

Witteveen + Bos



Internationale praktijk

Lezingenavond Aardbevingsproblematiek
KIVI Afdeling voor Geotechniek

Siefko Slob

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Balakot, Pakistan
Kashmir aardbeving M 7,6 - 8 oktober 2005

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Muzaffarabad



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De internationale ontwerppraktijk mbt aardbevingen

1. Normen en standaarden: internationaal, nationaal
2. Vaststellen belasting: hazard analyse en site response analyse
 - voorbeelden Doha, Mexico City en Jakarta
3. Aarbevingsontwerp:
 - voorbeelden Taman, Baku en Turkije

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1. Normen en standaarden

- De internationale norm: performance-based approach
 - Eurocode 8: Nationale annexes
 - IBC: International Building Code (USA)
 - ISO 19901-2:2004/API: petroleum industrie
 - PIANC: havens/waterbouw
- Amerikaanse normen:
 - ASCE 7 (2010) : <http://www.asce.org/structural-engineering/asce-7-and-sei-standards/>
 - NEHRP (2009): <http://www.nehrp.gov/>
- Nationale normen

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Performance-based approach

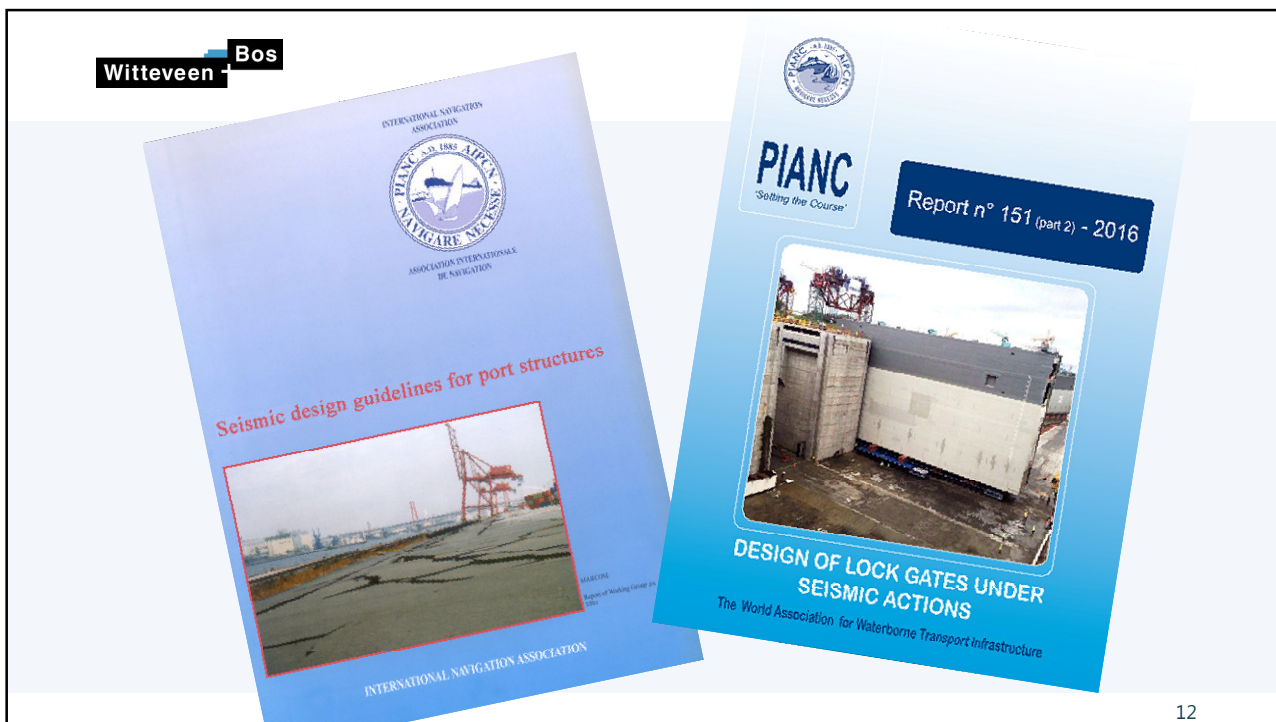
Engineering judgement (codes)

		Earthquake Performance Level			
		Fully Operational	Operational	Life Safe	Near Collapse
Earthquake Design Level	Frequent (43 yrs)		X	X	X
	Occasional (72 yrs)		X	X	X
	Rare (475 yrs)				X
	Very Rare (975 yrs)				

Essential / Hazardous
Safety Critical
Basic

Fig. 2. Combinations of earthquake hazard and performance levels proposed by Vision 2000.

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GOBIERNO DEL DISTRITO FEDERAL
México • la Ciudad de la Esperanza

GACETA OFICIAL DEL DISTRITO FEDERAL

Oficina del Gobernador del Distrito Federal 2009 E. 30 de Agosto

15 DE OCTUBRE DE 1984

ADMINISTRACIÓN PÚBLICA DEL DISTRITO FEDERAL

SECRETARÍA DE GOBIERNO

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MANUAL DE DISEÑO DE OBRAS CIVILES
DISEÑO POR SISMO

CFE

MEXICO | 2006

SNI
Badan Standardisasi Nasional

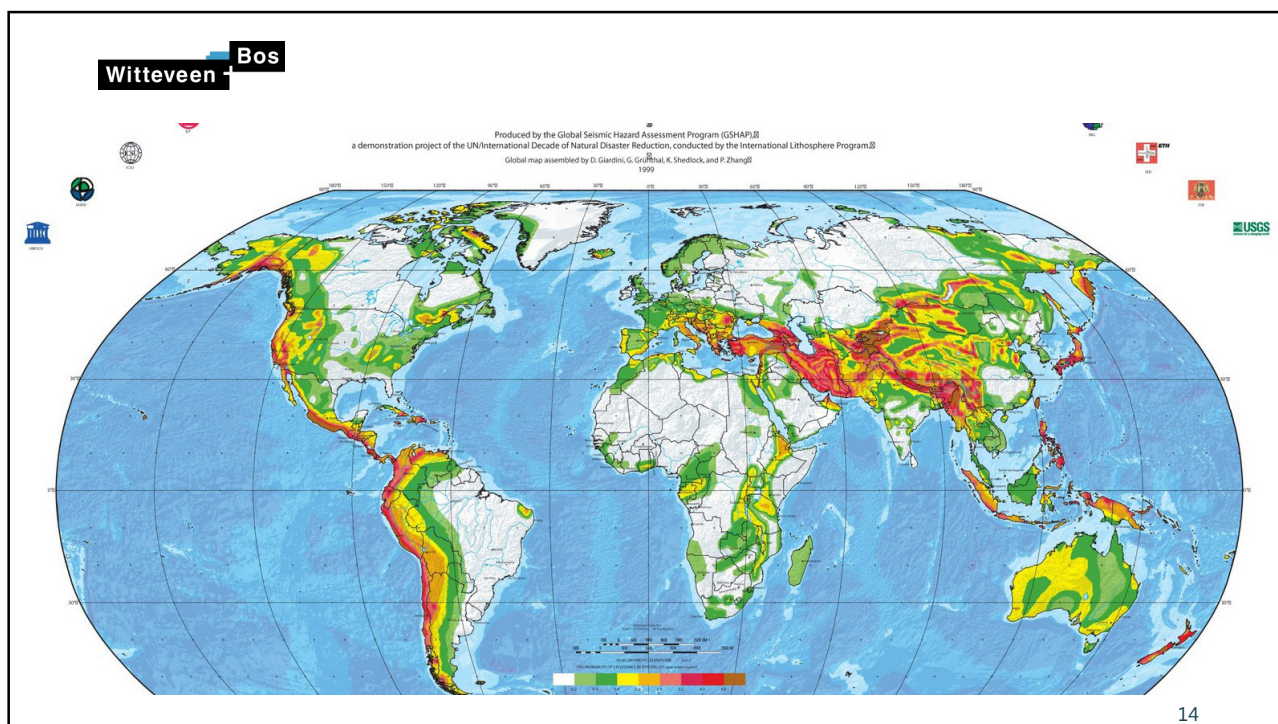
SNI 1726:2012

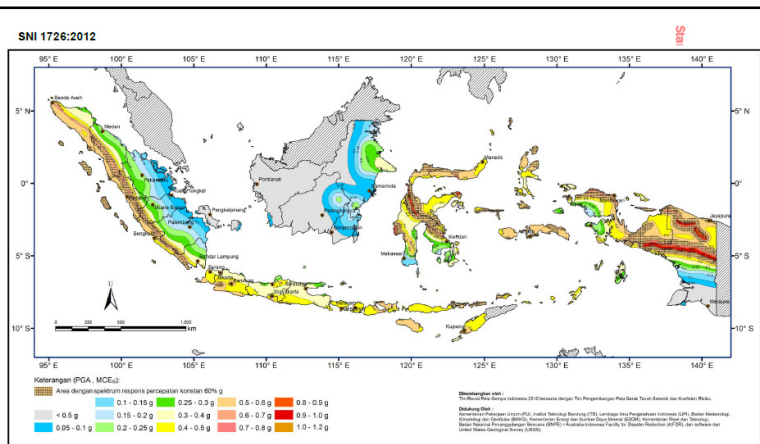
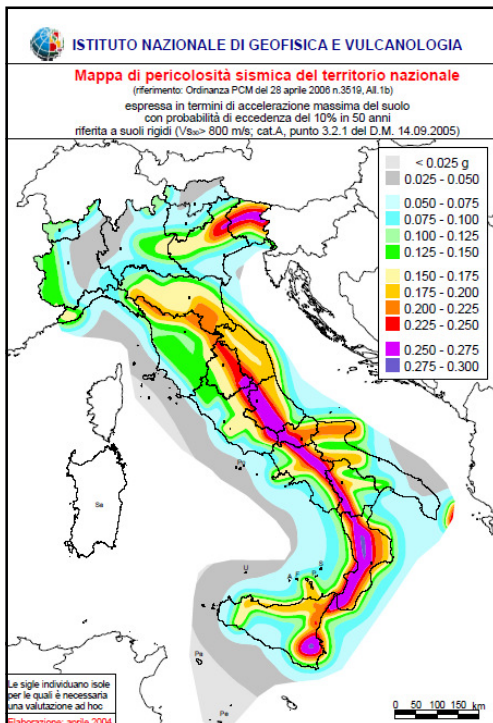
Tata cara perencanaan ketahanan gempa untuk struktur bangunan gedung dan non gedung

