Chapter 3

Wastes in Building Materials Industry

Marinela Barbuta, Roxana Dana Bucur, Sorin Mihai Cimpeanu,
Gigel Paraschiv and Daniel Bucur

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1. Introduction

In the last decades, due to the modern lifestyle, the progresses in industry and technology had led to an important increase in the amount and type of wastes. The problem of waste accumulation every year is all over the world. These industrial and agricultural wastes are by-products, slag, rice husk ash, bagasse, fly ash, cement dust, brick dust, sludge, glass, tires, etc. The wastes represent a major problem for the environment because the air pollution (the dust and very fine particles which spread in the atmosphere) and leaching toxic chemicals (arsenic, beryllium, boron, cadmium, cobalt, lead, manganese, mercury, molybdenum, selenium, strontium, thallium, hydrocarbon compounds, etc.) when are dumped in landfills, quarries, rivers or oceans. The capitalization of waste is difficult because of their variety, as well as their unknown properties over time.

Lately, the environmental sustainability became an important problem from the point of view of natural resources and that of wastes. The construction and the building materials sectors are involved in both processes: building industry is the largest user of natural materials and in addition a large amount of wastes results from the demolition of constructions.

The building material industry is a domain of interest for using the wastes and researchers have tried to produce new construction materials incorporating wastes. The new generation of building materials is developing on other theories in concordance with the sustainability of environment.

Concrete is obtained from natural aggregates, cement and water, compounds which make it a cheap material and easy to produce anywhere. Usually, ordinary concrete contains about 12% cement, 8% water and 80% aggregates by mass. Aggregates and water are from natural resources, only cement must be produced in fabrics, processes which are polluted the environment (for producing 1 m^3 of concrete a quantity of 480 kg of CO_2 is liberated in the atmosphere). For reducing the aggregate and cement consumption, the replacing materials obtained from wastes were studied.

Because the cement industry is responsible for 5-7% of worldwide emission of CO_2, (which means 1.6 billion tons of carbon dioxide into the atmosphere), in preparing concrete, the cement dosage can be reduced by using mineral additions, strategy that also can contribute to environment protection by preserving the energy and consume the huge quantities of wastes.

Near cement concrete other building materials are obtained by using wastes, such as: high strength concrete, which has in the mix different additions (silica fume, fly ash, etc.), asphalt concrete, bricks, pavements, roof tiles, prefabricated units, claddings, etc.

Some building materials are totally obtained from wastes, such as "green" materials. The new concept of green buildings offers more energy-and resource efficiency. This concept means the greening of building industry by using only green materials. The technologies of obtaining green materials are available, but their use in construction industry is limited.

The building material and construction industry is one of the principal users of wastes in the processes for obtaining materials or products, for constructing bridges or highways, in soil stabilization, in hydraulic construction, etc. From environmental considerations an extensive waste utilization in construction is recommended, although particular wastes may be too risky to use.

2. Waste classification

For many years a lot of wastes have been accumulated in the entire world and they influenced the environment and people life. The necessity of eliminating or at least, reduction of huge quantities of wastes is a priority of researches. Their use in the building material and construction industry is a one of the possibilities which can help to keep the environment clean.

In the building material industry there are used a lot of types of wastes, which can be classified as follows:

- **By-product waste** is the waste produced by industry which includes any material that is rendered useless during a manufacturing process from plants, mills and mines. Usually they are storaged in landfills, which are placed on agricultural fields or around big cities. Some examples of industrial waste are silica fume, slag, sludge, fly ash, sand paper, metals, glass, etc. [1].

The by-products which are used in construction are:

- **Silica fume** is resulted from the processes of obtaining ferrosilicon industry, as a very fine powder which is recuperated by filters from furnaces. The quantity of dust involved by burnt gases from the furnace represents about 35% from the quantity of the end product. Silica fume generally contains more than 85% SiO_2, and also other components in smaller quantities, such as: Fe_2O_3 (1.3 - 4%), Al_2O_3 (0.85 - 2.5%), CaO (0.4 - 0.8%), Mg (0.6 - 1.5%), C

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(1.1 - 2.5%). Silica fume has the shape of particles spherical and the specific surface is between 13000 and 23000 m^2/kg. Its spreading in the atmosphere has as effect the environment pollution [2].

