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INTERNATIONAL ATOMIC ENERGY AGENCY

END OF MISSION REPORT

ON

"SEISMIC SAFETY REVIEW MISSION FOR BELENE NPP SITE"

by

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(BUL/9/012-31)

SITE AND SEISMIC SAFETY OF NUCLEAR POWER PLANTS

Division of Technical Co-operation Programmes
DEPARTMENT OF TECHNICAL CO-OPERATION

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FINAL REPORT

SITE AND SEISMIC SAFETY OF NPPs

SEISMIC SAFETY REVIEW MISSION ON DESIGN BASIS EARTHQUAKE AT BELENE NPP SITE

ORGANIZED BY
THE INTERNATIONAL ATOMIC ENERGY AGENCY

REPORT TO
THE GOVERNMENT OF BULGARIA

Sofia, Bulgaria
3 - 7 July 1995

SITE SAFETY REVIEW MISSION

UNDER TC PROJECT (BUL/9/012)
DIVISION OF TECHNICAL CO-OPERATION PROGRAMMES

INTERNATIONAL ATOMIC ENERGY AGENCY

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CONTENTS

1. INTRODUCTION

Abstract:

Upon the invitation of the Bulgarian government through the Committee for the Peaceful Uses of Atomic Energy and within the framework of the implementation of the Technical Cooperation project BUL/9/012 related to site and seismic safety of NPPs, a mission visited Sofia 3 - 7 July 1995. The review team comprised three outside experts, Messrs. B. Mohammadioun (France), L. Serva (Italy), H.R. Schneider (Switzerland) and one staff member, A. Gürpinar (NENS).

The mission constituted a follow-up of the interim review of subjects related to tectonic stability and seismic hazard characterization of the site which was performed in September 1993.

The main objective of the mission was the final review of the subjects already reviewed in September 1993 as well as issues related to geotechnical engineering and foundation safety. An interim review of the latter was conducted in 1991.

The main terms of reference of the present mission was to verify the implementation of the recommendations of the Site Safety Review Mission of June 1990.

This document gives findings on geology - tectonics, seismology and foundation safety. In the end conclusion and recommendations of the mission are presented.

2. CONDUCT OF THE MISSION

The mission was conducted on the basis of technical reports prepared by Bulgarian specialists and extensive discussions during the meetings. English summaries of these reports were made available to the IAEA prior to the mission which, in turn, were transmitted to the experts. No site visits or other field excursion was performed.

The Mission Programme and the List of Participants are given in Annexes 1 and 2 respectively.

3. TECHNICAL SESSION FINDINGS

3.1 GEOLOGY AND SEISMOTECTONICS

A Report titled: "Investigations and activities for increasing the NPP "BELENE" SITE SAFETY - Volume A - SEISMIC SAFETY (Abstract) Sofia, December 1993", was reviewed.

It contains neotectonic and geophysical data, mainly concerning the Moesian platform, and a mathematical model for the assessment of the seismic hazard at the Belene site from the recognized main seismic zones (see seismology chapter).

A significant effort was made to clarify the potential presence and capability of some tectonic structures (such the ISKAR fault) present in the Moesian Platform. In particular, most recent measurements in this area were performed through the analysis of the attitude of two "Villafranchian surfaces and 6 Quaternary terraces. 1600 geological and geomorphological profiles were performed across these structures and checked with the analysis of 300 boreholes.

The data demonstrated that none of these faults show evidence of movement after the Vlashka orogenic phase of Plio-lower Quaternary age. Because of this, these structures cannot be considered capable.

It is important to point out that in the chapter regarding neotectonics, some values of uplifting and subsidence, in various sectors of the Moesian platform, are given. These values are not well constrained in terms of amount and age, therefore cannot be used for the definition of the tectonic rate of deformation in the Moesian platform. Because of this, a detailed recommendation has been given (see point 4.2 (2) 1). A magnitude 5 earthquake, considered to occur at 5 km from Belene site, however is considered reasonable to take into account the uncertainties of these values in the near region of Belene site.

