

Transportation and Disposal of Low- and Medium Level Waste using Fiber Reinforced Concrete Overpacks

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INTRODUCTION

Radioactive waste immobilization is an integral part of operations in nuclear facilities. The goal of immobilization is to contain radioactive materials in a waste form which can maintain its integrity over very long periods of time, thus effectively isolating the materials from the environment and hence from the public. This is true regardless of the activity of the waste, including low-, and medium-level waste (LLW, MLW).

A multiple-year research effort by Cogema culminated in the development of a new process to immobilize nuclear waste in concrete overpacks reinforced with metal fibers. The fiber concrete overpacks satisfy all French safety requirements relating to waste immobilization and disposal, and have been certified by Andra, the national radioactive waste management agency.

The fiber concrete overpacks have been fabricated on a production scale since July 1990 by Sogefibre, a jointly-owned subsidiary of SGN and Compagnie Générale des Eaux.

This presentation will cover the use of the fiber-reinforced concrete overpack for disposal and transportation, and will discuss their fabrication.

FIBER REINFORCED CONCRETE CONCEPT FOR DISPOSAL

COGEMA REQUIREMENTS

The institutional control period for disposal of LLW and MLW in France is 300 years. Once the waste has been solidified, there are two options available to the generator for its immobilization :

- . if a "low performance" overpack is used, the waste form must be improved or the disposal structures themselves must provide adequate immobilization,
- . if a "high performance" overpack is used, the overpack itself provides adequate immobilization, thus lessening the waste form and disposal structure requirements.

Needless to say, Andra's specifications for high-performance overpacks are much more stringent than for low-performance overpacks, requiring certain mechanical, physical and containment characteristics for both the materials of construction and the fabricated overpack. In addition to these tests, the performance of the fiber concrete overpack over a period of 300 years must be assessed before it can be certified as a high performance overpack.

Cogema, world leader in nuclear spent fuel reprocessing in France, made a decision in 1985 to immobilize certain waste types in high performance overpacks. Because no high performance container had yet been certified in France, Cogema undertook research and development on concrete formulations that would offer the following performance benefits :

- good mechanical strength,
- good resistance to microcracking,
- good radioactive containment properties, and
- long life, with 300 years minimum.

R & D ON FIBER REINFORCED CONCRETE

Researchers in several countries have studied the mechanical characteristics of fiber reinforced concrete for a number of years. It is not the purpose of this paper to review the large body of research available on the subject, but it should be noted that there is general agreement among researchers that fiber reinforced concrete has certain advantages compared to ordinary concrete or concrete rebar :

- the concrete is uniformly reinforced , and
- there is less micro-cracking in fiber reinforced concrete.

To develop a fiber reinforced concrete that met Cogema's requirements, two activities were conducted in parallel :

- Selection of metal fibers to be incorporated into the concrete, and
- Development of an improved concrete formulation.

Selection of metal fibers

Cogema chose the "Fibraflex" fiber (Figure 1) developed and fabricated by Seva, a company of the Saint-Gobain group. The non-crystalline state of Fibraflex gives it flexibility, strong mechanical properties and high resistance to corrosion.

