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Part 3

ASH AND SLAG HANDLING

3.5. Applications of ash and slag from power coals

3.5.1. Production of the building materials

3.5.1.2. Utilization of fly ash for manufacturing of new generation of building materials – artificial porous wood

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ABSTRACT

It has been developed an industrial technology for production of a new generation of building materials – Artificial Porous Wood based on the mixture of fly ash (the by-product of power plants) and plastics waste. The commercialization of the developed technolo-gy should considerable reduce the environmental burden on local Baikal-Irkutsk region by recycling of large amount of mineral and organic solid waste. Baikal Lake is the deepest lake of fresh and the purest water on the planet. The novel building materials which have unique technical, economic and environmental properties over other types of synthetic and some natural woods, are desig-ned for civil and industrial construction industry both for indoors and outdoors application.

1. ADVANTAGES OF BENEFITS OF ARTIFICIAL POROUS WOOD

At present Russia and other industrial countries accumulated a huge amount of non-disposable and non-recycling solid post-consumer waste which pollutes the environmental. There is a certain group of domestic and industrial wastes, which are typical ones in every region of Russia. These wastes include plastics, ash and slag waste, glass and paper waste, used car tires, etc. [1]. The largest volume of waste accumulated in the fuel industry. As has been reported by Russian State Environmental Control agency, 92 % of authorized waste disposal facilities are operated with violation of rules and they do not meet the sanitary regulation. As the results, it leads to degradation of soil, and secondary pollution of groundwater and surface water [2]. As to recycling of fly ash this is a serious problem for any country and region, because after landfilling fly ash becomes useless and unrecyclable. About 30 % only of fly ash is used as additive in the production of foamed and reinforced concrete and other mineral products.

The area of Baikal Lake at Eastern Siberia, Russia is native and intact unique territory needs to be protected from any types of waste, including solid waste such as fly ash and plastics. The environmental policy here should be well organized to protect the area from contamination of soil and water. To realize the policy the network should be developed in Baikal area for collection, transportation, and processing of these wastes in final commercial products using modern and environmentally friendly technologies.

In the Baikal-Irkutsk region the company "Irkutskzoloprodukt" arranges the main activity for utilization of fly ash and slag waste produced at all companies of the holding company «Irkutskenergo". The company "Irkutskzoloprodukt" purchases ash waste at power plants, controls it quality and technical properties, supplies the waste to consumers, and processes it to the final products.

The development of new materials should be based on the principles of economic efficiency and environmental priorities [3]. Ability to use fundamental knowledge related to chemical nature and physical structure of the industrial waste is necessary to create novel materials on their base and makes possible to get a new generation of various composites with unique properties at very low cost. The approach is valid for the development of new building materials as well.

Many types of commercial Artificial Wood (Synthetic Wood, Eco Wood, Plastic Lumber, etc) produce in many countries helps to resolve several global crises such as rapid disappearance of natural forests - the "lunge" of our planet, decrease accumulation of carbon dioxide in the atmosphere, prevent some global worming as well as recycle of billion tones of industrial and domestic solid waste. Until now, all commercial grades of Artificial Wood are very heavy and non-porous materials and they use wood waste (wood flour and fibers, sawdust) as filler; they are well known as WPC – Wood Plastic Composites. The APW has no wood at all and it uses fly ash as filler and porous (foamed) thermoplastic polymer waste as binder. The developed APW exceeds technical and economic properties of WPC and some types of natural wood because it posses much higher fire and heat resistance, chemical and water resistance, biological stability (decay, termites, mold, etc.) and longevity. At the same time the ATM cost is much less due to large content of polymer binder (the most expensive component) and significant amount (up to 70 %) of very inexpensive filler - fly ash.

