# USE OF INDUSTRIAL BY-PRODUCTS IN ROAD CONSTRUCTION: ENVIRONMENTAL EFFECTS OF FLY ASH

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## ABSTRACT

The number of studies on the possible utilization of waste materials or industrial by-products from certain building technologies is continuously increasing, although it started many years ago. There are numerous reasons for this. One aspect is to rationalize consumption of good quality natural resources and the other is to minimize large disposal of waste material and industrial by-products.
Out of a wide range of alternative materials used in road construction, a special place is given to fly ash. An advantage of this product is that it can be used in its original form, without any reprocessing or content change.
The benefits of this material, the fact that it is primarily waste material with changeable content should be considered. The decision to utilize fly ash should be based on the evaluation of possible impacts on soil and underground water. Namely, properties of fly ash depend on the type of coal used in power plants, this reflecting on the chemical and mineral characteristics of ash as well as metal concentration.
This paper describes the present understanding of fly ash impact on the environment, emphasizing Croatian research and application experience.

## 1. INTRODUCTION

Research on the possible utilization of waste materials and by-products of certain construction technologies, although present for years, are still continuously increasing. There are a number of reasons for this, one being a rational consumption of good quality stone material reserves and the requirements of the sustainable development concept set before each country, and the other being large quantities of waste materials stockpiling on the dumping sites.

The sustainable development concept emerges in the early nineties as a reaction to the problems, more or less noticed world-wide. According to the WCED-a (World Commission on Environment and Development), sustainable development is the development that meets the needs of the present without compromising the ability of future generations to meet their own needs.
Rapid economic development marked the period between the fifties and seventies of the last century, this having negative effects on certain segments of the environment. However, awareness of the threat to environment and the need to preserve natural resources for future generations was still not at such a high level to give any positive reactions. The first significant positive action at the global level was the United Nations Conference on Environment and Development, i.e. the Earth Summit, held in Rio de Janeiro in 1992. Croatia was one of the 179 countries participants. The resulting document of the Summit, Agenda 21 [1], in its integral text version sets down the main principles on which countries

must base their future decisions and programs, with respect to the influence of economic development on the environment.

## 2. WASTE MATERIALS AND INDUSTRIAL BY-PRODUCTS

According to the sustainable development guidelines the non-renewable sources of natural material need to be protected and the best and the most lucrative utilization method of all available resources created.
Very large quantities of natural stone materials from excavation are being used in construction industry, a significant percentage of these quantities being used in road and bridge construction processes. Such a continuous demand for natural materials reduces and impoverishes the natural sources, and the costs of supply and transport to areas lacking in quality stone materials significantly increase the overall construction costs Waste materials and industrial by-products, an alternative source of materials, can have a very significant role in road construction. Use of these materials primarily contributes to a more rational utilization of quality stone materials and it also has a positive influence on the environment with respect to stockpiling of waste materials.

Some types of alternative materials are being used in road constructions for a number of years already. This is the case in the most developed countries since they are at the same time their largest "manufacturer". Based on the research and experience conducted in the USA, [2], [3], there are various waste materials and industrial by-products that can be effectively utilized in road construction. These are materials requiring complex disposal of large quantities, and as such represent a threat to the environment. At the same time, if used as a substitute for standard materials or as their supplement, they also have a significant economic justification.
From a wide range of alternative materials used in road construction, fly ash, with its advantages, holds a significant position in relation to other materials, because it can be used in its original form, without any processing and change in composition.

## 3. FLY ASH

The term "fly ash" was officially used for the first time in 1937, in the USA, in an edition of the ACI (American Concrete Institute) presenting the results of a Study on fly ash. According to those results, fly ash was used for the first time in 1929, in USA during the construction of the Hoover dam where concrete with a percentage of fly ash in the binder was used. The first, wider use of fly ash in the construction industry occurred in 1949, during the construction of the "Hungry Horse Dam" in Montana, USA, where 120 000t of fly ash were added to cement in the concrete mixture. This marked the beginning of wide use of fly ash in concrete mixtures during construction of dams throughout the USA.
From then to the present day, fly ash has numerous other areas of utilization. Except in concrete mixtures where it was used as a substitute for a percentage of cement, it is also used in road construction as an additive to the binder, as an independent binding material in the execution of stabilized base courses, as filler in asphalt mixtures, and as material for execution of non-stabilized base courses and fills.

