French 1500 MW Fast Reactor Project Proposal of a Reactor Bearing Concrete Slab

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1. INTRODUCTION - GENERAL DESCRIPTION

If a circular form is obviously the best for the external protection and inner pressure of PWR Buildings, it doesn't allow an optimal use of the internal volume for equipments.

A rectangular island shape is then studied for the new French Fast Breeder Reactor (1 500 MW Project) even if the choice is surely not economical from a structural point of view. This option has mainly two consequences on the shape of the roof : a double curvature shape is no more naturally integrated in the general form ; even in case of a cylindrical roof a sub-structure is needed to carry its distributed horizontal reactions to lateral walls. A horizontal plate roof composed of steel beams and a reinforced concrete slab has been designed. The construction method of the roof is also simplified. The building can be covered very quickly just after erection of the steel beams. Work inside the building can continue when concreting the roof.

The Island with its 115m x 70m dimensions has no expansion joint. In fact, it is not easy to design such a joint in the middle of the building because of the position of the Reactor Vessel. In the other hand, with such a joint the building would have lost its stiffness coming mainly from the "box effect" and would have been much more sensitive to seismic effects and to the soil deformations in case of a soft soil.

The general shape of the Nuclear Island is shown on Fig. 1 & 2.

The Island, with all its 250 000 T mass, is entirely supported by paraseismical bearings made of particular neopren pads. Three main reasons have led to this choice :

- the intensity of seismic loads can be decreased if the main frequency of the bearings is low enough (around 1 Hz)
- the response spectra of different stores in such a building do not depend practically on the level of the store nor on the dynamic characteristics of the soil. It becomes then possible to have a "standard equipments design" which can be used in any site, as well as the building itself.
- the thermal expansion of the building becomes almost free.

Fig. 3 shows the general arrangement of the bearing pads at the top of concrete columns. Each column supports four 600 x 600 x 40mm pads coupled with 3 dampers, to give a total damping ratio of 15 %. There are 300 such columns under the building.

2. DESCRIPTION OF THE ACTUAL DESIGN OF THE REACTOR PIT

The complicate geometrical shape and distribution of main exchangers and pumps was at the origine of a selected bearing slab made of steel. Another advantage of this choice is to fabricate the slab in a site factory when concreting the reactor pit. The main vessel, made of stainless steel is suspended to this slab. The safety vessel is constituted by the concrete reactor pit itself, with a liner inside which is protected by a steel insulation and a water cooling system embedded in the concrete.

[illegible]

Architectural drawing of the Reactor Building (R.B.) showing a plan view. The drawing includes dimensions, a legend, and a title block.

Legend:

- - PIERCE
- - WALL

Dimensions:

Overall dimensions: 100' 0" x 100' 0"

Internal dimensions: 100' 0" x 100' 0"

Center dimensions: 100' 0" x 100' 0"

Title Block:

PROJECT: REACTOR BUILDING
 DRAWING: REACTOR BUILDING
 SCALE: 1/4" = 1'-0"

The horizontal effect of seism on the reactor components is reduced by paraseismical pads under the building. But these pads are unefficient for the vertical component of the earthquake.

To reduce the effect of this component, 4 x 22 spring boxes of 192t, adjusted for a frequency of 1.5 Hz, support the whole vessel pit.

The safety vessel had then to be fixed horizontally at its top and bottom. This was made with 8 neopren pads at each level with an angular distance of 45°. The bottom of the vessel is of course stiff enough to avoid any local deflection under pads reaction. This is not the case at the top where local deflection can exist under seismic reaction of the pads.

Of course the construction of the safety vessel bottom is not so easy. To be sure of good concreting conditions it was decided to concrete this part in a reverse position over the liner, to turn the whole part, to transport it to the final position and to complete it at the site.

Fig. 4 shows the general shape of the reactor pit. Fig. 5 shows the general arrangement of the cooling pipes and all the thickness of the wall. Fig. 6 gives a general idea about the construction method of the safety vessel (reactor pit).

3. GOING FORWARD - NEW DESIGN OF REACTOR SLAB

The basic solution of the reactor slab has of course many advantages but also some inconveniences which are mainly :

- To prevent stresses due to hindered thermal expansion this slab hangs from the top of the reactor pit through flexible steel collars. This connection is delicate because it joins a steel structure with a concrete one and does not allow the use of the stiffness an embedded junction could give.
- The slab is filled with radiation protecting concrete which does not participate in its resistance. However the problem of the transmission of loads from the steel plates of the slab to the concrete is not well known.
- The cooling is made either with water pipes welded to the lower plate or by an air cooling system, which takes an important part of the slab thickness.