- **Slag** is a co-product of the iron and steel production. Slag is usually a mixture of metal oxides and silicon dioxide. However, slags can contain metal sulfides and elemental metals. Slag is a valuable waste which can be used in agriculture, environment processes and construction industry [5]. In agricultural domain the slag is used for treatments for soil improvement. Other properties such as porosity, water holding capacity, bulk density make the slag suitable for using as adsorbent [4].
- **Sludge** refers to the residual material left from industrial wastewater or sewage treatment processes. It can also refer to the settled suspension obtained from conventional drinking water treatment and numerous other industrial processes [5]. This waste can be contaminated with toxic organic and inorganic compounds [4].

Another source of sludge and slag is from steel industry and they are generated as waste material or byproduct. They contain considerable quantities of valuable metals and materials. Different technologies are used for recovering the metallic parts, such as: classification, magnetic separation, leaching, roasting, etc. The wastes are then transformed in different sorts of waste, such as powder, conglomerate, etc. function the necessity of applied technology for a better use of natural resources and environment protection.

The paper industry that uses recycled paper as raw materials has as by-product paper sludge, which has a high content of calcium carbonate, organic materials and other minerals. Because its pozzolanic activity, the paper sludge can be used as cementitious materials in building industry.

- **Fly ash** is a residue from power plants or from different processes of incineration of solid materials. The fly ash is disposal on the landfill [6].

In Romania annually great fly ash (FA) quantities resulted: in 1980 resulted 15 million tons of FA, in 1985 obtained 30 million tons, and after 1990 the FA quantities decreased because the electricity consumes reduced. In our area annually resulted around 21740 tons of ashes (fly and bottom ashes). In the last twenty years resulted approximately 500 million tons of fly ash, from that a small part is capitalized. The FA unused is disposal on the landfill [7].

Toxic substances in the waste - including arsenic, mercury, chromium, and cadmium - can contaminate drinking water supplies and damage vital human organs and the nervous system. Ecosystems are also been damaged by the disposal of coal plant waste.

Fly ash produces environmental damage by causing air and water pollution on a large scale while the cost of storage of this waste is very high. The most serious problem is the hazard to atmosphere and underground water quality which would be a potential risk to the health and property of citizens and cause a huge stress to the economic and environmental system [7].

Another source of fly ash waste is from the solid waste incineration technology which is used in big cities of the world because its effectiveness in volume reduction, weight reduction and toxicity reduction, and also in energy and resource conservation. However, this technology produces fine fly ash residue which is equivalent to 2-5% of the original waste according to the Chinese researchers [8]. The municipal solid waste incineration (MSWI) fly ash can be used as raw material in sintering and preparing calcium sulphoaluminate cement (CSA), which had similar properties as the control cement [8].

- **Organic wastes** are generally biodegradable materials which are accumulated rapidly and for their storage it must design and realize great disposal landfills.

Biodegradable waste can be decomposed in a short period of time, under the natural conditions into the basic compounds, usually micro-organisms, bacteria, etc. This type of waste is found in municipal solid waste and is resulting from food, paper, biodegradable materials, etc. The wastes which are decomposed in the absence of oxygen are also considered as biodegradable waste and here are included wastes from manure, sewage, animal fat, palm fruit bunch, sugar bagasse, banana leaves, etc [1].

At the Iasi municipal sewage water treatment station, one of the greatest from Romania, a flow of 4.2 m^3/s has been processed daily, the sludge resulted by processing reaching an amount of about 3,600 t/day.

The fermentated sludge of the Iasi municipal treatment station had a neutral reaction and content in organic carbon of 29 - 34 %. The concentration of nitric nitrogen is low (0.16 - 0.42 ppm) and that of ammoniacal nitrogen between 24 and 830 ppm. The total content in macro-nutrients (N, P, K, Ca, Mg) from fermented sludge is 1.37 % N total, 1.19 % P total, 4.45 % K total, the calcium content is higher (3.12 %) and organic S and Mg have normal values comparable to those from soils.

The total content in heavy metals (Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn) of fermentated sludge is low, comparable to the one from soils, and under values of maximum admitted values in sludges, in order to be used as fertilizers for soils. Bacterial and fungic microflora of sludges has similar values to the ones of composts, size and composition of microorganism populations were very close to the ones of soils. The lack of bacteria from Salmonella group and a low number of coliform bacteria made a fertilizing material without contamination danger caused by pathogenic microflora from the fermentated sludge. Because the soils from the Moldavian area, most of them placed on slope lands, are poor in organic matter and nutrients, these sludge, adequately used, could be a substitute for a great part of expensive technological consumptions (mineral nutrients) and contribute to the improvement in organic matter content from soil.

