

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.
 - c. Numerical modelling and simulation, provided that information on the validation of the numerical model with results of actual full-scale

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.

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.

8. The BEA and SRS Outline Templates are attached in Annex D1 and Annex D2, respectively. These templates serve as a guide to illustrate on what are the essential information to be included and how this information could be presented in a more systematic manner.

1. The Blast Effect Analysis (BEA) shall be a document that presents a concise and comprehensive coverage of the following pertinent areas:
 - a. The key assessment outcomes on the identified components (cross-referenced from TVRA) which are exposed to the threats and then determine their corresponding impacts/consequences on the critical assets of the building.
 - b. Carry out risk prioritization on these outcomes according to the acceptance criteria which are agreed with the relevant stakeholder(s).
2. To facilitate the SBD review, the CP (Blast) should ensure that the BEA has comprehensively covered the following key areas:
 - a. Executive Summary

The executive summary shall provide a brief summary of the purpose of this BEA study and summarise the BEA outcomes, similar to Table A.

Table A – Summary of BEA Outcomes

S/N	Location	Element Type/ID	Existing Dimension	Existing Structural Details ²	Charge Weight & Standoff ³	Predicted Impacts/Consequences ⁴
Eg 1	Atrium	Column / 2A4	L800mm x W800mm Span: 4m	Conc Gr: 40 MPa Steel Gr: 460 MPa Main Rebar: 12T20 Shear Links: T10@200 Connection Details	250kg @ 1.5m	Column fails.
Eg 2	Office Room	Glazing / 4G5	L200mm x W300mm	Conc Gr: 40 MPa Steel Gr: 460 MPa Main Rebar: 10T40 Shear Links: T10@150 Connection Details	250kg @ 8m	Glazing fails, resulting in debris that may cause injury or death to critical personnel sitting inside office.

² The structural details shall include (but not limited) material grades, reinforcement details, connection details, etc, where applicable.

³ Standoff distance is defined as the distance measured from the center of charge to the structural surface of the critical asset facility.

⁴ The Consultant shall ensure that the predicted impacts/consequences are reflected consistently in the TVRA report.

b. Introduction

This shall provide a brief description of the project background, scope of the assessment and the security objective(s); and shall also include, but not limited, to the following pertinent information, so that the reader has an overview understanding of this project.

- i. Indication of development classification, e.g. Category (I/II/III) Infrastructure under the Critical Infrastructure Programme (CIP) Framework or High Profile Development (HPD).
- ii. Indication of new development or Addition and Alteration (A&A) works; and state the changes/modification for A&A works clearly, preferably illustrating them on drawings.
- iii. Description of the structural framing system.
- iv. State the development's locality and provide clear orientation of the development (e.g. illustrating public and restricted access areas on drawings).
- v. List of critical assets and threat scenarios (include the rationale behind the creation of each threat scenarios).
- vi. The location of the critical assets with its respective standoff distances from the threat shall be clearly illustrated on the drawings.

c. Design Methodology

This shall provide concise and comprehensive description on the design approach (quoting all relevant references, code of practices and standards that are being adopted for the design). It shall also include, but not limited to the following areas:

- i. All assumptions shall be listed clearly and provide appropriate explanation (substantiated with relevant references, code of practices and standards, if applicable) why such assumptions are adopted.
- ii. Derivation of explosive loading (all applicable weapon effects to be considered, e.g. blast overpressure, confinement effects, fragmentation, fireball and ground shock).
- iii. Description of methodology/software (e.g. CONWEP, Shock & Frang, Autodyn, ETABS, etc) for the derivation of each type of loading/weapon effects and the component responses to the structures.
 - For SDOF, methodology to derive the uniform distributed load is to be included.
 - If numerical simulation software is used, explanation on verification & validation of the results is to be included.

(Note that only the approved verification and validation of the software can be used for the numerical simulation.)