It is also important to point out that the chapter dealing with geophysics is difficult to read because a significant number of maps are missing. Some of these maps (scale 1:1 000 000) were presented during the meetings. In particular they show gravity and heat flow data and an interpretation of the anomalies of the macroseismic field of past earthquakes in terms of anomalies in the crustal structures.

However, there is little coordination between the work performed by the geophysicists and the neotectonists. The recommendation given in point 4.2 (2) 1, addresses this issue. The lack of coordination between the different areas of expertise (Neotectonics, geophysics and seismicity) is also evident from the content of seismic hazard chapter of the presented report and from the results of the meetings.

The seismic hazard analysis was performed in fact not taking fully into account the recommendations of the previous IAEA mission. Because of this a similar recommendation is given in point 4.2 (1).

3.2 SEISMOLOGY

Seismological investigations on the BELENE NPP site are based on the Bulgarian Seismicity catalogue, covering the period 375 - 1990. This catalogue, based on all available sources provides macroseismic and instrumental parameters in standard and uniform manner. The catalogue includes 812 independent events (411 shallow, and 401 intermediate depth). The accuracy of earthquake parameters are weak for events prior to 1900 and for the period 1901 - 1970 this accuracy has been improved considerably. The intensity evaluation are consistently reported in the MSK scale. For historical seismicity, the magnitude values are calculated from a relationship linking the Ms to epicentral intensity Io (This relationship, however, has not been provided in the report). In the light of these data and according to the geographic earthquake distribution the following seismic zones are delineated:

- Gorna orjahovitza zone situated at a distance 50 - 60 km from NPPB site (1913, M=7, Io=IX);
- Sofia zone at a distance of 180 km from the site (1641, M=6,9, Io=IX);
- Kresna zone situated at 250 km (1904, M=7,8, Io=X);
- Shabla zone at 320 km from the site (1444, M=7,5, Io=X, 1901, M=7,2, Io=X);
- Cimpulung and Vrancea zone at 230 km from the site (deep foci earthquakes, 1802, 1940, 1977, 1986, 1990, Io=IX, M=7,4);
- local seismicity in a radius of 30 km from the site, characterized by a low seismic activity during 1976 - 1991 by the existent monitoring network, only five microearthquakes of magnitude M ≤ 2,5 have been recorded during this period. These earthquakes are localized at a distance ≥ 20 km from NPP site.

Aside from the afore mentioned sources, some other zones have been analyzed separately and notably: the region of Dulovo (1892, M=7,0, Io=VII - VIII). With intensity at the site IBEL = VI. It has been mentioned during the discussion that this earthquake could have a deeper focus (in low velocity layer) and it must be treated separately.

The maximum expected earthquake magnitudes have been assigned for some zones. These values are equal to the observed ones increased by 0,3 - 0,5 including a safety margin. These values have been checked with the frequency-magnitude relation obtained for all source zones as well as with empirical relationships relating the magnitude to the length of fault or fault rupture.

Seismic hazard analysis has been carried out using both deterministic and probabilistic approach. This assessment is based on two step calculations:

(1) Determination of PGA resulting from each source zone, using the attenuation relationships established on the basis of European strong motion records (Italian, Yugoslavian etc.). The case of Vrancea earthquakes has been treated separately.

(2) Determination of spectral shape adapted to the soil geological condition of NPPB. Response spectrum representing Vrancea source zone has been calculated from recorded motions in Romania and Bulgaria.

However, the design parameters representative of other sample and particularly local moderate magnitude floating earthquake (M=5) are not clarified.

