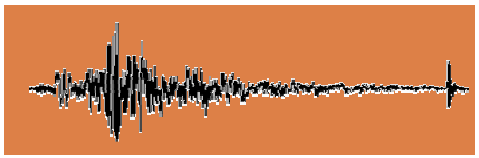
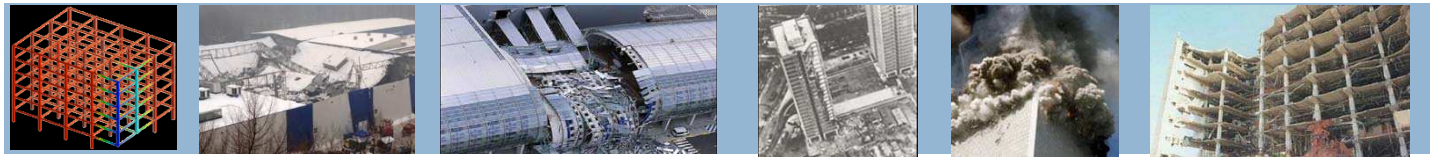
First International Conference for PhD students in Civil Engineering
"New Researcher Generation with Challenges in Civil Engineering"
CE-PhD 2012, 4-7 November 2012,
Cluj-Napoca, Romania

Structural conception and COllapse control performance based DEsign of multistory structures under aCcidental actions CODEC

Florea Dinu

Politehnica University of Timisoara, Romania





Design for reducing risk of collapse

- Modern society less and less accepts risk in civil engineering, but is not ready to increase the amount of funds to ensure a higher safety level to people (for new constructions, maintenance and strengthening of existing construction works)
- Robustness is an important issue

"A structure shall be designed and executed in such a way that it will not be damaged by events such as: explosion, impact, and the consequences of human errors, to an extent disproportionate to the original cause" - EN 1990

"The selected design situations shall be sufficiently severe and varied so as to encompass all conditions that can reasonably be foreseen to occur during the execution and use of the structure" - EN 1990

This Principle indirectly introduces the responsibility of the designer.

Accidental actions

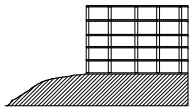
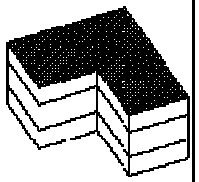
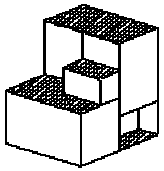
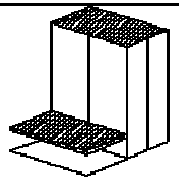
- Natural hazards:
  - earthquake, wind, snow, temperature – beyond the code provisions
- Abnormal actions:
  - Fire, gas explosion, blast, impact or collision
  - Design / construction error
  - Occupant misuse

Consequences of localised failure

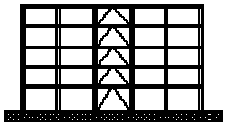
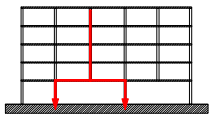
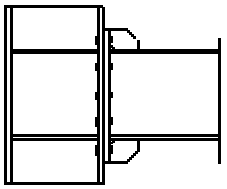
Identified problems

- There are no specific Guidelines for Robustness Performance Assessment of Buildings in Eurocodes
- Approaches in material related Eurocodes are different/absent
- EN1990, EN 1991-1-7 try to ensure robustness through accidental design situations
- CEN/TC 250 decided in 2009 to form an ad-hoc group on "Robustness", due to the concerns related to the limitations of the Eurocode provisions.
- The harmonised material is expected to be incorporated in EN1991 in the period 2013-2015

Multi-hazard design matrix

Site and building characteristics			Hazard					Interaction
			Seismic	Flood	Wind	Fire	Explosion	
1	Elevated building site		-	+	0	0	+	Highly beneficial for floods and external bomb explosion, not significant for wind or fire
2	Re-entrant corner plan forms		-	0	-	0	-	Stress concentration at corners, irregular behavior in case of earthquakes; localized wind pressures, amplification of shock wave in case of external blast
3	Very irregular buildings		-	0	-	-	-	Indirect load paths, stress concentrations in earthquakes, explosions. Localized high wind pressure, aggravates evacuation in case of fire
4	Large roof overhangs		-	0	-	-	-	Vulnerable to earthquakes (vertical motion), wind and also adjacent external blast. Mai pose risk also in case of fire evacuation

