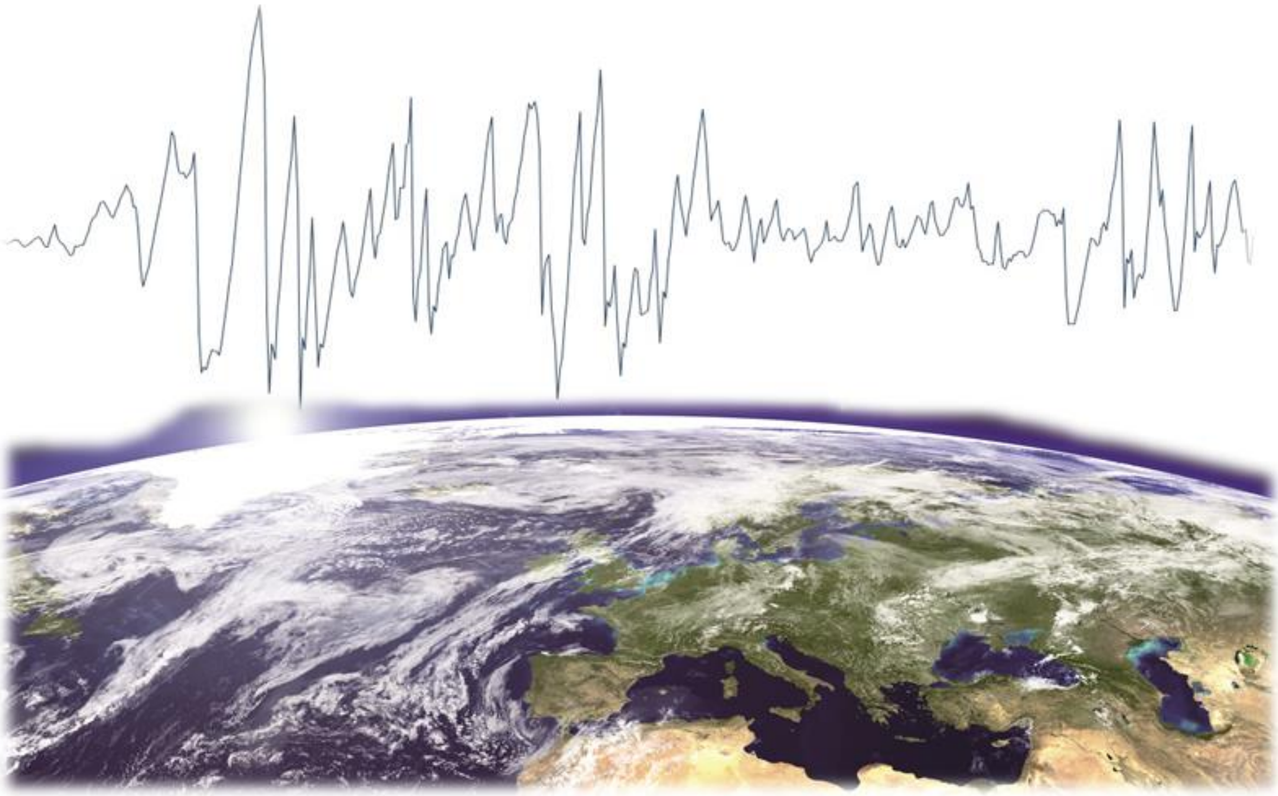

Earthquake Engineering

Capability Statement

Capability Statement: Earthquake Engineering

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Project details throughout this document may have been utilised the services of companies previously acquired by Royal HaskoningDHV.

Royal HaskoningDHV, headquartered in Amersfoort (the Netherlands), is one of Europe's leading project management, engineering and consultancy service providers. The company has offices in 35 countries in Europe, America, Australia, Asia and Africa. Over 6,500 professionals deliver first class solutions in the fields of aviation, maritime, waterways, infrastructure, planning, strategy, water technology, rivers, deltas, coasts, buildings, industry, energy and mining.

A group of 30 specialists, geotechnical and structural engineers, among them is actively involved in designing buildings, dams, dikes, bridges and other structures for earthquake loading all over the world. A variety of services in different stages of projects can be offered. Seimic expertise ranges from quickscans to complex in-depth studies. Royal HaskoningDHV always keeps an eye on the total project requirement.

The quality management system of HaskoningDHV Nederland B.V., part of Royal HaskoningDHV, has been approved against ISO 9001.

1 Quickscan

During early stages of projects it is relevant to identify the hazards and risks. A seismic hazard can govern a design and in worse cases, stop a project. Seismic quick scans are desk studies that make an assessment of the seismic hazard at a site based on available literature. The scans provide a overview of the expected seismic loads at a specific site as well as identify the risks, gaps and propose recommendations for designs and/or further studies.

Knowing the seismic hazard from a project site, Royal HaskoningDHV can perform a quick scan in order to identify and mitigate the most prominent risks.

