1ST ANNUAL SIBYL MEETING
Aristotle University of Thessaloniki
Thessaloniki, Greece, 15th – 16th February, 2016

Task C: Rapid and low-cost in-situ building vulnerability assessment (field work and preliminary results)

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Content

- ✓ Task C: Goals and methods
- ✓ Thessaloniki: Field work and preliminary results
- ✓ Cologne: Field work and preliminary results
- ✓ Achievements and challenges

TASK C: Rapid and low cost in-situ building vulnerability assessment

The goal of this task is the **development of a rapid, low-cost and scientifically well-founded approach for assessing the seismic safety of existing reinforced concrete (RC) buildings**, both residential and public.

The procedure will conform to existing design and construction rules of practice and will be suitable for undertaking a series of preventive checks of RC buildings in areas of seismic risk, as well as for the building damage assessment after earthquakes. By the use of this approach, it should be possible to assess the seismic safety of selected RC buildings in a short time (a few days per building), and in doing so allow Civil Protection (CP) authorities prioritize their classification of buildings, from those able to continue use to various levels of necessary repairs.

Actions	Deliverables
C1: Simplified integral structural model approach to seismic safety assessment (TUB) C2: Short-term structural monitoring and modal analysis of buildings (AUTH) C3: Site-effects assessment (AUTH)	DC1: Guidelines for the building assessment procedure and short-term monitoring (06.2016) DC2: Guidelines for undertaking site-effect surveys (06.2016) DC3: Documentation for the developed software tools (06.2016) DC4: Reports on the case studies (11.2016)

Action C1: Simplified integral structural model approach to seismic vulnerability assessment

This action involves the **development of an approach** that combines a rational assessment rate (**suitable for large areas in a short time**) with an improved accuracy of seismic performance of each building. The assessment procedure will conform to the design criteria of EC 8, but is based on a simplified integral structural model as a system with only a few degrees-of-freedom.

The assessment approach itself includes:

- ✓ **In-situ data collection** about the structure, geometry, materials, soil and environment using Non-Destructive Testing (NDT), dynamic measurement techniques and a topological engineering model.
- ✓ Generation of a **simplified integral structural model** of the building from the topological engineering model and **rapid seismic vulnerability assessment**. The assessment procedure is based on nonlinear structural analysis (**pushover**) and performance-based evaluation criteria that conform to EC8.

Experiments will be carried out at **three test sites** of different spatial extent, selected in conjunction with the involved Civil Protection authorities.

Knowledge levels and corresponding methods of analysis (EN 1998-3:2005)

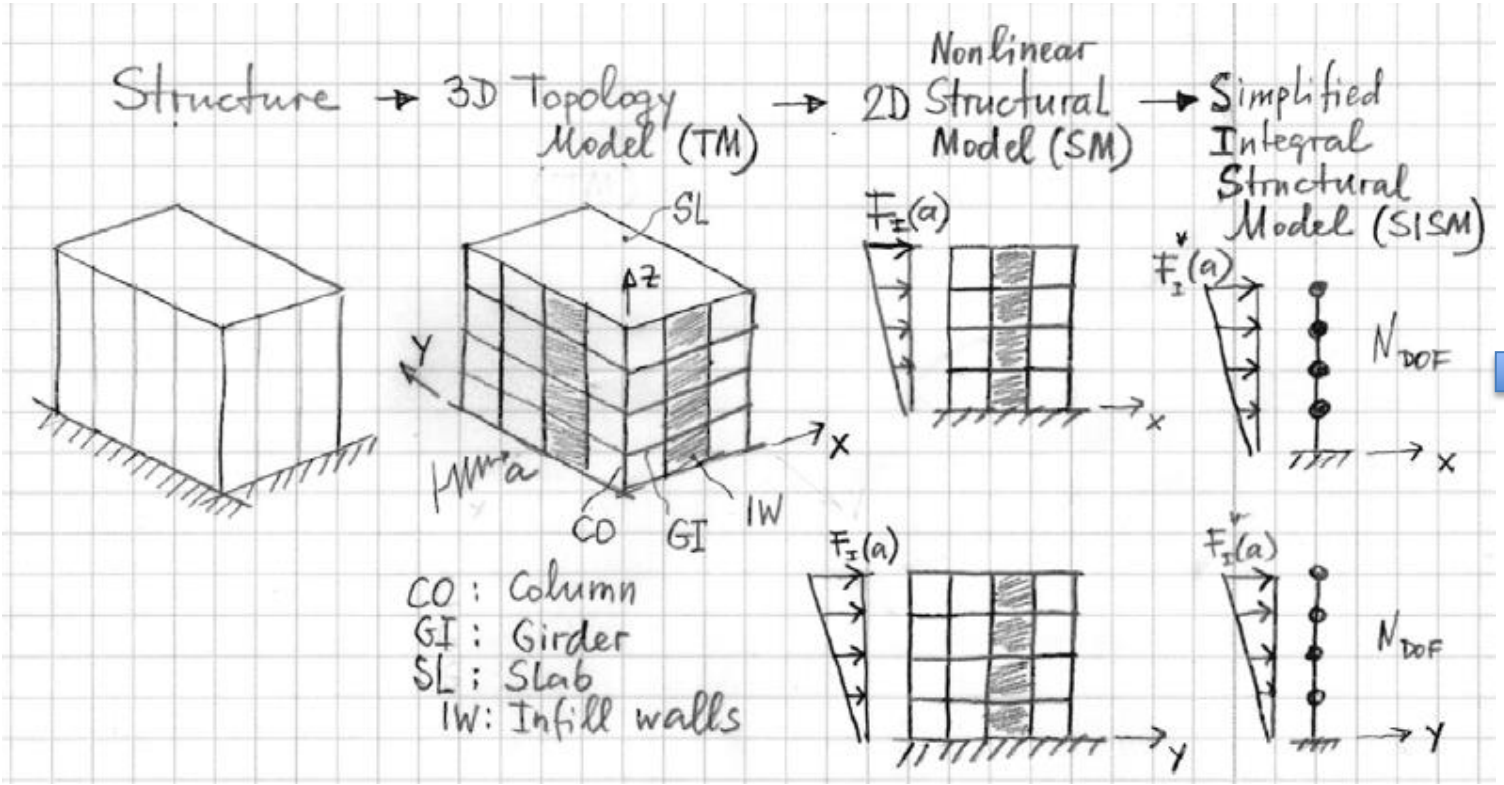
	KL1: Limited knowledge	KL2: Normal knowledge	KL3: Full knowledge
Geometry	From original outline construction drawings with sample visual survey or from full survey	From original outline construction drawings with sample visual survey or from full survey	From original outline construction drawings with sample visual survey or from full survey
Details	Simulated design in accordance with relevant practice and from limited in-situ inspection	From incomplete original detailed construction drawings with limited in-situ inspection or from extended in-situ inspection	From original detailed construction drawings with limited in-situ inspection or from comprehensive in-situ inspection
Material	Default values in accordance with standards of the time of construction and from limited in-situ testing	From original design specifications with limited in-situ testing or from extended in-situ testing	From original test reports with limited in-situ testing or from comprehensive in-situ testing
Analysis	Linear analysis methods, either static or dynamic	Linear or nonlinear analysis methods, either static or dynamic	Linear or nonlinear analysis methods, either static or dynamic
Confidence factors (CF)	1.35	1.20	1.00

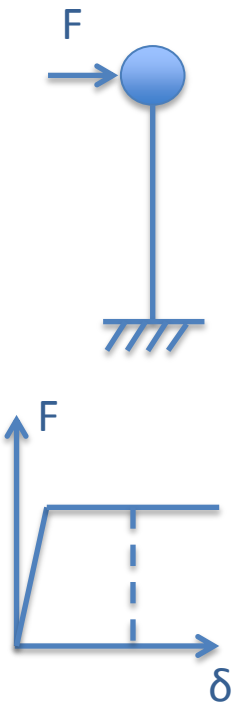
SIBYL approach

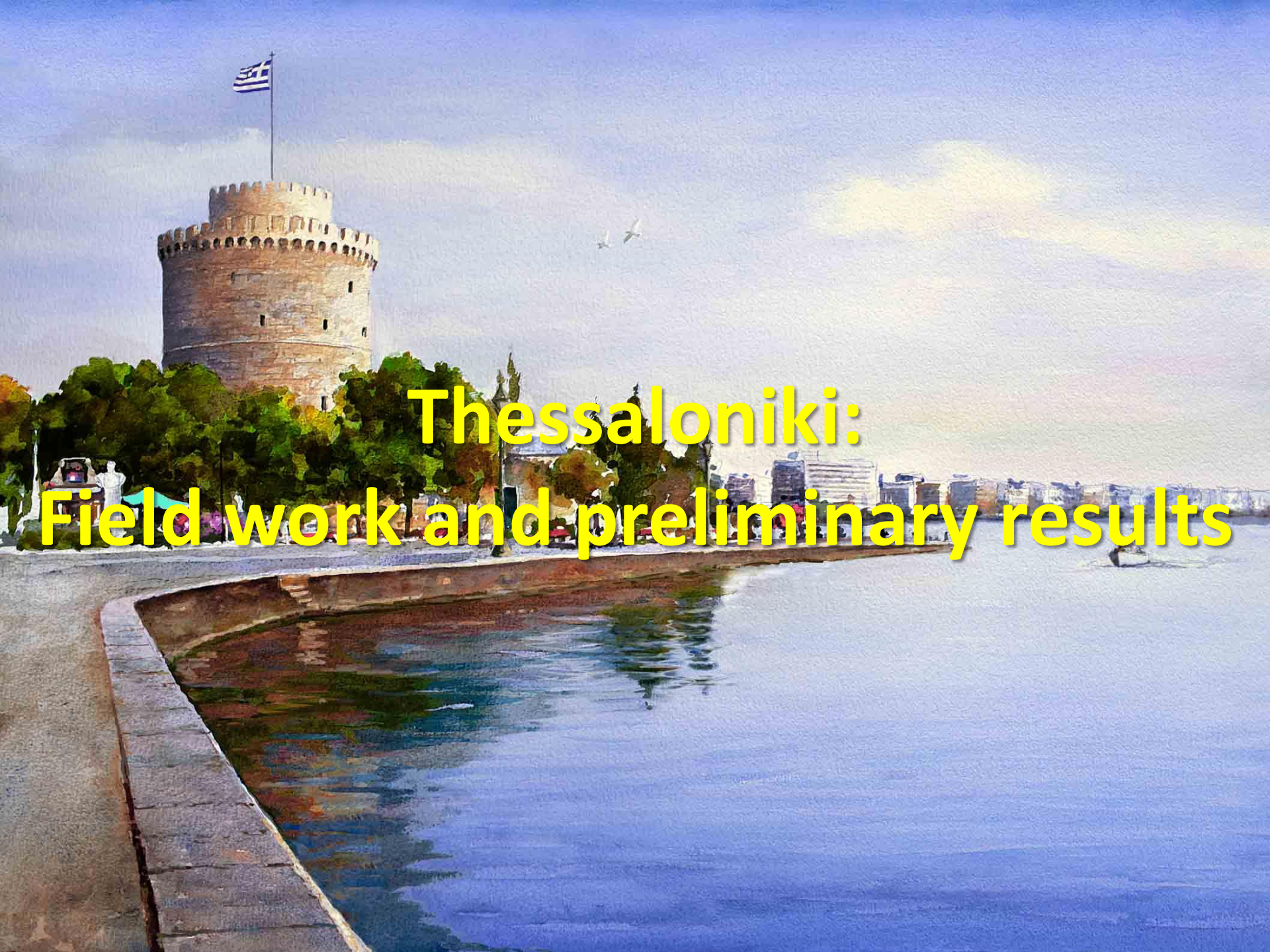
As SIBYL aims at "**developing of a fast and simple approach for assessment of seismic vulnerability of existing structures**" suitable for seismic vulnerability analysis of **large built-up areas in a short time**, in the framework of the project we will presumably remain within the levels of **KL1** and **KL2**. Additionally, we introduce and consider the level **KL0**, assuming **very limited state of knowledge**, when the design documentation and construction drawings are not available and the structural evaluation (as well as the vulnerability assessment) is based solely on a limited visual survey of the structure in question.

The developed **operational framework should be flexible, affording a range of different approaches (accuracy vs time)** to solve the problems of vulnerability analysis in different conditions. And the **choice of the appropriate approach will be done by the end-users** (Civil Protection authorities), depending on their needs, available time and affordable resources.

