An Overview of Recent Studies on Structural Damages of Containment Building Subjected to Steam Explosion Loads

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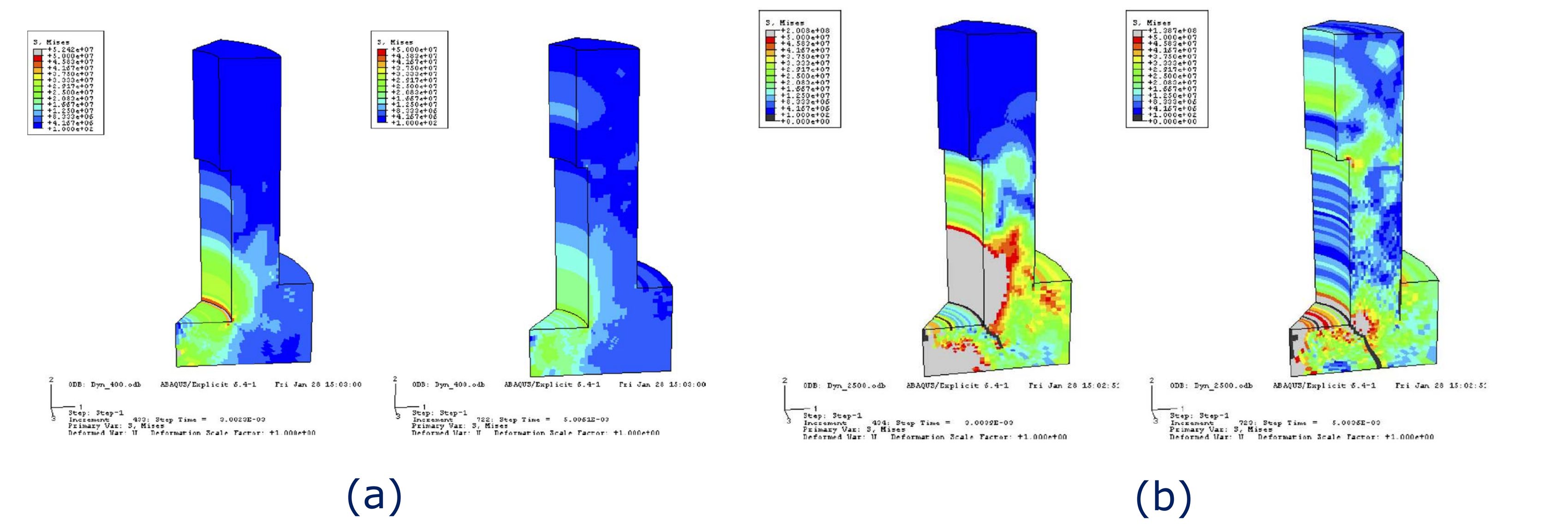
Introduction

- Up to date, it is still challenging to evaluate the structural damages of the containment buildings subjected to the steam explosion loads due to the complex shock waves, complex geometric structures, and complex mechanical behaviors of materials under dynamic loading [1].
- In this paper, some recent studies regarding numerical analysis to assess structural damages of the containment buildings under the steam explosion loads have been reviewed.

Cizelj et al. (2006)

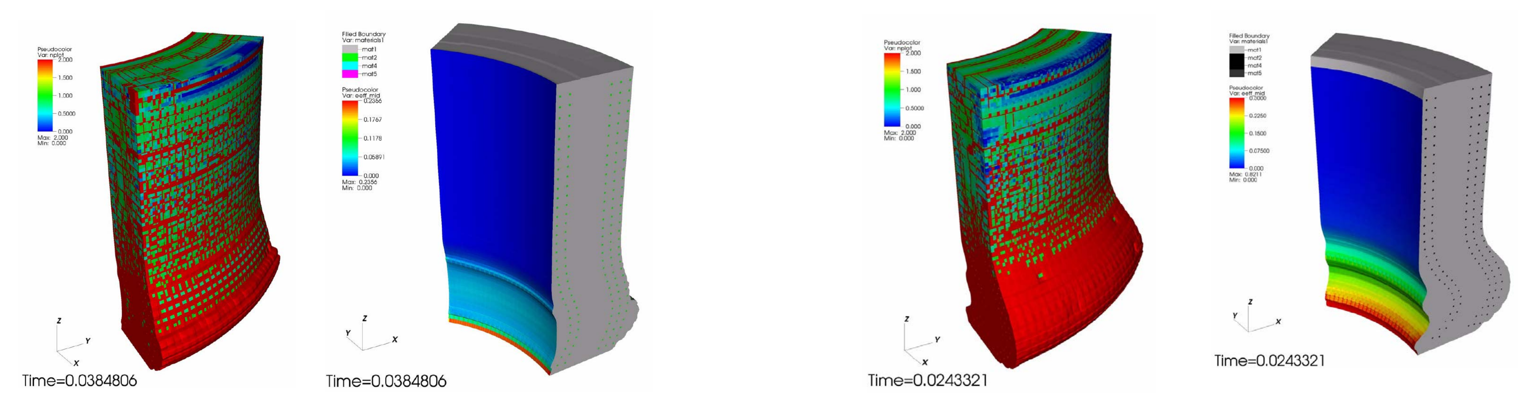
- Cizelj et al. carried out numerical research to estimate the steam explosion pressures and to evaluate the structural damages of the typical PWR cavity subjected to their steam explosion pressures [2].
- From structural analyses, it was concluded that no damage was observed in the case of the pre-mixture pressure of 40 MPa, and the localized damages from the minor to medium levels were also observed in the case of the pre-mixture pressure of 250 MPa.
- Although there were potential localized damages of cavity walls, the entire collapse of the whole cavity was prevented for both cases.