2 Seismic hazard assessment

Earthquakes are geo-hazards that often cause massive damages and casualties. The identification of this hazard at early stage in projects can be relevant as it can govern the designs and in extreme cases lead to an eventual project cancellation. To mitigate risks and offer seismic-resistant designs, different-level hazard studies can be performed to derive ground motion parameters for seismic design (e.g. PGA, PGV; Sa):

- Seismic desk studies (SDS): Literature study comprising state-of-knowledge on tectonics and seismicity from the region; compilation of previous hazard studies; provision of preliminary ground motion parameters derived from literature.
- Deterministic hazard assessment (DSHA): Determination of ground motion parameters for specific single scenario earthquake, expected to produce the strongest level of shaking at the site.
- Probabilistic hazard assessment (PSHA): Probabilistic determination of ground motion parameters considering all possible earthquake scenarios. Determines the frequency (amount of events in time) with which a seismic hazard will occur.

The best approach to follow might differ depending on the level of knowledge from the specific site; prescribed seismic-design codes to follow; structural occupancy or importance involved.

Royal HaskoningDHV experts are capable ofidentifying the best approach to determine the ground motion parameters for seismic design by executing any of the seismic hazard assessments using the latest tools (e.g. CRISIS2015 for PSHA), in compliance with best-international practice (e.g. EC8; IBC2012; ASCE7-10; PIANC; AASHTO).

Figure 1 Earthquake in Nepal, 2015 (M=7.8)

3 Ground investigation

The ground consistently presents one of the highest risks to any civil engineering project. In order for ground related risks to be managed effectively, it is essential that ground conditions at a site are established in sufficient detail for geo-hazards and the resulting risks are identified. Our engineers have the expertise to specify and manage the whole ground investigation process including the selection of appropriate contractors, tendering, contractual management and technical direction on site.

Geotechnical interpretation work is carried out with the benefit of many years of compiled knowledge on projects around the world. Particular ground investigation services include:

- Desk studies and literature reviews.
- Qualitative and quantitative risk assessments.
- Pre-tender walk-overs and surveys.
- Planning, design, procurement and supervision of site investigations.
- Borehole logging and design of laboratory test programmes.
- Offshore and over-water investigations.
- Interpretative assessment and reporting.
- Location and assessment of construction materials.

Important ground characteristics for seismic design include the soil stratigraphic profile, information on the ground water level, presence of potentially weak layers (which may differ from weak layers in static design) and the depth to bedrock. Required soil parameters may include shear wave velocity, small strain stiffness, cyclic stress-strain behaviour and peak and residual shear strength. Compared to static design, some of the required soil properties may be difficult to assess and can change significantly during an earthquake. This results in a relatively high degree of uncertainty in dynamic ground behaviour and amplifies the need for expert judgement.

4 Ground response analysis and site effects

Surface soil conditions of a site can significantly impact the seismic waves, leading to amplification of the ground motion (with related variations in frequency content, amplitude and duration) at the ground surface. Common types of site effects are amplification due to:

- impedance contrast among the soil/rock layers present at the site;
- topographic effect;
- basin effect.

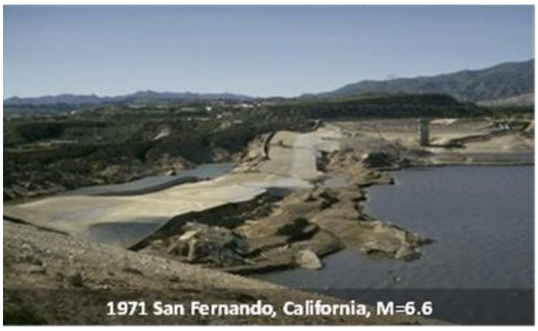

Figure 2 Earthquake in San Fernando, California, 1971 (M=6.6)

Royal HaskoningDHV geological and geotechnical earthquake engineers can identify and characterize possible site effects that can affect the seismic ground response of a site. Ground response analysis is performed with latest equivalent linear and nonlinear tools (e.g. Strata, Deepsoil, Plaxis) including:

- site-effects quantification;
- development of design response spectra and other design parameters;
- evaluation of dynamic stresses and strains for evaluation of liquefaction hazards;
- callibration of advanced 2- and 3-D fully dynamic nonlinear models (e.g. Plaxis, Diana).

5 Liquefaction and cyclic softening

Liquefaction is the phenomenon that is observed when there is loss of strength in saturated and cohesionless soils because of increased pore water pressure and hence reduced effective stresses due to dynamic loading. As a result of liquefaction, the soil merely behaves like a fluid mass with hardly any shear strength, which can lead to serious damage of structures constructed on such soils. Liquefaction induced ground failures include loss of bearing strength, lateral spreading, and flow failures, which can cause many engineering problems such as foundation failures, damage to utilities, slope failures, landslides and large displacements of earth dams.

Figure 3 Earthquake in Nigata, 1944 (M=7.6)

Lateral spreading can occur with very small slope angles of 0.3 to 5 % and will induce large lateral loads on any piles penetrating the liquefiable layer. If a non-liquefying layer is present on top of a liquefying (and laterally spreading) layer, this material will exert an even larger load on any installed piles. As the lateral spreading will be in the order of meters, sufficient soil strains are mobilised to generate full passive earth pressures.