Multi-hazard design matrix

Site and building characteristics			Hazard					Interaction
			Seismic	Flood	Wind	Fire	Explosion	
5	Steel structural frame		+	+	+	-	+	When properly detailed, is recommended in seismic and high-wind zones. Good in flood with proper detailing. Vulnerable to fire if is not protected or well detailed and designed. Low vulnerability in case of blast and explosion, offers multiple paths.
6	Indirect load path		-	0	-	-	-	Very vulnerable for seismic, wind and explosion hazards because poor structural integrity increases likelihood of collapse. Fire may further weaken structure.
7	Ductile detailing of structure and connections		+	0	+	+	+	Provides good plastic response. The structure has large ductility and is more resistant to collapse in case of extreme loading

The probability of collapse due to the extreme load events

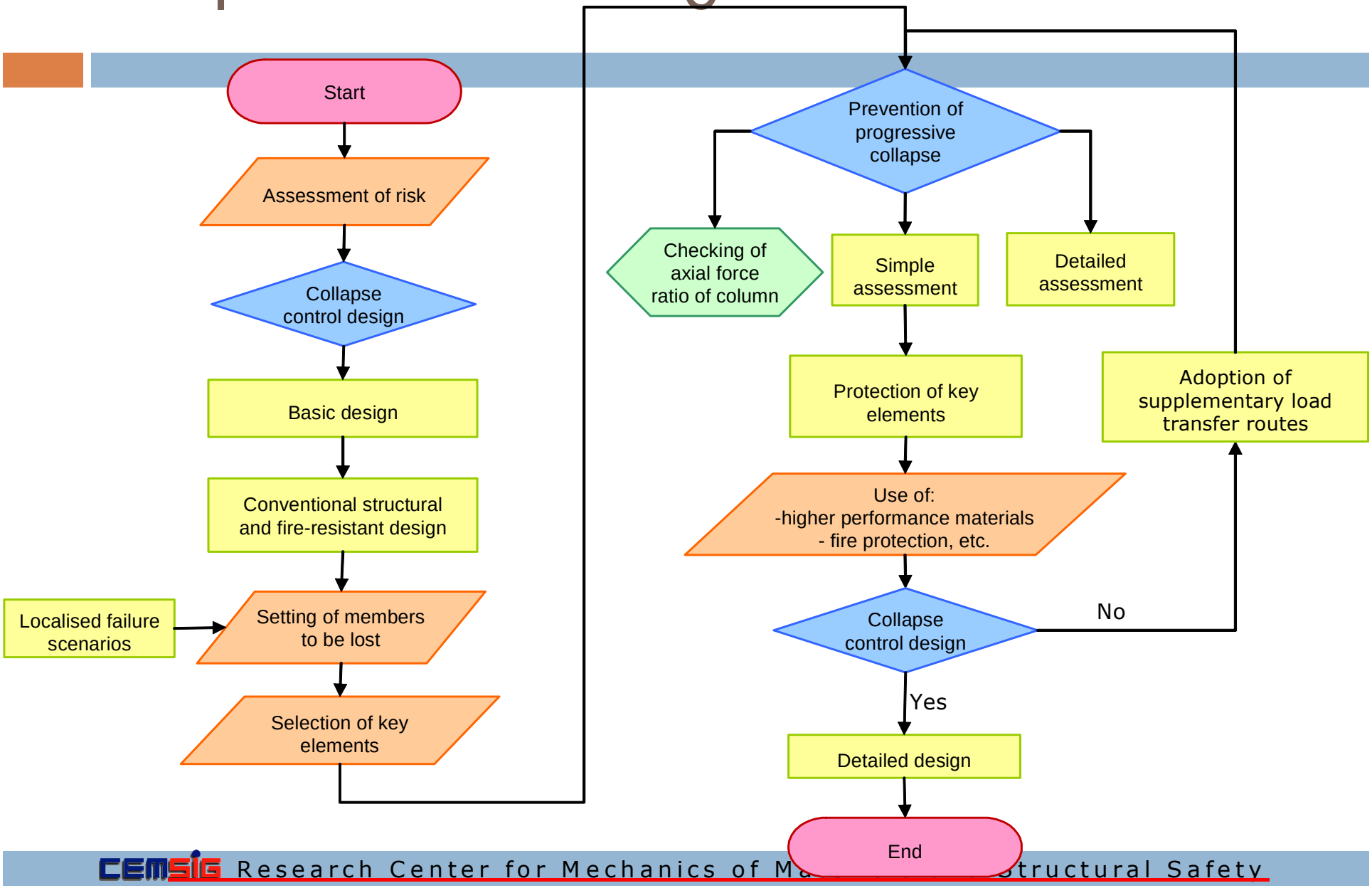
$$P(C) = P(C|LD)\, P(LD|H)\, \lambda_H$$

