer glass is another example of a suitable aggregate for concrete. The introduction of post-consumer recycled glass (including colored glass), substantially reduces consumer landfill waste and increases eligibility for LEED (Leadership in Energy & Environmental Design) Recycled Material credits. Glass is a unique inert material that could be recycled many times without changing its chemical properties. A major concern regarding the use of glass in concrete is the chemical reaction that takes place between the silica-rich glass particles and the alkali in the pore solution of concrete, i.e., alkali-silica reaction (ASR). This reaction can be very detrimental to the stability of concrete, unless appropriate precautions are taken to minimize its effects. Such preventative actions could be achieved by incorporating a suitable pozzolonic material such as fly ash, silica fume, or ground blast furnace slag in the concrete mix at appropriate proportions [12].

Specific measures and improvement of technological assets, but also staff training should be made in Albania prior implementing this recycling alternative. In any case, it is recommended to make a full study of the post-consumer glass amount in order to have a better idea of its recycling impact referring to all discussed above, mainly related to concrete.

2.3.c Dredged material, excavated material from tunnels and other

Dredged material is another example of the recycled material. At the moment in Albania this process is usually made periodically in the portal areas. The dredged material cannot be deposited in the open sea, (with minimal disposal costs)because

national legislation and international treaties are prohibiting such sea dumping, due to its contamination with heavy metals, dioxins, oils, etc. So, the material has to be deposited in engineered landfills at great cost. Treatment methods are already available, which render the material suitable for concrete production, because the heavy metals can be encapsulated chemically such that they cannot leach out. But the economics of such treatment methods are complicated by numerous factors, not all of which are of a technical nature [3]. Nowadays, even the dredge of Hydro Power Plants basins, and other ones constructed for other purposes (like the reservoir of Bovilla near Tirana for potable water) should be made, and in these situation the material can be directly used in concrete industry due to its origin.

The last comment is also valid, with small understandable corrections, for the material excavated from tunnels, no matter what will be their destination (infrastructure, river deviation tunnels, Hydro Power Plants tunnels, etc).

Other examples of materials that can be used in concrete are: waste wood, rubber tires, plastics, pulp, and paper mill residuals, alternatives that would not have an impact in Albania due to the lack of materials or their very small quantities.

3. Discussion

3.1 Future challenge in Albania

The very near future challenge in Albania is to correctly understand the mistakes made in the past regarding the overall development model chosen somehow, willingly or not, and to learn from these mistakes who resulted mostly in an unsustainable development, in many aspects and among them in the environmental one. All of these, should be in our opinion regulated by the laws, and if these are existent (very probable) than specific measures should be taken to apply them correctly and in any case. The construction industry and every sector in its function must be controlled in order to avoid further damages to the environment, while trying to implement new friendly technologies and trying to implement feasible measures that also contribute for a sustainable development and a better environment. The mentality that the environment was, it is and will always be in the conditions “to give”, no matter how is considered by the people and the state must come to an end.

4.Conclusions

Sustainable development is one of the main topics widely discussed in many countries, especially in those in a development phase, like Albania not happily is for more than 25 years. Usually this is related to the environment and more precisely how the overall development impacts it. So, in order to know how “sustainable” our development is, one must realize, perhaps in details, all the influencing factors. One of these is for sure the construction industry, closely related to the concrete industry (does not exist specifically but could be considered as an under-branch). Most of the times, construction industry and sustainable development toward the environment, don’t go so well along, but this is something that can be fixed with the needed efforts, measures and strategies, starting mixing up the concepts to get what is known as “Sustainable Construction”. There are various means to achieve sustainable construction and one of the means is through Green Concrete. Green Concrete technology is one of the major steps that a construction industry can implement to achieve sustainable construction with various means as widely discussed above. With Green Concrete Technology we can reduce the amount of raw materials used, reduce CO_2 emission, reuse/ recycle some types of waste materials, so influencing in a rehabilitation environment process or a preservation one in general, for future use or the generations to come and hopefully sustain it forgot amount of time. The usage of Green Concrete ensures sustainable development and it’s gaining its popularity ever since its inception, but for sure it is not the magic medicine and should not considered like one (other environment related measures must be taken). For Albania, no matter what of the specific measures discussed will be embraced, it is very urgent to understand at first the degradation scale of our environment for almost 25 years, build a strategy for sustainable development and later on implement it.

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