Understanding Risk
Balkans Conference
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UNIVERSITY of GREENWICH

Applying the lesson learnt from precast industrial buildings in Italy to the Balkans

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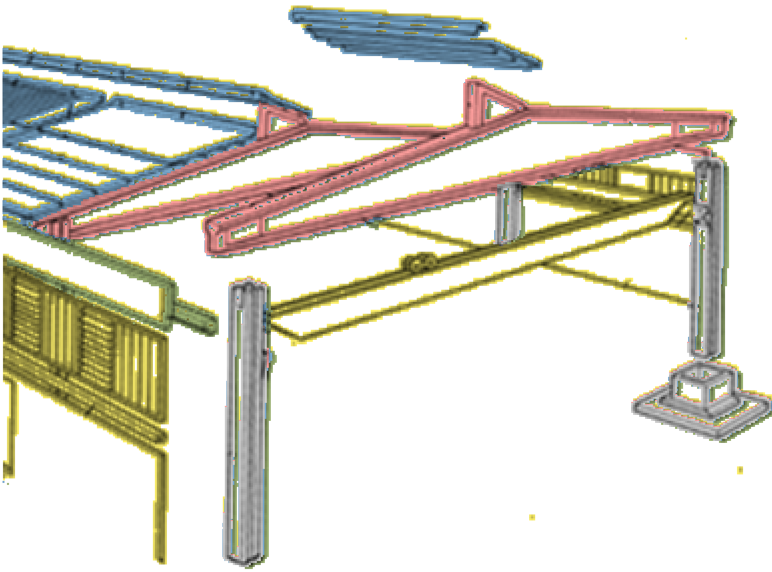
- Seismic Performance of precast RC buildings in past events

- Vulnerability assessment of precast buildings in Italy and in the Balkans
- Risk mitigation measures: lesson from precast buildings in Italy

- Conclusions

Precast industrial buildings



<u>Column structures:</u>

- socket foundations
- precast columns
- hinged pre-stressed precast beams
- precast RC cladding panels

Precast structures are typically used for **<u>industrial buildings</u>** in Italy and in Europe (mainly one-story)

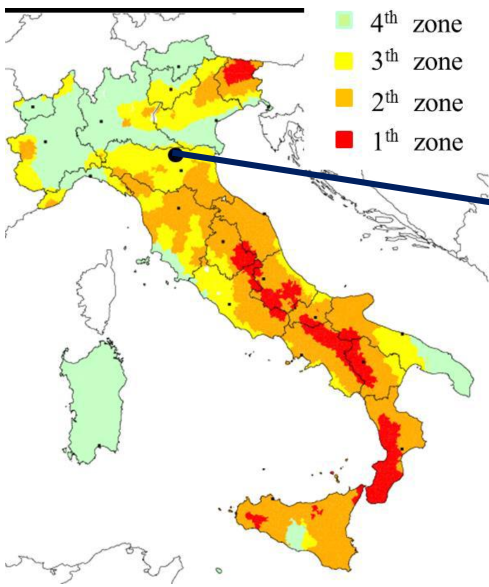
Past events affecting precast buildings

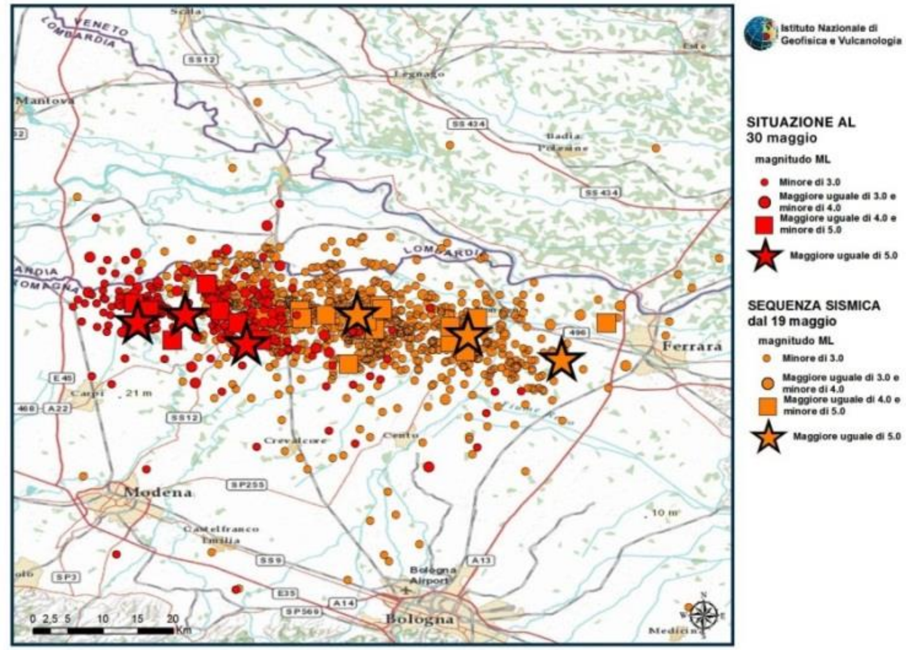
Several past events severely hit precast industrial buildings in Europe