BSN

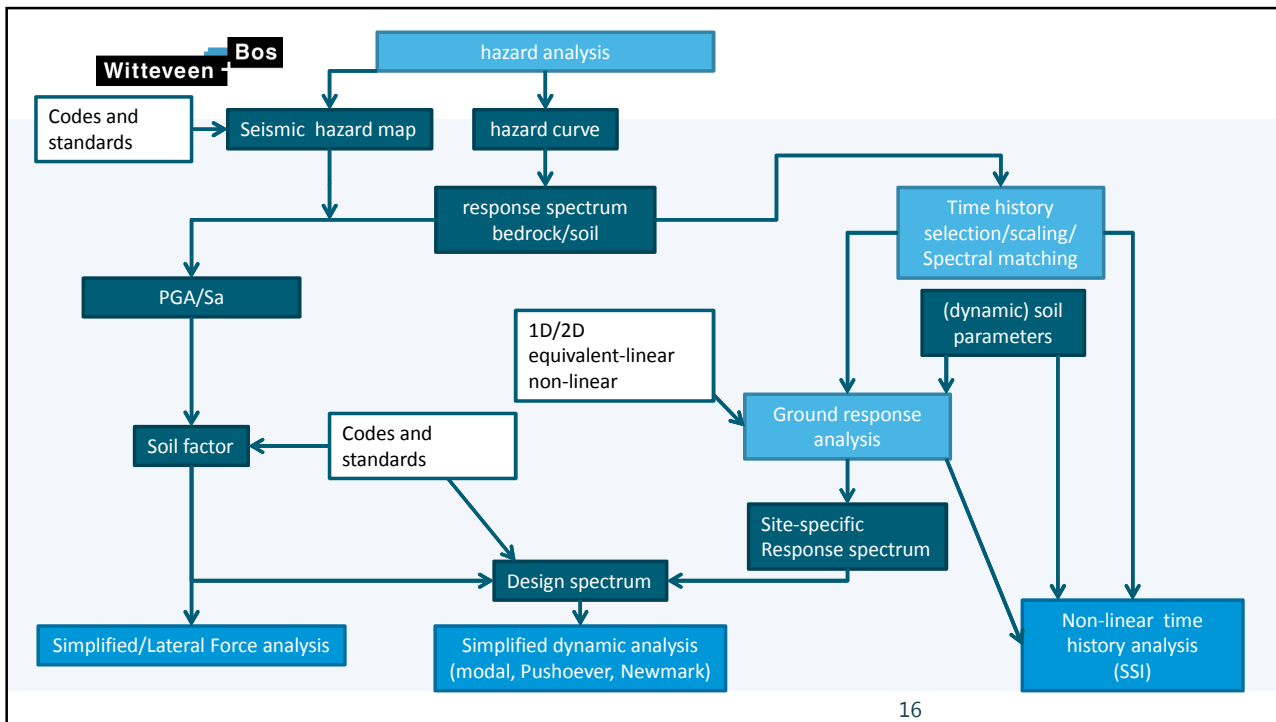
Badan Standardisasi Nasional

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Gambar 11 - PGA, Gempa maksimum yang dipertimbangkan rata-rata geometrik (MCE_d), kelas situs SB



2. Vaststellen aardbevingsbelasting: seismic hazard analysis

- Hazard: De (aanvaardbare) kans dat er een aardbeving optreedt
 - in een specifiek gebied of op een bepaalde locatie
 - binnen een specifieke tijdspanne (design life)
 - met een bepaalde overschrijding van de groundbeweging (p_g , p_{gv} , s_a , s_v)
- Uitgedrukt als (acceptable) probability of exceedance (p) within a design life (t_L) return period (herhalingstijd) (T_R)
 - 10% 50 jaar: 475 jaar herhalingstijd
 - 5% 50 jaar: 975 jaar herhalingstijd
 - 2% 50 jaar: 2,475 jaar herhalingstijd

$$T_R = 1 / (1 - (1 - p)^{1/t_L})$$

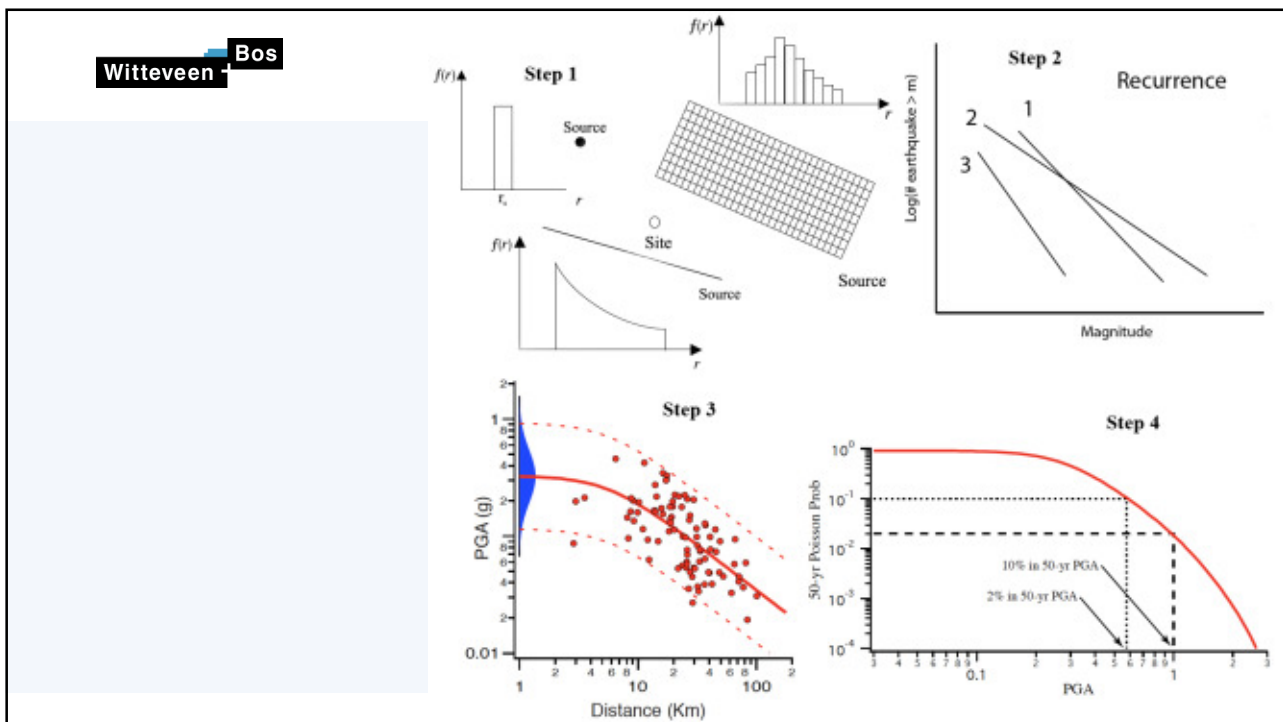
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Probabilistic Seismic Hazard Analysis (PSHA)

Basiselementen:

1. Analyse van de aardbevingscatalogus
2. Definitie van het seismische bronnen obv catalogus en tectonische setting
3. Evaluatie van bronnen in termen van frequentie-Magnitude relaties (Gutenberg-Richter): a, b parameters
4. Definieer de attenuatie relaties (Ground Motion Prediction Equations)
5. Bereken de cumulatieve hazard

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Onzekerheden in PSHA

- Aleatorische variabiliteit
 - De natuurlijke willekeurigheid van een proces
 - Voor discrete waarden: de kans van optreden van elke waarde
 - Voor continue variabelen: kansdichtheidsfunctie
- Epistemische onzekerheden
 - Onzekerheden als gevolg van onvolledige kennis van het proces
 - de wetenschappelijke onzekerheid over het model
 - Alternatieve modellen

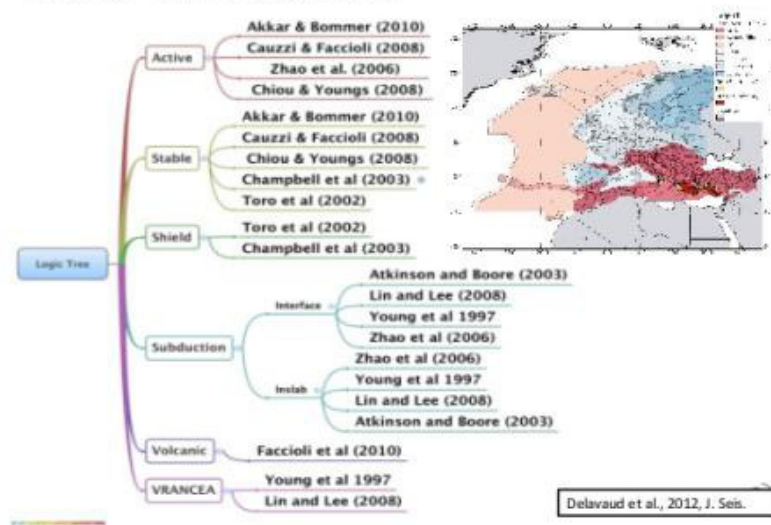
Vangen van de epistemische onzekerheden

Met een 'logic tree' kunnen epistemische onzekerheden worden vastgelegd en gekwantificeerd.

- Onzekerheden over seismische zones
- Onzekerheden in GMPE
- Bij elke onzekerheid worden alternatieve opties gepresenteerd.
- Subjectieve waarden worden vervolgens toegekend aan elke vertakking

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SHARE - GMPE Logic Tree



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SharQ Crossing, Doha City, Qatar



