MECHANICAL BEHAVIOR OF THE ASBESTOS-CEMENT CONTAINER FOR GEOLOGICAL DISPOSAL OF α LEVEL TECHNOLOGICAL WASTES FROM COGEMA REPROCESSING PLANTS

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ABSTRACT

For the safety assessment of the SGN asbestos cement container concept selected by COGEMA for the conditioning of cemented technological wastes from the UP3-UP2 800 reprocessing plants, a general survey has been carried out to confirm both its confinement capacity and its mechnical strength. This safety assessment relates to the latter aspect. It implies two stages: first, the material characterization of asbestos cement and epoxide resin used in sealing and assembling; second, the finite element calculation of induced stresses and strains under storage conditions with regards to the experimented mechanical characteristics. We infer some damage in packaging materials in case of misoperation in conditioning process.

INTRODUCTION

A previous paper (1) has presented the CEA characterization program performed on asbestos cement samples and the first results obtained on physical, mechanical and migration properties. We now present the mechanical behavior analysis of this new type of waste packaging consisting of a composite assembled container. The purpose of the present study was to determine the behavior of the container under an hydrostatic pressure of 15 MPa, which is assumed to be representative of the mean geological repository conditions. As pointed by the Basic Safety Rule (BSR) III 2.e relative to surface storage waste package approval, mechanical characteristics have also to be characterized. This type of waste package can be compared with the steel reinforced concrete one, which is already commonly used for solid wastes. The asbestos cement container is justified by its high mechanical resistance without reinforcement. The major advantage of the adopted decontamination workshop and container concept is that it ensures the confinement of all the upstream units of the plant, which implies using sealed casings for discarded equipment (pumps, valves, ejectors, chopper blades...). On the other hand, this package concept involves void sections of up to 10% of the usable volume.

Description of the Asbestos Cement Container (See Fig. 1)

Two types of container have been designed according to the activity content:

- 50 mm in thickness, 1200 mm in height and 850 mm in outer diameter (wastes issuing from intervention areas and $\beta\gamma$ hazards and to be disposed of mostly in surface storage),
- 75 mm in thickness, 1500 mm in height and 1000 mm in outer diameter (wastes issuing from hot cells and α hazards and to be disposed of in geological storage).

