터널과 지하공간, 한국암반역학회
Vol. 2, 1992, pp. 95~101

"Rock cavern stadium". A research program related to public use of Underground caverns

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ABSTRACT

Norwegian technology related to preinvestigations, planning, design and construction of large underground caverns is wellknown worldwide. However, so far this technology is only slightly verified through scientific reports and documentation.

The "Rock cavern stadium" research program is an interdisciplinary program related to the ongoing building and future use of Gjøvik Olympic Subsite which is the largest cavern in the world for public purposes with a span of 61 meters and a height of 25 meters.

The estimated budget for this program is about USD 4 million which is made possible through grants from The Royal Norwegian Council for Scientific and Industrial Research as well as through contributions from Norwegian and Swedish companies that are participating. The program is carried out in collaboration with The Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology, The Norwegian Geotechnical Institute and The Eastern Norway Research Center.

The research program will continue until the end of 1994 to ensure that input comes from a full period of use in this stadium with different activities like exhibitions, conferences, concerts etc being included as verification through full-scale measurements and observations.

The research program has five subtasks. Three of these are related to subjects like Energy consumption, HVAC installations, Fire safety design, Engineering geology and Rock mechanics, Environmental aspects.

The fourth subtask is concerned with the collection of basic data, results and experience from these three subtasks to provide a basis for national Norwegian guidelines related to this inter-

* 1992年 6月 接受.

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disciplinary subject area. The guidelines will first be presented as a manual for planning and engineering purposes.

The realization of this research program is a unique opportunity to enhance the expertise that has been acquired from this cavern stadium. By involving research in this extraordinary project from the excavation and building phase to its subsequent use, this will give the participants know-how and expertise which is very much in demand internationally.

The coordination of the international activities between the participants as well as preparation of participations and presentations in international conferences and symposium are included in the fifth task of this national research program.

Introduction

The rock cavern stadium is under construction at Gjøvik, 110 kilometers north of Oslo, the capital of Norway. This is the largest cavern in the world that is built for public purposes. The leading Norwegian companies in preinvestigations, construction and design are involved in this project which is likely to be one of the most attractive sports arenas in the Winter Olympic Games in 1994. The "Rock stadium" research program at the Olympic subsite in Gjøvik has run from May 1991 and will finish at the end of 1994. The program is realized through grants from The Royal Norwegian Council for Industrial and Scientific Research as well as through contributions from Norwegian and Swedish companies that are involved. The interdisciplinary research program is made possible through complementary collaboration between The Norwegian Geotechnical Institute(NGI), the Foundation for Scientific and Industrial Research at the Norwegian Institute of Technology(SINTEF) and The Eastern Norway Research Center.

Organization and financial basis

The research program is organized with a project manager and a steering committee with representatives from the contractors, the financial contributors, and the research organizations participating. A project committee and the subtask leaders coordinate the activities and the relations between the five different subtasks. To ensure that results from recent research and development are included in the ongoing construction and design, the contractors will receive information such as stress measurements, geological mapping and rock-mass classification, crosshole seismic tomography, georadar, core index testing, numerical modelling, vibration monitoring and results from stress and deformation monitoring.

The program has an estimated budget of NOK 25 mill(Norwegian kroner). About 45 % of this total is paid to the owner of the rock stadium to ensure that the plant can be used for research and development purposes throughout the period of this research program.

Subtasks

The research program is split into five different subtasks;

Subtask 1 : Energy consumption, HVAC installations, Fire and Safety design

Subtask 2 : Engineering geology and Rock mechanics

Subtask 3 : Environmental aspects

Subtask 4 : Guidelines, codes and regulations

Subtask 5 : International marketing of products and technology related to preinvestigations, design, construction and use of underground caverns

Subtask 1 : Ventilation, energy, fire and safety

Ventilation

The actual rock stadium is designed with a public area with a capacity of 5800 occupants. The ventilation of this public area is designed with a ventilation-by-displacement system as an alternative to ventilation-by-complete-mixing. This way of room ventilation implies that air is supplied through inlets located in the lower region of the area, and extracted through a distributed extraction system near the ceiling. Velocity and temperature distribution in the public area are studied by the use of CFD-simulations, to ensure that the climate and comfort are in accordance with the design criteria.

Energy savings

A computer code for calculations of the individual contributions from the different heat transfer mechanisms to the total heat surface load has been developed. This computer code NRAD enables the user to study the heat exchange in sports arenas with ice surfaces, when different activities or operations like ice-laying, training without spectators etc, occur. This code has been used to predict the energy consumption for the rock stadium. Later these results will be verified by measurements.

In the proceeding work another computer code, FRES, first worked out to study the total energy consumption in buildings from heating, ventilation and lighting. This computer code will be modified to a certain extent so that NRAD can be a subsystem of the FRES computer code.

Fire and safety

Smoke ventilation systems can be designed as a part of the conventional ventilation system. Information about the main parameters describing the fire scenario i.e. estimated smoke production(m^3/s) is needed to do this. Because of the geometry and total air volume, there are scarcely any codes and guidelines for smoke control, restrictions on the of materials etc for public areas like this rock stadium. This is also the reason why discussions about fire and safety were put into focus in early discussions about choosing between the alternatives of underground or daylight establishments.

For fire safety reasons, smoke movement is studied and the design of the smoke control system is optimized both by using calculations with zone-models and numerical computerized fluid dynamics simulations. Situations with a fire occurring either in the public area or in the sports arena are studied. The modelling of the heat release is done with approximate methods with input parameters from full-scale measurements and from standardized laboratory test methods.