λ_H= rate of occurrence of the extreme load or hazard

P(LD|H)= probability of local damage given that the extreme load occurs

P(C|LD)= probability of collapse given that local damage occurs

Collapse control design flowchart



Collapse control performance based design of multistory structures

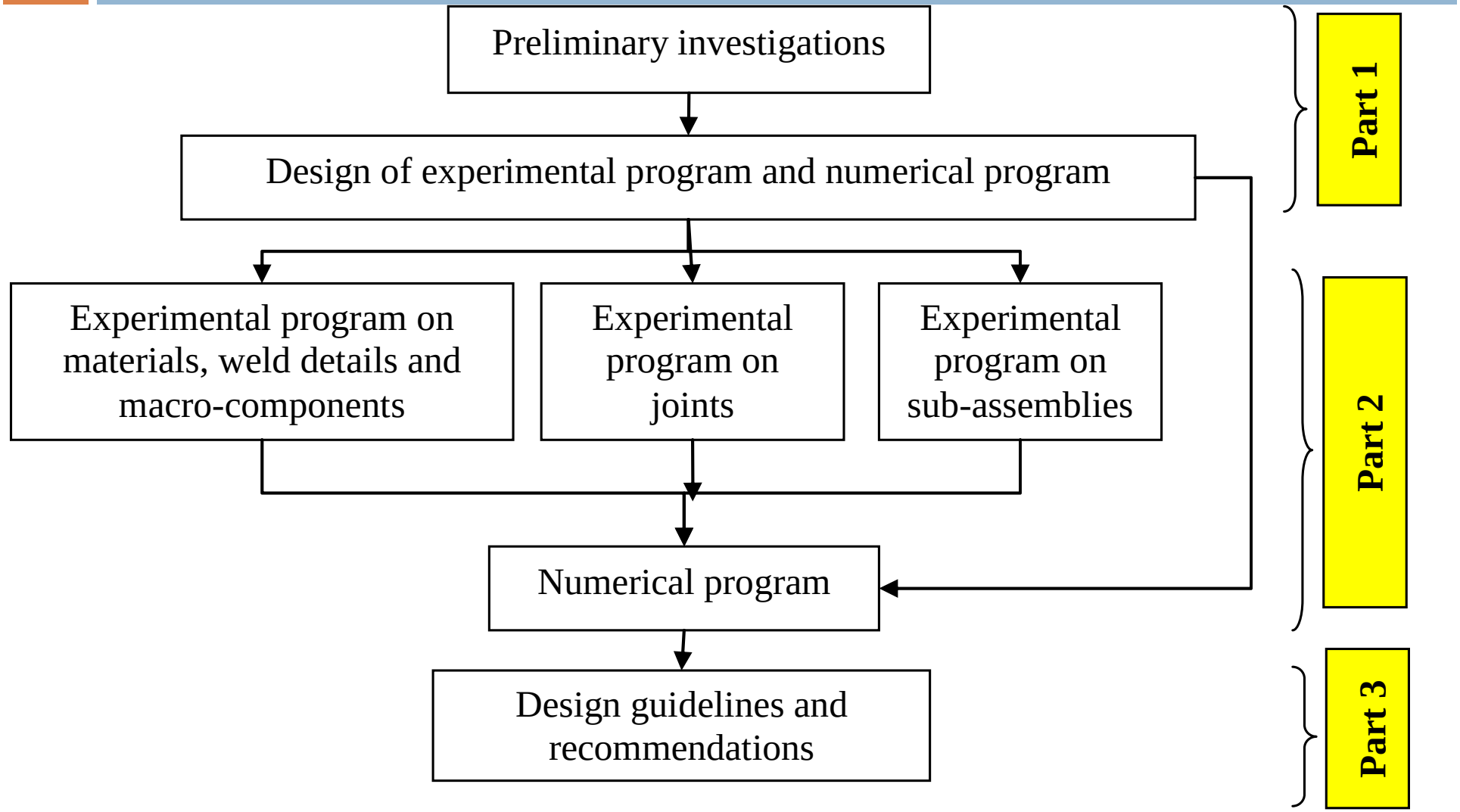
- Direct Design:
  - Specific Local Resistance Method (key element design)
  - Alternate Path Method (structural redundancy)
- Indirect Design:
  - Prescriptive design – requires a minimum level of connectivity for structural members