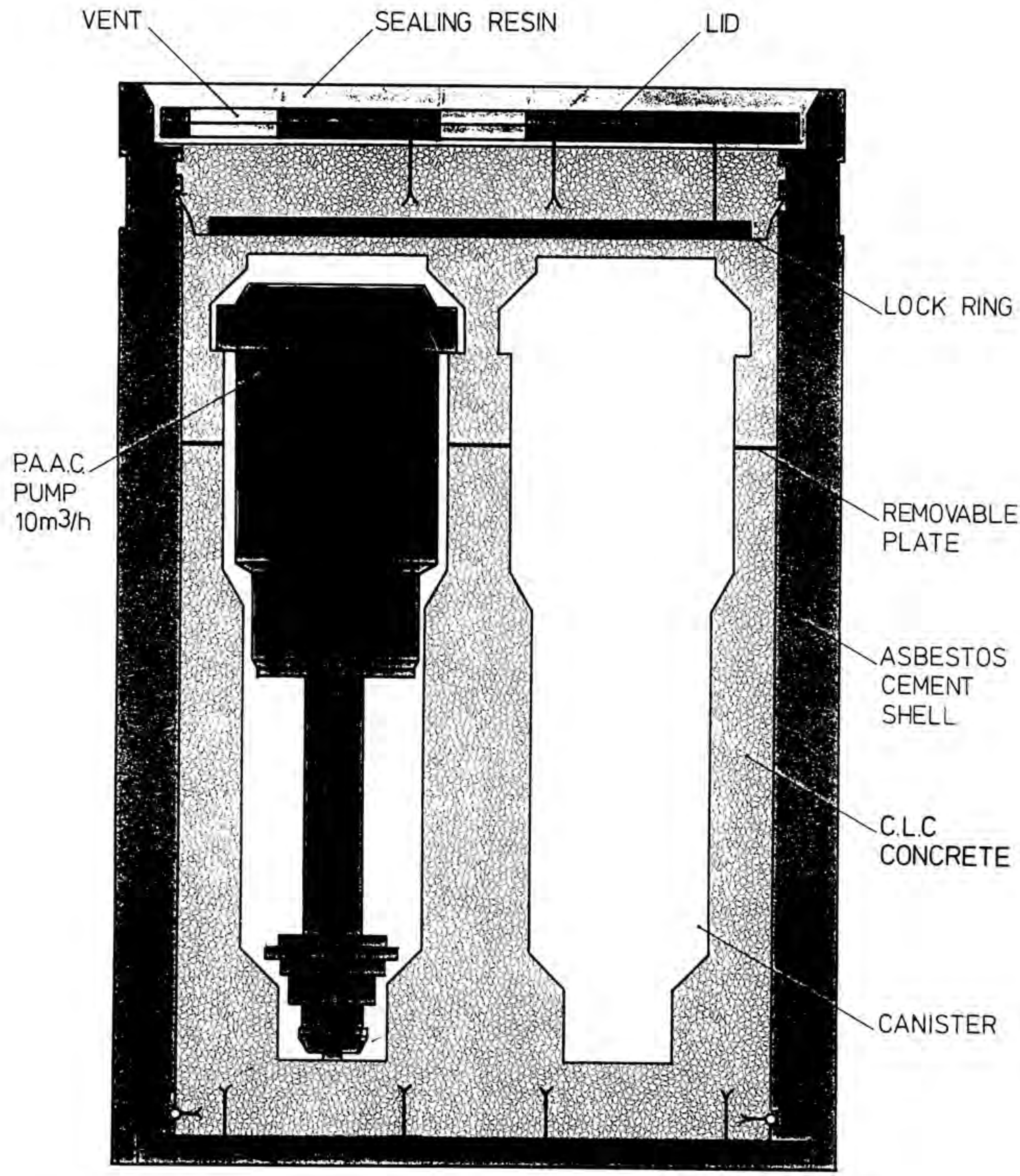
The main parts and constituents of the package are:

- an asbestos cement shell (Portland Cement) manufactured with the same industrial process as is used for the water distribution pipes and machined at the extremities in order to anchor top and bottom lid,
- a lid consisting of a steel plate with fork type anchors welded on it. Two holes are machined in it, one for cement grouting and resin injection, the other for venting,
- a lock ring acting both as a centring device and a counter hydraulic thrust device during and after grouting for the waste drum and the discarded equipment sealed casings,
- the bottom part is similar to the lid apart from the lack of holes in it and that it is factory set up, i.e., matted with epoxide resin on the asbestos cement machined shell,
- after cement hydration, an epoxide resin is injected into the top part of the container, in order to fill the remaining space led after cement grouting and to ensure the final sealing of the waste package.
- filling with flying ash slag cement (CLC) mortar brings rigidity to the package as a whole and enhances confinement performances.

We must emphasize that if AC is not so efficient as simple cement as regards the diffusion (1,2). Its advantages reside in mechanical resistance, grain size fineness and industrial qualification areas. As the annular layer of free embedding with cement mortar cannot be guaranteed if no spacers or special grating basket are provided, it is imperative to check that the AC container cannot burst even with void sections or without the added resistance of this free mortar layer.

Potential Failure Analysis Logic

To make sure that the asbestos cement container does not burst, the liability to brittle fracture or buckling of the asbestos cement shell, the top and



DIAMETER: 1000mm
HEIGHT: 1500 mm

Fig. 1. Asbestos Cement Container.

bottom plates and the whole assembly, must be first considered. Our logic consisted in considering two stages for each set of working conditions:

- the asbestos cement container is empty. If it works without bursting, it is unnecessary to describe the filling constituents,
- if not, we need to roughly describe the filling constituents, to take into account their contribution to the mechanical resistance.

