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Capability Project

The Loss and Needs Assessment Module

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ABBREVIATIONS AND ACRONYMS

ABBREVIATION/ACRONYM	DESCRIPTION
ALFED	Aluminium Federation (UK)
AN	Annealed Glass
ASTM	American Society for Testing and Materials
ASCE	American Society of Civil Engineers
ATC	Applied Technology Council (US)
BRI	Building Research Institute (Japan)
CFRP	Carbon Fiber Reinforced Plastic
D	Damage Index
FEMA	Federal Emergency Management Agency
GEM	Global Earthquake Model
IBC	International Building Code
ICC	International Code Council
IGU	Insulating Glass Units
L&NAM	Loss and Needs Assessment Module
LAM	Laminated Glass
LoF	Level of Functionality
NIST	National Institute of Standards and Technology
NISTIR	National Institute of Standards and Technology Interagency Report
NZSEE	New Zealand Society for Earthquake Engineering
PEER	Pacific Earthquake Engineering Research Center
PVB	Polyvinyl Butyval (a resin)
r.c.	Reinforced concrete
SDOF	Single-Degree-Of-Freedom
SEI	Structural Engineering Institute (US)
S.F.	Safety Factor
UBC	Uniform Building Code
UMW	Unreinforced Masonry Walls

GLOSSARY OF TERMS

Acceleration-sensitive non-structural component	A non-structural component sensitive to and subject to damage from inertial loading. Once inertial loads are generated within the component, the deformation of the component may be significant; this is separate from the issue of deformation imposed on the component by structural deflections (see deformation-sensitive non-structural components)
ATC – 58 Project	The Applied Technology Council (ATC) – US -has entered into a contract with the Federal Emergency Management Agency (FEMA) –US- to develop a next generation of performance-based seismic design guidelines for buildings (project ATC-58). The work includes a building taxonomy and damage states for several structural and non-structural components.
Bending moment	It exists in a structural or non-structural component when a moment is applied to this component so that it bends. It can be calculated by multiplying vector forces (loads or reactions) by the vector distance at which they are applied.
Building downtime	In this work the estimated downtime is limited to the downtime required to complete the repair work.
Component	One of the many parts, both structural and non-structural, that together comprise a building.
Concrete masonry	Masonry constructed with solid or hollow units made of concrete.
Consequences	The consequences covered in this work are the losses resulting from earthquake, blast/impact or fire damage in terms of repair and replacement costs, repair time and construction manpower and material needs.
Curtain wall system	An outer covering of a building in which the outer walls are non-structural.
Damage Index (related to seismic or blast/impact loading)	Released internal bound energy over initially available internal bound energy.
Damage – or limit - state	For a particular component, or the building as a whole, a range of damage conditions associated with unique consequences.
Deformation-sensitive non-structural component	A non-structural component sensitive to deformation imposed on it by the drift or deformation of the structure, including deflection or deformation of diaphragms.
Demand	A parameter that is predictive of component or building damage states, including peak floor acceleration, peak story drift, peak floor velocity or peak component force (or stress).
Displacement	The total movement, typically horizontal, of a component or node.
Economic loss[1]	In this work the assessment of economic loss is limited to the direct cost of rehabilitating or replacing structural and non-structural earthquake, blast/impact or fire damage.
Fire resistance rating	The period of time a building element, component or assembly maintains the ability to confine a fire, continues to perform a given structural function, or both, as determined by tests or the methods listed in ICC, 2000 (chapter 7 on fire resistance) that are based on

[1] This is synonymous to economic impact defined in SEC (2010) 1626 Final. In this work the assessment of the economic impact is limited to the cost of rehabilitation of buildings.

	fore exposure and criteria specified in ASTM 119.
Floor acceleration	At a floor level, the acceleration of the centre of mass relative to a fixed point in space.
Floor velocity	At a floor level, the velocity of the centre of mass relative to a fixed point in space.
GEM (Global Earthquake Model)	In the GEM project researchers from different countries are developing a physical earthquake risk estimation model of global use. In it a common terminology or taxonomy is critical to document variations in building design and construction practices around the world
In-Plane Behaviour	Behaviour that occurs in the direction parallel to the orientation of the element, which is typically a wall. The term is often used to describe failure, where for instance door and window openings in a wall may no longer have right angle corners.
Instability global	Total failure of the building.
Instability local	Failure of a building component.
Inter-story drift	The relative horizontal displacement of two adjacent floors in a building. Inter-story drift can also be expressed as a percentage of the story height separating the adjacent floors.
Intumescent	A substance that swells as a result of heat exposure, thus increasing in volume and decreasing in density. Intumescents are typically used in passive fire protection.
Load	Any type of force exerted on an object.
Non-structural components	In this work these are components that are a permanent part of the building and are not part of the structural system.
Operating loads	Loads under normal service conditions
Out-of-Plane Behaviour	Behaviour that occurs in the direction perpendicular to the orientation of the structural element, which is typically a wall. The term is often used to describe failure, where for instance a wall may deform outwards or completely collapse into the adjacent street or valley.
Rebar	Steel reinforcing bar.
Rehabilitation	This term is taken in this work to include repair, retrofit, restoration and replacement and is used interchangeably with these words.
Reinforced concrete	Concrete in which steer reinforcement bars (rebars) have been incorporated.
Repair cost	The cost, in preset Euros, necessary to restore a building to its pre-damage condition, or in the case of total loss, to replace the building with a new structure of similar construction.
Repair time	The time, in weeks, necessary to repair a damaged building to its pre-damaged condition.
Replacement cost	The cost, in present Euros, necessary to replace a building that has been damaged beyond the point of practicable repair, including costs associated with demolition and removal.
Replacement time	The time, in weeks, necessary to replace a building that has been damaged beyond the point of practicable repair, including time associated with demolition and removal of debris.
Strength	The maximum axial force, shear force, or moment that can be resisted by a component.
Structural components	Building components that are part of the intended gravity, seismic, blast/impact or fire forces resisting system, or that provide measurable resistance to these forces.
Structural system	An assemblage of structural components that are joint together to