- 2012 Northern Italy earthquake
- 1998 Adana-Ceyhan (Turkey)
- 1999 Golcuk earthquakes (Turkey)

- The events highlighted the high vulnerability of precast buildings in Europe
- Opportunity to collect data and investigate seismic performance

Case-study: Italy (2012)





M5.9 on 20th May

- 7 fatalities
- 20 injuries
- 5000 displaced

M5.8 on 29th May

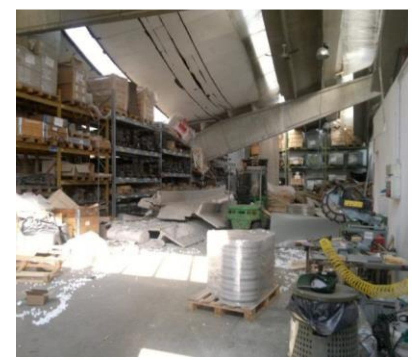
- 20 fatalities
- 350 injuries
- 15000 displaced

1 bn EUR Economic damage

5 bn EUR induced economic damage

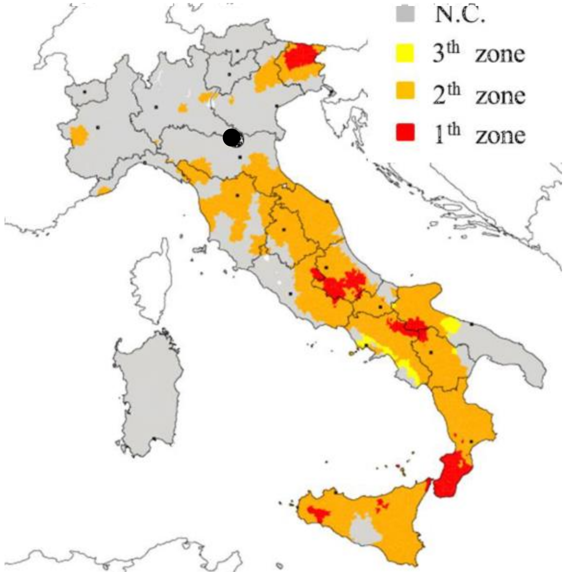
>50% of precast buildings suffered severe damage

Inadequate capacity



High density and use

Case-study: Italy (2012)



Seismic hazard map up to 2003

Inadequate capacity

All structures in Emilia designed up to 2003 did not take into account seismic design

High density

The area around the epicentre is a heavily industrialised area, hosting an industrial hub of biomedical companies