Cohesionless soils that have a factor of safety for liquefaction larger than 1.0 may still develop excess pore pressures during an earthquake. The amount of pore pressure build-up is linked to the factor of safety for liquefaction. Relevant relations are based on the original work by H.B. Seed.

As for cohesionless soils, saturated plastic silts and clays have the potential for strength loss and rapidly increasing strains during dynamic loading as well. This is referred to as cyclic softening. Royal HaskoningDHV has ample specialist expertise available to evaluate the potential for liquefaction and/or cyclic softening and design remedial measures when needed.

6 Slope stability assessment

Earthquakes can trigger landslides on natural slopes and large deformations on embankments, levees and other man-made sloping structures that can lead to failure. The resulting damage of these types of failures can be minor to catastrophic.

Evaluation of seismic slope stability is a regular and important activity of geotechnical earthquake engineers. At Royal HaskoningDHV our engineers can recommend the most adequate approach for every project (Figure 4).

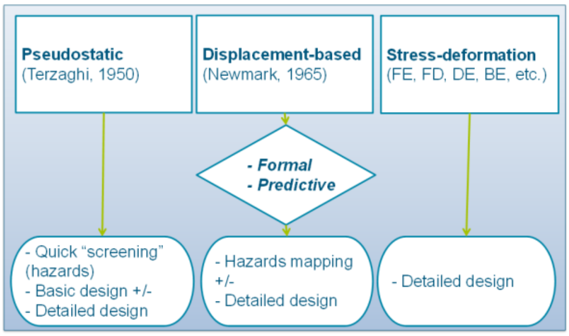

Figure 4 Approaches calculate co-seismic slope stability

The pseudostatic method is the most frequently used for its simplicity using a simple limit-equilibrium method and requiring only a seismic force destabilizing force to assess the performance of the simplified slope (Figure 5). It provides an index of seismic instability but it is conservative. Displacement-based methods provide a more accurate approximation to the deformation expected at a slope, by quantifying the displacements (Figure 6) a slope might suffer under specific seismic scenarios (represented as scaled time histories matched to the design spectra). For this different approaches are possible: formal Newmark and simplified predictive models. The added value of displacement-based methods is twofold: more economic design solutions aligned to performance-based design practice, regularly based on expected deformations. There are simple tools (e.g. spreadsheets; D-Stab) for these methods. More advanced numerical tools (e.g. Plaxis) are used for detailed design to either confirm the interpretations from the previous methods, improve designs of critical sections or overall design of important structures.

The complexity of the analysis depends on the project nature, requirements and level of risk of the structures involved.

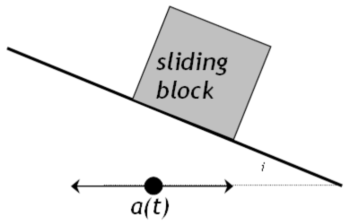

Figure 5 Seismic destabilizing force acting on the sliding block

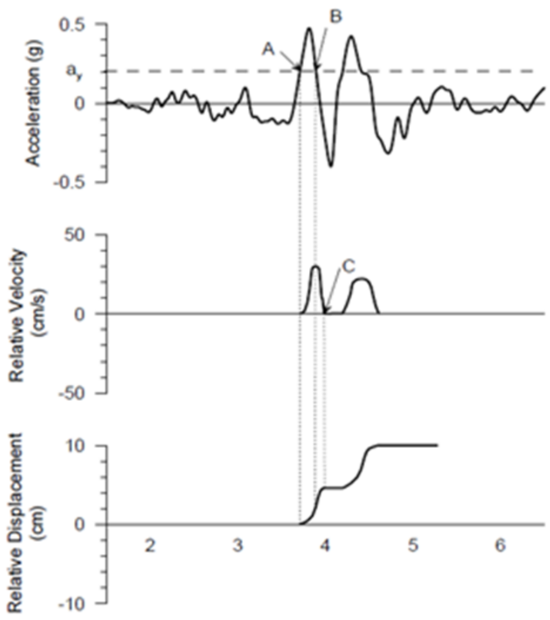

Figure 6 Newmark analysis principle

7 Retaining structures

Earthquakes have caused permanent deformation of retaining structures in many instances. The dynamic response of even the simplest type of retaining wall is quite complex. Walls can move by translation and/or rotation. The relative amounts of translation and rotation depend on the type and design of the wall and the magnitude and distribution of dynamic wall pressures are again influenced by the mode of wall movement.

Retaining walls are most commonly analysed for earthquake conditions using pseudo-static methods, in which pseudo-static accelerations are applied to the active (and passive) wedge. The vertical force is usually ignored in the standard pseudo-static analysis as the vertical pseudo-static force acting on the active wedge usually has a minor effect on the design of a retaining wall.

