Utilization of concrete as a construction material in the concept of Radioactive Waste Storage in Slovak Republic

Igor Hudoba[1]

Využitie betónu ako konštrukčného materiálu v koncepcii uskladnenia rádioaktívneho odpadu v Slovenskej republike.

The nuclear power energy for the production of electricity seems to be, along with the alterantive ways like the wind, solar and geothermal energy, the only possibility how to cover the increasing needs for the energy in the human population. The adoption of nuclear power energy concept for the production of electricity is always a hot topic of discussion not only on the professional, but also on the political level. The join of problem of the electricity production in nuclear power plants is the disposal and storing of radioactive waste. The increasing amount of low and medium radioactive waste needs a serious concept of a long term policy in the radioactive waste management. In general, a period of 300 years is a minimum time span in which the storing facilities have to guarantie the safety of human population and environment against radiation and radiation-chemical danger. A correct design of the storage place for the radioactive waste is a challenge for experts in the fields of material science, geoscience, construction etc. This paper is dealing with the basic information about the concept, material and construction basis of the low a medium radioactive waste storage in Slovak Republic.

Key words: *high performance concrete, fibre concrete, strength, durability, service lifetime*

Introduction

One of the most important decisions concernig the whole concept of storing is the material basis of storage facilities. The storage place is usually designed as a multi-barrier system because of very specific needs in comparisson with an ordinary waste storage place. The containment vesel in the form of a different type of container is a primary protection barier in the whole protection system. There are different concepts of containers from the construction material, size and the form point of view. The container can be made of a metal, steel, glass or composite material. Each of the concept has some adventages and disadvantages. At present, the construction materials on the cementitous basis become most preferable for the containers, production. The high quality concrete was chosen for the box containers production in the management of low and medium radioactive waste storing in Slovakia. The advantage of such a material is not only the durability but also the technological and economical aspects. The design concept of a container made of concrete is based on two main requirements:

1. The design, concrete mix composition and the technology have to guarante that the properties of hardened concrete will be not changing during the extremely long period of 300 years.
2. The integrity of the container after its fullfiling and storing in a central storage place environment will be guaranteed in the required time span. It means that the container must fullfil all criteria of reliabilitty.

A general concept of the low and medium radioactive waste storage in the Slovak Republic

In the 90-ties of the last century, a project of the central storage place for low and medium radioactive wastes nearby the Nuclear Power Plant Mochovce was realized. This location is adequate for specific reasons, mainly for its geological and hydrogeological conditions. At present, a first part of the whole planned capacity of the construction is built and is ready to store containers with the radioactive waste. The reinforced concrete is a dominant construction material of the underground chambers. Fig. 1 shows the bird view on the finnished part of central stortage place. The box chambers are organized in parallel rows. The containers with the radioactive waste are placed into the chamber by stages in three layers. The capacity of one chamber is 90 containers. When the capacity of the chamber is full, the ceiling consisting of reinforced concrete precast panel is placed and the chamber can be definitly closed. Fig. 2 shows the schematic underground chambers' cross section in a definitive container´s storage position. The upper part of the storage place construction consists of a multi-layer system of insulations and soil. The loading capacity of the precast reinforced concrete ceiling construction has to guarantee that the containers into the chamber will be not loaded by an overburden part of soil layers. There exist a logistic plan how the containers, after its

[1] *Assoc. prof. Igor Hudoba, PhD,* Department of Concrete Structures and Bridges, Faculty of Civil Engineering, Slovak University of Technology Bratislava, Radlinského 11, 813 68 Bratislava, SR, Tel.: (++421 2)59274 547, igor.hudoba@stuba.sk
(Recenzovaná a revidovaná verzia dodaná 8. 1. 2007)

transport from the processing centre in the nuclear power plant, will be placed into the underground chamber. Fig. 3 shows how a container is transporting and placing into the chamber by using of cran facilities.

High performance fibre reinforced concrete box container

Material properties of the high performance fibre reinforced concrete

The concept of high performance fibre reinforced concrete (HPFRC) mix design was based on a french licence (fy. SOGEFIBRE) and later partially modified on the domestic material basis. Its composition consists of river aggregates, sand, filler, modified cement, silica fume, superplaticizer and water. Metal strip fibres FIBRAFLEX is serve as a fibre reinforcemet. The high quenching rate solidifies the liquid metal in an amorphous, non-crystaline state and giving the fibres its flexibility and very good mechanical properties. Tab. 1 shows the basic mechanical properties of the FIBRAFLEX fibres. Because of the chromium content in the FIBRAFLEX alloy, the stips fibres are highly resistant against corrosion. The content of the FIBRAFLEX fibres in 1 m^3 of the concrete mix is 1,37 %. Tab. 2 shows the basic mechanical properties of the hardened HPFRC.

Tab. 1. Mechanical properties of the FIBRAFLEX fibres.