### 3.1. Production of fly ash

Fly ash is a by-product produced in the electric utility industry or power plants during the process of combustion of coal in boiler furnaces. In such furnaces, during the process of coal combustion at a temperature of 1000-1600$^{o}$C, volatile substances and organic particles are combusted, while mineral impurities from the coal (e.g. quartz and clay) appear as incombustible residue. This residue is quickly transported to a lower temperature zone where it solidifies into spherical particles, and as fine powdery material it is collected into special baskets by electrostatic precipitators. This ash is known as fly ash and makes 75-85% of the overall ash quantity. The rest are larger ash particles which fall to the bottom of the boiler furnace, forming bottom ash. Quality of fly ash largely depends on the type and quality of used coal as well as the combustion technology.

### 3.2. Properties of fly ash

### 3.2.1. Physical properties of fly ash

Properties of fly ash primarily depend on the type of source coal used for combustion, its grade, chemical and mineral composition and the conditions of the combustion process.

According to its physical composition, fly ashes consist of very fine powdery particles, particle size composition of 1 - 400 microns, of amorphous, glassy structure and predominantly spherical shape, which is a result of the smelting process followed by rapid cooling during production. Its color varies from light brownish to dark grey.
Size and morphology of fly ash particles significantly depend on the maximum temperature achieved during combustion. Differences in particle size distribution, the morphology and surface area properties influence the reactivity of fly ashes and the water requirement of the composites to which the flay ash was added.

Fly ashes have more or less marked pozzolanic properties that enable it a wide range of applications in the construction industry. It has been determined that the pozzolanic properties are more expressed when the particle size is under 20 microns, i.e. that the finer fly ash fractions are “worth more” for the binder than the coarse fly ash particles. [4].

### 3.2.2. Chemical properties of fly ash

According to the chemical composition, fly ash consist of silica, alumina, calcium, iron, magnesium, sulfate, alkali oxides and combustible matter. The chemical composition varies and depends on the type of source coal, as is shown in the table bellow:

Table 1 – Average ranges for chemical composition of fly ash

| Chemical component | Fly ash from Anthracite or bituminous coal | Fly ash from lignite coal or lower quality coal |
|---|---|---|
| | Mass.(%) | Mass.(%) |
| $SiO_2$ | 48 | 38 |
| $Al_2O_3$ | 28 | 22 |
| $Fe_2O_3$ | 9 | 4 |
| CaO | 4 | 24 |
| MgO | 2 | 5 |
| $SO_3$ | 1 | 3 |
| Loss by burning | 5 | 1 |

The main distinction between fly ashes is precisely in their chemical composition, thus the HRN EN 142277-4 [5] standard defines two groups of fly ash:

Siliceous fly ash (alumina-silicate fly ash) - fly ash, where essential chemical components are silicates, aluminates and iron oxides, expressed as $SiO_2$, $Al_2O_3$ and $Fe_2O_3$ and which has pozzolanic properties, and
Calcareous fly ash (sulfo-calcitic fly ash) - fly ash where essential chemical components are silicates, aluminates, calcium oxide and sulfates, expressed as $SiO_2$, $Al_2O_3$, CaO and $SO_3$ and which has hydraulic and pozzolanic properties.

### 3.3. Applications of fly ash

A waste material can rarely be used in construction industry in its original form, without any reprocessing or content change as fly ash can.
Fly ash can be utilized in two ways:

- As a binding component, when the addition of fly ash initiates certain chemical reactions as a consequence of pozzolanic activity (indirect application of fly ash)
- As filler, when the physical properties of mixtures need to be improved by increasing the percentage of fine particles (direct application of fly ash)

Possibilities of utilizing fly ash in road construction, directly or indirectly, are numerous:

- As an additive in concrete mixture preparation where fly ash replaces a percentage of cement (usually up to 20%); at the same time this method of fly ash utilization is one of the oldest and is considered as the first method of utilization of a waste material in construction industry
- As an additive in cement production, considered as the most common utilization method,
- As binder or binder component (cement-ash or lime-ash) of stabilizing mixtures used for preparation of grained pavement structure base course.
- As main material in stabilizing mixtures, stabilized by cement, lime or other type of fly ash,
- As main material for construction of fills, where larger and medium size particles are used,
- As additional material for construction of fills, when the particle size composition of main material needs to be improved,
- As filler in asphalt mix preparation, when the physical properties of the mix need to be upgraded,
- For preparation of road base of agricultural roads, for soil leveling …

This most certainly does not outline all application possibilities of fly ash and research in this field continues.

