*Proceedings of the 16th International Conference on Soil Mechanics and Geotechnical Engineering*

*doi:10.3233/978-1-61499-656-9-2465*

# About necessity of arranging geotechnical protections at the objects of nuclear power

## Sur la nécessite de construire des protections géotechniques aux objets d'énergie atomique

V.N. Zhivoderov
*The firm "OOO Transgidrostroi", Moscow, Russia*

ABSTRACT
The paper describes the essence of the problem arisen when arranging the protective geotechnical measurements during the elimination of the consequences of the accident at the Chernobyl nuclear power station (NPS). In spite of the 18 years passed after the accident, still now the existing normative documents do not envisage an obligatory arrangement of protective geotechnical measurements at the NPS being designed and constructed. The author carried out an analysis of the situation turned out and proposes the recommendations to solve these problems.

RÉSUMÉ
Le mémoire décrit l'essence du problème apparu en construisant les protections géotechniques, quand les suites de l'accident à la centrale électrique atomique (CEA) de Tchernobyl étaient écartées. Malgré que 18 ans se sont écoules après cette accident, encore aujourd'hui les documents normatifs existants ne prévoient pas la construction obligatoire de protections géotechniques aux CEA étant projetées et construites. L'auteur a rempli une analyse d'une situation s'étant arrangée et propose les recommandation pour résoudre ces problèmes.

## 1. INTRODUCTION

The problem of arranging geotechnical protections at the objects of nuclear power arose for the first time, when carrying out the restoration works at the Chernobyl nuclear power station (NPS), where geotechnical protections had not been incorporated in the design.

In spite of the borne in this case considerable losses of specialists, manpower and equipment, the Russian normative documents and also the European norms do not reflect up to now the necessity of obligatory arranging of geotechnical protections at the objects of nuclear power. The situation turned out causes the questions requiring prompt decision: "What to do, that there would be no necessity of building geotechnical protections under conditions of the strongest radiation fields?" and "How to save human lives, equipment and large material means?" Simply stated, is not it better to struggle against the reasons of a phenomenon, and not against its consequences?

Before obtaining answers for these and other questions we would like to provide some information concerning the restoration works and arranging geotechnical protections at the Chernobyl NPS.

## 2. SHORT INFORMATION

In the Ukraine (the territory of the former USSR) in the night of 26 April 1986 the accident occurred, which was the greatest of the known ones in nuclear power. The roofing was wholly demolished and the upper part of the 4th power unit was broken down at the functioning Chernobyl power station.

In the first several days after the accident thousands and tens of thousands Roentgen per hour were discharged to the atmosphere with steam and smoke. Such doses were registered in radiation fields inside and near the 4th unit. In the morning of 28 April 48 hours after the accident a considerable increase in the radiation level was registered on the shore of Sweden and Finland (at the distance more than 1200 km from the Chernobyl NPS). The transfer of radioactive substances by an air way was observed also in other countries of the world. The location of precipitation fallen was determined by the wind direction and the velocity of transfer of air masses. The fourth May the radioactive substances were found also on the soviet scientific-research vessel in the Atlantic Ocean at the distance of 4000 km from Chernobyl.

From the above the principally new is the comprehension of the fact that during accidents at the objects of nuclear power the radioactive exhaustions, like in the cases of nuclear tests, do not know national frontiers. And the problems of countries having nuclear power become the problems of many countries. The number of reactors at the NPS for several leading countries of the world is: USA - 120, France - 62, Japan - 51, Great Britain - 38, Russia - 34, Germany - 32, Canada – 22 (totally more than 500 reactors in the world). Therefore to solve the arising tasks the necessity of uniting the efforts of the all International society is put in the forefront. The best effect in such cases can be expected from the system preventive measures.

## 3. THE WORKS DURING ELIMINATING THE ACCIDENT

The protective geotechnical measures including the design and the engineering preparation of works at the Chernobyl NPS were carried out under the conditions of a hard radiation contamination, which involved human victims and health breakdown of the liquidators of the accident.

