NAM

Groningen 2013

Preliminary Structural Upgrading
Strategy for Groningen

Issue 5 | 30 July 2013

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Executive summary

This report provides a summary of the proposed approach for a preventive structural upgrading strategy for existing buildings in the Groningen region. It is one of the studies for building damage reduction as outlined in the letter of Minister Kamp to the Dutch Parliament of 11 February 2013.

NAM has commissioned Arup to undertake this study.

The preventive structural upgrading strategy will be the basis for an implementation plan. Finalization and execution of the plan is subject to the outcome of other studies, discussion with relevant stakeholders and decisions around the future Groningen gas production

The proposed approach in this report is based on the following three study components:

1. Seismic risk, structural upgrading and implementation studies;

2. A prioritization approach; and

3. Two implementation pilots to test technical feasibility (pilot 1) and operational implementation (pilot 2).

As the development of the relevant Eurocode 8 National Annex for the Netherlands is expected to take several years, the development of a NPR (Nationale Praktijk Richtlijn) has recently been initiated by the Ministry of Economic Affairs. It has been agreed that the NEN –institute will develop the NPR as a precursor for this National Annex. Arup and NAM will assist in supporting the NEN-committee preparing the NPR. The results of this structural upgrading study will be an input for the NPR document for existing buildings.

The design guidance proposed in this approach will be based on elements of the Eurocode, FEMA and ASCE and can be seen as the basis for the future NPR (Nationale Praktijk Richtlijn) for the structural upgrading of existing buildings. The aim is to produce the first preliminary outline design guidance for existing houses early next year, subject to agreement on seismic hazard.

The design guidance will be developed in a step-by-step methodology. Pilot 1 will focus on 10's of buildings and will be executed in batches, each consisting of a number of specific buildings. Each (pilot 1) building will be further sub divided in phase 1 which is the testing of design and phase 2 is the testing of execution.

Pilot 2 will focus on 100's of buildings and follow a similar approach as pilot 1.

This approach aims at getting maximum learning value from the initial structural upgrading activities, so that a systematic implementation approach for the preventive structural upgrading strategy can be developed that includes actual 'on the ground' experience and can therefore aim at a realistic and efficient preventive structural upgrading implementation plan. Target for the first version of the preventive structural upgrading Strategy is Q4 -2013.

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No preliminary results can be provided at this stage as these are currently being developed on the basis of the seismic hazard parameters received from KNMI on 2nd of July 2013 (see appendix G).

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1   Introduction

This report provides a summary of the proposed approach for a preventive structural upgrading strategy for existing buildings in the Groningen region. It is one of the studies for building damage reduction as outlined in the letter of Minister Kamp to the Dutch Parliament of 11 February 2013.

Preventive structural upgrading for existing buildings is applied in several seismic regions around the world, mostly on the initiative of building owners, but also backed up with local or national legislation.

The Groningen situation is unique as (and for this reason examples from other regions cannot be simply copied):

- The earthquakes are caused by gas extraction, known as induced earthquakes;

- There is very limited knowledge and experience in the Dutch building industry in the design and construction of earthquake resistant buildings and the structural upgrading of existing buildings; and

- Most of the building stock in Groningen consists of unreinforced masonry (URM), which in general, without special design features, has a poor response to earthquakes.

The goal of this report is to outline progress on the development of an approach for a preventive structural upgrading strategy, which will be the basis of the project implementation plan that will enable large scale implementation of structural upgrading measures to existing buildings in the region in the future. This approach has been developed in collaboration with NAM over the last few months. Experience with earth quake measures elsewhere will be considered and used where possible, e.g. the approach after the Liege earth quake in 1983.

The work presented is work in progress and therefore preliminary. It forms the basis for current discussions and thinking and is aimed to form a framework for the preventive upgrading strategy for large scale implementation. It addresses the studies and implementation pilots to be undertaken to arrive at this preventive upgrading strategy.

An introduction to earthquakes, general principles to earthquake resistant design and structural upgrading can be found in Appendix A.

2 Approach for a Structural Upgrading Strategy

2.1 Elements of the Approach

The approach to come to a **structural upgrading strategy** has three basic elements:

- **Studies**;

- **Prioritization**; and

- Implementation **pilots**.

This approach is aimed at finding the right balance between technical rigor and speed of implementation of the study.
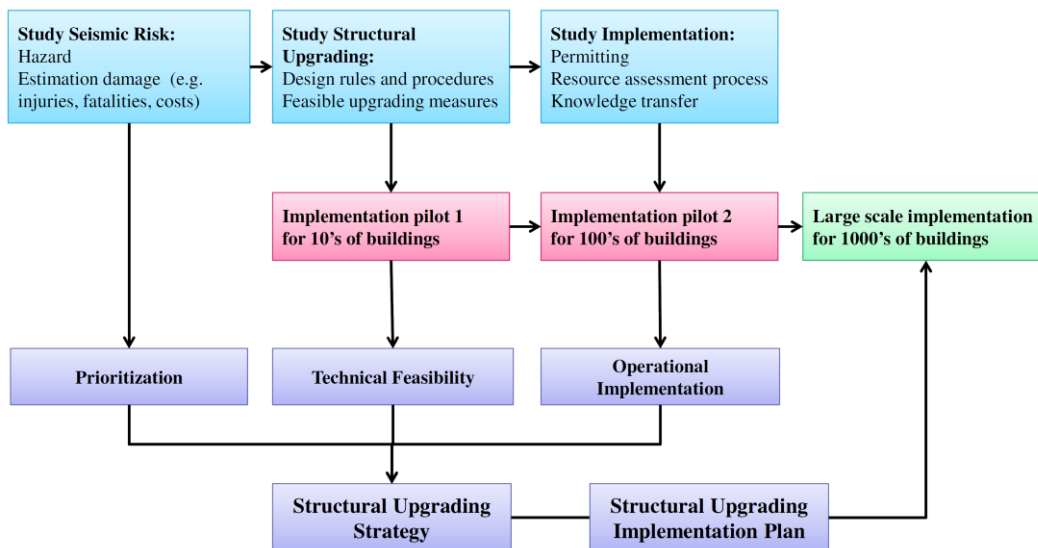

Figure 1: Elements of the approach.

2.1.1 Studies

2.1.1.1 Study Seismic Risk

The seismic risk study aims to **quantify expected losses** (potential building damage, casualties and financial loss) for a specific area caused by the seismic hazard resulting from induced earthquakes.

In the context of the upgrading strategy, the seismic risk study is **one of the tools to prioritize** the implementation of studies, implementation of pilots and large scale implementation.

The outcomes of the seismic risk study can also be compared to other types of risks (natural and manmade) and can be a basis for **discussion of acceptability** of the risk caused by the Groningen field operations as part of the overall study work commissioned by the Minister.

Details for the study seismic risk are outlined in Appendix B.

2.1.1.2 Study Structural Upgrading

The structural upgrading study aims to develop **design guidance** for structural upgrading of the Groningen region building stock within the context of Dutch building practice and available regulatory framework. The aim is to develop **design rules and protocols** for **typical buildings**, representative for a large proportion of the Groningen region building stock and to develop a **design procedure** for **unique buildings**.

The results of the structural upgrading study will be an input for the NPR currently being developed by the NEN-institute. The results of Arup's work for NAM will be made available by NAM to the committee preparing the NPR.

The structural upgrading study has the following steps:

- Assess the performance of buildings and building types;
- Develop design procedures, design rules and protocols for structural upgrading; and
- Develop feasible structural upgrading measures for local implementation.

The study addresses different building typologies:

- Damaged buildings;
- Houses;
- Historic buildings; and
- Other buildings.

Most of these building typologies have sub-typologies that are representative for 10's, 100's or 1000's of buildings and can therefore be seen as typical and representative of the types of buildings in the Groningen region.