The von-Mises stresses contour of the reactor cavity wall under the pre-mixture pressure of 40 MPa (a) and 250 MPa (b) [2]

Noble (2007)

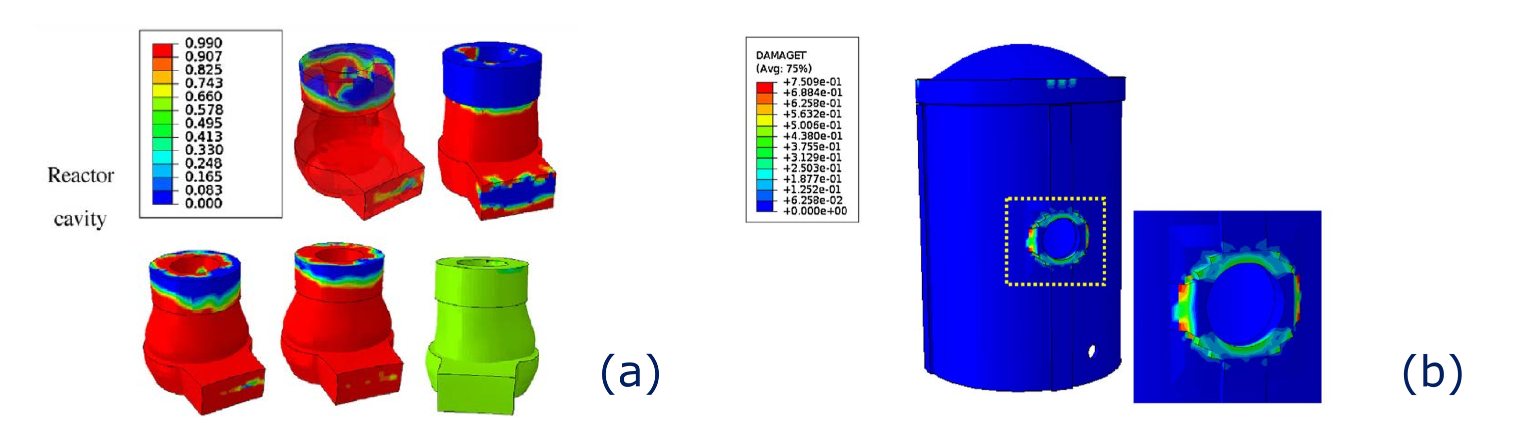
- Noble reported a series of numerical analyses, including finite element model assumptions for ESBWR pedestal wall and its failure criteria [3]. The report aims at determining the structural damages of the ESBWR pedestal wall subjected to steam explosion pressures.
- For the 300 KPa-sec case, it was seen that concrete was fully damaged at the base of the pedestal wall, however, the damaged concrete may be confined within the rebar mat. It was also observed that peak strains of the steel liner were near 20~24% at the base of the pedestal wall. Thus, total failure of the pedestal wall may be prevented.
- For the 600 KPa-sec case, it was shown that concrete was extensively damaged throughout the base of the pedestal wall. It was also seen that effective plastic strains of the steel liner and all the rebar reached a level of 30% and 20% at the base of the pedestal wall. Thus, the pedestal wall would fail for the 600 KPa-sec case.



Concrete damage and effective plastic strain of inner steel liner of the cavity wall for the 300 KPa-sec case (a) and the 600 KPa-sec case (b) [3].