- **Mineral wastes** are resulted from the industry processes where the natural resources are transformed in products. In construction industry a lot of natural raw materials are used in natural state. Mining, from the exploration to the closing stage, has a severe impact on the environment. Environmental impact can be direct through the activities: prospecting; exploration; site improvement; extraction; mineral preparations; mineral storage and preparation for delivery; transportation to beneficiary [9].

All technical stages in the minerals exploitation have an important impact on the environment and community life; the dust waste is very aggressive in the atmosphere, in water and soil because of the fine particle and toxic elements. The huge noise from technological processes is also an inconvenient for the community.

- **Inert waste** is waste which is neither chemically or biologically reactive and will not decompose in time. Examples of inert wastes are sand, drywall, and concrete. The inert waste typically requires lower disposal fees than biodegradable waste or hazardous waste.

In the industry of building materials the raw materials are used in natural state and as processed materials (case in which they are transformed in other materials (lime, cement, plaster, additives, etc). Among the raw materials there are: clay, calcareous, gypsum, dolomite, marble, mica, granite, etc. Natural aggregates are obtained from gravel from river or from quarry. Because the aggregates are used in different sorts as sizes, the natural aggregates are usually crushed for obtaining an imposed granulometry. A lot of powder waste remains after aggregate selection and their disposal affect the vegetation of the environment.

- **Agricultural wastes** are resulted from agricultural domain. They are biodegradable in time, but during the degradation process they must be storage in special places. For eliminating the wastes usually these wastes are burned, the powder resulted can be used as fine part in construction.

- **Construction demolition wastes** are resulted from new construction, rehabilitation or the demolition. As waste materials from construction can be: wood, drywall, masonry, metal, concrete, plastic, glass, cardboard. The construction waste quantities are bigger in metropolitan areas, where there are more buildings. Usually the construction waste is storage in landfills.

Construction wastes are obtained during the building process or after demolition. Different types of materials such as bricks, concrete, mortar, wood, steel rebar, insulation material, electrical wiring, plastic materials, glass, iron plate, tile, sanitary pieces, etc. which can be unused or damaged. According to specialty literature about 10% to 15% of materials are lost from the total building material, quantity which varies from site to site [4]. The uncontrolled disposal of this waste is very dangerous for the environment because building materials can contain toxic substances such as lead, asbestos, aluminum, etc.

The recycling demolished waste as aggregate in ordinary concrete offers a solution to the preservation of natural resources and the disposal of construction residues.

- **Transportation industry wastes** are represented by used tires, asphalt and concrete aggregate. Huge quantities of tires were used in artificial reefs, break waters, dock bumpers, soil erosion control mats, etc. [4].

3. Wastes from industry used in building materials

The concrete became a more interesting building material because it has improved its properties and also it is suitable for combining with different types of wastes. The presence of additions and/or fibers is also important because it can improve the performances of concrete or they allow the use of smaller quantities of cement.

The use of different waste in the concrete mix or for obtaining new types of concretes had as result the development of a new type of construction materials: green materials. In this category is included inorganic polymer concrete which is obtained predominantly from industrial waste materials. Concrete of any type had been used as it is or in combination with other materials, the most known being the steel with which had resulted reinforced concrete and prestressed concrete, that are still today very common and useful in construction industry. Polymer concrete is a new type of concrete in which the cement is replaced by a polymer. A high variety of waste are used for obtaining concretes of different requirements related to strength, to chemical resistance, with high durability, rapid hardening, etc.

An important way to use the wastes is to introduce them as a powder or filler in the composition of construction materials (cement, concrete, asphalt, etc.) or to use as aggregates (concrete or bricks from demolition can be used as an aggregate, steel slag can be transformed into aggregates, etc.). Concrete is one type of building material that can incorporate many types of waste such as silica fume, fly ash, cinder, husk, tires, glass, etc. Concrete is used for obtaining structural elements and constructions of any type.

3.1. By-product wastes

- **Silica fume** is specially used as mineral admixture in concrete because of the fineness of the particles which can fill better the spaces between the components of concrete mix. The new types of concretes (the high strength and high performance concrete, ultra-high performance concrete, with compressive strengths going to 150-180 MPa), high strength polymer concrete, etc. that are used in the new modern structures are obtained by adding in the mix silica fume in dosages between 8-12% [3]. Experimental studies shown that the compressive strength of concrete can increase with about 20% in the case of a dosage of 10% silica fume [10]. The behavior of different types of elements realized with high strength concrete under loading is improved, their resistant capacity is higher and the sizes of structural elements are reduced in comparison with structures realized of ordinary concrete.

