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AGING MANAGEMENT FOR SAFETY RELATED CONCRETE STRUCTURES IN SWITZERLAND

P. Zwicky[1] and D. Kluge[2]

[1]Basler & Hofmann AG, CH-8029 Zürich, Switzerland
[2]Swiss Federal Nuclear Safety Inspectorate, CH-5232 Villigen-HSK, Switzerland

1. INTRODUCTION

The operating life of most of the nuclear power plants in Switzerland is not formally restricted by time-limited operating licences. The licensing authority requires that the Utilities report periodically on the plants' condition in order to prove that the safety requirements are still being fulfilled. Because the older plants have been in operation now for more than 20 years, the question of aging effects has to be addressed in future condition assessments more systematically. The Swiss Federal Nuclear Safety Inspectorate required in 1991 that all utilities develop their aging management programs, addressing structural condition as well as the mechanical and electric equipment. This presentation summarizes the current practice in Switzerland, and the first steps being taken towards an aging management program for the concrete structures, including equipment anchorage.

2. CURRENT PRACTICE FOR CONCRETE STRUCTURES

The aging management of concrete structures in nuclear power plants is currently not regulated in Switzerland. Measures of maintenance and surveillance are usually based on common engineering judgement. Special investigations or remedial works are normally the result of visible structural damage. In some cases extensive prevention measures have had to be taken for concrete structures.

Table 1 summarizes the nuclear power plants in Switzerland, their age, and some typical structural maintenance problems and remedial measures.

In addition to the listed experience, the Utilities spend a large amount of effort on the maintenance of non-safety related structures, especially with the internal structures of the cooling towers in Gösgen and Leibstadt.

The current policy is focussed on preventive measures and on the immediate repair of any visible degradation: it includes:

Table 1: Nuclear Power Plants in Switzerland: Some typical maintenance and repair problems in safety related structures

Plant	Reactor Type	Start of Operation	Age	Backfitting (Buildings)	Typical Maintenance Problems: Building/ Structure	Degradation
Beznau Units I + II	PWR 2x350 MWe	1969/71	24/22	1991/92 (NANO)	*Reactor building*	
					- outer concrete shell	cracks
					- fuel pool	leakage of borated water
					- decontamination coatings	cracks
					Auxiliary buildings	
					- roof isolation	humidity/cracks
					- penetrations for piping	splitting off
Mühleberg	BWR 350 MWe	1972	21	1989 (SUSAN)	*Reactor building*	
					- roof	cracks
					- stack (bottom area)	cracks, percolation
					outer torus structure	
					- access	humidity
Gösgen	PWR 1000 MWe	1979	14	-	*reactor building*	
					- dome	cracks (under observation)
Leibstadt	BWR 1000 MWe	1984	9	-	*steam tunnel*	anchorage failures of joint tapes

- periodic visual inspections;
- periodic testing of special structural elements, such as anchorage elements and joint tapes;
- early and thorough repair of any detected failures.

However the Utilities recognize the need for estabilishing a sound technical and administrative basis for long-term aging management. The approach should be more systematically planned and documented.

3. REQUIREMENTS OF THE HSK

In December 1991 the Swiss Federal Nuclear Safety Inspectorate (Hauptabteilung für die Sicherheit der Kernanlagen, HSK) presented all four Swiss utilities with the requirement to establish a systematic aging management program (Alterungs-Überwachungsprogramm, AÜP). The programm should address all safety related aspects of the plant, including structures and mechanical and electrical equipment. The following steps are recommended:

- Identify potential degradation modes;
- Identify those areas of the classified plant elements exposed to degradation mechanisms;
- List the periodic tests and maintenance programs on the site already practised;
- Assess the data provided by state-of-the-art inspection techniques for aging management;
- Catalogue further measures for the appropriate surveillance and safety assessment of the aging process

The Utilities have now the task to develop their plant specific AÜP according to the following time schedule:

- Mühleberg	mid 1993
- Beznau	mid 1994
- Gösgen	mid 1995
- Leibstadt	mid 1996

4. FIRST STEP: BASIC STUDY

With a basic study the HSK's structural consultant summarizes the state-of-the-art in the field of aging management of nuclear concrete structures (HSK/Basler & Hofmann, 1992): the problem definition, a review of worldwide research and experience and the basic technical requirements. This study is intended to initiate the required activities and provide the Utilities with guidelines for their plant specific aging management program.

The study combines information from the research programs of the US Nuclear Regulatory Commission (Naus et al, 1993), and the US utility organisations (NUMARC, 1990; EPRI, 1987), with the state-of-the-art in the conventional concrete technology as documented in local codes and guidelines (SIA, 1987 and 1990).

Table 2: Basic Elements of Aging Management for Concrete Structures

Action	Criteria, Basic Data
1. List and prioritize complete structures, critical parts of structures (including equipment anchorage elements)	- safety function - environmental exposure - inspectability and early identification - potential consequences of failure
2. Periodic Condition Assessment for important structures (or parts)	- documented plant history - surveillance, inspections, maintenance: documents and experience - fundamentals in materials and aging effects, available inspection methods - experience exchange
3. Repair measures and/or redefinition of inspection program	

The assessment of degradation mechanisms, and their influence on structural aging, are currently well understood. During normal operation in the specific nuclear environmental, factors such as radiation or elevated temperature do not seem to reduce the durability of the concrete structures significantly. The most important degradation mechanism is assumed to be the corrosion of the reinforcing steel, especially in structural elements which are not accessible for inspections. The foundations and the outer walls embedded in the soil require special attention. The inspection methods available for the diagnosis of non-nuclear concrete structures are in general adequate for nuclear structures too.

With the present state of knowledge, the service-life of nuclear power plants will not be limited by degradation of the concrete structures. This has to be verified in each individual case with a technical assessment of structural safety, serviceability and durability. Equipment anchorage elements embedded in the concrete have to be included, and treated with special attention. The decommissioning phase also has to be taken into account for service-life predictions. The basic study provides a rough outline for an appropriate inspection programm (Table 3).

5. FURTHER STEPS

The Utilites have formed a working group with the task to develop a basic document for the plant specific aging management programs. The Group has representatives of all the four nuclear power plants. They will inform the HSK continuously about the progress of their work.

As an immediate measure the Utilities are collecting various material fragments which become available during construction works. The fragments are then stored as a source of information on aging related properties.

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Table 3: Outline of an inspection program for important safety related concrete structures and equipment anchorage elements

	Baseline Inspection	**Intermediate Inspection**	**Main Inspection**	**Special Inspection**
Level 0 Data collection	collect all basic data for the aging management of the important safety related structures	update	update	update
Level 1 visual inspection	- visual examination: cracking, spalling, humid areas, visable corrosion - crack mapping - surface knocking - electromagnetic detection of reinforcing steel (location and depth) - rebound hammer			
Level 2 a) non (or minimally) destructive inspection		- carbonation - porosity, density - tension tests of anchorage elements	- spot checks for embedded structures (excavation)	
b) laboratory tests		investigation of material fragments available from construction work	- concrete core tests compressive strength porosity density microstructure chloride - reinforcing steel corrosion tensile strength ductility fatigue strength - pullout tests of anchorage elements	
Level 3 special investigation				- static load tests - geodetic deflection measurement - vibration tests and modal analysis - radiography - infrared thermography