Handbook: 1. Structural Upgrading - Version 0.0

Process step: 2. RVS

Engineering Inspection Manual RVS

Building type: CC1b

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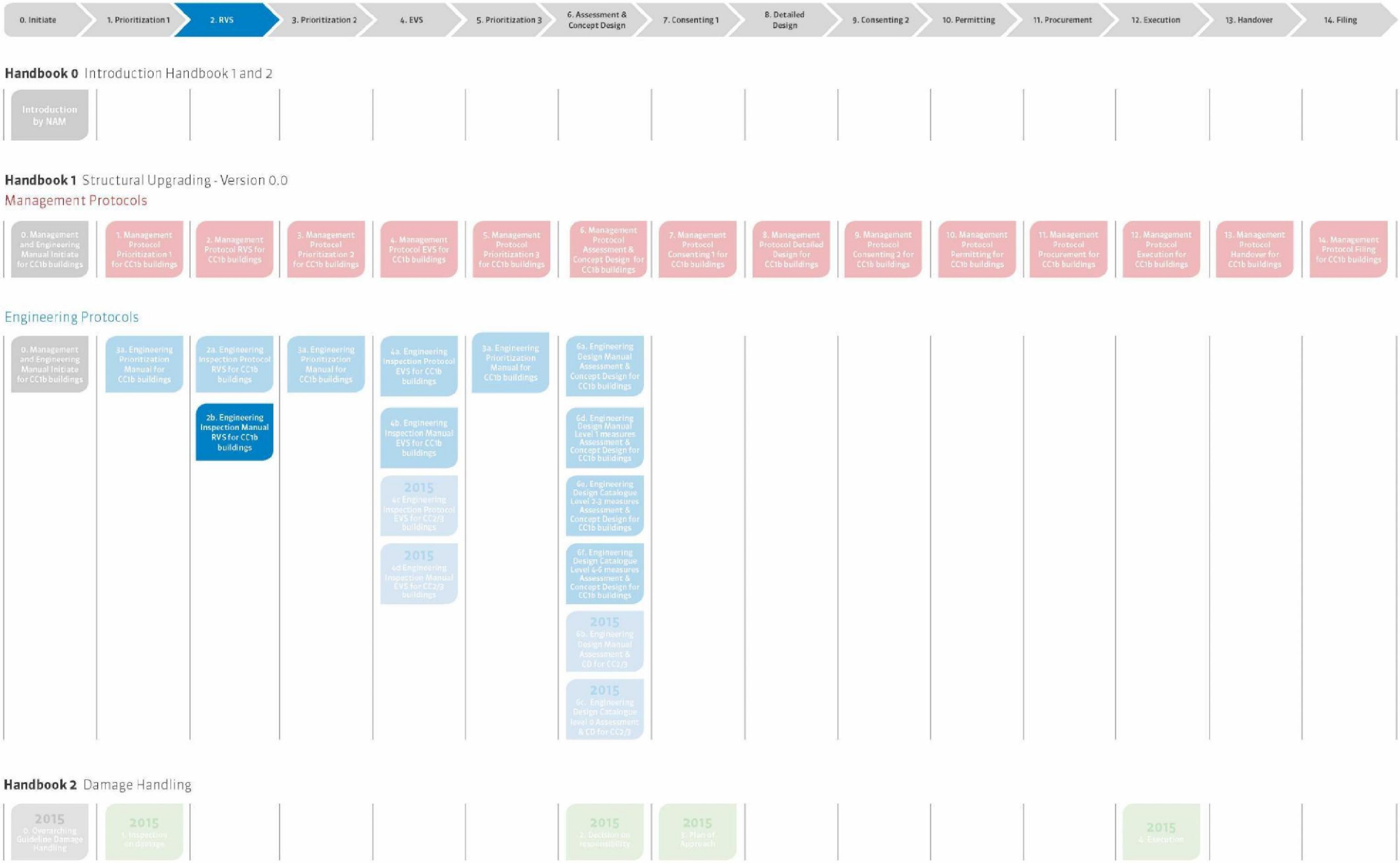
2b

Groningen Earthquakes - Structural Upgrading

Process Management Model CENTRE SAFE HOUSING (CVW)

HANDBOOKS LARGE SCALE IMPLEMENTATION

VERSION 0.0



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Preface

Handbook 1 Structural Upgrading is prepared by Arup for the Nederlandse Aardolie Maatschappij (NAM).

Handbook 1 is a collection of protocols, manuals and catalogues that underpin the process of large scale implementation of structural upgrading of existing buildings.

Users of Handbook 1 will be third parties responsible for large scale implementation of structural upgrading of existing buildings.

Any methodology or guidance prepared by Arup for Handbook 1 takes into account the particular instructions and requirements of NAM and addresses their priorities at the time. Priorities are likely to change over time and this guidance will need to be updated accordingly.

The protocols, manuals and catalogues in Handbook 1 Version 0.0 are indicative only and they represent the preliminary knowledge developed at the date of issue for the assessment and structural upgrading of Consequence Class 1b (CC1b) buildings in the Groningen Region.

The protocols, manuals and catalogues have been produced in the absence of Dutch national regulations and design codes relating to seismic issues.

Due to the parallel execution of activities required by the compressed programme, the guidelines in this Handbook will be updated on a 6 monthly basis until Q1 2017 and must be read as incomplete and /or containing inaccuracies until that date. After that date they will need to be further reviewed and updated on a periodic basis to reflect developments in knowledge, methods and the regulatory regime.

Handbook 1 is to be read in conjunction with the other related documents outlined in paragraph 1.2.1 and, in case of any discrepancy, in the order of priority stated. The other related documents are also in the process of development and so may impact future developments of Handbook 1.

Handbook 1 is only to be used by those with suitable training and experience.

Comprehensive, site-specific assessments must be independently developed and cannot rely on the protocols, manuals and catalogues of Handbook1 alone. Full responsibility for the assessment and structural upgrading of buildings shall remain solely with the third party.

1 Introduction

1.1 Intention of Use and intended Users

1.1.1 Intention of Use

There are two separate Handbooks available: one for the large scale implementation of structural upgrading of the existing buildings in the Groningen region and one for the handling of earthquake-related damage.

These Handbooks are referred to as follows:

- Handbook 1: Structural Upgrading;
- Handbook 2: Damage Handling;

This document is part of Handbook 1 SU and provides guidance on the implementation and interpretation of the Rapid Visual Screening (RVS) of CC1b buildings (houses). It is used in Process Steps 2 – RVS, in conjunction with Parts 2 of the Management Protocols ("Red Book").

The detailed process description for the RVS of CC1b buildings can be found in the report "Engineering Inspection Protocol RVS for CC1b buildings V0.3".

This manual describes the current method to carry out a RVS. Over time, the screening, protocol and the manual will evolve based on new input from the Structural Upgrading Studies and the experiences gathered from the execution of the screenings. Therefore, it is to be expected that this manual will be updated several times to capture the latest insights.

1.1.2 Intended Users

Generally, users of Handbook 1 will be third parties responsible for large scale implementation of structural upgrading of existing buildings.

More specifically, this document has been written with a defined purpose and application in mind. For the reader of this report to use it to its intended purpose a specific level of expertise and professional background is required. The minimum required skill level to read/use the book is a Structural engineer with at least 5 years of relevant experience and knowledge in the Dutch building construction. It is further assumed that the person using this document will have received an introduction and training by an experienced professional on how the methods, procedures and guidelines described in this report are applied to a specific case.

1.2 Related Documents & Developments

1.2.1 Related Documents

This report is part of the Structural Upgrading Handbook which shall be used in consideration of other documents that may have a higher legal status or relevance to the structural upgrading process. If contradictions occur between different reference documents and this document, the following order of precedence of documents needs to be considered:

1. Nationwide legislation (e.g. Woningwet, Bouwbesluit)
2. Local regulations
3. International normative references (e.g. Eurocodes + National annexes)
4. Nationwide normative references (e.g. NEN-codes)
5. Nationwide specific references (e.g. NPRs)
6. Project specific references (e.g. NAM Basis for Design)
7. **Project specific guidance (Handbook 1: Structural Upgrading); and**
8. International references (e.g. ASCE, FEMA, Eurocode 8)

1.3 Background

The Rapid Visual Screening (RVS) is a preliminary building assessment process designed to collect as much building information as possible from the public realm (without entering the property boundaries), with a clear focus on high risk building elements. HRBEs are falling hazards or elements contributing to the collapse risk. The information collected is being used to assess the seismic risk of buildings and building elements within a given consequence class and prioritising further to allow for more detailed assessments and/or mitigation measures for high risk building elements.