The most difficult and urgent problems arose already in the first day after the disaster. As a result in extremely short terms and under the specific conditions the following works were carried out:

1. Arranging dams and dykings in low places of the terrain to avoid the contamination by a surface run-off of different water areas around the NPS site.
2. Reconstruction of the rain collector in Pripyat' town for accumulating and pumping-out potentially contaminated surface waters.
3. Construction of an anti-filtration "wall in ground" on the NPS site (2113 m long and about 32 m deep) to prevent

the propagation of contaminated underground waters (Fig.1).

4. Arranging a system of drainage wells to intercept contaminated underground waters.
5. Under-foundation water-cooled plate of the reactor room.

The last measure was conditioned by an ignition of the graphite brick-work of the reactor and melting of the structures of the active zone under an action of ultra-high temperatures, which caused a threat of penetrating of a high-radioactive melt under the foundation of the reactor room. According to design assessments the melt of the active zone could pass into ground to the depth up to 10 m. The consequences of this could be very hard, with an intensive radioactive contamination of underground waters and their ingress into rivers Pripyat' and Dnepr, and also into the water-bearing levels used for water supply.

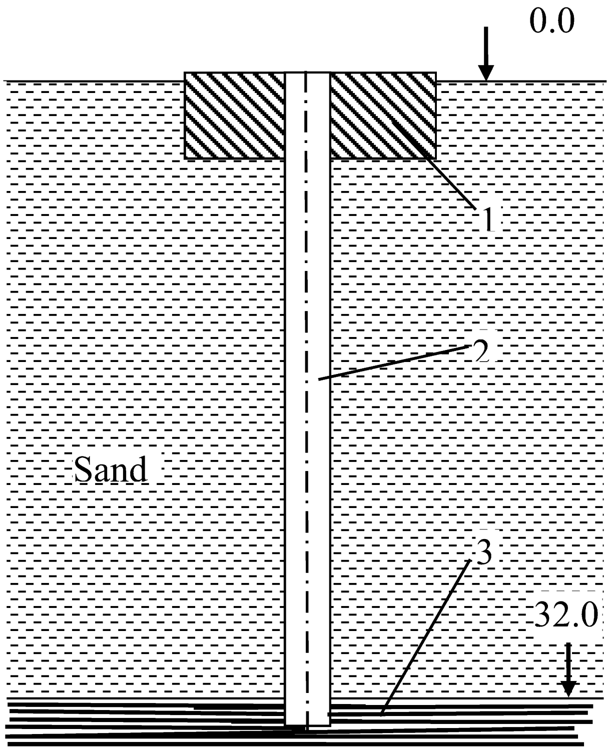


Figure. 1. The construction of the wall in ground: 1 – guiding pit, 2 – lumped clay, 3 – Jurassic clays

To the foundation of the damaged reactor an approaching adit 160 m long was worked. The reinforced concrete under-foundation plate has the dimensions 30 x 30 m in plan and the thickness of 2.5 m. The excavation of ground of the under-foundation space was carried out by by stopes of 1.5 m wide. To locate concrete pumps 2 buildings were constructed of foundation blocks sheathed with lead sheets. After completion of placement of concrete the filling up grouting of possible hollows was carried out by contact under the foundation bottom. All works at the plate were completed in 25 days.

The works were carried out 24 hours a day in 4 shifts. An engineering preparation included additionally an obligatory carrying out a radiation reconnaissance and preliminary radioactive decontamination works in all objects. All protection geotechnical measures including an issue of design documentation, quality control and the delivery of works were carried out in 5.5 months.

## 4. LESSONS OF CHERNOBYL

By the results of an analysis of the geotechnical works carried out promptly (under conditions of environment strongly contaminated by the radiation) the following can be said.

In Chernobyl an accident occurred, which was heavier than that "designed" one, for which the reactor construction of this station was rated. Serious violations of the reactor operating conditions and such consequences as an explosion in the active zone and combustion of graphite were not taken into attention for a single reason - owing to their little probability. The protection on occasion of such an accident was not provided by the project, therefore the disaster implied a considerable radioactive contamination of vast territories and required evacuation of hundreds thousands of people.