+

>80% of industrial buildings has a precast RC structure

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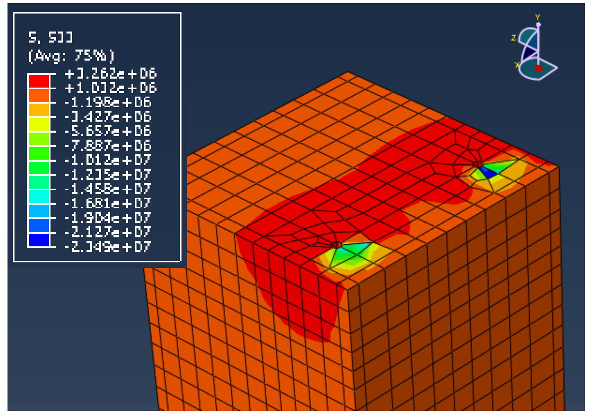
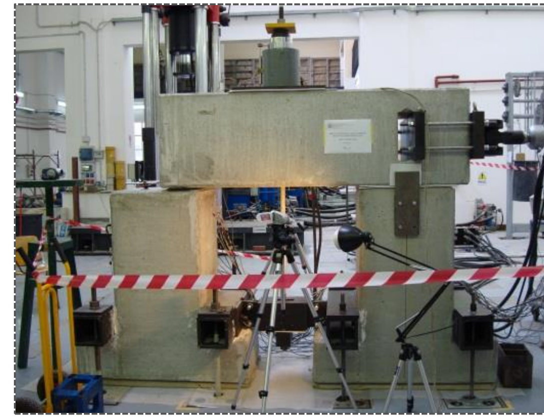
How to reduce the risk of precast structures?

Engineering approach

- Numerical analysis
- Expert judgement
- Experimental tests





Vulnerability assessment

- How will the structure behave when an earthquake occur?
- What are the main weak points of the structure?
- How can the performance improved?

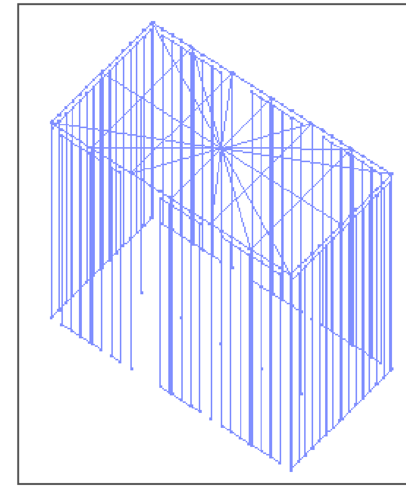
Retrofitting measures

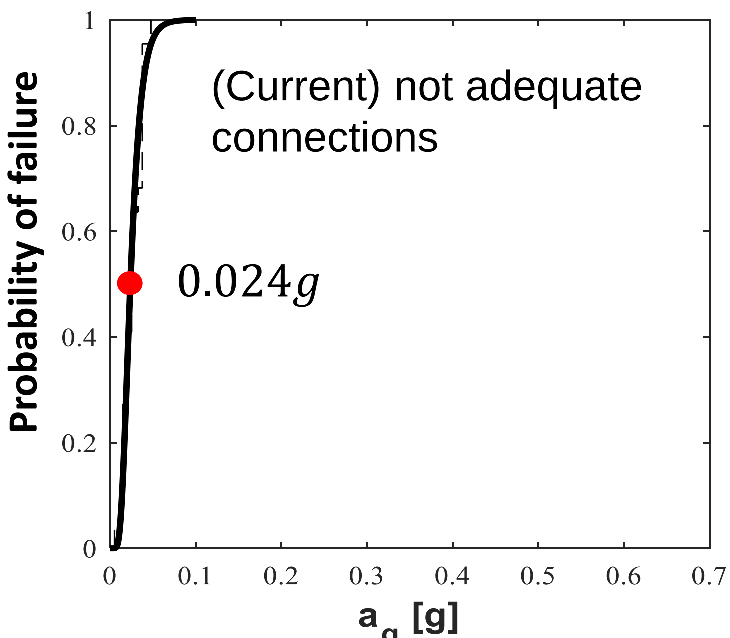
- Classify the structures according to their features
- Identify the buildings with the largest risk
- Optimize the resources to prioritise the retrofitting actions