### 3.4. Influence of fly ash on the environment

By definition, fly ash is waste material produced as a result of coal combustion in power plants. Since this type of energy production is very widespread, numerous countries had to face the problem of ash disposal since the quantities of ash produced were rapidly increasing and piling up on the dumping sites.
According to the US data reports [3], out of the overall annual quantity of fly ash produced, approximately 25% is only used, while the remaining quantities are piled up on stockpiles or dumping sites, thus becoming an increasing environmental problem.
A percentage of fly ash used in road construction industry as an alternative to the commonly used road construction materials reduces the quantities on the dumping sites and with it the problems caused by such storage or dumping.
The already mentioned application options of fly ash and a long term experience in such applications prove its advantages. However, one must not forget that this is only waste

material with variable chemical and mineralogical composition whose uncontrolled application could have harmful effects on human health, surrounding soil and waters. Namely, properties of fly ash depend on the type of coal used in the combustion process and the process itself in the power plants, and this significantly influences the change in ash composition, possible radioactive properties and heavy metal concentration.
Prior to deciding on whether to use fly ash, all possible negative consequences of its use have to be considered.

### 3.4.1. *Estimate of fly ash impact on the environment*

Impact of fly ash on the environment and human health can be analyzed in three ways: In what way can the environment be threatened, what fields of the environment can be threatened and how big is the possible threat.

According to the authors Chesner et al. [3] the environment and human health can be threatened by:

- The presence of heavy metals (As, Cd, Cu, Cr, Hg, Pb, Zn etc.,) and organic matter (benzol, phenol etc.) that are leached or soluble in water and thus influence the quality of surface and ground water and the surrounding soil,
- Fine dust containing toxic and organic elements which can cause respiratory problems in humans,
- Presence of volatile metals (As, Hg, Cd, Pb, Zn) and organic matter (chlorinated hydrocarbons) released at high temperatures and as such present a threat to human health.

#### 3.4.1.1. *Leaching*

Leaching, movement of water through materials containing soluble components, significantly influences the surrounding soil, surface and ground waters.
Variable chemical composition of fly ash can contain elements that will infiltrate ground or surface waters by leaching and ultimately present danger to the flora and fauna. Toxic elements are arsenic, barium, chromium, cadmium, selenium, silver.
Methods of determining the pH values and elements (As, Cd, Cr, Va, Cu, Ni, Pb, Zn, Cl, $NO_3$ and $SO_4$) are defined in the European standard prEN 12506 “Characterization of waste-Chemical analysis of evaluates”.
While determining the possible degree of leaching, among the already presented data on the percentage of hazardous elements present, it is also necessary to have an insight of the hydrological conditions of the environment and the permeability of materials and surrounding soil.

Numerous research projects have tested the degree of potential leaching through construction materials and infiltration into the ground and surface waters through the surrounding soil. Baldwin et al. [6], in conclusion of a comprehensive study on leaching from different waste materials have pointed out that the possible hazardous influence of toxic elements is within very strict valid regulations on water quality, i.e. it does not exceed the allowed limits.
Table 2 presents the standard elements whose presence in the soil and water is being detected in Great Britain [7]

