F. How to properly present the finite element calculation note?

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This paragraph provides the minimum elements that must be included in a note in order to provide a clear description of a finite element calculation model.

First of all, the modeling note cannot be the first note of the project. It is either preceded or accompanied by the general assumptions note. The general assumptions note provides essential information about materials, foundation stiffnesses, load cases and combinations, and all the justifications that will have to be carried out on the structure. Ideally, the two notes are written in parallel.

Often, points that would have their rightful place in the hypothesis note or in the modeling note are deferred to a later note. This way of doing things is harmful insofar as the clarifications arrive afterwards with a very long note containing the results and sometimes even the justifications ... generating tensions with the Project Manager in charge of the verifications (or the controller) when the latter will require to complete the work or even redo it and, above all, wasting time for all the parties involved.

It is fundamental to understand that there is a real leverage effect involved and that it is better to spend some time detailing and fixing the elements at the beginning and have them validated. This will greatly improve the process.

Let us not forget that in a basic verification mission, the general hypothesis note is the only one that will be subject to an in-depth examination by the Project Manager.

F.1 Note introduction - Description of the object of the calculation

a) The EF calculation note must begin with a brief reminder of the object under study. Excerpts from blueprints are always welcome.

b) The study phase should also be mentioned. If the study phase is advanced, it is interesting to remind how the subject has been treated in the previous phases. Sometimes a simpler model was developed in the previous phase, sometimes a manual calculation was done. In both cases, the note should compare the results of the simplified model and the more complete model.

c) It is advisable to specify the calculation objectives, i.e. the justifications that one intends to carry out with this model: global stability, internal efforts, deformations... The model is not an objective in itself, it is merely a tool to obtain a result.

d) It is not mandatory to use a single model for all project justifications. Specify what will not be covered by the current model but by another sub-model.

e) The modeling note must declare all documentary references used: blueprints with their index, market parts, calculation or geotechnical notes.

f) In case of a model update, the changes made must be explicitly traced.

g) The note must describe the principle of the results exploitation, the direct software outputs and the possible post-processing that are contemplated.

F.2 Geometrical description of the model

a) The physical boundaries of the study should be very clearly defined: which elements are modeled and which are not. Some secondary structures often do not need to be modeled (stairs or walkways, equipment). Some main structures can be simplified such as bridge abutments or piles, which can be represented by supports with their flexibility. In case of a succession of structures, the modeling boundaries must be described with the way to take into account the interaction with adjacent non-modeled structures.

b) Hypotheses for geometric simplification, choice of nodes and sections must be set out in detail. The provision of a complete listing of the calculation file cannot satisfy this request. Drawings are required. Hand sketches, which the engineer uses when coding, can advantageously be provided. They help understanding the modeling logic.

c) If there is an exchange between the drawing software and the finite elements software, it is interesting to indicate it.

d) All the units used must be explained: distances, forces, stresses and masses. By default, the SI system is preferred.

e) Define the global coordinate system for the model and recall the efforts sign convention for all support reactions.

f) The same applies to the finite elements: the local coordinate system and the sign conventions adopted by the software for stresses and strains should be indicated.

g) Images and graphic outputs are interesting to visualize the model, but they should be accompanied by the corresponding descriptions. A modeling note consisting of a series of screenshots is not acceptable.

F.3 Finite elements description

a) As discussed in Chapter B, the software choice depends on many criteria. It is necessary to explain, even briefly, why the software used is appropriate. If it has computational limitations, do not hesitate to write it down and explain how these limitations will be overcome.

b) Description of FE properties: this part is often missing in the description, yet some software has a wide variety of element types that do not have the same functionality. In particular, for plate models, the elements take or do not take into account membrane effects, which may change the results; this is also the case in 1D for shear strain in beams.

c) Describe the number of nodes, the size of the elements, the mesh type. If a mesh refinement test has been performed (as recommended in paragraph d), report it.

d) For a bar model, a table of the mechanical properties of the bars must be provided.

e) The link between the global coordinate system and the local coordinate system should be illustrated with screenshots. Most software programs have quite explicit ways of displaying the coordinate systems. Note that it is often possible and useful to force the coordinate systems in order to facilitate the results analysis.

f) It is interesting to give the number of elements as well as the number of degrees of freedom of the model.