In the ordinary cement concrete or polymer concrete, silica fume is added in different percentages, as replacement or not of cement, for improving the properties, in particular the compressive strength, durability characteristics, bond strength [10, 11]. These good effects of silica fume on the concrete are resulting from the fact that the particles of silica fume are very small and also from the pozzolana reaction of silica fume with cement paste components. In the behavior of structural elements it was observed according to experimental studies, that the failure of beams was improved, the concrete with silica fume had a better behavior to shear force, the number of cracks in tension zone at failure was reduced, which indicate that elements are less destroyed at failure [11].

In the hydraulic constructions, concrete with silica fume responds better to requirements of hydraulic construction because this concrete has a better behavior to frost-thaw cycles, to abrasion, cavitation, is resistant to chemical attack and it is less permeable, facts which result in a smaller dosage of cement.

Silica fume is also used for obtaining other types of concrete, such as self-compacting concrete, fiber reinforced concrete, polymer concrete. In the case of polymer concrete from experimental studies it was concluded that the increase in compressive strength is not too much as in the case of tensile strength.

Also the addition of silica fume decreased the content of polymer, which is an expensive material [2, 12]. The good behavior of concretes with silica fume can be used for realizing hybrid elements for constructions such as beam or columns, to which the tension zone is realized of polymer concrete, that has a better behavior in tension, and the compression zone of high strength concrete, having in view the better behavior of concrete in compression [11].

- **Slag** can be used in preparing composite cements or as aggregates in preparing concrete [12].

Slag cements are used in concrete structures because it gives some advantages, such as: less carbon dioxide emission, during the production, lower hydration heat during hardening, low permeability and good resistance to sulphate attack [13].

Ground granulated Blast Furnace Slag (GGBFS) improves the flexural strength and compressive strength of concrete and asphalt mixes, which recommend its use in roads, highways, pavements, hydraulic constructions, etc. Ground granulated slag is used in producing cement concrete as mix compound of the concrete or as component of cement. The use of ground granulated slag as component of concrete has the advantage of using it in different dosages, which is important in obtaining desired properties. Ground granulated slag can be used in obtaining Portland blastfurnace cement, which contains up to 5% until 95% of filler. Also, this type of waste can be used in preparing concrete as cementitious material due to its hydraulic property. In this case the fineness of ground granulated slag must appropriate to that of cement or even greater. The use of ground granulated slag used in obtaining concrete is benefic for the environment, but also it improves some properties of concrete such as: fresh concrete has a better workability, structure of hardened concrete is more compact, that resulting in increasing the long term strengths and durability. The content of ground granulated slag in the mix and its fineness depend on the purpose for which it is used in obtaining specific properties of concrete. Research studies reported a replacement of cement with dosages between 10 and 80% from the cement mass. The smaller quantities of waste are for increasing mechanical properties and high dosages are for improvement the resistance to chemical attack [14, 15].

The ground granulated blast furnace slag is also used in asphalt concrete for roads, highways, pavements, etc. An important utilization in the last time is to obtain high performance concretes, with improved durability, which is required in bridges, marine constructions, hydraulic dams, etc.

Another possibility of consuming ground granulated slag waste is to manufacture fibers which can be used in production of insulation material as slag wool [16].

Experimental studies on concrete with aggregates obtained of steel slag had shown that this type of waste can be used in road construction or in infrastructure works because the presence of steel increased the density of hardened concrete. Good mechanical properties were obtained in the case of cement concrete and polymer concrete with slag aggregates and addition of silica fume [3].

- **Sludge** is used in the production of concrete as filling material because its benefits such as improving the compressive strength, freeze-thaw resistance and waterproofness. Also it can be used as replacement of fine aggregates in asphalt paving [4].

The paper sludge is used for obtaining blended cements which contain 90% Portland cement and 10% waste. Also, the paper making waste can be processed to obtain a composition of cellulose fibers and clay which is suitable to use as insulating material or as filler in building materials [17, 18].

The utilization of paper waste sludge obtained from a paper industry, as a replacement to the mineral filler in various concrete mixes was experimentally analyzed [18]. Concrete mixes containing various contents of the waste (3, 5, 8 and 10%) were studied and the results shown a recommended replacement of sand of about 5% for obtaining concrete for masonry construction.

- **Fly ash**

The fly ash utilization is diversified in time and referring to construction industry this waste is used in: cement and concrete manufacturing, production of bricks, tiles and pavements, lightweight aggregates, etc. The new researches used fly ash in obtaining eco-concrete, which eliminated from the mix the cement, the geopolymer obtained being a material more friendlily with the environment. Although a large proportion of global FA is used by the building industry, there is a still proportion which is disposed of in ponds or landfills [4].