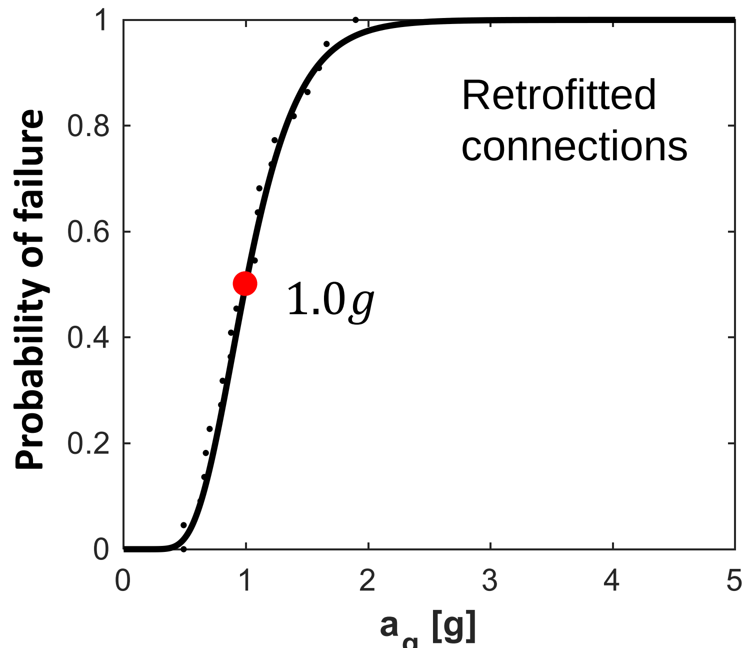
Vulnerability assessment of Italian precast buildings

<u>Example for one-storey new buildings</u>

Panels have been the main cause of casualties and damage







Connections between panels and structures are weak

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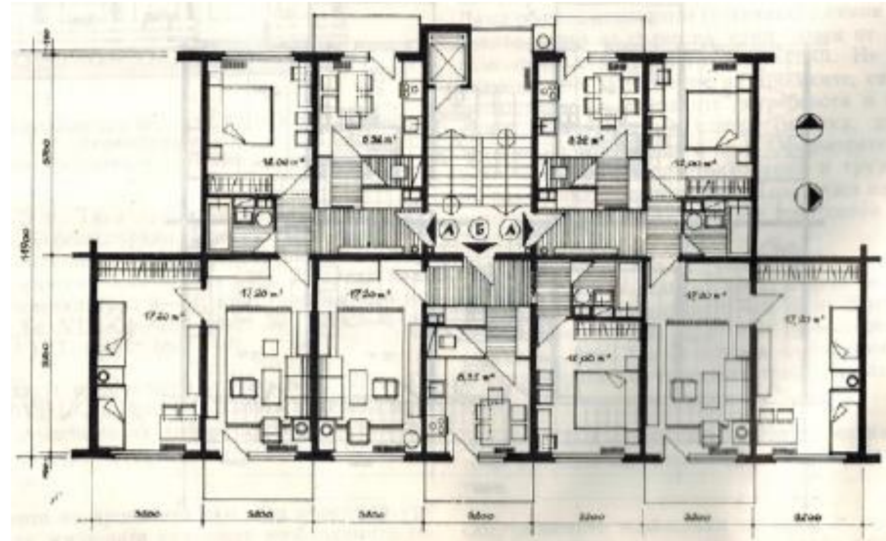
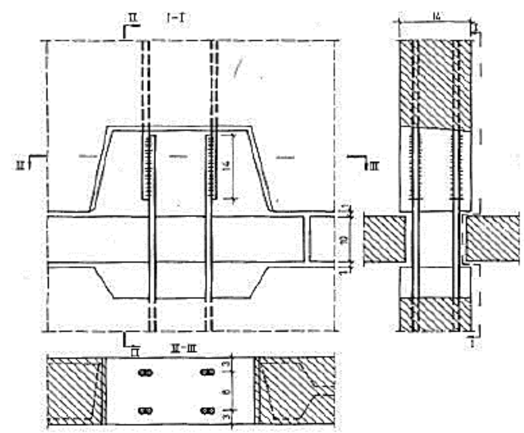
Large-panel precast buildings in the Balkans

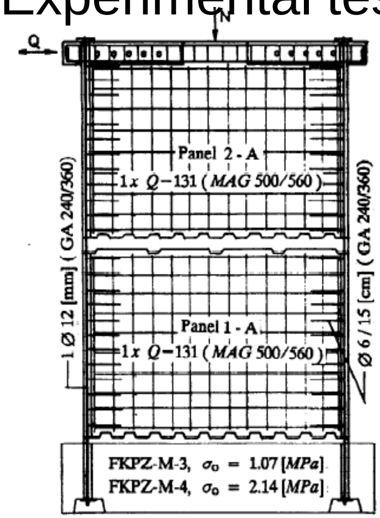


- No Storeys: 6-9
- Resisting System: RC Unconfined Squat Shear Walls
- Precast panels with cast in-situ joints