SISM concept

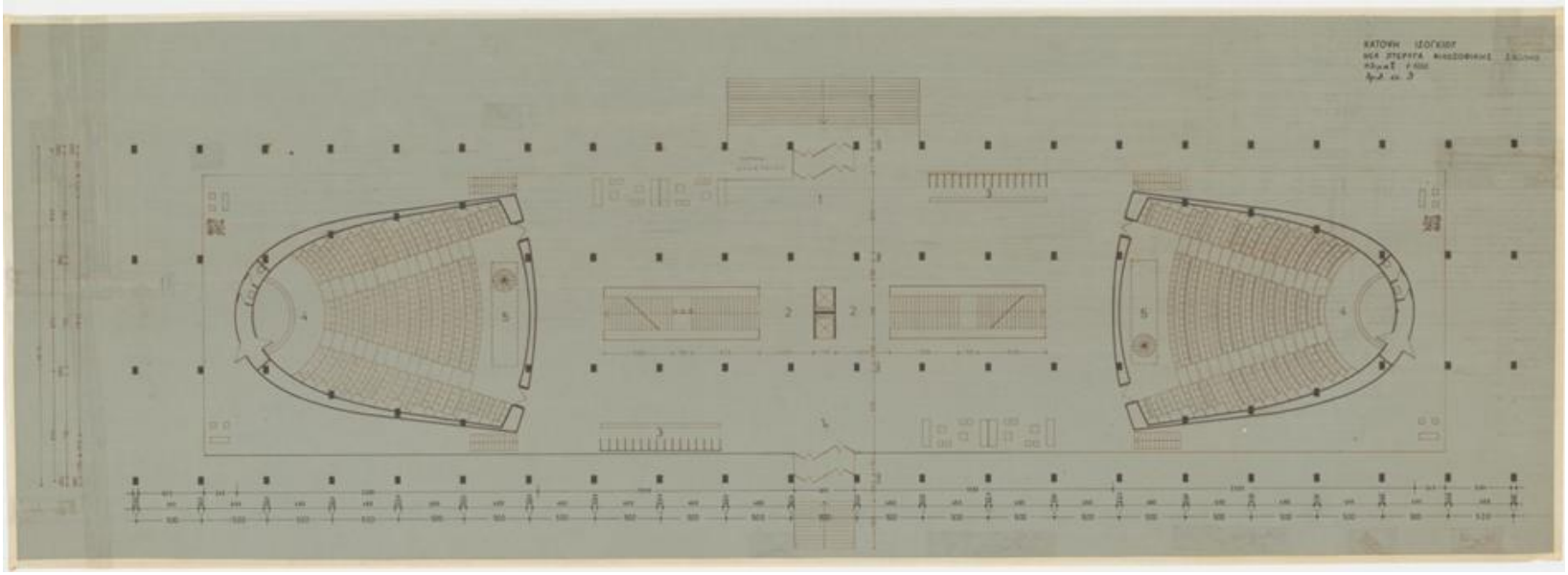


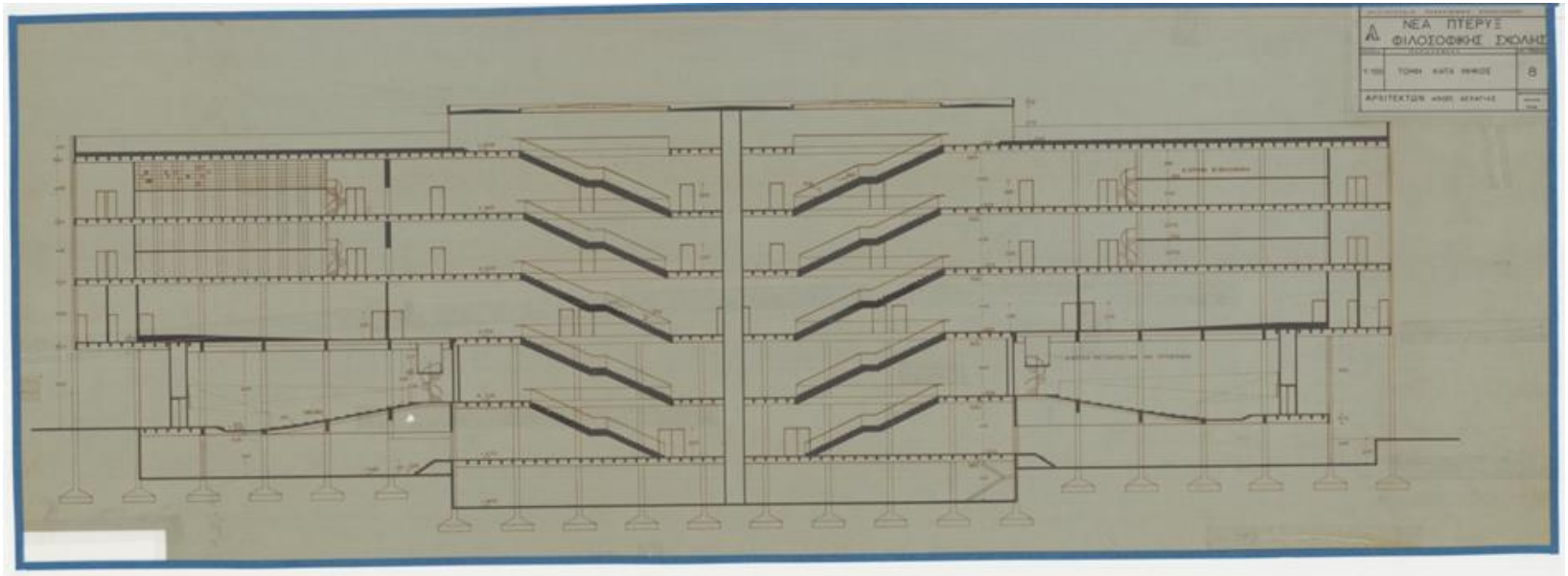



Thessaloniki:
Field work and preliminary results

The building of the Faculty of Philosophy, AUTH

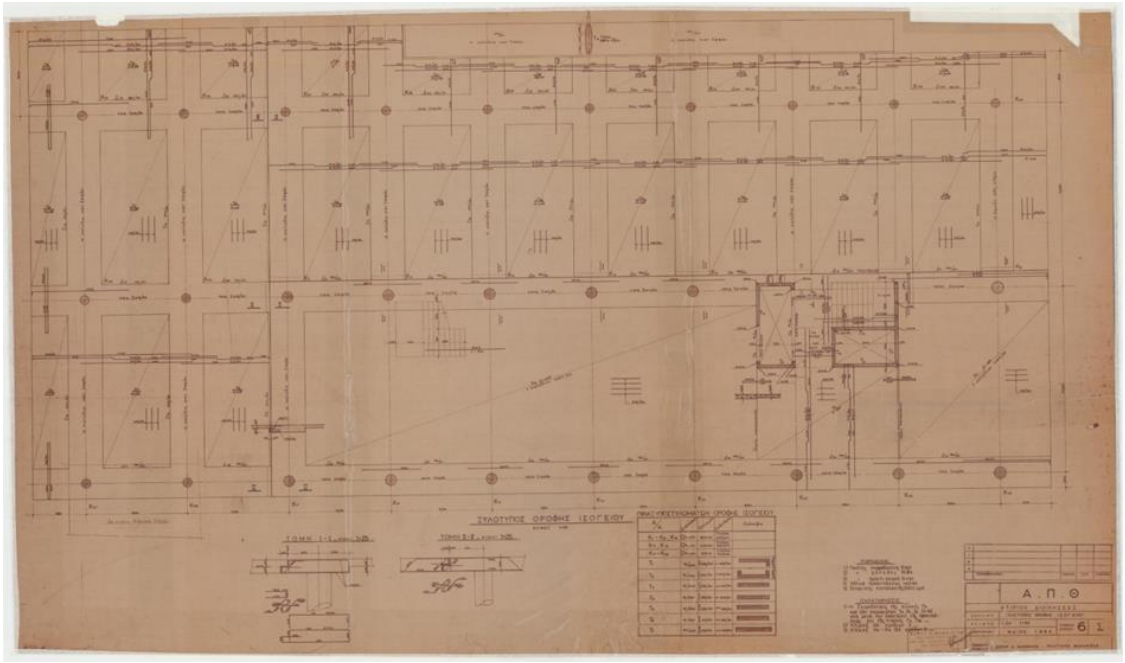
Original design drawings

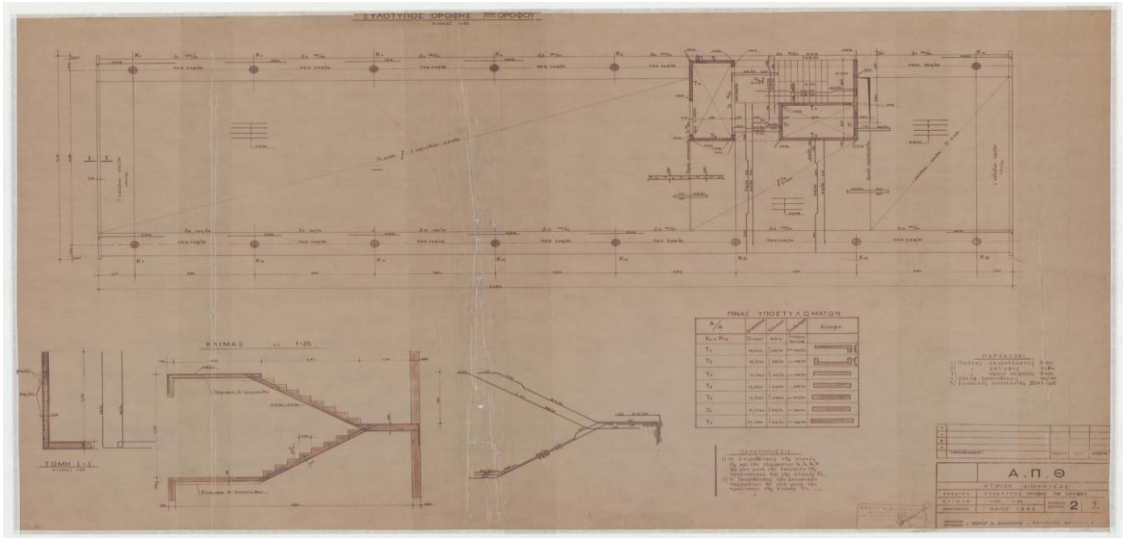




Administration building, AUTH

Original design drawings





Ambient vibration measurements, system identification and modal analysis for the building of the Faculty of Philosophy

MACEC 3.3

A MATLAB TOOLBOX FOR EXPERIMENTAL AND OPERATIONAL MODAL ANALYSIS

Sensors and time of vibration measurements (September/October 2015)

	array	array	1st	1st	1st	1st	1st	1st	1st	1st	1st	1st	1st	1st	1st	1st	1st	1st	1st	1st	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	2nd	
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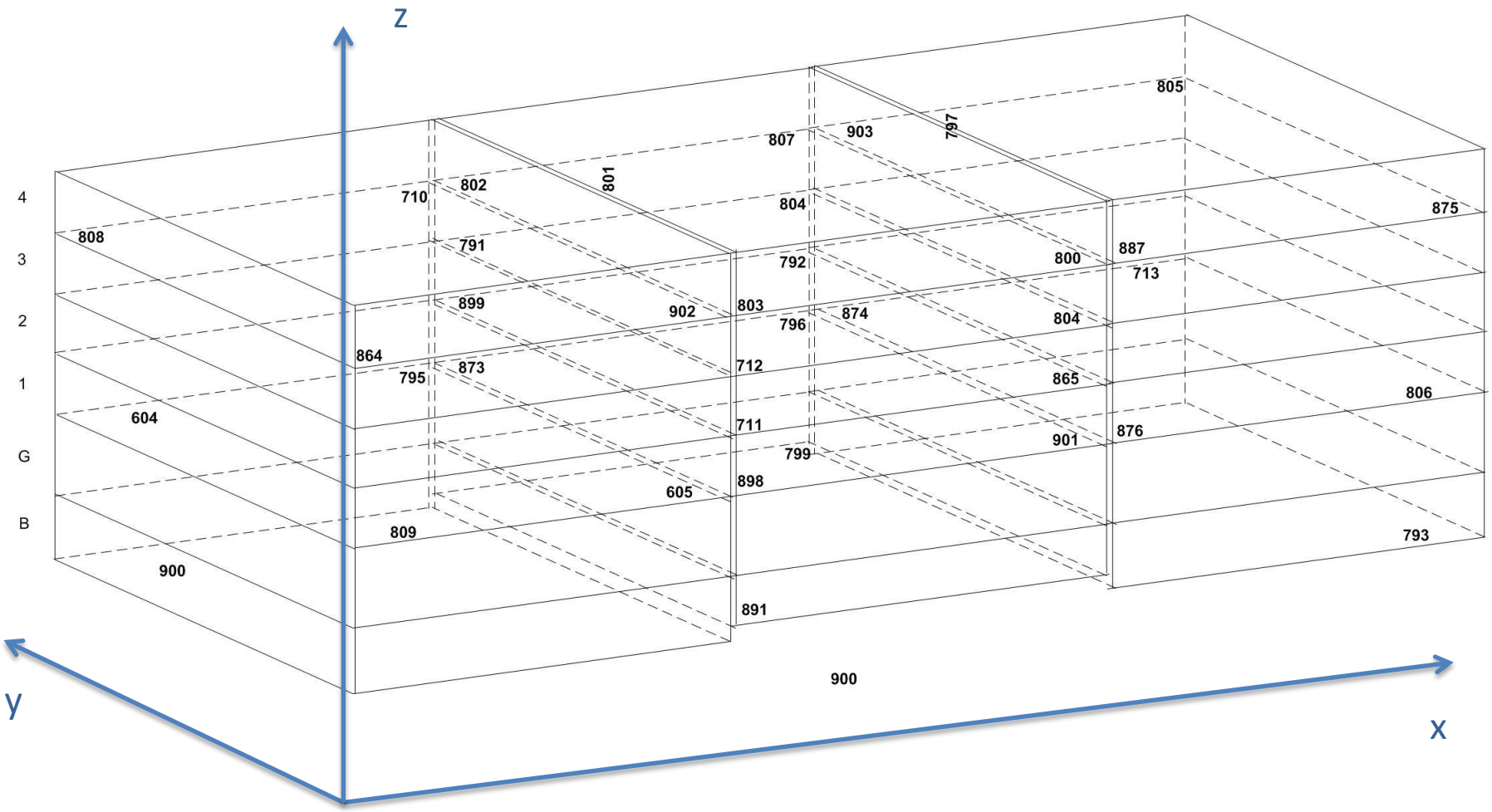
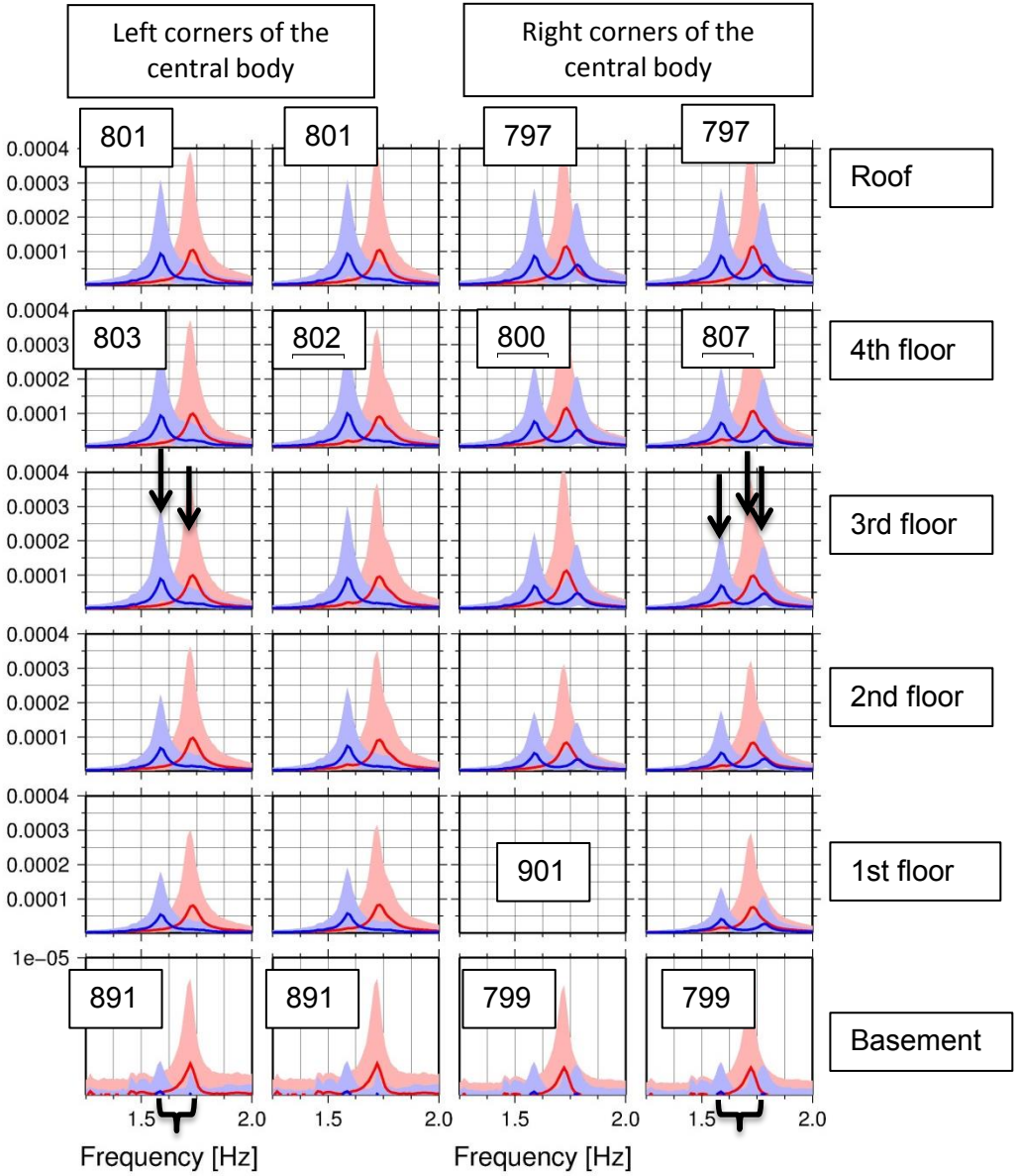
Dynamik Statik

Spatial arrangement of the sensors

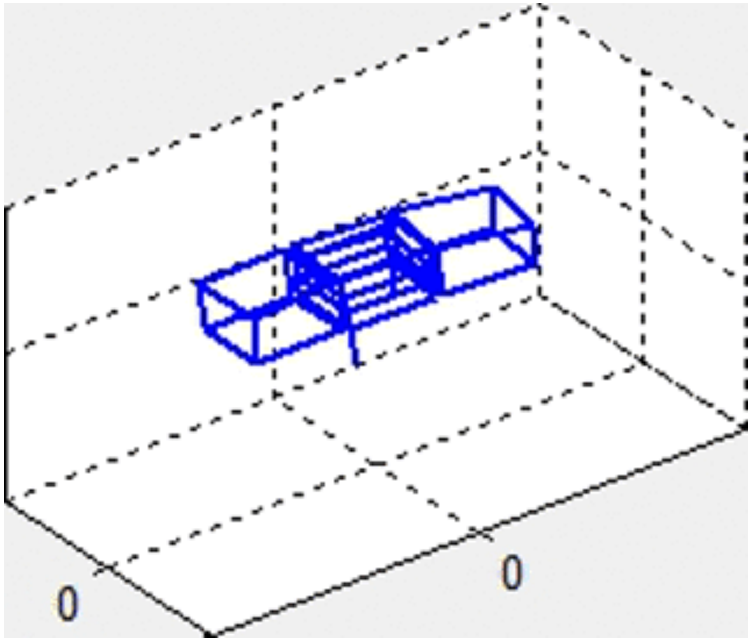


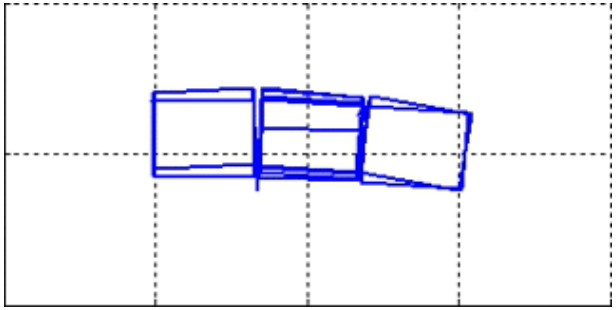
Dynamik Statik

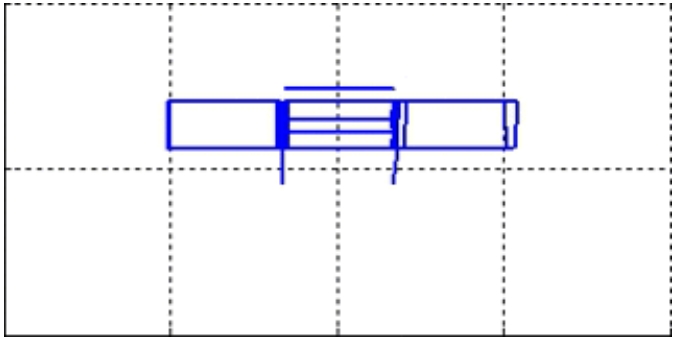
The vibration spectra in the central part of the building