Due to anisotropy, we also assume, since no design criterion is available, that we may compare the maximum calculated stress, according to R,Z,θ directions to the uniaxial performance of rupture experimented with representative and normalized specimens, if necessary machined in three directions, in order to predict the mechanical behavior of the package constituents.

Experimental Determination of Rigidity and Mechanical Resistance Characteristics

Each component has been mechanically characterized in a unixial way except for the asbestos cement material which is composite, requiring that the specimens be cut in three directions.

The asbestos cement material features a brittle fracture behavior. Machining of the samples from asbestos cement container prototype from SGN was consequently pretty difficult, also, compounded by the lathe attribution.

The rather poor tensile strength of the asbestos cement, principally in the direction perpendicular to the fibers, led to specimens with cross section larger than normalized ones.

The results (3,4) are given in Table I.

TABLE I

Material Characteristics

. Asbestos material cement (EVERITUBE)

Young's modulus	Poisson's ratio	Shear modulus
E_{rr} = 21,500 MPa	γ_{rz} = .26	G_{rz} = 8,130 MPa
E_{zz} = 26,050 MPa	$\gamma_{r\theta}$ = .306	$G_{r\theta}$ = 7,590 MPa
$E_{\theta\theta}$ = 30,650	$\gamma_{z\theta}$ = .306	$G_{z\theta}$ =10,090 MPa

Rupture	Tensile strength	Compressive strength
σ_r	6 MPa	190 MPa
σ_z	17 MPa	140 MPa
σ_θ	33 MPa	150 MPa

. Epoxide resin material (CDF CHIMIE 3100 A)

Young's modulus	Poisson's ratio
E = 4,000 MPa	γ = .4

Tensile Strength	Compressive Strength
30 MPa	65 MPa

. Steel material : Young's modulus E= 20,000 MPa
Poisson's ratio γ= .35

. Cement mortar : Young's modulus E= 35,000 MPa
Poisson's ratio γ= . 15

For computation purposes the following critical assumption must be made on the experimental characteristics of asbestos cement material:

- Some Poisson's ratio values have been slightly adapted in order to reflect the symmetry condition of the rigidity matrix.
- Some of Young's modulus aberrant values have been eliminated (artefacts).
- The rigidity values are consistent with the fact that the fiber direction random distribution, according to the manufacturing process is

$$-30^0 < \theta < +30^0$$ with repsect to the plan.

- Due to the anisotropy of the asbestos cement the shear modulus is not equivalent to the torque modulus. This leads to some complication involving consideration of a fictive octogonal sample instead of a cylindrical one and using a formula with limit values.

WORKING CONDITIONS (See Fig. 2)

Surface Storage Conditions (experimented with the French "Site de Stockage de la Manche")

The asbestos cement container is supposed to be at the bottom level of the basement slab according to the Manche Site monolith type concept. There are two other asbestos cement containers stacked on it (2 x 1950 kg). At the tope of the monolith, the reinforced concrete that supports the tumulus structures, i.e., four levels of stacked REP solid wastes concrete container (6,000 kg each). Over this stacking column there is a 6 m impervious earth layer. We make the assumption that the concrete slab is damaged. Consequently, the loaded containers have to withstand the pressure corresponding to a 36,000 kg mass.

Normal Stacking Condition

We assume that the above loading is evenly distributed on the top of the CAC container.

Upset Stacking Condition

In this pessimistic case, only the AC shell is loaded, and the interface region becomes of special concern.

Provisional Geological Conditions (based upon an hypothetical concept)

The loading pressure due to the response of surrounding rocks and structures with thermal