The strengthening measures will be developed on the basis of structural analysis on these building types and thereafter tested on 10's of buildings in order to verify the

applicability and appropriateness of the measures. In order to develop a systemic approach, measures will be tested in two pilot projects. Each pilot will be undertaken in a design (1) and execution phase (2).

The outcome of the structural upgrading study and the implementation in pilot 1 will be **a technical framework** for large scale implementation. It is important to note that pilot 1 and 2 are **already** part of the **actual implementation** of preventive strengthening measures (especially for the damaged buildings).

Besides holistic structural upgrading measures for entire buildings, this study also addresses mitigation measures to strengthen specific structural elements within buildings with high risks at lower level earthquakes. These include chimneys, parapets, building decorations or any other free standing building elements that could fall off even at low levels of ground shaking. These specific risk elements will be identified during an building inspection campaign for which a 'higher risk building elements mitigation strategy' is currently being developed with a target to start by end-Q3 2013.

Details for the study structural upgrading are outlined in Appendix D.
Details for the higher risk building elements mitigation strategy are outlined in Appendix F

2.1.1.3   Study Implementation
This study aims to develop a methodology for large scale implementation. Based on the technical framework, large scale implementation will be developed as per the following approach:

- Development of final design strategy:
  - o Develop strategy for typical and unique buildings;
  - o Develop information and design documentation strategy; and
  - o Document the design strategy for dissemination.
- Embedment of final design strategy in recommendations, design codes and legislature;
- Develop knowledge transfer strategy; and,
- Develop process of larger scale implementation, including management, scoping, programming, planning, information management and prioritization.

The resulting preventive structural upgrading strategy for large scale implementation is planned to be tested in Pilot 2 on 100's of buildings in order to test and improve the effectiveness, speed and efficiency during implementation.

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2.1.2   Prioritization

In between the time of identifying the general need and the actual strengthening, several months to years can pass and there is a need for **prioritization**. The process has three basic steps:

- **Identification:** to identify the buildings with the highest potential seismic risk, based on the hazard, structural vulnerability and/or the consequences of failure in an earthquake;

- **Performance evaluation:** to assess the gap between current and required structural performance; and

- **Structural upgrading:** to actually achieve the required performance in a cost effective way using conventional and innovative upgrading measures.
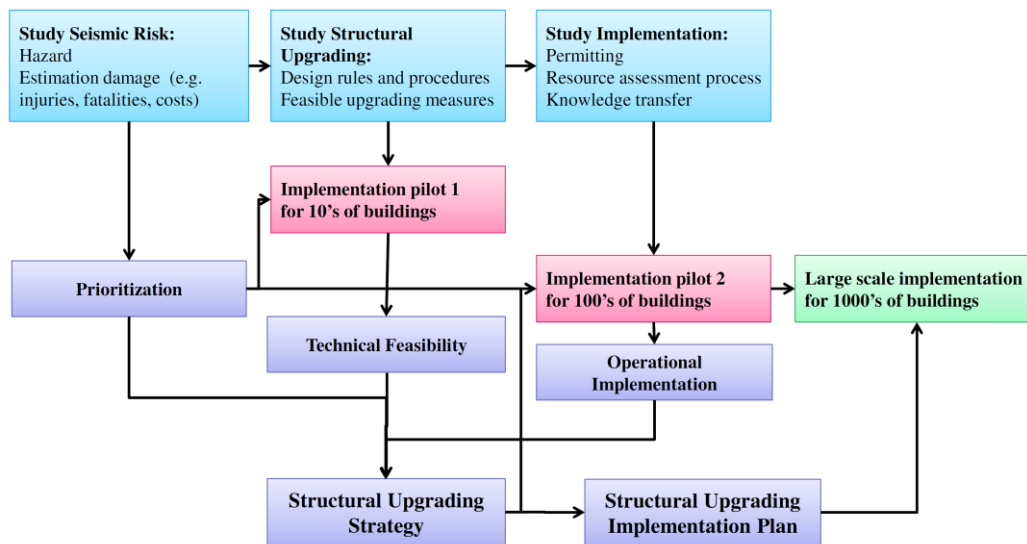

Figure 2: Prioritization within the study.

Methods of identification are determined by:

- **The NAM claim handling team**, who capture data of significantly damaged buildings following earthquakes;
- **Seismic risk study** outcomes;
- **Pre- and post-earthquake inspections** using different screening standards (e.q. FEMA 154, ASCE 31 and ATC-20).

Details for the prioritization are outlined in Appendix C.

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2.1.3 Implementation Pilots

Implementation pilots are used to test the design and application of structural upgrading measures. Two pilots, each with two phases are proposed:

- **Pilot 1, Phase 1:** small scale **testing of design**;
  - **Pilot 1, Phase 2: small scale testing of execution;**
- **Pilot 2, Phase 1:** large scale **testing of design;** and
  - **Pilot 2, Phase 2: large scale testing of execution;**

Pilot 1 is to test the technical feasibility of the proposed design procedure and structural upgrading measures. Pilot 2 is to test the operational implementation. Pilot 1 will be performed on 10's of buildings and pilot 2 will be performed on 100's of buildings (the exact number will be determined later, once initial results become available).

Pilots 1 will be performed in batches of selected buildings. The phase 1 design works of pilot 1 are currently underway on the first 11 buildings (see appendix E for information on the various batches during pilot 1).

2.2 Relationship of the different elements and other studies/activities

The relationships between the different elements of the approach are shown in Fig. 1.

Studies will overlap in time, but basic progression is from left to right, starting with the seismic risk study and finishing with the implementation study. The implementation pilots tie in with this sequence.

There are several relationships with other studies and activities not undertaken by Arup. These parallel studies provide important input to this study:

- **Definition of seismic hazard** by KNMI and subsurface experts (incl. NAM); The seismic hazard will be input to the Arup work

- **Identification of potential significant damage** of existing buildings following earthquakes by existing NAM claim handling team: The identification and damage report data of damaged existing buildings is an input to the Arup work

- **Development of national design guidance (NPR and National Annex to Eurocode 8)** on the structural upgrading of existing buildings by NEN: The results of Arup's work for NAM will be made available by NAM to the committee preparing the NPR.

The definition of the seismic hazard for both the seismic risk study and the structural upgrading study is undertaken by KNMI and the subsurface experts (incl. NAM). Arup is in communication with these groups to ensure that the outcomes of these studies can be used efficiently as input for the seismic risk and structural upgrading study.

The identification of significant damage is used to prioritize specific buildings for entry in Pilots 1 and 2.

Details for the study seismic risk are outlined in <u>Appendix B.</u>

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2.3   Knowledge management and learning

The studies and implementation pilots are to **learn how to undertake large scale implementation** in an effective and timely manner.

As the problem and the context are undefined and unique it is assumed that the process is not a linear process, but cyclic with defined feedback loops.

There are two ways of **learning**:

- **Feedback loops:** The process builds up in small steps with a cyclic character. New learning and insights resulting from the different steps in the studies and implementation pilots give feedback to assumptions of previous steps;

- **Scaling:** The implementation pilot process builds up to deal with an increasing scale. The first implementation pilot will focus on 10's of buildings; followed by the second implementation pilot which will possibly focus on 100's of buildings. Results from all pilots will be documented and used to develop the preventive upgrading strategy and plan.