- iv. Stating the appropriate acceptance criteria, e.g. Glazing: GSA 3A, Support rotation: $\leq 2^\circ$ (PDC - Protective Design Center), Human and Equipment survival criteria.
- v. The design methodology and acceptance criteria shall be discussed and agreed with the relevant stakeholder(s); and the stakeholder(s)' agreement in acceptance of the criteria and/or undertaking of any form of residual risks shall be properly documented in this report.

d. Blast Effect Analysis

The blast effect analysis is done at component levels in identifying the survivability of the key components which are likely subjected to the blast threats. Thereafter, determine the corresponding consequences and impacts on the critical assets of the building.

The various design checks are to be done in accordance to relevant and prevailing codes and practices, reference and standards. As a guide, CP(Blast) could refer to the design checks tabulated in Table D for reference.

3. The report generated should comprise, but not limited to, the above key items in separate chapters and should generally follow the order listed.
4. Relevant documents and drawings shall be attached in the Appendix of the report for easy reference and a suggested list is as shown in Table B.

Table B – List of information⁵, Required in the Appendix

S/N	Description of Documents/Drawings
1	Site/Location Plan
2	Architectural Layouts and Elevations ⁶
3	Architectural Details, e.g. opening sizes of doors, louvers, windows, etc ⁶
4	Structural Layouts and Elevations ⁶
5	Structural Details, e.g. dimensions and reinforcement details for columns, beams and slabs ⁶
6	Layout(s) showing the location of critical assets and their respective standoff distances from the threat
7	Layout(s) showing the demarcated boundary of public and restricted access areas

⁵ Provide only those documents/drawings (NOT the entirety) that are relevant to this study. Drawings shall be provided in PDF format, A3 size with details clearly annotated. Reports and/or other kind of information shall be provided in PDF format.

⁶ If detailed information are not ready to be included in the drawings, Consultant is to provide key preliminary information (e.g. indication of floor levels, access points, beams/slabs/columns/walls dimensions and rebar details, etc.) that are essential for review.

8	Drawing(s) showing all changes that are relevant to the SBD submission for the facility (applicable for A&A works and any SBD amendment submission)
9	References, Code of Practices and Standards, where applicable
10	For Structural Components: detailed calculations for all local and global checks
11	For Non-Structural Components (e.g. glazing, equipment, roller shutter, etc): detailed calculations that are relevant to justify its survivability
12	For Human Injury Prediction: detailed calculations that are relevant to justify its survivability
13	Analysis and results from design software

1. The Structural Resiliency Study (SRS) shall be a self-contained document that presents a concise and comprehensive coverage of the following pertinent areas:
 - a. The key assessment outcomes from Threat, Vulnerability and Risk Assessments (TVRA) and Blast Effect Analysis (BEA) Reports, and the resulting stakeholder(s) decisions on which risks to address and/or accept.
 - b. The proposed mitigation measures to be carried out on site.
2. To facilitate the SBD review, the CP (Blast) should ensure that the SRS has comprehensively covered the following key areas:
 - a. Executive Summary
 - i. This executive summary must be presented in a clear and unambiguous manner, so as to facilitate the SBD review process as well as subsequent tracking, checks and/or audits of approved works by CPS.
 - ii. It shall covers the following main areas:
 - Essential background⁷ underlying this SRS report.
 - Summary of identified components⁸ for “Actual Implementation” of mitigation measures (refer Table C for typical listing).
 - Layout(s) indicating the locations of the identified components with respect to those of the critical assets.

Note

The intent of the executive summary is twofold.

First, is to present the key assessment outcomes from TVRA & BEA, and the resulting stakeholder(s) decisions on which risks to address and/or accept.

⁷Two main aspects; (i) key assessment outcomes from TVRA & BEA, and (ii) the resulting stakeholder(s) decisions on which risks to address and/or accept. As per standard international practices, protective security design is a risk-tiered process, i.e. not all risks can be addressed within practical means, and hence focus ought to be accorded to scenarios of higher risks. CP (Blast) must assist stakeholder(s) to rationalize a practical way forward in view of other non-security operational requirements. For A&A projects, it is of utmost importance that existing site constraints are accounted for upfront during design.