The methodology that has been used in probabilistic analysis is a classical one and is well presented in the report. However, the sensitivity studies that have been carried out particularly in the delimitation of source zones as well as in domain of different attenuation relationships must be included in the final report. The procedure used in deterministic approach is ill presented and the strong motion data base that have been used is not clearly identified. The intensity attenuation relationships have been established using some major historical earthquakes for Gorna Orjahovitze zone. These relationships have been used in the determination of the PGA values on the NPPB using Russian intensity - acceleration relationships (MEDVEDEV). In this matter international practice indicates not to use such questionable correlations which attempt to link the macroseismic intensity to a single parameter of ground motion and very often PGA. The damaging effects of an earthquake is due to all characteristics of strong ground motion such as duration, frequency content etc..

Finally the methodology used in the determination of ground motion representative of the floating earthquakes (M=5, h=5, d=5) is totally missing in the report. During the presentation, it has been pointed out that his type of equarthquakes are not important for the safety of NPPB. It is important to highlight that in compliance with IAEA guide the ground motion levels include the effects of all sources including floating earthquakes, independent of design procedures and the type of structures.

3.3 FOUNDATION SAFETY

3.3.1 Introduction

Based on the conclusions of the last Site Safety Review Mission, October 7 - 11, 1991, the following aspects were to be addressed in more detailed investigations to assess and verify the foundation safety of buildings and structures important to the overall safety of the Belene NPP

(a) Liquefaction potential, in particular of the water supply channels

(b) Dynamic soil-structure-interaction of:

- Reactor buildings (units 1-2) taking into account the lower strength interfaces (e.g. hydro-insulation sheet) between the concrete slab and the foundation material
- Diesel generator building: pile foundation

(c) Long-term behavior and effectiveness of the diaphragm walls enclosing the reactor units 1-2.

For this mission the following summary reports related to the foundation safety have been provided by the Bulgarian Authorities:

- Assessment of the seismic safety of the industrial water supply channels and the related facilities: Liquefaction potential evaluation of saturated sand deposits (synthesis report), Part II.1.1, Oct. 93, Sofia by Energoproect.

- Physical-mechanical characteristics of the gravel fills below and around reactor buildings and of the concrete - hydroinsulation and concrete - compacted gravel fill interfaces (Synthesis report), Part II.1.3.1, Feb. 95, Sofia, by Energoproect.

- Assessment of the reactor building foundation safety in respect to shear resistance of the concrete-hydroinsulation and concrete-compacted gravel fill interfaces at earthquake loads. (Synthesis report) Part II.1.3.2, Feb. 95, Sofia, by Energoproect.

- Seismic safety assessment of pile foundations of diesel generator building. Part II.1.4., Feb. 95, Sofia, by Energoproect. (The content of this report was exactly identical to part II.1.3.2., apparently due to a mistake in the copying process).

- Assessment of the long-term behavior of the cut-off (diaphragm) walls of units 1 and 2 and their influence on the foundation of the main reactor buildings on the site (Synthesis report) Part II.1.2., Sept. 93, Sofia, by Energoproect.

- Investigations and activities for increasing of the NPP "Belene" site safety (Summary), Dec. 93, Sofia, by Geophysical Institute Bulgarian Academy of Sciences, ("Dynamic soil characteristics", pages 144-172).

- Prediction of foundation slab tilt of the reactor building, March 95, Sofia, received during the mission from Mr. T. Petkov to supplement information on the behavior of the reactor foundation.

The reports summarize the investigations and results available (mainly as raw data, or in Bulgarian) during the last mission in 1991. Additional investigations (field or laboratory) have not been carried out since then.
The following statements and conclusions are mainly based on the summary reports. Additional discussions and explanations with the Bulgarian experts complemented that information and will also be incorporated in this review.

3.3.2 Liquefaction Potential

(a) Conclusions and recommendations of last mission (1991)

- Liquefaction is probable to occur for $a_{max} \geq 0.2g$.
- Results and investigations are to be documented in a report written in English.
- The areas (plan view) as well as the layers (cross sections) indicating liquefaction potential should be shown in the final report.
- Reliable values of a_{max} will be provided by the experts in seismology.
- Recommendations for remedial actions (in case of expected liquefaction) should be elaborated.