In the cement production the fly ash is used in the composition, in different quantities and the cement obtained are named composite cements [6].

In the cement-concrete production, a part of cement is replaced with different dosages of fly ash, normal dosages being between 10-40% and up to 75%. The advantages of using fly ash in concrete are given by the reduction of cement dosage, and also by the beneficial effects which improve concrete properties (mechanical strength and durability resistance), reduce bleeding, reduce cracking, decrease the heat during hardening of concrete [4, 19]. Experimental studies on cement concrete with fly ash shown that the addition of fiber, near fly ash is beneficial in improving the properties. Statistical optimization of mechanical properties for a concrete with 10% replacement of cement recommended for example for glass fiber type, a percentage of 1% from the concrete mass and a length of fiber of 35 mm in the case of compressive strength and higher percentages and smaller length, in the case of tensile strengths.

In obtaining the inorganic polymer concrete, which is a “green” material, fly ash that is considered alkali activated cement, replaces totally the cement from the mix. In fly ash-based geopolymer binder, fly ash reacts with an alkaline solution and the geopolymer paste acts as only binder for aggregates. The basic ingredients of fly ash-based geopolymer concrete are fly ash, sodium hydroxide, sodium silicate, fine aggregates and coarse aggregates [20].

The formulation of high-performance materials that are stronger and more durable than conventional cement-based materials has emerged as an issue of considerable importance in the construction industry. It is possible to utilize fly ash to produce a high-performance material at a potentially lower cost and without compromising its structural integrity. The high-performance polymer concrete made with fly-ash fillers presents the compressive strength, flexural strength, creep deformation and bond strength with values bigger than that of Portland cement concrete. Even in the case of fly ash the polymer dosage can be higher than in the case of other additions, the mechanical properties are increased in comparison with polymer concrete without addition. The use of fly ash as an aggregate in polymer concrete is very promising because it could be used as an overlay in pavement, bridges, and runways or in precast applications such as utility, transportation, and hydraulic components [21].

Industrial fly ash is also used for the production of low-strength material, also known as 'flowable fill'. It is used as a replacement of compacted soil in cases where the application of the latter is difficult or impossible. Also other wastes such as the cement kiln dust, asphalt dust, coal fly ash, coal bottom ash and quarry waste are used for preparing low-strength building materials. The content of these wastes in the mix is between 25-50%.

3.2. Organic wastes

One of the methods of consuming *sewage waste* was the obtaining of methanol gas or caloric fuel which is used for generation electrical powder. Another use is to transform it in powder and to use as fine addition in building materials.

The use of sewage sludge as an organic fertilizer has become of particular interest in the light of the EU Directive concerning the use of sewage sludge, which creates the need for cleaner production technology.

Sewage sludge can be an alternative for the protection of ecosystems. Firstly, sludge-borne organic matter is a crucial factor in improving aggregate stability and water holding capacity of soils, so that the risk of erosion may be reduced. Secondly, sludge-borne nutrients can make sewage sludge an excellent and cheap organic fertilizer for the crops [22]. However, the presence of inorganic and organic contaminants can hider such use of sewage sludge [23]. Moreover, it is well known that the application of organic materials to soil can sequester C, and thus contributes to the improvement of reduction of CO_2 in the atmosphere.

The sludge or the ashes obtained by burning the sludge can be used for obtaining ceramic products such as tile, brick block, pavement, etc. Several works have been carried out in this field [24]. The results from these works concluded that the use of treatment plant sludge as an additional component in a construction material, Portland cement concrete, is possible. The characteristics of sludge were evaluated. Also, it was necessary to analyze other properties such as the origin of the sludge, the components used, and the compatibility of the sludge within the cement matrix and the production of samples. Studies were conducted on the effect of sewage sludge ash on the workability of cement mortars.

A nonlinear reduction of workability in mortars containing sewage ash was observed. In their researches Monzo et. al. [24] reported the influence of sewage sludge ash (SSA) on the properties of cement mortar: a reduction of workability when a part of cement is replaced by sludge ash because it's higher water absorbtion characteristic. Studies on pozzolanic activity of SSA have shown that it contributed to the improved of compressed strength, but its effect is influenced by the sulfur content. The high sulfur content of sewage waste seems to have little influence on compressive strength of mortars containing sewage ash.