Chunyu et al. (2014)

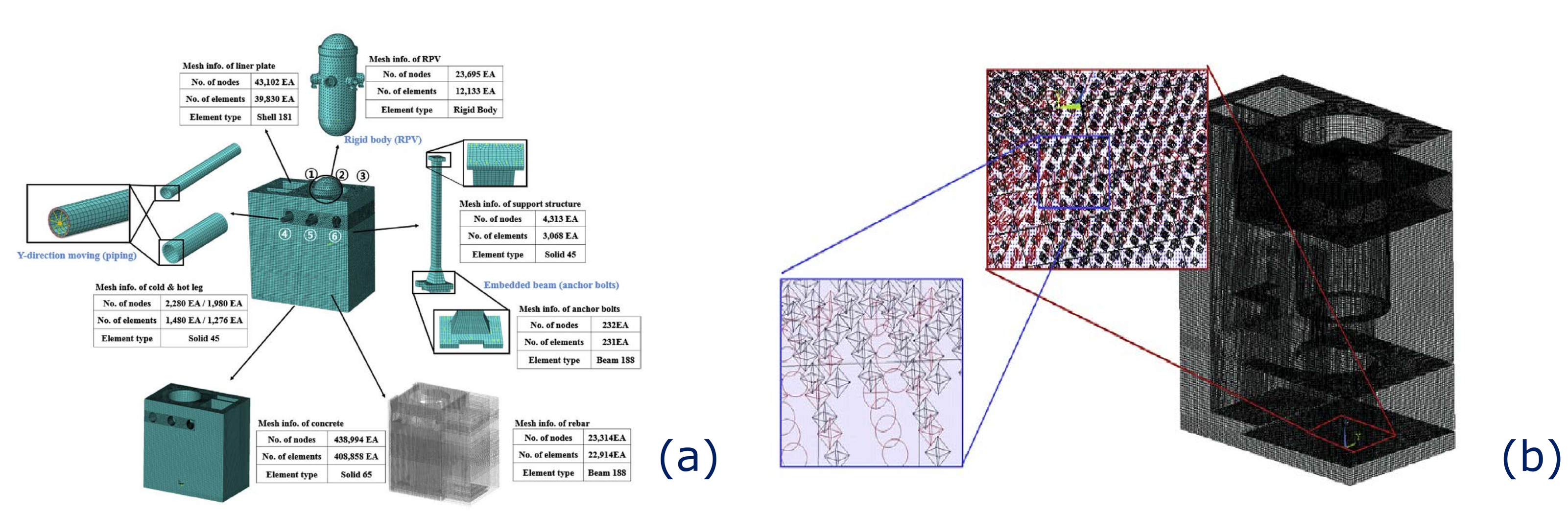
- Chunyu et al. conducted a series of numerical studies to assess the structural damages of a whole containment building of the CPR1000 subjected to steam explosion loads [1].
- In particular, a scalar damage parameter, d in the concrete damaged plasticity model was chosen to determine the damage and failure of the CPR1000 containment building, where d = 0 indicates no damage and d=1 means complete failure.
- It was shown that both the reactor cavity and the baseboards were severely damaged, however, the basement was partially damaged.
- No damage to the penetration part of the containment wall was observed since an only small fraction of blast energy was transferred to the containment. Finally, the structural integrity of the containment wall can be ensured.



Damage of the reactor cavity (a) and containment wall (b) affected by steam explosion loads [1]

Kim et al. (2015)

- Kim et al. performed primarily numerical analyses to evaluate structural response and damages of the reactor cavity under various steam explosion conditions [4].
- For this, a combined numerical approach with CFD analysis and FE analysis was carried out to predict the steam explosion pressure loads.
- It was shown from FE analysis that the maximum stresses of rebar were higher than the corresponding yield strength, whereas the maximum stresses of the concrete were sufficiently lower than its yield strength. Small vertical displacements of major components were observed compared to their overall dimensions.
- It was concluded that there were potential minor or medium local damages of the reactor cavity, however, the structural integrity of the reactor cavity was maintained under the steam explosion conditions.



Combined FE models (a) and damages of concrete for the reactor cavity (b) [4]

Conclusions

- Overall, various structural failure criteria were used to determine the structural damages of the containment buildings subjected to the steam explosion loads.
- Further, the detailed discussion needs to determine proper structural failure criteria for structural integrity assessment of the containment buildings under steam explosion conditions.

ACKNOWLEDGEMENT

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