Mononobe and Matsuo (1929) and Okabe (1926) developed an equation that can be used to determine the horizontal pseudo-static force acting on the retaining wall. This method is often referred to as the Mononobe-Okabe method and is included in Eurocode 8. As a pseudo-static approach, the M-O method has its limitations and more advanced (dynamic) analyses are for example necessary for strong earthquakes or for soils that experience significant loss of strength during earthquakes. Our experts are able to perform appropriate analyses in the required level of detail in any stage of a project.

8 Ground improvement

Ground improvement techniques are commonly used at sites where the existing ground conditions are expected to lead to unsatisfactory performance, generally as a result of insufficient soil strength and/or stiffness. During earthquakes, other factors can contribute to unsatisfactory performance. In particular, the buildup of excess porewater pressure can lead to very large deformations. Consequently, commonly used techniques for mitigation of seismic hazards often involve reducing the tendency of the soil to generate excess porewater pressure during earthquake shaking as well as increasing the strength and stiffness of the soil.

A wide variety of soil improvement techniques are available for mitigation of seismic hazards. The costs of these methods vary widely, and the conditions under which they can be used are influenced by the nature and proximity of structures. The most common methods can be divided into four main categories: densification techniques, reinforcement techniques, grouting/mixing techniques and drainage techniques. When required in a project, Royal HaskoningDHV's experts are able to select and design the appropriate state-of-the-art ground improvement measures.

9 Response spectrum analysis

An elastic response spectrum characterizes the maximum response of structures with a certain amount of internal damping to earthquake loading at a specific location with defined subsoil conditions. Examples of two response spectra are plotted in Figure 7. Different types of earthquakes can be distinguished, such as tectonic and induced by human activity, all with different characteristics. The elastic response spectrum, which is derived from the applicable building code (e.g. EN 1998-1 in Europe) or extracted from a dedicated seismic hazard assessment, is the basis for the lateral force method or a response spectrum analysis. While the former method quickly produces results for simple structures or structures that can be simplified to single-degree-of-freedom (SDOF) structures, the response spectrum analysis is basically a linear-elastic analysis carried out in the frequency domain. It involves all natural frequencies of the structure and projects them on the elastic response spectrum. The resulting structural behavior due to the specified earthquake loading is generally obtained by combining the modal contributions by the SRSS or CQC method. Even impulsive and convective (sloshing) modes of liquids inside containers can be accounted for. Royal HaskoningDHV uses the FEM software Scia and DIANA to perform those tasks. For piping the software AutoPipe is deployed.

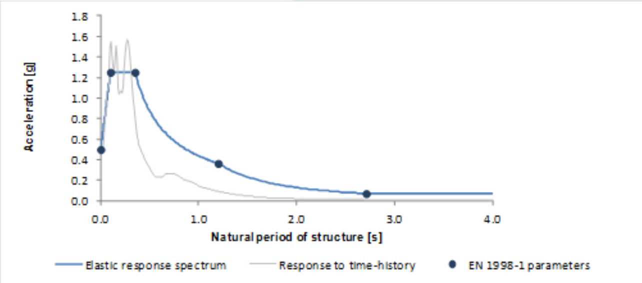

Figure 7: Examples of elastic response spectra

10 Time-history analysis

Historical earthquakes, both tectonic and induced, have been recorded in so-called time-histories of which an example is depicted in Figure 8. Time-histories can be transformed to a response spectrum by determining the maximum response to the time-history of a series of SDOF systems with defined natural frequencies and damping ratios. Conversely, artificial time-histories can also be generated to match an elastic response spectrum. In a time-history analysis the structure is loaded at the base by the accelerations of the time-history and its structural response is evaluated in the time domain. Non-linear elasticity, hysteretic and dissipative behaviour can be taken into account as opposed to a response spectrum analysis. Again the FEM software DIANA is deployed to perform those tasks.

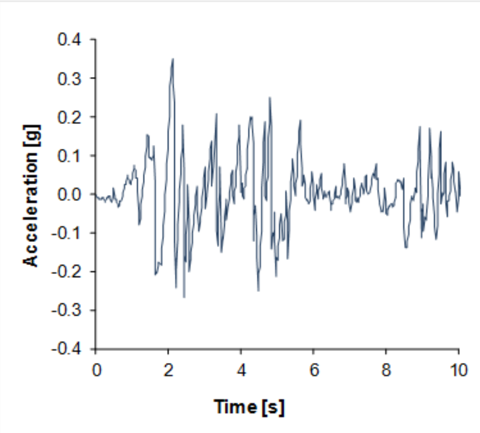

Figure 8 : Example of recorded tectonic earthquake time-history (El Centro, Mexico 1940)

11 Push-over analysis

In a push-over analysis the ductile behaviour of the structure is modeled by applying a gradually increasing load pattern corresponding to the primary mode shape up to failure of the structure or exceedance of limiting plastic strains. Non-linear behavior is accounted for by introducing plastic hinges which is monitored during the analysis. This provides a basis for investigating the post-elastic behavior and dissipative properties at a local level, which is more precise than using global behaviour factors from a building code. This insight is particularly useful for irregular structures where ductility demand can be concentrated in certain parts of the structure. The push-over analysis is used to determine the displacement capacity of the structure, i.e. the displacement of the deck or roof at which limiting plastic strains will be exceeded. The actual displacements during the earthquake are subsequently determined using a demand analysis, e.g. capacity spectrum or substitute spectrum method using proprietary software. Royal HaskoningDHV uses advanced modeling techniques and material models in SAP and DIANA to carry out push-over analysis. A key-input to the pushover analysis is moment-curvature analysis of the plastic hinges, an area in which Royal HaskoningDHV also has significant experience. For masonry structures the special-purpose program 3Muri is used.

