Energiforsk Seminar: "Anchor Bolts for Nuclear Power plant Applications-Design and Assessment

Stockholm 2015-11-03

Design work for future evaluation of anchor plate capacity in existing or new structures

1. Scope

The aim of the present paper is to present the principal problems regarding the design of anchor plates for process installations in a nuclear plant. The anchor plates constitute the border line between the civil concrete structure and the internal process installations. Thus cooperation is needed between the civil designers and the process designers. Both parties must be aware and respect the tolerance requirements of the other party.

The paper includes the following issues:

- A historical background of how anchor plates in present plants were designed originally
- An example from Oskarshamn lll illustrating how previous reviews of existing plants could be done
- Ideas on the same procedure for future evaluations with regard to latest research works

2. Original design in the 70ties and 80-ties of anchor plates in Nordic NPPs

The "bulk part" of anchor plates were chosen among various standard plates (in the order of 20-50 different types). For a NPP of the 70-ties and 80-ties the number of standard plates was in the order of "some ten thousand". For special cases special anchor plates were designed for "large forces", notably for the reactor containment. In the present paper those large special plates have been omitted, as they often were affected by some few dimensioning load cases only. For the large bulk of plates there might be a large number of load cases to be considered with the various types of failures as presented by previous speakers of the present seminar,

Each standard plate was denoted with allowed loads (3 forces F1, F2, F3 and 3 moments M1, M2, M3 around 3 coordinate axes) based upon requirements on how adherent steels profiles might be placed on the plate.

In principle the choice of anchor plate was made by the process designer and checked by the civil designer. For obvious reasons, the civil designer was responsible for the concrete structures including loads from the anchor plates. The process designer had to regard not only tolerances for the process equipment but also the tolerances for the construction (Typical values: +/- 50mm in the surfaces of walls, columns, slabs and beams and +/- 20mm perpendicular to the surface).

The choice of anchor plate was made due to the geometrical requirements and due to the actual forces and moments. With regard to forces and moments the following simple formula was used:

"a" =allowed (different values for SLS and various ULS cases)

$F1/F1a + F2/F2a + F3/F3a + M1/M1a + M2/M2a + M3/M3a < 1$

This formula is conservative. In general it was used instead of making analyses for the actual forces and moments. As a rule it was considered easier and more rational to use a larger standard plate than to make additional analyses for a smaller plate. Moreover, in general the process designers did not analyze various load cases but combined the maximum forces and moments although those were calculated for different load cases. The cost for the choice of a larger plate than necessary was in the same order as engineering costs for the evaluation

Conclusion: The method for the original choice of anchor plates resulted in general conservatism regarding load bearing capacities

3. Review example: Project PULS for Oskarshamn III

Several NPPs built in the 70-ties and 80-ties have been updated during the last decade mainly due to additional safety requirements and/or effect increase of the plant. One example is the PULS project of Oskarshamn lll (carried out by OKG/Westinghouse with SWECO as civil consultant for the anchor plates).For the PULS project it was decided to reanalyze all the anchor plates with regard to new codes and to up-dated process loads. As a brief general estimation the new codes were more conservative than the old ones and the up-dated loads were smaller than the original loads. However, there were also cases when the loads had been increased.

A brief analysis for the bulk part of standard plates showed that the majority probably would satisfy the new requirements but it would be time consuming to analyze plate by plate using general hand calculation methods. Thus, it was decided to develop a special software scanning programme in order to sort out the “approved plates” making it possible to reduce the amount of hand calculations.

The new codes were more conservative than the old ones and among other things based on the research works done by prof. Rolf Eligehausen as presented earlier on the present seminar. Prof. Eligehausen was specially engaged by OKG/Westinghouse to make guidelines for the PULS project with regard to his own research work and to requirements in ACI and Eurocodes. Simultaneously it was decided by OKG/Westinghouse to engage Prof. Lennart Elfgren and Martin Nilsson of Luleå University to perform research on the influence of surface reinforcement adjacent to an anchor plate. Their work was concentrated on tensile capacity for anchor bars with regard to surface reinforcement. Their results were not used in the scanning programme but in the cases where later additional hand calculations were needed.

Design inputs to the scanning programme:

-All loads were supplied by Westinghouse process designer in a standardized format complying with the scanning programme.
- For each plate the allowed 3 forces and 3 moments were calculated according to the guidelines from Prof. Eligehausen
-For each plate the values for the allowed 3 forces and 3 moments were listed. These values were reduced with regard to adjacent holes and recesses in the concrete structures. Credit was made for the fact that the concrete structure had an age of appr. 25 years, i.e. with higher strength than at construction.
-When 2 or more plates were placed close to one another special considerations were made. In general it was assumed that the adjacent plates might be loaded simultaneously. In the scanning programme such cases were conservatively simplified as an imaginary free edge between the adjacent plates (Evidently a most conservative approach).

Results of the scanning. Additional hand calculations:

- The order of 70%-90% of the bulk plates were approved due to the scanning procedure. This is of course a success story. On the other hand, still some thousand plates had to be dealt with using additional conventional time consuming hand calculations.
- The additional hand calculation for "not approved" plates included the research results from Elfgren/Nilsson and also included special calculations for groups with several adjacent plates.
- If the first hand calculations did not show positive results, the plate was inspected on site. In several such cases the jointed steel profile was fixed with smaller tolerances than originally allowed. With more favourable geometry than assumed it was often possible to verify the bearing capacity.
- For a "small" number of plates it was judged necessary to replace the plate, preferably with a new plate in the vicinity of the old one. This was done not only due to load capacity reasons.
- With considerable effort it proved possible to show that all the anchor plates of Oskarshamn lll fulfilled today´s requirements. This would hardly have been possible without the newly achieved research results from Elfgren/Nilsson.

Conclusions

There are 2 major reasons why it was possible to prove the feasibility of the existing anchor plates:

- General conservatism in the original design from the 70-ties and 80-ties
- The existence today of efficient IT tools. At present, it is not any problem to analyze each load case and thus to take credit of earlier conservatism. Thus, it was rational to develop and use a scanning programme

More "approval possibilities" should be added to the scanning programme not the least the latest research results. An important aim would be to increase the bending moment capacities by crediting existing bending reinforcement in the vicinity of the anchor plate. The same applies to the allowed forces for "pry-out" failure and similar.

4. Design procedure for future plants

There are no facts indicating that the “Anchor plate option” should be abandoned as the border line between process equipment and civil structure.

For future plants it would be rational to repeat the principle from the 70-ties that the process designer makes the choice of anchor plates. This choice should be made using a scanning programme in order to reduce general conservatism. As the authors understand the code development, the concrete structures for a future NPP will be constructed with general shear reinforcement. As a consequence, it would be rational that each anchor plate is combined with some shear bars around the periphery of the plate. Thus, the allowed forces and moments for the various anchors probably may be increased considerably.

5. Final words

It is axiomatic that future research results would be important for the rational design of anchor plates in future plants

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