One of the most important lessons of Chernobyl lies in the fact that for any reactor in an NPS it is necessary to take into account the heaviest, "over-design" emergency events. When analyzing such situations it is necessary to assume that "everything is possible", admitting the occurrence of the most unbelievable failures of the equipment, disturbances in operation and errors of the personnel (including also the possibility of committing an act of terrorism).

Therefore for each NPS on any geological base obviously the question must be studied: "What will happen, if the reactor falls under similar or even heavier conditions than those, which have led to the Chernobyl disaster?" This will enable one already at the designing stage to evaluate its possible radioactive consequences under specific hydro-geological conditions and compare them with admissible ones. And hence - to prepare beforehand and take necessary measures to protect the population and the environment (Fig.2).

In the International Scale of classifying the gravity of accidents at NPS developed by the IAEA Committee 3 large accidents of reactors are considered as examples: in Great Britain (Windscale, 1979), in the USA (Three-Mile Island, 1979) and in the USSR (Chernobyl, 1986). The most heavy was the accident at the Chernobyl NPS, it was related to the highest 7-th category (see the Table 1). The accidents of the 7th category are characterized as ones "influencing the health of the population more than one country". Existing facts and the IAEA conclusions impose a high responsibility and require a serious revaluation of existing safety norms in the construction part of NPS and a new approach to the elaboration of the normative documentation. Normative rules, in author's opinion, must envisage obligatory requirements for a before-project substantiation, designing and arranging reliable geotechnical protections.

Possible costs of expenditures for carrying out these works are insignificant (Fig. 3).