F.4 Mechanical description of the model

a) The properties of the materials must be fully explained: density, Young's modulus, Poisson's ratio, static behavior law, shrinkage, creep or relaxation laws...

b) Boundary conditions must be correctly described. The static diagram must be recalled, along with how the supports are modeled. If a stiffness matrix is introduced, explain how it has been calibrated from geotechnical parameters.

c) If supporting devices are present, specify whether they are modeled by bars with special characteristics or by special connections in the model.

d) Non-structural elements (equipment) must be listed and it must be specified which ones are modeled or, conversely, taken into account as loads. As indicated in c), this choice depends on the stiffness and mass of these non-structural elements.

e) The way in which efforts and loads are introduced is not evident. It must be specified whether the software does automatic load placement, incremental load positioning or whether load cases are entered manually.

f) In the case of a force to be introduced on a cut, it is necessary to illustrate how this force diffuses in the model (spider connecting the edges of the cut).

g) In general, and in particular for seismic or dynamic calculations, it is necessary to detail how the masses are introduced into the model. If the mass of the elements is generated automatically by the software, in the assembly areas, there are volumes counted twice; it is therefore necessary to be able to correct the densities. Non-structural elements modeled by load cases are not recognized as masses and have to be added. A manual verification of the global mass of the model is always useful and reassuring.

F.5 Demonstration of the self-monitoring approach

Self-monitoring is a fundamental element of the modeling quality.

This self-monitoring process must be visible to the person who is going to verify the calculation note.

a) Tests and elements of verification of the mesh validity must be mentioned.

b) All the model validation tests that have been conducted contribute to win the controller's trust. It is not a question of providing a large amount of information and data, but just indicating the tests that have been conducted.

c) On the other hand, the verification tests for the vertical load calculations are absolutely essential. They must at least include the structural self weight, the self weight of the equipment, a uniformly distributed load and cases of thermal loads.

d) This also includes global mass verification for dynamic and seismic models.

F.6 Description of effort recovery and post-processing

a) It is necessary to describe in which form the efforts or displacements of the model are recovered (listings, graph and chart reading, screen display).

b) In cases where the results are expressed in a local coordinate system and a change of coordinate system is necessary afterward, the risk of error is frequent. The validity of the baseline change must be demonstrated.

c) In general, the process of post-processing the efforts, with the associated tests, should be described.

d) For combinations and envelopes, it is necessary to say whether they are made by post-processing or directly by the software. In the second case, it is necessary to indicate if the combinations are formed manually or if they are automatic (source of error). In any case, it must be specified whether the combinations and envelopes generate concomitant forces or not.

F.7 Results report

The results are often presented in the form of tables, sometimes cumbersome to understand.

a) As said before, the system of units must be defined and the units must be systematically indicated in the table

columns.

b) It is necessary to recall the vertical loads calculation for elementary load cases.

c) The dimensioning values in the tables must be highlighted (highlighted, circled or put in bold or red, etc.).

d) Result listings should not be in the body of the text. They make the document more difficult to understand and lead to unnecessary printing. They will be placed in an appendix.

F.8 Specific complements for volume elements

a) The choice of cross-sections must be consistent with the expected results and must be consistent with the critical plans of the structure.

b) In the same way as for surface elements, the software offers a wide variety of volume elements, with different codes. Some elements are very specific to certain materials and certain types of calculation. It is necessary to refer to the software's manual to choose the "simplest" element, unless there is a very particular need.

c) It is advisable to give priority to results in the form of steel mapping highlighting the dimensioning points and specifying whether the values are smoothed or at nodes, for example.

d) In the case of forces integration on a cross-section, it is useful to explain the method chosen.

F.9 Specific complements for non-linear calculations

a) It is necessary to provide the behavior law used, which may be different from the standard law of the software.

b) It is interesting to present, in the calculation note, the evolution of a remarkable magnitude (displacement of a point, specific effort, etc.) during the increase of the load, to visualize the plasticity.

F.10 Specific complements for dynamic calculations

a) If a spectrum automatically provided by the software is used, it must be demonstrated that it has been verified to be consistent with the expected spectrum.

b) It is necessary to define the selected damping (which is not the same in dynamics and seismic) and/or the behavior coefficients for seismic calculations.

c) The participating masses and mode participation coefficients must be given mode by mode, and modal combinations and modal sign conventions must be specified, if applicable.

d) Modal deformations should be presented for the most representative modes. The modes shape is an important element in verifying the global structural behavior.

e) For a calculation by time steps, as for the non-linear calculation, it is interesting to present the temporal evolution of the representative quantities (displacements, accelerations, etc.).

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