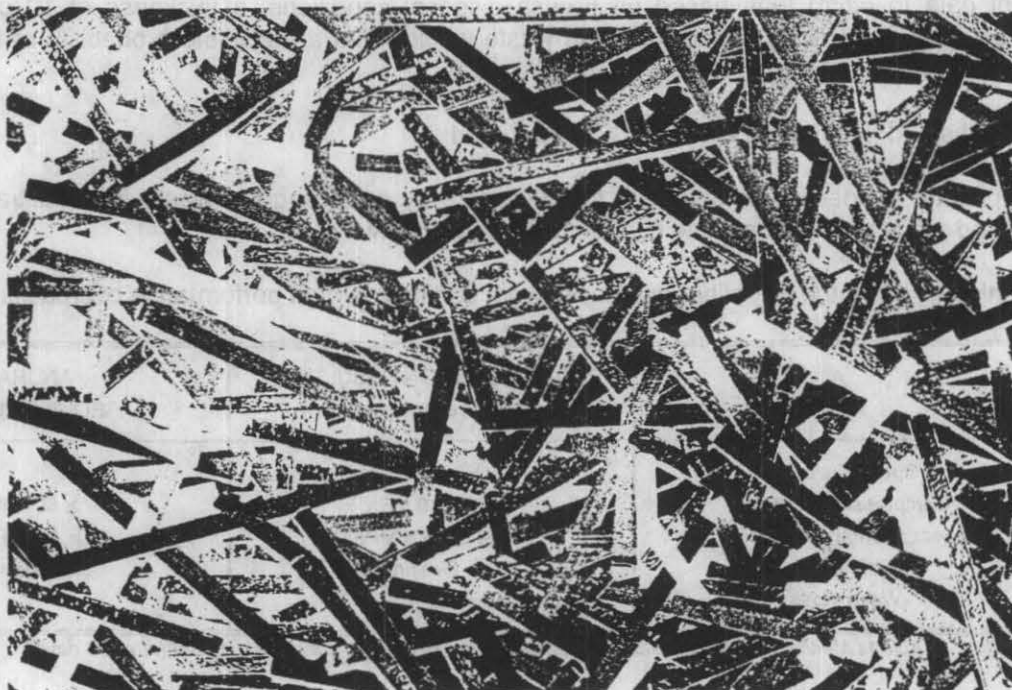


Figure 1 : Fibraflex reinforcing fibers

Concrete formulation

A modified concrete formulation was developed to allow incorporation of the fiber and to improve the concrete's containment properties.

FIBER REINFORCED CONCRETE CHARACTERIZATION PROGRAM AND CERTIFICATION IN FRANCE

Characterization testing was conducted on the fiber reinforced concrete to demonstrate its conformance to Andra specifications [1]. Test results are shown in Tables I through III.

Based on the results of the characterization program, two types of packages received Andra certification :

- The CBF-C1 cylindrical package (January 1991), and
- The CBF-K cubical package (September 1991).

Sogefibre's fiber reinforced concrete overpacks are protected by French patents 88.16337 (December 12, 1988) and 89.08050 (June 16, 1989).

In parallel with the characterization program, the long-term integrity of the Sogefibre fiber reinforced concrete overpacks was assessed, both by testing and by computer modelling of overpack deterioration and subsequent radionuclide migration. Although not all test results are in, there is sufficient data to affirm that, based on French disposal conditions, a thickness of 10 cm of fiber reinforced concrete entirely surrounding the waste would have a negligible probability of failure and would :

- withstand mechanical loads for 300 years, and
- provide radioactive containment for 300 years by protecting the waste from infiltration water and preventing radionuclide migration via water pathways.

It is on this basis that the Sogefibre overpacks were certified as high performance overpacks by Andra.

	PRODUCTION RESULTS (after 1 year of operation)	ANDRA REQUIREMENTS
Specific gravity	2.4	
Compressive strength	60-70 MPa	≥ 50 MPa
Shear strength by splitting	4.5 - 5.5 MPa	≥ 4.5 MPa
Shrinkage	≈ 290 μm/m	≤ 300 μm/m
Weight loss	2 %	

Table I : Mechanical and physical properties of fiber reinforced concrete material (after 28 days)

	TEST CONDITIONS	TEST RESULTS	ANDRA REQUIREMENTS
Effective diffusion factor	1 year		
Tritiated water	2 cm pellet	< 7.1 10 ⁻⁵ cm ² /day	< 1.5 10 ⁻³ cm ² /day
Cesium	1 cm pellet	< 2.4 10 ⁻⁵ cm ² /day	< 10 ⁻³ cm ² /day
Water permeability		< 1.5 10 ⁻²⁰ m ²	
Nitrogen permeability		3.10 ⁻²⁰ m ²	≤ 5 10 ⁻¹⁸ m ²

Table II : Containment properties of fiber reinforced concrete material (after 28 days)