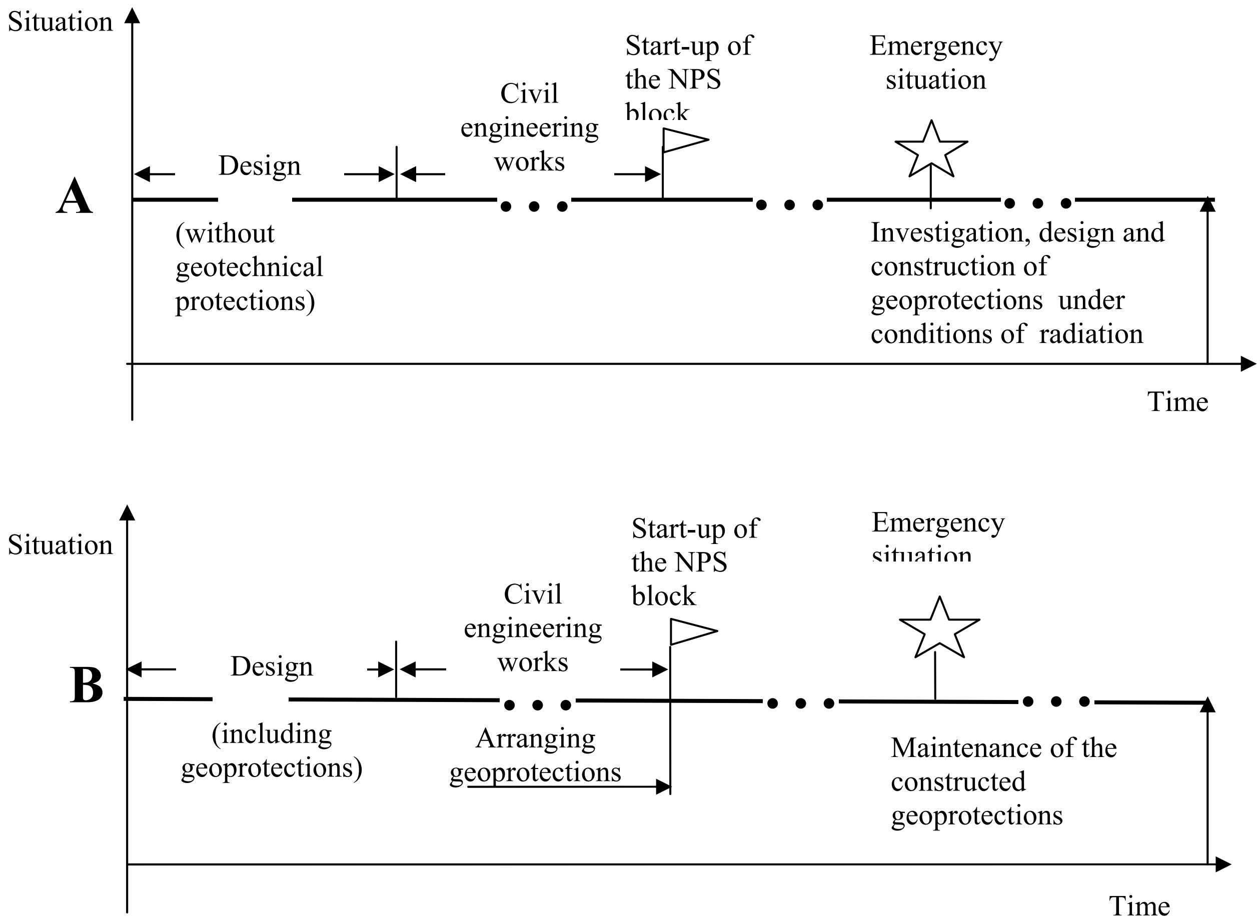


Figure. 2. The diagram of arranging geotechnical protections at nuclear power stations.
A - the existing sequence of constructing NPS (without geotechnical protections)
B - the sequence of constructing NPS proposed by the author

Table 1: The International Scale of accidents at NPS by the Assessment of the IAEA

| Category | Accident | What happened | External consequences and safety measures | Examples |
|---|---|---|---|---|
| 7 | Global accident | Destruction of a reactor and ejection to the environment of a considerable share of radio-active products (more than 1000 TBk in $I^{131}$ ) | Possibility of sharp irradiation strikes and subsequent influence on the health of the population in large territories in more than one country | Chernobyl, SSSR, 1986 |
| 6 | Heavy accident | Considerable destruction of an active zone of a reactor with ejection of radio-active products up to several hundreds TBk in $I^{131}$ | The possibility of influencing the health of the population, the necessity of realizing an anti-accidental plan in a limited territory (partial evacuation) | Windscale, Great Britain, 1957 |
| 5 | Accident with a hazard for environment | Destruction of a part of an active zone with ejection of radio-active products up to tens hundreds TBk in $I^{131}$ | The possibility of certain influence on the health of the population. In some cases partial carrying out anti-accidental measures (iodine prophylactic) | Three-Mile-Island, USA, 1979 |
| 4 | Accident in the limits of the NPS | Partial destruction of an active zone with ejection of radio-active products in the limits of the NPS building | The irradiation of the population with dozes not higher than 1 rem. Measures to protect the population are not needed usually. The possibility of sharp irradiation strikes of the personnel | Saint-Laurent, France, 1980 |

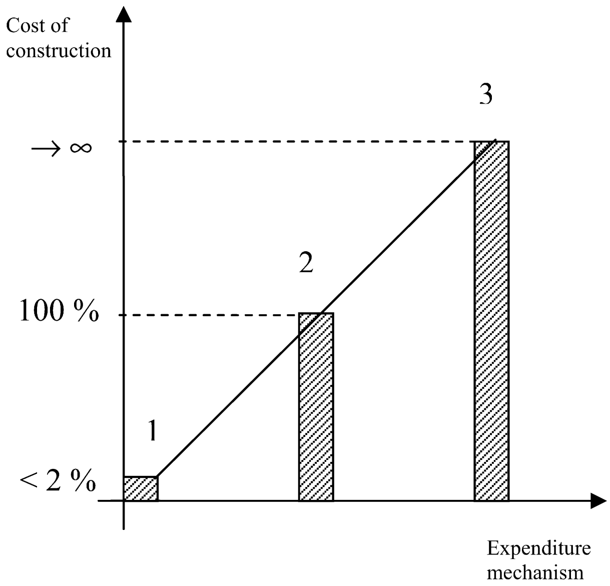


Figure. 3. Possible relationships of the cost of geotechnical protections when constructing NPS