Table 2 – Leachates found using the DIN 38414-S4 and NRA extraction methods

| Typical range of leachable elements for UK PFA (mg/L except pH) | | | |
|---|---|---|---|
| Aluminum | <0,01* to 9,8 | Manganese | <0,01* |
| Arsenic | <0,1* | Molybdenum | <0,1* to 0,6 |
| Boron | <0,1* to 6 | Sodium | 12 to 33 |
| Barium | 0,2 to 0,4 | Nickel | <0,01* |
| Calcium | 15 to 216 | Phosphorus | <0,1* to 0,4 |
| Cadmium | <0,04* | Lead | <0,01* |
| Chloride | 1,6 to 17,5 | Sulfur | 24 to 510 |
| Cobalt | <0,01* | Antimony | <0,01* |
| Chromium | <0,1* | Selenium | <0,01* to 0,15 |
| Copper | <0,01* | Silicon | 0,5 to 1,5 |
| Fluoride | 0,2 to 2,3 | Tin | <0,1* |
| Iron | <0,1* | Titanium | <0,1* |
| Mercury | <0,001* | Vanadium | <0,01* to 0,5 |
| Potassium | 1 to 19 | Zinc | <0,02* |
| Magnesium | <0,1* to 3,9 | pH | 7 to 11,7 |
| Notes: the above data include a seawater-conditioned sample resulting in higher chloride values. The Boron content may also be increased. *Indicates below detection limit | | | |

Except leaching, which can have a hazardous influence on the surrounding water and soil, the quantities of dust also play a significant part in atmospheric pollution. This occurrence is turning into a problem, especially during windy weather. Precisely because of this, it is very important that materials with a large percentage of fine particles, like fly ash, be transported in closed trucks and immediately upon arrival to the construction site, be spread and used.

Threat to some parts of the environment can be studied through different possibilities of fly ash application in pavement structures.
Fly ash has numerous applications in the pavement structure: in pavements (asphalt and concrete mixtures), in stabilized base courses, in non-stabilized base courses and execution of fills. Work on the execution of pavement structure includes numerous instances, like transport and storage of materials, spreading of materials, mixing, compaction, placing and removal of executed course during road reconstruction. Even during work execution harmful effects can be noticed that can have a negative influence on the environment and human health, e.g. release of large quantities of fine dust or leaching of toxic elements in the surrounding soil and water, which occurs subsequently.

The following data are important when evaluating harmful effects of fly ash on the environment: position of the course in the pavement structure and its designed thickness, is fly ash bonded with bitumen or cement and in what quantities is it applied.
Namely, materials bonded with bitumen and cement tend to have significantly lower leaching abilities for two reasons: first, ash particles are surrounded by a bitumen or cement layer preventing water seepage, and second, bonded materials are mainly used for upper base courses that are, compared with the lower base courses, thinner.
Considering the above mentioned, as well as the fact that this material, when well compacted, has a very low permeability, usually $10^{-7}$ m/s, there is no significant influence of hazardous elements on the surrounding waters and soil due to leaching.

A similar conclusion could be reached for non-stabilized base courses under the condition that they are of average thickness and not permanently exposed to moist or damp conditions.
Large quantities of fly ash are being used in road fills, be it as basic material for construction of fills, or as supplement when particle size distribution of the basic material needs to be improved. With such large quantities of fly ash being used, the quantities of toxic elements that can leach into the waters and surrounding soil become significant, although it is a low concentration of such elements.
This problem can become even bigger if the drainage from fills is directly released into the watercourse, endangering the living organisms in it. If these watercourses are used for water supply of the surrounding population, or the fly ash fills threaten the springs and ground waters intended for the same purpose, the problems are even more increasing.
Although the toxicity effect is low in these circumstances, it must be treated since it can cause changes in the taste and smell of water.

Picture 1 shows the construction process of a stabilized base course of pavement structure, where the sources and means of hazardous effects of applied materials on the environment are clearly seen.
The works include transport of materials, unloading at the construction site, application of stabilizing agent, spreading and compacting.
The complete work process results in large amounts of dust being released in the air, whose effects are local and momentary. This kind of pollution stops with the completion of work and there are no significant environmental effects.
Intensive leaching of hazardous elements from the executed course into the surrounding soil and waters appears during construction works, during a period when the executed course surface is unprotected and exposed to rain. As a rule, this occurrence is decreased with the execution of the next course or pavement structure surfacing.