(b) Technical findings of this mission (1995)

- The "fine-grained and silty sand", with thicknesses up to 6.3 m, have been found to be susceptible to liquefaction under dynamic excitation. This loosely deposited layer is located below the natural groundwater level.

- The natural groundwater level, exerting a strong influence on the liquefaction potential, generally lies somewhat below the ground surface. it communicates hydraulically with the water level in the river Danube. In periods of high Danube water levels the groundwater level at the NPP-site can reach the ground surface.

- Detailed liquefaction analyses show:

a_{max}	**Liquefaction probable down to ...**
≤ 0.15 g	no liquefaction
0.16 g	4.5 m
0.17 g	8.0 m
0.18 g	11.5 m
0.20 g	17.0 m

This table is valid for the case of the groundwater level reaching the soil surface. Furthermore it applies to layers of saturated fine sands.

In the case of a natural groundwater level (not reaching the ground surface), liquefaction is not expected to occur for $a_{max} \leq 0.2$ g according to the report presented.

- Values of a_{max} for assessing the liquefaction potential

The valid value of ^{ama} is not known yet and will be provided by the experts of seismology Discussions so far do however indicate a lower limit of an applicable $a_{max} \geq 0.24$ g to be used for liquefaction studies.

- Emergency cooling system in case of damage to the water supply channels

As reported during the discussions, an independently functioning cooling system is designed. In case of any damage to the channel structures this planned water reservoirs would take over the function of supplying cooling water to the reactors. This emergency system would be maintained to be ready to use at any time and should apparently be able to supply cooling water as long as needed (e.g. until the channels are repaired).

3.3.3 Dynamic soil-structure-interaction

(a) Conclusions and recommendations of last mission (1991)

As soon as seismic input data (seismic loading, G = f (strains), D = f (strains), etc.) become available, dynamic soil-structure interaction analyses are to be carried out for the reactor buildings (slab foundation) as well as the Diesel generator buildings (pile foundation). The following factors need to be considered:

- 3-D effects, if the 2-D computations indicate this to be necessary.
- Interface slip or failure between the hydro-insulation sheet and foundation materials, under static and dynamic loads.
- Model boundaries which realistically simulate field behavior.
- Allowable deformation, tilt to compare with computational results.
- Simple calculation models (e.g. rough hand calculation) should be used to check the validity of the complex FEM-analyses.

(b) Technical findings of this mission (1995)

- The required dynamic soil characteristics G = f (strain) and D = F (strain) are now available for 4 soil layers for the Kozloduy site. Due to the similarity of the subsoil conditions of Kozloduy and Belene, those values as determined in the IZIIS laboratory, Skopje can be applied to Belene at this stage.
- The soil-structure-interaction analyses performed so far used the FEM-Programs FLUSH and STARDYNE. The changes in the shear modulus G and damping D with increasing strains have not been considered. In addition, the reports available are difficult to follow, since they only seem to cover parts of the more comprehensive reports in bulgarian. The content of the report on the pile foundation of the Diesel generator building has not at all been available to the IAEA-experts.
  In any case, the soil-structure-interaction-analyses are still far from being a solid basis for judging the safety and performance of the foundations. Considerable more work needs to be done in analysis, interpretation, summarizing and documenting the results.
- The properties of the plastic hydro-insulation are available and reported in final form.

3.3.4. Long-term behavior and effectiveness of the diaphram walls enclosing the reactor units 1-2

(a) Conclusions and recommendations of last mission (1991)

Careful studies have verified the effectiveness of both types of the used diaphram walls to safely withstand the expected loading conditions. This study is completed (in 1991) and needs only to be reported in a final form.