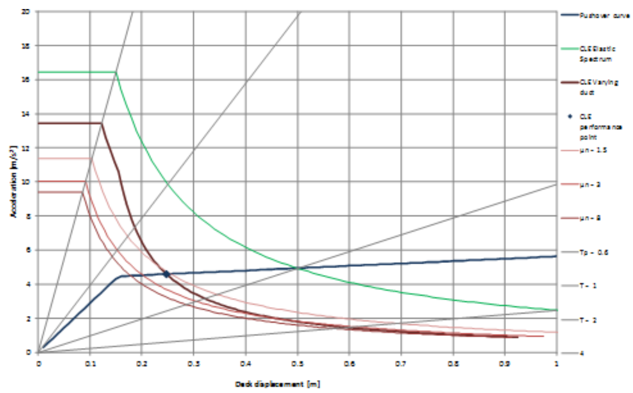

Figure 9 Example of push-over analysis results

12 Soil-structure-interaction

Standard earthquake analysis of buildings often does not take into account the interaction with the sub-soil, the so-called soil-structure interaction. This is done so because it is believed that leaving out the soil-structure interaction most of the time is conservative and taking into account the soil-structure interaction makes calculations more complex. However, soil-structure interaction changes the behaviour of the structure under an earthquake load and it is possible that soil-structure interaction is not beneficial. For instance, soil failure can cause different structural failure modes that are overlooked by a fixed base analysis. For important structures, codes can require taking into account soil-structure analysis. This is also done for structures where failures can cause damage to the surrounding area, like nuclear power plants or LNG tanks. Furthermore it can be beneficial with the assessment of existing structures to take into account soil-structure interaction since it can reduce the costs for retrofit significantly.

13 Retrofit of existing buildings

A special expertise is seismic-risk mitigation through seismic assessment and retrofit of existing structures and buildings. Royal HaskoningDHV has extensive experience in this field of earthquake engineering due to projects in the Dutch province of Groningen that suffers from induced earthquakes caused by the natural gas exploitation.

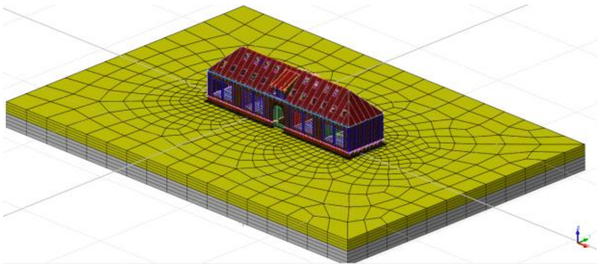

Figure 10 Finite element model of a building with soil for non-linear time history analysis

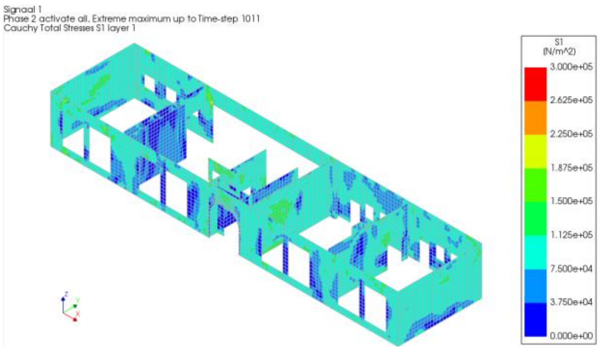

Figure 11 Example of calculation results of a non-linear finite element analysis

Modal respons spectrum analysis, push-over analysis and non-linear time-history analysis are applied in this field of expertise. Site respons calulations and full modeling of soil-structure interaction are also used because incorporating the specific properties of the local soil and foundation give a better description of actual earthquake excitation of the structure (see Figure 10 and Figure 11). This is most of the time advantageous since this generally reduces the earthquake excitation but it can also show amplification of the earthquake signal due to the specific local soil properties. Knowledge has been gathered of non-linear finite element modeling and implementation of failure mechanisms of materials and structural parts such as masonry walls.

14 Detailing of structures

Proper detailing of structures is of paramount importance to withstand earthquake loading. In general the first step is to decide on the level of ductility to be created in the structure. EN 1998-1 distinguishes between low, medium and high ductility, with associated rules for detailing and suitable materials. An example of additional detailing for earthquake loading is shown in Figure 12. Design for low ductility is possible in low seismicity areas.