1 - the cost of geotechnical protections

2 - the cost of constructing an NPS

3 - Expenditures for geotechnical protections under emergency conditions

## 5. UNSOLVED QUESTIONS

However many indefinite things remain up to now. In particular, when arranging geotechnical protections to struggle against contaminated underground waters, there are no unique answers for the questions:

1. Which contour of a geotechnical protection is the optimum in plan? (closed, half-closed, solid or with remaining windows, with or without drainage etc.).
2. Which is preferable: a solid "wall in ground" or a grouted screen combined with a drainage system? In which cases?
3. Drainage system. Which is the depth and diameter of wells and which is the step between wells? Where to pump out (to convey) contaminated waters? Which protective measures should be applied, if radioactive contaminations fall into water-bearing levels? Which criterion of a dangerous contamination is to be used? Who determines this value and undertakes further actions in controlling the drainage system in a whole?
4. At which distance from the NPS the protective geotechnical arrangement should be designed and realized and which specific conditions should be taken into account?
5. How to distribute the geotechnical protections and just which of them are the most expedient under specific engineering- geological and hydro-geological conditions?

Similar and many other questions arise also when designing and constructing geotechnical protections for the purpose of struggling against contamination of surface run-offs.

## 6. PROPOSITIONS AND RECOMMENDATIONS

1. It is advisable to note a high urgency of the problem of localizing contaminated underground and surface waters and the necessity of solving the task of arranging geotechnical protections at the objects of nuclear power.
2. For the simplification and solution of the problem it is possible to divide the theme of the localization of contaminated waters into two parts:
   - Geotechnical protections of underground waters;
   - The struggle against contaminated surface run-off.
3. The geotechnical protection of underground waters can be in turn represented as:
   - General methods of struggle in regions of rivers, lakes, ponds, seas, reservoirs and other water areas;
   - Arranging protective systems in a region of the main centre of accumulation and concentration of contaminated underground waters (in the territory of a nuclear power station).
4. The greatest hazard of contamination of the environment, including underground waters, is in the region of the site of a nuclear power station. Therefore it would be expedient to begin the works for investigation and preparation of the basis for creating normative documents from geotechnical structures at NPS.
5. To ask the Leaders and Organizers of the 16-ICSMGE Conference Osaka-2005 to consider the possibility of setting up a work group (with a participation of the Russian side), which would be able not only to coordinate scientific-technical developments in the direction of preparing normative documentation, but also to formulate the Program for elaborating unified methods for rehabilitation of potentially-contaminated underground water massives and special-purpose tasks of this important geotechnical direction.

## 7. CONCLUSIONS

1. An advance in the problems of the safety of nuclear power objects is possible only with organizing a collective approach, which envelops and takes into account all consequences of the disasters occurred known up to now. Measures for localization of contaminated underground and surface waters have a great importance for the life of the society and environment.
2. In a case of a large accident at a nuclear power station the geography of the propagation of the radiation contamination is unpredictable and is defined primarily by the direction and the strength of motion of prevailing winds.
3. The problems of arranging geotechnical protections discovered when eliminating consequences of the accident at the Chernobyl NPS showed that the solution of the questions considered is a long-term problem of an unprecedented complexity, which can be successively solved only by way of uniting the efforts of the international association.
4. The concentration of efforts in the development and subsequent introduction into construction of obligatory and recommended normative documents, regulating the erection of geotechnical protections for struggling against radiation-contaminated underground and surface waters, acquires particular importance.

In author's opinion, a considerable role in this area could be represented by the Russian part with the support of the international direction