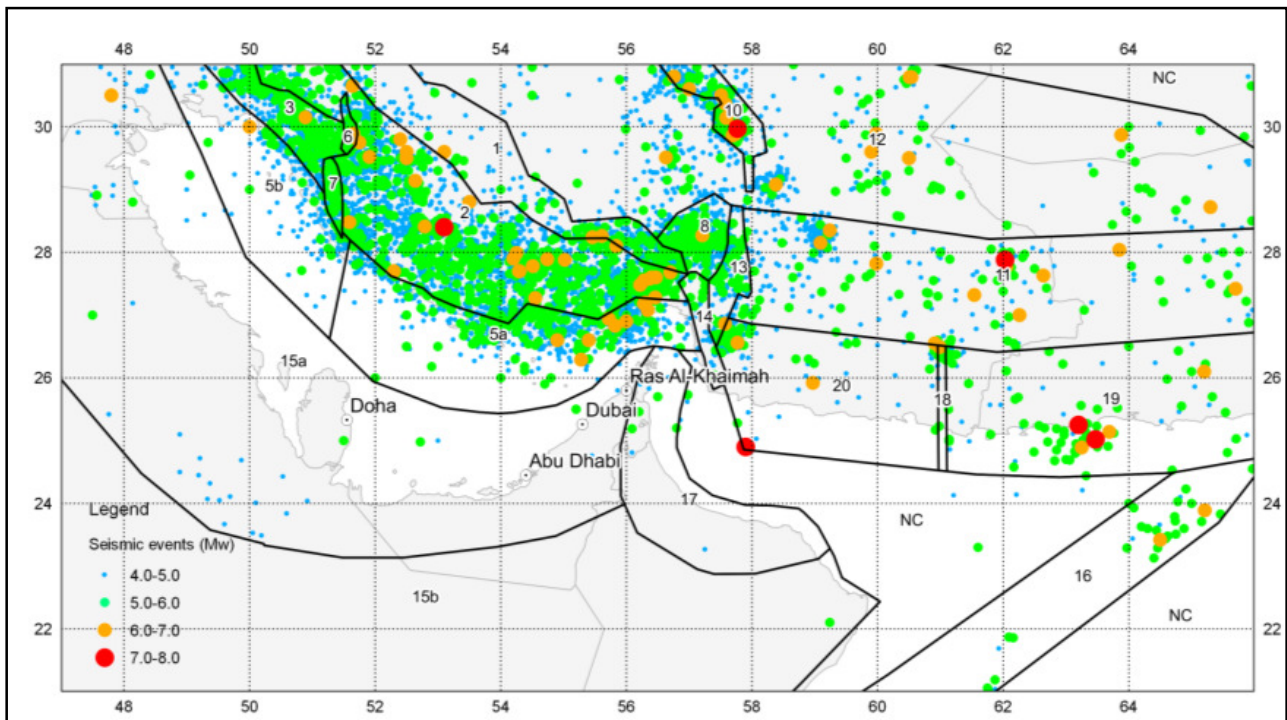
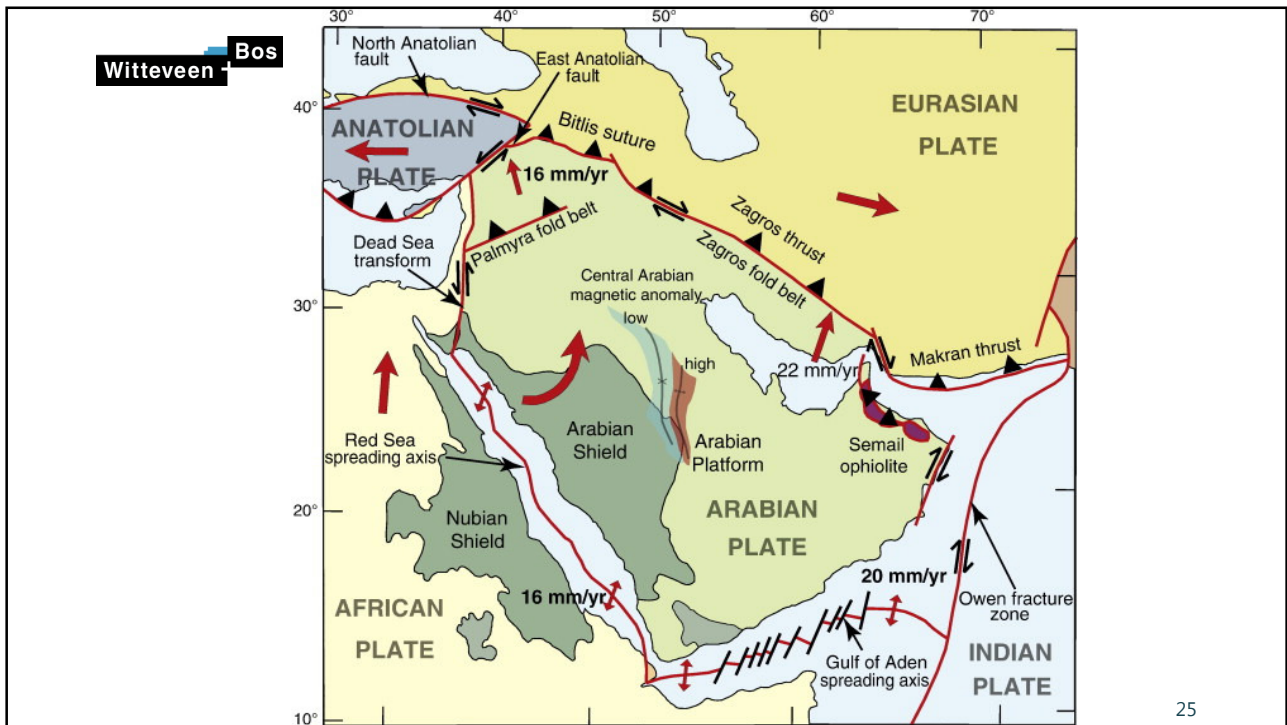
© 2011 SANTIAGO CALATRAVA

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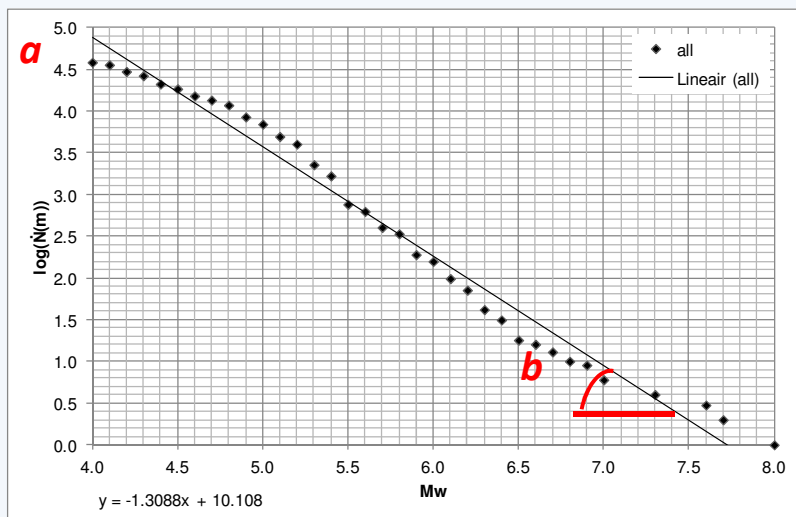
SharQ Crossing (TEC project)

- OG: Calatrava/Ashgall
- Bruggen: slanke constructies (lage eigenfrequentie)
- kwetsbaar voor aardbevingen in Iran, aan de overkant van de Golf
- Arabische plaat heel stabiel
- In April 2013: M 6.3 en 7.9 (ZW en Oost-Iran)

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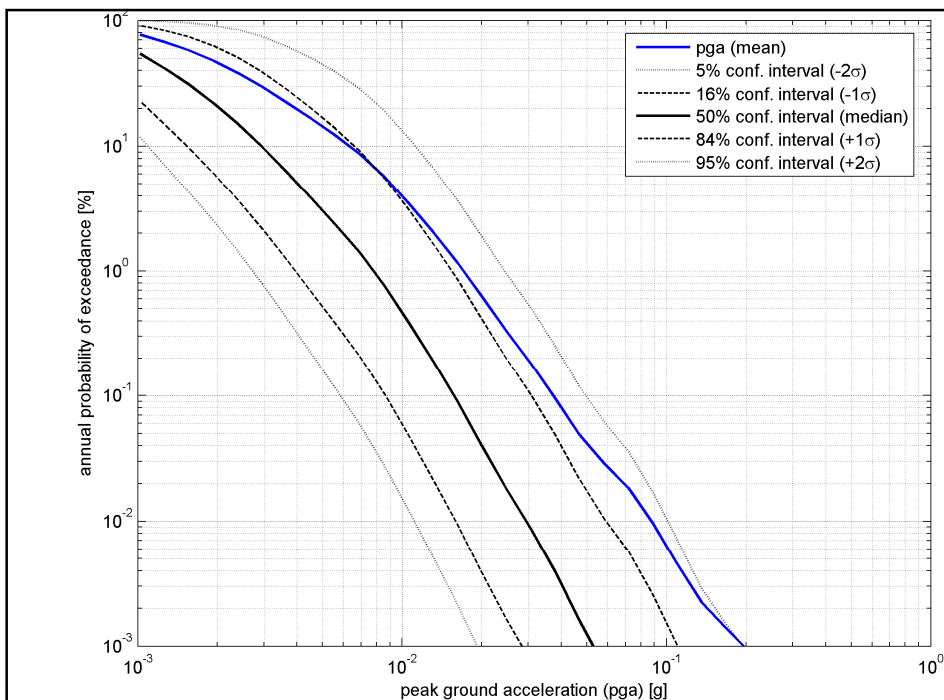