Structural conception and COllapse control performance based DEsign of multistory structures under aCcidental actions, 2012 - 2015

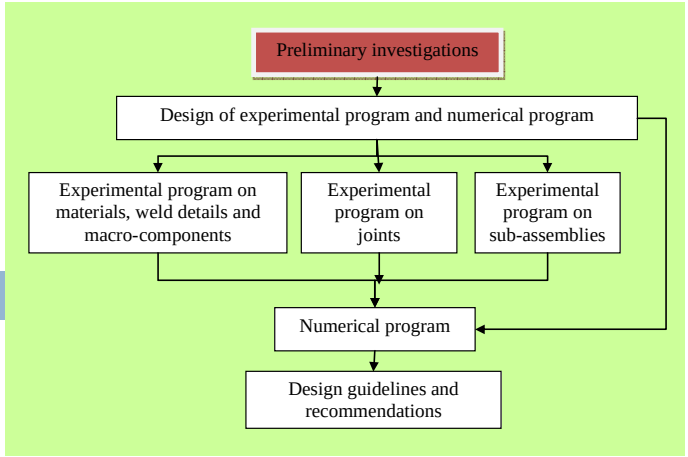
Partners

- Politehnica University of Timisoara - coordinator
- Tehnical University of Cluj Napoca
- URBAN-INCERC
- The National Institute for Research and Development in Mine Safety and Protection to Explosion : INCD – INSEMEX
- SC ACI CLUJ SA

Project phases

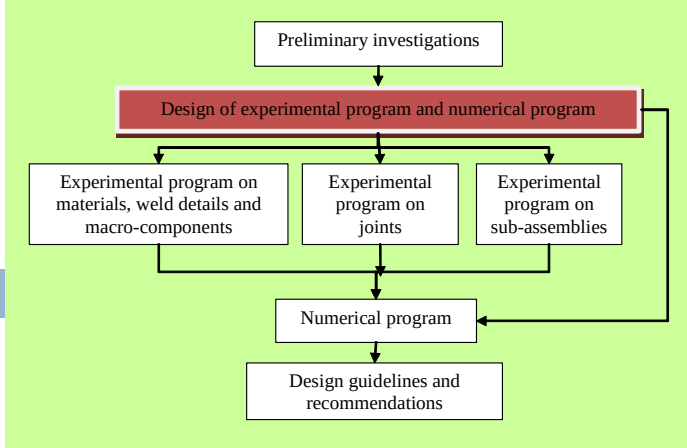


Preliminary investigations

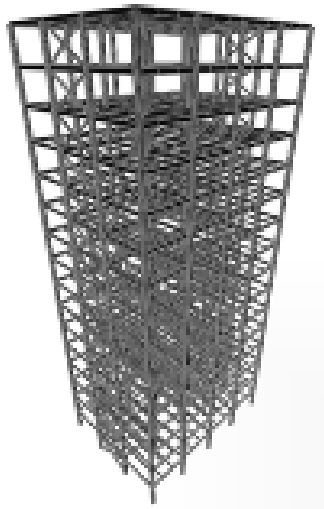


- Tasks:
  - review of existing methods, structural concepts and analytical tools for evaluating the progressive collapse potential of new and existing buildings, identification of gaps in knowledge
  - evaluation of effectiveness of collapse control based design for protection of building structures in case of accidental actions