	provide regular interaction or interdependence in resisting the intended forces.
Taxonomy	A hierarchical classification system.
Two-Way Walls	Any class of walls supported on at least one vertical and one horizontal edge (Vaculik and Griffith, 2007)
Unreinforced Masonry Wall (UMW)	Clay brick or concrete or natural stone units bound together using lime or cement mortar to form o wall, without any reinforcing elements such as steel reinforcing bars.
Wythe	A continuous vertical section of a wall, one masonry unit in thickness

EXECUTIVE SUMMARY

The objective in Task 3.3 is to develop a Module that will determine the repair needs of the structural and nonstructural components of a monitored reinforced concrete building subjected to operational, seismic, blast/impact or fire loading, in terms of repair cost, construction manpower, construction materials and repair duration. Additionally, this Module will determine the amount of debris and building functionality.
These objectives are focused to the needs of the building owners, the construction and insurance industry and reconstruction and recovery planners.

This report presents the developed methodology for the above Module.

The developed methodology:

- Is a unified methodology for the assessment of economic loss and needs resulting from any of the extreme events under consideration (earthquake, blast/impact, fire) that can be extended to include additional extreme events.
- Is based on the assessment of physical damage at the component and global level due to the extreme events under consideration and the assessment of the direct economic consequences of such damage.
- Provides a detailed taxonomy of all structural and nonstructural components of a reinforced concrete building. This taxonomy provides naming of all components that are consistently used throughout the set of WP3 reports.
- Facilitates global collaboration by being consistent, as much as possible, with existing building taxonomies developed for national use (e.g., in the (US) ATC – 58 project) or for international use (e.g., the GEM building taxonomy).

In this work the partners elaborated appropriate damage states[2] for all structural and nonstructural components for all extreme events under consideration and, based on these, estimated the economic loss and needs of all structural and nonstructural components for all extreme events under consideration.

For **structural components**:

(a) in the case of seismic loading, the damage states are based on the damage index for the component, an input from the Structural Model in Task 3.2. The damage index of structural members is the ratio of the released internal bound energy over the available internal bound energy. This index and the resulting damage state are far more credible than present methods as they are based on the results of a detailed structural analysis permitted by sensor measurements in the monitored building.

(b) In case of explosion there is an initial state where the air pressure generated by the explosion exerts on the structural members, mainly those lying in the vicinity of the explosive charge, a sudden transversal blast loading with a duration of some milliseconds. As a result of this some of the structural members together with the associated nonstructural components might reach a point beyond practicable repair. These structural members will be an input to this model. The no longer functioning structural members, together will all the nonstructural members attached to them, will be part of the debris calculation in this work. Damage to the remaining components (structural and nonstructural) will be due to blast induced vibrations and, thus, the damage states developed for, the similar, seismic vibrations are appropriate and have been used for this type of blast damage as well.

(c) In case of fire the input from the structural model will be in the form of safety factors (S.F.s) for each structural component that will determine the need for intervention. Additional input from the structural model will include the midspan deflection in beams and temperatures that will determine the type of intervention.

[2] Used terms are defined in the Glossary.

(d) In the case of operating loads the input from the structural model is in the form of S.F.s that determine the need for intervention.

For **nonstructural components**, in the case of seismic or blast damage, the damage states are based on input (e.g., interstory drift, peak floor acceleration) from the Structural Model in Task 3.2. In case of fire, the damage states are based on input from the temperature sensors on time of exposure and maximum temperature.

Emphasis has been placed on exterior, non load bearing, masonry walls, prevalent in r.c. buildings in the seismic prone countries of Europe and elsewhere (e.g., in Australia or New Zealand), because the assessed damage of these walls will be used to calibrate satellite based damage maps after an earthquake (WP4). Here, based on published experimental and analytical work on seismically damaged masonry walls and using input from the structural assessment in Task 3.2, the partners were able to assess, the seismic damage of these walls.

The estimates of nonstructural damage, economic loss and needs are continuously updated as estimates of physical damage of the structural system change with time (e.g., due to seismic aftershocks).