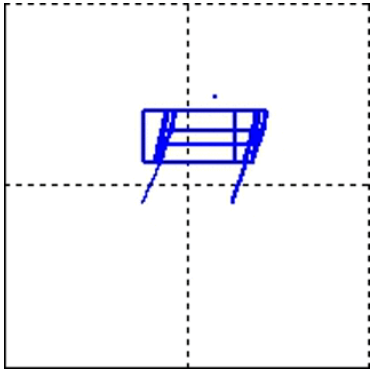


1st mode (f=1.60 Hz)









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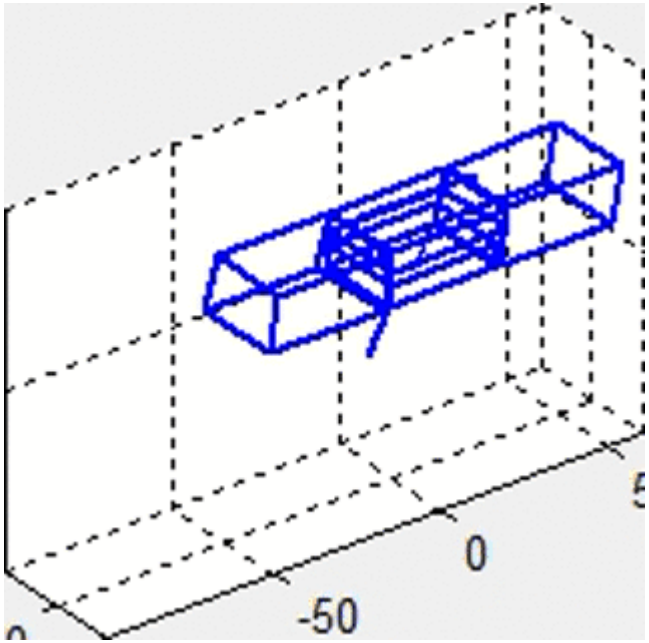

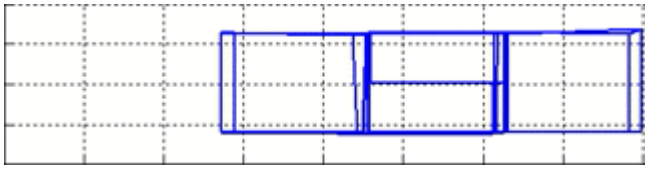

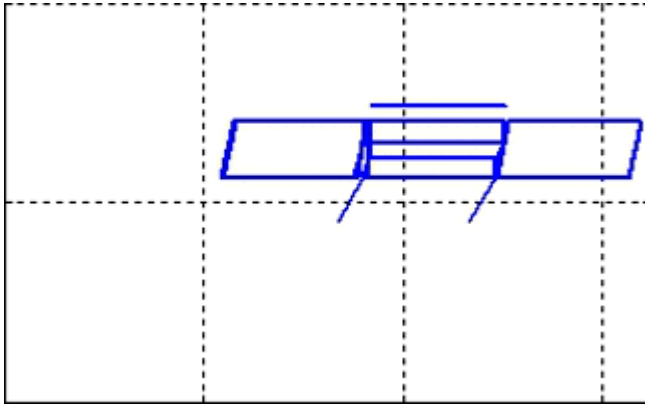

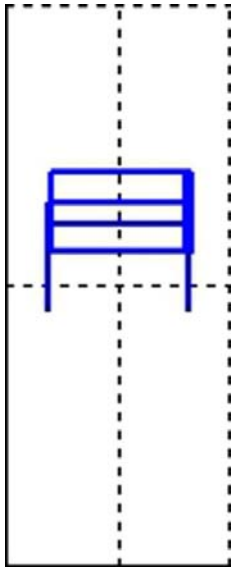

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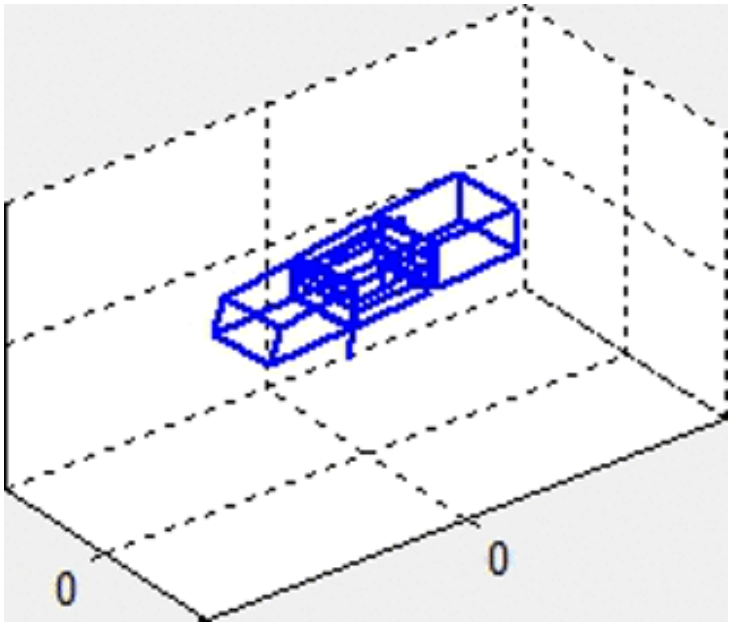
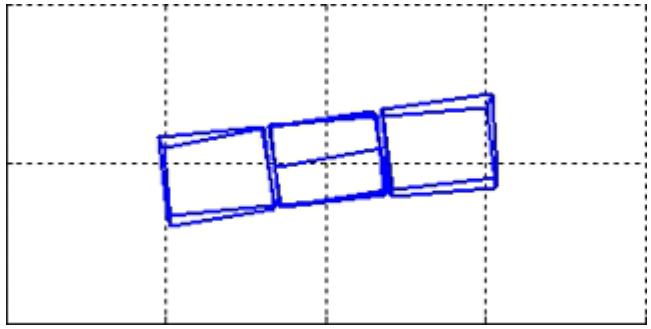
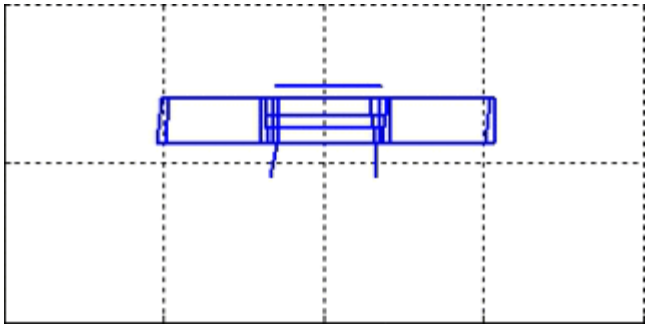
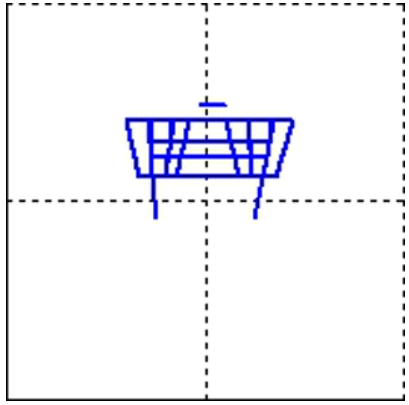
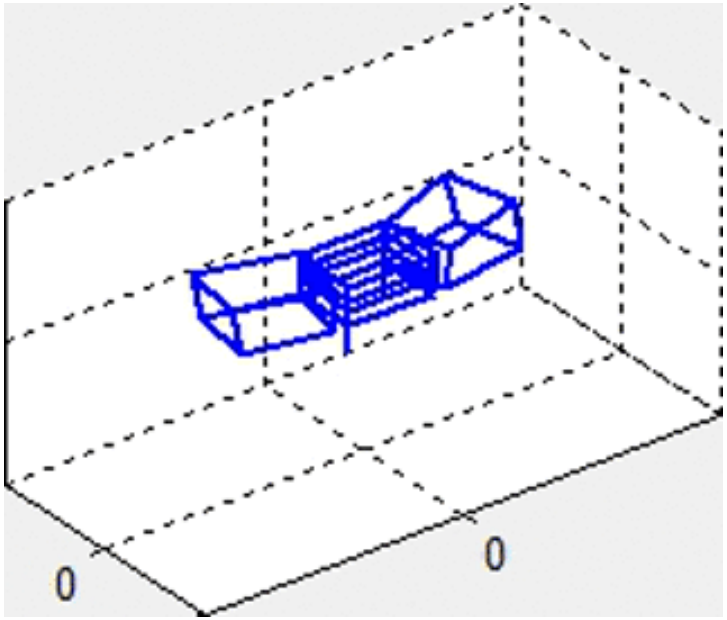


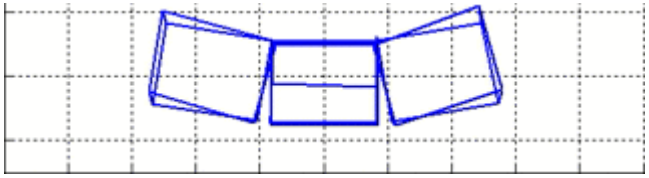


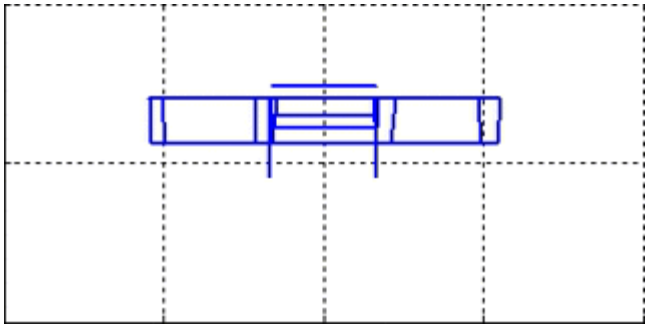


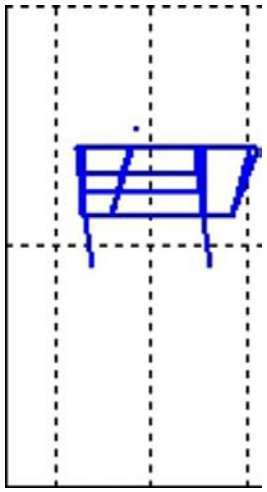


4th mode (f=2.10 Hz)









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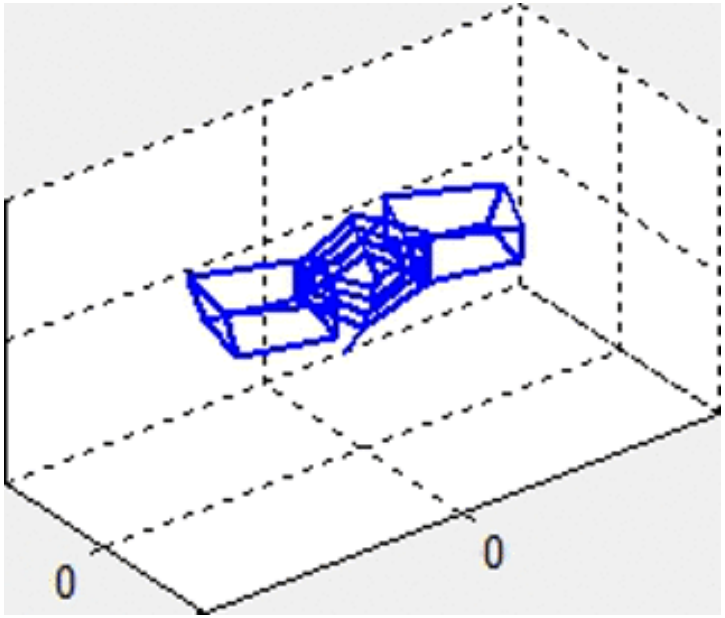