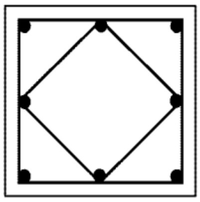

Figure 12 Example of additional concrete column rebar for earthquake loading according to EN 1998-1

For higher seismicity, specific parts of the structure must be selected to safely absorb the imposed earthquake energy. In some cases commercially available seismic base isolation systems may be applied instead, which basically enlarge the first natural period of the entire structure to such a level that the overall seismic response is reduced drastically.

15 Quantitative risk analysis

Quantitative risk analysis (QRA) is an important method for calculating the potential risks due to the handling, storage, et cetera of dangerous goods. The potential risks are a product of probability of failure and possible effects. The occurrence of earthquakes may influence the probability of failure and therefore the potential risk of industries using dangerous goods. Insight in the potential risks and the influence of the possibility of earthquakes is necessary for preventing major hazards and taking the right measure to prevent major hazards.

Royal HaskoningDHV has vast experience in quantitative risk assessments related to all kinds of (major) hazards for industry and transport of dangerous goods. The additional (external) risk of an installation by adding the probability of failure due to an earthquake (or flood) to the failure frequency in the existing QRA of the facility can also be calculated. This additional failure frequency will be based on the studies listed in the paragraphs above.

Royal HaskoningDHV have extensive experience with QRA for the process and chemical industry as well as the oil and gas industry (upstream and downstream). Reference is made to the list of projects below.

Royal HaskoningDHV also have extensive experience with performing second opinion checks on QRA's prepared by others and with performing effect calculations for potential incidents.

Client	Project
Sonneborn	Chemical plant with (a.o.) SO3 (Amsterdam)
Croda	Chemical plant
Caldic	Chemical plant
Stahl Europe	Chemical plant
BASF	Chemical plant
Sachem Europe	Fine chemicals plant
Dr. W. Kolb Nederland B.V.	Chemical plant
Tanatex B.V.	Chemical plant
Century Aluminium Vlissingen B.V.	Anode production
Various (a.o. Flora Holland, 3 refrigeration plants in Waalwijk)	Ammonia cooling plants
Various (a.o. Bosman; C1000; ATM; Norit; KLM Cargo)	Storage of dangerous goods (PGS-15)
Various (a.o. Utrecht, Roermond)	LPG filling stations
Various (a.o. Contrall, Tango)	Petrol filling stations
Various (a.o. Argos)	Fuel depots
Various (a.o. Vopak, Rubys)	Chemicals depots
Various (a.o. Verbrugge, Waalwijk)	Container terminals
Port of Rotterdam	Various QRA's related to shipping
BP Refinery Rotterdam	Refinery QRA
Various (a.o. NAM, Vermilion, TAQA)	QRA's for on and offshore oil and gas installations
DSM	Idem
Teijin	Chlorine
Road	Supercritical CO2 transport
Various pipelines (e.g. Supercritical CO2, Natural Gas, ethylene oxide	QRA's
Accsys	Wood treatment (Acetic acid anhydride, Acetic acid)
KLM E&M	Galvano, Jet fuel, PGS15
Various (a.o. 4Gas B.V., Petro Vietnam and Aqaba)	LNG terminal

Table 1: Recent project references of Royal HaskoningDHV with respect to QRA's

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16 Projects

Royal HaskoningDHV has applied earthquake engineering in many projects around the world over the past decades. The recent projects listed in the table below demonstrate the company's current capability with respect to earthquake engineering.

Project	Client	PGA	Seismic Hazard Assessment	Ground response analysis	Liquefaction and cyclic softening	Slope stability assessment	Ground improvement	Lateral force method	Response-spectrum analysis	Linear-elastic time-history analysis	Non-linear elastic time-history analysis	Retrofit of existing structures	Push-over analysis	Soil-structure-interaction	Displacement based design	Detailing according to EN 1998
BUILDINGS																
Ashgabat International Airport, control tower and terminal, preliminary design, 2013	Polimeks	0.60*g			•			•	•		•			•		
Ashgabat International Airport, utility buildings and infrastructure, detailed design, 2013	Polimeks	0.60*g						•	•							
Bedas Building Structural Strengthening Istanbul, 2007	BEDAS	0.40*g							•	•	•			•		
Bursa Modern Housing Project, 2010	Sinpas REI	0.40*g									•			•		
Control tower Flaming Airport, Bonaire 2013	Rijkswater-staat Netherlands	0.15*g						•								
Dutch Embassy building Kabul, 2010	Dutch Ministry of Foreign Affairs	0.40*g							•							
Dutch Embassy Islamabad,Pakistan, 2003	Dutch Ministry of Foreign Affairs	0.39*g							•				•			
Dutch Embassy New Delhi, India, 2005	Dutch Ministry of Foreign Affairs	0.24*g											•			