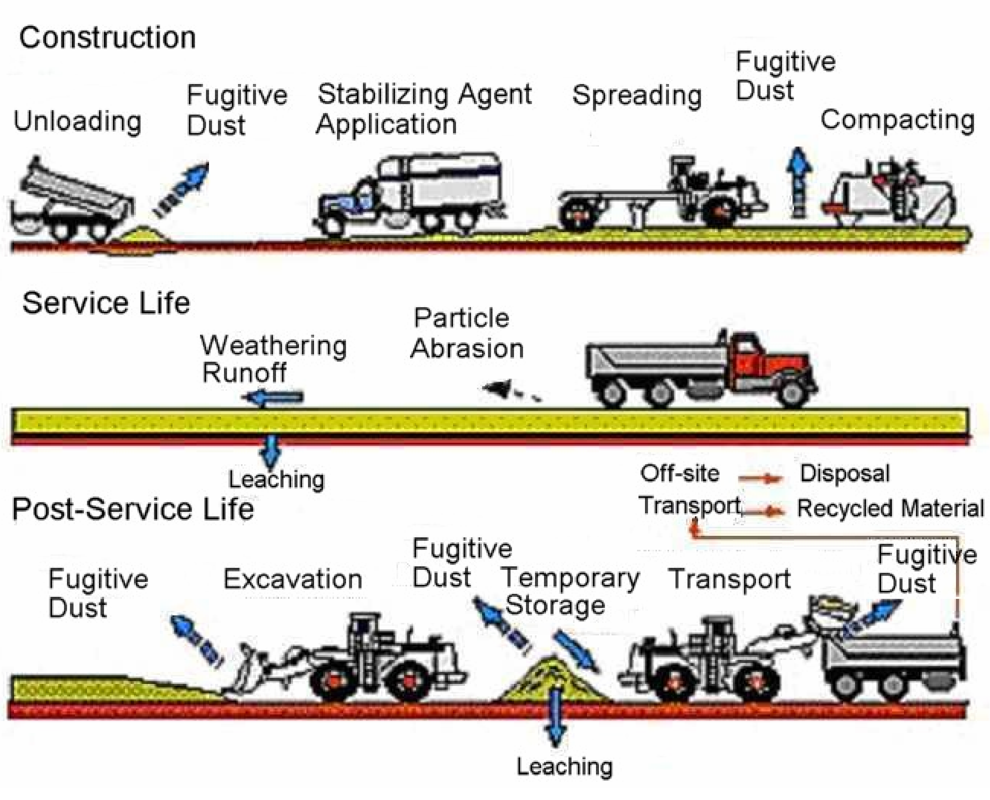


Figure 1 – Execution of a pavement structure stabilized course [3]

#### 3.4.1.2. *Radioactivity of fly ash*

Use of fly ash for construction purposes is in some cases somewhat limited due to the fact that the radioactivity level of this material is higher compared to the radioactivity level of other waste materials, which is a result of the concentration of natural minerals in coal.

Green [8] published the results of radioactivity tests undertaken in Great Britain, which included tests on fly ash, materials containing fly ash as component and dumping sites. Results showed that radioactivity level of other materials does not increase if fly ash is added, that there is no danger to the health of workers or local population and that each potential risk can very easily be detected by measurements on the construction site or dumping site.

The International Union of Producers and Distributors of Electrical Energy (UNIPEDE) published the results of radioactivity testing of fly ash undertaken in some European countries, and proposed average values to be 200 Bq/kg. Table 3 [8] shows average radioactivity values (for uranium U and thorium Th) for various European countries.

Table 3 – Radioactivity in pulverized fly ash (PFA) in Bq/kg (UNIPEDE)

| Reports from | PFA from | U-series | | | Th-series | | |
|---|---|---|---|---|---|---|---|
| | | Min | Max | Average | Min | Max | Average |
| Germany | Germany | 93 | 137 | 119 | 96 | 155 | 121 |
| | UK | 72 | 105 | 89 | 3 | 94 | 68 |
| | Australia | 7 | 160 | 90 | 7 | 290 | 150 |
| | Poland | | | 350 | | | 150 |
| Italy | Italy | 130 | 210 | 170 | 100 | 190 | 140 |
| Denmark | Denmark | 120 | 210 | 160 | 66 | 190 | 120 |
| Sweden | Sweden | 150 | 200 | | 150 | 200 | |
| Belgium | Belgium | 112 | 316 | 181 | 88 | 277 | 150 |
| Spain | Spain | 80 | 106 | 91 | 77 | 104 | 89 |
| Germany | | | | 189 | | | 118 |
| Czech R. | Czech R. | 35 | 190 | 129 | 62 | 142 | 90 |

Since fly ash quantities used for fills are much larger then quantities used for other purposes in road construction, most research activities of fly ash influence on the environment have been undertaken precisely on road fills.
Based on the data of previous research [9], [10] it can be concluded that fly ash does not represent an environmental hazard despite the risk of leaching and concentration of toxic elements, or potential radioactivity.
Storage and use of fly ash does not require additional protection measures except the usual protection measures required in construction industry.

