

ANNEX D

REQUIREMENTS FOR BLAST EFFECT ANALYSIS (BEA)/ STRUCTURAL RESILIENCY STUDY (SRS)

1. The BEA/SRS documentation shall include:
 - a. Derivation of the explosive loads:
 - i. blast overpressures (free-field, reflected and/or confined);
 - ii. fragmentation;
 - iii. explosion-resultant fireballs; and
 - iv. ground shock.
 - b. Indication of physical dimensions and material properties of all structural components (including reinforcement details for reinforced concrete components) analysed;
 - c. Computation of the ductile mode response (i.e. flexure, diagonal and direct shear) of the building components;
 - d. Computation of the brittle mode response (i.e. spalling, breaching and cratering) of the building components; and
 - e. Assessment of the consequences of the explosive loads on the critical assets.
2. Structural details and material properties from the structural engineering team, rather than assumed ones, shall be used for the analysis.
3. For response analysis of structural components (i.e. load-bearing members, e.g. columns, beams, slabs, walls etc.), the below specified methodologies shall be applied:
 - a. Single-Degree-Of-Freedom (SDOF) or Multi-Degree-Of-Freedom (MDOF)¹ for analysis of ductile mode response (flexural, diagonal and direct shear) when subjected to air blast from an explosive charge at a scaled standoff distance of $\geq 0.4 \text{ m/kg}^{1/3}$, and otherwise when the scaled distance is less than $0.4 \text{ m/kg}^{1/3}$, SDOF or MDOF shall not be used;
 - b. Methods found in Unified Facilities Criteria (UFC) 3-340-02 for determination of whether a concrete component will spall or breach when subjected to a case/uncased explosive charge in contact/near-contact.

¹ MDOF (rather than SDOF) shall be used where it is not appropriate to analyse a structural component from another connected component independently of each other.

- c. Numerical modelling and simulation, provided that information on the validation of the numerical model with results of actual full-scale blast tests conducted on equivalent structural components and scaled distances is made available to MHA upon request.
4. For response analysis of non-structural components (e.g. brickwall, glazing, doors, equipment etc.), the following methodologies shall be applied:
 - a. Methodologies and guidelines defined in established codes and/or literature, provided that a complete copy of the codes / literature used is made available to the MHA upon request and that relevant sections of the codes / literature used in the analysis are clearly pointed out; and/or
 - b. Numerical modelling and simulation, provided that information on the validation of the numerical model with results of actual full-scale blast tests conducted on equivalent structural components and scaled distances are made available to MHA upon request.
5. For global structural response using Alternate Load Path analysis where a structural column or load-bearing wall is assessed to fail due to explosive loads, the analytical procedures set out in the United Facilities Criteria (UFC) 4-023-03 shall be adopted. Considerations such as dynamic increase factors, load factors, joints resistance functions, pass/fail criteria for joint rotations, etc., have to be incorporated.
6. Results from actual full-scale blast tests can be used for analysis, provided that the tests are conducted with equal or higher blast loads on test subjects similar to the analysed components and that full information of the tests are made available to MHA.
7. MHA reserves the right to request for additional information and clarification from the CP on the methodologies used in the analysis.