Shielded Modular Above Ground Storage Buildings For Low Level Radioactive Waste

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ABSTRACT

A new generation of storage buildings called Shielded Modular Above Ground Storage Buildings (SMAGS) are being designed by MMM Group to be constructed by Atomic Energy of Canada Ltd. (AECL) to store low-level nuclear waste. These facilities will store wastes that have been sorted and compacted into tagged steel containers. Each building is designed to hold up to 3 to 5 years of waste, depending on waste production levels, and allows for improved waste management and easy retrieval for eventual disposal. The buildings are designed for 50-year life.

INTRODUCTION

Atomic Energy of Canada Limited (AECL) manages the majority of Canada's low-level radioactive waste programs, except for those associated with the power generating stations. AECL stores some of its solid low-level radioactive wastes at its Chalk River Laboratories site (CRL) in Ontario. This waste consists of items such as protective clothing, paper towels, glassware, equipment and building materials that have become contaminated by contact with radioactive materials. They originate from AECL's research activities or from other companies, hospitals or universities.

A new generation of storage buildings called Shielded Modular Above Ground Storage Buildings (SMAGS) are being constructed by AECL. These buildings evolved from the Low Level Storage Buildings (LLSB) used by Ontario Power Generation (OPG). Each building is designed to hold up to 3 to 5 years of waste, depending on waste production levels, and allows for improved waste management and easy retrieval for eventual disposal.

The first of six SMAGS buildings has been in operation since 2008 at Chalk River Laboratories site. The second building is in the early stages of construction. This paper describes the design concept of these SMAGS buildings.

DESIGN CONCEPT

The design of the SMAGS building complies with the National Building Code of Canada [1], National Fire Code of Canada [2] and National Fire Protection Association Code NFPA 801 (2003) Standards for Fire Protection for Facilities Handling Radioactive Materials [3].

The building is not heated or cooled and is designed to withstand inside ambient temperature between-35°C and +40°C.

The SMAGS concept uses prefabricated concrete technology for the walls, columns, beams and roof, thereby maximizing quality and optimizing project schedule through the minimization of field construction activities (Figures 1 and 2). The building's inside dimensions are approximately 46 m long x 29.5 m wide x 6 m inside clear height. It provides interior space of about 8,100 m^3 for storage of waste containers. The building is unheated but contains lighting, ventilation, fire detection and electrical power supply. The objectives when determining key building features were the provision of secure confinement, control of packaged radioactive waste materials and having a facility with negligible combustible materials of construction.

The walls have a 360 mm shielding thickness and are constructed of overlapping 'shiplap' precast panels that limit radiation streaming though the panel joints. The roof is composed of pre-cast concrete members that provide a concrete shielding thickness of at least 50 mm. The joints between adjacent roof members is filled by a continuous reinforcing bar and grout that provide 40 mm of shielding to prevent radiation streaming.

The floor is a concrete slab on grade with a double barrier arrangement (Figure 3 and 4). The concrete floor offers the first barrier and a pre-moulded membrane placed under the floor slab, serves as a secondary containment barrier against any moisture that may condense under or seep through the SMAGS building floor slab to the environment. The membrane will convey any such moisture to one of the external sump tanks. Another sump tank will collect any water accumulating on the top of the floor.

RADIATION PROTECTION FEATURES

The SMAGS buildings are designed to store low-level solid radioactive waste materials in latched steel containers. The buildings are designed to achieve the following radiation protection features:

1. Building wall panels (360 mm thick) are designed to eliminate radiation streaming between panels or around panel edges by using a lapped joint and grouting the joint. The precast roof double tee members (50 mm thick concrete) are designed such that there is no "shine" emitting between the tees.

2. Mechanical ventilation is provided to prevent build up of airborne radionuclides inside the building and to control levels of CO and NOx to within the levels permitted by NBCC 2005 [1], for a storage garage.

3. Air leakage from the building is minimized through careful construction practices and the use of sealants or other means that will remain effective for over 50 years without maintenance.

4. An L-shaped masonry wall is erected inside the overhead door and person-door to act as shielding to prevent radiation streaming when the doors are open.

STRUCTURAL DESIGN

Eastern Canada is located in a stable continental region within the North American Plate and, as a consequence, has a relatively low rate of earthquake activity. The site is located at a moderately active seismic area and the structure is designed using the latest National Building Code of Canada, NBCC 2005 [1]. All applicable live loads as required by the National Building Code of Canada 2005 edition such as wind, earthquake, snow and temperature changes are considered in the design.