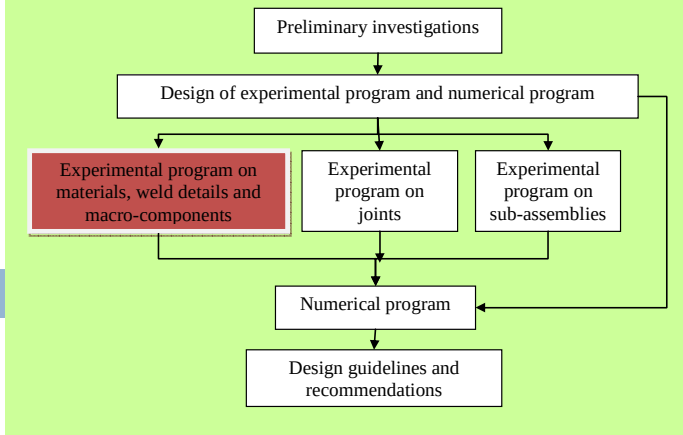
Design of experimental and numerical program



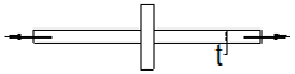
- Tasks:
  - design of specimens for experimental program, based on case study structures: typology, materials, technology of execution, loading parameters, data acquisition, rigs and test set-up, supply of materials and specimens.
  - design of numerical program



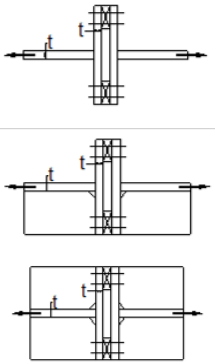
Experimental program on materials, welds details and macrocomponents



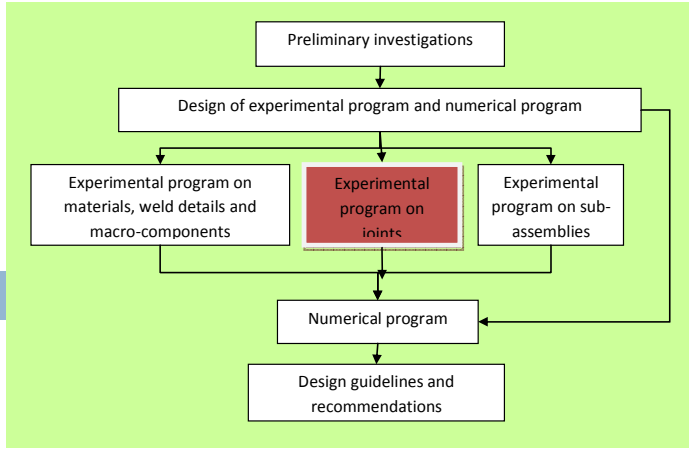
- Tasks:
  - Experimental tests on base materials and weld details

Weld detail	Weld	Thickness	Loading	Strain rate	Total
Butt weld 	Single bevel Double bevel	3	1M + 2C	2	36
Transversal cruciform weld 	Single bevel Double bevel Fillet	3	1M +2C	2	54

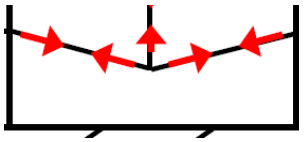
  - Experimental test on T-stub macro-components

