

## Scabbing and Perforation of R/C Walls Designed for Aircraft Impact Protection

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### **Abstract:**

As an accepted standard for assessment of aircraft impact, NEI 07-13 provides formulae for evaluating missile penetration, backside scabbing, and complete perforation of reinforced concrete walls impacted by hard missiles generated from aircraft crash scenarios. In NEI 07-13, the jet engine is considered bounding for damage due to hard missile impact, and thus the formulae are based on previous testing and research involving turbojet engines, typical of military aircraft, and modified for the more crushable turbofan engines typical of large commercial aircraft. The testing results used as the bases for these formulae necessarily had some limitations on the range of parameters considered, most notably the mass and impact velocity combination (momentum) of the impacting missile and the configuration of the reinforced concrete wall including concrete strength and reinforcement density. The testing was mainly concerned with as-designed walls and accidental crashes, and thus only considered nominally reinforced walls of typical concrete strength. The goal of aircraft impact assessments is to identify design enhancements that help protect the plant in case of aircraft impact, and one area for improved protection is strengthening concrete walls. Strengthened concrete walls can involve higher strength concrete, thicker sections, enhanced reinforcement, or a combination of these. These strengthened walls along with the size and velocity of engines under consideration for malevolent aircraft impact mean that the parameters of interest may be outside the applicable range of the formulae in NEI 07-13. Considering that the formulae for perforation and scabbing are independent of reinforcement ratio, which implies that a heavily reinforced wall is no more protective against hard missile impact than a lightly reinforced wall. The NEI formulae would be considered conservative in this regard, but the intent of NEI 07-13 is to provide methodology for median based, best estimate assessments for aircraft impact as a beyond design basis event.

This paper introduces methodology used to investigate local perforation and scabbing in a reinforced concrete wall stemming from impact by a turbofan engine as representative of hard missile impact due to aircraft impact, which is outside the applicable range of formulae in NEI 07-13. The intent is to better credit the actual resistance of the wall using methods consistent with the NEI 07-13 methodology for structural assessments.

The outline of the methodology is as following;

A model for a representative hard missile is developed and benchmarked to the NEI 07-13 perforation and residual velocity formulae within the formulae limitations. A reinforced concrete wall model for assessing the potential for scabbing is developed and benchmarked to test data. These modeling methods are then used to study the resistance of a reinforced concrete wall to scabbing and perforation under the conditions of interest. Having developed the finite element representation of the impacting engine and the reinforced concrete wall model to determine the extent of concrete scabbing, the benchmarked engine is impacted against the design wall. Then, the methodology is validated through comparison between past test result and the analysis result.

An analytical approach is developed and shown in this paper for best estimate assessment of scabbing and perforation of reinforced concrete walls when the conditions of interest for scabbing and perforation are outside the range of the limitation of NEI 07-13 formulae.

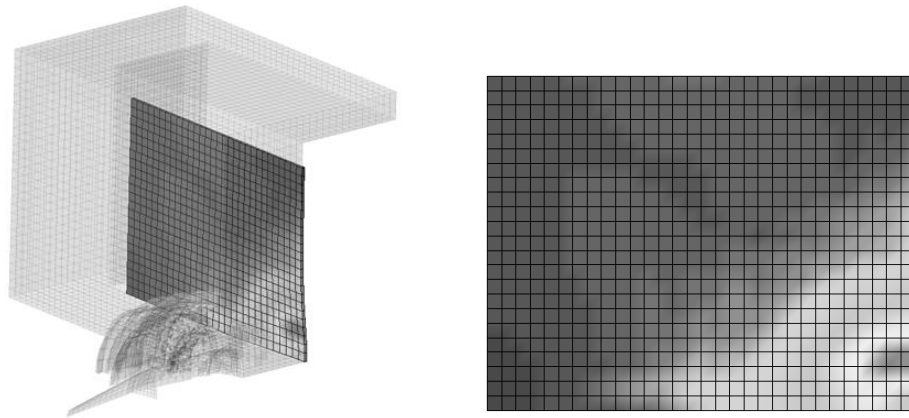


Figure: Finite Element model for impact analysis (Kjolsing, E. et al. 2017)

**Keywords:** *Aircraft Impact, hard missile impact, Scabbing, Perforation,*

**Reference:**

1) Kjolsing, E., James, R, Nagashima, G., Mori, K., (2019) “Scabbing and Perforation of R/C Walls Designed for Aircraft Impact Protection,” SMiRT-25, Charlotte, NC, U.S.A.