Large-panel precast buildings in the Balkans

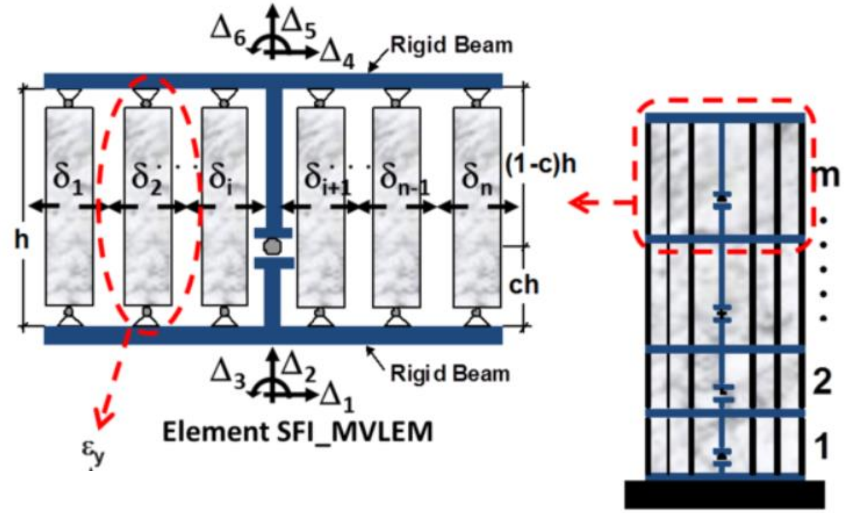
Experimental test



Bozinovski Z.L. (1994)

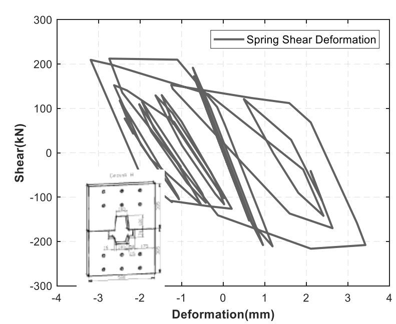
calibration

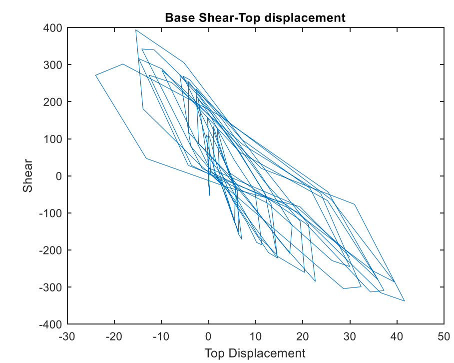
Numerical model in OpenSees



Wall Model

Kolozvari, K. et al. (2015)