### 3.5. Croatian experience in application of fly ash

### 3.5.1. Characteristics of Croatian fly ash

The only “manufacturer” of fly ash in Croatia is the thermo-electric power plant Plomin which, until the year 2000, used domestic coal from the Raše and Labin coal mines. Since fly ash obtained from this coal had a significant radioactivity level, all testing on the possible use of this fly ash were soon abandoned, and the use of this fly ash restricted.

After the year 2000, thermo-electric power plant Plomin switches to new operation technology and starts using imported coal for combustion, with a low sulfur level, not exceeding 1%. The coal is imported from South Africa, Australia, Columbia and Indonesia.

Chemical and particle size distribution analyses of fly ash samples obtained from imported coal are shown in the table below:

Table 4 – Chemical and particle size distribution analyses of fly ash

| Chemical analysis | |
|---|---|
| | Test results (%) |
| Moisture in sample | 37,87 |
| silica $SiO_2$ | 53,95 |
| Aluminum oxide $Al_2O_3$ | 21,83 |
| Iron oxide $Fe_2O_3$ | 8,17 |
| Calcium oxide CaO | 4,32 |
| | |
| Sulfur oxide $SO_3$ | 0,38 |
| Chlorides $Cl^-$ | 0,005 |
| Calcium oxide, CaO-freed | 0,00 |
| Loss due to combustion – incombustible | 3,69 |
| Particle size distribution analysis | |
| Percentage of particles in an interval (mm) | Test results (%) |
| 0-0,063 | 78,9 |
| 0,063-0,20 | 20,2 |
| >0,20 | 0,9 |

Fly ash radioactivity test results, obtained on the basis of gamma-ray spectrometry measurements of samples are shown in the following table:

Table 5 – Fly ash radioactivity test results

| Sample | Activity (Bq/kg) | | |
|---|---|---|---|
| | $^{40}K$ | $^{226}Ra$ | $^{232}Th(^{228}Ra)$ |
| Fly ash | 563,5±14,1 | 81,5±2,0 | 59,0±2,4 |
| Tolerated values (according to N.N.108/99) | 3000 | 300 | 200 |

Based on Article 20 of the Ordinance on the requirements, means, places and deadlines for systematic testing of ionizing radiation, types of substances in the environment and their radioactivity (Official Gazette no. 108/99), the maximum level of radioactive pollution of construction materials used in construction industry must satisfy the following:

$$\frac{C_{Ra-226}}{300} + \frac{C_{Th-232}}{200} + \frac{C_{K-40}}{3000} \leq 1$$

Where:
$C_{Ra}$, $C_{Th}$, $C_K$ natural and artificial radionuclides

The tests show that fly ash satisfies the set environmental criteria (sum of quotients from the above given expression is 0,75450 <1) and that it can be used in construction industry without any restrictions.

At the moment, the complete quantity of fly ash produced in the thermo – electric power plant Plomin is being transported to the nearby cement factory "Koromačno" where it is used as an additive material in cement production.
This has multiple environmental values. Fly ash is put to good use, all produced quantities are immediately transported and no dumping sites are created. Influence of fine dust on the environment is minimal in this procedure since fly ash is stored in a concrete silo until transportation, capacity app. 1200 $m^3$ , loaded into a truck cistern and transported to the cement factory.

### *3.5.2. Croatian experience in the use of fly ash*

As already mentioned in the previous item, due to long-standing inadequate quality of fly ash obtained from Croatia's only thermo-electric power plant, Plomin, fly ash was not used in construction industry nor had there been research undertaken on its possible application and use.
Croatian experience in fly ash utilization was based on the research and utilization of "foreign" fly ash.
The criteria for fly ash selection were primarily based on the respective fly ash properties, but also on the distance of the thermo-electric power plant where it is produced. This is how the research of fly ash from the thermo-electric power plant "Kakanj" began, from the neighboring Bosnia and Herzegovina, which was being tested as possible additive in cement production. [4].
Initial research of stabilizing mixtures with a percentage of fly ash in the binder were undertaken in 1996, at the Faculty of Civil Engineering in Osijek, [11], the fly ash used for testing being supplied from the thermo-electric power plant in Pécs, from the neighboring Hungary.
Research on stabilizing mixtures with similar composition have been expanded and continued in 2004, [12], and here also, fly ash from the Pécs power plant was used. Extensive laboratory tests were undertaken on over 600 stabilization mixture samples, including testing of mechanical and elastic properties: compressive and indirect tensile strength, the dynamic modulus of elasticity, dynamic shear modulus and the Poisson coefficient.
Environmental effects of fly ash utilized in stabilizing mixtures were not studied.