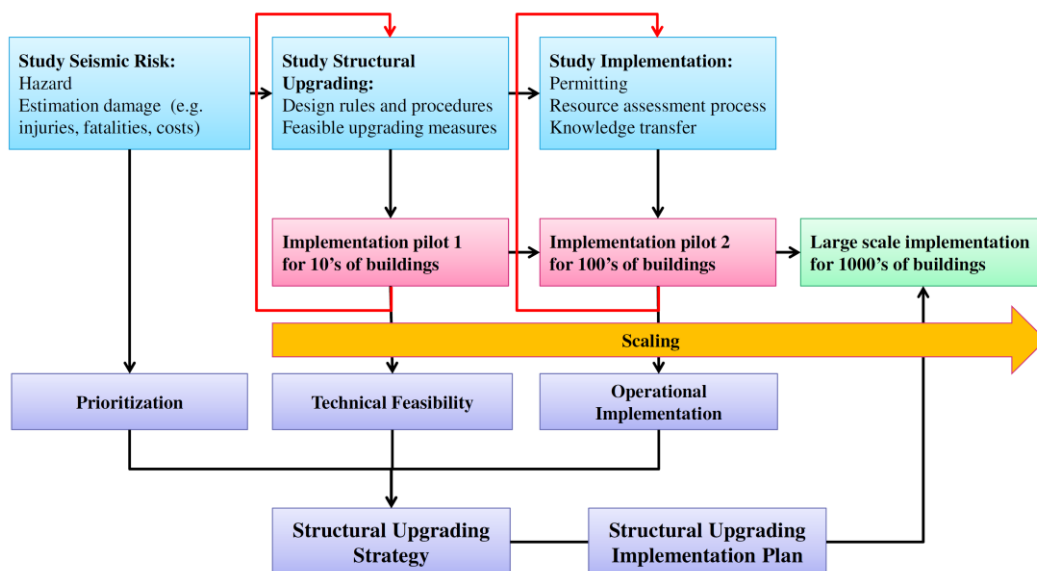Figure 3: Learning: feedback loops and scaling.

This process will lead to a **refinement of the knowledge base** starting with an approximate 'quick and dirty' approach, than leading to more refinement with associated verification and validation.

In the studies, the implementation pilots and the subsequent large scale implementation large sets of data will be monitored and documented using GIS applications.

3   Program

A Program is added as <u>Appendix G.</u>

Main key milestones are:

- Start Pilot 1, Phase 1:   May 2013;
- Start Pilot 1 Phase 2:   Q3 2013;
- Start Pilot 2:   Q4 2014;
- Initial design guidance for existing houses: Q1 2014;
- Outline design guidance for existing houses: Q4 2014;
- Completion of Pilots 1, for existing houses: Q4 2014;
- Start large scale implementation: Q4 2015;
- Continued Studies: 1-3 years;
- Duration large scale implementation: multiple years;
- Start construction:
    - Higher risk building elements strategy*:   Q3 2013;
    - Typical houses: Q1 2014;
    - Damaged buildings: Q1 2014;
    - Historical buildings: Q3 2014;
    - Other buildings   Q3 2014.

Subject to outcome of other studies, decision on Groningen field production by Minister Kamp and discussion with relevant stakeholders

4   Preliminary results

No preliminary results can be provided at this stage as these are currently being developed on the basis of the seismic hazard parameters received from KNMI on 2nd of July 2013.

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5   Conclusions

- An approach is presented for the structural upgrading strategy which will be the basis for the structural upgrading implementation plan.

- The approach is based on a combination of three study components comprising of; seismic risk assessment, structural upgrading and implementation studies, a prioritization approach, and two implementation pilots to test technical feasibility and operational implementation.

- The full development of the Eurocode 8 National Annex for the Netherlands is expected to take several years; the development of a NPR (Nationale Praktijk Richtlijn) is suggested as a precursor for this National Annex. The NPR will be developed by and under the responsibility of the NEN-institute. NAM will make the results of Arup's work available to the committee preparing the NPR. The results of this structural upgrading study will be an input for the NPR document for existing buildings.

- The design guidance proposed in this approach and under development will be based on elements of the Eurocode, FEMA and ASCE and may be used as the basis for the future NPR (Nationale Praktijk Richtlijn) for the structural upgrading of existing buildings. The aim is to produce the first preliminary outline design guidance for existing houses early next year, subject to agreement on seismic hazard.

- No preliminary results are given at this stage as these are currently being developed on the basis of the seismic hazard parameters received from KNMI on the 2nd of July 2013. The initial seismic risk study results are expected end of 2013 and will be incorporated in the preventive structural upgrading strategy that is scheduled for completion by the end of this year.

- The 'higher risk building elements mitigation strategy' is currently being developed in collaboration with NAM. It is intended to ensure priority mitigation of the structural building elements that present a higher degree of risk of significant damage or injury. These risks are related to for instance; chimneys, free standing walls, parapets and ornaments falling down even at low levels of ground shaking. This strategy will accelerate and prioritize the mitigation of risk elements and forms in fact an (independent) first part of the implementation strategy of preventive upgrading.

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Appendix A

Introduction to earthquakes and earthquake resistant design

A1   Earthquakes and their effects

Earthquakes are caused by rupture of the earth's crust along planes of weakness called "faults". Built-up strain energy is released by the sudden fracture, and vibrations spread outwards from the source as seismic waves (similar to water waves spreading across the surface of a pond when a stone is thrown into it). Seismic waves from an earthquake can be recorded by sensitive instruments all over the world, but the seismic waves attenuate (become weaker) with distance and strong shaking is only felt relatively near to the source of the earthquake.

Earthquake effects on structures can be due to several different hazards:

- **Direct ground shaking** – the effect of the ground vibrating back and forth leads to inertial forces in structural elements and their connections.

- **Shake down settlement** – ground shaking can lead to compact settlement of loose soils.

- **Liquefaction** – shaking of saturated soils can lead to a build-up of water pressure in the voids, which reduces the forces holding the soil particles together, and results in the soil losing strength and behaving like a liquid.

- **Landslides** – shaking can also destabilise slopes and trigger landslides;

- **Ground surface fault rupture** – this only affects structures directly straddling a fault and is extremely unlikely in the Groningen region due to the small magnitude of the induced earthquakes.

- **Tsunami or seiche** – fault rupture or landslide disturbance of the sea bed can throw up large waves known as tsunami that can spread across oceans and cause damage far from the source of the earthquake. Similar waves can occur in confined water bodies such as lakes or canals and in this case they are referred to as seiche waves.

The ground shaking effect is generally of most concern. Structures are generally designed to stand up under the vertical acceleration of gravity, but in areas that do not face frequent earthquakes, they are not always designed to resist horizontal accelerations.

The size of earthquakes at their source is measured by various **magnitude** scales (the first scale was due to Richter, and therefore magnitude is often referred to as "Richter magnitude", although the original Richter magnitude is used much less frequently than other scales). Magnitude is a logarithmic quantity, meaning that an increase by one magnitude unit represents a tenfold increase in ground shaking amplitude, and a thirty-fold increase in energy release.

The felt effects of earthquake ground shaking at a location, is referred to as the **intensity**. Macroseismic intensity scales, quantify intensity in an area based on human felt effects, effects on objects and nature, and effects on structures. Two common macroseismic intensity scales are the European Macroseismic Scale (EMS) and the Modified Mercalli Intensity scale (MMI).

The amplitude of earthquake ground shaking at a location is measured on special instruments. Near the earthquake the instruments are referred to as strong-motion instruments and record in terms of ground acceleration. These records will need to be investigated for the earthquake effects on structures. Far from the earthquake the instruments are referred to as seismograph instruments and record in terms of ground

displacement or velocity. These records are used by seismologists to determine the precise location and depth of the earthquake along with other seismological parameters.

A2   General principles of earthquake-resistant design

In areas of the world where earthquakes occur more frequently, principles of earthquake-resistant design are embedded in seismic design codes. For example, Eurocode 8 contains seismic design provisions for Europe (although the specific application depends on the National Determined Parameters (NDP's), specified in the National Annex for each country, and the Eurocode 8 has no National Annex containing NDP's for the Netherlands). These principles are developed on the basis of structural analysis, laboratory testing and observations from real earthquakes.