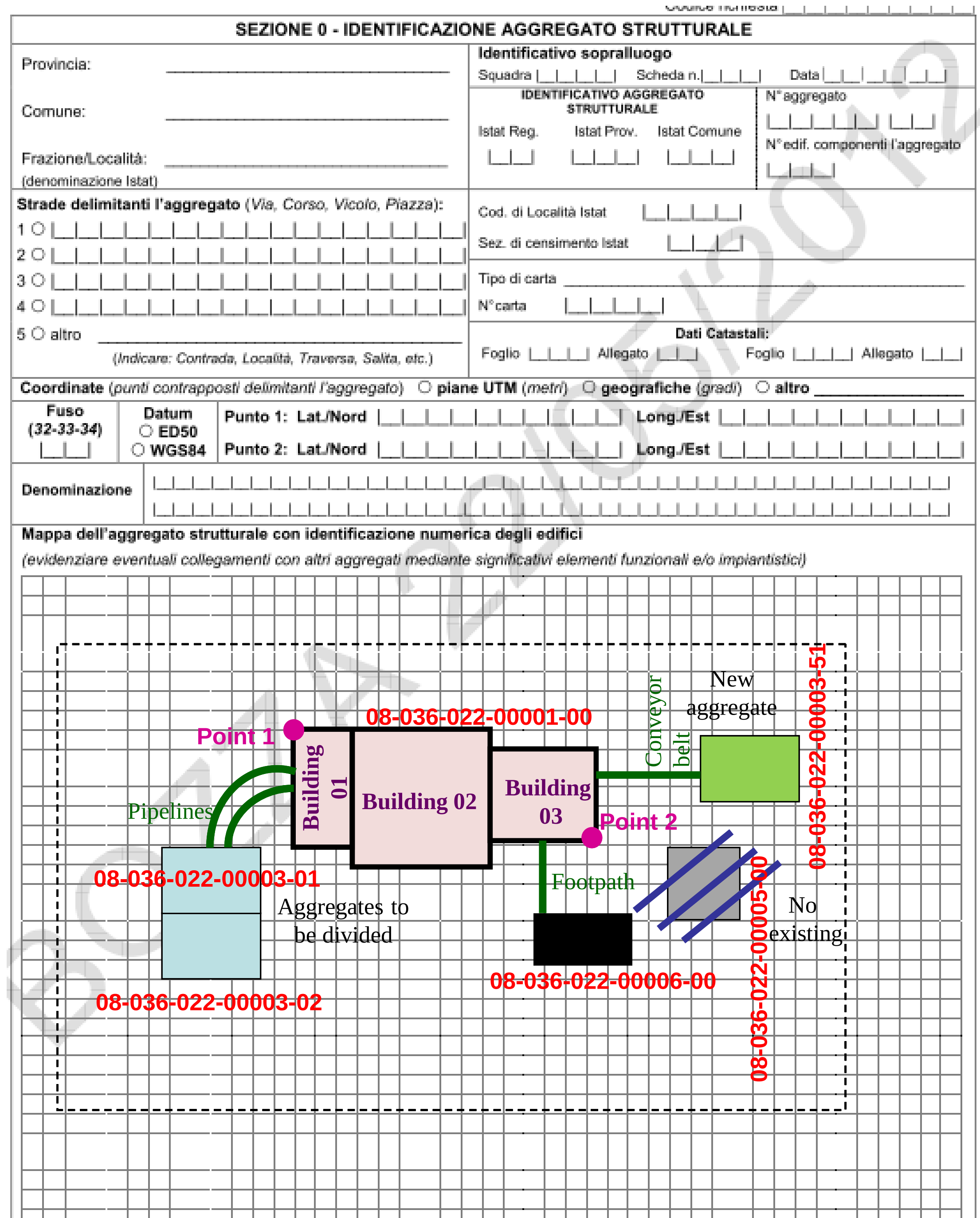


The seismic performance of Balkan precast buildings can be assessed via numerical methods looking at (a) connection failure and (b) panel damage

Capacity assessment form

- Bespoke form for precast structures
- Collection of the data required to predict the vulnerability
- Good reliability of the data collected by experienced and trained surveyors

http://www.protezionecivile.gov.it/resources/cms/documents/Manuale_GL_Aedes.pdf


SEZIONE 0 - IDENTIFICAZIONE AGGREGATO STRUTTURALE

Provincia:

Comune:

Frazione/Località: (denominazione Istat)

Identificativo sopralluogo

Squadra | Scheda n. | Data

IDENTIFICATIVO AGGREGATO STRUTTURALE

Istat Reg. | Istat Prov. | Istat Comune

N° aggregato

N° edif. componenti l'aggregato

Strade delimitanti l'aggregato (*Via, Corso, Vicolo, Piazza*):

1 ○

2 ○

3 ○

4 ○

5 ○ altro

(*Indicare: Contrada, Località, Traversa, Salita, etc.*)

Cod. di Località Istat

Sez. di censimento Istat

Tipo di carta

N° carta

Dati Catastali:

Foglio | Allegato | Foglio | Allegato

Coordinate (*punti contrapposti delimitanti l'aggregato*) ○ piane UTM (*metri*) ○ geografiche (*gradi*) ○ altro

Fuso (*32-33-34*)

Datum ○ ED50 ○ WGS84

Punto 1: Lat./Nord | Long./Est

Punto 2: Lat./Nord | Long./Est

Denominazione

Mappa dell'aggregato strutturale con identificazione numerica degli edifici

(*evidenziare eventuali collegamenti con altri aggregati mediante significativi elementi funzionali e/o impiantistici*)

