A Systems Approach to Assess the Vulnerability of Buildings to Bomb Blast

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S. R. M. S. R. Chandratilake

Department of Civil Engineering
University of Moratuwa
Sri Lanka

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ABSTRACT

A blast event lies within the social system and involves people. Hence vulnerability to blast loading can be considered a socio-technical or "soft" system, where our ability to model and hence predict bounds on behaviour is poor. Even where the "hard" part of the system is concerned (i.e. structural response), blast loading is difficult to idealize and its effects cannot be fully predicted. For all the above reasons, the analysis of vulnerability to blast loading must be grounded in past experience. Grounded Theory is a way in which theory is built from phenomena. Theory is considered as being grounded in phenomena; the reliability of data forms the basis for claiming the phenomena exist. Once the specific phenomena in the different case studies have been identified, they can be generalized into concepts. Coherence among concepts is the appropriate grounds for theory formation and acceptance. Grounded Theory is "explicity emergent" and does not test a hypothesis. For the above reasons, Grounded Theory was used to structure this ill-structured research problem that also required a reliance on experience.

The main objective of the study was to construct a hierarchy of concepts, which would constitute aspects that contribute to building vulnerability, using case histories. "Vulnerability" is treated as the top level concept, itself consisting of other concepts. Ten case studies of blast loading were chosen. These represented a variety of building uses, structural form and construction material, and also reflected a variety of explosive types and different locations worldwide. Data (e.g. statements) from case histories were used to identify phenomena. It was possible to extract 63 phenomena relating to building vulnerability from these case studies; some concepts were repeated in the case study phenomena. It was observed that the concepts lent themselves to hierarchical structuring. Some of the concepts could be grouped into a single concept that "emerged" from the former. The 63 original phenomena were used to generate 52 concepts, at various levels in the hierarchy. The hierarchy that was constructed consisted of seven levels. Each emergent concept can be called a "holon" – i.e. it is a whole when considering its constituent lower level concepts, and a part when considering an emergent higher level concept it contributes towards.

The top levels of the hierarchy obtained differed somewhat from those that were previously constructed using "top down" approaches based largely on literature surveys; this demonstrates the value of a "bottom up" approach that seeks to "listen to the data" from case studies. Level 2 of the hierarchy shows that the vulnerability due to blast effects is a social process where context too plays a key role; hence due consideration must be given to context when seeking to assess or reduce vulnerability. Some of the concepts that were frequently repeated in the case study phenomena are "advance warning", "standoff distance", "nature of terrorism", "confinement", "building layout", "structural redundancy", "security" and "glass"; a method of weighting is required to account for the importance of such concepts (reflected in their repetition) within the hierarchy.

The assessment procedure combines existing numerical models as well as ways of processing vague information and expert judgements. It is also a very flexible tool which allows the handling of various types of artefacts which are significantly different from past experience. Experts will use linguistic assessments to measure the evidence about the dependability of holons to sustain their function in a particular blast incident. Linguistic assessments are matched to interval probability numbers. An interval number is used to capture, in practical manner, features of fuzziness and incompleteness. Interval Probability Theory (IPT) is used to combine evidential support values throughout the hierarchy. A computer implementation of the model was developed to show its potential for practical use. The software developed was used to apply the methodology to a building located in the heart of Colombo. The interpretation of results shows the potential of the model to be used as a management tool for practical decision making.

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DECLARATION

The work included in this thesis in part or whole has not been submitted for any other academic qualification at any institute.

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Signature of the Candidate

Certified.

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Signature of the Supervisor

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NOTATION

AND	- Logical operator for the intersection of sets.
Indep	- Independence.
Maxdep	- Maximum dependence.
Mindep	- Minimum dependence.
Mutexc	- Mutual exclusive.
OR	- Logical operator for the union of sets.
P(A)	- Probability of A.
$[S_n(A), S_p(A)]$	- Interval probability number, where $S_n(A)$ and $S_p(A)$ are defined as the lower and upper bounds of the probability P(A) for any event or proposition A.
$P(A \cap B)$	- Intersection between events A and B.
$P(A \cup B)$	- Union between events A and B.
$S_n(A)$	- Necessary support for the proposition A.
$S_p(A)$	- Possible support for the proposition A.
W_A	- Weight of A.
W_B	- Weight of B.
ρ_{AB}	- Dependence relationship between A and B.