2. RAW MATERIALS RESOURCES IN BAIKAL-IRKUTSK REGION FOR PRODUCTION OF APW

2.1 Fly Ash

In Baikal- Irkutsk region it was accumulated about 80 million ash wastes for a number of years, which represents a serious source of pollution in the region. The total annual output of ash waste about 1,7 million tons generated is 13 large power plants using the solid fuel. On the other hand, every year the coal consumption in the region increases. For example, in 2007 it was processed 10 million tons of coal, whereas in 2008 — 14 million tons. By 2015 is predicted to process about 26 million tons of coal. It is projected that within a next few years in the Baikal-Irkutsk region all the slag heaps would be filled out.

A number of power plants already started to design projects targeting to dry and mix ash with soil and put the mixture in special reservoirs in order to reduce the land area for accumulation of non-disposable ash. In this regard, the development of new industrials processes and materials based on fly ashes looks not only a local but international problem.

Taking into account a huge amount of fly ash available for recycling and usage for production of APW it has been studied several types of fly ashes generated by various power plants in Baikal-Irkutsk region. An important factor for selection of fly ash for the project was the possibility of fly ash separation at power plants by the dry process.

The main component (filler) for APW production is fly ash with the following characteristics:

- Ash must not contain even trace amounts of radioactivity;
- Ash must have a minimum sulfur content (less than 0,1 %) and carbon (less than 1 %);
- Humidity ash should not exceed 0,5 %;
- Optimal factional composition of the ash - 0,1-3 microns.

For APW production it has been used the local fly ash with the following characteristics (Tables 1 and 2) and it met all federal save certificates in terms of metal oxides and traces of radioactive elements.

2.2 Plastic Waste

Because of significant volumes of PVC waste in Baikal-Irkutsk region, the PVC waste has been chosen as the polymer binder for APW technology at this stage of the project.

3. DEVELOPMENT OF INDUSTRIAL APW TECHNOLOGY

The ability of thermoplastic polymers materials for many recycling cycles (melting-remelting processes) without significant deterioration of their basic properties has been considered as the serious advantage for many-times recycling of APW articles. Multiple recycling ability of materials represents the most fashionable approach for the modern green engineering [4].

The main processing technique for industrial production of APW has been chosen an extrusion process. It is based on melting of thermoplastic binder with fly ash as filler, foaming of the mixture using commercial blowing agents and pass the melt-ash mixture through a special hollow die which has a cross section (profile) corresponding to the profile of the final items (boards, rhombic, tongue and groove, etc.) and cooling the extrudate in the water bath. The technology has been design for the regular extruders and adjustable for injection molding technique as well. The extrusion process is a high speed continuous one and it can be fully automated.

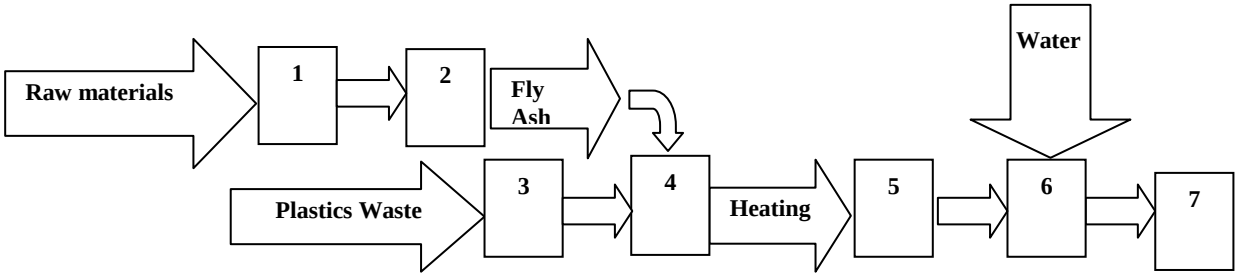

Fig. 1. Scheme of Industrial Production of APW by Extrusion Technique: 1 – metering, weighting an mixing of raw materials, 2 – pre-treatment of fly ash, 3 – feeding of plastics waste, 4 – feeding of fly ash, 5 – extrusion, 6 – cooling of APW articles, 7 – storage of ready-to-use APW articles.