The thermo-electric power plant Plomin, meanwhile, started using coal of higher quality and producing fly ash with better properties. The Civil Engineering Faculty of the Osijek University plans to undertake new studies, this time with fly ash from Croatian thermo-electric power plant. First contacts in this direction have been made with the representatives of the Plomin power plant.

### *3.5.3. Legal framework of environmental protection in the Republic of Croatia*

Environmental protection had become a very important factor in the long-term development process of Croatia. According to the National Environmental Protection Strategy (Official gazette no. 46/02) the scope of environmental protection needs to be extended, respecting two key guidelines [13]:

1. The Sustainable development concept

2. Process of accession to the EU by harmonizing Croatian legislature and criteria to those valid in the EU countries

Two groups of priorities have been pointed out in the field of environmental protection, their choice being based on the degree of development of individual parts of environmental protection measures, and the EU Action Plan, i.e. interests of the EU in defining the environmental protection policy and strategy. The first group of priorities includes, among other, activities like waste management, water protection, air and soil quality.
Precisely through activities like these, the construction industry can significantly improve the present situation and contribute to successful implementation of sustainable development.

Group of all Acts and Regulations, governing a very wide field of environmental protection in Croatia, consists of more than one hundred Acts. Some Acts and Regulations are not at the required level of expertise, which is a result of insufficient coordination between expert and scientific institutions at the level of enactment of sub-Acts. There are also discrepancies between individual regulations. Therefore new laws are under preparation, the new Soil Protection Law, Law on Nature protection, Supplement to the Ordinance on maximum emission values of pollutants in the air and a large number of other new Acts and Laws. Such activities in legislature are a result of a new, large project of the Ministry of Environmental protection, Physical planning and Construction, the "Harmonization of Croatian Technical legislation with the EU Guidelines " initiated in 1997.
Republic of Croatia is a signatory to more than thirty international conventions and agreements, committed to implement changes in legislature and ensure resources for such implementation (introduction of new technologies).

A system of environmental monitoring is very important for the protection of environment. This monitoring system serves to detect and record changes, supervises compliance with standards, enables acquiring knowledge of the processes and predicts changes in the environment. The system of monitoring in Croatia is for most parts of the environment still at its beginnings, the most developed monitoring system being for water quality - monitoring of the quality of surface waters is done at the national level and can be considered developed and well organized.

Utilization of alternative materials in construction industry and adopting regulations for this utilization is a process where Croatia significantly lags behind industrially developed countries, where such materials are being used for a number of years already.

## 4. CONCLUSION

Fly ash is considered an industrial by-product with extensive utilization possibilities in the construction industry. It is the first material used as a substitute to standard materials. Reasons for this are twofold; large quantities of ash piling up on the dumping sites started to become an environmental problem and had to be decreased, while, on the other side research of the ashes unveiled its good properties, primarily positive effects of delayed pozzolanic reaction.
Numerous researches implemented till the present day confirmed the utilization of fly ash in construction industry and showed even greater possibilities to use this industrial waste product.
Fly ash can be used in the road construction process in ten different ways, directly and indirectly, in all pavement structure courses and fill.
Despite a long-standing application of fly ash and its advantages, prior to its utilization all possible negative hazardous consequences on the waters and surrounding soil must be

considered. Namely, as a product of coal combustion in thermo-electric power plants, is has a changeable chemical and mineralogical composition, thus problems with leaching of toxic elements into the waters and surrounding soil can occur as well as a problem of potential radioactivity.
Results of various tests on the possible hazardous influence of fly ash showed that storage and utilization of fly ash does not require additional protection measures outside of those usually applied in the construction industry.

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