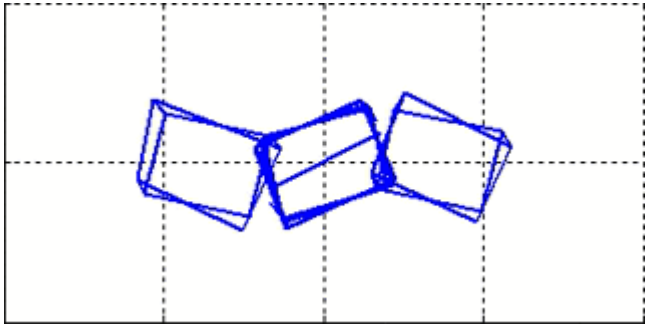

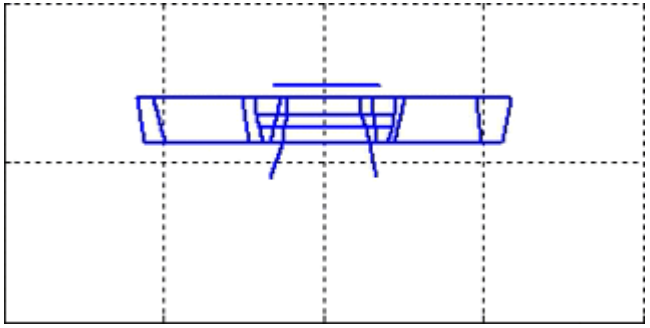

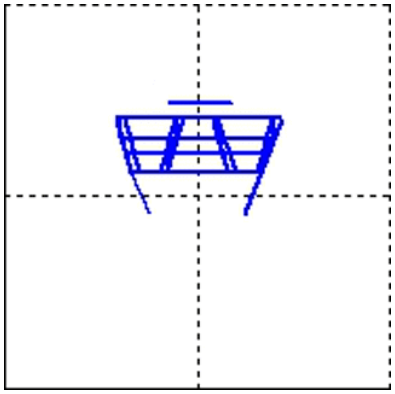

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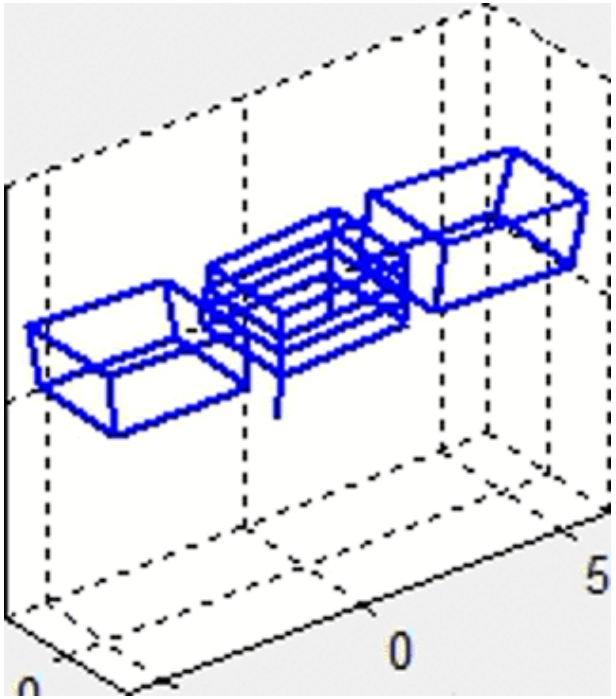
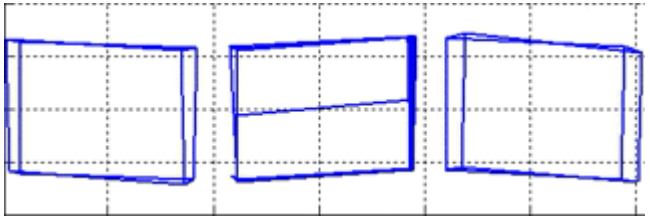
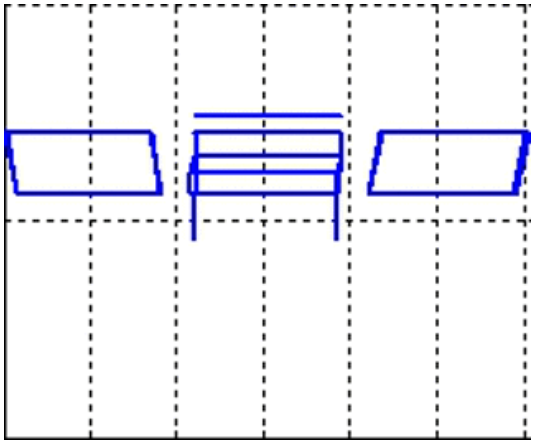
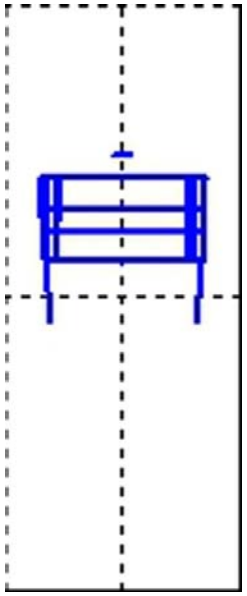
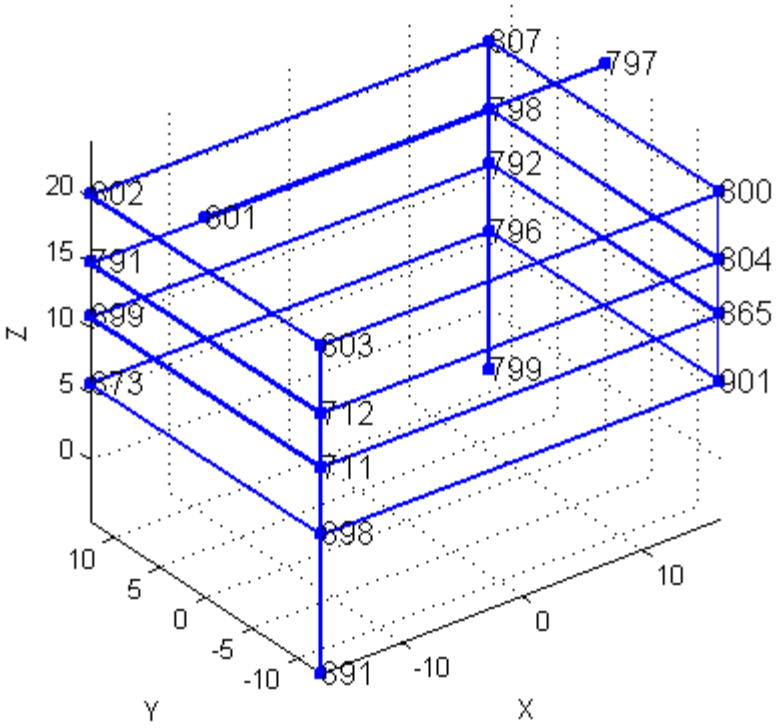




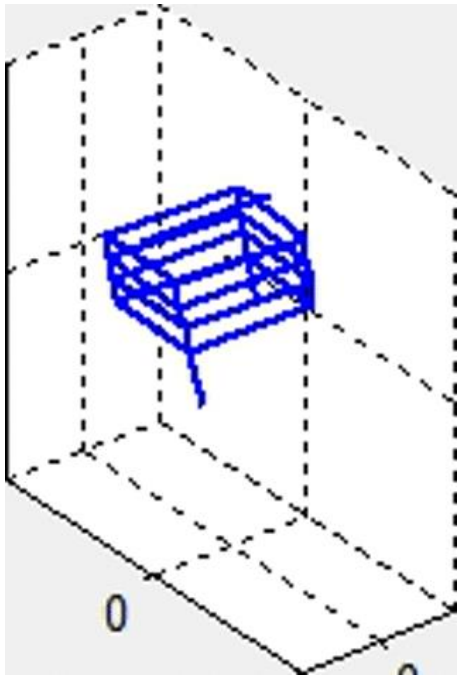


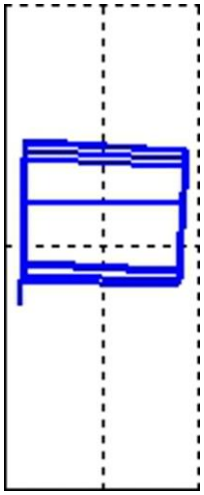


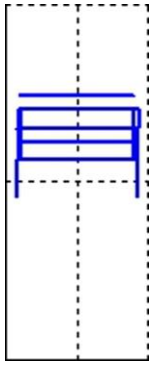
Central part of the building

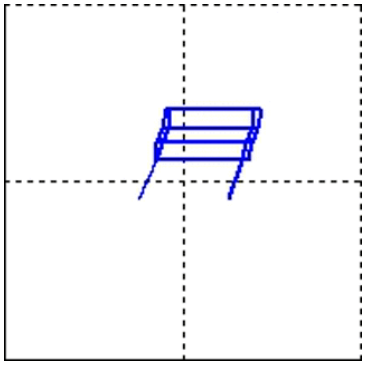


1st mode (f=1.60 Hz)

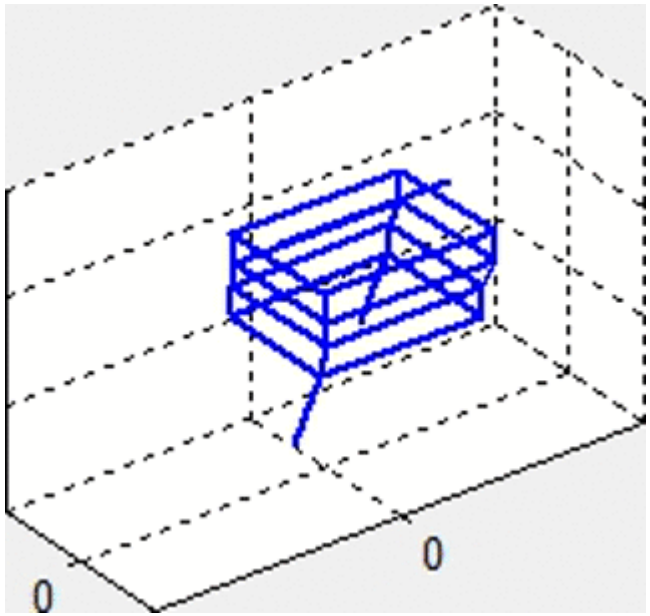


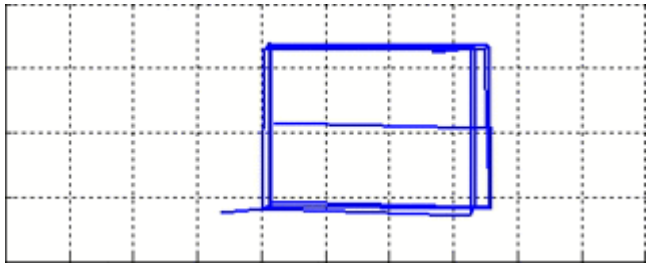


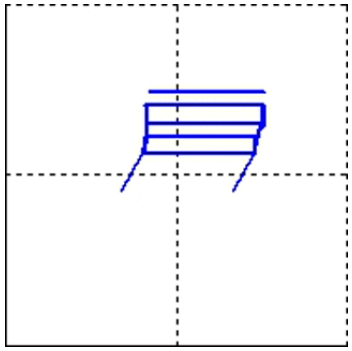


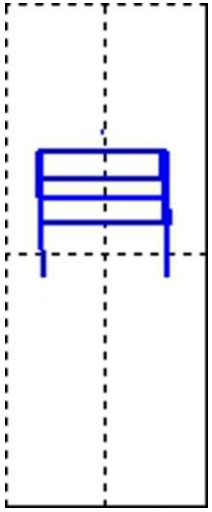


2nd mode (f=1.72 Hz)

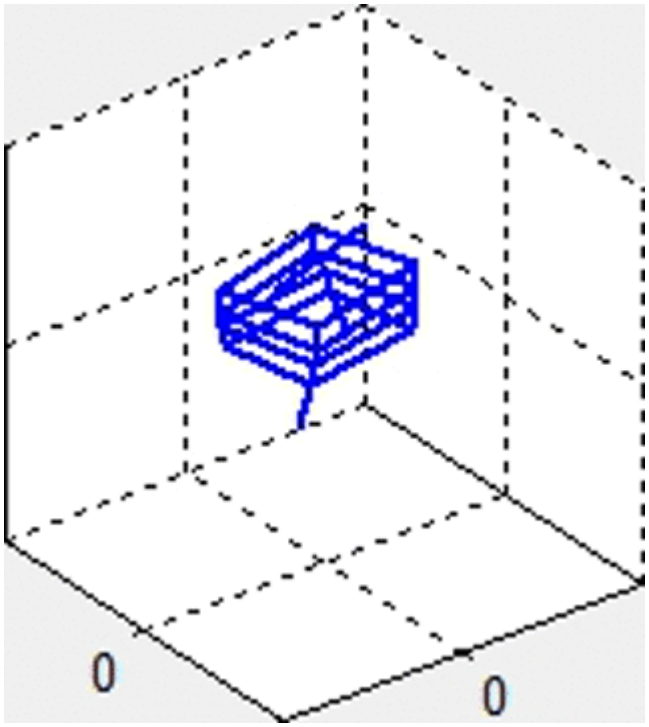


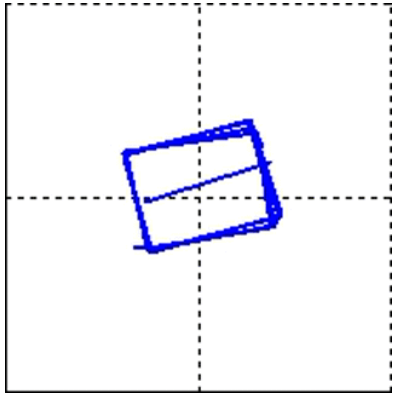


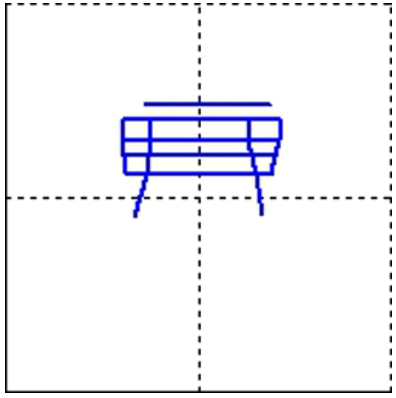


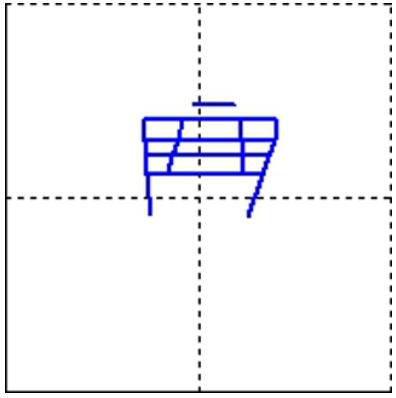


3rd mode (1.78 Hz)









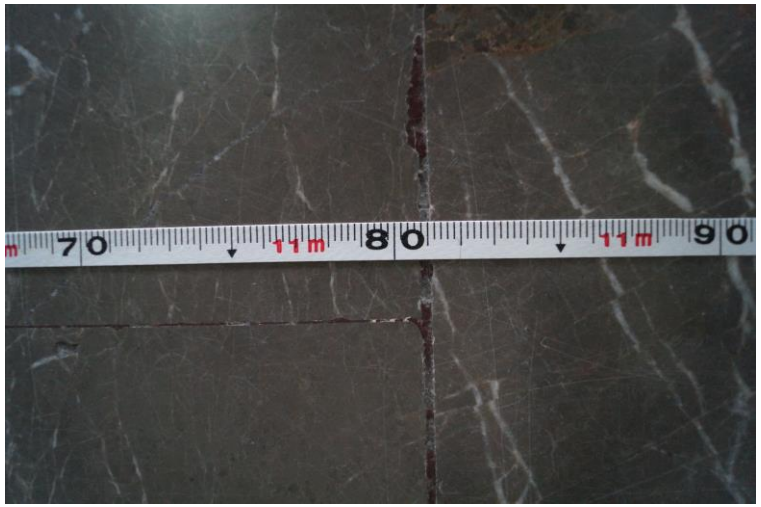
Structural survey and data collection

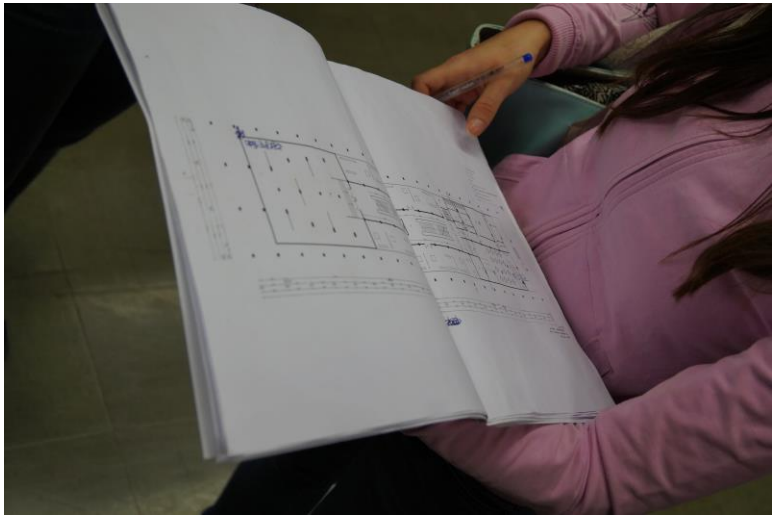
Keeping in mind the objectives of the Task C: ”Rapid and low cost in-situ building vulnerability assessment”, we engage **easily-accessible methods and tools**, combining analysis of **available original design documentati**on and the **simulated design** with a **limited in-situ inspection** including the **visual survey and measurements** of the existing structures and the methods of **non-destructive in-situ testing**.

The information to be collected for the structural modeling includes as follows:

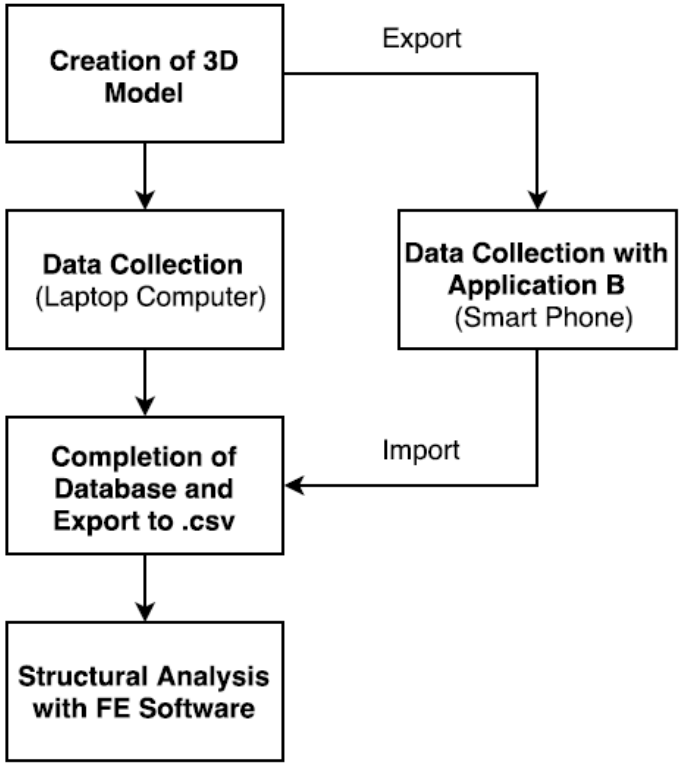
- ✓ **current physical condition** of the structural elements and possible presence of damage or degradation;
- ✓ **geometry** (including overall structural geometry and member sizes, possible geometrical distortions or deficiencies);
- ✓ **structural details** (presence and amount of steel reinforcement in columns, beams and walls and depth of concrete cover);
- ✓ **mechanical properties** of construction materials (in particular, concrete strength and elasticity modulus, steel yield strength, ultimate strength and ultimate strain).