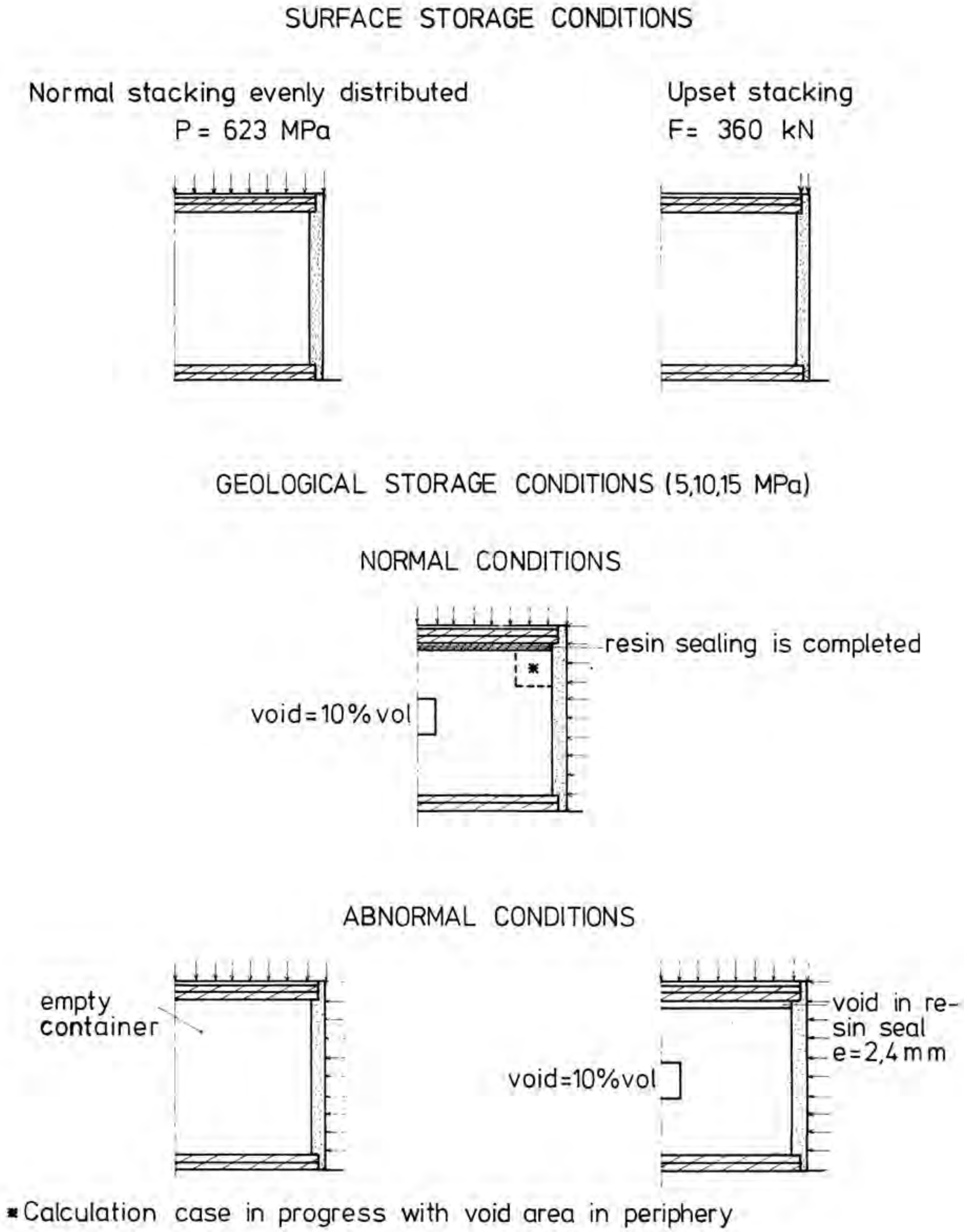


Fig. 2. Loading Conditions.

expansion and to the overburden of rocks after the vault convergence or collapse of the gallery, varies in the range of 5 to 15 MPa in our hypothesis, depending mostly on the depth of the disposal and on the host rock type. A previous study (5), using the concept of gallery and basement slab type repository, led to a maximum of 10 MPa for the pressure loading as an order of magnitude with a granite host rock.

Stress and Strain Calculations

Finite Element Modeling

The computer calculation of the pressure response of the asbestos cement container was performed with a linear elastic model code using the orthocylindrical coordinate in order to save computer time. The finite element mesh was narrowed in region of special concern, i.e., the assembly of the end plates with the AC shell (see Fig. 3).