There are several key qualitative aspects of seismic design that require cooperation between engineers and architects:

- Regularity in plan (ideally a rectangular floor plate and symmetric structural system, with floor mass distributed evenly); and

- Regularity in elevation (i.e. limited discontinuities or changes in wall thickness up the height of the building).

Regarding the choice of materials, reinforced concrete and steel can be designed and detailed to behave in a ductile way, which means that they can plastically deform when shaken by an earthquake. Brick or stone masonry buildings without any steel reinforcing bars generally behave in a brittle way (no warning behaviour before they fail when overloaded), which makes them in fact a less appropriate structural material in highly seismic areas. Both California and New Zealand, for example, banned unreinforced masonry (URM) for new buildings after destructive earthquakes in the 1930s. URM may be acceptable in areas of low to moderate seismicity, but structural connection details must be carefully detailed to prevent walls from collapsing out of plane.

Even in highly seismic areas, large earthquakes are relatively rare. Therefore, it is not considered economical to design conventional buildings to remain undamaged under the rare ground shaking associated with a large earthquake. Design codes are based around ensuring that the building remains standing so that building occupants can safely exit the damaged buildings (this is referred to as life safety design). Buildings designed for "life safety" can still be significantly damaged when subjected to the level of shaking foreseen by the design code.

A3   General principles of structural upgrading

The main principles of earthquake resistant design have developed over the last 50 years, and design rules are continually updated. Therefore, even in countries with well-developed design codes and engineering education, existing buildings predate modern design provisions, and therefore represent generally a higher risk of collapse in an earthquake than more modern buildings. In the Netherlands, seismic-resistant design principles have never been mandated, despite a small risk due to tectonic earthquakes in the south (as seen in the 1992 Roermond earthquake). Therefore, it is expected that the results of the present study will show that some types of buildings in the Groningen area may require structural upgrading to be able to demonstrate adequate seismic resistance.

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The first step in structural upgrading is to carry out a seismic assessment to identify structural deficiencies (if any). Assessment can be carried out to different levels of detail – from an initial qualitative "walk over" study to pinpoint glaring problems with the structure, to detailed computer analysis modelling.

Structural deficiencies are different for every building type and material, and may be unique to an individual building. Typical deficiencies fall into the following categories (from FEMA, 2006):

- **Global strength**: the structural walls or other components are not strong enough to resist the effects of earthquake forces;

- **Global stiffness**: structural components are not stiff enough to keep the displacements imposed by earthquake shaking to acceptable levels;

- **Configuration**: plan and elevation irregularities can lead to concentrated damage in limited parts of the structure;

- **Load path, diaphragms and foundations**: the structural components need to be all tied together in such a way that forces caused by inertial effects on roofs and floor slabs can be carried down to the foundations of the building and into the ground;

- **Component detailing**: local details (such as placement of reinforcement in reinforced concrete, or weld details in steel structures) can have a disproportionate effect on structural response, and may need to be strengthened; and

- **Other**: geologic hazards (liquefaction and slope failures), pounding with adjacent buildings, and deterioration of structural materials can all be identified as seismic deficiencies in a structural assessment.

For typical URM buildings (such as Dutch masonry houses), the most common structural failure and risk to life safety is due to unbraced parapets and walls falling out of plane due to poor connections to floors and roofs. A study in Belgium following the Liege earthquake, 1982, proposed details to strengthen connections between walls, floors and roofs to inhibit this failure mechanism. This kind of rehabilitation is also carried out in areas of moderate seismicity, such as Italy, where there are a large number of URM buildings –both representing the cultural heritage of the towns and cities, and even modern construction. It is intuitively clear that masonry walls will be much weaker when shaken out of plane when standing by themselves than if they are tied together and can act like a box.

Tying walls, floors and roofs together is an appropriate retrofit in areas of low to moderate seismicity. However, even when appropriately connected, walls must still be strong enough to carry the imposed seismic forces. These forces can be especially high in areas of high seismicity, and for heavy structures such as masonry buildings. Therefore, even after allowing for improved connections between walls and floors, it is important to assess the strength of the walls acting in their in-plane direction. Typical strengthening measures for insufficiently strong masonry walls may be concrete or shotcrete overlays (i.e. adding a layer of reinforced concrete to the outside of the wall), or adding steel frames to reduce the loads that must be carried by the walls.

Besides typical strengthening measures, structural upgrading can also imply the application of base isolation to buildings. For base isolation, buildings are put on spring devices, so that the earthquake motion has a reduced affect in the buildings. This application is normally used for very special buildings such as governmental or historical buildings, or buildings with an important post-earthquake function, such as hospitals.

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Appendix B

Seismic Risk Study

B1   Introduction

A seismic risk assessment is being carried out to quantify expected losses (damage, casualties and financial losses) under moderate sized earthquakes. The risk study will allow the highest risk areas and building typologies to be identified and to feed into the structural upgrading study.

The seismic risk assessment methodology can be divided into four main components:

- **Seismic hazard assessment**;
- **Building exposure assessment**;
- **Building vulnerability assessment**; and
- **Building risk calculation**.

B2   Seismic Hazard Assessment

This section of the report briefly describes the methodologies to determine the ground motion hazard from induced earthquakes.

Three approaches for estimating seismic hazard are adopted in the study:

- **Deterministic seismic hazard assessment (DSHA)**. The two main ingredients are:
  - A seismic source scenario in terms of earthquake magnitude and location and appropriate ground motion prediction equation(s) to calculate the ground motion level resulting from the scenario earthquake. Arup are carrying out this assessment for three scenarios; all are for an earthquake of $M_W = 5$ at 3 km depth defined at the locations of the previous induced earthquakes that have been recorded recently in the area:
    - Hoeksmeer, 24/10/2003 (53.295ºN, 6.792ºE);
    - Huizinge, 16/8/2012 (53.345ºN, 6.672ºE); and
    - Zandeweer, 7/2/2013 (53.389ºN, 6.667ºE).

The deterministic seismic hazard assessment is undertaken to provide a reasonably conservative estimate of the losses (building damage, casualties and financial losses) that could occur in the event of a single magnitude Mw=5 earthquake, i.e. an earthquake considerably larger than any that has been recorded to date in the Groningen region. The single earthquake scenarios do not however provide an indication of all the cumulative losses that could occur over the lifetime of the gas field due to induced earthquakes.

- **Probabilistic seismic hazard assessment (PSHA)**, which combines the elements of seismic source zones, earthquake recurrence and the ground motion prediction equations to produce hazard curves in terms of level of ground motion and an associated annual frequency of exceedance. The Royal Netherlands Meteorological Institute (KNMI) has undertaken probabilistic seismic hazard assessments for the induced seismicity in the Groningen region (Eck et al., 2004; 2006; Dost et al., 2012). This methodology is based on that originally proposed by Cornell (1968), modified to include for variability and uncertainty in the various input parameters. The probabilistic seismic hazard assessment has not yet been received from KNMI. It is intended that the results of the KNMI probabilistic seismic hazard assessment will be used to provide an estimate of the long term seismic hazard in the region and will be used by Arup as input for the seismic risk and structural upgrading studies. A limitation of the use of probabilistic seismic hazard assessment is that it assumes that the earthquake occurrence is time independent. However, this is not the case in Groningen where the rate and size of induced earthquake is interpreted to be related to gas extraction and is therefore time dependent.