Integrated dose	10 ⁶ Gray
Dose rate	1.2 - 1.4 10 ³ Gy hr ⁻¹
Sample weight	5 kg
TEST RESULTS	
Volume of H ₂ generated	0.220 L
Radiolytic return ratio G (H ₂)	0.017
Volume of O ₂ consumed	1.14 L
Radiolytic return ratio G (O ₂)	- 0.09
No cracks	

Table III : Radiation resistance of fiber reinforced material

TRANSPORT OF FIBER REINFORCED CONCRETE OVERPACKS

The waste generator's plant and the disposal facility are generally located at different sites, and waste must therefore be shipped by road or rail between them. The waste may be conditioned either at the generator's site or at the disposal facility. When the waste is conditioned at the generator's site, such as at a reprocessing plant, Sogefibre's fiber reinforced concrete overpack meets IP2 and Type A transportation overpack requirements [2].

Drop and compression tests were performed on every model in Table IV.

CONTAINER		OVERALL DIMENSIONS (mm)	USEFUL VOLUME (liter)	MINIMUM THICKNESS (mm)
SHAPE	MODEL			
CYLINDRICAL	CBF-C1	1200 H 840 D	330	74
	CBF-C2	1500 H 1000 D	700	74
CUBICAL	CBF-K	1.700 all sides	3000	100

Table IV : Sogefibre fiber reinforced concrete overpacks

Test conditions and results are given in Table V.

OVERPACK	OVERALL WEIGHT FOR DISPOSAL (kg)	DROP TEST (CORNER)		COMPRESSION TEST	
		HEIGHT (m)	RESULTS	COMPRESSIVE LOAD (kN)	RESULTS
CBF-C1	1700	1.2	Spalling/no crack	985	1st crack
CBF-C2	3000	1.2	Spalling/no crack	1000	no crack
CBF-K	11500	1.2	Spalling and cover displacement	1000	no crack

Table V : Transport tests results on Sogefibre fiber reinforced concrete overpacks

All overpack models retained their containment properties during the tests.

Waste that will be conditioned at the disposal facility is not immobilized inside the overpack for transportation, nor is the concrete cover sealed. This allows the waste to be grouted inside the overpack at the disposal facility. In the case, a new overpack design was developed to withstand the drop test. In this type of overpack :

- waste is conditioned in a liner of polyethylene, steel, etc..., for containment, and
- steel wire reinforcement is added to the overpack walls.

0.9 m drop test was performed on an 11.5 t cubical overpack with a 3.8 cm²/meter linear concrete reinforcement and a cubical polyethylene liner. The concrete wall exhibited spalling and cracking, but the steel wire reinforcement and the good mechanical characteristics of the fiber reinforced concrete prevented the concrete wall from being breached, which would have exposed the liner. The liner was completely intact.

This version of fiber reinforced concrete with steel wire reinforcement, combined with a liner meets IP2 and Type A requirements for transportation. The overall wall thickness of the overpack should be increased to include the wire reinforcement while maintaining the required 10 cm layer free of any corrodable material, consistent with 300 year durability assessment.

FABRICATION OF FIBER REINFORCED CONCRETE OVERPACKS

DESCRIPTION OF OVERPACKS

Three fiber reinforced concrete overpacks, described in Table IV, were designed to meet Cogema's requirements. Figures 2 and 3 show the CBF-C1 and CBF-K overpack models respectively.

Of course, the overpacks can be customized by Sogefibre to meet the specific requirements of the client with respect to :

- Geometry (cylindrical, cubical, etc...)
- Dimensions,
- Wall thickness,
- Closure system,
- Handling system, and
- Surface finish of outer walls.

An example of a fabrication option is the elaborate shape of the anti-float cover for cylindrical fiber reinforced concrete overpacks, shown in Figure 2, which prevents the drum of waste from floating when the fiber reinforced concrete container is filled with grout.