T-stub	Loading	Strain rate	Temperature	Total
	2M+2C	2	2	48

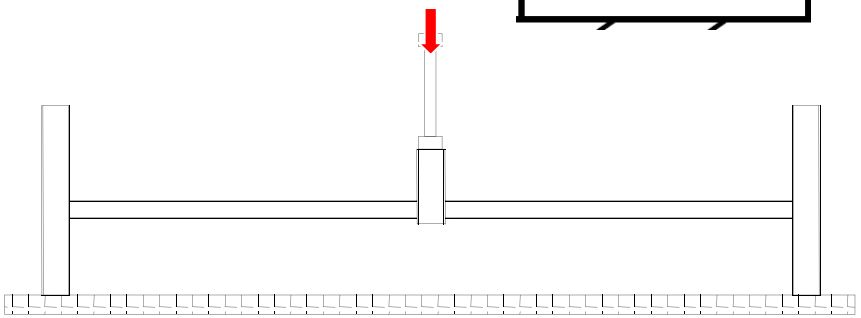
Experimental program on joints



- Tasks:
  - Experimental test on joint specimens

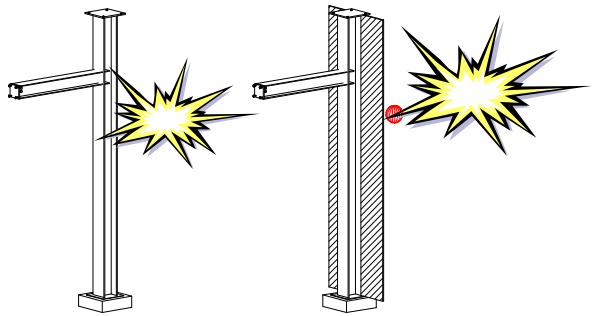


2 types x 3 capacity x 2 velocities = 12 specimens x2 = 24 specimens

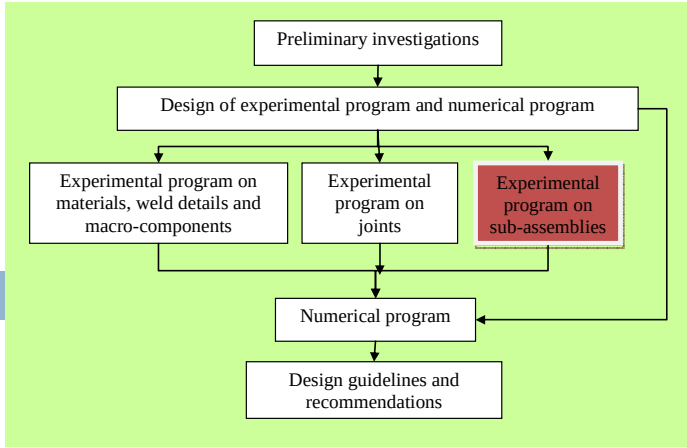


  - Testing on joints in blast conditions

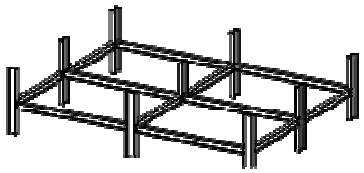
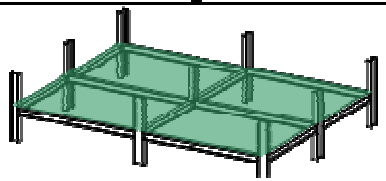
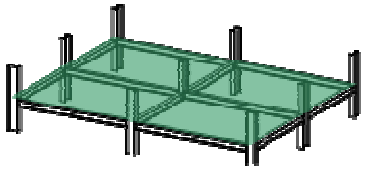
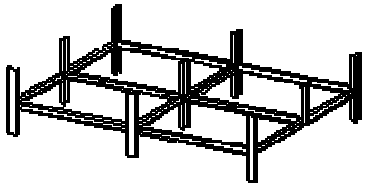
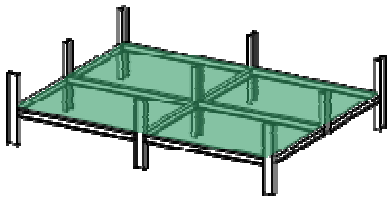
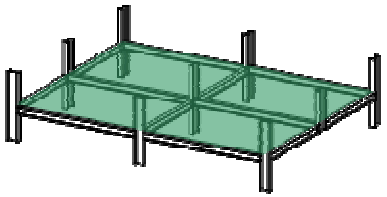
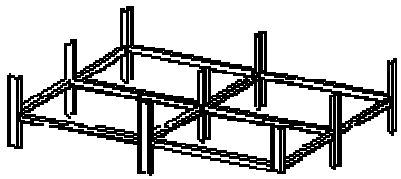
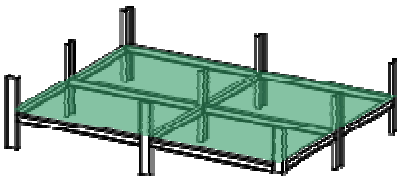
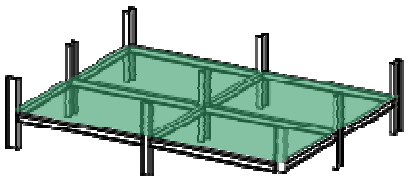
2 types x 2 stand-off distances = 4 specimens