Studies of evacuation situations have been carried out for the stadium to estimate the time required to get from the public area to the surrounding safe area. Results and estimates are related to the efficiency of the smoke extraction system.

Subtask 1 : Ongoing activities 1992

Activity-number	Activity
1	Quality control of Energy and HVAC-installations
2	Development and verification of computer codes for energy consumption and thermal storage
4	Fire and Safety

Subtask 2 : Rock engineering and engineering geology

Research work in 1991 has concentrated on recording all data and registrations made throughout the planning and construction phases. Particular attention has been given to the effect of vibrations during the hectic construction period when there were high structural loads because of blasting. A near by digital telecommunication central is monitored specially.

The construction work progressed well, and at the end of 1991 it was 4 months ahead of schedule. This high tempo gave the research group very limited time to evaluate and process the data that hed been acquired.

Nevertheless, the group has taken great care that nothing has been left to chance in the quality control and verification work during this important acquisition phase. The data for the various sub-activities have been consecutively checked to ensure the necessary basis for the decisive processing phase in 1992, which is planned to be completed in 1993.

The most significant results in 1992 are those concerned with the analyses of rock mechanics and the measurements of the rock mechanics which revealed that the deformations were well within the limits that had previously been calculated. This means that the geological investigations and calculations have been quite successful.

This will give the project weight and increase its marketing value when the results are presented internationally. The results will be processed further in 1992-1993 to particularly study the measured displacements in the rock mass, the loads on the rock mass and the instrumented bolts, measured tension in the rock mass, and the relia-

bility of the different mathematical models of varying complexity that were employed. An important aim is to improve the basis for decision-making for consultants in future projects.

A flagship project in 1991 has been the development of a Norwegian radar system that is tailored to "look" into rock formations and detect internal structures such as cracks and identify weakness zones. A prototype of the radar system is now fully developed and will be presented internationally in 1992 at conferences and in journals.

Subtask 2 : Ongoing activities 1992

Activity-number	Activity
5	Rock Mechanics and instrumentation at Gjøvik Rock Stadium
6	Evaluation of Rock Support
7	Engineering Geology
8	Geophysical Measurements
9	Numerical Analysis Non linear behaviour of jointed rock mass
10	Blast Vibration Monitoring
15	PC Based System for Dynamic Monitoring
16	Georadar Development

Subtask 3 : Environment, safety, documentation

During the construction work in the Gjøvik area(urban) there has been a questionnaire survey concerning the effect of information on the local residents, public impression of the construction work on the Gjøvik Olympic Rock Stadium. This data is now prepared for further processing.

A draft method has also been prepared about how people's experience of the "windowless environment" can be compensated for in the practical site design. The method is based on a paper study which includes a review of results from series of interviews with people who have worked/stayed in such underground facilities.

The basic idea of this method is to enhance the spectators' experience of well-being and safety by manipulating the design of underground stadiums. The method is to give architects and designers variables that are known to be important for the experience of well-being and safety underground, and will include guidelines concerning design. The remaining work on this method will be related to the transformation of the theoretical variables into operational scales.

Subtask 3 : Ongoing activities 1992

Activity-number	Activity
11	Information Strategies and Information Problems towards the Neighbourhoos.
14	Risk and Public Debate.

Subtask 4 : Guidelines, codes and regulations.

This subtask was initiated in 1992 and is related to the preparation of guidelines as far as preinvestigations, design, construction and use of underground caverns are concerned. The project plans imply that relevant information from consultants, contractors, suppliers and manufacturers, codes and regulations from abroad, public authorities as well as input from the ongoing research programs, will be combined to work out an updated and fully extended version of the Norwegian Codes and Regulations related to use of underground caverns for public use.

Subtask 5 : International marketing of products and technology related to preinvestigations, design, construction and use of underground caverns

Norwegian companies have been individually exporting konw-how, technology and equipment related to planning, design and construction of underground caverns for many years. The participants in this interdisciplinary research program intend to use the reports and documentation which now will be available as verification of the standards of these products and further use this to enhance such activities in order to obtain a share of the internationál market.

Subtask 5 is included in the research program during early 1992 to mark the results and initiate and coordinate team activities related to the international exposure.

Summary

"Rock cavern stadium" is an interdisciplinary research program related to the ongoing construction and futrue use of the world's largest cavern for public use. The cavern with a span of 61 meters, height of 25 meters and a length of 100 meters will be one of the sites in connection with the Winter Olympic Games in 1994. The research program has an estimated budget of NOK 25 million, and will be carried out in the period from 1991~1994.

Main subjects in this research program are ventilation system design and efficiency, energy savings, fire and safety strategies and design, preinvestigations of rock structures, verifications and control of the shock response of neighbouring installations, as well as the development of guidelines for evacuation procedures and relations between design and public behaviour.

The results and documentation from this program will be used as input to an updated and extended version of the Norwegian Codes and Regulations related to construction design of underground caverns for public use.

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Acknowledgements

This work has been supported by the research program "Rock cavern stadium"; The Royal Norwegian Council for Scientific and Industrial Research, Gjøvik municipality and the following companies; Statkraft, Teledirektoratet, Noteby, Dyno Industrier A /S, Veidekke A/S, Selmer A/S, Fortifikasjon A/S, Statoil Norway, The Foundation of Scientific Research at the Norwegian Institute of Technology(SINTEF), The Norwegian Geotechnical Institute and The Eastern Norway Research Center.