Tensile strength [MPa]	2000
Modulus of elasticity [GPa]	140
Specific surface [m^2/kg]	10

Tab. 2. Mechanical properties of the HPFRC.

Age [days]	**7**	**28**	**90**
Compressive strength f_c [MPa]	47,80	71,1	87,8
Tensile strength $f_{ct,spl.}$ [MPa]	4,05	4,59	5,28
Tensile strength $f_{ct,bend.}$ [MPa]	6,74	7,73	8,52
Modulus of elasticity M [GPa]	32,68	39,63	40,99

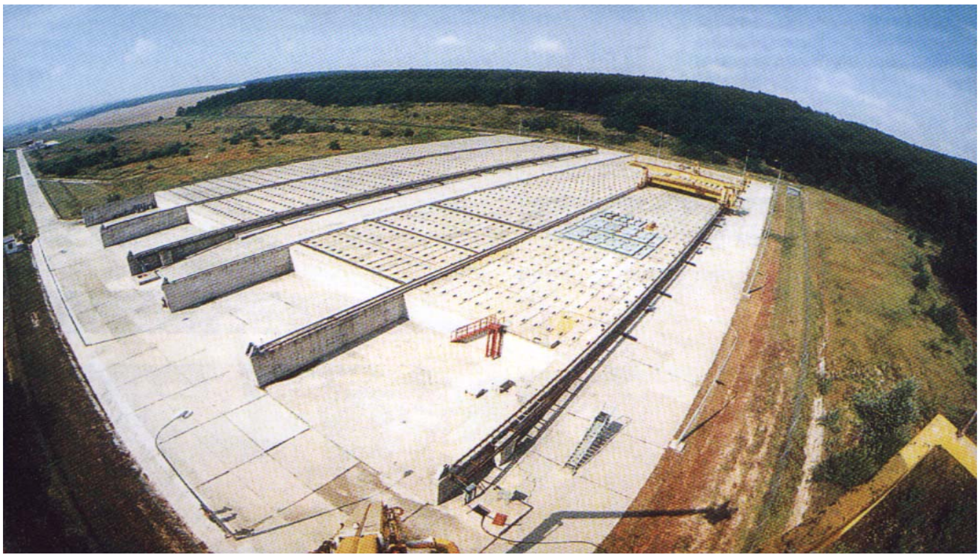

Fig. 1. Bird view on the first finished part of the central storage place.

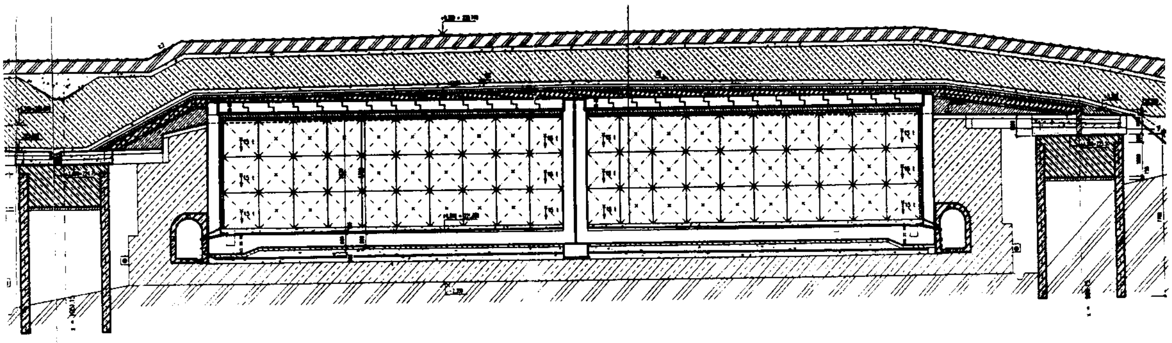

Fig. 2. Schematic cross section of the twins of underground chambers in a definitive container´s storage position.