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- **Monte Carlo Hazard Assessment.** An alternative methodology is under development to reassess the probabilities of induced earthquakes due to gas production from the Groningen field. Monte Carlo methodology is used to generate large statistically representative catalogues of induced earthquake simulations (in space and time) for the region and to combine these with published earthquake ground motion prediction equations to estimate the probability of ground motion shaking at the surface. This methodology importantly takes into consideration the influence of gas extraction on the rate and size of potential future induced earthquakes.

Arup will consider the implementation of the results of the Monte Carlo seismic hazard assessment into the assessment of seismic risk for the life of the gas field. If this results in significant differences in the hazard and risk assessments they will be taken as input for an update of the seismic risk and structural upgrading studies. It is important to note that the seismic hazard and risk assessment results are likely to continue to change in the future as and when more information becomes available (e.g. from (sub-) surface data acquisition campaigns).

B3   Building Exposure Assessment

This section describes the compilation of the building exposure database for the Groningen region. The building (exposure) database is compiled in Geographical Information System (GIS) software and contains data on the location and character of all buildings. The initially identified study region has an approximately 15 km radius circle centred at the epicentre of the Huizinge earthquake (53.345°N, 6.672°E). The Huizinge quake was taken as this was the location of the biggest induced earthquake to date. The building exposure database is now being expanded to over a much larger area related to the full geographical extent of the Groningen field.

A summary of all the collected building information is shown in Table B1 and buildings materials and typologies are summarised in Table B2. The building typologies used are based on practice in the USA adapted to the particular characteristics of the buildings in the Groningen region.

Compilation of information on all buildings in the study area is a significant and time consuming exercise. Building data is obtained from a range of commercially available databases. These datasets require validation through cross-checking, systematic visual checking through on-line resources such as Google Street View, and through actual surveys of buildings on the ground by engineers. Not all of the building characteristics are provided through commercially available datasets and in particular the building structural typology must be determined based on interpretation of other data (such building location, age, height and usage) and through engineering judgement.

Table B1: Information currently collected for the buildings included in the risk assessment

Type of information	Method
Location and Address	Locations based on TOP10NL data [Basis Registratie Topografie, Kadaster]. Two separate datasets with the addresses: the Bridgis dataset features the x- and y-coordinates and he DataLand dataset provides detailed information on building typology, usage, value and the year a building was built for these addresses.
Construction Type	A combination of GIS data, field surveys and satellite imagery tools such as Google Street View are indentify construction material (masonry, reinforced concrete, timber etc), number of floors, building age and building typology. The classification was based on available fragility/vulnerability relationships with consistency with Strengthening work stream
Height and Number of Floors	Number of floors is derived combining the height data from the Actueel Hoogtebestand Nederland (AHN) [Rijkswaterstaat], a digital height map for the Netherlands developed from laser scan data, and the building shapes from the topographic map.
Occupancy Category	residential, commercial, industrial, agricultural, religious governmental, emergency, educational

Table B2: Initial building typologies for risk assessment

Label	Material	Description	Age	Storeys
URM1	Unreinforced brick masonry	Detached/villa/semi-detached, flexible diaphragms	pre-1920	1-2 storeys
URM2				≥3 storeys
URM3			1920-1970	1-2 storeys
URM4				≥3 storeys
URM5		Detached/villa/semi-detached, rigid diaphragms	post-1970	1-2 storeys
URM6				≥3 storeys
URM7		Terraced house, flexible diaphragms	pre-1920	1-2 storeys
URM8				≥3 storeys
URM9			1920-1970	1-2 storeys
URM10				≥3 storeys
URM11		Terraced house, rigid diaphragms	post-1970	1-2 storeys
URM12				≥3 storeys
RC1	Reinforced concrete	Concrete bearing wall, rigid diaphragms	post-1980	1-3 storeys
RC2			post-1970	≥4 storeys
W	Wood	Wooden barns of all ages (with possible non-bearing masonry façade)	All	All
S1	Steel	Lightweight steel frame structures (e.g. industrial, building footprint larger than 200 m2)	post-1960	<15 metres

S2		Other steel buildings (steel offices, residential)	post-1960	>15 metres
UNCL	Unclear	Objects with unknown functions, objects under construction, objects with functions to be determined	All	All
OTHER		To be ignored in the calculation of risk: - Electricity poles - Demolished and non-existing buildings. - Caravans - Boats - Docking bays - Defence buildings	All	All

B4   Building Vulnerability Assessment

This section describes the compilation of the building vulnerability characteristics for the Groningen region.

Fragility and loss functions are two sub-components of the "vulnerability" component of seismic risk assessment. Vulnerability refers to estimated losses (direct financial losses, business interruption costs, and human injuries or fatalities) for a given level of ground shaking. This may be broken down into estimated levels of damage for a given level of ground shaking ("fragility functions"), and estimated losses for given levels of damage ("loss functions").

Financial losses are measured by a loss ratio (or damage ratio) which gives the total repair cost as a proportion of the value of the building. This allows them to be scaled up automatically with inflation and different construction costs and currencies. A loss ratio of zero means that no repairs are required; whereas a value of 1.0 means that the building requires full replacement. Predicted loss ratios can then be multiplied by local building values and replacement costs to obtain total repair costs.

Human losses are measured in terms of a proportion of building occupants who are injured to a certain severity level, or killed, as a function of building damage. Human fatality ratios are generally zero (i.e. it is assumed there is no loss of life) for low to moderate levels of damage, but other injury levels may occur. Experience from earthquakes around the world indicates that most fatalities occur in partially collapsed and collapsed buildings. Human casualties are presented for day time and night time scenarios to take into account the difference in distribution of the population during day and night.

Empirical fragility and loss functions, based on damage and loss statistics collected following earthquakes elsewhere in the world, will need to be used in this study as no specific data for the Groningen region exist. These functions have been developed on tectonic earthquakes and therefore they will need to be calibrated, e.g. by using the damage statistics already compiled from induced earthquakes in the Groningen region. As analytical building modelling results become available from the structural upgrading work stream, these results will be also used to validate or modify the adopted set of fragility functions. Additional analytical calibrations will be considered as part of the seismic risk studies.

Fragility functions (and usually loss functions) are specific to a particular building classification. The classification includes building material and structural system, as these are the most important parameters for identifying the vulnerability of a building to earthquake shaking. In this project, fragility functions are selected from the Global Earthquake Model (GEM) compendium, an international project to develop and improve methods and tools for seismic risk assessment.

Following selection of appropriate fragility functions, these are verified and calibrated based on earthquake damage data collected in the following Dutch earthquakes: the 1992 Roermond earthquake

(Pappin et al., 1994) at about 40 locations in the epicentral area; the August, 2012 Huizinge earthquake. The most appropriate set of fragility functions was identified for masonry buildings (as these were the only building types with significant damage reported in these two Dutch earthquakes), and the existing functions were modified to match the data. Fragility functions for other building materials selected from the GEM compendium could not be modified, as no damage data were available from the Dutch earthquakes for building material types other than URM.

The fragility functions allow determination of probability of proportions of different levels of damage (referred to as damage states) for a given level of earthquake ground motion amplitude measured in units of peak ground acceleration (PGA). Further work is now on-going to determine the level of earthquake shaking in terms of acceleration spectral amplitudes and to investigate the correlation of building damage with location specific acceleration response spectra.

B5   Seismic risk calculation

The seismic loss is calculated using the following steps:

- The expected distribution of PGA values are determined for each earthquake scenario, and total building numbers within each PGA band for each building type are found for selected ranges of PGA across the study area;

- For each PGA range and building type, expected numbers of buildings in each damage state (DS) are found (e.g. "slight damage", "moderate damage", etc.);

- Damage loss is the sum of numbers of buildings in each damage state;

- Human loss ratios are found for each damage state, and multiplied by the expected occupancy of the building. This gives expected numbers of injuries and fatalities in each building, which can be summed to give the total number of casualties expected from each scenario in the study area; and

- Financial loss ratios are found for each damage state, and multiplied by the cost of each building. The sum of all repair costs gives the total financial loss of the earthquake (neglecting indirect losses due to repair time and loss of business, etc.).