Results Analysis

- Under surface storage conditions, (see Table II). No case shows stress and strain values beyond rupture. Even with an empty container there are substantial safety margins with respect to breaking. The constituents of the container are not heavily loaded considering their intrinsic capabilities.

- Under geological conditions, (see Table III). The stresses are much more severe.

--When empty, the AC container cannot withstand the pressure loading even with the lowest value of 5 MPa. This is due to over deflection of the top lid which leads to excessive loading in the resin-asbestos cement assembly for both epoxide resin and asbestos cement materials (tension and compression).

--When filled and incorrectly sealed-i.e., when resin injection has failed to replace the cement shrinking-the loading of the epoxide resin and of the asbestos cement in the region of concern seen above remains consistently above the accepted limits with regards to the uniaxial resistance performances measured on samples. Even for the lowest pressure loading of 5 MPa there are no safety margins and the asbestos cement container's failure is anticipated.

TABLE II

Surface Storage Conditions

loading condi. / Item	normal stacking & empty container	upset stacking & empty container	upset stacking & filled container
Lid deflection	1.56 mm	0 mm	0 mm
max. cement shrinking	3 mm	-	3 mm
max. A.C tensile stress	9.6 MPa	2.2 MPa	1.3 MPa
A.C. tensile strength	17 MPa		
usage factor	0.57	0.13	0.08
max.AC compressive stress	- 24 MPa	- 9.6 MPa	- 9.5 MPa
AC compressive strength	- 140 MPa		
usage factor	0.17	0.07	0.07
max. resin compressive stress	- 22.5 MPa	- 4.4 MPa	- 4.4 MPa
resin compressive strength	- 65 MPa		
usage factor	0.35	0.07	0.07
Comments	no failure anticipated	no failure anticip.	no failure anticip.

--In turn, when filled and correctly sealed-

i.e., when no void remains at the top of the container the usage factors of the materials are quite satisfactory. For a 5 MPa pressure loading we find a compressive stress of 14 MPa in the resin and 9.6 MPa in the A.C. Even with the highest pressure loading of 15 MPa there are safety margins with respect to failure of the container (we assume linearity of the pressure response when being well below the rupture values).

CONCLUSION

Assessment of the induced stresses and strains in the asbestos cement container under storage condition leads us to conclude that the design is satisfactory.

Under surface storage loading, margins with respect to failure are substantial.

Under geological storage loading, the design is still satisfactory under nominal process conditions.

In case of defective resin injection through the top lid of the container, the study shows some excessive values which could damage asbestos cement and resin materials of the container in the range of a 5-15 MPa hydrostatic pressure.

The concept's supporters must consequently elaborate a rigorous quality assurance procedure in order to prevent this faulty conditioning process situation.