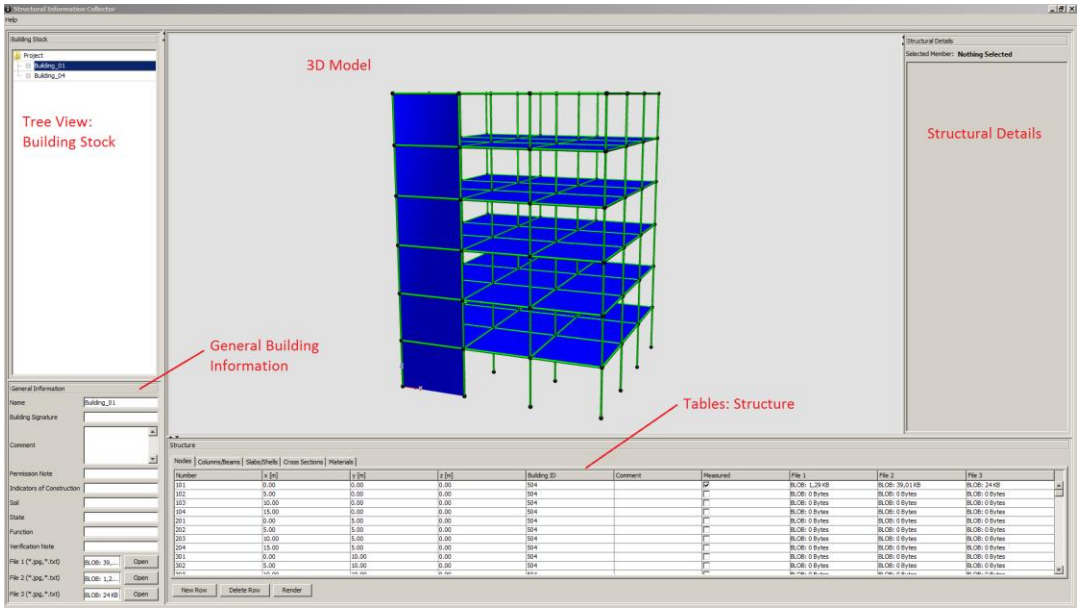
Data collection tools and methods



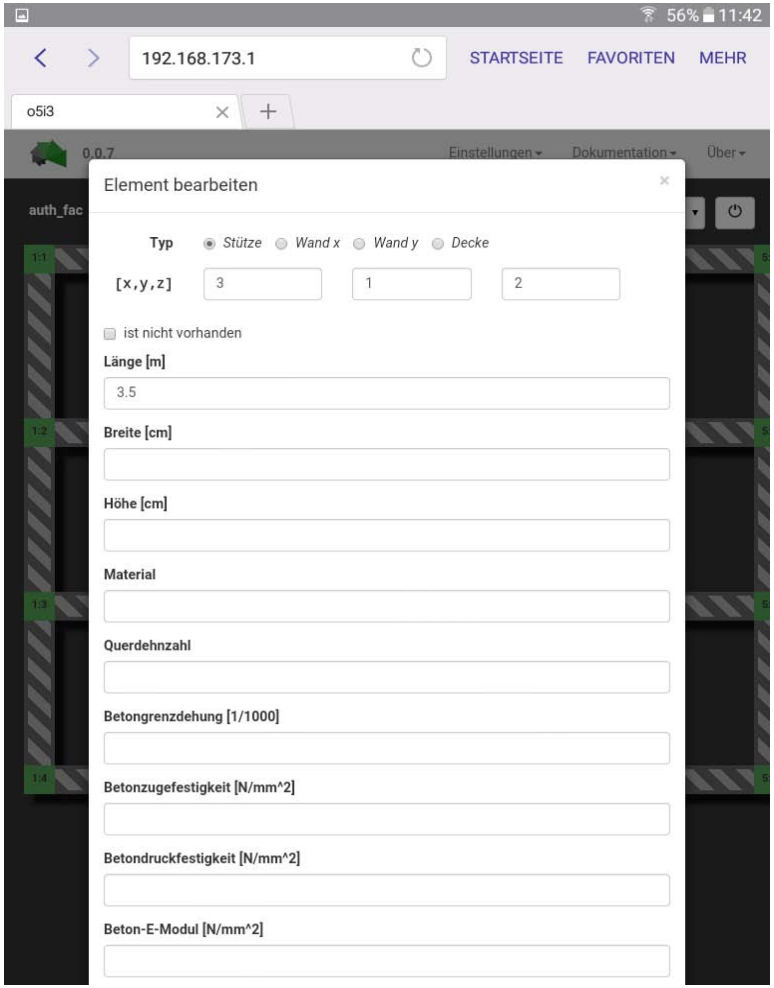


Data collection tools and methods

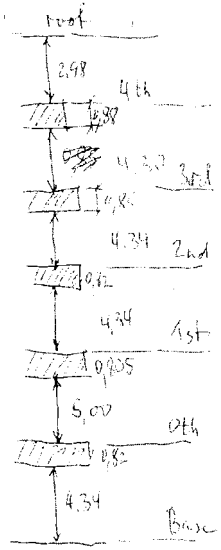




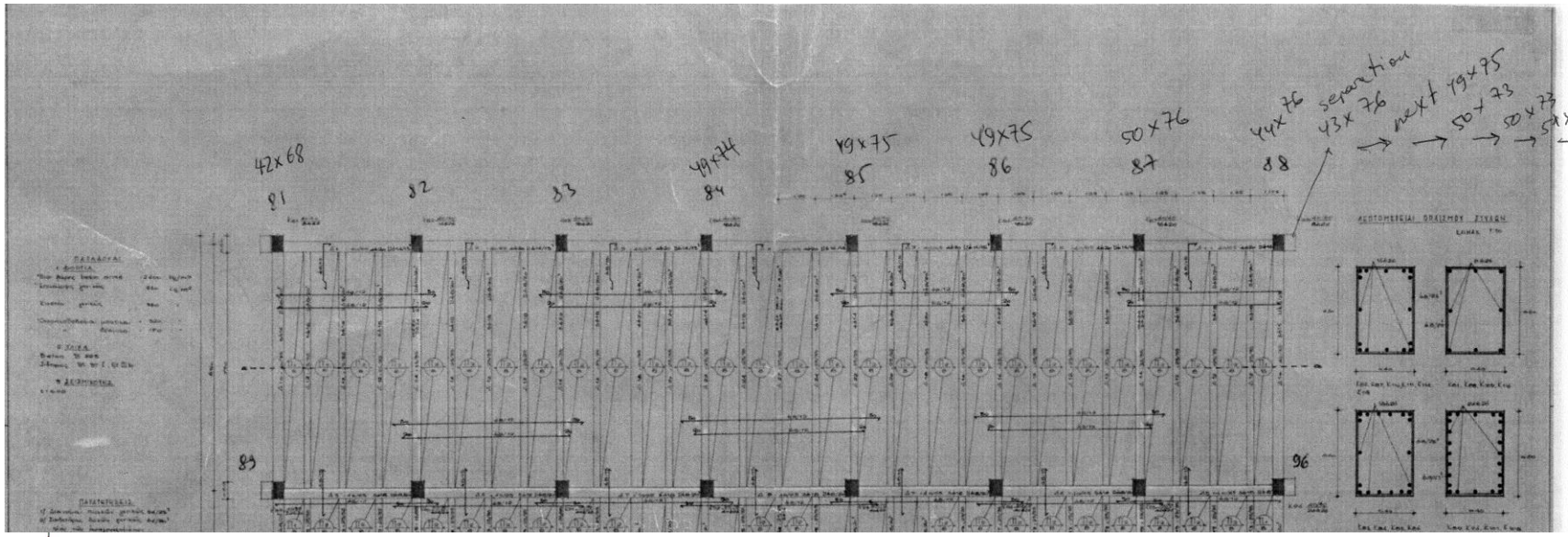
Data collection tools and methods



In-situ structural survey and data collection

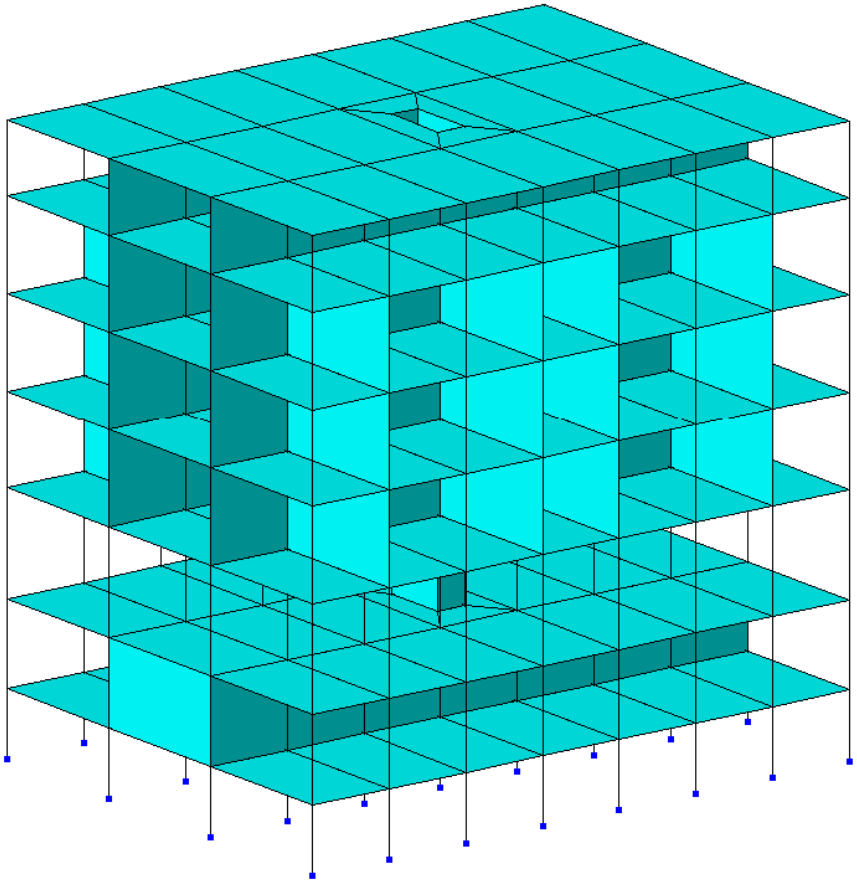


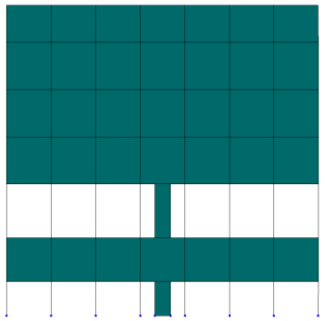
One additional storey detected

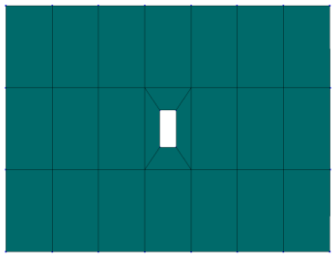


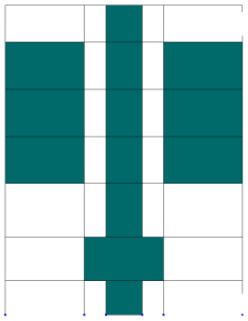
Dynamik Statik

FEM Modelling (LIRA)

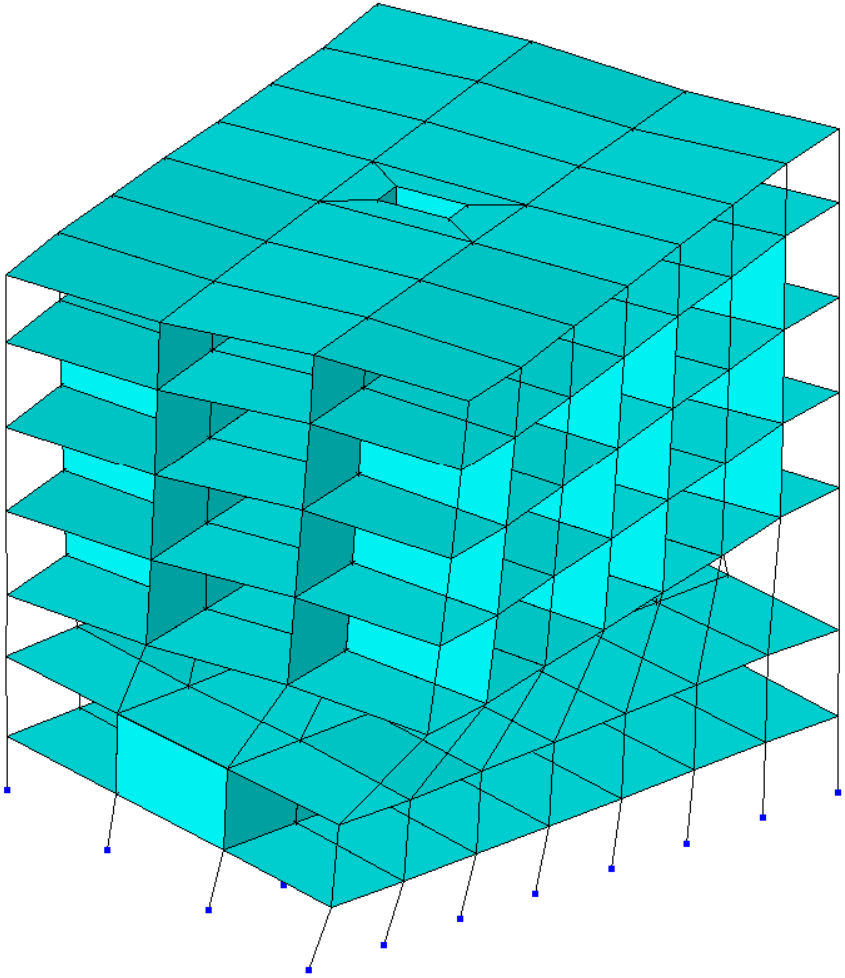


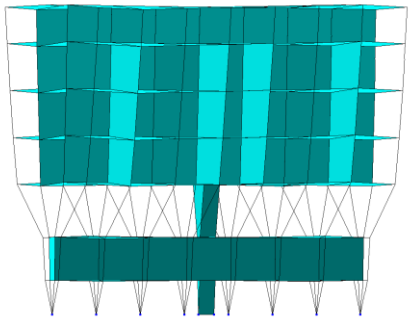


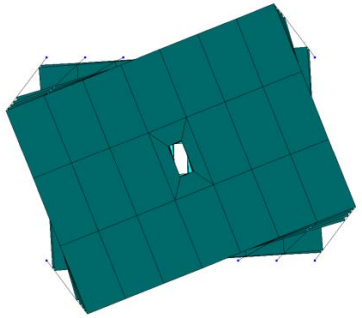


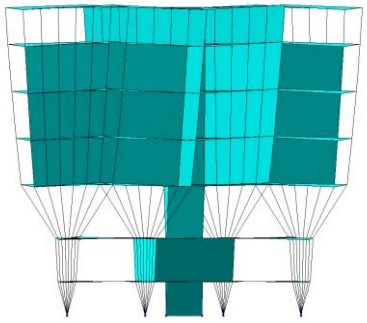


Mode shape 1 (f=1.28 Hz)

