FDLV112 - Computation of stopping with reserve under seismic request

Abstract:

The goal of this case test with the modelization A is to taking into account validate the functionalities of computation coupled fluid-structure of stopping with reserve under seismic request in the assumption of incompressibility, therefore of added mass for reserve like that of forces added to model the motion of training of this reserve due to the seismic excitation. With the modelization A, computation is linear, transitory on modal base.

The modelization B to the validation of the sequence Code_Aster - MISS3D by the frequential method of coupling in interaction (ISFS) soil-fluid-structure contributes. One tests there simply the reading of the impedances of soil and the seismic forces calculated by MISS in ISFS, in order to be able to proceed to a seismic response by harmonic computation in *Code_Aster* in ISFS. In taking into account in the coupling part of field of soil, one carries out a modal analysis preliminary then to a harmonic analysis . The modal results correspond to the eigen modes of the stopping with mass of added water obtained with the modelization A and the seismic results of responses constitute a case of non regression.

The modelization C contributes to the validation of the functionality of modelization of the added mass of fluid per assignment of point masses to the nodes of the interface fluid-structure by means of option `MASS_AJOU` of operator `AFFE_CARA_ELEM`. This modelization only requires to take into account structure of stopping and not the water reserve, nor the soil. The modal results correspond to the eigen modes of a stopping with mass of added water obtained with modelization A.

The modelization D B take again the modelization with the sequence *Code_Aster* - MISS3D and utilize the functionalities of resolution with taking into account or not of the spatial variability of incidental seismic field by the operator `DYNA_ISS_VARI` with key word `ISSF`. Without variability, one notes results of seismic responses close to those of modelization A.

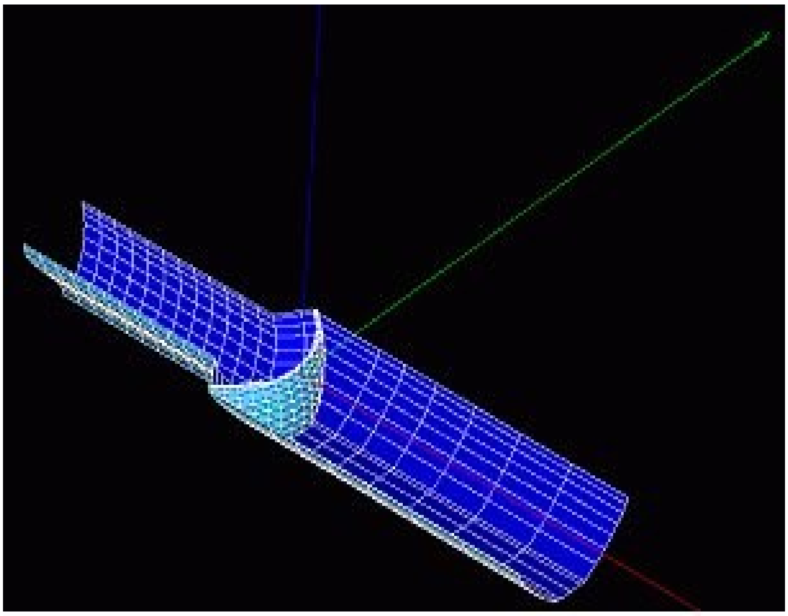
1 Problème of reference

1.1 Geometry

the complete geometry is made up by the arch dam, of reserve necessary and sufficient to the modelization A as well as various interfaces 2D necessary also to the modelization B [Figure 1.1-a].

One has B 4 possible types of interface necessary to the modelization by the CodeAster *sequence* - MISS3D [bib1] with the frequential method of coupling in interaction (ISFS) soil-fluid-structure.:

- the interface soil-structure,
- the interface soil-fluid,
- the interface fluid-structure,
- the soil-free interface.



Appear 1.1-a: model complete stopping and of its reserve with its interfaces

1.2 Properties of the materials

the structure
the mechanical characteristics used for concrete structure are indicated in table 1.2-a. :

E	$36000\ MPa$
ν	0.2
ρ	$2400\ Kg/m^3$

Table 1.2-a: structural features

the soil
the soil mechanics characteristics used only for the modelization B are those indicated in table 1.2-b. They correspond to a very tough soil to approach test FDLV112A.

