Earthquake architecture

balancing conflicting objectives

P5 presentation
Design
Building technology
Research

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- Introduction earthquake issues
- Problem statement
- Research impact earthquake engineering on architecture
- Design
- Conclusion
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- earthquake Huizinge
- gasfield Groningen
- Uptill now ca. 1000 earthquakes
- man-made: hypocenters at only 3 km depth
- larger impact on a smaller scale
- man-made: hypocenters at only 3 km depth
- larger impact on a smaller scale
- peak ground acceleration of 0.4 g
- seismic mass: lateral force on buildings
- The building stock of Groningen is not engineered for seismic resistance...
- For: self-weight and windforce
- Stacked construction: unreinforced masonry
independent of gas production: earthquakes will be a problem for the coming decades
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Conclusion
- Large scale structural upgrading task
- New approach needed for new buildings
- Seismic engineering seems to be the job of the structural engineer....?

- Retrofit techniques and earthquake principles
  - impact on the appearance and functioning
  - pose limitations on design
How to develop a strategy which prevents having to compromise on aspects such as architectural and functional quality?
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Seismic hazard
- Seismic mass: lateral force on buildings
Figure 24. Out-of-plane failure of unreinforced masonry walls. — Rutherford and Chekene

Figure 25. In-plane failure of unreinforced masonry walls. — Rutherford and Chekene

Shaking perpendicular to the wall

Shaking parallel to the wall
Seismic hazard

Toolbox: design principles and engineering solutions
Retrofit techniques

Level 0: Temporary measures

Level 1: Mitigating falling hazards

Level 2: Improve connection wall-diaphragm

Level 3: Stiffening the floor

Level 4: Strengthening of existing

Level 5: Adding new walls of frames

Level 6: Strengthening the foundation

Alternative: base isolation

Level 7: Demolition and rebuild
**Design principles**

- Resisting elements at perimeter
- Build with light materials
- Build with ductile materials
- Regular plan and elevation
- Adequate connections and stiff
- Prevent re-entrant corners
- Locate CoM and CoR at the same
- Dissipation of seismic energy by dampers
General methods

- Resistant
- Flexible + damping
- Base insulation
Seismic hazard

Toolbox: design principles and engineering solutions

Stakeholders: values and criteria
Values and criteria
- matrix: matching building objectives and criteria with earthquake principles and techniques
objectives are often conflicting!
Seismic hazard

Toolbox: design principles and engineering solutions

Stakeholders: values and criteria

Integral performance objective

Seismic design
Towards design

- Research existing
- Design new building
- Learn from weaknesses existing
stiff, brittle  

flexible, ductile
stacked construction

robust connections
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Earthquake center

- Governmental department for earthquakes
- Public interface in the region
- Function:
  - public case management
  - relieve inhabitants
  - handle complex damage claims
Design strategy
Design objectives
- No backoffice: clear routing
- Inviting public entrance
- Public, semi-public and private functions
Architecture

- Relation to small scale environment
- Spectacular appearance
- Double height spaces
Sustainable principles

- Use of natural, renewable material
- Natural lighting
- Energy generation
- Water re-use
- Showcase for earthquake proof building
- Exposed structure
- Innovative techniques
Design location
- **Objective**: relation to surrounding buildings: bricks?

- **Conflict**: heavy and brittle

- **Solution**: relate to other aspect: pitched roofs / farms
Design
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Introduction  Problem statement  Research  Design  Conclusion
Structure

Resistant

Flexible + damping

Base insulation

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PRESLAM: prestressed laminated timber technology
Controlled rocking + Energy dissipation
Design principles

- Resisting elements at perimeter
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- Dissipation of seismic energy by

Source image: Training: ontwerpen gebouwen op aardbevingen from the Marcel de Boer, Arup
Construction elements in two main directions: transverse and longitudinal.
- **objective:** open space, translucent building

# **conflict:** transversal seismic elements?

> **solution:** portal frames
- objective: open, inviting facade

# conflict: large brittle glass pane / movement

> solution: plastic cushion facade

- extremely light (1% of glass)
- can deform to 3 times own length
Sanitary units
Sanitary units
Introduction  Problem statement  Research  Design  Conclusion
- objective: concrete floor as stiff diagram, thermal mass

# conflict: heavy --> inertia forces

> solution: concrete timber composite floor
- **objective**: asymmetric portals

- **conflict**: torsion in facade

- **solution**: narrow strips, flexible timber sandwich panels
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Conclusion

- Optimal solution between conflicting objectives
- Exciting building with innovative techniques
employee visit

- a. reception desk
- b. open office area
- c. private offices
- d. kitchen
- e. cantine
- f. social area on stairs
- g. conference / meeting room
- h. multifunctional room
Introduction  Problem statement  Research  Design  Conclusion

1. reception desk
2. regional information point
3. consultation space
4. workshop area
5. knowledge space
6. exhibition & multimedia area
7. presentation space
8. coffee corner
Any questions?