⁸These involve both structural and non-structural components. Typical listing include column, wall, slab, beam, brickwall, door, window systems etc. Component supports, e.g. frame and mullion design for glazing, which are integral to the overall blast-resistant performance, must be accounted for.

Second, is to provide a concise and yet comprehensive coverage of the proposed mitigation measures to be carried out on site (*only excluding the detailed calculations which interested readers can refer to in later part of report*).

This executive summary must be presented in a clear and unambiguous manner, so as to facilitate the SBD review process as well as subsequent tracking, checks and/or audits of approved works by CPS.

Table C – Summary of identified Components for Implementation of Mitigation Measures

SN	Location	Layout ⁹	Critical Asset		Component		Proposed Mitigation Measure	
			Name	Blast Effect	Type	ID	Description	Schematic ¹⁰
1					C	1		Refer to Annex Page 1
2					C	2		Refer to Annex Page 1
3					B	1		Refer to Annex Page 2

Legend¹¹

- C : Column
- W : Wall
- S : Slab
- B : Beam
- BW : Brickwall
- D : Door
- G : Window Systems

b. Introduction

Similar to the “Introduction” in the BEA Report Template.

c. Design Methodology

Similar to the “Design Methodology” in the BEA Report Template.

⁹Layout(s) contain the locations of the identified components with respect to those of the critical assets. These part-prints in pdf must only include relevant dimensions and markups. Irrelevant layers in original drawings, e.g. M&E services, architectural features etc. must be omitted for ease of reference.

¹⁰The submitted schematics must indicate all relevant details, such as reinforcement arrangement for concrete components, glazing layup and frame bite, door stiffeners etc., to be done in accordance to prevailing standards such as ASCE 59-11, UFC 3-340-02, PDC TR-06-01, PDC TR-06-12 etc. They can be included as separate annexes for ease of reference. These contents must reflect buildable designs with actual site implementation in mind, for avoidance of doubts.

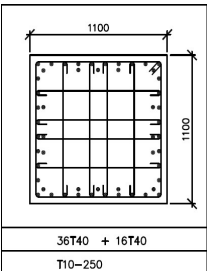
¹¹The legend can be readily amended to reflect additional components not captured in current template.

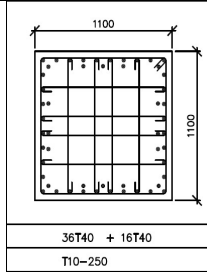
d. Protective Hardening Measures Design Analysis

The blast effect analysis shall be done at a component level where each affected structural and non-structural component is individually analysed against blast. All assumptions adopted shall be clearly stated with appropriate explanation (substantiated with relevant references, code of practices and standards, if applicable) why these assumptions were adopted. All design parameters (e.g. materials properties, factors applied, etc) used in the design shall also be clearly stated.

The CP (Blast) shall provide a detailed list of all the physical hardening/non-hardening measures so as to allow CPS to easily track the implementation of the various measures. A sample is as shown in Table D for reference.

Table D – Details of Physical Hardening/Non-Hardening Measures

Element Type/ID	Structural Dimensions	Threat Scenarios	Design Checks (Pass/Fail?)	Proposed Hardening/Non-Hardening Measures Details	Measures To Be Implemented (Y/N/NA?)
		<i>(to list only the worst scenario)</i>	<i>(to list down all the checks that had been done)</i>		
Column / 2A4	1,100mm x 1,100mm Column Height: 4m Main Rebars: 36T40 + 16T40 Links: T10-250 c/c X-Sectional Details 	250kg VBIED at 6.5m (along ABC Avenue)	Pass Breach, Spall & SDOF	Not Required *If the component was able to withstand the blast load, and no physical hardening measures are needed to be implemented, then just state “ Not Required ”.	
Column / 1A3	1,100mm x 1,100mm Column Height: 4m Main Rebars: 36T40 + 16T40 Links: T10-250 c/c X-Sectional Details	20kg PBIED at 0.2m (at screening station)	Fail Breach & Spall	i. CP (Blast) shall state the hardening measures (if any) and provide structural details of these hardening measures. ii. CP (Blast) may wish to include technical specification of the proprietary materials/technology	