(b) Technical findings of this mission (1995)

A comprehensive written report summarizing the results already available during the last mission, has been presented as requested by IAEA during the last mission, thus fulfilling the requirements of this investigation topic, after the minor corrections suggested have been done.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 GENERAL

(1) The purpose of the present mission was to review the seismic safety of the Belene NPP site as well as aspects related to geotechnical engineering and foundation safety. This constitutes the follow up of the Site Safety Review Mission of June 1990. An interim review of the seismotectonics and seismic hazard evaluation was made in September 1993. The final review of aspects related to other site related phenomena was performed in October 1994.

(2) For geotechnical engineering and foundation safety aspects this was the second review since June 1990. An interim review was conducted in October 1991. In general, satisfactory topical reports have been prepared corresponding to all the recommendations in this area. In cases where sufficient data from Belene were lacking, data from similar deposits in the Kozloduy area have been used. It is intended to collect specific data to Belene in the future in order to confirm the results of such studies. The mission agrees with this approach. Specific recommendations related to geotechnical engineering and foundation safety are given in Section 4.4..

(3) Although considerable synthesis effort was made and some specific tasks were performed in relation to the preparation of the seismotectonics and seismic hazard evaluation report, a part general recommendations (3-5) as given by the IAEA mission of September 1993 are still valid for the future revision of this document. Specific recommendations regarding this subject are given in Sections 4.2. (geology) and 4.3 (seismology).

(4) The Site Safety Review Mission of June 1990 had recommended, inter alia, the deployment of a local seismic network in the Belene near region. On the request of the Bulgarian authorities the IAEA contributed financially to the procurement of the instruments of this network. Unfortunately this network is still not operable and valuable data (especially in relation to near field earthquakes) cannot be made available. It is strongly recommended to make all efforts to put this network in operation in the nearest future.

(5) The mission confirms the conclusion of the result of June 1990 review that ffom the seismotectonic and seismic hazard point of view, there are no characteristics of the site to preclude it from being used as a suitable site for a NPP. Implementation of the recommendation of this report will mainly assist to complement the work already performed and demonstrate in a comprehensive way the seismic safety of the site with respect to the proposed design basis parameters.

(6) It is recommended to have an independent review of the results of the implementation of the recommendations contained in this report.

4.2. GEOLOGY AND SEISMOTECTONICS

(1) The construction of a well defined tectonic framework is recommended for the construction of the seismotectonic model to be used for the seismic hazard assessment at Belene site.

According to the IAEA 50-SG-S1 (Rev. 1) the model should be more detailed going from regional to near regional and site vicinity scales. Type of studies and investigations and geographical scales to be used are well defined in this document.

The seismotectonic model should define the tectonic structures (active and/or capable) and zones of diffuse seismicity (if present) significant for the site from the seismotectonic point of view.

The definition of the tectonic structures should include:

(a) geometry
(b) style and rate of deformation
(c) rheology of the material involved in the deformation and/or dislocation.

These data could be essential for the estimation of the location of the related maximum potential earthquakes.

(2) Special emphasis should be given to the tectonic structures located in the:

- so-called Moesian platform
- area between the platform and the Balkanides (pre-Balkanides)

In this report, it is important to point out that the seismotectonic structures should be defined with a consistent database of neotectonics, geophysics and seismicity data. These data should address the items listed in point a, b and c (see point 1).

(3) Moesian platform

At the present stage the problem of the presence of a possible capable structure along the ISKAR river has been resolved. An acceptable database was reported to demonstrate that this fault cannot be considered capable after the Vlashka orogenic phase (Plio-lower Quaternary age).

Geophysical and neotectonic data pointed out the preference of other potential capable faults in the Moesian platform. A reliable database was provided to prove that some of these faults (see Chapters 1 and 2 of the English report) have the same behavior of the ISKAR fault. However there are not enough information to understand if all the significant faults present in the Moesian platform have been studied in the same detail. With the available information it is not possible in fact to know if all the tectonic structures affecting the Neogene sequence identified by the geophysical data, have been studied in detail with this issue. Therefore more coordination is required between geophysical and neotectonic data, in the Bulgarian and Romanian territories.