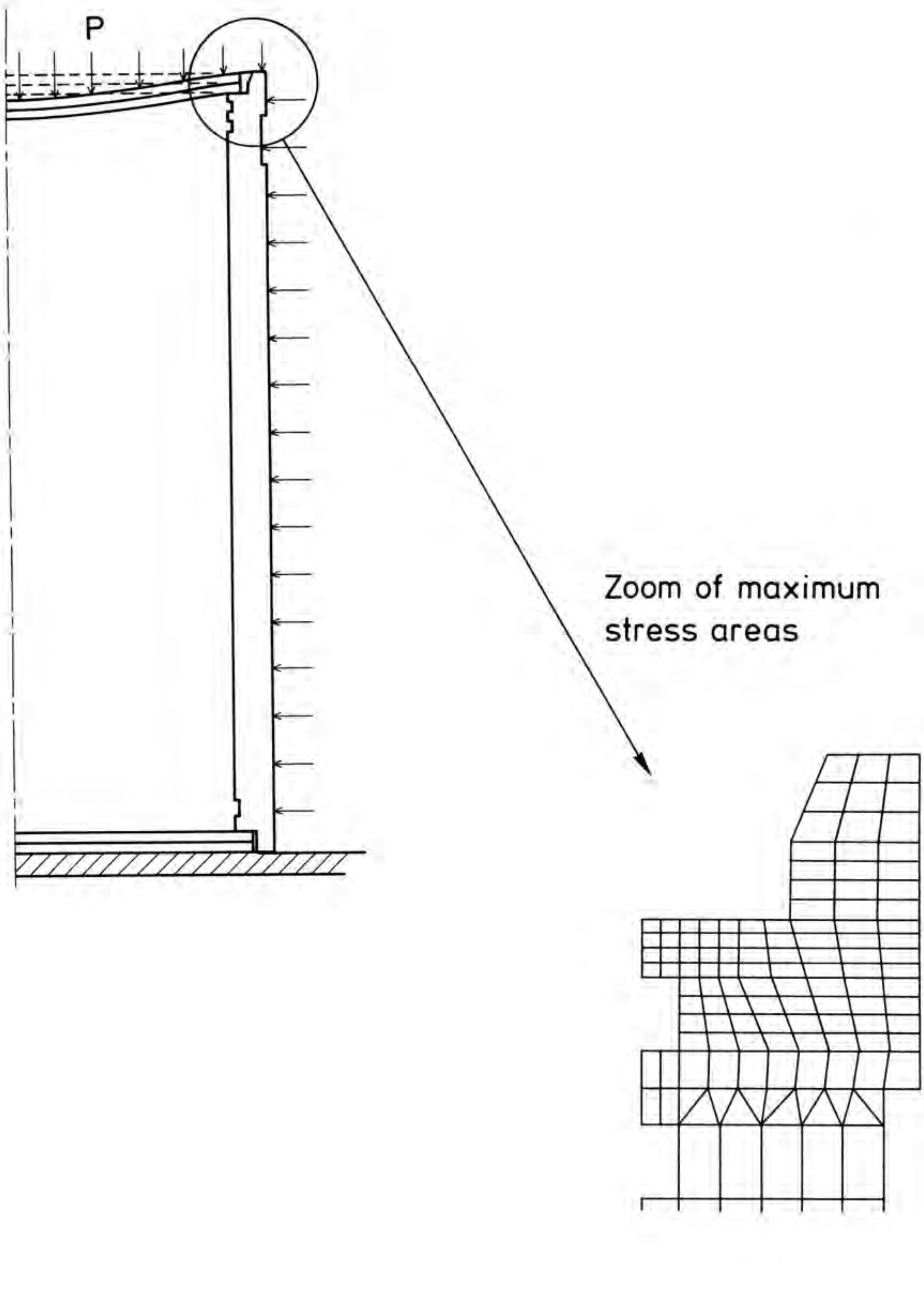


Fig. 3. Stress and Strain Calculations.

TABLE III

Provisional Geological Conditions

load. cond. / items	empty	normal. filled& correc. sealed	normal. filled& incorr. sealed	normal. filled& incorr. sealed	normal. filled& incorr. sealed
	5 MPa*	5 MPa*	5 MPa	10 MPa	15 MPa
max.cement shrinking	-	3 mm			
lid deflection	15 mm not lim.	0.19 mm	15 mm lim.to3	30 mm lim.to3	45 mm lim.to3
max. AC tensile stress	33 MPa	-	43 MPa	50 MPa	52 MPa
AC tensile strenght	6 MPa				
usage fac.	5.5	-	7.2	8.3	8.7
max. AC com.stress	-209 MPa	-9.6 MPa	-153 MPa	-220 MPa	-270 MPa
AC comp. strenght	- 140 MPa				
usage fac.	1.49	0.07	1.09	1.57	1.93
max. resin com.stress	-309 MPa	-14 MPa	-160 MPa	-230 MPa	-280 MPa
resin com. strength	- 65 MPa				
usage fac.	6.1	0.22	2.46	3.54	4.31
Comments	antici- pated failure	no fail. anticip. id for 10/15 MPa	anticipated failure		

* Load displacements and strains, proportional in case of 10 and 15 MPa pressure conditions.

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