Moreover, Casanova et al. [25] observed that cement degradation processes had been observed when gypsum contaminated aggregates or sulfide-bearing aggregates are used in concrete mix.

The sludge or the ashes obtained by burning the sludge can be used for obtaining ceramic products such as tile, brick block, pavement, etc.

The sewage sludge ash can also is used as replacement of sand addition to brick clays which presented a high resistance to fire than normal brick clays.

Sewage sludge can be converted into slag, and as glass materials it is used to produce crystallized glass for ceramics technology.

From the environment point of view, the researchers Cenni at al. [26] studied the possibility of using fly ash resulted from co-firing of coal and sewage slag as additive in bilding materials, because the European standards forbid their use. Their studies shown that the ash from co-firing contained components such as unburned carbon, alkali, magnesium oxide, etc. with a reduced concentration as standard requirements. The authors required modifications in European standards for limiting elements that can be unfavorable by using them in building materials. Fytily and Zabaniotou [27] re-analyzed in a review article the use of sewage sludge in construction industry. Other use, such as incineration of sewage sludge is another way for consuming this waste, but it needs a rigorous control of gas compounds which depends on the technology that is used.

3.3. Mineral waste

The inert mineral waste resulted from quarries, from industrial processes can be used as aggregate or fine part in obtaining building materials and construction products. In any type of concrete these waste can replace different sorts of aggregates, contributing to preservation of natural resources.

The research studies in this domain shown that in building material industry a lot of inert waste can be used, such as granite, marble, limestone in the production of different materials: concrete, bricks, prefabricated elements, etc. The use of marble and granite waste in concrete preparing has shown that they improved the mechanical properties, workability and chemical resistance of concrete [28]. The polymer concrete with marble waste is of great interest because the marble addition or the marble used as aggregates improve the properties of concrete and contribute to a reduction of polymer content. The marble waste can also be used in the production of other building materials, such as ceramic products, where can be used as mix component, or in asphalt production as aggregate sort.

3.4. Construction demolition waste

The construction sector produces high quantities of wastes, over80% being solid waste which is dumped. Some of these wastes may have particular health, safety and environmental concern, such as, asbestos materials with lead-based paint coating and lighting waste. These materials are not included in the present review.

Until now, the construction practice was thought unsustainable because, not only it is consuming enormous quantities of stone, sand and drinking water, but also huge quantities of cement [4]. Modern reinforced concrete structures begin to deteriorate in 10 to 20 years. So, an important problem of concrete structures is that of increasing their durability. New types of concretes obtained by using Portland cement replacement materials and recycling the concrete removed from structures will contribute to the sustainability of building material industry [29]. Also, it must realize that the resources for construction industry are limited and the new technologies of obtaining building material must be based on the existing wastes.

The construction wastes are easier for recycling because they were parts of constructed buildings and as raw materials they were analyzed as raw materials. The concrete from demolition can be used as aggregate. Recycled-aggregate concrete is prepared by completely substituting of natural aggregates [30]. In many cases in the concrete mix there are also used superplasticizers and supplementary cementing materials (for example fly ash). Also, in the recycled-aggregate concrete mix, the cement can be replaces by fly ash or other by-product.

The other materials resulted from constructions such as wood, masonry, metal, plastic, fiber glass, polystyrene granules, etc. can be used in building industry. In the category of “green concrete” which means a concrete with waste, they are introduce in the mix different additions, some as filler. Cement concrete with wood waste is a concrete of low strength, and with characteristics of a lightweight concrete. In the case of cement concrete with polystyrene granules, experimental studies shown that the mechanical characteristics can be comparable with that of an ordinary concrete, even the density indicates a lightweight concrete [3]. A specific property of cement concrete with polystyrene is that of elastic behavior of material under loads, in the case of high dosages of polystyrene.

The concrete with polystyrene spheres was studied from a long time, and near the fact that it is a lightweight concrete other advantages recommend its use in construction. Concrete with polystyrene can be prepared in site or to obtain prefabricated units in factories. The properties of concrete with polystyrene are influenced by polystyrene dosage and by the size of granule. It has been shown that these properties can be significantly improved by adding steel fibers or additions (silica fume, fly ash, etc.) in the concrete matrix or by decreasing expanded polystyrene sphere size.

The polystyrene waste can be also used in manufacturing lightweight concrete blocks or surface units, with improved thermal insulating properties, by introducing the polystyrene sphere as lightweight aggregate in the concrete mix [33].