E	$300000\, MPa$
NU	0.16
RHO	$2000.\, kg/m^3$
BETA	0.1

Table 1.2-b: characteristics of the soil

the fluid

Celerity	$1500\, m/s$
RHO	$1000.\, kg/m^3$
BETA	$0.$

Table 1.2-c: characteristics of the fluid

2 Reference solution

2.1 Method of calculating used for the reference solution

the data of this test are drawn from a general study implementing the features of *Code_Aster* to deal with the problems of seismic analysis of the concrete dams [bib2]. For the modelization A, the got results were confronted with those obtained with software EACD dedicated to this kind of computation. However, there no were precise statements of value with this software. This is why one directs oneself towards a numerical solution and results of non regression got exclusively with *Code_Aster*. For the modelization B, the results got in modal analysis on the first frequencies are compared with the peaks of resonance of modelization A. nature different from the results makes that one also directs oneself towards a numerical solution and results of non regression got exclusively with *Code_Aster*.

2.2 Results of reference

One tests maximum acceleration according to the 3 directions and the response sprectrum of oscillator corresponding for a damping of 5% to the medium node of higher edge of the stopping. One also looks at the first peaks of resonance or eigenfrequencies due coupled system.

2.3 Uncertainty on the numerical

solution Solution.

2.4 Bibliographical references

1) D. CLOUTEAU: “Manual of reference of MISS3D – version 6.3 – Power station Searches SA”

2) CHAMPAIN E: “Seismic Analysis of the concrete dams with *the Code_Aster*” - NT HT - 62/01/023/B

3) I. ZENTNER: “Interaction soil-structure in seismic analysis with spatial variability” document *Code_Aster* U2.06.12

3 Modelization A

3.1 Characteristic of the modelization

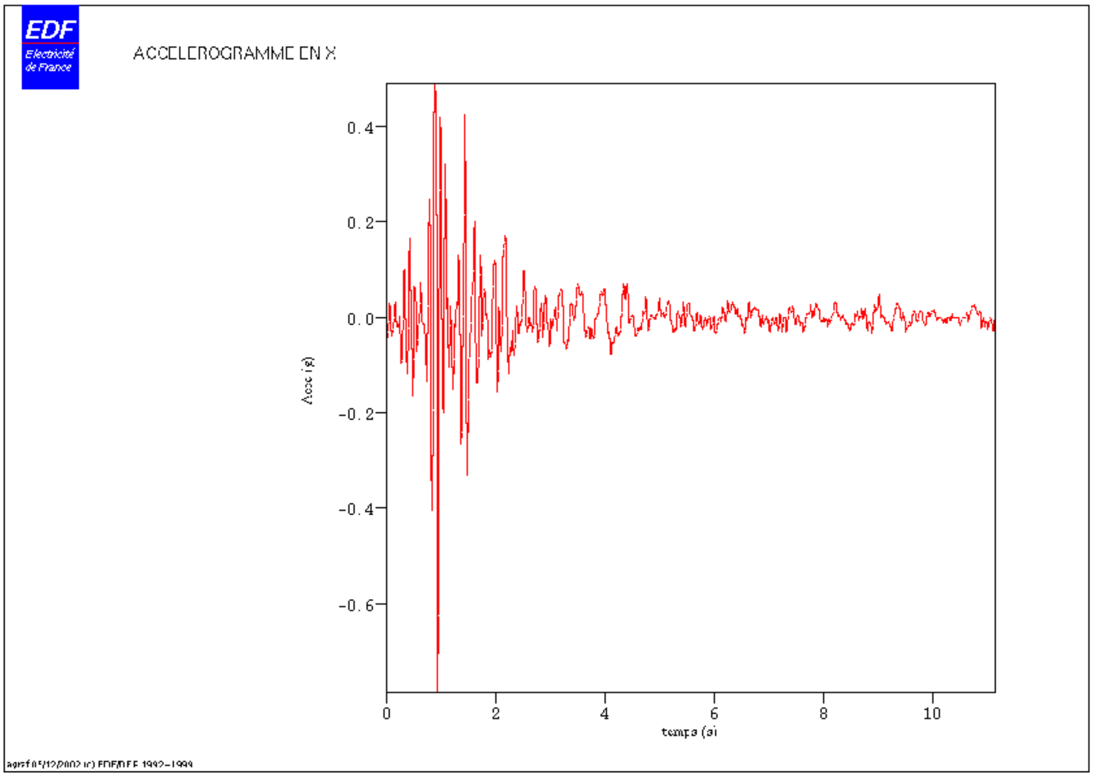
The modelization A relates to the incompressible fluids with added masses. One thus models only the stopping and not the reserve of water. The latter is taken into account only in the macro - command `MACRO_MATR_AJOU`.