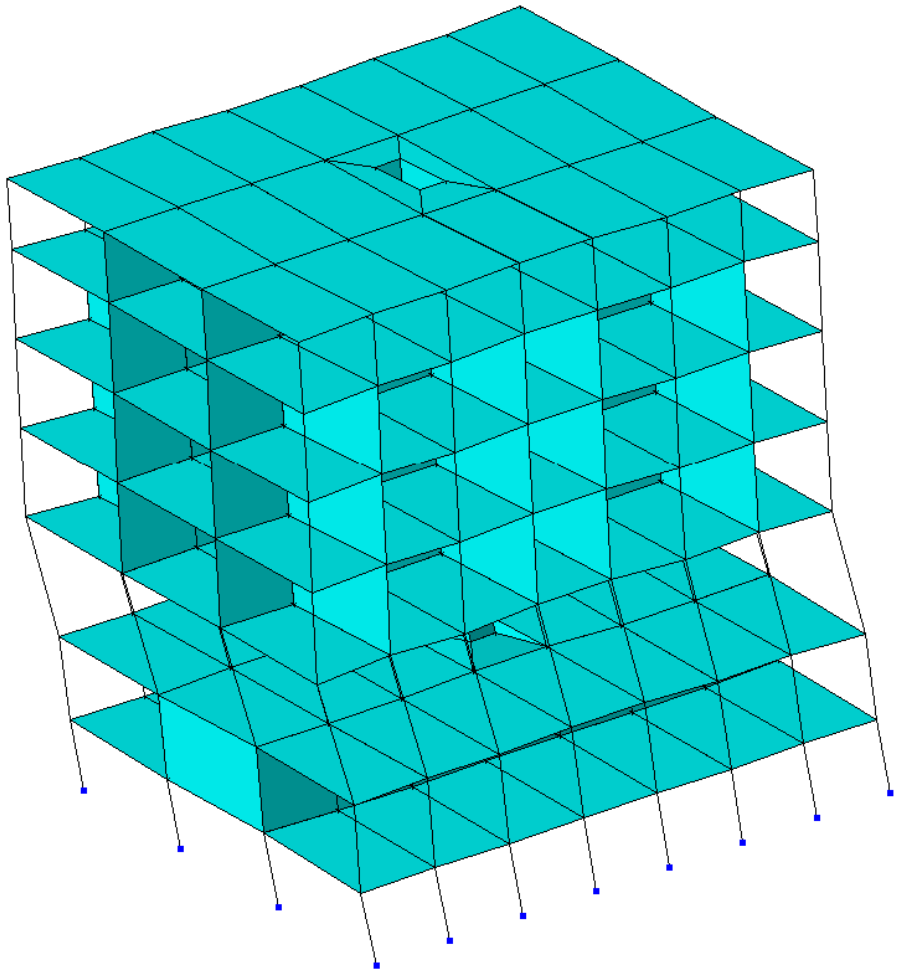


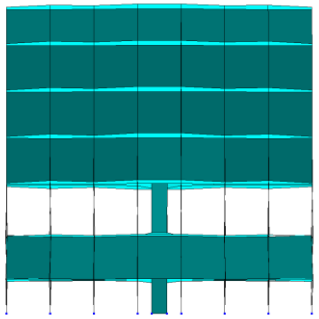


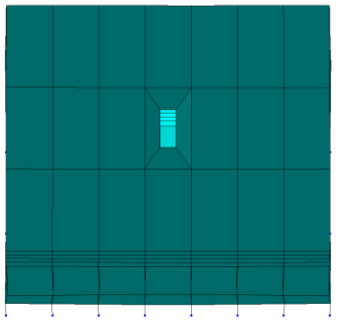


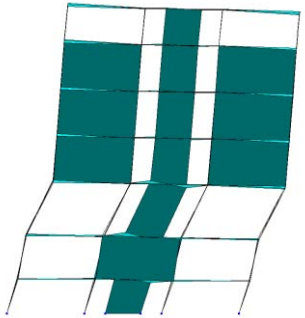


Mode shape 2 (f=1.49 Hz)

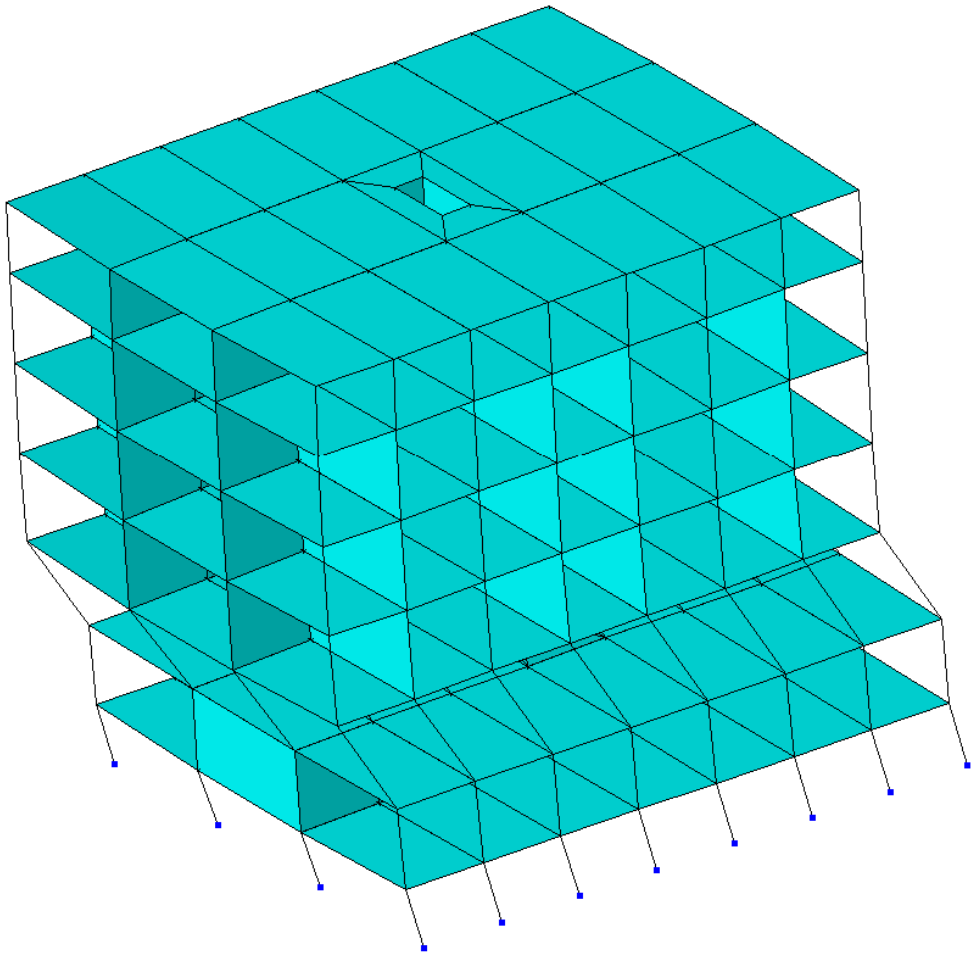


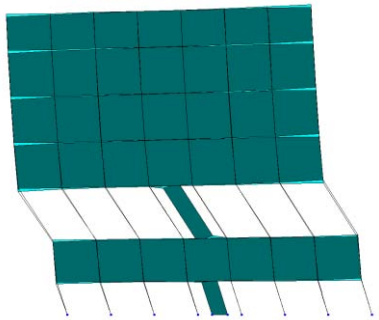


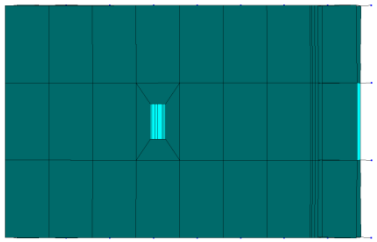


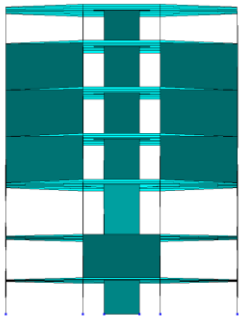


Mode shape 3 (f=1.75 Hz)

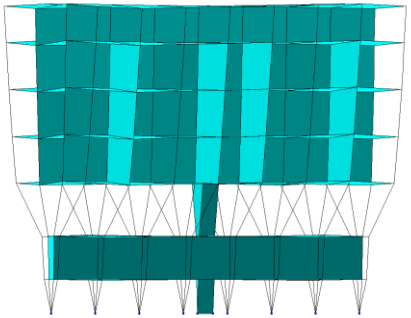


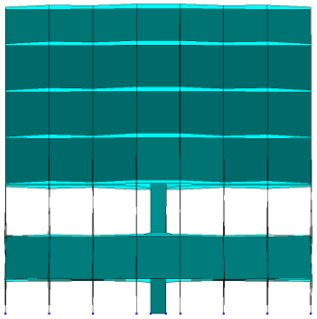


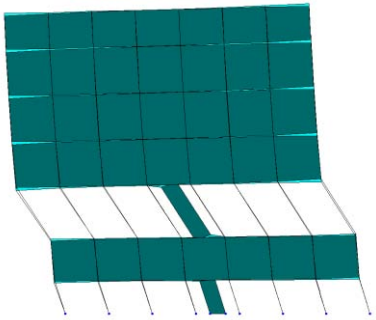


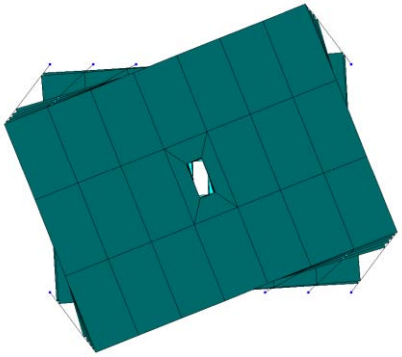


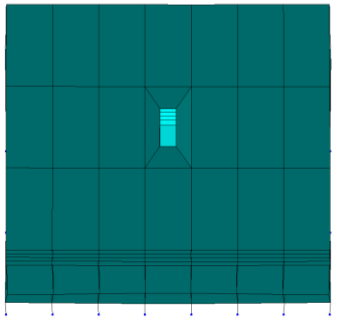
Mode shapes (comparison with OMA)