3.5. Transportation industry waste

The used tires are occupying a large landfill space and generate important problems to the society: one is that of hazard fire which is almost impossible to extinguish and the other is related to the people health. The European Association of Tyres and Rubber producers had estimated in 2009 that a quantity of 3.2 millions of tons of used tyres, from which 96% were re-used: 18% were retreated, 38% were recycled and 40% were used for burning in production of energy [32]. In Romania the recovery ratio is under 10%, in this context capitalization is a challenge for researchers.

The wastes of tyres are used in different purposes: for fixing and sealing soils in agricultural domain, in hydraulic domain (retaining walls, breakwaters), etc. [32].

The tyre waste can be used in natural form, cut in aggregates or in powder. Rubber aggregate is often used in construction works for obtaining light concrete or for road pavements. The experimental studies showed a percentage of around 25% from the mass for obtaining properties comparable with that of ordinary concrete. Higher quantities of tire waste result in decrease of mechanical properties [34]. The rubber increases the capacity to absorb energy from impacts, thus reducing the damage from collisions and increases the deformability and ductility of concrete. Rubber granulate is used for kindergarten play areas.

Once asphalt-rubber mixtures started to be regulated in the 1990s their use in pavements for roads and highways increased significantly [4]. The main advantages of pavements containing tires are their greater resistance to temperature variations and frost-thaw cycles, reduced noise, lower maintenance costs, a better drainage and an increase service life.

In different types of concrete the tire waste is used in various ways. In the concrete mix, the aggregates can be replaced by rubber particles in dosages between 0 - 45 % by volume. As indicated in the literature the concrete with used tire presented an decrease in mechanical characteristics, the use domain of materials obtained with this type of waste presents some advantages which derive from good damping properties, good thermal and acoustic performances [17].

In this direction, obtaining tough materials can be realized by introducing rubber particles in any mix. Concrete of any type is a brittle material. Small quantities of rubber in combination with other additions, can contribute to a better behavior of concrete, without affecting its mechanical properties.

Waste tire can be used as powder in obtaining cement concrete, polymer concrete, concrete with fibers, etc. Tire powder can be introduced in the mix as filler or to replace a part of fine aggregates. In the case of epoxy polymer concrete with powder of tire waste the experimental tests shown that the concrete is lightweight concrete with low mechanical properties, that recommend this concrete for pavement, prefabricated elements for sound protection, thermal insulation, etc [34]. Also this type of concrete showed a very good behavior to attack of chemical agents, abrasion resistance, so its use as floor in chemical industry or as pavements can be a possibility.

Waste tire can be used also in combination with other materials, such as glass fiber reinforced composite, in this case the tire waste being used as replacement of sand and for a better protection against pollution caused by noise. This composite can be used as façade panels for the cover of different buildings.

Rubber tires can be used in embakement as a lightweight filling material for soil reinforcement.

3.6. Other types of wastes used in building materials

- **The plastic materials** represent today an important category of waste. Most of them are re-used in different domains. Polypropylene, polyethylene, polyvinyl alcohol, polyvinyl chloride, nylon, aramid, polyesters are used as short plastic fibers in concrete elements. In the concrete production these fibers are currently used for obtaining high strength concretes, shotcrete, self-compacting concrete, etc [35]. Polyethylene terephthalate (PET) is one of the most used plastic in the entire world, especially for obtaining beverage containers, which are generally thrown away after single usage and their disposal creates serious problems to the environment. Some PET wastes are recycled for obtaining new products, other wastes are used as short fiber reinforcement in structural concrete, also as synthetic coarse aggregates for lightweight concrete, or as resin for polymer concrete [35].
- **The inorganic solid waste** can also be vitrified in solid-like glass materials that are used to manufacture aggregates for the construction industry for obtaining tile and bricks. No ashes are produced because at more than 5,000ºC, all the molecules are disintegrated.
- **Wastes of fiber** of different types (glass, polypropylene fiber, carbon, polyester, textile, etc.) and length are used din obtaining concrete with disperse reinforcement. The properties of fiber reinforced concrete depend on the fiber type, the geometry, the percentage of fiber, orientation and distribution of fiber, mixing and compaction of concrete.

The various applications of fiber reinforced concrete such as shotcrete in underground works, precast products, architectural panels, hydraulic constructions, etc. had contributed to the rapid development of this new building material.

3.7. Agricultural waste used in building material

Wastes from agricultural activities are in very high quantities, especially in some places of the world and they are another source of environment pollution and social problems because their accumulation in landfills and uncontrolled burning.