3.2 Characteristics of the mesh

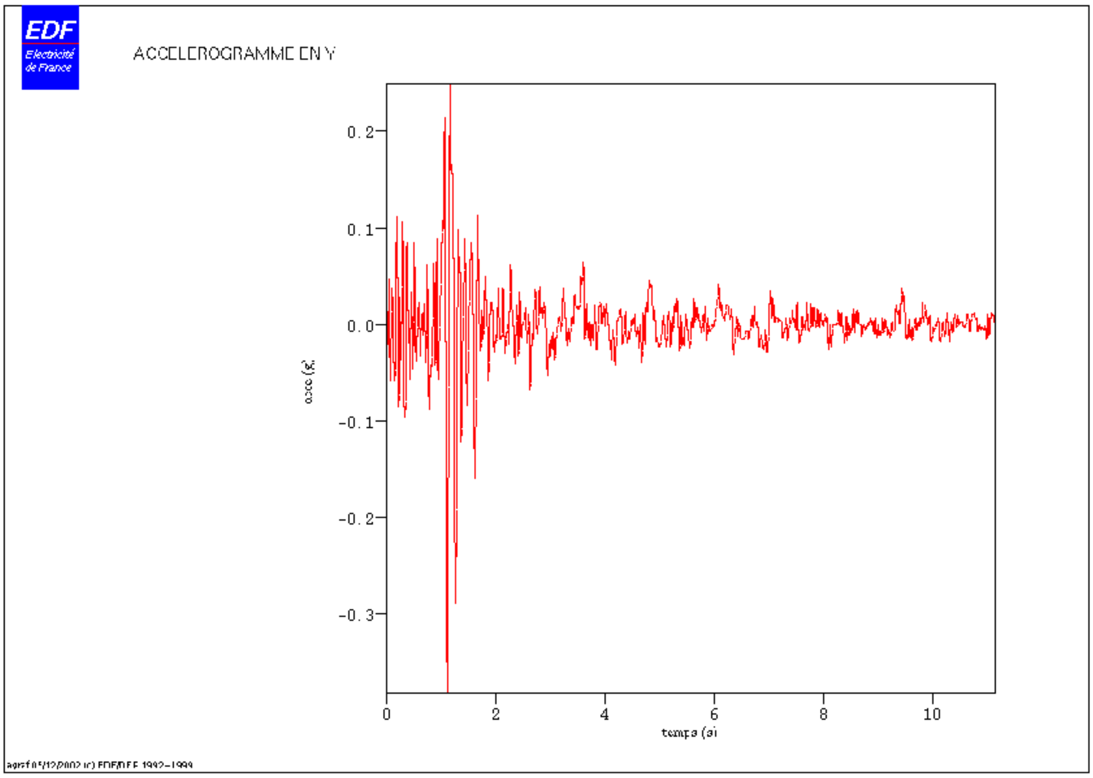
The mesh understands 80 meshes type PENTA15 and 696 meshes of type HEXA20.
The stopping is modelled in 3D.