- measures which are proposed for use.
- iii. CP (Blast) shall state the likely residual risk (if any) faced by the affected assets within the building after implementation of the physical hardening measures.
 - v. If no measures could be implemented to mitigate the risk(s), the CP (Blast) shall indicate reason(s) why this can't be mitigated and the corresponding residual risks associated with this.
 - v. CP (Blast) shall proposed contingency plans to reduce the residual risks, if applicable.
 - vi. The relevant stakeholders' agreement on the above items are required to be sought and properly documented in this report.

The following is a list of essential design checks necessary to analyse both structural and non-structural components.

For Structural Components:

Scaled Distance of $Z \leq 0.4\text{m/kg}^{1/3}$

- a. Use approved validated and verified Finite Element Analysis

Scaled Distance of $Z > 0.4\text{m/kg}^{1/3}$

- a. Local Response Checks
 - breaching/spalling calculations
 - derivation of design fragment and fragment penetration calculations (applicable for National Emergency Threats only)
- b. Global Response Checks
 - derivation of blast loads
 - flexural response calculations
 - direct and/or diagonal shear checks

For Non-Structural Components:

- a. Glazing
 - glazing details, e.g. glazing make up, frame section properties
 - derivation of blast loads
 - lite response calculations
 - frame reactions calculations
- b. Human Injury Prediction
 - location of critical personnel
 - derivation of blast loads, e.g. air blast, fireball, etc and fragmentation effects, if any (need to also consider possible blast pressure ingress into buildings)
 - consequence assessment, e.g. lung damage, fatality, etc
- c. Equipment Damage Prediction

- location of critical equipment
- mounting arrangement
- derivation of blast loads and fragmentation effects, if any (need to also consider possible blast pressure ingress into buildings, and failure of façade that will result in debris impinging on equipment)
- assessment of damage to equipment
- equipment blast tolerance limit (maybe able to obtain this from vendor), if any

3. The report generated should comprise, but not limited to, the above key items in separate chapters and should generally follow the order listed.
4. All recommendations proposed by the CP (Blast) have to be reviewed and accepted by the RP as the RP is presumed to be implementing all of the recommendations stated in the final SPP submitted to CPS.
5. Relevant documents and drawings shall be attached in the Appendix of the report for easy reference and a suggested list is as shown in Table E.

Table E – List of information¹² Required in the Appendix

S/N	Description of Documents/Drawings
1	Site/Location Plan
2	Architectural Layouts and Elevations
3	Architectural Details, e.g. opening sizes of doors, louvers, windows, etc
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5	Structural Details, e.g. dimensions and reinforcement details for columns, beams and slabs
6	Layout(s) showing the location of critical assets and their respective standoff distances from the threat
7	Layout(s) showing the demarcated boundary of public and restricted access areas
8	Drawing(s) showing all changes that are relevant to the SBD submission for the facility (applicable for A&A works and any SBD amendment submission)
9	Structural Hardening Details/Shop Drawings
10	Technical Specification of Proprietary Materials/Technology Measures
11	References, Code of Practices and Standards, where applicable
12	Supporting Documents/Certification and/or Performance Specifications for Blast Door, Blast Wall, Blast Valve, Vehicular Dynamics Assessment for Vehicle Security Barrier, etc
13	For Structural Components: detailed calculations for all local and global checks
14	For Non-Structural Components (e.g. glazing, equipment, roller shutter, etc): detailed calculations that are relevant to justify its survivability
15	For Human Injury Prediction: detailed calculations that are relevant to justify its survivability
16	Analysis and results from design software

¹² Provide only those documents/drawings (NOT the entirety) that are relevant to this study. Drawings shall be provided in PDF format, A3 size with details clearly annotated. Reports and/or other kind of information shall be provided in PDF format.