As noted above, work is ongoing to investigate the correlation of building damage with acceleration response spectra with the expectation that this may provide a better means to estimate the potential for future building damage than calculated PGA values alone.

The loss results are presented in terms of tables and graphs of potential damage to buildings, potential casualties and potential direct financial loss.

The loss statistics are used to determine the preventive structural upgrading requirements and incorporate these in the preventive upgrading strategy. The strategy will be developed on a systematic basis for setting of priorities and allowing cost/benefit calculations to be undertaken for a range of upgrading options. In some cases the upgrade scope may not be economically justified and such considerations will also have to be addressed in the approach to the structural upgrading strategy.

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B6 Information access and management

The seismic risk study uses and produces **a large quantity of information** in the form of datasets, maps, tables, diagrams and figures which is based on a complex methodology with a large number of assumptions.

The current database for the 15 km radius contains 66,000 buildings with about 10 building characteristics required per buildings that have to be reviewed and validated. The expanded building exposure database may include over 150,000 buildings.

In order to manage and communicate this information Arup has proposed to provide an information system in which the stakeholders can directly interact with the information and query the assumptions, methods and results.

As the strengthening project is expected to run over several years, Arup has advised NAM to purchase or develop a system in which NAM stores and tracks all project information, so that NAM remains independent from external parties for data management and has a historical overview for future reference. Arup will deliver the information in their systems to this NAM system, preferably in automated manner.

Arup will also set up their information management in such a way that future data when it becomes available (e.g. new measurements from sensors, new earthquake data, etc.) directly can be analysed and validated against the prior results.

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Appendix C

Prioritization

C1   Introduction

As it is impossible to upgrade all the buildings in a small time frame, implementation pilots and large scale implementation must be prioritized. For the prioritization of individual buildings there are two aspects important for prioritization:

- Seismic risk;

- Importance.

Prioritization applies to this study, as well as the large scale implementation that will be based on the outcomes of this study.

C2   Prioritization based on seismic risk

Prioritization based on seismic risk has the levels of identification, filtering, ranking of buildings, building typologies or building characteristics based on specific seismic risk.

In order of importance, the most important for the current building stock are:

- **Damage:** buildings with damage, from earthquakes and other causes have lesser strength and could be unstable. Buildings with more damage are prioritized against buildings with less damage;

- **Location:** where is the building in relation to seismic hazard. Prioritization will take place in which areas with higher seismic hazard will be prioritized against buildings with lower seismic hazard;

- **Building material:** brittle materials with low strength will be prioritized against ductile materials with high strength. The following order applies: unreinforced masonry, reinforced concrete, timber and steel;

- **Age:** older buildings have more deterioration of materials and have building materials of lower strength and quality;

- **Structural system:** Different building systems have different resistance to earthquake action; and

- **Building irregularities:** Building with plan or elevation irregularities will be prioritized over those that are regular.

C3   Prioritization based on importance

Prioritization can take place based on consequence of failure of the building or the importance of the building. There are different reasons to assign importance to buildings:

- **First responder function:** buildings that need an increased performance, as they are part of the first response system following an earthquake. These are normally buildings such as hospitals, fire stations, police stations, governmental administration buildings, schools and sports halls.

- **Cultural value:** buildings that have very high significance for a country or region.

C4   Prioritization Method

The following prioritization is proposed:

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- **Significant damage** status – from NAM claim handing team;

- **Seismic hazard** – work from higher to lower PGA contours (determined by KNMI);

- **Screening** of areas at two levels:

    - Using FEMA 154: Rapid Visual Screening of Buildings for Potential Seismic Hazards;

    - Using ASCE 31: Seismic Evaluation of Existing Buildings; and,

- **Detailed performance evaluation.**

With regards to **screening,** teams of trained surveyors will identify buildings within areas of high seismic hazard, using FEMA 154. Then an inventory will be created and rankings will be undertaken. Using ASCE 31 the highest priority buildings will be further evaluated, after which an inventory will be created and ranking will be undertaken. The highest ranked buildings will be first to undergo detailed performance evaluation.

Results for the FEMA 154 and ASCE 31 screening will be added to the GIS database.

The higher risk mitigation strategy is currently being developed and the first inspections are expected to start around end-Q3 2013 (as currently planned by NAM).

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Appendix D

Study Structural Upgrading

D1 Introduction

The structural upgrading study aims to develop design guidance for structural upgrading of the Groningen building stock within the context of Dutch building practice and available regulatory framework. The aim is to develop design rules for typical buildings, representative for a large proportion of the Groningen building stock and to develop a procedure for unique buildings. The results of this structural upgrading study will be an input for the NPR document currently being developed by the NEN – institute for existing buildings. The results of Arup's work for NAM will be made available by NAM to the committee preparing the NPR.

The structural upgrading study has the following steps:

- Assess the performance of buildings and building types;
- Develop a design guidance (rules and protocols) for structural upgrading; and
- Develop feasible structural upgrading measures for local implementation.

D2 Development of an approach

D2.1 Typical vs. unique

Typical building types are representative for a significant proportion of the building stock, while unique buildings are one of a kind. The aim is to develop design rules and protocols for **typical buildings**, representative for a large proportion of the Groningen building stock and to develop a design procedure for **unique buildings**. Lessons learned from the study of typical and unique buildings can be captured in the design rules and protocols.

The following study typologies have been defined:

- Damaged buildings;
- Houses;
- Historic listed buildings; and
- Other buildings.

Characteristics for those typologies are given in Table D1.

Table D1: Characteristics building streams. (make text in the blue boxes white)

	Damaged buildings	Houses	Historic listed buildings	Other buildings
Number	Small	**Large**	Smaller	Smaller
Prioritization	**High**	Average	Average	Average, but high for first responder buildings
Material	Mostly URM	Mostly URM	Mostly URM	**Different materials**
Importance visual integration structural upgrading measures	Average	High	**Very high**	Average
Complexity	Higher	Average	High	High
Typical/Unique	Mostly unique	**Typical with limited number of sub-typologies**	Mostly unique with some sub-typologies	Mostly unique with many sub-typologies

This initial choice for these streams is based on the following:

- **Damaged buildings** have an increased seismic risk and need prioritization;
- **Houses** are the largest proportion of buildings and can be divided into a number of typical sub-typologies;
- **Historic listed buildings** need specific upgrading measures as the visual appearance is protected;
- **Other buildings** are a mixed group with different materials (mostly not URM) and structural typologies.

D2.2   Performance evaluation

Different levels of analysis may be performed to evaluate performance of buildings. Each level of analysis implies a more detailed assessment and makes it possible to be more precise in assessing the level of structural upgrading required. The following levels will be used:

- **Approximate** analysis e.g. static equivalent load method;

- **Detailed linear** analysis, using GSA*; and

- **Detailed non-linear** analysis, using LS – DYNA*.

Each increase in level of analysis will require increased analysis effort and require more expert judgement to interpret the results. The more precise analysis will in most cases result in the level of structural upgrading required to be reduced and therefore be cost beneficial.

Both GSA and LS-DYNA are advanced computer model simulation software packages

D2.3   Structural upgrading

There are many methods of structural upgrading. The aim is to come to effective and efficient measures taking the following factors into account:

- Expected seismic deficiencies in existing building stock;

- Applicability to local construction;

- Architectural impact;

- Disturbance;

- Standardization possibilities;

- Speed of implementation; and

- Costs.