Two large geological features are well recognized in the Moesian platform. These are the Lom depression and the North Bulgarian swell. However a complete understanding of these features is still lacking. For example there are no data for a reasonable estimation of the geometry, age, type and rate of deformation. Some data have been provided regarding the total uplifting and subsidence. However, time intervals of these movements are still not well constrained. In this regard, geodetic data should be compatible with the geological slip-rate. If not, a reasonable explanation should be given. The same can be stated for the near region of Belene NPP, although it is reasonable to infer that the choice of a floating earthquake of M=5 cover these uncertainties.

Of particular interest for Belene site, is the so-called North Bulgarian swell. A clear definition of this feature is required because it has a great influence on the possible location of an earthquake of Dulovo, 1892 type. At this stage of the work there are no data to preclude a similar event located at the western border of the swell (more than 60 km east of Belene).

Area between the Moesian platform and the Balkanides (pre-Balkanides)

In this area an important neotectonic feature was recognized (the so-called Gorna-Orjahovitza basin). However, the geometry and age, style and amount of deformation is still not well defined. It is therefore recommended to get these data as soon as possible for the location and the possible assessment of the maximum potential earthquake to be composed with the one consistent with this zone on the basis of seismic data.

Furthermore it is recommended also to clarify if other features like the one now described are present in this area. If yes, they should be treated as seismogenic structures and their location and maximum potential earthquake established.

4.3. SEISMOLOGY

The mission reviewed a large body of scientific documents dealing with geology, geophysics and seismology as well as seismic hazard level on NPPB. On the basis of these information, further investigations and clarifications are required in order to prepare a final report which complies with the recommendations of IAEA 50-SG-S, (Rev. 1):

1. The first indispensable step of seismic hazard analysis is to establish a regional seismotectonic model. A direct product of this model is seismogenic structures and zones of diffuse seismicity.

2. Determination of the a_{max} of each source zone must be directly related to the aforementioned seismotectonic model.

3. A special study must be carried out on the 1892 Dulovo earthquake in order to clarify if it belongs to crustal activities or a deeper event.

4. The same data base on geology and seismology should be used in seismic hazard level determination either in deterministic or prohabilistic approach. Sensitivity studies that has been carried out in both methodologies must be clearly reported in the final report. The attenuation relationships used for the evaluation of PGA exhibit very significant dispersion. These should be checked using relationships based on new strong motion data collected in Europe or other similar tectonic environments.

5. It has been mentioned in the previous mission recommendations that in the determination of response spectra to avoid two step calculations, namely calculating the shape of the response spectrum on the basis of a strong motion population and to anchor to a given value of PGA, which is derived from an attenuation relationship established in the framework of another database. It is recommended to calculate directly the ordinate of response spectrum, for different values of damping, knowing magnitude and distance and soil conditions.

6. Response spectrum corresponding for the floating earthquake (M=5, R=5), must be determined, using the strong motion recorded in the near field of recent earthquakes. The shape and level of floating earthquake should not be influenced by structural behavior considerations.

4.4 FOUNDATION SAFETY

The substantial amount of field investigations, laboratory tests as well as computations performed have been documented in summary reports written in English.

Based on the information in the reports, the presentations of Bulgarian experts and subsequent discussions during the advisory meetings, the conclusions related to the foundation safety of the NPP Belene are:

4.4.1. Conclusions

(a) <u>Liquefaction potential</u>

- Depending on the depth to the actual groundwater level, liquefaction of the saturated layers of fine sands is expected to be initiated from $a_{max} \geq 0.15$ to 0.20 g.

- The exact value of a_{max} to be used for liquefaction studies is not yet known and will be provided by the experts of seismology. Discussions so far indicate a lower limit of $a_{max} \geq 0.24$ g.

- An emergency cooling water system using water reservoirs has been designed corresponding to SL2 as a safety related structure. It will supply the required cooling water in case of any damage to the water supply channels (e.g. by soil liquefaction).