The ground motion used by NBCC 2005 [1] represents a “relatively rare event with a probability of exceedance of 2% in 50 years, or a return period of 2500 years (probability of 0.0004). The design approach recommended and the procedures given in NBCC 2005 [1] are based on this level of probability.

Based on field testing and measurements, the Geotechnical Report for the site identified the SMAGS site as Site Class “C”, as per NBCC 2005 [1]. This represents a “Very dense soil and soft rock” condition for the site.

Inside the SMAGS2 building low-level radioactive material is stored in steel containers which will maintain their integrity under all expected design loads. Hence the building can be considered as a “Normal Importance” category building (NBCC Clause 4.1.2.1). However, as a conservative approach the building design is verified assuming the building is of “High Importance” category.

SMAGS building is primarily a shear wall building. The roof system acts as a diaphragm and transfers lateral load to the shear walls. The failure mode of this building under severe seismic load is likely to be the failure of the connectors at the top of the wall and anchors at the base and subsequent failure of the wall panels. This will lead to the collapse of the roof beams. The wall panels are designed as “Moderately ductile” as per NBCC 2005 [1].

The floor slab is designed to support the concentrated point loads of the waste containers, the live loads of vehicles (fork lift) used to load the waste packages as well as any impact loads due to waste containers being accidentally dropped. The floor slab is designed considering various container stacking patterns such that the building can be safely filled in any sequence without causing excessive cracking or differential settlement in the slab. The floor slab is also designed to withstand the impact force from the top most container falling on one edge.

The concrete slab on grade is cast in one continuous pour with no control joints. Two fibreglass sump tanks are used to collect and monitor any liquid accumulated above and below the concrete floor slab.

CONTAINMENT CONCEPT

The outer structural elements of the SMAGS building form the waste storage perimeter for the storage building and establish the first building-based barrier to activity release. These structural elements include the building roof, walls, floor and all penetrations provided in these elements and shall be designed to minimize water of any origin from contacting the contents of the stored waste packages.

An under-floor impervious membrane is installed to channel any water that may pass through the concrete floor. The membrane system used in SMAGS has been extensively reviewed and evaluated to ensure leak tightness and integrity over the life of the structure. After installation, the membrane is flood tested as per ASTM Standard D 5957 [4]. This membrane, acting as the second building-based barrier to activity release, directs any escaped water by gravity to a sump that is accessible from outside the building for routine inspection and water removal. Water collected in this barrier system is examined for contamination to ensure that the waste isolation objective is accomplished.

VENTILATION SYSTEM

The ventilation system provides the airflow necessary to meet the requirements of both AECL's Non Reactor Nuclear Ventilation Standards and NBCC 2005 [1] requirements for a storage garage.

The ventilation system of SMAGS building is of the forced air type and operates continuously during the loading phase of the building (3 to 5 years).

The ventilation system is able to provide a minimum of 2.34 air changes per hour when the diesel fuel lift truck is in operation for carbon monoxide control.

During the loading phase, the exhaust fan within the building exhausts 5,667 litres per second (an equivalent of 2.34 air changes per hour). Air change is estimated based on the gross volume of an empty SMAGS building as per the requirements of the NBCC 2005 for a diesel powered forklift in a storage building and this satisfies the requirements for contamination zone 2. When the building is occupied the mechanical ventilation system provides a minimum of 3.9 litres per second supply of outdoor air per square meter of building floor area.

FIRE DETECTION SYSTEM

SMAGS building is designed to meet the fire safety requirements as per NFC 2005 [2] and NFPA 801-2003 [3].

Fire detection in SMAGS building is achieved by the use of beam smoke detectors or a Linear Heat Detector (LHD). When LHD system is used, cables are installed in such a way that they can be replaced if required without accessing the area above the stored boxes. A Fire Hazard Analysis (FHA) of the design has been performed by a third party. The FHA includes a review of the fire detection and alarm system.

QUALITY ASSURANCE AND SAFETY FEATURES

The design and construction of SMAGS is carried out according to the Quality Assurance (QA) requirements of CSA N286 series of Canadian Standards for Nuclear Power Plants [5]. These Standards are based on a set of 16 common quality assurance principles. These principles define the essentials for ensuring that items and services will be of the required quality.