D3   Development of legal and regulatory framework

There is no legal or regulatory framework for seismic hazard in the Groningen region. In this context Eurocode 8 might offer a relevant framework. In relation to casualties, the purpose of Eurocode 8 is to ensure that in an event of earthquakes lives are protected. To satisfy this, the ultimate limit states associated with collapse or with other forms of structural failure, which might endanger the safety of people, are checked.

D3.1   Current situation

For tectonic earthquakes in the EU the framework for assessment of strength is Eurocode 8. Eurocode 8 is localized for each country of the EU by the use of a National Annex with Nationally Determined Parameters (NDPs) which focus on the following issues:

- Seismic hazard;

- Site response; and

- Applicability to local construction.

For the Netherlands there is no National Annex and NDPs and Eurocode 8 is not required by the Dutch Legislation (Bouwbesluit 2012). The use of Eurocode 8 in the Netherlands is on a voluntary basis and requires development of a National Annex and NDPs. Development of the National Annex and NDPs is foreseen by the NEN institute, but is expected to take several years.

The development of a National Annex and NDPs offers potential for the management of the risk from induced earthquakes in Groningen. Based on the specific situation a National Annex and NDPs could be developed that includes induced earthquakes for a specific Groningen context.

Eurocode 8.3 gives design guidance for existing buildings, but this section is not very comprehensive or sufficiently detailed to give appropriate guidance for the structural upgrading measures for the Groningen region.

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D3.2   Way forward

As the development of the National Annex and NDPs for Eurocode 8 could take several years, the development of a NPR (Nationale Praktijk Richtlijn) has been suggested by the NEN institute as a precursor for this National Annex. The design guidance described in this report will be an input for this NPR document for existing buildings, based on:

- Development of acceleration contours for the Groningen region based on deterministic seismic hazard assessment (DSHA), probabilistic seismic hazard assessment (PSHA) and/or Monte Carlo Hazard Assessment (as defined in Appendix B2);

- Target building performance is defined by life safety performance, using earthquake hazard levels of 10% probability of being exceeded in 50 years (equivalent to a earthquake return period of 475 years);

- Use of Eurocode for design guidance on performance evaluation and structural upgrading measures. The use of ASCE 31 and ASCE 41 as design guidance for performance evaluation for elements and aspects that are not covered by the Eurocode, specifically Eurocode 8 and the NPR;

- Use of structural upgrading measures from other countries with similar construction as the basis for local structural upgrading measures (Belgium, UK, Italy and the USA);

- Develop design guidance in the form of procedures, design rules and protocols for specific building types in Groningen; and,

- Use above design guidance for the formulation of a concept Nationale Praktijk Richtlijn (NPR) for existing buildings to ensure a legal and regulatory framework.

D4   Detailed approach for different streams

For all the different streams the process for implementation pilot phases is similar although some of the details are different. The following steps are applicable to all streams and are applied to each building in the study:

- **Pilot 1, Phase 1:**
    o Gather data;
    o Performance evaluation; and
    o Conceptual design structural upgrading measures.

- **Pilot 1, Phase 2:**
    o Detailed design structural upgrading measures; and
    o Construction.

D4.1   Damaged buildings

The aim of the study on damaged buildings is to develop design guidelines for damaged buildings in the form of a design procedure.

The selection of damaged buildings will be executed by NAM, in consultation with building owners and other key stakeholders. The total number of damaged buildings, which will be analysed, will be determined during the process.

The 'damage claim' team within NAM responds to damages claimed by building owners. Damages are prioritized by the damage claim team based on a survey by a structural specialist. The damaged condition of these buildings might be caused by damage of different nature, such as earthquakes, settlements, foundation problems, building alterations, design or constructional shortcomings, poor maintenance or combinations of these causes.

When a study for a building is undertaken the first step is to do two surveys:

- To assess the **safety** of the users, taking ATC-20 as basis; and

- To identify **potential seismic hazards**, taking ASCE 31 as basis;

D4.1.1   Safety survey based on ATC-20

The safety survey is normally used in post-earthquake situations and has as objective to get people back into safe homes, and to keep people out of unsafe structures. The ATC-20 is intended to be rapid and uses green, yellow and red tags to indicate the safety level:

- **Green (inspected):** safety has not been significantly changed compared to undamaged state;
- **Red (unsafe):** threat of live safety for entry or occupancy in all or most of the structure;
- **Yellow (restricted use):** some risk from damage in all or part of the building. Entry, occupancy, and lawful use are restricted in accordance with the area, occupancy duration, or other restrictions.

Note that a green safety level does not indicate that the building is safe and it can be deficient to the code and be seismically vulnerable.

For many cases a red safety level will result that the building is demolished. If the aim is for the building to be structurally upgraded (and it is tagged red or yellow) then there will be an assessment if there is a need to shore, prop or strap components of the building will safeguard the building from falling down until it is upgraded.

Owners and users of the building and the NAM will be notified of the status and the resulting restrictions of the building use. If the safety level status is red or yellow this will be indicated on the building or parts of the building.

D4.1.2   Potential seismic hazard survey based on ASCE 31

The seismic hazard survey based on ASCE 31 aims to identify the "weak links" in the building's lateral force resisting system that can lead to significant failure and/or collapse. The buildings are reviewed for the Life Safety Performance Level: building performance that includes damage to both structural and non-structural components during a design earthquake, such that: a) partial or total structural collapse does not occur and b) damage

to non-structural components is not life threatening. The checklist identifies compliance, non-compliance or not applicable. Compliant statements identify conditions that are acceptable. Noncompliant statements identify conditions that are in need of rehabilitation. At this point, deficiencies can be rehabilitated or further evaluation can be performed. Evaluation has to prove that the deficiencies are actually not deficient or structural upgrading measures have to improve these 'weak links' in a satisfactory way.

D4.1.3   Performance evaluation

The performance evaluation has two aspects:

* Evaluation of the causes of damage recorded; and

* Evaluation of seismic performance.

D4.2   Houses

The aim of the study on houses is to develop design guidelines in form of design rules and protocols of sub-typologies and to develop design guidance in form of a procedure for unique houses.

D4.2.1   Houses

Based on the database of buildings in the region the most common housing sub-typologies are identified. The sub-typologies that are studied are given in Table D2.

Table D2: Sub-categories.

Nr	Type		Floor	Note
1	T1	Terraced house	Concrete	90% of the terraced houses build after 1960. Concrete was introduced as a building material for regular houses around 1953. Therefore it is assumed that primarily concrete floors are used for terraced houses.
2	T2a	Semi-detached	Wood	70% of the semidetached houses build after 1960. Therefore it is assumed that primarily concrete floors are used for semidetached houses.
3	T2b	Semi-detached	Concrete	
4	T3a	Detached	Wood	Roughly 40% of the detached houses build after 1953. At least 60% of all detached houses will have wooden floors. The other 40% will contain wooden floors, concrete floors or both.
5	T3b	Detached	Concrete	

6	T4	Labourers cottage	Wood	Typical building found in rural area in the neighbourhood of farms
7	T5	Mansion	Wood	Typical square building found in towns and villages in the area
8	T6	Large masonry villa	Wood	Large masonry residence containing a ground level and at least 2 stories. Richly decorated with ornaments and generally well maintained.
9	T7a	Barn (old)	-	Wooden frame combined with a thatched roof, a roof with roof tiles or corrugated sheeting. Walls consist of masonry, with a height of approximately 3 meters. Roofs have a relatively steep slope.
10	T7b	Barn (new)	-	Steel braced frame combined with a roof of corrugated sheet. Walls mostly made of masonry, with a height of approximately 3 meters. Roofs have a relatively small slope.

Note that sub-typologies will be studied and not specific buildings. Pictures therefore give an indication of a sub-typology and do not represent a specific house.