Bepalen van G-R parameters per brongebied

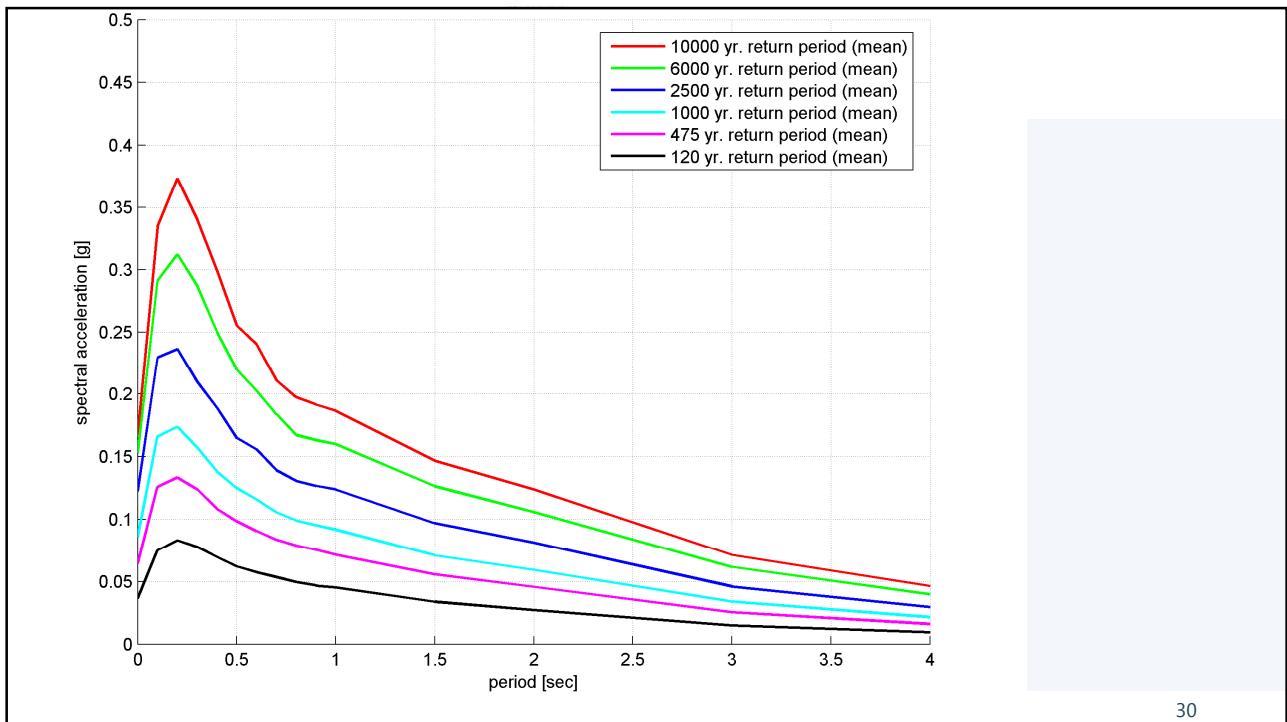
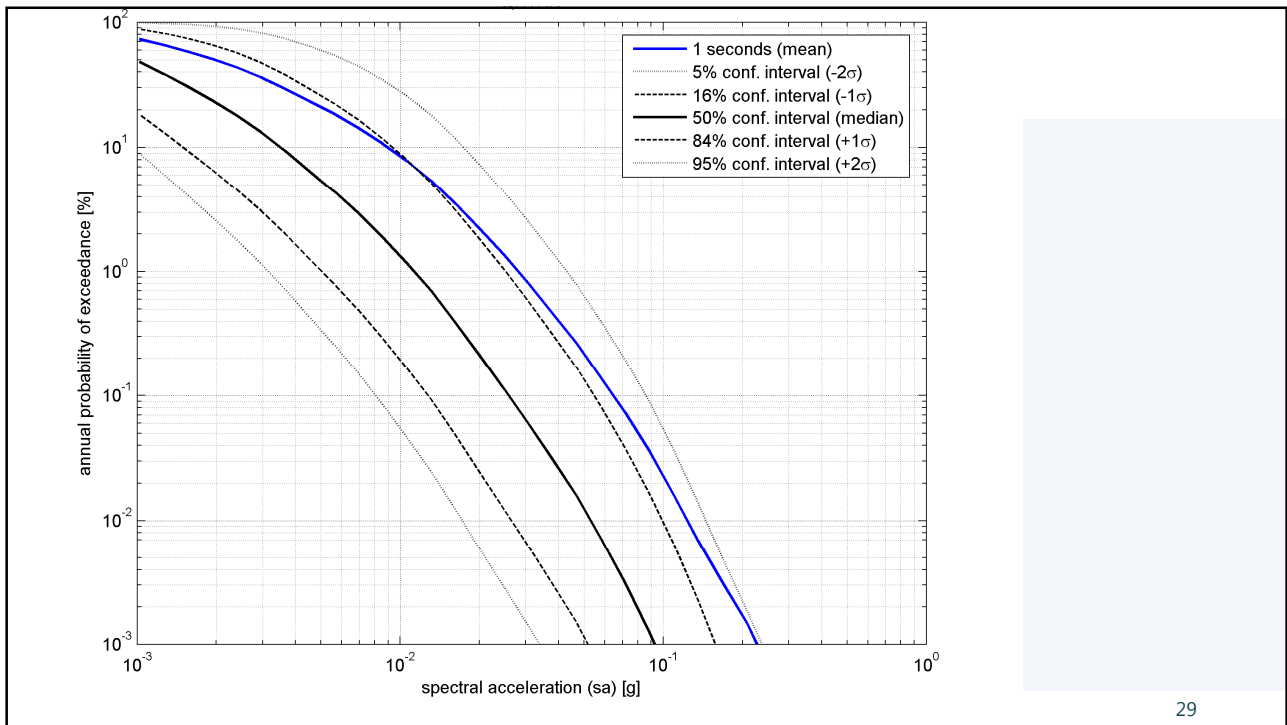


$$\log_{10} N = a - bM$$

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NAICM (New International Airport Mexico City)



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NAICM (TEC project)

- OG: Grupo Aeroportuario de Ciudad de Mexico
- JV: NACO/RHDHV/TADCO/SACMAG (TASANA)
- Zeer krachtige aardbevingen, relatief ver van de site
- Michoacán, 19.09.1985, Magnitude 8,1
- Texcoco lake, zeer slappe sedimenten
- Site 40 km²

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Site effects erg belangrijk in Mexico City

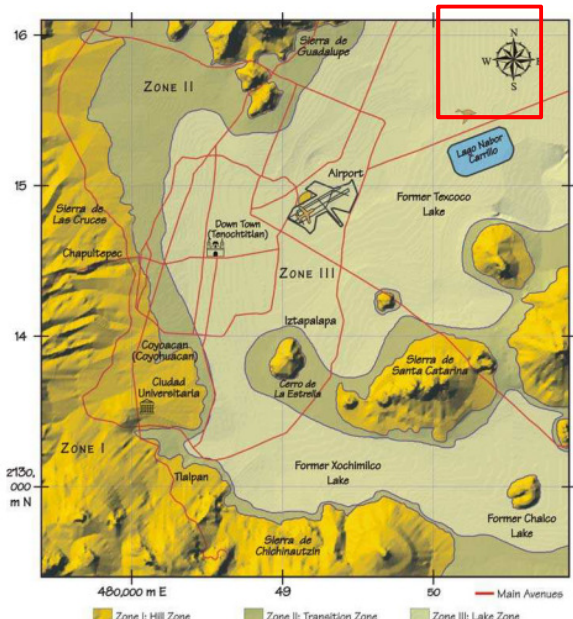
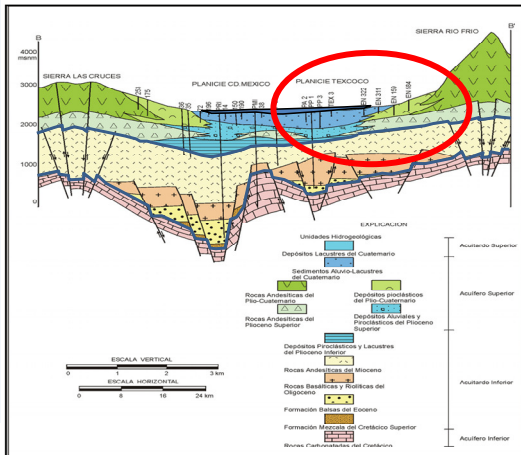
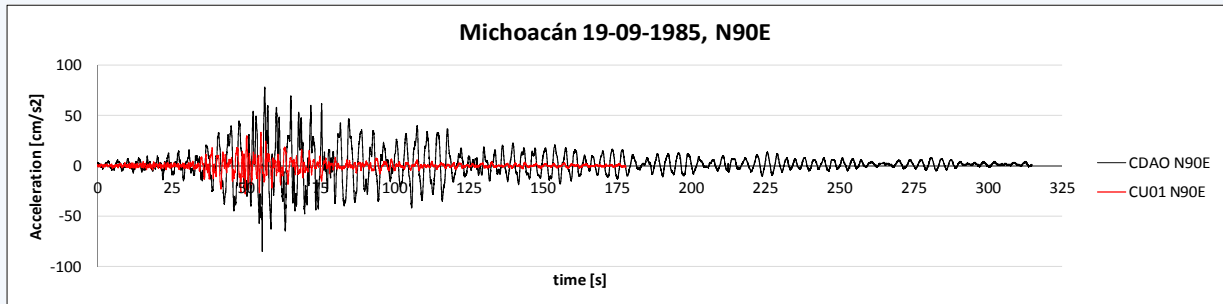
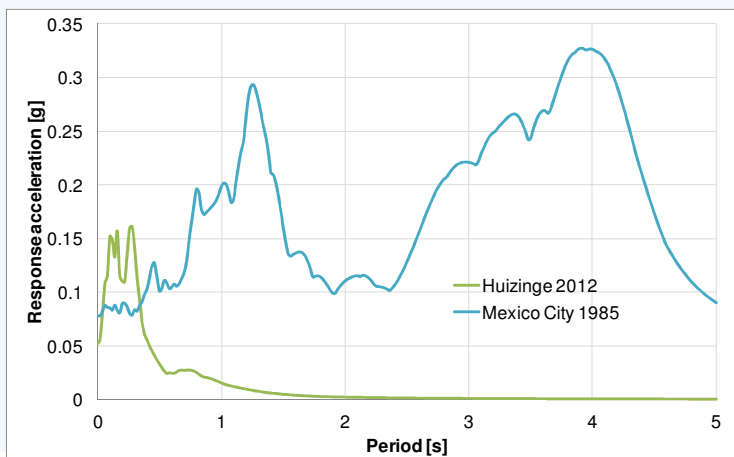


Fig. 4 Digital elevation model and Mexico Basin Seismic zoning (Flores-Estrella 2004)

Vershil tussen bedrock en maaiveld gemeten signaal



Vershil tussen "Groningen" en Mexico City

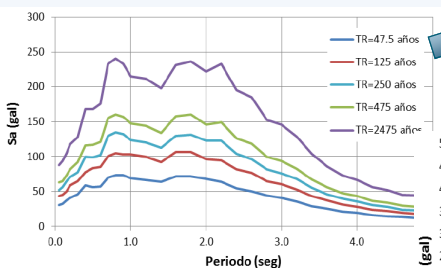


Huizinge: M 3,6
Afstand: 3 km

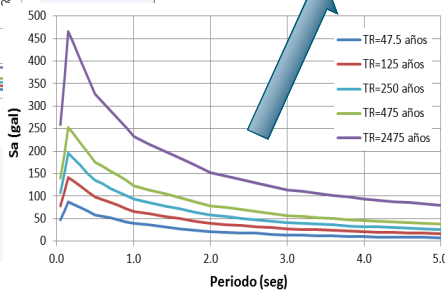
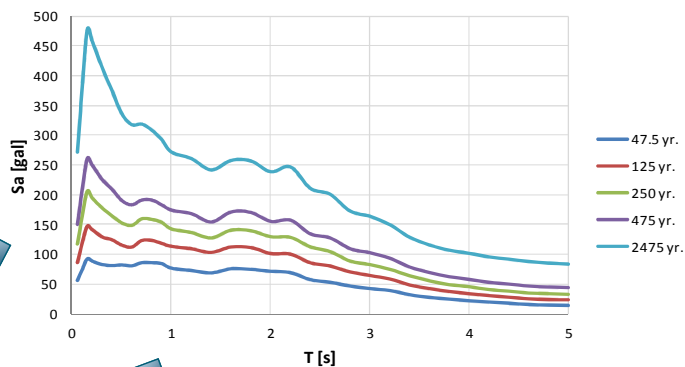
Mexico City: M 8,1
Afstand: 300 km