(b) Dynamic soil-structure-interaction

The soil-structure-interaction analyses are still in an early stage. Realistic computations taking into account the latest information available concerning G=f (strain) and D=f (strain) as well as considering the aspects recommended in 1991, have not been carried out.

The safety of the foundations and its expected performance can therefore not be judged reliably from the results available today.

The required dynamic input parameters for FEM - computations are available:

- static properties of the hydro-insulation sheets. These values can also be used for dynamic analyses with a certain level of conservatism.

- G=f (strain) and D=f (strain) can be taken from the investigations done for similar soils at Kozloduy.

(c) Long-term behavior and effectiveness of the diaphram walls

This task has been completed, after minor corrections recommended in the next chapter have been completed.

4.4.2. Recommendations

Based on the conclusions and the findings during the technical sessions, the recommendations for further actions are:

(a) Liquefaction potential

- The assessment of liquefaction potential should be checked in the light of new conclusions reached during this meeting. In particular the following factors influencing liquefaction need to be taken into account:

  - a_{max} according to the conclusions reached in the field of seismology
  - $a_{des} = a_{max}/2$ may be used to assess the liquefaction potential.

- In addition it is recommended to prepare maps (plan view and cross sections) to show the zones of liquefaction in a condensed and final form:

  For free field situations:
  - for $a_{max} = 0.15$ g
  - for $a_{max} = 0.20$ g
  - for $a_{max} = 0.25$ g

In addition the influence of structures could also be discussed or shown, if this proves to be useful.

- Remedial action plans should be prepared in order to be ready to efficiently repair any future damage occurring to the channel structures as a result of liquefaction.

(b) Dynamic soil-structure-interaction

The recommendation given in 1991 still applies and should be fulfilled.

It is recommended to carry out the following tasks:

Both foundation types: Comment on the limitations of the subsoil model adopted as well as on the FEM-Programs used.

- The definitions of the factors of safety need to be clearly given. In addition allowable factors of safety are to be determined in correspondence with the required safety levels.
- All the input parameters, results, interpretations and conclusions with respect to the FEM-analyses need to be reported in a concise and comprehensive manner.

Pile foundation: • Investigate 3 cases:

- No soil between the piles (G=0), extreme case.
- Soil between the piles with $G=G_{max}$ extreme case.
- Soil between the piles with G=f (strain) and D=f (strain), realistic case.

(c) Long-term behavior and effectiveness of the dicphregu walls

- Table 5, page 9, shows misleading typing errors with respect to the order of magnitude of the compression strength and needs correction.
- The fairly high acceptable hydraulic gradients, as compared to the investigations cited in the report, could give rise to discussions. They could be left out from the report without losing any substance.

Outside the earlier outlined scope of the above report, but concerning the topic, it is further suggested to perform the following tasks which would add to the foundation safety:

- A systematic evaluation of the entire groundwater lowering or drainage system should be performed to verify the inerplay of different components. This involves answers to questions such as:

  - What is the groundwater level at which dewatering inside the diaphram walls should start?

  - Where is the pumping water to be discarded?

  - Are the pumps to be driven by electricity or by any other means?

  - Are the pumps activated automatically or manually?

  - What happens if the pumping system does not function in case of an emergency?

In addition it would be extremely useful to actively prove the effectiveness of the diaphram walls by the following simple in situ checks:

- Perform pumping tests inside the diaphram walls.

- Install piezometers to record the groundwater level inside the diaphram wall. The permanent use of the piezometer would in addition allow to monitor and verify the functioning of the planned drainage system.

From the discussions, it is understood that most of these questions have been answered satisfactorily.

ANNEX 1

MISSION PROGRAMME

2 July 1995	-	Arrival of experts
3 July 1995	-	Planning meeting Working Group meetings
4 - 5 July 1995	-	Working Group meetings
6 July 1995	-	Report preparation.
7 July 1995	-	Exit meeting

ANNEX 2

LIST OF PARTICIPANTS

Mr. Y. YANEV, President CPUAE

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