These facts led us to investigate the feasibility and the interest of a reinforced concrete reactor slab alternative.

This alternative consists of a resisting slab made of reinforced concrete which can be directly embedded to the top of the reactor pit. This allows :

- to cancel the delicate connection between two elements of different materials,
- to compensate largely the lower rigidity of the concrete slab,
- to cancel the non-axisymmetrical deflection problems on the upper part of the reactor pit linked to seismic horizontal bearing supports.

The inner face of the slab is covered with a thin steel liner anchored in the concrete, similar to the one studied for the reactor pit.

The cooling system is also similar to the reactor pit one : water pipes embedded in the concrete behind the liner, which avoid longitudinal welding of pipes.

4. DESCRIPTION OF THE REINFORCED CONCRETE SLAB

The concrete slab has the same thickness and the same stiffness as the basic steel solution. In fact embedding the slab on the vessel pit compensates largely the lower stiffness of the concrete for the same thickness.

The cooling system of the slab is composed by water pipes located in the concrete and about 10 cm away from the internal liner. This configuration, already selected for the safety vessel gives two protection screens between the water and the reactor sodium : the liner, and 10 cm of concrete.

Fig.4 : General shape of the reactor pit

Fig.5 : Arrangement of the wall thickness

Fig.6 : Construction method of the safety vessel

The power to be evacuated by the cooling system is about 1 500 W/m² in normal conditions which is quite the same than in safety vessel. The cooling system is composed of a 5 cm Neyrcal insulation and 20 cm distant cooling pipes.

The same cooling system is foreseen for the cylindrical holes of equipments. We hope that the insulation will not be necessary.

The internal liner of the slab is used also as shuttering when concreting the slab. This shuttering is suspended to an external steel structure used as a gantry. Hanging the shuttering permits to stock the main vessel in the safety one before putting in place the shuttering.

The main vessel is welded on a thick plate on which are welded the liner and some hangers sockets. Hangers can be either prestressed or reinforced rebars.

To avoid heterogeneous weldings in sensitive parts of the hanging structure of the main vessel the thick plate and the sockets are in stainless steel (as well as the main vessel) when the liner is in 8 mm normal steel.

Fig. 7 & 8 give the general arrangement of such a slab.

Because of the limited place and to avoid too difficult concreting conditions sockets are used instead of splices and end anchorages for all reinforcing rebars.

The mean density of reinforcing steels is surely high but not exceptional for such a structure because less than 250 kg/m³. Concreting between cylindrical holes will need certainly a particular attention but the reinforcement design is made so that it can be done without any risk.

5. CONCLUSIONS

Our preliminary studies lead to the possibility of a concrete slab for the safety vessel.

Obviously, some points would require more complet studies before foreseeing definitively such an alternative solution. Main points to be analyzed are the following :

- check that with just one cooling system working (as it is the main assumption for all studies) the liner is cooled enough and that with both systems it is not too cold to condensate the sodium vapor
- try to make a constant thickness slab which will be better for the continuity of the slab with the pit, the anchorage of the liner at angles and for cooling pipes (no high and down point). This new configuration can not be foreseen before a very careful examination of the cooling system at the top of the main vessel which has to guarantee an allowable low temperature at the top welding.

Of course we will have to consider also the influence of the slab construction method on the general schedule of works.

All these points have to be studied certainly. We think that a detailed design for each of them can be made without any problem.

The only serious remaining problem is related to the fact that the concrete deflections increase with time. The delayed deformations would come either from the cracking effect of the concrete or from shrinkage and creeping. Their compatibility with the equipment tolerances have to be checked later on.

It must be noticed that the concrete is confined by a liner which avoids the water migration to outside and decreases highly the effect of shrinkage and creeping. In other hand we think now about very high strength concrete with nominal strength of about 60 to 100 MPa which have important advantages like : a high tensile strength, a low shrinkage and a relative fast and low creeping compared to normal concrete.

Fig.7 : Radial section of the concrete slab

Fig.8 : Plan view of the concrete slab