Uitgangspunt

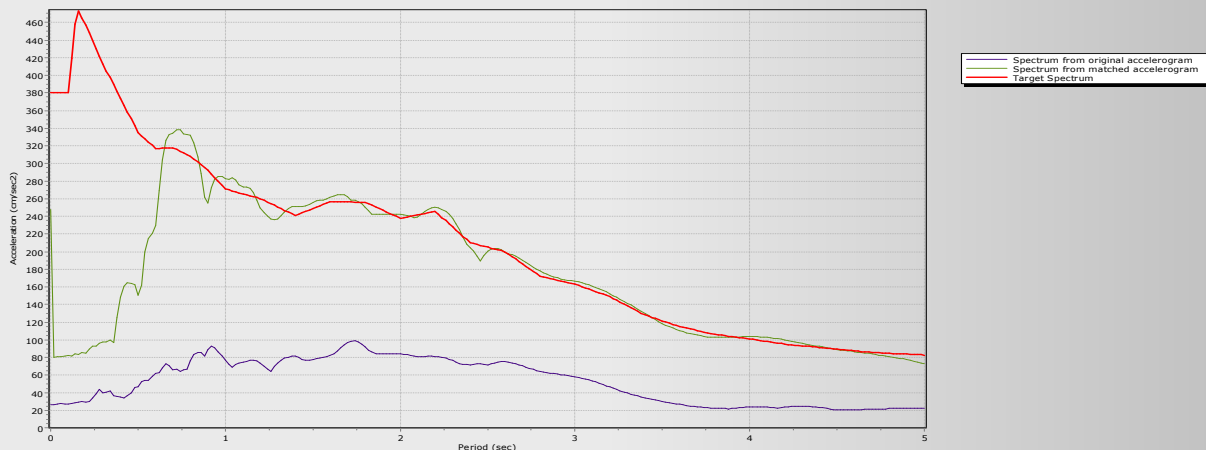
Hazard analyse door UNAM



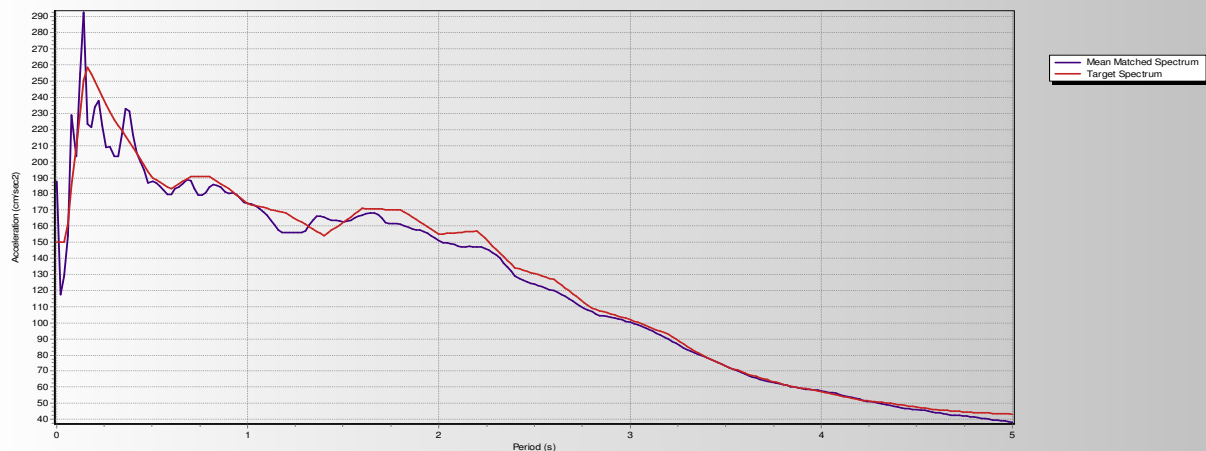
Uniform hazard spectrum



Spectral matching of selected time histories

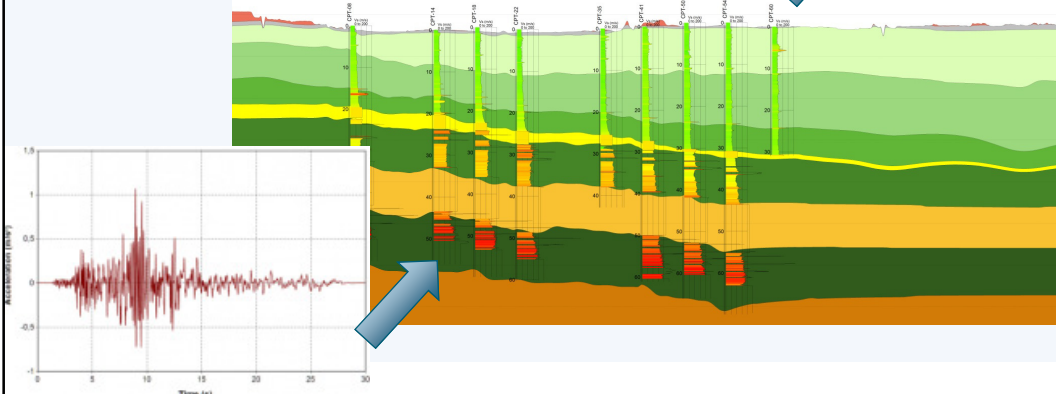
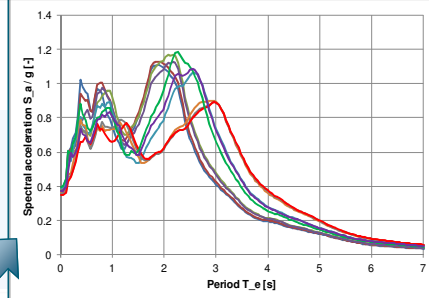


Mean matched spectrum

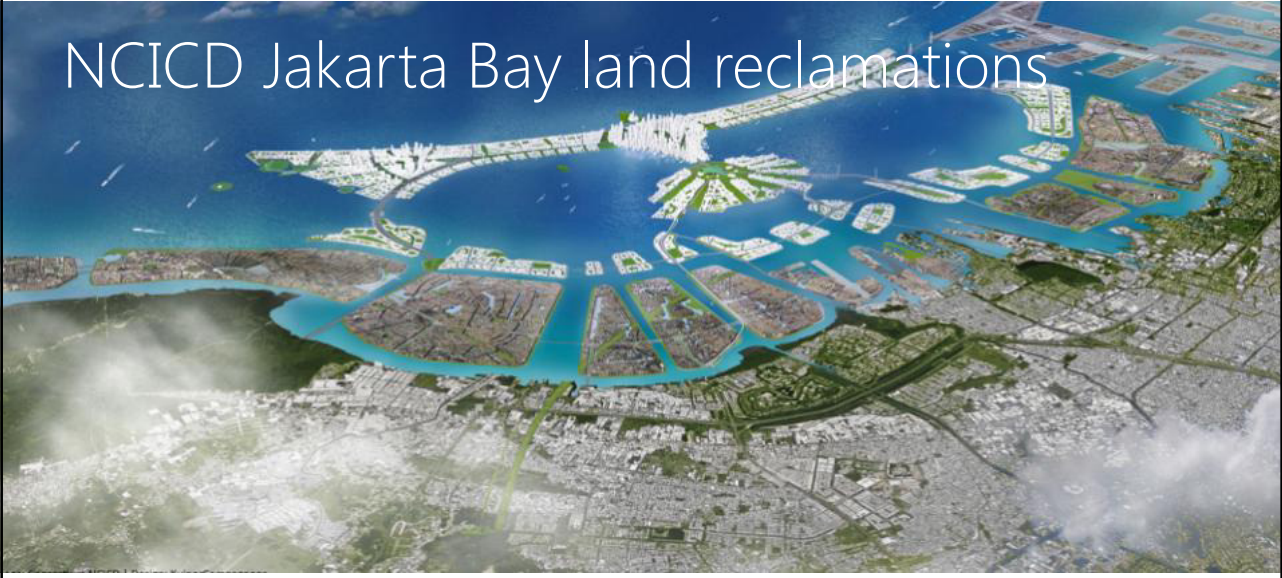


Bepalen van site effecten

- 1D equivalent linear obv 3D grondmodel



NCICD Jakarta Bay land reclamations



Jakarta seismic setting

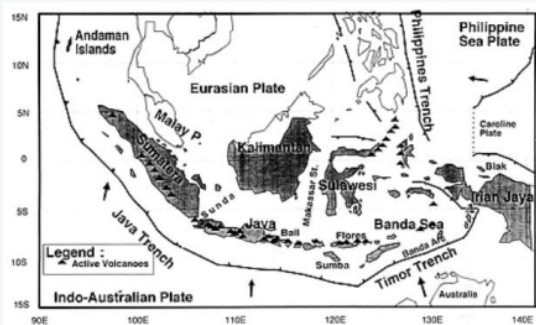


Figure 2.4. Map of 4 main tectonic plates in Indonesia

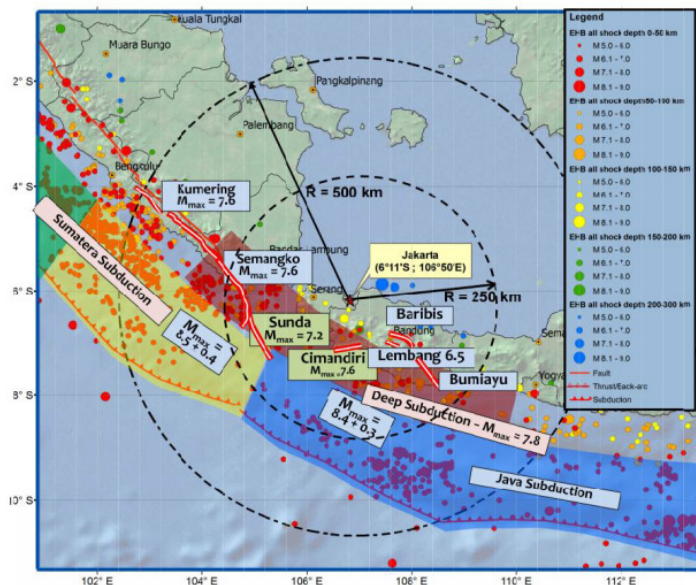


Figure 2.7. Seismic sources influencing Jakarta region [Irsyam et al., 2015]