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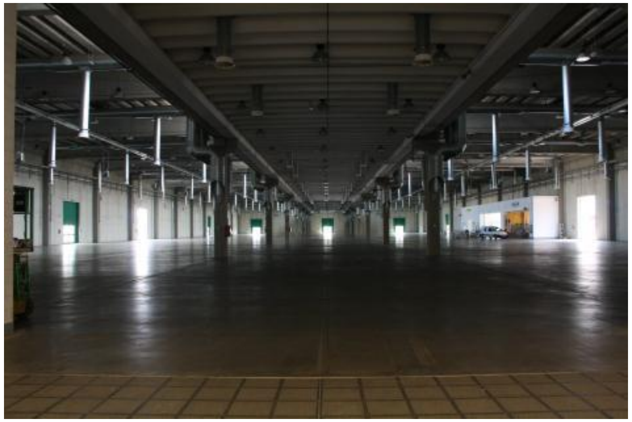
Capacity assessment form

Example of use

One-storey precast building in Italy built in 1998

Specific structural and nonstructural features

Large span and height	Friction connections	Heavy RC panels
		

Capacity assessment form

Example of use

Use

SEZIONE 2a	Geometry			
N° Piani totali con interrati	*Altezza media di piano* [m]	*Superficie media di piano* [m²]		
○ 1	1 ○ 2.7÷3.49	A ○ ≤ 200	L ○ 2500 ÷ 3000	
○ 2	2 ○ 3.5÷4.99	B ○ 200 ÷ 250	M ○ 3000 ÷ 3500	
○ 3	3 ○ 5.0÷6.99	C ○ 250 ÷ 300	N ○ 3500 ÷ 4000	
○ 4	4 ○ 7.0÷9.99	D ○ 300 ÷ 400	O ○ 4000 ÷ 4500	
○ ≥ 5	5 ○ 10.0÷13.99	E ○ 400 ÷ 500	P ○ 4500 ÷ 5000	
Piani interr.	6 ○ > 14.0	F ○ 500 ÷ 650	Q ○ 5500 ÷ 6000	
A ○ 0	*Altezza massima libera pilastri*	G ○ 650 ÷ 900	R ○ 6000 ÷ 7000	
B ○ 1		H ○ 900 ÷ 1200	S ○ 7000 ÷10000	
C ○ 2	7 ○ Valore [m]:	I ○ 1200 ÷1600	T ● 10000÷15000	
D ○ ≥3	|__|__|,|__|__|	J ○ 1600 ÷2000	U 0÷20000	
		K ○ 2000 ÷ 2500	V 000	

Connections

	Connessioni	Modalità di approfondimento				
	Tipologia di connessione	Non identificata	Presunta	Da interviste	Da elaborato	Ispezione diretta
		A	B	C	D	E
2	Trave – pilastro/parete	○				
2a	**Appoggio**	❑	●	❑	❑	❑
2b	**Cerniera** (ad es. barre verticali su mensola)	❑		❑	❑	❑
2c	**Semi-incastro** (ad es. parz. resistenti a flessione)	❑		❑	❑	❑
2d	**Incastro** (ad es. emulazione c.a. in opera)	❑		❑	❑	❑
2e	A travi contigue collegate	❑		❑	❑	❑
4	Copertura – trave / Copertura - pilastro	○				
4a	**Appoggio**	❑	●	❑	❑	❑
4b	**Cerniera** (ad es. inserti metallici a secco)	❑		❑	❑	❑
4c	**Semi-incastro** (ad es. parz. resistenti a flessione)	❑		❑	❑	❑
4d	**Incastro** (ad es. emulazione c.a. in opera)	❑		❑	❑	❑

Panels

		Pannelli di tamponatura
1	○	Assenti
2	❑	Prefabbricati orizzontali appesi esterni al filo pilastri
3	❑	Prefabbricati orizzontali appesi interni al filo pilastri
4	❑	Prefabbricati orizzontali infilati
5	❑	Prefabbricati verticali con chiave di taglio alla base
6	●	Prefabbricati verticali senza chiave di taglio alla base
7		efabbricati verticali infilati
8		efabbricati impilati
9		c.a. gettati in opera
10		ıratura
11	❑	Sandwich
12	❑	Lamiere grecate semplici
13	❑	Pareti stratificate a secco
14	❑	A base di legno
15	❑	Altro (specificare)