3.3 Mechanical boundary conditions and loadings

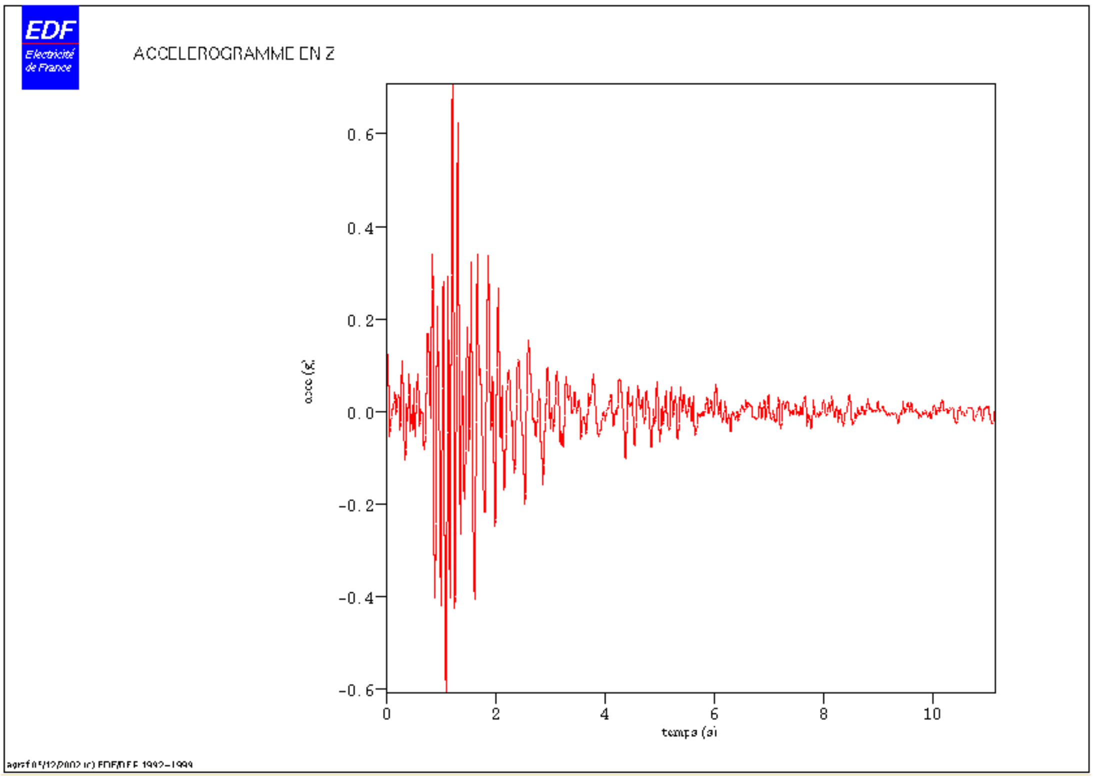
One blocks the node $N130$ at the base of the stopping and one imposes on the nodes group $BARFOND$ which constitutes the bottom of the stopping in contact with the foundation, a uniform displacement in all the directions. The node $N130$ interdependent of all the group $BARFOND$ is subjected to a seismic excitation in the 3 directions of space. The 3 accelerograms are represented on the figures [Figure 1.3 - has], [Figure 1.3-b], [Figure 1.3-c] below.



Appear 1.3-a: Acceleration Appears X



1.3-b of it: Acceleration Appears Y



1.3-c of it: Acceleration in Z

3.4 Quantities tested

One tests in m/s^2 maximum acceleration according to the 3 directions and the response sprectrum of oscillator corresponding (SRO) for a damping of 5% to the node $N1909$, medium of higher edge of the stopping.

4 Results of the modelization A

4.1 Values tested

Identification	Reference (m/s^2)
ACCEX ($t=1.0\,s$)	5.85886
SROX ($f=9.0\,Hz$)	17.6053
ACCEY ($t=1.0\,s$)	2.80757
SROY ($f=9.0\,Hz$)	9.7625
ACCEZ ($t=1.02\,s$)	– 0.77467
SROZ ($f=17.4\,Hz$)	3.81459

4.2 Summary of the results

the got results were confronted with those obtained with software EACD dedicated to this kind of computation. Although there no were precise statements of value with this software, the study [bib2] concluded with a good agreement with *Code_Aster*. However, one refers in this test with results of non regression got exclusively with *Code_Aster*.

5 Modelization B

5.1 Characteristic of the modelization

The modelization B contributes to the validation of the sequence *Code_Aster* - MISS3D by the frequential method of coupling in interaction (ISFS) soil-fluid-structure.
The software ProMISS3D [bib1] uses the frequential method of coupling to take account of the interaction soil - fluid-structure. This method, based on the dynamic substructuring, consists in cutting out the field of study in three subdomains:

- soil,
- fluid,
- the structure.

It results 4 possible types of interface from them:

- the interface soil-structure,
- the interface soil-fluid,
- the interface fluid-structure,
- the soil-free interface.

The modelization B by *Code_Aster* only requires to take into account structure of stopping and not the water reserve, nor the soil. It is enough to define their various interfaces in 2D.