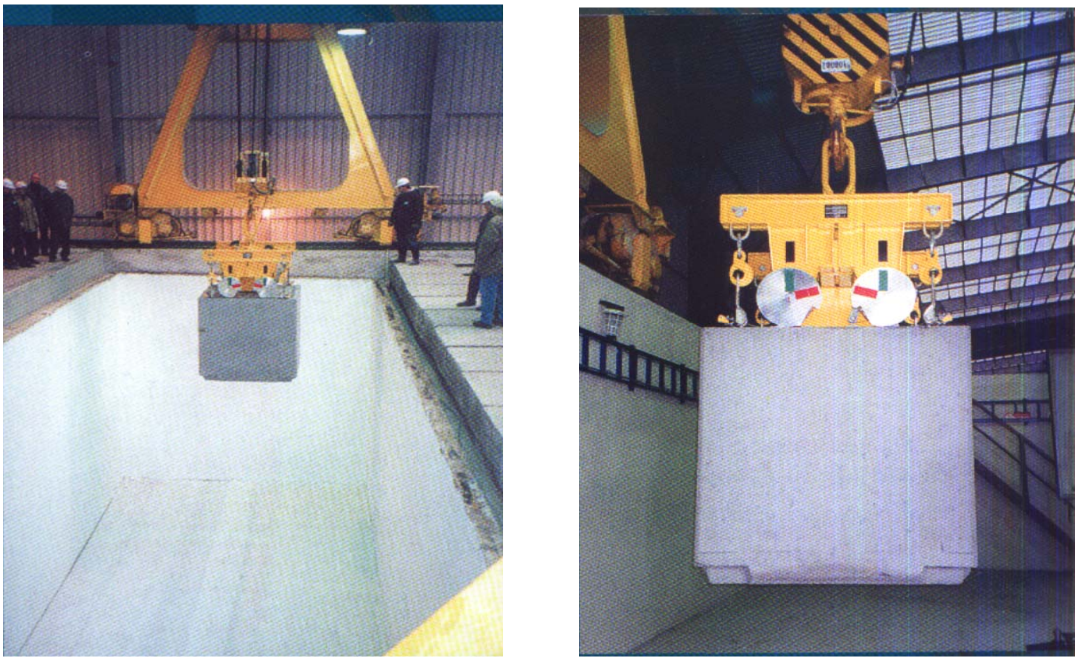

Fig. 3. Manipulation of the container during the process of its placing into the chamber of storage place.

A high quality of HPFRC in the sense of higher strength parameters goes hand in hand with other good physical properties. Because of HPFRC high durability requirements in the life span of 300 years it is necessary to pay attention on the choice of concrete mix constituent, especially the aggregate and cement. In general, the longtime durability of hardened HPFRC has to be appoved by the accellerated test of durability [1], [2]. The process of the concrete mix production is realized in a fully automated plant with an electronic control. There exists a complex quality control at all stages of the container fabrication. The process of concrete mixing is controled by a computer.

HPFRC container and its fabrication

The form and size of the box container is shown in Fig. 4. The internal capacity of the container is 2,9 m^3. The body of the box container is made as a precast element in the bottom up position by using of massive steel mould. The mould with the fresh concrete after the vibration is placed for 16 hours in the hall environmet and after this time the mould is twisted to the bottom dowm position and the container is demoulded (Fig. 5). A newly made container is covered by a plastic cover in order to create optimal curing conditions during the process of maturity.

The complete construction of container consists of the box body, the cover plate with two openings with caps (Fig. 6).

Low and medium radioactive waste are placed into the container by using of special technological. The waste inside the container is immobilized by a cementitous slurry. The full container is hermetically closed, transported to the central storage place and placed into the underground chamber (Fig. 3).

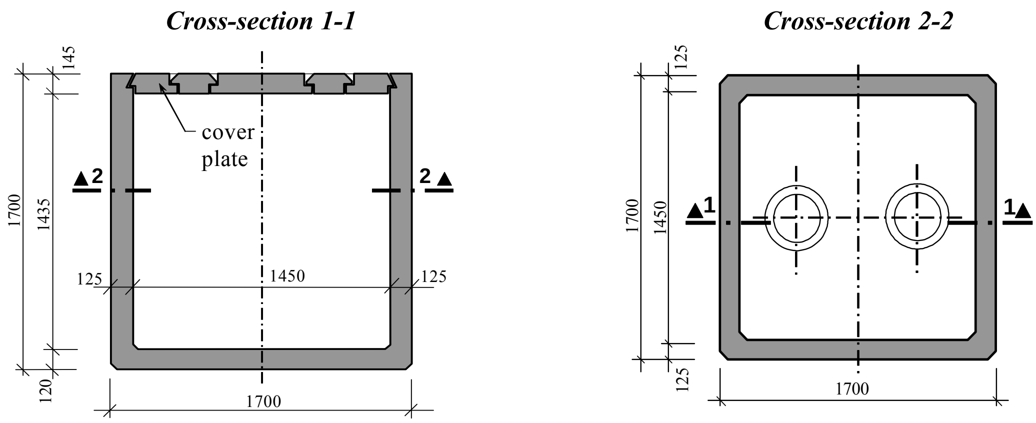

Fig. 4. Form and size of the container.

a.) *b.)*

Fig. 5. Stages of container fabrication:
a.) Container steel mould after finishing of concrete placing and vibration.
b.) Process of concrete maturity under the plastic cover.

Fig. 6. Precast container body and cover plates made of HPFRC.

Conclusions

A new generation of concrete, especially the high performance concrete and cementitous fibre composites, seem to be a dominant construction material in the radioactive waste management in the future decades. A previous experience in foreign countries and our own experience in Slovakia as well can confirm that the high performance concrete is able to fullfil all demanding requirements concerning the longterm storage of radioactive wastes. Today, it is extremely important to present to the public a clear concept of the radioactive waste storage based on the results of research [3], [4], serving as a good model for other countries.

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