This RVS screening activity commenced in autumn 2013 and it was limited to the Loppersum town. The team involved comprised of senior structural engineers with international experience in the design of buildings in seismic regions. Initially the team were given the following tools:

- A first version of the inspection application tool for data acquisition on site (during the visit);
- Building information extracted from the GIS data base;
- A first version of the algorithm for the determination of an S-score.

With the above tools the screening team carried out site visits on pre-planned addresses and streets in order to evaluate the individual buildings from public areas adjacent to the buildings. The following modus operandi was set by the senior team in order to obtain the maximum possible amount of building information available in the minimum amount of time:

- Deepening the knowledge on the local building stock and focusing on the construction typologies and details used during the different ages, through:
  - Acquisition and consultation of available guidelines/ manuals;
  - Meetings with manufacturers of building components;
  - Meetings with local engineering consultants external to the project;
- Internal coordination meetings focused on the inspection procedures in relation to the abovementioned goals;
- Frequent on-site visits.

Based on the knowledge gained, the team developed and gradually enriched the first version of the handbook to guide inspectors through the identification of potential risks associated with the structural condition of the building elements. In addition, the handbook provided preliminary guidelines to assist the engineers in the identification and validation of potential structural deficiencies at element level and the context of the type of deficiency detected (such as cracks, excessive deformations) and the potential risk during a seismic event.

These structural deficiencies were summarised in a list of possible High Risk Building Elements (HRBE's) that are a combination of elements based on international guidelines (for example chimneys and parapets) and elements that are specific for the building stock that has been screened (for example lack of mortar, lack of cavity ties, missing roof cladding). See chapter 3.4 of this document for a further description.

This handbook has allowed the improvement of the inspection application and, with it, a more detailed, effective and standardised methodology for the acquisition of data in the field.

Subsequently, having consolidated the above procedure, it was possible to perform an additional step, which consisted of associating each structural deficiency with a related recommendation. This step requires, in some cases objective judgment of the issues and a second opinion from a more senior engineer. In addition to the RVS, a subsequent and more detailed screening – Extended Visual Screening EVS (also involving an internal building survey) was recommended to further assess the potential HRBE inside and outside the building.

In the attempt to transfer the experience gained in standard procedures, the team recognised the need to develop temporary structural solutions in order to mitigate the risk associated with elements of the building that were posing an imminent life safety risk to the residents or the public. When suspected or obvious immediate life safety issues are identified, a restrictive use of the space (internal and/or externally adjacent to the building) is recommended in order to initially mitigate the safety risk to people.

In parallel to the development of inspection procedures/rules, a training activity was organised for the personnel directly involved in the inspections process, focusing in particular on the following aspects:

- Raising awareness of seismic issues;
- Supervising specific aspects of RVS;
- Promoting discussion of the risk associated with structural / non-structural elements of a building during a seismic event.

Subsequently, the handbook was incorporated in the RVS manual with further refinements and insights based on the experience gained throughout the first few months of RVS screenings.

Currently, the inspection team is involved in the further development of the RVS manual based on the knowledge gained from the completion of 4,500 RVS inspections carried out in the Loppersum municipality in 2014. The team is also involved in transferring further the knowledge acquired during the EVS inspections in the Loppersum town CC1b building (subsequent to the RVS inspections performed in 2013) in order to enrich the definition of the elements that require particular attention during the RVS and the related recommendations.

2 Goal and Scope of RVS

2.1 Goal

This manual is specifically applicable to the RVS process for existing Class CC1b buildings (houses).

The RVS has two main goals:

1. To identify buildings or elements of buildings that pose a high risk to people, in case of a seismic event; and
2. To obtain building information for prioritisation of the subsequent Extended Visual Screening (EVS).

2.2 Scope

The RVS is a screening with a visual inspection of the building from the public realm only. The specific objectives of the screening are:

- Identify external High Risk Building Elements (HRBEs), defined here as elements, such as chimney and parapets, which could pose a life safety risk during a seismic event;
- Gathering information that will enable definition of a building performance expressed through the use of a scoring system (calculated for unreinforced masonry buildings " URM" only). This scoring system is referred to as a Structural Hazard Score or "S-score", and is calculated for each building. The S-score provides information of the relative vulnerability of the structural lateral-load-resisting system;
- Validation and (initial) improvement of GIS data in order to improve risk assessment studies data; and
- Collection of additional information of interest at the request of stakeholders, e.g possibility to fit solar panels.

Only the primary residential building for a given address is assessed during the RVS. The result of the RVS will prioritise the follow up, consisting of either measures on HRBEs or an Extended Visual Screening.

This second level screening and evaluation will be carried out based on the recommendations from the RVS and prioritised on S-scores and vulnerability, including identification of HRBE's.

3 Rapid Visual Screening in detail

3.1 General

The screening consists of the information gathering prior to the inspection and a visual inspection of the building from the public realm. Information is collected from different sources, see 3.2.

All gathered data prior to and during the inspection is recorded by an application on a mobile device. This application is linked to an online information system.

The RVS procedure consists of the following elements:

- Gathering information before the inspection (refer 3.2);
- Performing a building inspection to retrieve the object data (refer 3.3);
  - Execute Safety Assessment (refer 3.3.2);
  - Complete Checklist in RVS application (refer 3.3.3);
- Identifying High Risk Building Elements and provide recommendations (refer 3.4);
- Collection of information for calculating the S-score (refer 4);
- Writing the RVS report (refer 0).

In the next sections these elements are described in more detail.

3.2 Gathering Information before the inspection

Prior to the inspection, the following information should be collected:

i. Address;

ii. Object description;

iii. Plan dimensions;

iv. General structural materials;

v. Damage report (if available).

In general, this information will be obtained by consulting:

- The GIS-data (i. to iv.) or other interactive sources such as Google Street View, etc.;
- The coordinator of damage handling (v.).

The inspector should take notice of any relevant information obtained from recent damage reports.

3.3 Building Inspection

The inspection is carried out by a team that comprises of at least two inspectors. The inspectors will not enter individual properties and will not be in direct contact with individual property owners.

The inspector validates the data gathered prior to the inspection (section 3.2) and gathers specific building information in order be able to prioritise further.

The data gathered during the inspection is recorded on an application. Some information is pre-loaded in the application from the GIS-database, prior to the inspection.

During the inspection the inspector is required to verify the GIS-data wherever possible, including building information that is not visible from the outside.
For example, the thickness of a cavity wall could be deducted or assumed. The inspection will not produce exact dimensions or detailed material information, but it should verify initial GIS-data and amend it where applicable. See the application presented in section 3.3.3.

3.3.1 Buildings to assess on a given address

The following assessments are carried out during the RVS:

- Safety Assessment (refer 3.3.2)
- HRBE - assessment using 13 available typologies (refer 3.4).
- S-score - Geometric assessment of the building (refer 0)

Not all of the above assessments are carried out for all buildings on the property. Figure 1 and Table 1 below provides an overview which assessment is to be carried out for which of the buildings at a given address.