- **Rice husk** is generated by the rice milling process, from which 78% of weight is rice, broken rice and bran and the rest of 22% is husk. Some quantities of rice husk is burnt, which is polluting the environment. In the composition of rice husk there is nearly 20% silica, which after thermal treatment converts to a crystalline form that is with high reactivity, ultrafine size and large surface area. Because it's high pozzolanic activity the rice husk silica is used in obtaining high strength concrete instead silica fume. The cementing properties of rice husk offer the possibility of its use in ordinary concrete as cementitious material, for replacing cement or in production of supplementary cementing material [31]. Other uses are referred to its use as filler in polymer concrete, green concrete or in production of green building materials.

- **Banana leaves ashes** had been studied because it's pozzolanic activity which arises from the content of amorphous silica. The banana leaf ash is obtained by burning at a controlled temperature. The use as addition in mortar and concrete for civil structures had some advantages such as a reduction of costs of building materials and the consumption of huge quantities of banana produced every year [36].
- **Bamboo leaf** waste was experimentally analyzed because it's pozzolanic property which can be used for introducing this waste in cement composition. The test results shown that in composition of bamboo leaf waste the SiO_2 are 78.7%., being a very reactive pozzolan, comparable to silica fume. The blended cements obtained with bamboo leaf waste in a percentage of 10 and 20% showed the same compressive strength as the witness cement [37, 38].
- **Bagasse ash** is a waste sugar factory and it is used in obtaining blended Portland cements [39] or as replacement of cement in concrete in dosages of 10 to 30% of binder.

Natural cellulosic fibers can be used in the design and manufacturing of composite materials. The natural cellulosic fibers are bagasse from sugar cane, banana trunk from the banana plant and coconut coir from the coconut husk. The banana fiber exhibited the highest ash, carbon and cellulose content, hardness and tensile strength, while coconut the highest lignin content [40]. In combination with other additions, the concrete prepared with natural fibers exhibits good mechanical properties.

4. Conclusions

The useful life of a material in place, however, is always related to the particular combination of environmental factors to which it is subjected, so that durability, or service life, must always be related to the particular conditions involved.

In the last years, the degradation of environment is more pronounced because the measures of protecting the surrounding natural places were not respected and maybe, not understood. The increase of population, the huge energy which is needed, the development of industrial processes, all these resulted in a higher consumption of natural resources, more wastes and a higher pollution [41].

New building materials have developed because the new tendencies of obtaining eco-materials and protection of natural resources [42]. There are many years since when the cement industry has incorporated significant quantities of wastes (silica fume, fly ash, blast furnace slag, metakaolin, ceramic waste, etc.) because energetic, economic and environmental protection reasons. In recent years, alternative additions - bagasse ash, bamboo leaf ash, paper sludge, have been studied as components of eco-cements. The new generation of building materials which are combined with different types of wastes can offer a possibility of consuming disposal materials and reduce the environment pollution.

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Also, the development of composite construction materials with low thermal conductivity using wastes will be an interesting alternative that would solve simultaneously energy and environment concerns [43].

The concrete of any type can be obtained by adding wastes, with experimental studies and statistical optimization, which help to characterize the new materials.

The developments in building materials must be sustainable and in the same time they ensure a ratio cost-energy that satisfy the modern requirements. The addition of wastes to concrete can improve or diminish some properties of the material. Therefore, a combination of wastes is often used or other materials are introduced into the composition to compensate for any disadvantages. These materials can be fibers of different types or lengths (steel, glass, polyester, carbon, bore, textile, etc.) or nanomaterials (nanotubes of carbon, nanoargillaceous materials, etc.).

New building materials based on nano-materials will develop and will influence the construction sector. Waste can be used for producing nanopowder or other nano-products which by using new nanotechnologies allow obtaining a new generation of cement based materials, more durable, with higher mechanical properties or even with desired properties, such as electrical conductivity as well as temperature, etc [44]. Today, nanotechnologies are in pre-exploration stage and must find application from experimental research to applications.

Construction composite materials are developing on the base of new researches in the recycling domain as an innovative option with environmental, economic and performance benefits.

Author details

Marinela Barbuta[1], Roxana Dana Bucur[2], Sorin Mihai Cimpeanu[3], Gigel Paraschiv[4] and Daniel Bucur[2]

1 “Gheorghe Asachi” Technical University in Iasi, Faculty of Civil Engineering and Building Services, Romania

2 University of Agricultural Sciences and Veterinary Medicine in Iasi, Romania

3 University of Agronomical Sciences and Veterinary Medicine in Bucharest, Romania

4 University Politehnica of Bucharest, Romania

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