Jakarta geology – thick (very) soft soil deposits

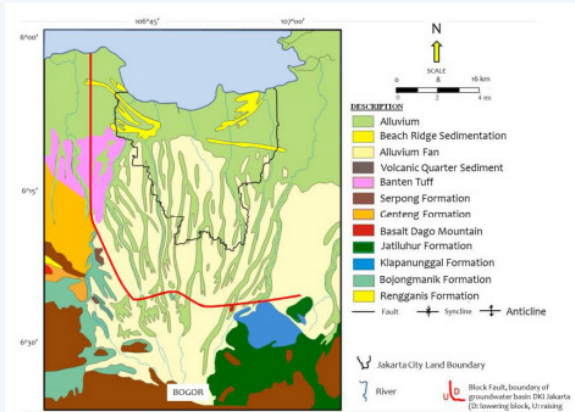


Figure 2.1. Geological map of Jakarta [Fachri *et al.*, 2002]

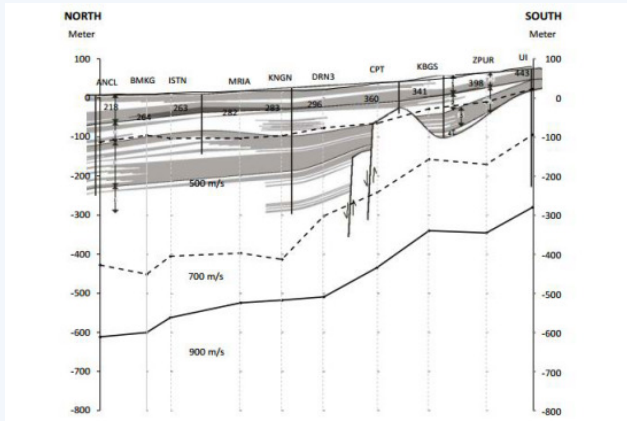


Figure 2.3. Shear wave velocity profile of Jakarta in north-south direction [Ridwan *et al.*, 2014]

Stochastic site response analysis - input

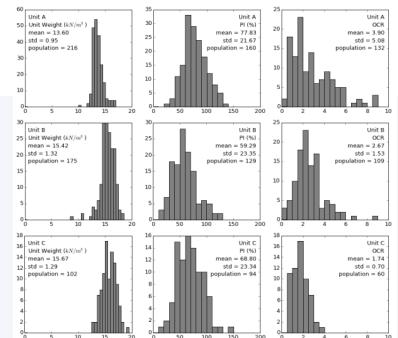
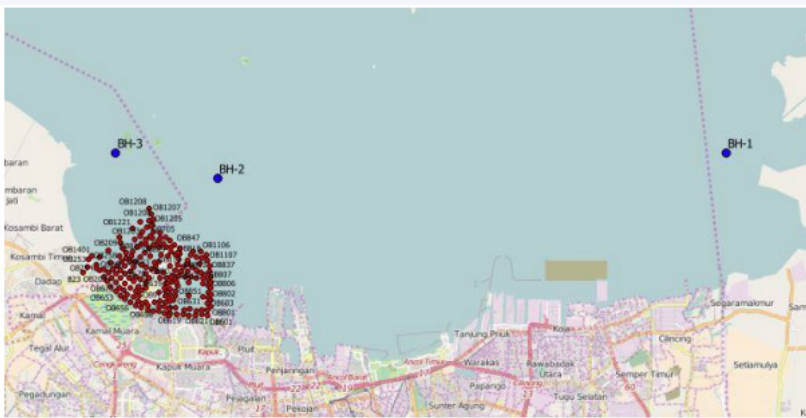


Figure 3.9. Histograms for lab test data of the three combined main clay units

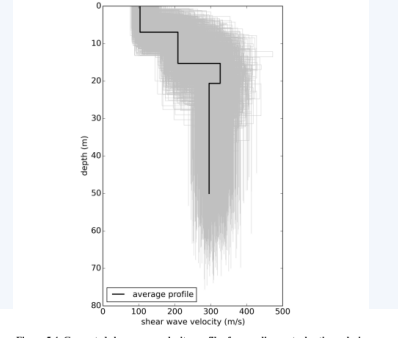


Figure 5.4. Generated shear wave velocity profiles for non-linear stochastic analysis

Stochastic site response analysis - results

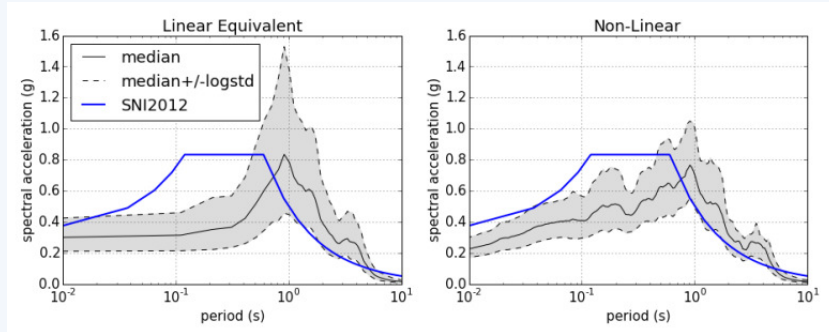
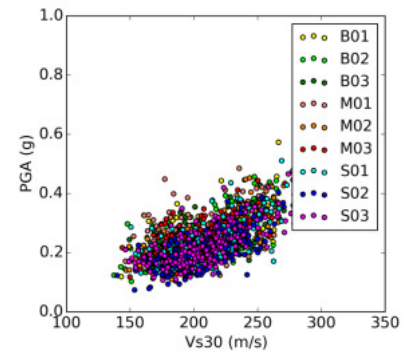


Figure 6.1. Median and standard deviation of 5% damped response spectrum for all ground motions



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Nonlinear models for GRA

Nonlinear models can be used to improve and optimize site response results, specifically for soft sites. But what about their performance?

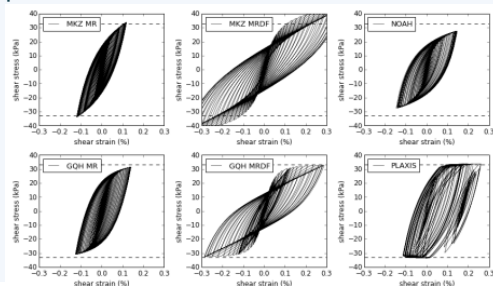


Figure 6.34. Hysteresis loop for all non-linear models (sand profile, 2.5 Hz input motion 0.4g)

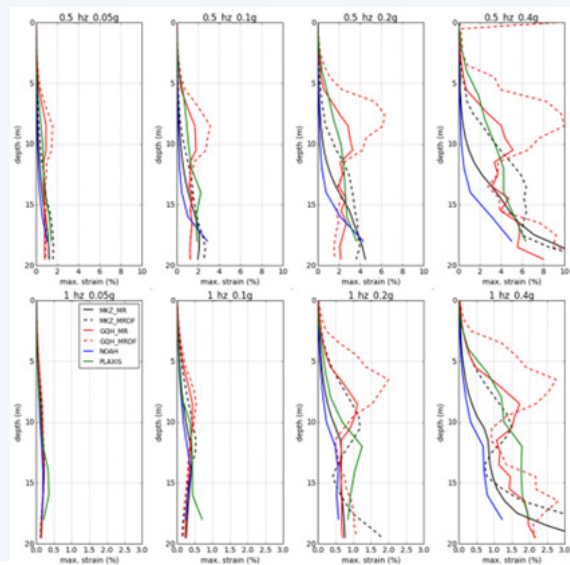


Figure 6.25. Maximum shear strain profiles for clay model

Nonlinear models for GRA

Results for multi-layered profile

Sensitivity of results for PGA and selected nonlinear model

Plaxis can be a proper stable model if proper set of parameters is selected

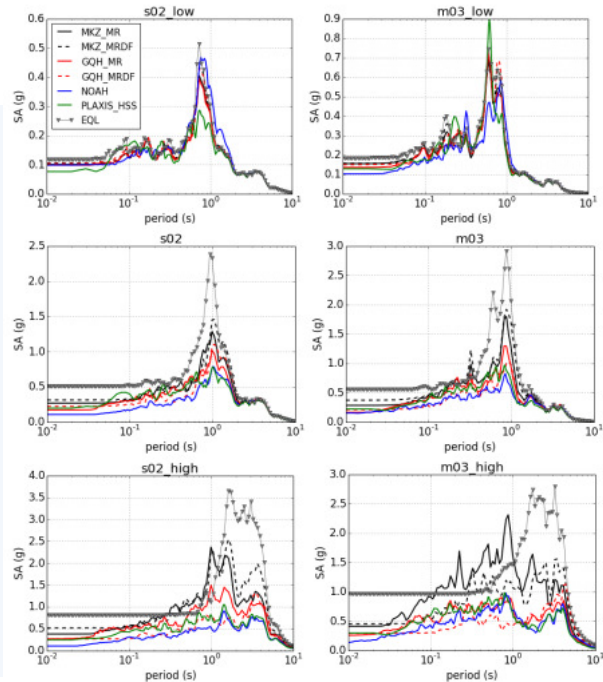


Figure 6.35. 5% damped response spectrum for multi-layered profile B5

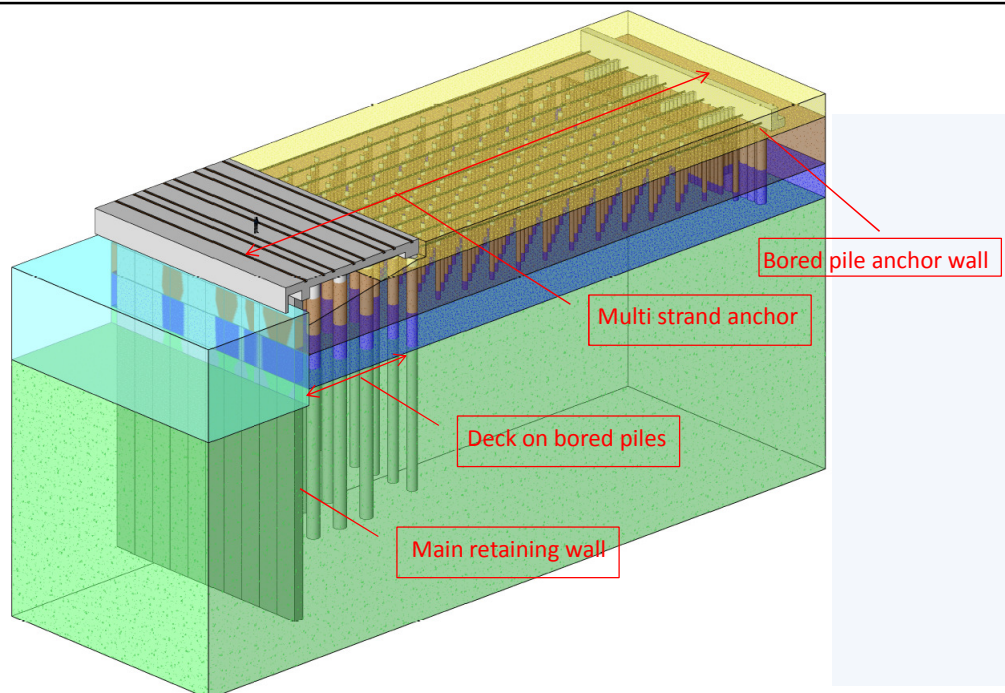
Baku international sea trade port



Baku international sea trade port

- Detailed design of new concrete quay wall structure
- Land reclamation and liquefaction design
- Performance based seismic design of quay walls (plastic hinging, equivalent concrete stiffness at high load levels, managing sequence of failure)
- Signal selection and processing, site response analysis, soil-structure interaction analysis
- Performance evaluation for initial operational, seismic and post-seismic state of the structure