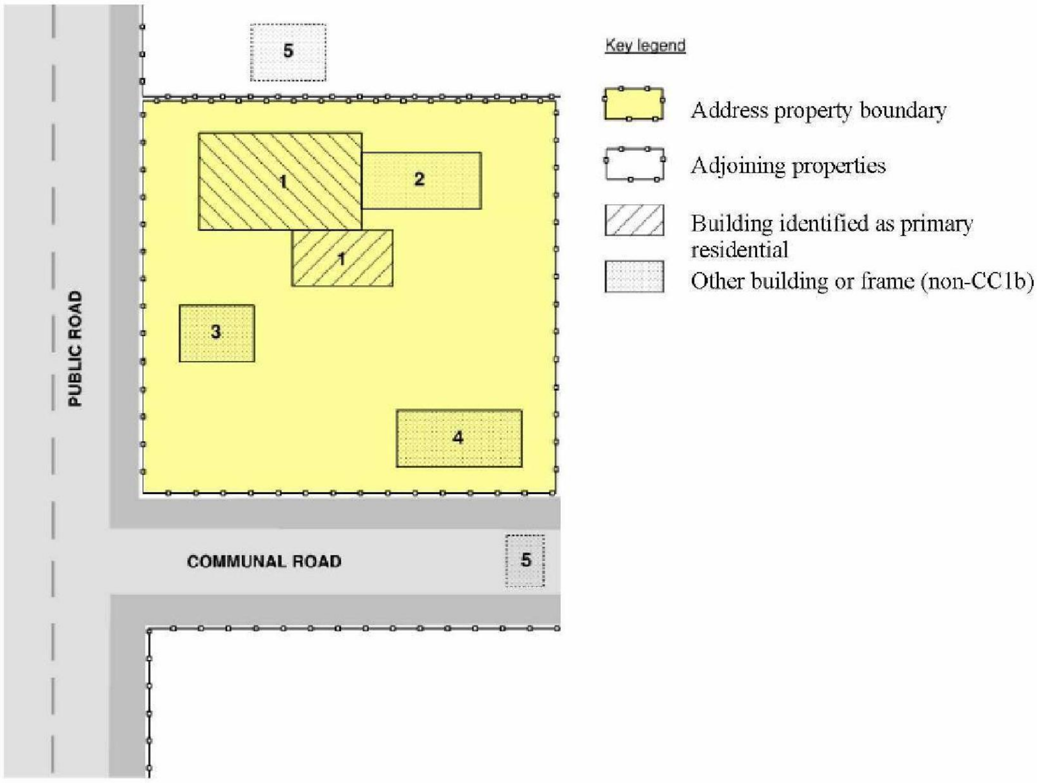

Figure 1 Indicative plan sketch showing scope of work within or outside the property boundaries.

Ref.	Description	Safety Assessment	HRBEs	S score
1	Primary residential building	x	x	x
2	Building extension (attached) which is not considered to be contributing to the S-score of the primary residential building.	x	x	
3	Non-residential building or frame, within the property boundaries, which is believed to be sufficiently close to pose a real potential risk to the primary building.	x	To be addressed as HRBE #13	
3-[R]	As **3** but residential building.	x	x	x
4	Non-residential building or frame, within the property boundaries, which is sufficiently distant to pose no direct risk to the primary building.	x		
4-R	As **4** but residential building.	x	x	x
5	Building or frame (non-CC1b), outside the property boundaries, which is believed to be sufficiently close to pose a real potential risk to the primary building.	x	To be addressed as HRBE #13	

Table 1 Scope of work RVS.

3.3.2 Safety Assessment

In all cases the building should firstly be evaluated in accordance with the Safety Assessment procedure. During this assessment it may be found that the building is at immediate structural risk for the following reasons:

- The condition of the building. The condition of the building can be affected by the level of maintenance that the building has received;
- The structural quality of the building. The structural quality would be affected by settlement or bad construction, and/or previous seismic events; and
- Existence of a building elements, which for instance form an immediate falling hazard, or damaged elements with an immediate adverse effect.

For the follow up in such situations refer to Engineering Inspection Protocol RVS for CC1b buildings V0.3.

3.3.3 RVS Application

The building data will be recorded in the application. This data will form the basis for the computation of the building vulnerability, see chapter 0.

The RVS application contains 13 sections. Each section contains several topics:

1. Inspection information: general information about the performed inspection
2. Emergency situation: report on the Safety Assessment (refer to 3.3.2)
3. Address information: check of GIS data
4. Object description: e.g. address use, building year, etc.
5. Object dimensions: e.g. height, storeys, footprint area, etc.
6. Form aspects: e.g. irregularities, presence of basement, roof type, etc.
7. Structural materials: walls, floors, etc.
8. Structural characteristics: e.g. joint structure, foundation, presence of cavity walls, wall thickness, presence of ties, etc.
9. Maintenance level: e.g. general, masonry, mortar, etc.
10. Façade inspection: e.g. length, % of openings, etc.
11. High Risk Building Elements (HRBEs): see section 3.4
12. Solar cells present: information not related to the seismic risk evaluation
13. Confirmation inspector: signing off the inspection application.

In the appendix 4 a further description of the sections is given, with an overview of the data being collected by the application and an explanation of where the data relates to.

3.4 High Risk Building Elements

HRBEs as defined in this section can be described as all elements, structural or non-structural, that are considered to pose a direct and immediate danger to the users of buildings and/or the public in areas adjacent to those buildings.

Identification of HRBEs is one of the key targets of the inspection. The inspectors have to identify these elements during the inspection. Based on given inference rules (section 3.4.1 to 3.4.13), recommendations are given on identified HRBEs.

All recommendations will be noted and will be used for prioritisation. Examples of experiences of HRBEs with comments and recommendations are included in Appendix 1.

Identifying HRBEs

Figure 2 Overview of High Risk Building Elements (notional building).

Item	HRBE	section
1	Walls out of plane (bulging walls, out of plumb) Gables	3.4.1
2	Slender columns, cracked columns	3.4.2
3	Cracked or deformed walls	3.4.3
4	Cracked lintels/ spandrels	3.4.4
5	Lack of ties, punching elements	3.4.5
6	Parapets, balcony, etc.	3.4.6
7	Slender chimneys	3.4.7
8	Deformed or damaged chimneys	3.4.8
9	Missing roof cladding or loose bricks	3.4.9
10	Lack of mortar between bricks	3.4.10
11	Dormers of brick work	3.4.11
12	Lack of cavity ties	3.4.12
13	Other	3.4.13

Table 2 Definition of HRBEs.

Background

The developed Risk Reduction Strategy, as currently described in the Overall Process Outline, states that there are two types of risk to life safety:

- Falling hazard: this is a risk to people outside the building;
- Building collapse hazard: this is a risk to people inside the building.

Identifying the HRBEs contributes to the risk assessment, since they all relate to one of the mentioned life safety risks. To put the HRBEs, and the following recommendations, into the perspective of the risks, the HRBEs are categorised as shown in Table 3. An indication to the total risk for an HRBE indicated as falling hazard, is given by means of a (subjective) qualification High/Medium/Low. For HRBE's indicated as collapse hazard, they are categorised in governing failure types (In Plane or Out of Plane).

		Falling hazard (elements)		Collapse hazard (building)	
HRBE No.	**Description**	**Applicable** (X=yes)	**Impact** (High/Medium/ Low)	**Applicable** (X=yes)	**Governing failure type** (OOP=Out Of Plane IP = In Plane)
HRBE 1	Walls out of plane			X	OOP
HRBE 2	Slender columns, Cracked columns			X	IP
HRBE 3	Cracked walls			X	IP
HRBE 4	Cracked lintels			X	IP
HRBE 5	Lack of ties, punching			X	OOP
HRBE 6	Parapets etc.	X	H		
HRBE 7	Slender chimneys	X	H		
HRBE 8	Deformed chimneys	X	M		

		Falling hazard (elements)		Collapse hazard (building)	
HRBE No.	**Description**	**Applicable** (X=yes)	**Impact** (High/Medium/ Low)	**Applicable** (X=yes)	**Governing failure type** (OOP=Out Of Plane IP = In Plane)
HRBE 9	Roofing	X	L		
HRBE 10	Lack of mortar			X	IP
HRBE 11	Dormers of brick work	X	M		
HRBE 12	Lack of cavity ties	X	M		
HRBE 13	Other	(X)	(all)	(X)	(all)

Table 3 Categorization of HRBEs to type of risk
Note that a combination of hazards and/or failure types per HRBE is possible.

Recommendations
The inspectors have to identify the visible HRBEs. Either the inspectors and/or the engineering team have to recommend actions, based on the inference rules for each HRBE.