Royal HaskoningDHV

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Dutch Embassy Teheran, Iran, 2006	Dutch Ministry of Foreign Affairs	0.37*g						•								
Eroglu Kagithane Housing Project,2013	Eroglu	0.40*g												•		
Firestation Bonaire 2013	Rijks-gebouwen-dienst Netherlands	0.15*g						•								•
Groningen, ca. 200 MRS and 20 NLTH analyses of Schools and Public Buildings, 2016-2017	Nederlandse Aardolie Maatschapij (NAM)	0.42*g			•				•		•	•		•		
Istanbul 1453 Housing Project, 2013	Agaoglu	0.40*g									•			•	•	
Marmarapark Shopping Mall, 2012	ECE Investments	0.40*g									•			•	•	•
Tarin Kowt Airfield, 2010	Deutsche Gesellschaft für Internationale Zusammen-arbeit	0.24*g						•								•
Tsunami Escape, 2008	Dutch Embassy	0.30*g						•								
Vinamilk smart storage	Vinamilk	0.09*g							•							
INDUSTRY, ENERGY & MINING																
Angola 159,000 m3 LNG, detailed design, 2009	Toyo Kanetsu K.K.	0.10*g							•	•				•		

Royal HaskoningDHV

Project	Client	PGA	Seismic Hazard Assessment	Ground response analysis	Liquefaction and cyclic softening	Slope stability assessment	Ground improvement	Lateral force method	Response-spectrum analysis	Linear-elastic time-history analysis	Non-linear elastic time-history analysis	Retrofit of existing structures	Push-over analysis	Soil-structure-interaction	Displacement based design	Detailing according to EN 1998
Bartin Cement Plant Turkey, 2009	Bilim Makina INC	0.40*g												•		
Bintulu LNG tank 7, 2016	Sato Kogyo, Petronas	0.09*g							•							
BTC Crude Oil Pipeline, 2013	Tekfen Construction	0.40*g												•		
Dutch Lady Ha Nam	Royal Friesland Campina	0.12*g						•								
Greenfield Brewery Kilinto – Addis Ababa	Heineken Breweries Share Company	0.82*g						•								
Habeco	Habeco	0.08*g						•								
Jordan Dike 18 Seismic Stability, 2008	Àrab Potash Company	0.30*g			•	•								•	•	
L'Oreal Jababeka	PT. Yasulor Indonesia	0.30*g						•								
Lahad Datu LNG, bid design, 2012	Sato Kogyo Malaysia	0.22*g						•								
Monas Project, detail design of production building, boiler building, pipe bridge & tank farm	PT. Rckitt Benckiser Indonesia	0.35*g						•								
Morocco Samir Mohammadia Refinery Plant, 2007	Tekfen Consulting	0.40*g												•		
MSD Indonesia Packaging Project	PT. Schering Plough Indonesia	0.10*g						•								

Royal HaskoningDHV

Project	Client	PGA	Seismic Hazard Assessment	Ground response analysis	Liquefaction and cyclic softening	Slope stability assessment	Ground improvement	Lateral force method	Response-spectrum analysis	Linear-elastic time-history analysis	Non-linear elastic time-history analysis	Retrofit of existing structures	Push-over analysis	Soil-structure-interaction	Displacement based design	Detailing according to EN 1998
Nestle Kejayan BO Plan Expansion	PT. Nestle Indonesia	0.15*g						•								
Nestle Panjang, Filling Room and Dry Mix Extension	PT. Nestle Indonesia	0.20*g						•								
NW380 planned electrical powerline, 2013	TenneT Netherlands	0.43*g							•	•						
OTSUKA New SVP Factory Indonesia	PT. Otsuka Indonesia	0.15*g						•								
P9 pumping station, pipe works and canal, 2014	Dead Sea Works	0.29*g			•	•		•						•	•	
Pepsico	Suntory Pepsi Viet Nam	0.11*g						•								
Poti Tank Storage Space, Georgia, 2002	Üstay Construction INC	0.40*g												•	•	
Quang Ngai Brewery	Sabeco	0.08*g						•								
Quickscan Chemical plant (pipeline) Delftzijl, 2013	AkzoNobel Netherlands	0.43*g							•							
Quickscan salt pipeline Delfzijl-Midwolda, 2013	AkzoNobel Netherlands	0.43*g							•							
Radar Merauke in Timika, Merauke, Saumlakki	PT. Ebdesk Indonesia	0.30*g						•								
Rijeka Container Terminal, 2013-2014	Port of Rijeka Authority	0.40*g												•		•

Royal HaskoningDHV

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Project	Client	PGA	Seismic Hazard Assessment	Ground response analysis	Liquefaction and cyclic softening	Slope stability assessment	Ground improvement	Lateral force method	Response-spectrum analysis	Linear-elastic time-history analysis	Non-linear elastic time-history analysis	Retrofit of existing structures	Push-over analysis	Soil-structure-interaction	Displacement based design	Detailing according to EN 1998
Seismic Evaluation BOPEC, Bonaire 2016	Bonaire Petroleum Corporation C.V.	0.16*g	•													
Song Lam Brewery	Sabeco	0.11*g						•								
Vinamilk Dielac II	Vinamilk	0.08*g							•							
Wrigley	Wrigley	0.09*g						•								
Azerbaijan Shah Deniz Project, 2003	Tekfen Construction	0.40*g												•		
Fujairah VLCC piping, 2014	Port of Fujairah	0.12*g						•								
Bukavu piping project, 2013	Heineken	0.11*g						•								
Kisangani piping project, 2013	Heineken	0.11*g						•								
Kigali piping project, 2012	Heineken	0.11*g						•								
Adana Power Plant, piping, Turkey, 2001	Siemens	0.50*g						•								
Water Tanks Appingedam, 2016	Waterbedrijf Groningen	0.27*g			•			•								
INFRASTRUCTURE																
Ankara Pozanti Highway Engineering Structures, 2009	Tekfen Construction	0.40*g									•			•		