Number of impacted people after the earthquake

Low capacity of connections (as highlighted in past events and previous studies)

Retrofit of connections is needed

Retrofitting measures

How to improve the capacity? → Retrofitting of structures → Money - investment / Interruption of use

"Immediate operations for overcoming the emergency in Emilia"
D.L. 6 June 2012 n. 74 converted in Law on 1 August 2012 n. 122

Uniform approach to risk mitigation

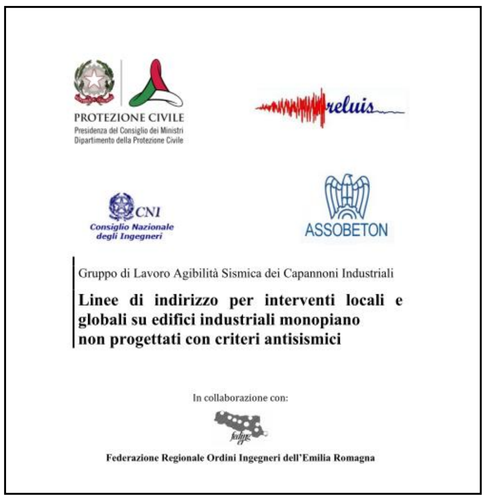
Two phase process:

- **Step 1**: Removal of the most significant structural deficiencies
- **Step 2**: Extensive and systematic actions in order to achieve the required performance, integrating into a broader context the actions of the first phase


PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile
reluis
CNI
Consiglio Nazionale degli Ingegneri
ASSOBETON
Gruppo di Lavoro Agibilità Sismica dei Capannoni Industriali
Linee di indirizzo per interventi locali e globali su edifici industriali monopiano non progettati con criteri antisismici
In collaborazione con:
Federazione Regionale Ordini Ingegneri dell'Emilia Romagna

Gruppo di lavoro Agibilità Sismica dei Capannoni Industriali, ReLUIS

Retrofitting measures


PROTEZIONE CIVILE
Presidenza del Consiglio dei Ministri
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reluis

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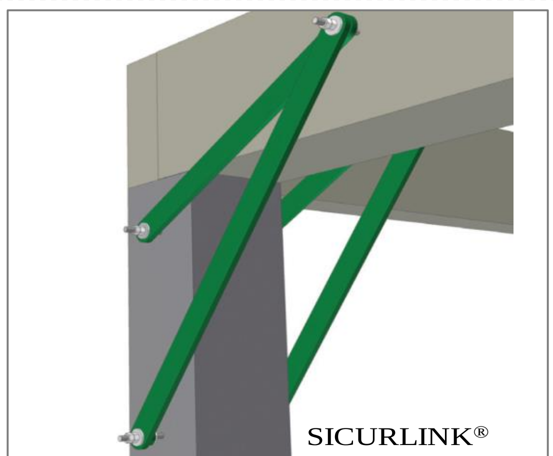
Weakness

A. Inadequate connections

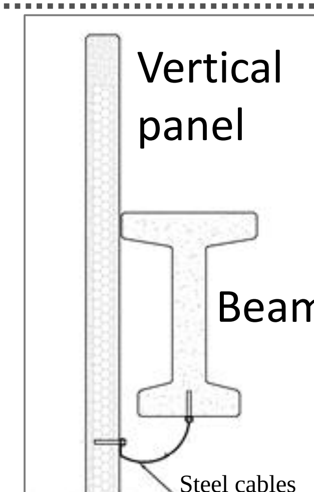
B. Inadequate panels

Retrofitting measure

A. Additional elements



B. Overturning control



Proposed approach for the Balkans - Conclusions

Study of the capacity and weaknesses in existing buildings

↓

Engineering study: tests and analysis

↓

Definition of the classes of buildings with low capacity

Optimize the resources for risk mitigation

↓

Training of engineers for collecting data

↓

Identification of the classes of buildings: assessment form

Decision about retrofitting actions in buildings at risk: guidelines for practitioners

↓

Investment plan for retrofitting with prioritization

Thank you for your attention