The following actions could be made:

1. Urgent Action
2. Further Investigation
3. No action

1) An Urgent Action should be required for any situation of clearly exceeding the given inference rules (section 3.4.1 to 3.4.13) but also on engineering judgment. In this instance the Urgent Action Procedure is to be followed.
2) A Further Investigation is selected according to the given inference rules. The extent of the deficiencies are described and photographed for further assessment. The element is not posing an immediate or urgent issue and the maintenance level is fair or good.
3) When reported as " No Action" no follow up is defined. This should be verified during the following engineering and design stages.

The final recommendation(s) should always be checked by the engineering team.

In case of severe damage the inference rules do not apply, and each such case should be assessed individually.

3.4.1 HRBE 1_Walls out of plane (bulging walls, out of plumb)

This item is to be selected when masonry walls show out of plane deficiencies (bulging wall, out of plumb) or gable walls with visible rotational mechanism.

Background information

Bulging walls have been frequently found in the region. Bulging may affect the entire wall or only the external leaf of a cavity wall. Bulging often takes place so slowly that the masonry doesn't crack, and therefore it may go unnoticed over a long period of time. The bulging of the whole wall may be due to thermal or moisture expansion of the walls, or to contraction of the inner leaf. This expansion is not completely reversible because once the wall and its associated structural components are pushed out of place, they can rarely be completely pulled back to their original positions.

The effects of the cyclical expansion of the wall are cumulative, and after many years the wall will show a detectable bulge. Inside the building, separation cracks will occur on the inside face of the wall at floors, walls, and ceilings. Bulging of only the outer masonry leaf is usually due to the same gradual process of thermal or moisture expansion: in this instance masonry debris can accumulate behind the bulge and prevent the wall from returning to its original position.

In very old buildings, small wall bulges may result from the decay and collapse of an internal wood lintel or wood-bonding course, which can cause the inner course to settle and the outer course to bulge outward. When wall bulges occur in solid masonry walls, the walls may be insufficiently tied to the structure or their mortar may have lost some or all of its bond strength.

Masonry walls that lean (invariably outward) represent a serious, but uncommon, condition that is usually caused by poor design and construction practices, such as particularly inadequate structural tying or poor foundation detailing/workmanship. When tilting or leaning occurs, it is often associated with parapets and other high level walls, especially those with heavy cantilevered masonry cornices. Leaning can produce separation cracking on the end walls and cracking on the interior wall face along floors, walls and ceilings.

Regardless of the origin of the damage, bulging walls increase the vulnerability of the buildings to seismic events and should be addressed in order to reduce the vulnerability as well as to eliminate existing risks to life for non-seismic situations.

Assessment

- The out of plane issues to be assessed when present are:

Walls out of plumb: this relates to the amount by which a wall is leaning. In accordance with NEN-EN 1996-2:2006 (art 3.4), the vertical permissible deviations are:

- For a single storey 20 mm; (see Table 4; verticality);
- In total height of three storeys, it is allowed to have a deviation of 50 mm; (see Table 4; verticality).

Note: since this might be difficult to estimate precisely it is recommended to find a reference plane where possible.

Table 4 Permissible deviations for new masonry elements, NEN-EN 1996-2:2006 (art 3.4, table 3.1).

Position	Maximum deviation
Verticality	
in any one storey	± 20 mm
in total height of building of three storeys or more	± 50 mm
vertical alignment	± 20 mm

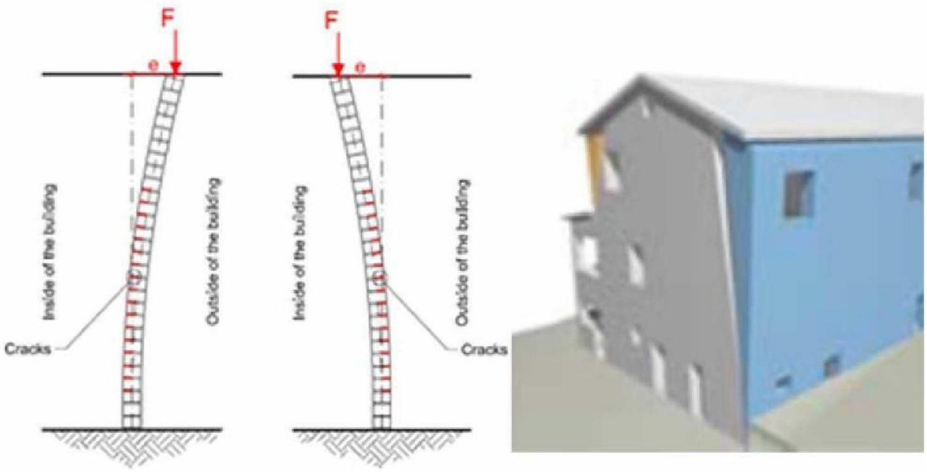

Figure 3 Out of plumb walls.

Bulging wall: Bulging might have been caused by loading from above, movement in the building, lack of wall to floor connections, lack of restraint from orthogonal walls, and possible foundation problems, etc.

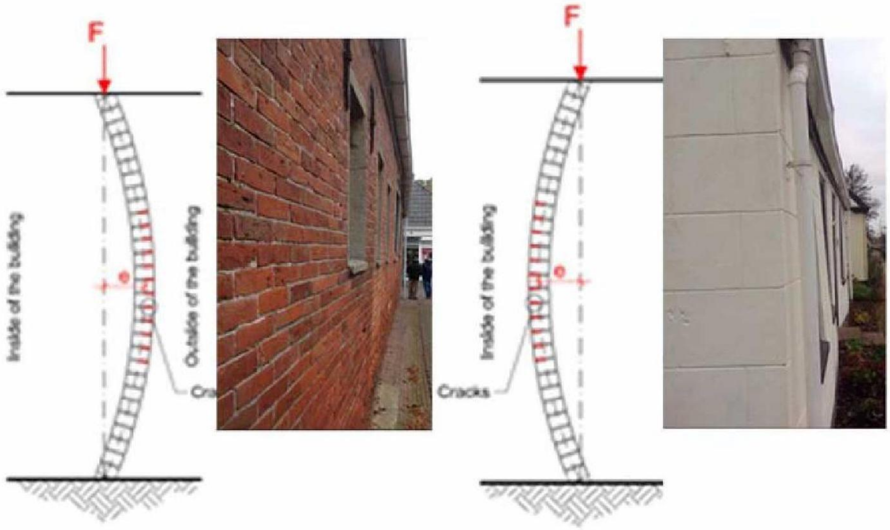

Figure 4 Bulging walls.

Recommendation

a) URGENT ACTIONS: When the deviation clearly exceeds the limits of Table 4 and/or the number/size of the cracks are clearly showing that there is a danger for the entire building, an "Urgent Action" is required.

b) FURTHER INVESTIGATION: When the deviation likely exceeds the limits but pose no danger for the entire building, this element of the building of particular concern should be reported as needing further investigation.

c) NO ACTIONS: If there is no out of plane issue identified.

- <u>Gable wall:</u> This is considered as a HRBE element when the following is observed:

- Rotational mechanism: it might be possible to clearly see a triggered mechanism. It can be recognized by cracks in some typical positions.

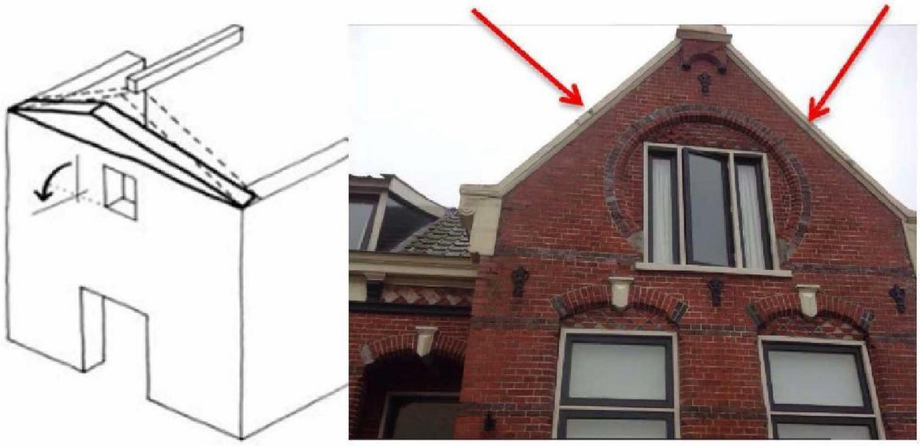

Figure 5 Rotational mechanism gable wall.