One of the main raw material (binder) for APW production is thermoplastic polymer waste such as Polyvinyl Chloride (PVC), Polyethylene (PE), Polypropylene (PP) waste or their mixtures with virgin polymers in form of powder, granules, or flakes [7]. For production APW with reproducible properties it should be fulfilled two main requirements for fly ash - the same chemical and physical properties, the same purity and uniformity. This is an ideal case scenario.

Uniformity means that plastics wastes should have similar technological properties such as viscosity, range of melting temperature, glass transition temperature, etc. In this regard, we have been tested and formulated the basic requirements for plastic waste:

- To test the local PVC and PE waste.
- PVC and PE waste should not contain any mechanical or chemical impurities.
- PVC and PE waste should have particle size of 1…5 mm.

4. TESTS OF RAW MATERIALS AND APW SAMPLES

In cooperation with this company "Irkutskzoloprodukt" it has been chosen several tests for fly ash generated by various local power plants (Tables 1 and 2). The ash for testing has been selected based on a number of characteristics indicated in the passports of slag materials, such as humidity, grain size and chemical components of ash [6].

It has been used commercial conical twin screw extruder Model "SJSZ - 60 ROHONGROUP 60/125", China at different ratios of ash and polymer content. The final content of PVC-Ash was 40:60 at various concentrations of blowing agents and other ingredients of formulations. The produced APW articles have the texture of natural wood and porous structure. The APW profiles can have different size and shape depending on the requirements of the consumer.

Scheme of Industrial Production of APW by Extrusion Technique is shown in Figure 1.

Table 1. **Chemical Analysis of Fly Ash for APW Production**

Type of Oxides	Amount, %
L.O.I.	below 5
SiO_2	45.1-52.7
TiO_2	0.3-0.4
Al_2O_3	6.5-11.4
Fe_2O_3	17.2-9.0
CaO	24.5-12.5
MgO	5.2-7.2
K_2O	0.2-0.1
Na_2O	0.5-0.4
SO_3	3.40-0.56

Table 2. **Size Analysis of Fly Ash for APW Production**

Sieve size, mm	0,315	0,14	0,08	П
Fraction, %	-	-	0,4	99,6

The APW samples of various formulations have been tested for physical and mechanical properties, fire and chemical resistance according to the Federal standards (GOST).

5. APPLICATION OF THE DEVELOPED APW BUILDING MATERIALS

The new APW materials are designed not only for construction industry but for packaging, furniture, shipbuilding and automotive industries as well [8].

As to the construction industry APW can be use both for outdoors and indoors usage.

For outdoors application: sidings of houses, decking, docking, beams, garden furniture and sidewalks, patios, exterior window and door frames, fences, roof slate, railway sleepers, marine piers, etc.

For indoors application: floors, ceilings, doors, interior windows and door frames, interior padding the walls, shelves, cabinets, furniture, veneer, etc.

This technology makes it possible to produce APW articles of any shape, length, color, odor, surface texture and any cross-sections: rectangular, square, round and oval logs, tongue-and-groove as well as hollow boards and logs.

Commercial production of APW easy to organize at the existing plants for extrusion production of items based on thermoplastic plastics.

CONCLUSIONS

It has been developed a novel family of Artificial Wood with Porous Structure –Artificial Porous Wood (APW). The APW uses fly ash as filler and plastics waste as binder; it does not contain any wood waste. APW exceeds the current commercial Artificial Wood grades filled with wood waste and some natural wood in terms of weight, density, strength, buoyancy, thermal conductivity, fire- and thermal resistance, and water- and bio resistance.

The cost of the developed APW is less than other types of Artificial Wood and some natural wood because the formulations are based on two types of very inexpensive ingredients – mineral waste (fly ash) and organic waste (plastics waste).

Commercial production of APW should have a significant impact at the environmental safety of Baikal-Irkutsk region because it would consume billion tons of fly ash and plastics wastes which contaminate this native and intact unique territory.

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