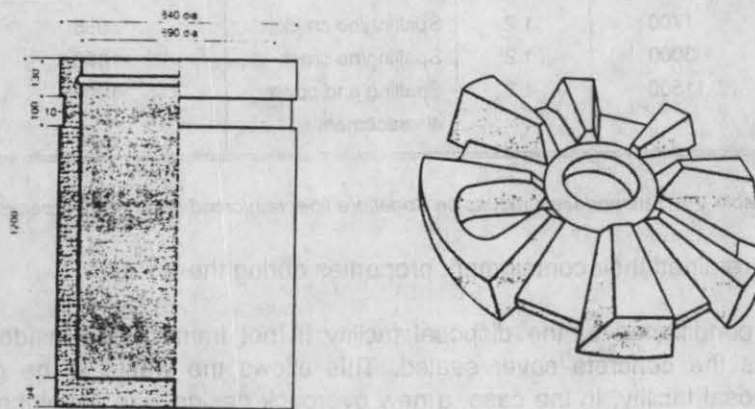


Figure 2 : CBF-C1 overpack with anti-float cover

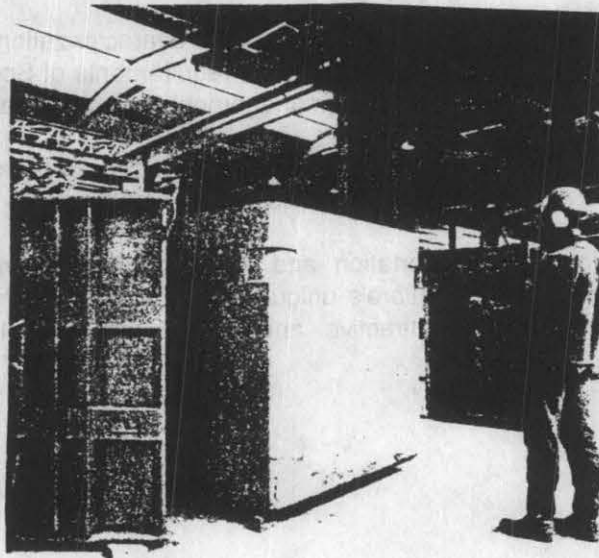


Figure 3 : CBF-K Overpack

FIBER REINFORCED CONCRETE CONTAINER FABRICATION FACILITY

The large numbers of fiber reinforced overpacks required by Cogema led to the construction of a facility dedicated to their fabrication in Valognes, in the province of Normandy, France. The 12,000 overpacks per year facility commenced operations in July 1990.

Cogema has imposed very stringent fabrication specifications on Sogefibre to guarantee that all fiber reinforced concrete overpacks, including their covers, meet Andra specifications for both the materials of fabrication and the fabricated overpack, which are also very stringent. The overpacks are fabricated in accordance with quality assurance procedures (Level 2 of French Quality Assurance Standards), with special emphasis given to the following production aspects :

- stringent control of all incoming materials, including cement, sand, aggregates and fibers,
- control of process parameters, such as measurement of concrete ingredients and mixing times,
- measurement of concrete shrinkage and mechanical strength on test samples taken from each production batch,
- dimensional and visual inspection of products, and
- product traceability.

Most operations at the Valognes facility are performed remotely by computer, which results in a high production-to-staff ratio and eliminates hard physical labor.

The facility design was significantly influenced by the high quality and technology standards of the nuclear industry, making it one of the most advanced facilities in the concrete industry.

CONCLUSION

Five years of research & development, including substantial characterization testing, resulted in the development of a fiber reinforced concrete that meets the requirements of Sogefibre's client, Cogema and was certified by the national radioactive waste management agency in France, Andra.

Sogefibre has successfully developed a full-scale fabrication process for the fiber reinforced concrete overpacks and has fabricated overpacks commercially since July 1990.

With safety requirements for the transportation and disposal of low- and medium-level waste becoming more stringent every day, Sogefibre's unique overpack design, high quality materials and demonstrated safety offer generators attractive and comprehensive solutions for their waste management needs.

REFERENCES

- [1] Andra specification STE 119.581S, "Technical Specification for Packages Holding Immobilized Heterogeneous Waste Delivered in Durable Overpacks and Intended for Disposal in a Near-Surface Facility".
- [2] IAEA Regulations 1985, modified 1990.