Recommendation

a) URGENT ACTIONS: Urgent actions are required in the following scenarios:
(i) If horizontal cracks along the gable wall are significant (approx. > 5 mm) and/or the gable wall is quite deformed.
(ii) Vertical cracks, which are formed between the gable and the roof, are other indicators of detachment of the gable (see red arrows in the picture).
(iii) When it might be assumed that when if a small horizontal force is introduced, the gable wall could collapse or displace significantly further.

b) FURTHER INVESTIGATION: If a horizontal crack along the gable wall is identified, such that rotation of the gable wall may have occured, but no further signs as described under a). The connection between the wall and roof/storeys should be checked in the further assessment.

c) NO ACTIONS: If there is no horizontal crack along the gable wall identified and/or the gable wall is not deformed.

In the event loose bricks are identified on gable walls, the inspector should request a maintenance letter to the owner to inform him of the possible danger.

3.4.2 HRBE 2_Slender columns or cracks in concrete/masonry columns

-Slender columns

Background

This item is to be selected when structural columns are thought to have a potential issue related to their slenderness. Slender columns are potentially vulnerable to P-delta effects under horizontal displacements which could lead to premature failure of the element. For further and more detailed seismic assessments, the construction material, as well as the loads applied to the element, are also relevant.

Assessment

Columns are said to be slender if its cross-sectional dimensions are small compared with its length, as opposed to short columns where the strength of the element is governed entirely by the strength of materials and the geometry of the cross-section.

The degree of slenderness is generally expressed in terms of slenderness ratio, L/r where L is the unsupported length and "r" is the radius of gyration, or L/b where "b" is the least lateral dimensions of the column. Masonry columns can be considered to be slender when:

- the ratio of the effective length to the least lateral dimensions of the column is greater than 12;
- the ratio of effective length to the least radius of gyration is greater than 45, .

Recommendation

a) URGENT ACTIONS: When the column is slender and appears clearly under-sized when compared with the supported loads.

b) FURTHER INVESTIGATION: This should be recommended if the slenderness issue is not clear and the maintenance level needs to be examined more closely.

c) NO ACTIONS: Potential HRBE not confirmed because no slender columns have been found.

- <u>Cracks in concrete or masonry columns</u>

Background

It is important to note that vertical cracking in a masonry column can be an indication that the element is overloaded and that brittle failure may be imminent. In this case an assessment of the column capacity should be carried out.

Assessment

This item is to be selected when relevant cracks are seen in masonry or concrete columns. Figure 6 shows examples of general cracks for (reinforced) concrete columns and a vertical cracks in a masonry column.

Figure 6 Cracks in concrete or masonry columns.

Recommendation

a) URGENT ACTIONS: "Urgent Action" is required when the width of the crack is significant (approx. > 1-2 mm) and the direction of the crack is vertical (crack likely to be due to inadequate vertical load capacity).

b) FURTHER INVESTIGATION: When inspectors notice an external crack in columns, they should state that the crack requires "further investigation".

c) NO ACTIONS: Potential HRBE not confirmed because no cracks have been identified.

3.4.3 HRBE 3_Cracked or deformed walls

This item is to be selected when the walls showing significant (in terms of size, shape, frequency) cracks (diagonal, horizontal at pier ends, horizontal at floor level or vertical along wall edges, etc.)

Background

In general the cracks that are identified during investigations are likely to be caused by a combination of seismic actions, settlement and structural weakness. This section is intended to give an illustration and a brief explanation of cracks that could be expected to be identified during an RVS. This will also include cracks which are not very common but might be found in the buildings in a seismic area.

The general mechanisms/cracks that can be found in buildings after a seismic event can be understood from the standard mechanisms described by ASCE 41-13. The possible failure mechanisms are shown in Figure 7.

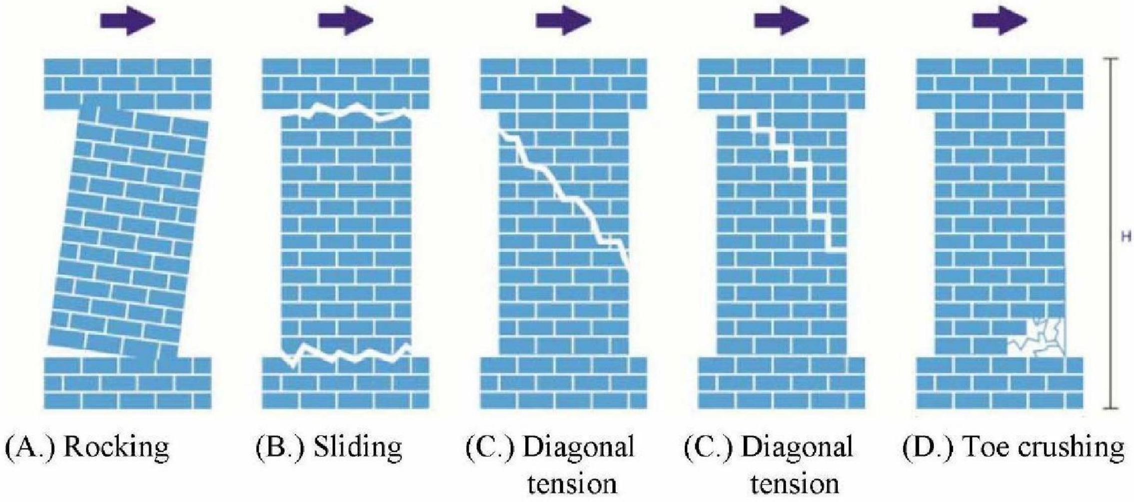

Figure 7 URM failure mechanisms (ASCE 41-13).

A. Rocking: mortar joints opening up at top and bottom of the pier, and the pier is rocking on its base;
B. Bed joint sliding: sliding of all or a portion of the pier along mortar bed joints;
C. Diagonal tension cracking: shear failure in the pier leading to diagonal tension cracking;
D. Toe crushing: the masonry crushing at the toe of the rocking wall;

Buildings showing such cracks might already have a reduced capacity due exposure to previous seismic events.

Assessment

Figure 8 shows the overview of cracks which may be seen, with the following crack typologies:

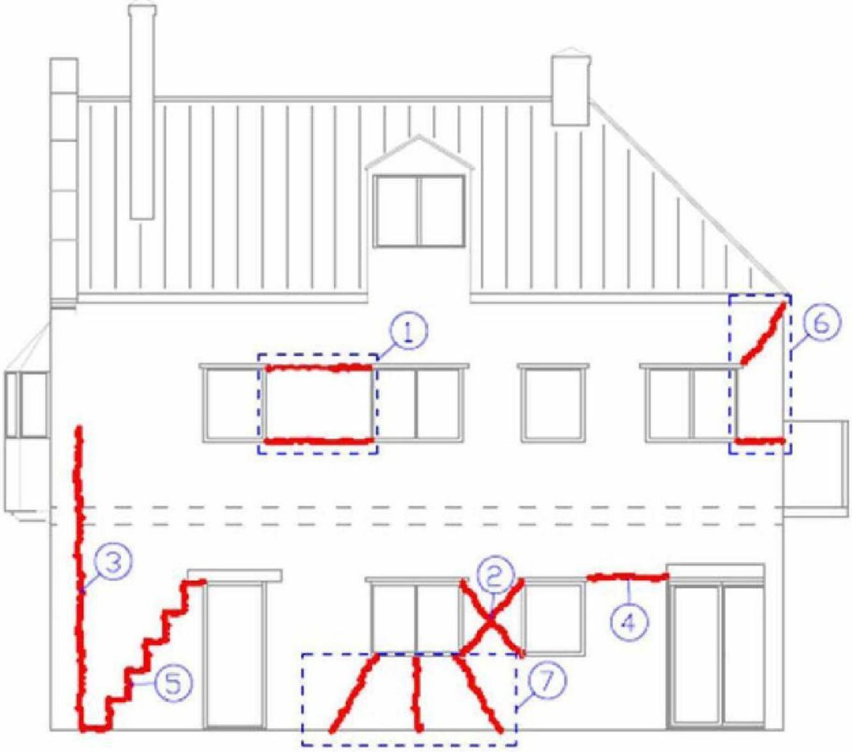

Figure 8 Overview of cracks belonging to HRBE 3.