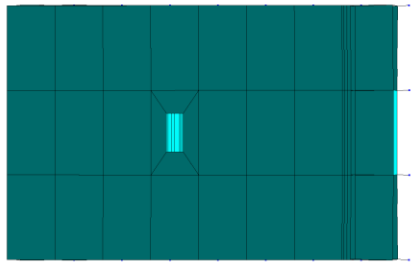


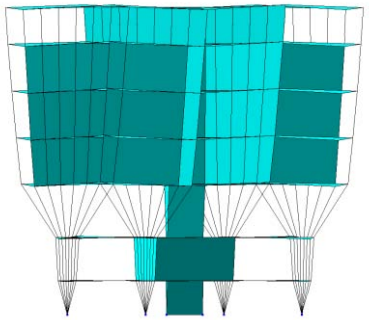


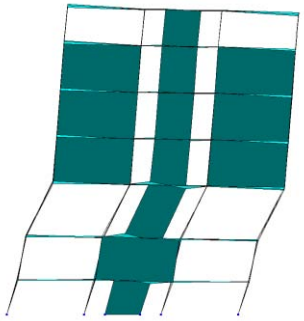


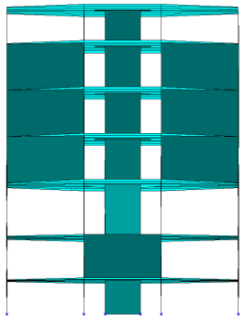












f=1.28 Hz

f=1.76 Hz

f=1.49 Hz

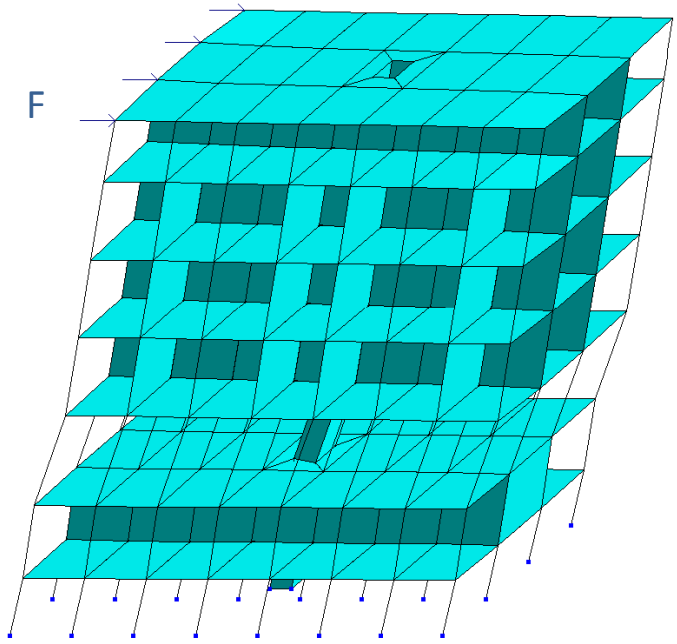
f=1.60 Hz

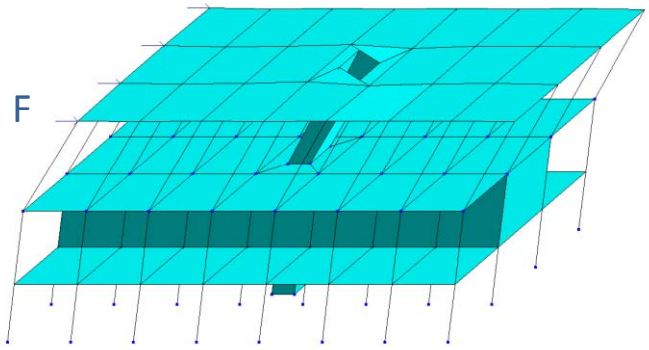
f=1.75 Hz

f=1.72 Hz

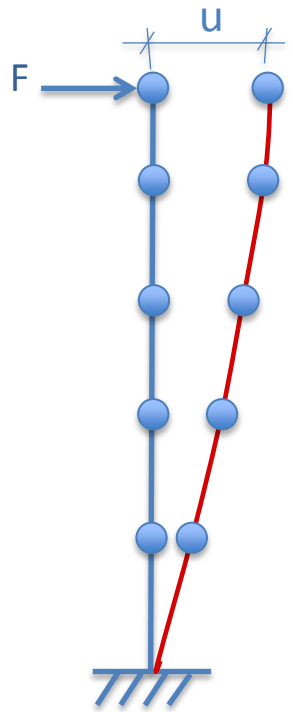
Dynamik Statik

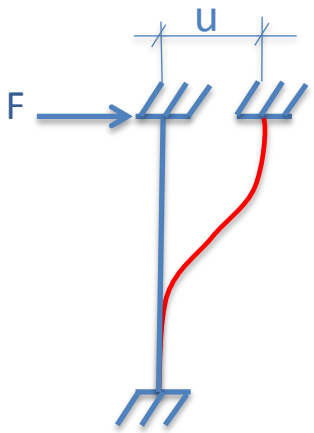
Simplified model by displacement method





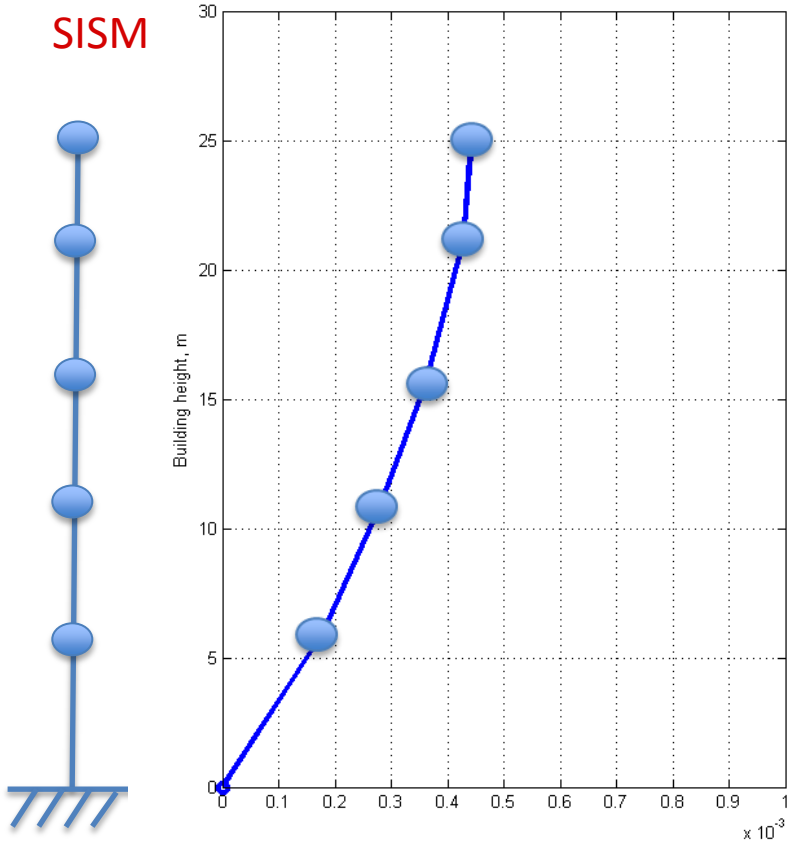
$$K = F / u$$



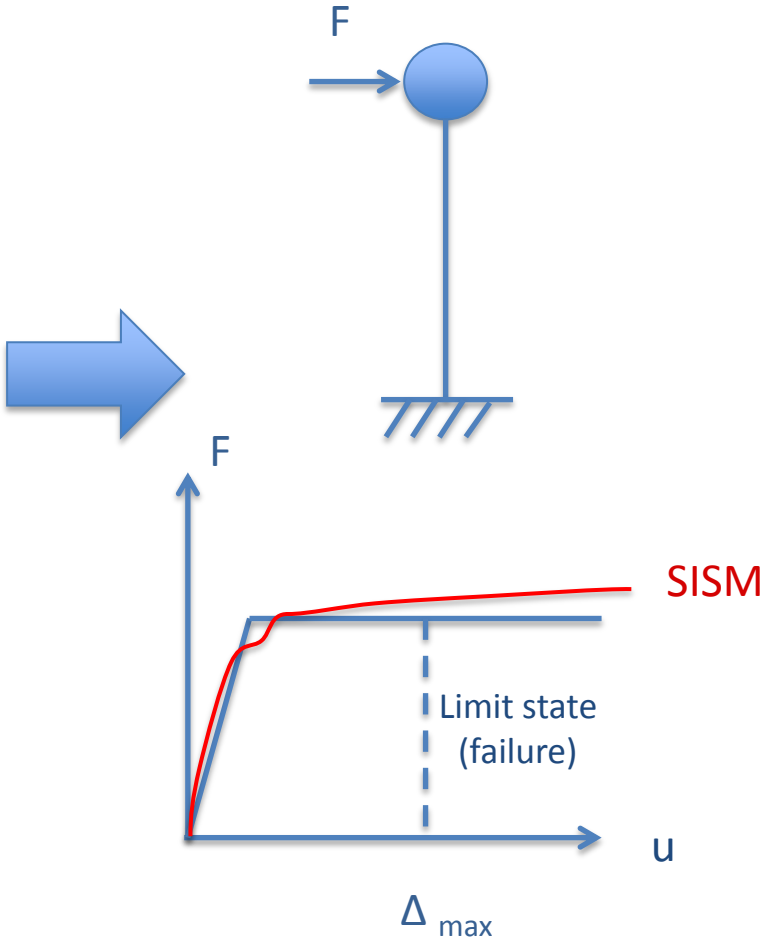


Simplified model

SISM



Simplified model
for fragility analysis



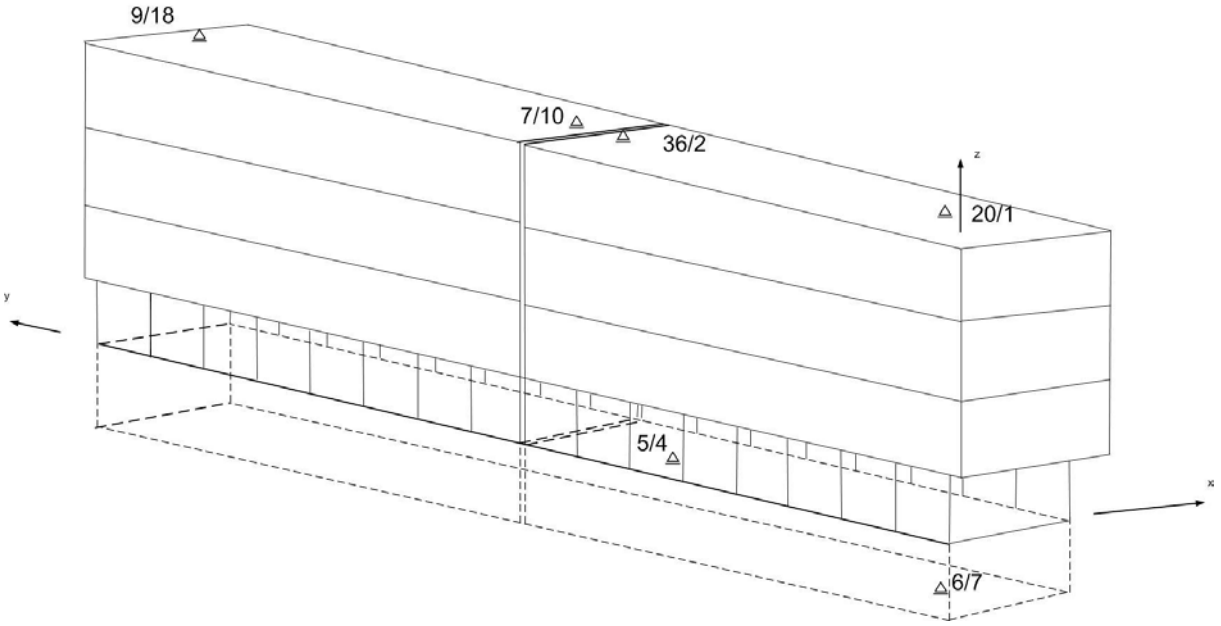

Cologne:
Field work and preliminary results

Investigated schools in Cologne

NN	School Name	Address	Date & Time
1	Humboldt-Gymnasium	Kartäuserwall 40, 50676 Köln	Mo.30.11 8-12
2	Alfred-Müller-Armack Berufskolleg	Brüggener Str. 1, 50969 Köln	Di.01.12 12-16
3	Henry-Ford-Realschule	Karl-Marx-Allee 43, 50769 Köln	Mi.02.12 8-12
4	Berufskolleg Ehrenfeld	Weinsbergstraße 72, 50823 Köln	Mi.02.12 12-16
5	Otto-Lilienthal-Schule	Albert-Schweitzer-Straße 8, 51147 Köln	Do.03.12 8-12
6	Gymnasium Thusneldastraße	Thusneldastraße 17, 50679 Köln	Do.03.12 12-16
7	Gymnasium Kreuzgasse	Vogelsanger Str. 1, 50672 Köln	Fr.04.12 8-12