5.2 Characteristics of the mesh

the use of the sequence *Code_Aster* - ProMISS3D requires to only net:

- the stopping arches in 3D,
- the various interfaces in 2D which are: soil on the surface, the surface of soil in contact with the bottom of reserve, the foundation of the stopping in contact with the soil, the surface of the stopping in contact with reserve.

The mesh provided to *Code_Aster* understands 1745 nodes on the whole and the following elements:

- The mesh voluminal of structure of stopping of 625 elements tetrahedrons TETRA10 in the group $STRVOU$,
- The mesh of the interface soil-structure including 80 surface elements QUAD8 and TRIA6 in the group $ISOLSTR$. This mesh group must be directed with its directed norm towards the soil,
- The mesh of the interface fluid-structure including 142 surface elements QUAD8 and TRIA6 in the group $IFLUSTR$. This mesh group must be directed with its directed norm towards reserve,
- The mesh of the interface fluid-soil including 126 surface elements QUAD8 and TRIA6 in the group $IFLUSOL$. This mesh group must be directed with its directed norm towards reserve,
- The mesh of the free soil including 280 surface elements QUAD8 and TRIA6 in the group $SLIBREM$.

5.3 Mechanical boundary conditions and loadings

One excites structure in the horizontal direction X with a loading of acceleration imposed on surface of the soil in harmonic far field $\gamma=\gamma_o \sin \omega t$ of unit modulus for various pulsations. That amounts in *Code_Aster* imposing this loading by means of key word `EXCIT_SOL` in `IMPR_MISS_3D`.

One calculates the eigen modes on basis blocked by considering a limiting condition of fixed support to the interface soil – structure by blocking the node $N316$ at the base of the stopping and while imposing on the nodes group $ISOLSTR2$ which constitutes the bottom of the stopping in contact with the foundation, a solid condition of connection.
Then, one calculates the static modes of constrained type from this limiting condition of fixed support by successively imposing a unit displacement of each of the 6 degrees of freedom of the node $N316$ of this interface.

5.4 Quantities tested and results

One carries out the computation of the first eigenfrequencies by integrating the impedance of soil and fluid with that of the field of structure.
One tests in m/s^2 acceleration in the direction X obtained for 2 frequencies with the node $N253$, medium of higher edge of the stopping.
One A finds the first 5 eigenfrequencies of a stopping with mass of added water obtained with the modelization around respectively: $3.5\,Hz$ $3.6\,Hz$ $4.9\,Hz$ $6.2\,Hz$ $7.5\,Hz$.

5.5 Summary of the results

the modal results correspond to the eigen modes of a stopping with mass of added water obtained with the modelization A and the seismic results of responses constitute a case of non regression.

6 Modelization C

6.1 Characteristic of the modelization and the mesh

The modelization C contributes to the validation of the functionality of modelization of the added mass of fluid per assignment of point masses to the nodes of the interface fluid-structure by means of option `MASS_AJOU` of operator `AFFE_CARA_ELEM`.
The modelization C by *Code_Aster* only requires to take into account structure of stopping and not the water reserve, nor the soil. It is enough to define the interfaces soil-structure and fluid-structure.

The mesh provided to *Code_Aster* is exactly the same one as that of modelization B but one takes into account in the modelization only the following parts :

- The stopping arches in 3D, which leans on the voluminal mesh of structure of stopping of 625 elements tetrahedrons TETRA10 in the group $STRVOU$,
- the interface soil-structure whose mesh understands 80 surface elements QUAD8 and TRIA6 in the group $ISOLSTR$,
- the interface fluid-structure whose mesh understands 142 surface elements QUAD8 and TRIA6 in the group $IFLUSTR$.

6.2 Mechanical boundary conditions and loadings

One calculates the eigen modes on basis blocked by considering a limiting condition of fixed support to the interface soil-structure by blocking the nodes group $ISOLSTR2$ which constitutes the bottom of the stopping in contact with the foundation. One affects then characteristics of point mass on the interface fluid-structure consisted the group $IFLUSTR$ by means of option `MASS_AJOU` of operator `AFFE_CARA_ELEM` .

6.3 Quantities tested and results

One carries out the computation of the first eigenfrequencies.
One finds the first 4 eigenfrequencies of a stopping obtained with the modelizations A and B around respectively: $3.5\,Hz$, $3.6\,Hz$, $4.9\,Hz$, $6.1\,Hz$.