Figure 8 provides an overview of cracks which are possible to define with the following crack typologies that belong to HRBE 3:

1. Flexural crack: this could be caused by rocking or by toe crushing (see figure 7). It could also represent another failure mechanism like bed joint sliding. This type of crack has been noticed in piers and is typical of seismic behaviour;
2. Shear crack: this is generally caused by diagonal tension (see figure 7), and are typical due to a seismic impact. It is less likely to be found in the buildings in the region, because the earthquakes to date have not been of high intensity;
3. Vertical cracks located close to the edge of the walls are generally due to settlement of the return wall and lack of connections between walls;
4. Bed joint sliding (see figure 7). The crack pattern could be diagonal or horizontal;
5. Diagonal cracks in one direction. This mechanism shares characteristics with diagonal tension and bed joint sliding because it results in a stair stepped crack along the joints, and might be caused by settlement. The stepped pattern is characteristic of settlement, where the bricks are softer and where there is harder mortar that may have caused the bricks to crack;
6. Corner damage. Might be due to rocking mechanism (see figure 7); and

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7. Vertical or slightly oblique cracks. This typology of cracks might be caused by settlement.

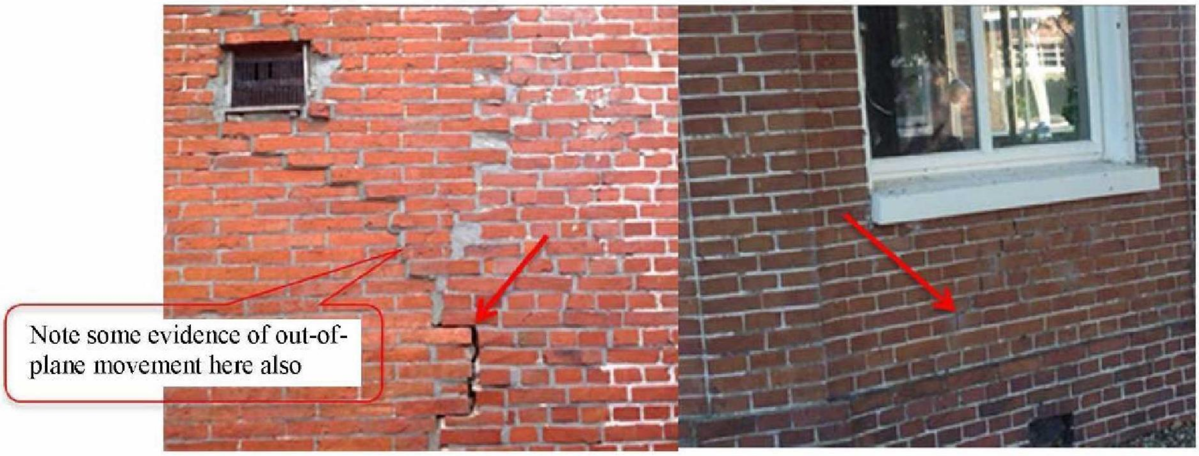

Figure 9 Examples of cracks.

Recommendation

a) URGENT ACTIONS: Urgent action is required in the following scenarios (i) When the width of the crack is significant (approx. > 5 mm) and/or the element is quite deformed.
(ii) When one or more cracks are present and the safety of the entire building is compromised, (as described in items 1-7, Figure 8).

b) FURTHER INVESTIGATION: When relevant structural cracks are reported, "further investigation" is required.

c) NO ACTIONS: Potential HRBE not confirmed because no crack has been identified or the crack is categorised as hairline. Sealed cracks should be reported.

Also signs of previous repairs attempts and cases where these have re-opened should be recorded.

3.4.4 HRBE 4_Lintels and spandrels showing deflections and/or cracks

Background

In the region, many signs of damage (cracks) are visible in spandrels (above openings) and lintels. Distinction can be made between:

- Spandrels with a lintel;
- Spandrels without a lintel.

It is very common in old buildings with solid walls to have no lintel above the openings. In these cases, the spandrels are supported by the window frames.

In more recent buildings (especially those with cavity walls) concrete or steel lintels are usually present.

The area of masonry below an opening at ground floor could also be identified as a spandrel, but cracks in this location are considered to belong to high risk element HRBE 3.

Assessment

The cracks found for this category HRBE 4 are represented in Figure 10.

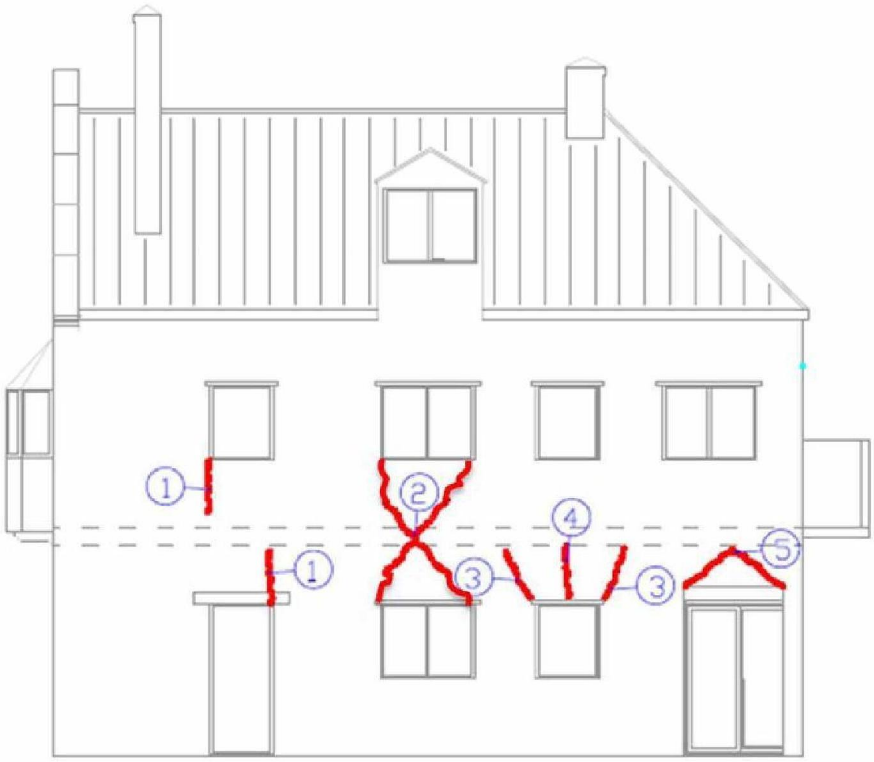

Figure 10 Overview of cracks belong to HRBE 4.

Figure 10 provides an overview of cracks which are possible to define with the following crack typologies that belong to HRBE 4:

1. Vertical cracks occur simultaneously in the corners of the openings. These cracks are caused by seismic loads when the spandrel is weak compared to the piers;
2. This is a shear crack and could be caused by seismic loads when the spandrel is weak compared to the piers. The shear crack can also occur when settlement occurs;
3. The cracks labelled 3 could be the result of concentrated horizontal loads above the spandrels. It can also occur when there is insufficient strength in the lintel;

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4. The cracks labelled 4 could be the result of concentrated horizontal loads above the spandrels. It also occurs when there is insufficient strength in a lintel; and
5. The crack labelled 5 is a consequence of there being insufficient strength in the window frame and where there is no lintel or where the lintel has failed:

Note – it is not always possible, nor necessary, to determine the cause or causes of cracks/deflections, but it is important to record all characteristics such as out-of-plane movement, approximate width and shape. Also signs of previous repairs attempts and cases where these have re-opened should be recorded.