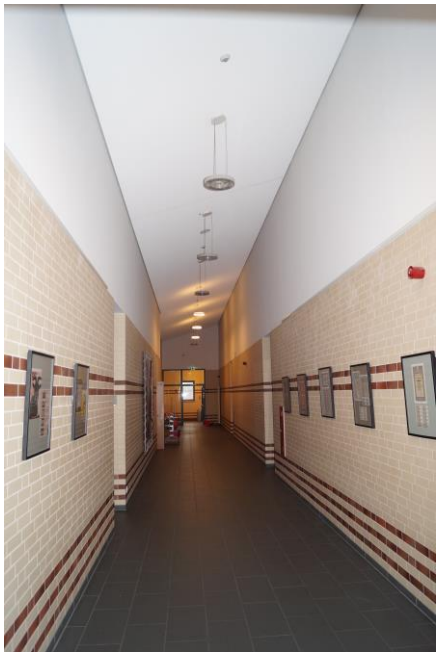
Survey time 2 h, measurements 1 h

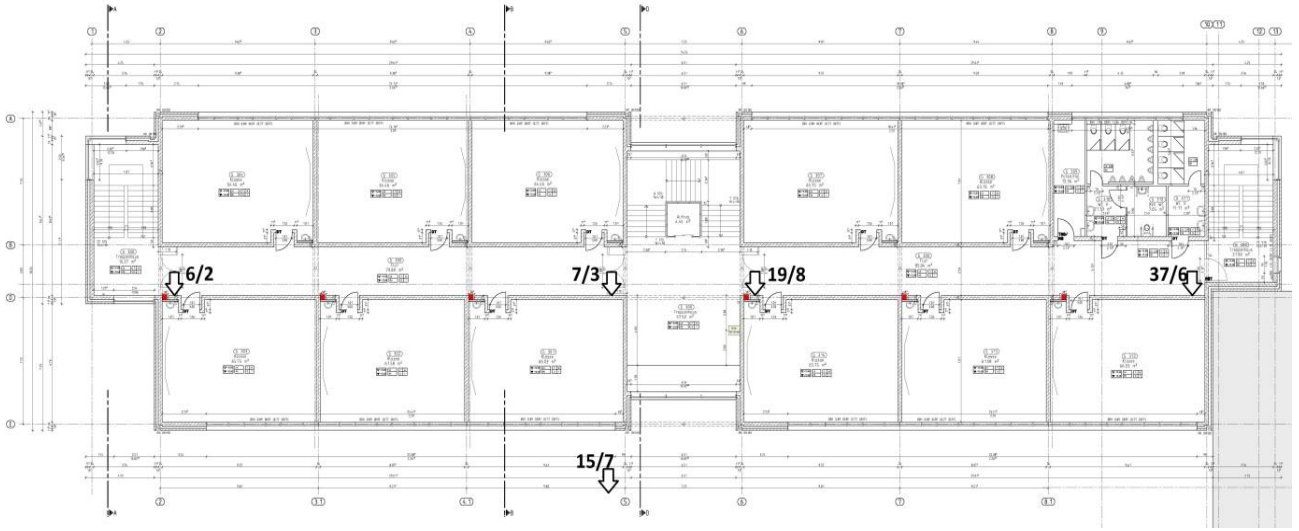
Humboldt-Gymnasium



Dynamik
Statik

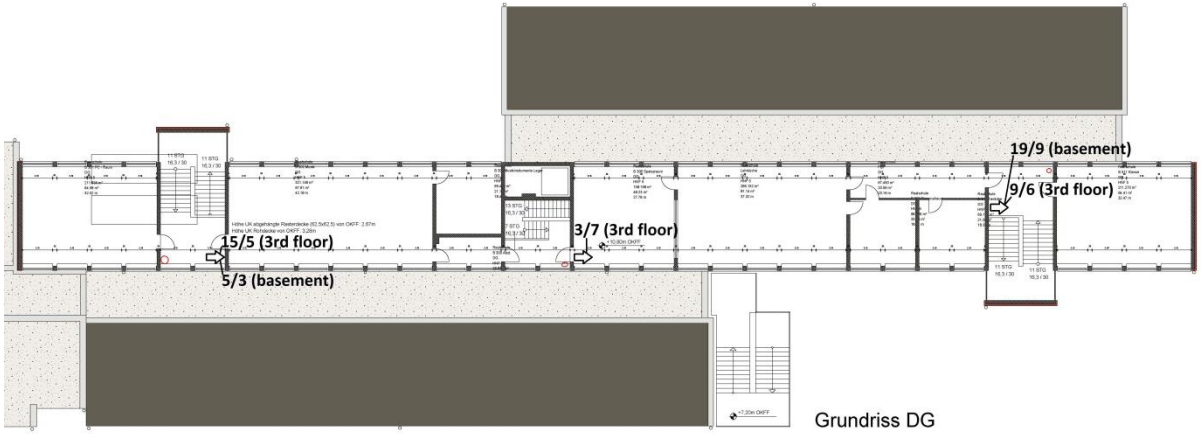
Alfred-Müller-Armack Berufskolleg





Dynamik Statik

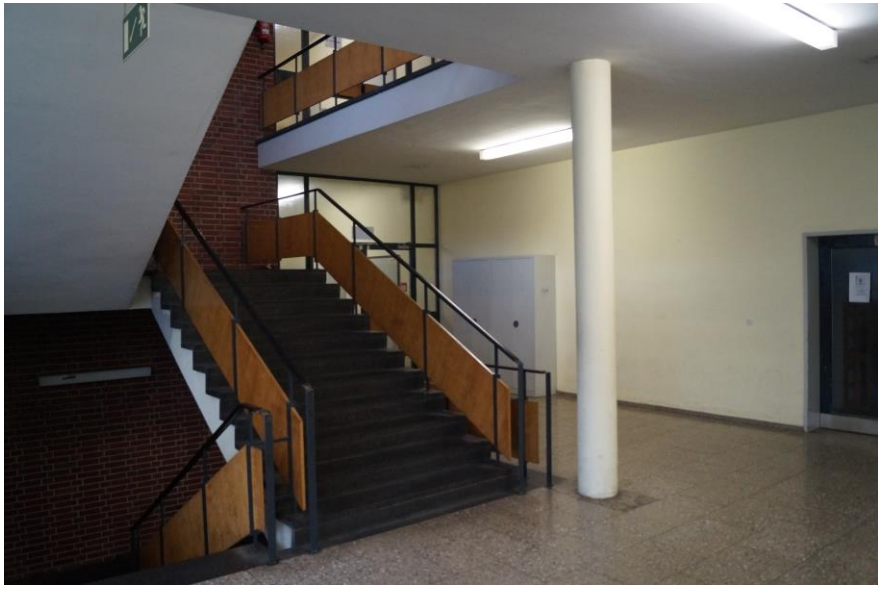
Henry-Ford-Realschule

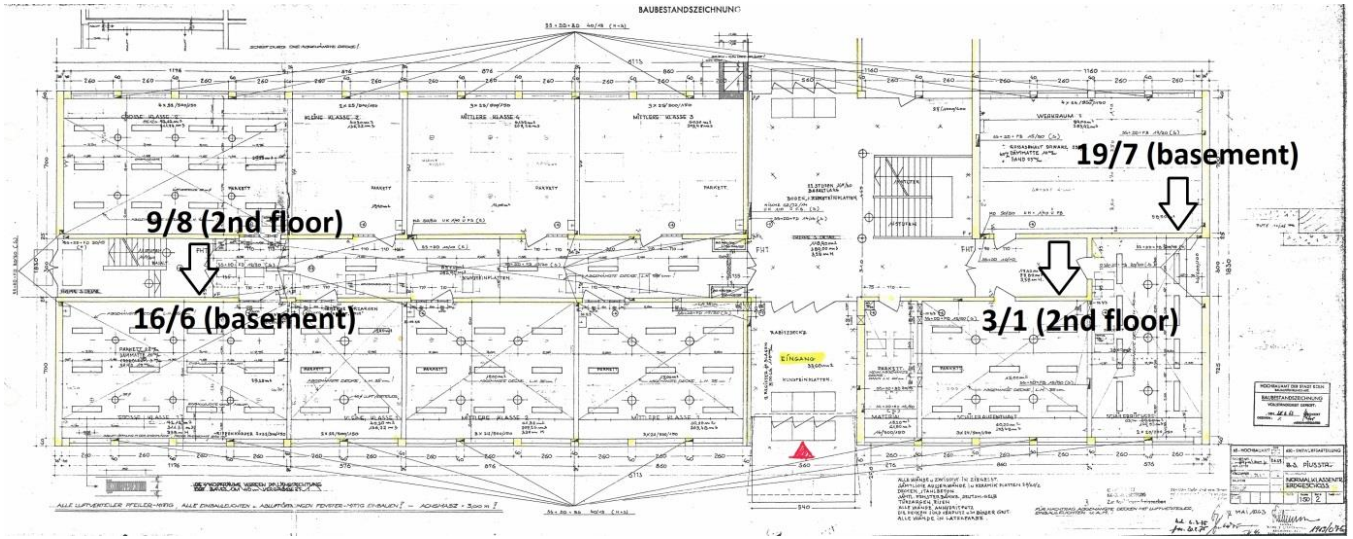


Grundriss DG

Dynamik Statik

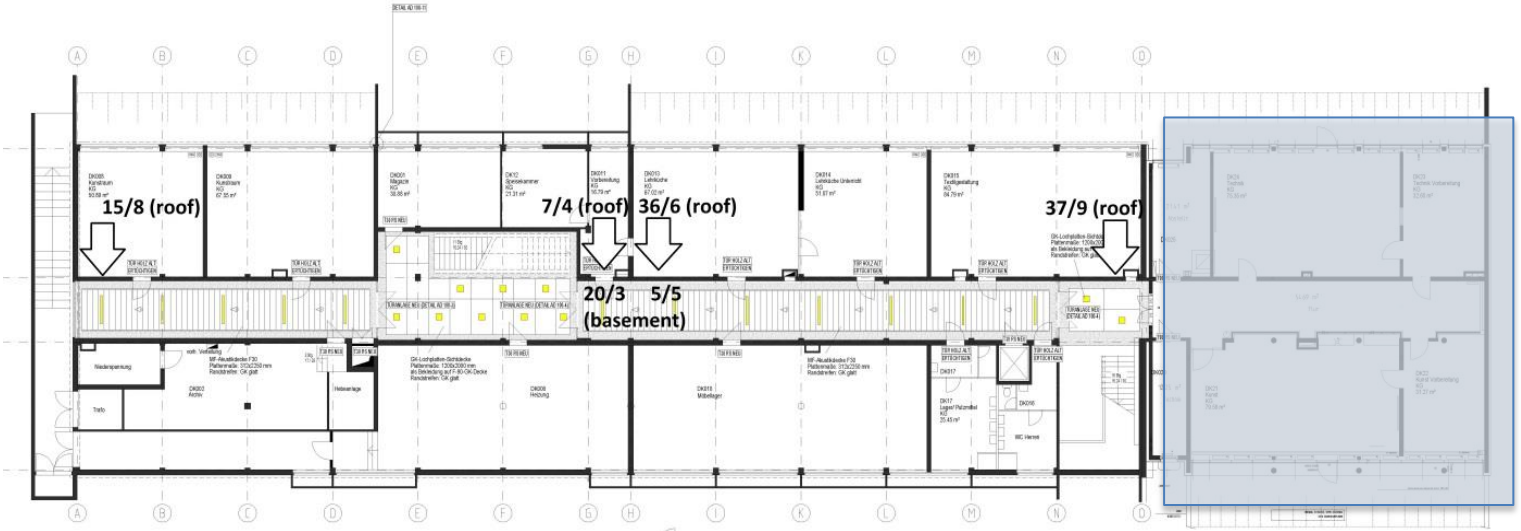
Berufskolleg Ehrenfeld



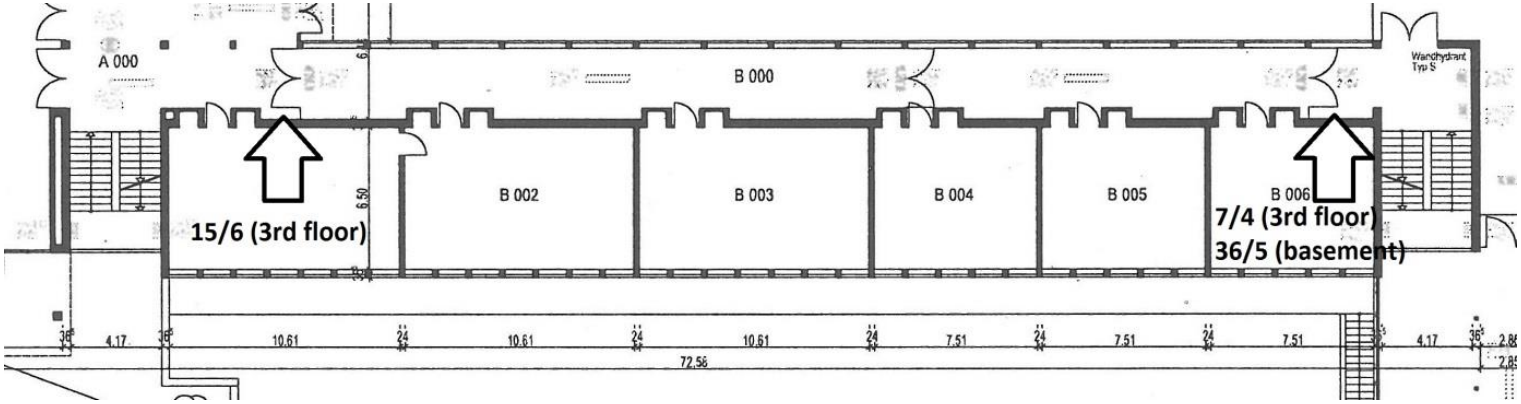


Dynamik Statik

Otto-Lilienthal-Schule

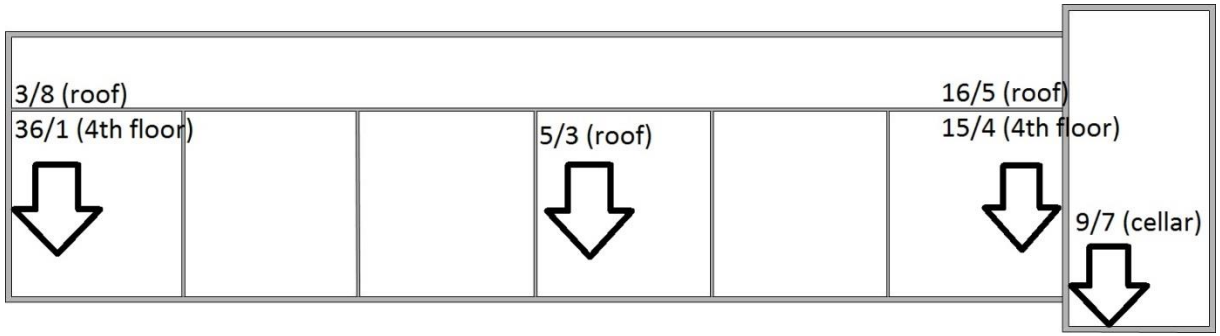


Gymnasium Thusneldastraße



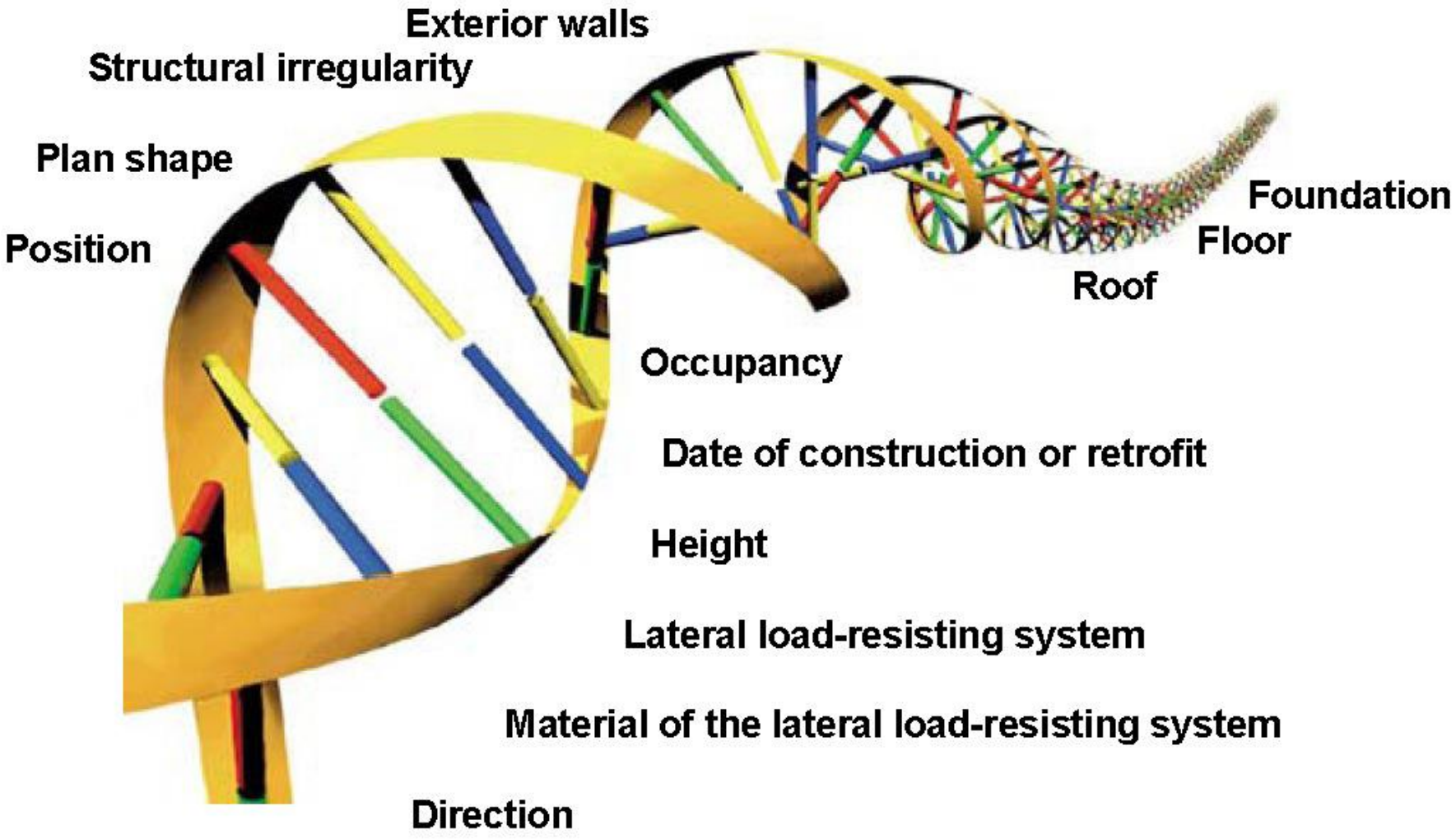
Dynamik Statik

Gymnasium Kreuzgasse



Dynamik Statik

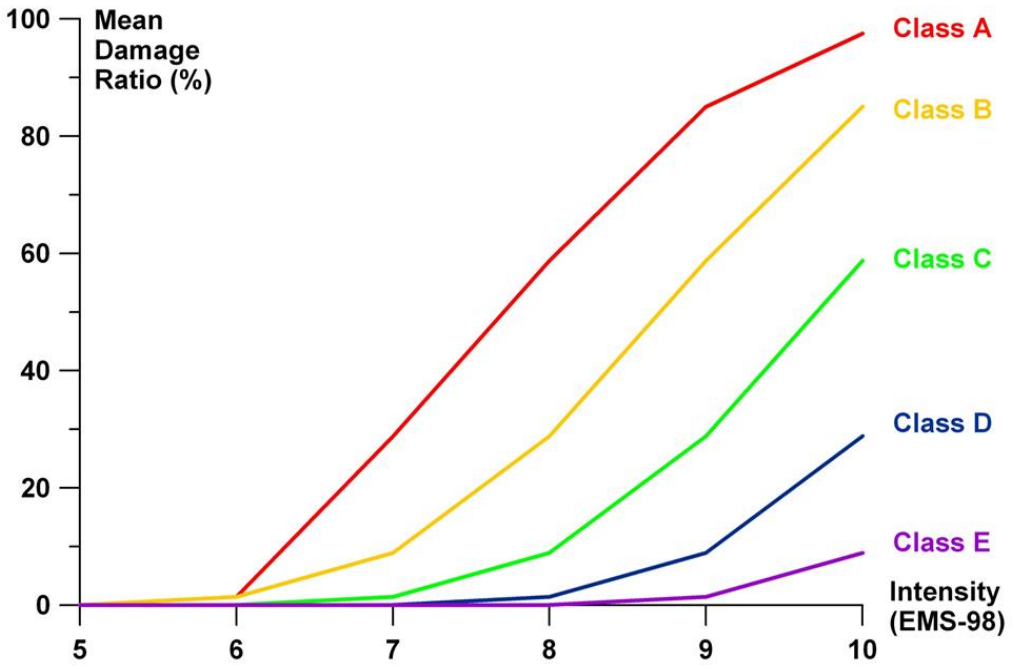
Attributes of GEM Taxonomy (Building genome)



EMS-98 based vulnerability estimation

	Type of Structure	Vulnerability Class A	B	C	D	E	F
MASONRY	rubble stone, fieldstone	○					
	adobe (earth brick)	○	—				
	simple stone	····○	····—				
	massive stone		—	○	····—		
	unreinforced, with manufactured stone units	····—	○	····—			
	unreinforced, with RC floors		—	○	····—		
	reinforced or confined			····—	○	—	
REINFORCED CONCRETE (RC)	frame without earthquake-resistant design (ERD)	····—		○	····—		
	frame with moderate level of ERD		····—		○	—	
	frame with high level of ERD			····—		○	—
	walls without ERD		····—	○	····—		
	walls with moderate level of ERD			····—	○	—	
	walls with high level of ERD				····—	○	—
STEEL	steel structures			····—		○	—
WOOD	timber structures		····—		○	—	

○ most likely vulnerability class; — probable range;
····range of less probable, exceptional cases



Summary table for the investigated school buildings

NN	School		Taxonomy string (code)	General information /preliminary findings
1	Humboldt-Gymnasium		DX /CR+CIP /LH /DY /CR+CIP /LH /HEX:4+HBEX:1 /YAPP:1956 /EDU+EDU2 /BP1 /PLFR /IRIR+IRVP:SOS+IRVS:CHV /EWMA /RSH1+RMTO+RC+RC1+RWCP /FC+FC1+FWCP /	Year of construction - 1956 Number of schoolchildren - 1200 Structural system – mixed, RC, masonry Vulnerability class - C
2	Alfred-Müller-Armack Berufskolleg		DX /M99 /LWAL /DY /M99 /LWAL /HEX:4+HBEX: /YAPP:2007 /EDU+EDU2 /BP1 /PLFR /IRRE /EWMA /RSHO /FC+FWCP /	Year of construction - 2007 Number of pupils – 3000 (800) Structural system – masonry shear walls Vulnerability class - C
3	Henry-Ford-Realschule		DX /CR /LFINF /DY /CR /LFINF /HEX:4+HBEX:1 /YAPP:1965 /EDU+EDU2 /BP2 /PLFR /IRIR+IRVP:POP /EWMA /RSH2+RMTO+RC+RCWCP /FC+FWCP /	Year of construction – ca. 1965 Number of schoolchildren - 850 Structural system – mixed, RC, masonry Vulnerability class - C
4	Berufskolleg Ehrenfeld		DX /M99 /LWAL /DY /M99 /LWAL /HEX:3+HBEX:1 /YAPP:1960 /EDU+EDU2 /BPD /PLFR /IRIR+IRPP:TOR /EWMA /RSH1+RC+RWCP /FC+FWCP /	Year of construction – ca. 1960 Number of schoolchildren - not specified Structural system – mixed, RC, masonry Vulnerability class - C
5	Otto-Lilienthal-Schule		DX /CR /LFINF /DY /CR /LFINF /HEX:3+HBEX:1 /YAPP:1969 /EDU+EDU2 /BP1 /PLFR /IRIR+IRVP:IRVO+IRVS:POP /EWMA /RSH1+RC+RWCP /FC+FWCP /FOSDL	Year of construction - 1969 Number of schoolchildren – not specified Structural system – mixed, RC, masonry Vulnerability class - C
6	Gymnasium Thusnelda-straße		DX+PF /CR /LFINF /DY+OF /CR /LH /HEX:4+HBEX:1 /YAPP:1967 /EDU+EDU2 /BP1 /PLFR /IRIR+IRPP:IRHO+IRVP:POP /EWMA /RSH1+RC+RWCP /FC+FWCP /	Year of construction - 1960s Number of schoolchildren - 843 Structural system – mixed, RC, masonry Vulnerability class - C
7	Gymnasium Kreuzgasse		DX+PF /CR /LH /DY+OF /CR /LH /HEX:5+HBAPP:1 / /EDU+EDU2 /BP1 /PLFR /IRIR+IRPP:IRHO+IRVP:CHV /EWMA /RSH1+RMTO+RC+RWCP /FC+FWCP /	Year of construction – not specified Number of schoolchildren - 979 Structural system – mixed, RC, masonry Vulnerability class - C

Achievements and challenges

- ✓ Rational interface between SISM and conventional vulnerability models
- ✓ Rational procedure of in-situ inspection (priorities, difficulties, techniques)
- ✓ Model validation and verification by use of operational modal analysis
- ✓ Successful case studies
- ✓ Challenges (nonlinear behavior)

Thanks for your attention

Ευχαριστω για την προσοχη σαςη

Danke für Ihre Aufmerksamkeit

Grazie per l'attenzione