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Project	Client	PGA	Seismic Hazard Assessment	Ground response analysis	Liquefaction and cyclic softening	Slope stability assessment	Ground improvement	Lateral force method	Response-spectrum analysis	Linear-elastic time-history analysis	Non-linear elastic time-history analysis	Retrofit of existing structures	Push-over analysis	Soil-structure-interaction	Displacement based design	Detailing according to EN 1998
Baku By-pass Highway Slope Stability Rehabilitation, 2008	Makyol-Copli JV	0.40*g									•			•		
Bursaray B line LRTS, Turkey, 2006	Bursa Metropolitian Municipality-Siemens-Tekfen-	0.40*g									•			•		
Dubai Iconic Bridge, 2008	Nakheel	0.15*g						•						•		
Istanbul Metro System, 90 km, 6 Lines, Turkey, 2009	Istanbul Metropolitian Municipality	0.40*g												•		
Sabiha Gokcen International Airport Second Runway, 2011	ARUP	0.40*g									•			•		
KAASKAR (Grade Separated Junction of King Abdul Aziz Square & Improvement of King	Municipality of Jeddah	0.10*g							•					•		
Tahliya Intersection	Municipality of Jeddah	0.12*g							•					•		
The Bosphorus Rail Tube Crossing Istanbul Turkey, 2013	Avrasya Consulting	0.40*g												•		
Avcilar-Ambarli Landslide Remediation Project, 2005	Istanbul Metropolitian Municipality	0.40*g									•			•		
Strait Crossing European Under Pass, 2011	Yapi Merkezi-SKEC JV	0.40*g									•			•		
New International Airport for Mexico City 2015-2016	Grupo Aeroportuario	0.40 *g		•	•	•										
Ring Zuid Groningem 2017	Combinatie Herepoort	0.13*g		•				•								

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MARITIME																
Ambon Bay Land Reclamation	PT. Karya Unggulan Gemilang	0.53*g			•									•		
Baku New International Sea Trade Port	Ministry of Transport	0.22*g			•	•		•						•	•	
Batangas Bay Tsunami Study (LNG plant), Philipines 2016	FGen LNG Corporation	n.a.	•													
Beira Quay 11, Mozambique 2016	CdM; CFM	0.16*g	•													
Buyukcekmece Marina, Istanbul Turkey,2010	Marina Istanbul	0.40*g									•			•		
Callao Muelle Norte Port structures, Peru 2012	APMT	0.43*g			•	•			•				•	•	•	•
Candarli Port, Izmir Turkey, 2009	DLH-Altinok Consulting	0.60*g									•			•	•	
Cayman Islands Cruise Berth Facility 2017	Cayman Islands Government	0.26*g	•		•				•							
Container Terminal at Kingston, Jamaica 2016-2017	EGIS	0.29 g	•	•	•		•				•					
Damen Song Cam Shipyard	Damen Song Cam	0.13*g						•								
Dubai Palm Deira Marine Waterfront Structures, 2009	Nakheel	0.15*g		•	•	•				•				•	•	
GOA Shipyard	GOA Shipyard Ltd	0.16*g							•							

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Dubai Deira Islands, 2016	Van Oord	0.15*g		•	•	•					•					
Kargı Earth Dam Project, 2010, Turkey	Makyol	0.40*g												•		
Lamongan shipyard 2010 – 2011		0.30*g							•							
Land Reclamation Tanjung Bunga Makassar, Indonesia 2013	PT. Gowa Makassar Tourism Development	0.20*g			•									•		
Maritime Yard Project, Saudi Arabia 2016-2017	Saudi Aramco	0.10*g	•		•											
Mersin Port, Turkey 2009	DLH-Altinok Consulting	0.45*g									•			•		
Terminal Portuario General San Martin, Pisco Peru, 2015	Consorcia Paracas	0.43*g	•				•		•				•	•	•	
Pluit City Land Development Project, Indonesia 2013	PT Muara Wisesa Samudra	0.30*g			•	•								•		
Ruwals Takreer oil loading jetties, detailed design 2010-2011	GS E&C Corporation	0.11*g							•							
Umm Qasr Port, Iraq 2016-2017	Basrah Multipurpose Terminal (BMT)	0.16*g	•													
Toros Tarim Ceyhan Mobile Erection Area, 2010	Tekfen Construction	0.40*g									•			•		

Table 2: recent project references of Royal HaskoningDHV with respect to earthquake engineering

Notes:
g = gravity acceleration (9.8 m/s^2), PGA = peak ground acceleration at surface level