The cracks/deflections in the lintels may pose high loadings onto the window frames. It might be the case that only small deflections on these window frames are visible; in general it is not plausible to find collapsed frames. Further investigation will have to be completed to demonstrate that the situation is safe.

Figure 11 Examples of cracks in spandrels with or without lintels.

Recommendation

a) URGENT ACTIONS: Urgent action is required in the following scenarios:
(i) When the width of the crack is significant (approx. > 5 mm) and the element is quite deformed.
(ii) When the inspector have noticed one or more cracks are present as described in items 1-5 (Figure 10) and/or the safety of the entire or part of the building is compromised.

b) FURTHER INVESTIGATION: When inspectors identify some cracks in spandrels above openings or in lintels as shown on Figure 110 this should be reported as required "further investigation".

c) NO ACTIONS: Potential HRBE not confirmed because no crack has been identified or the crack is categorised as "hairline".

3.4.5 HRBE 5_Lack of ties, punching elements

Wall damaged because of [assumed] lack of ties (floor connections), walls damaged because of pushing elements (roof, etc.).

Background

Since lack of ties form a seismic risk, this should be identified as a HRBE. It is possible to find cracks caused by pushing/thrusting elements such as the roof where there are inadequate ties.

Assessment

The cracks corresponding to this category are illustrated in Figure 12 and Figure 13. The lack of ties, between roof, floor and walls that are pushed by roof rafters, might result in the formation of cracks in the corner of the buildings (see crack 1 below). This item is used to record cracks or damage caused by punching elements for example floor beams or roof rafters (see crack 2 below).

It is possible that some out-of-plane movement might also be observed.

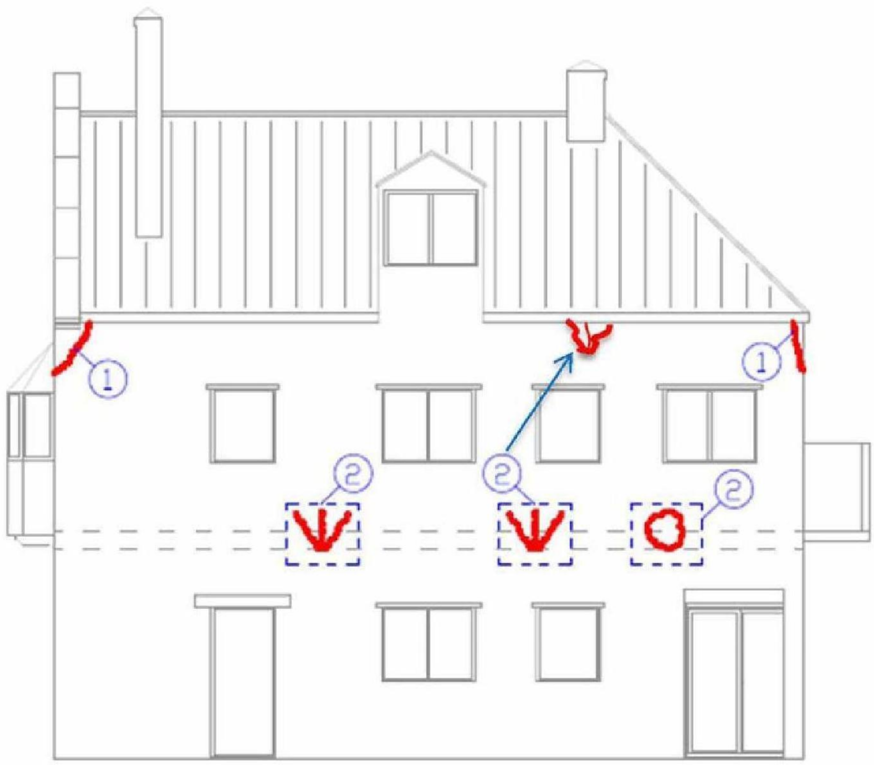


Figure 12 Overview of cracks belong to HRBE 5.

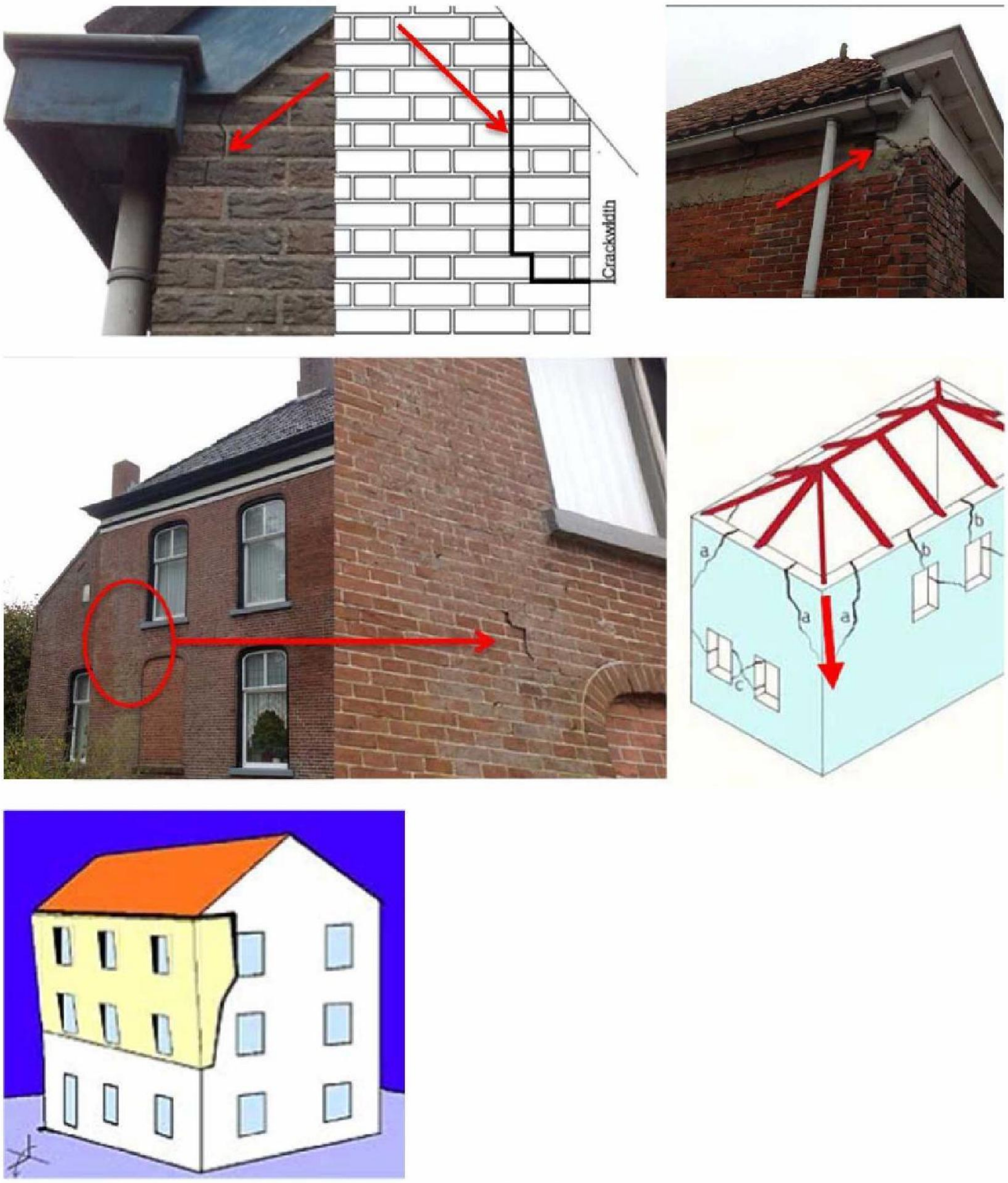


Figure 13 Cracks caused by pushing or punching elements.