CONCLUSIONS:

The SMAGS buildings provide adequate protection for the safe storage of low-level radioactive wastes at AECL sites for a 50-year life. These buildings are designed and constructed efficiently with negligible combustible materials of construction. The precast concrete components of the superstructure permits higher construction quality level and speed of construction. The floor slab without any joints and the under floor membrane provide a double barrier leak proof construction. Adequate provision exists for fire detection, emergency exits, ventilation and maintenance.

REFERENCES:

1. NBCC 2005, National Building Code of Canada.
2. NFC 2005, National Fire Code of Canada,
3. NFPA 801 (2003), Standards for Fire Protection of Facilities Handling Radioactive Waste, National Fire Protection Association.
4. ASTM Standard D 5957 – 98 (2005), Standard Guide for Flood Testing Horizontal Waterproofing Installations.
5. CSA N286, Management system requirements for nuclear power plants. Canadian Standards Association.

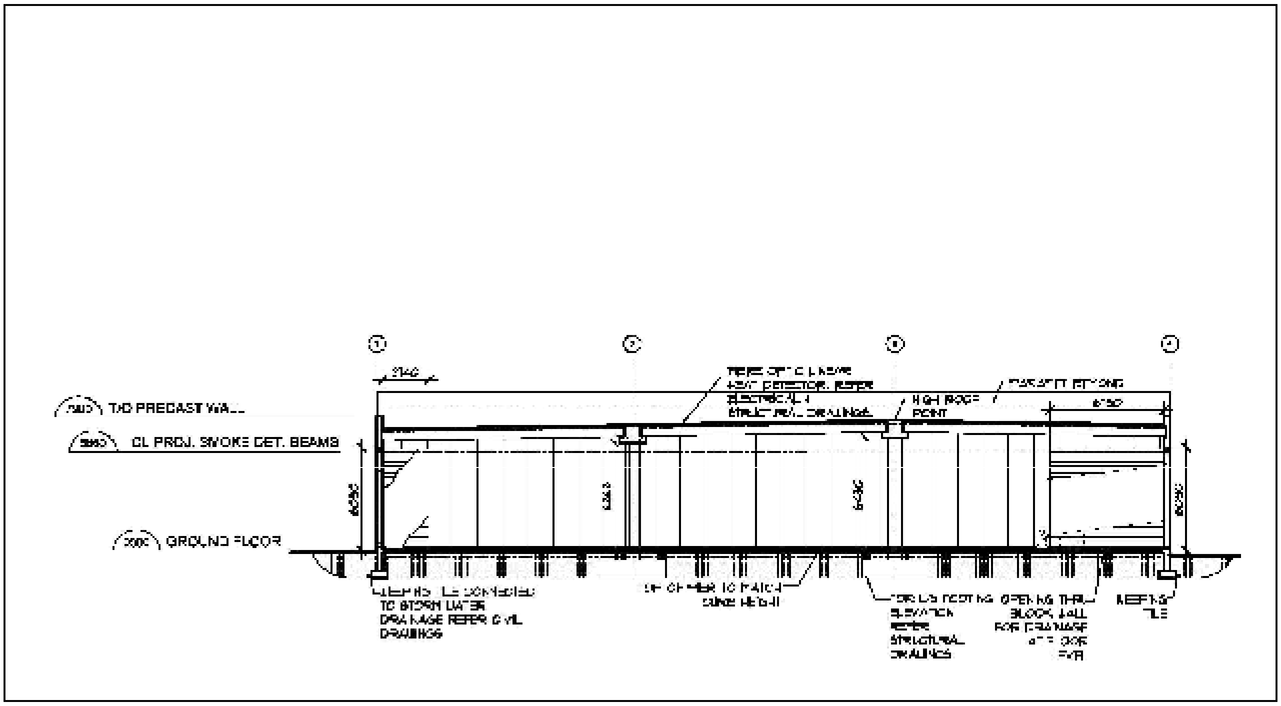

Figure 1: Longitudinal Section of SMAGS Building

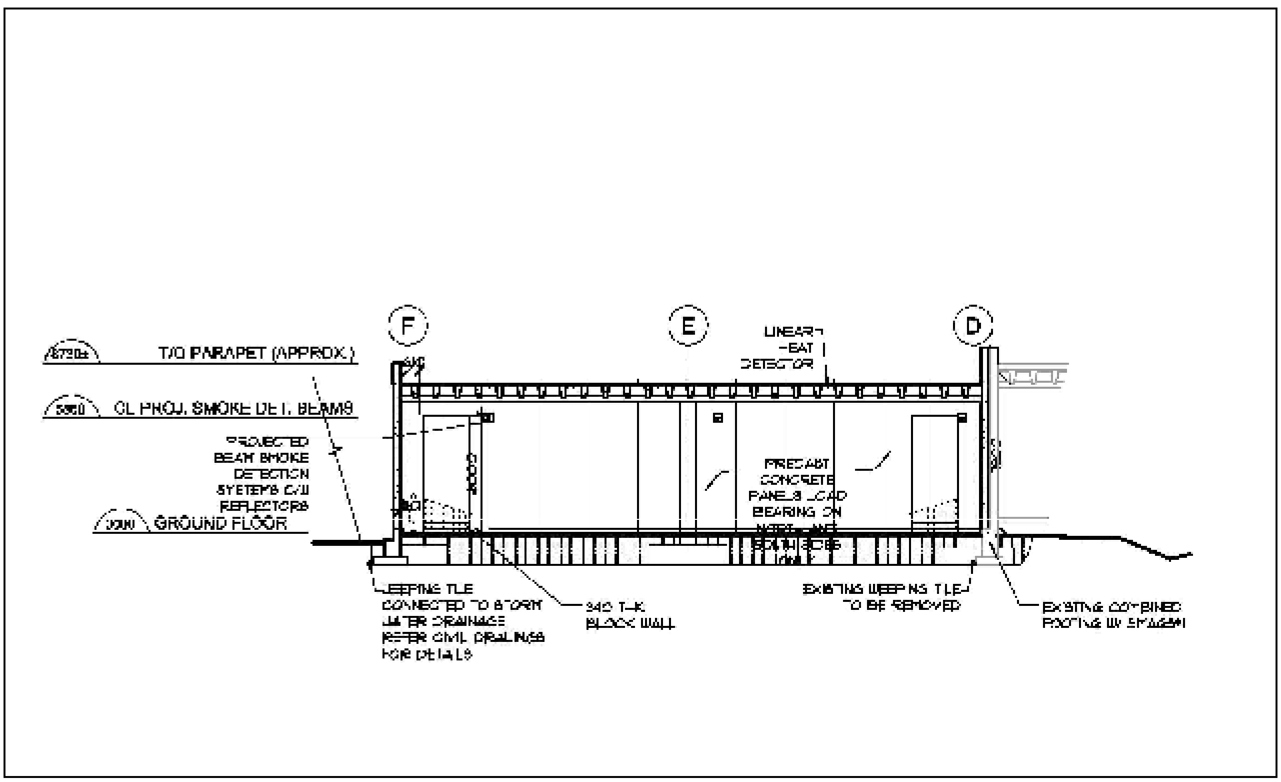

Figure 2: Cross Section of SMAGS Building

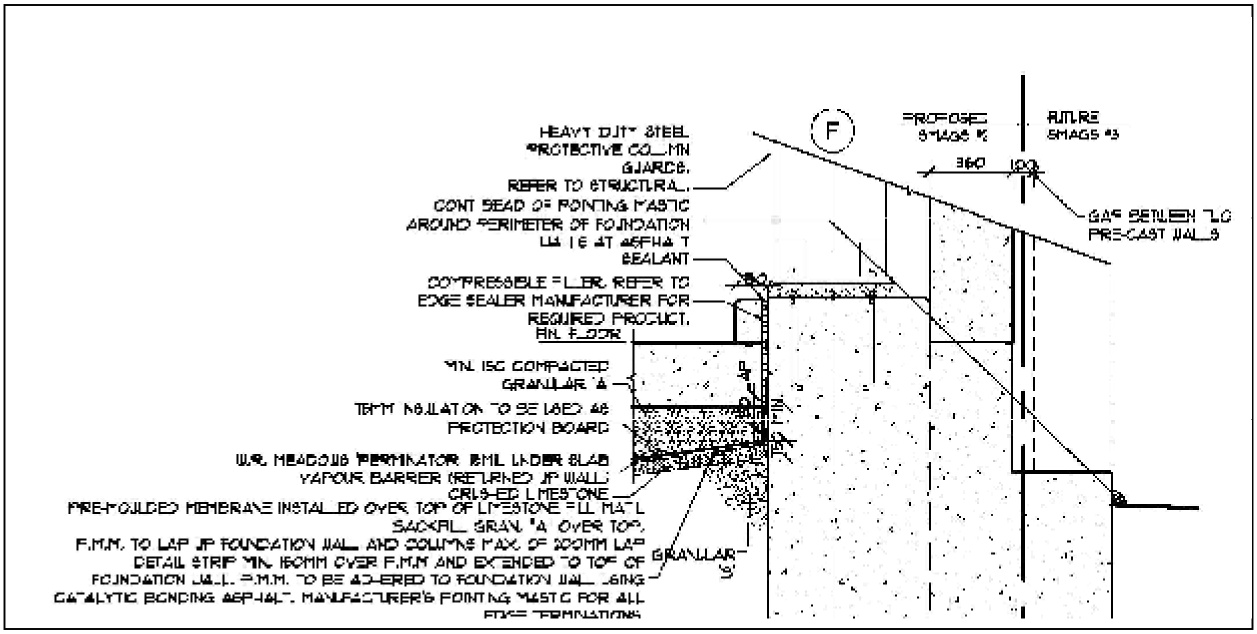

Figure 3 Membrane Layout

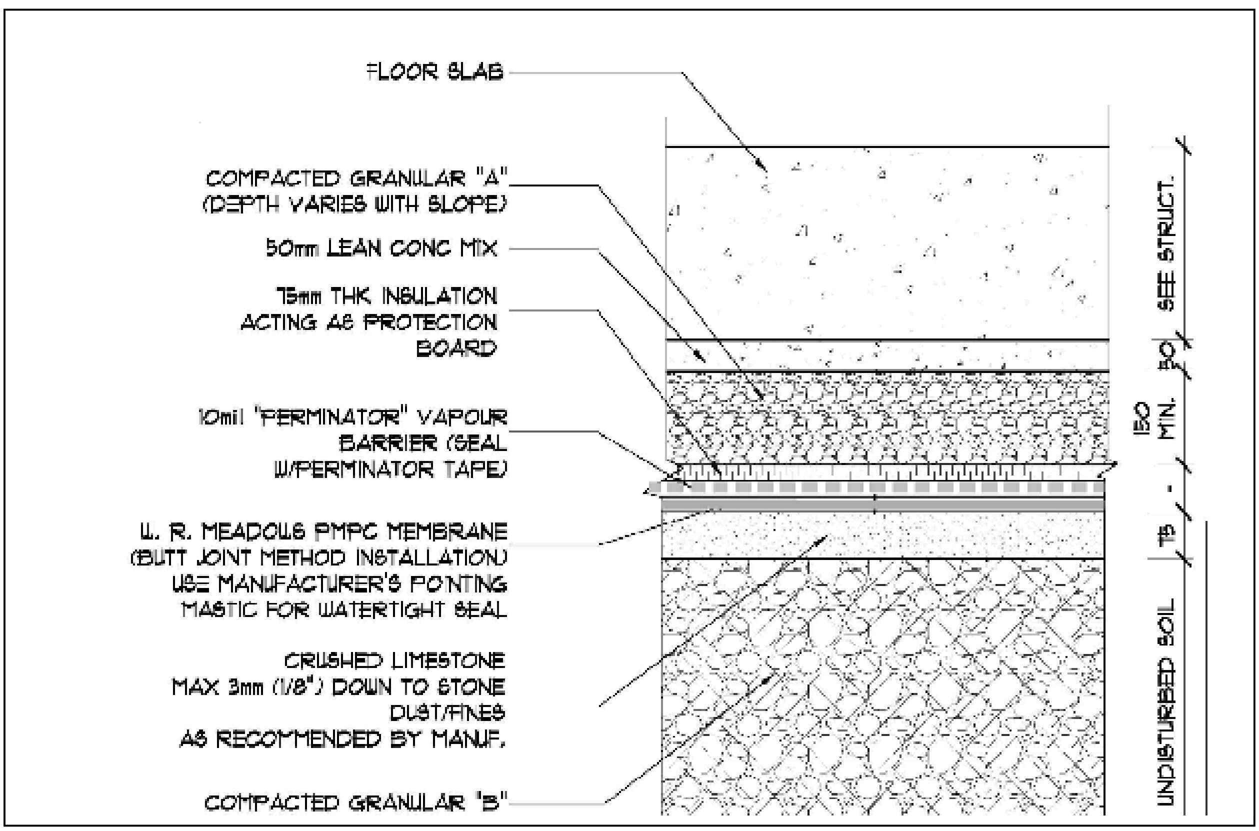

Figure 4: Slab and membrane Section