6.4 Summary of the results

the modal results correspond to the eigen modes of a stopping with mass of added water obtained with the modelization A and confirmed by the modelization B with sequence *Code_Aster* - MISS3D by the frequential method of coupling.

7 Modelization D

7.1 Characteristic of the modelization

The modelization D, like the modelization B, contributes to the validation of the sequence *Code_Aster* - MISS3D by the frequential method of coupling in interaction (ISFS) soil-fluid-structure.
Moreover, it also utilizes the functionalities of resolution with taking into account of the spatial variability of incidental seismic field by the operator `DYNA_ISS_VARI` [bib3] with key word `ISSF`.
The modelization D, like the modelization B, only requires to take into account structure of stopping and not the water reserve, nor the soil. It is enough to define their various interfaces in 2D.

7.2 Characteristics of the mesh

the use of the sequence *Code_Aster* - ProMISS3D requires to only net:

- the stopping arches in 3D,
- the various interfaces in 2D which are: soil on the surface, the surface of soil in contact with the bottom of reserve, the foundation of the stopping in contact with the soil, the surface of the stopping in contact with reserve.

The mesh provided to *Code_Aster* understands 1745 nodes on the whole and the following elements:

- The mesh voluminal of structure of stopping of 625 elements tetrahedrons TETRA10 in the group $STRVOU$,
- The mesh interface soil-structure including 80 surface elements QUAD8 and TRIA6 in the group $ISOLSTR$. This mesh group must be directed with its directed norm towards the soil,
- The mesh of the interface fluid-structure including 142 surface elements QUAD8 and TRIA6 in the group $IFLUSTR$. This mesh group must be directed with its directed norm towards reserve,
- The mesh of the interface fluid-soil including 126 surface elements QUAD8 and TRIA6 in the group $IFLUSOL$. This mesh group must be directed with its directed norm towards reserve,
- The mesh of the free soil including 280 surface elements QUAD8 and TRIA6 in the group $SLIBREM$.

7.3 Mechanical boundary conditions and loadings

One excites structure in the horizontal direction X with a loading of acceleration imposed on the surface of the soil in far field. That amounts in *Code_Aster* imposing this loading by means of key word `EXCIT_SOL` in `IMPR_MISS_3D`.
The node $N316$ interdependent of all the formuleest $ISOLSTR2$ thus subjected to the seismic excitation in the form of imposed acceleration. The accelerogram is the same one as that used in the modelization A and is represented on the figure [Figure 1.3 - has].
One calculates the eigen modes on basis blocked by considering a limiting condition of fixed support to the interface soil – structure by blocking the node $N316$ at the base of the stopping and while imposing on the nodes group $ISOLSTR2$ which constitutes the bottom of the stopping in contact with the foundation, a solid condition of connection.
Then, one calculates the static modes of constrained type from this limiting condition of fixed support by successively imposing a unit displacement of each of the 6 degrees of freedom of the node $N316$ this interface.

7.4 Quantities tested and results

One proceeds to 2 resolutions with operator `DYNA_ISS_VARI`, one with a parameter of spatial variability `PARA_ALPHA=0` equivalent to a response without taking into account of the spatial variability and the other with a parameter of spatial variability `PARA_ALPHA=0.5`.
For these 2 results, one tests in m/s^2 maximum acceleration in the direction X obtained with the node $N253$, medium of higher edge of the stopping, at the same time on the temporal accelerogram like on the response sprectrum of corresponding oscillator (SRO) for a damping of 5%.

For computation without spatial variability, one finds results close to those of modelization A. the results of maximum acceleration in the direction X obtained with the node $N253$ with or without spatial variability are synthesized on the table below:

Without Variability	Acceleration (m/s^2)
ACCEX ($t=1.0\,s$)	5.56
SROX ($f=10.7\,Hz$)	17.62
With Variability	**Acceleration (m/s^2)**
ACCEX ($t=1.0\,s$)	4.36
SROX ($f=10{,}7\,Hz$)	13.69

7.5 Summary of the results

the seismic results of responses constitute a case of non regression but one can say that those obtained without seismic spatial variability correspond to those of a stopping with mass of added water obtained with modelization A. the results of seismic responses with spatial variability present compared to the case without variability a gain of an order of magnitude expected from approximately 25%.