There is a large variety in shape and size for the farms in the area. They can range from a labourers cottage until farms with the size and shape of the large masonry villa. For this stage it is assumed that the farms in the area are represented by the envelope of the results from the detached houses, the labourer's cottage, the mansion and the large masonry villa. Combined with the two types of barns on this list, these buildings will cover all farms in the area.

As seen in the table above, most of the typical houses in the Groningen region are made of low-rise unreinforced brickwork in combination with concrete and timber elements. The low-rise houses usually consist of brick walls with openings for windows and doors. Floors are either made of timber or made of pre-fabricated concrete elements, while roofs are mainly timber, covered with roof tiles. Such houses have not been designed to resist earthquakes, hence the need for further analysis and study to develop design guidance.

D4.3 Historic heritage buildings

Historic heritage buildings include listed and non-listed buildings that have historic significance. Examples of historic heritage buildings are churches, monasteries, windmills and castles. Also train stations, pumping stations and farms can be historic heritage buildings. Most of these buildings will be made of stone or brick masonry and most will have been built before 1940.

The selection of historic heritage buildings will be done by NAM in consultation with building owners and local authorities. The total number of historic heritage buildings which will be analysed is not fixed and will be determined during the first pilot based on experience gained in this process.

D4.4 Other buildings

Other buildings include public service buildings (hospitals, schools, bus and train stations, town halls, museums and governmental offices), industrial buildings (production facilities, energy plants, ports and data centres), retail buildings, offices and parking facilities.

Under consideration is a study to specially look at a specific sub-set of other buildings with a higher importance. This higher importance is due to the need for those buildings in first response after an earthquake – such as hospitals, fire stations, police stations, governmental administration buildings, schools and sports halls.

The selection of other buildings will be done in consultation with building owners and local authorities. The total number of other buildings which will be analysed is not fixed and will be determined during the first pilot based on experience gained in this process.

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Appendix E

Implementation Pilots

E1   Introduction

Implementation pilots are used to test the design and application of structural upgrading measures. Two phases are proposed:

- **Pilot 1, Phase 1:** small scale **testing of design**;
    - **Pilot 1, Phase 2:** small scale **testing of execution;**
- **Pilot 2, Phase 1:** large scale **testing of design;** and
    - **Pilot 2, Phase 2: large scale testing of execution;**

Phase 1 and 2 of the first pilot are to test the technical feasibility of the proposed design procedure and structural upgrading measures and will be performed on 10's of buildings. Pilot 2 is to test operational implementation and will be performed on 100's of buildings.

E2   Pilot phases 1 and 2

Pilots 1 will be performed in batches of specific houses selected on their typology. The first 11 buildings are now underway for the phase 1 of the first pilot.

- **Phase 1:**

    o   Gather data;

    o   Performance evaluation; and

    o   Conceptual design structural upgrading measures.

- **Phase 2:**

    o   Detailed design structural upgrading measures; and

    o   Construction.

NB: Please note that during the first two pilots temporary preventive measures are foreseen as per the 'higher risk building elements mitigation strategy' (see appendix F)

E2.1   Average Turnaround Time

As the nature of the buildings is different, the turnaround time is applicable for buildings as indicated in Table E1.

Table E1: Turn around.

In months	Gather information	Performance evalation	Concept design	Detailed design	Permitting + owner agreement	Construction
Houses	0,5	1	1	3	3	6
Damaged buildings	1	1	1	3	3	6
Historic buildings (church)	1	2	2	6	3	18
Other buildings (school)	1	1,5	1,5	4	3	8

E2.2   Batches

Phase 1 and 2 will be performed in batches. Batches in Table E2 will be performed:

Table E2: Batches

	Batch 1	Batch 2	Batch 3	Batch 4	Batch 5
Typical Houses	5	5	Additional if needed		
Damaged buildings	4	10	5	Additional if needed	
Historic buildings	1 Church	1	3	5	Addional if needed
Other buildings	1 School	1	3	5	Addional if needed

E2.3   Development of design guidance for houses

Based on the results of the first three batches design guidance will be developed for houses. The development of design guidance will start after finishing Phase 1, but can only be completed after finishing Phase 2. A first outline of the design guidance can be given after finishing Phase 1, which in turn will be an input for the development of the Nationale Prakltijk Richtlijn (NPR)

The design guidance will have the form of a design procedure for all houses with a more explicit design guidance for typical houses in the form of design rules and protocols.

E2.4   Development of design guidance for historic and other buildings

Based on the results of the first batches from pilot 1, design guidance will be developed for historic and other buildings. The development of design guidance will start after finishing phase 1, but can only be completed after finishing phase 2 (of the first pilot). A first outline of the design guidance can be given after finishing phase 1 of the first pilot.

The design guidance will have the form of a design procedure for historic and other buildings with a more explicit design guidance for typical historic and other buildings in the form of design rules and protocols.

Appendix F

Higher Risk Building Elements
Mitigation Strategy

F1   Introduction

The 'higher risk building elements mitigation strategy' is intended to identify, assess and mitigate the structural building elements that present a higher degree of risk of significant damage or injury. These risks are related to for instance; chimneys, free standing walls, parapets and ornaments falling down even at low levels of ground shaking. It is likely that these risks can be mitigated at relatively low cost and well before the large scale implementations take place.

The content of this strategy - and therefore this appendix - is preliminary as this is currently being developed in collaboration with NAM. This strategy will form the first part of the implementation strategy of the structural upgrading strategy. It can be seen as the first step to proactively mitigate risks and undertake (preventive or temporary) strengthening measures to buildings as outlined in the letter of Minister Kamp to Dutch Parliament of 11 February 2013.

F2   Program & Surveying Methodology

The first pilot started in May 2013 and may continue into 2015, depending on how fast the phase 2 can be developed and executed. To ensure that throughout this pilot phase potential risks to people are being identified and resolved in a proactive manner the following approach is proposed;

- Identification of buildings with high building risk elements using screening according to FEMA 154 and ASCE 31 procedures using mobile specialist screening teams;
- Assessment of mitigating activities – structural upgrading or removal – for specific buildings elements;
- Implementation of mitigating activities.

The implementation of this strategy is expected to start end-Q 3 2013

It is important to note that the aforementioned FEMA 154 and ASCE 31 are surveying methods which have been tried and tested for similar purposes following tectonic earth quakes in other countries,

F3   Identification of buildings with high risk elements

High risk building elements can be identified using the following procedure:

- **First screening level:** Identifying immediate and obvious higher risk external elements and identifying buildings needing more detailed evaluation using a first pass screening method.
- **Second screening level:** more detailed evaluation of those buildings assessed as higher risk, by way of site surveys, and identification of elements needing mitigation.

F3.1   First Screening Level

The methodology adopted for the initial screening level will be based the FEMA 154 'Rapid Visual Screening of Buildings for Potential Seismic Hazards'. This document gives guidance on: how to prepare for, carry out, and asses the information arising from surveys on large numbers of buildings.

The FEMA 154 method is also used as the first screening method to prioritize the implementation works (see appendix C) and thus forms a clear interaction with these works.

F3.2   Second Screening Level

If during the initial survey, buildings or elements thereof are identified as posing a higher risk, a second survey will be undertaken. This survey will be based on the ASCE 31 method. The results from this 'second pass' survey will identify high risk elements for which mitigation actions are needed.

The ASCE 31 method is also used as the second screening method to prioritize the implementation works (see appendix C) and thus forms a clear interaction with these works.

Appendix G

Seismic Hazard Parameters by
KNMI

G1 Preliminary KNMI Hazard Parameters and Contour Maps

G1.1 Preliminary KNMI contour map

This appendix will be included when the relevant contour maps are officially issued by the KNMI

G1.2 Preliminary hazard parameter explanation

This appendix will be included when the hazard parameter explanation is officially issued by the KNMI