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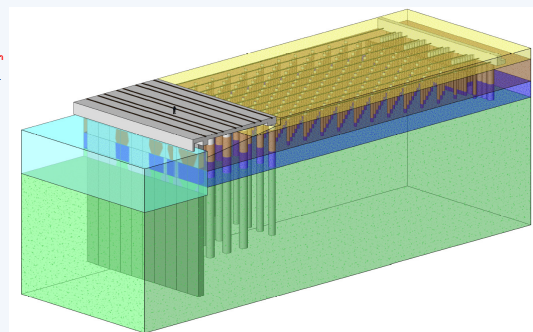
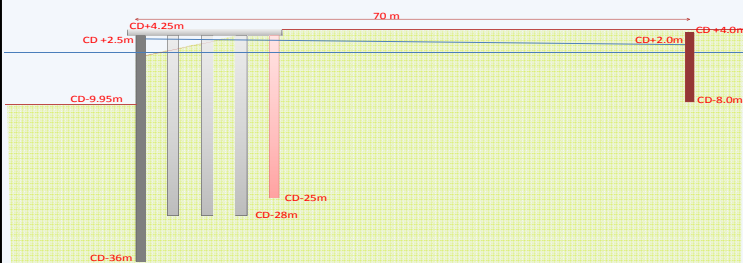
Final quay wall design

- Quay wall structure
- Main retaining wall (Diaphragm wall D=1.2m)
- Deck with bored piles (D=1.5m and D=1.2m)
- Anchor wall of bored piles including L-shaped capping beam (D=1.2m)
- Multi-strand anchors (37 strands, spacing 3m)
- Liquefaction measures
 - Jetgrout columns in front of anchor wall
 - Cased stone columns

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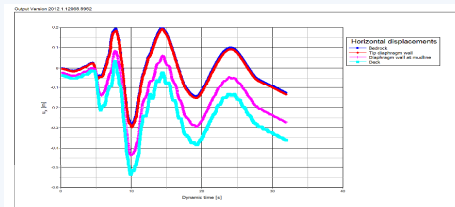
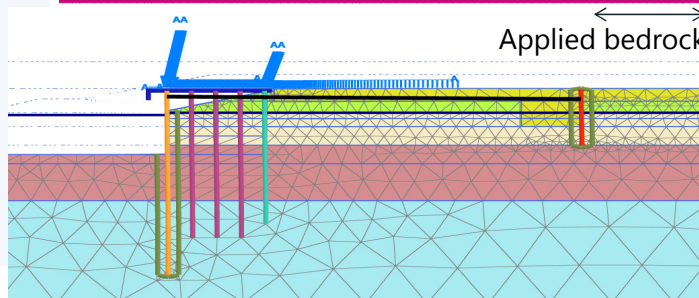
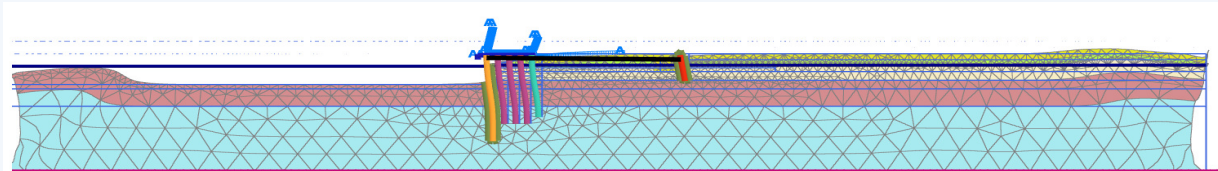
Soil-structure interaction

- dynamic time history analysis: interaction fill, retaining wall, piles, anchorage
- Separately stability checks Kranz, Bishop



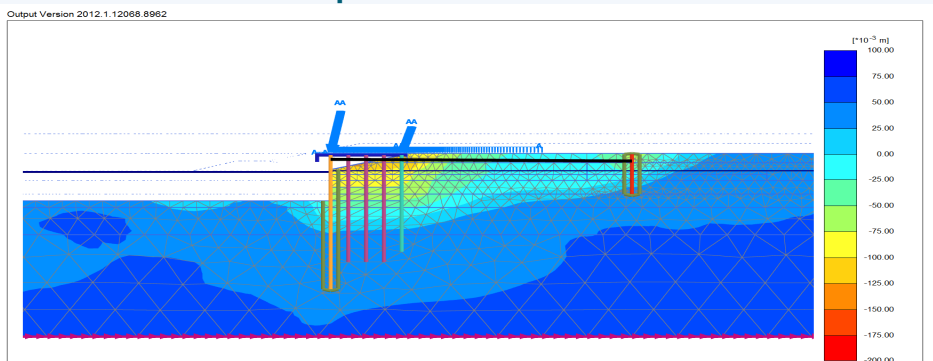
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Quay wall structure calculations



PLAXIS Output Version 2012.1.12088.8962 SS_QWDA_L2_KOC_HSS ... 6187 Witteveen+Bos Consulting engineers 26-08-2013

Residual seismic displacements



Phase displacements Pu_x
 Maximum value = 0.5496 m (Element 24 at Node 1641)
 Minimum value = -0.2793 m (Element 13 at Node 27978)

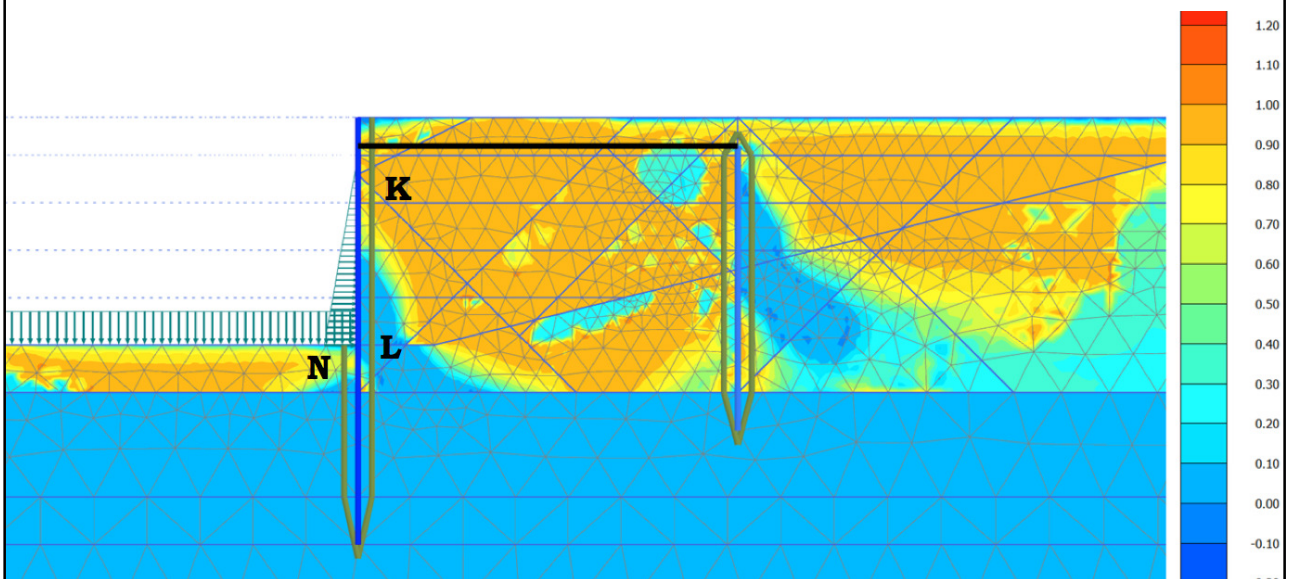
PLAXIS Project description: SS_QWDA_L1_KOC_HSS ... Step: 6187 Date: 26-08-2013 User name: Witteveen+Bos Consulting engineers

Conclusions

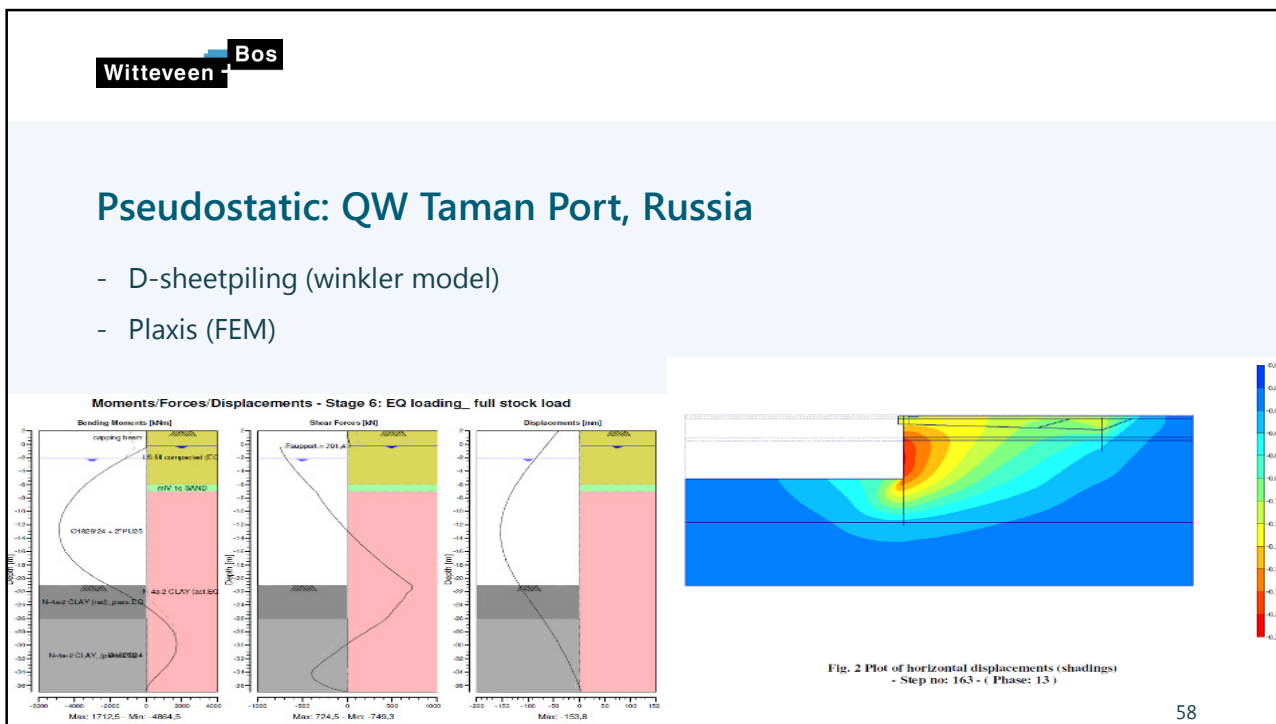
Challenges for practising engineers:

- Generally desirable to account for SSI but no prescribed methods (e.g. Eurocode)
- Straightforward design procedures lacking
- Tools are available, but their performance?
- Crucial elements still missing
- Understanding of (local) hazards (liquefaction!!!!)
- Selection of design approach
- Preferred failure sequence, deformation criteria are crucial

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Requirements for analysis methods (Pianc, 2006)

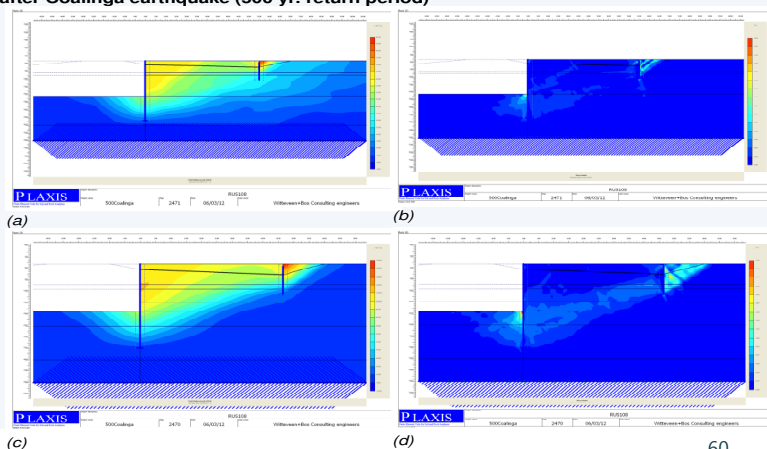
Analysis	Performance grade			
	Grade C	Grade B	Grade A	Grade S
Simplified				
Simplified dynamic				
Dynamic				

	Stage
	Preliminary design
	Final design

Dynamic: QW Taman, Russia

- 12 quays
- Lengths: 400-1187 m
- Total length: 9355 m

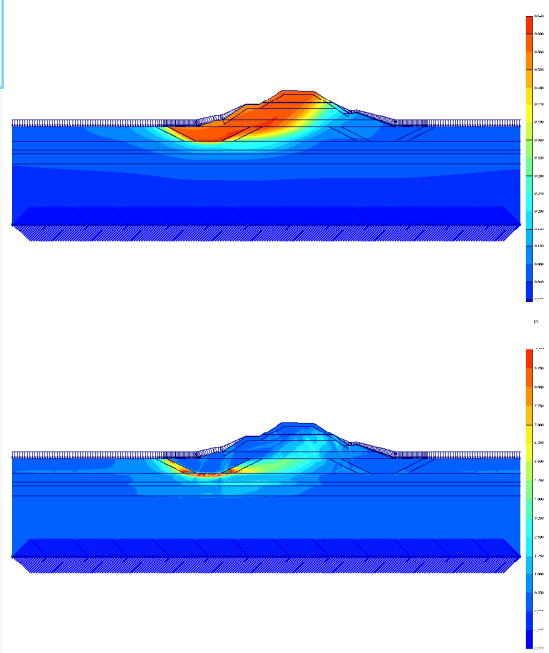
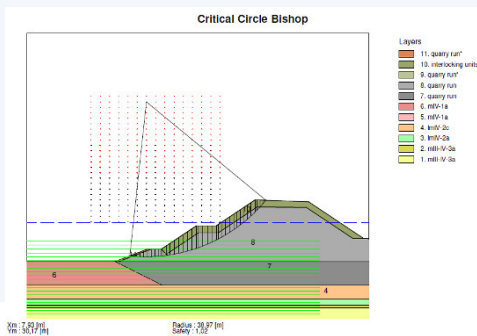
Total displacements and total strains from front wall from quay 2 (a, b) and quay 9 (c, d) after Coalinga earthquake (500 yr. return period)



6 sections
Total length: 7500 m

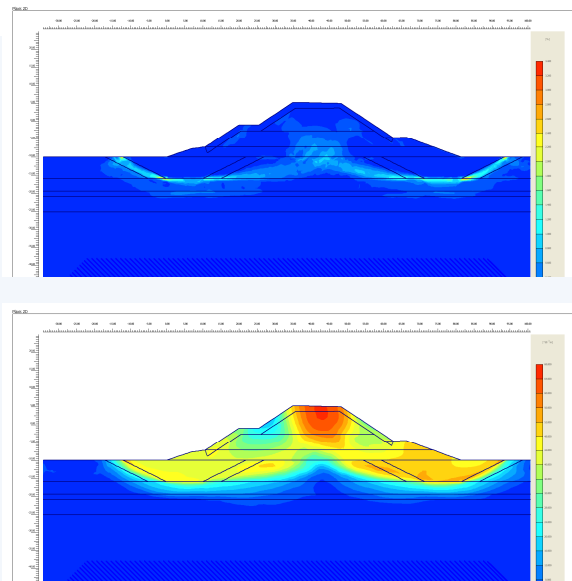
Pseudostatic: BW Taman Port, Russia

- Deltares-Stability (Slip circle)
- Plaxis (FEM)



Dynamic: BW Taman, Russia

- Lower displacements than pseudostatic
- Displacements in both directions
- Soil improvement at toe is effective



Vopak Terminal, Marmara, Turkije



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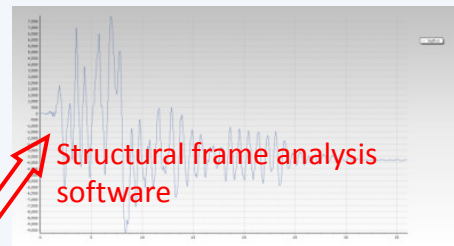
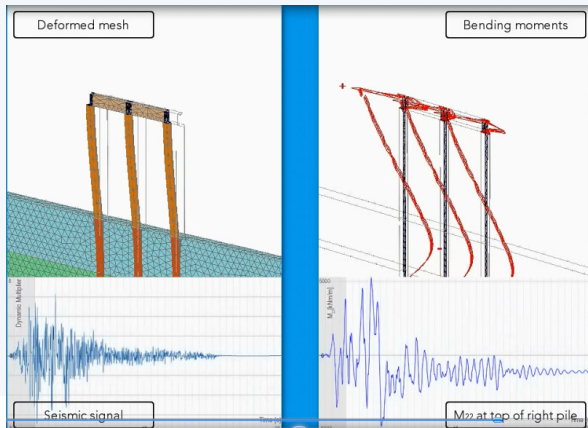
Vopak Terminal, Marmara, Turkije

- Extreem hoge aardbevingsbelasting
- Veilig ontwerp mogelijk door ductiele plastische zones bij aansluiting palen – dek
- Dit gedrag is lastig vast te stellen door simpele analyses
- Oplossing door volledig dynamisch model van ondergrond en constructie te maken.
- Obv opgelegde aardbevingstrilling vervolgens de respons van de constructie en de kritische verbindingen beoordelen

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Vopak Terminal, Marmara, Turkije

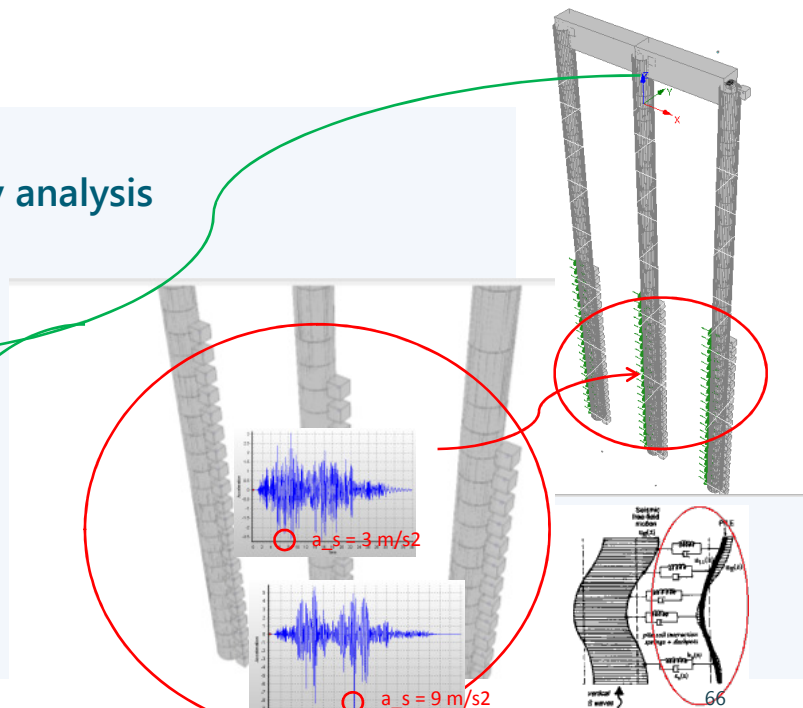
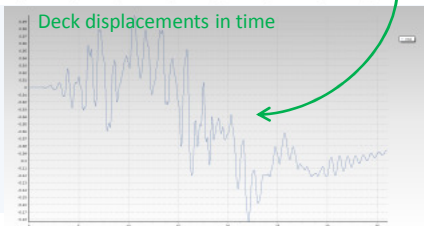
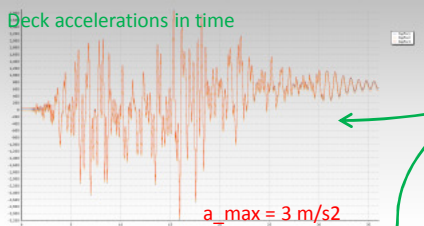
Plastische zones in de grond en aan de paalkoppen maakten veilig ontwerp mogelijk



Structural frame analysis software

Deck-pile connection bending moments in time

Dynamic time history analysis



Witte

In the following part we will show two PLAXIS-generated animations played side-by-side with two exported graphs.

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Witteveen + Bos