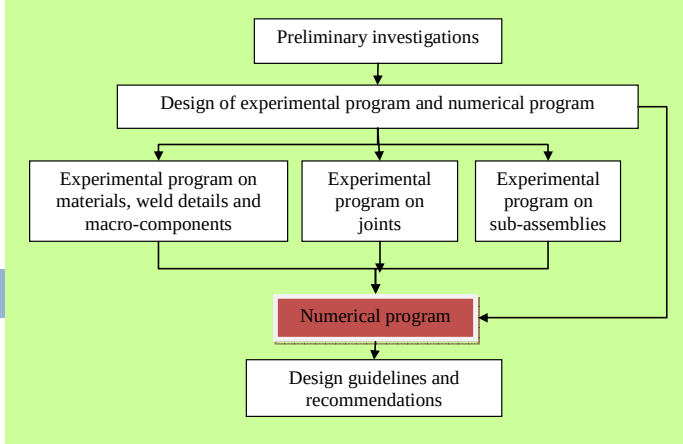
Experimental program on sub-assemblies



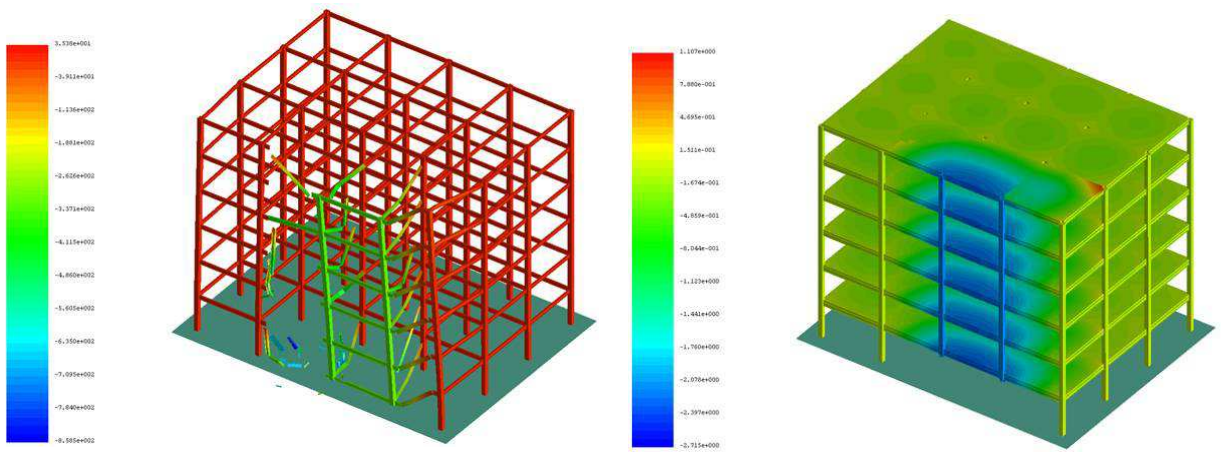
- Tasks:
  - Experimental test on subassembly specimens

Column loss	Specimen: No concrete slab Two-way action	Specimen: Concrete slab One-way action	Specimen: Concrete slab Two-way action	Total
Central				3
Penultimate				3
Corner				3

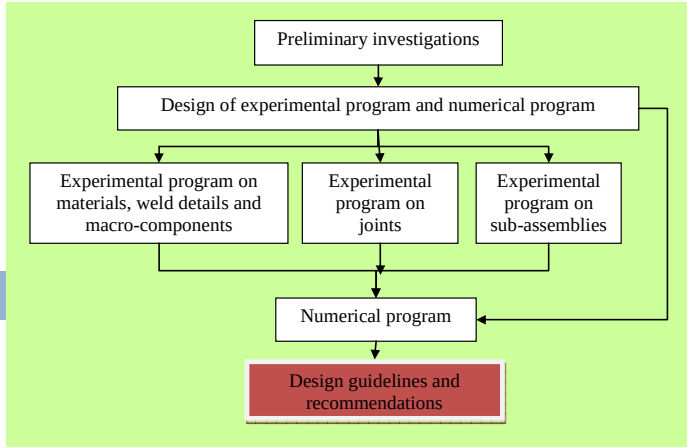
Calibration and validation of numerical models based on test results



- Tasks:
  - Calibration and validation of numerical models based on test results
  - Assessment of progressive collapse resistance by collapse control approach
  - Case studies



Design guidelines and recommendations



- Deliverables :
  - Synthesis of the results: A summary report on the results of the project will be provided. The most important findings and conclusions are presented.
  - Guidelines for the collapse control performance based design of multi-story frame buildings against accidental actions
  - Recommendations for best practice in selection of structural system, fabrication and material requirements for improving the robustness

Expected impact

- Added value of the results: numerical models, acceptance criteria, data collection and specific recommendations for designing buildings against progressive collapse
- Dissemination of project results