Recommendation

In general, the following recommendations apply:

a) URGENT ACTIONS: When the width of the crack is significant (approx. > 5 mm) and a rotational mechanism (out of plane overturning) is triggered, it might be recognised by several cracks, an "Urgent Action" is required. The safety of the entire or a part of the building is not secured.

b) FURTHER INVESTIGATION: When cracks due to lack of ties in connections between roof, floor and walls which are pushed by roof rafters or due to punching elements (e.g. floor beams) are recognised, a more detailed inspection is required in order to assess the level of damage. Even in cases where the cracks are relevant (< 1-2 mm) or no rotational mechanism is recognised the connection detail needs to be investigated.

c) NO ACTIONS: Potential HRBE not confirmed because no crack has been identified or when the crack is categorised as “hairline”.

Two cases of specific HRBE 5 cracks are presented in Table 5 and Table 6 to guide decision making when making a recommendation(s) on HRBE 5. However, these guidelines are indicative and there is no absolute rule. Judgment is required and if in doubt a second opinion should be sought from a suitably qualified engineer.

Table 5 Decision tool HRBE 5 (1).

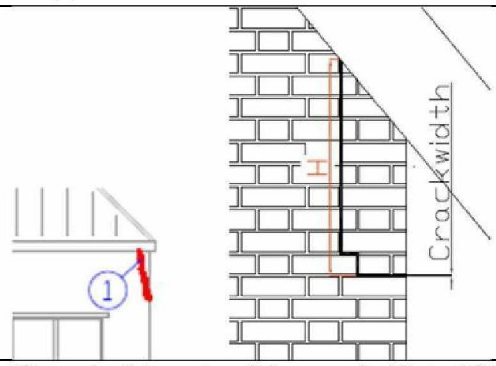
Crack case 1	
Urgent Action	If vertical length of the crack, H, > 200 mm and the crack width is approx. >5mm the wall might collapse.
Further Investigation	Further investigation should be carried out, if the vertical length of the crack (H < 200 mm) and the thickness of the crack is between approx. 2-5 mm because the wall might rotate. It is important to complete a more detailed inspection in order to assess the level of damage.
No Action	If the crack is categorised as hairline.

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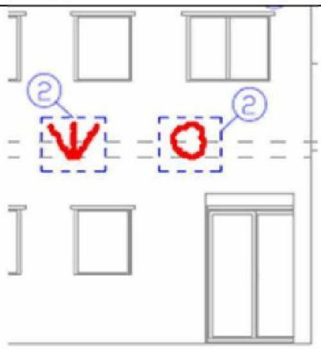
Table 6 Decision tool HRBE 5 (2).

Crack case 2	
Urgent Action	If the cracks are approx. > 5 mm) and a rotational mechanism has been triggered it is possible that part of the wall could collapse.
Further Investigation	If the cracks are between approx. 1-2 mm it is important to carry out more detailed inspection in order to assess the level of damage and to investigate the connections.
No Action	If the crack is categorised as hairline.

3.4.6 HRBE 6_Parapets, balconies, cantilever, canopies and decorative

This HRBE relates to parapets, balconies, cantilever elements, canopies and decorative elements that are on top of gable walls. These elements constitute a risk even when they are not showing any signs of damage.

Background

The elements mentioned above should be labelled as potential falling hazards. Apart from the collapse risk, the risk from detached masonry elements falling on people inside and also outside buildings should be reduced. It is noted that in both the Roermond (1992) and Christchurch (2011) earthquakes, the majority of casualties occured to people outside buildings due to falling objects. A notable feature is that HRBE falling hazard failures typically occur at significantly lower levels of shaking than building collapse.

Figure 14 A few examples of parapets, balconies, cantilever or canopies (all potential falling hazards).

- <u>Parapets</u>

Assessment

Because of their location, typically around the perimeter of buildings, unreinforced masonry parapets are particularly at risk during a seismic event. Unreinforced masonry parapets, cornices, and appendages pose a significant falling hazard onto access/egress routes especially open to the public and should be considered as seismically vulnerable. They have caused numerous injuries and required costly repairs in past earthquakes. While the function of parapets is “non-structural,” they are a structural concern that requires engineering expertise to address.

When assessing seismic upgrading measures required for a parapet, the condition and maintenance requirements should be considered concurrently. Potential defects may typically include mortar loss or cracking, degraded bricks and being vertically out-of-plumb. The need for parapet maintenance is a common problem due to its exposure to the weather.

A parapet can be a high risk building element if the limit of slenderness is exceeded, if the stability is compromised by the detail at the base (damp-proof course) or when there is corrosion of the connections or no connection at all. The parapets can be categorised by the material they are made of (concrete, masonry and steel parapets). Different slenderness limits apply as below:

- Concrete h/d = 3.0
- Masonry h/d as shown in 7;
- No slenderness limit for steel parapets, the only issue is the corrosion of the connections.

The table below shows the maximum allowable slenderness for masonry parapets for different seismicity areas. (See Basis for Design PGA levels).

Table 7 Maximum height (h)-to-thickness (d) ratios for URM parapets based on ASCE41-13 section A7.8.1.

Area of seismicity	Surface acceleration	Maximum permitted aspect ratio (h/d)
Area of low seismicity	<0.13g	2.5
Area of moderate seismicity	0.13g<x<0.2g	2.5
Area of high seismicity	>0.2g	1.5

Recommendation

a) URGENT ACTIONS: When the h/d ratio clearly exceeds the limit (masonry and concrete parapets) and where it is obvious that the parapet has been poorly maintained, an "Urgent Action" is required. Poor maintenance would be indicated by: steel corrosion, severe cracks in masonry, cracks and corrosion in reinforced concrete parapets.

b) FURTHER INVESTIGATION: When the inspector identify a slender parapet as defined above (concrete, masonry), or where there is evidence of corrosion of the connections is an issue (steel), further investigation is required.

c) NO ACTIONS: This item is not a HRBE where the h/d ratio is less than indicated for concrete and masonry, or where it is clear that the steel has been well maintained.

In the event that loose bricks are identified on parapets, the inspector should request a maintenance letter to the owner to inform him of the possible danger.

- <u>Cantilevering element, balcony, canopy</u>

Assessment

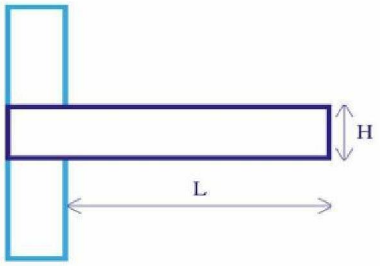


Figure 15 Cantilever, balcony and canopy.

L is the length of the structural element and must be measured up to the outer leaf, h is the height of the structural element. When the ratio L/h > 1.5 (cantilever element and balcony) or L/h > 2.0 (canopy) the slenderness should be evaluated. Where it has been identified that an element of the building has L/h>5, the element may not be able to withstand seismic loading.

Recommendation

a) URGENT ACTIONS: An Urgent Actions is required under the following scenarios:
(i) When inspectors identify severe cracks (>2 mm) in masonry or a reinforced concrete cantilever element near the intersection with the wall
(ii) When the L/h ratio clearly exceeds the limit (slenderness issue)
(iii) When there is evidence that the element has been poorly maintained (steel corrosion, cracks and corrosion in reinforced concrete slabs).

b) FURTHER INVESTIGATION: This action should be recommended if the structural support system is not clear, where there could be a slenderness issue or when the maintenance level needs to be examined more closely.

c) NO ACTIONS: Potential HRBE not confirmed because none of these issues identified above applies.

3.4.7 HRBE 7_Slender masonry chimneys

Slender masonry chimneys are classified as high-risk elements for the same reason as HRBE 6, since they pose a potential falling hazard, even where there are no signs of damage.

For examples of slender chimneys see Figure 16.

Figure 16 Examples of slender chimneys.

During the inspection of masonry chimneys caps of various types and materials can be found over masonry chimneys. These caps and ornaments are reasonably common in the Groningen region. See Figure 17 and Figure 18 for examples.

Appendix 3 is included in order to formalise a standard approach in the assessment of masonry chimneys with accessories (e.g. cap and ornaments) during the screening and give clear directions in their assessment as HRBE.

Figure 17 Example of chimneys with caps.

Figure 18 Example of a chimney with ornament.

Assessment

A chimney is defined as slender when the height (h) to width (b) ratio exceeds certain limits.

The table below shows the maximum allowable slenderness (aspect ratio height/width) for masonry chimneys within different seismicity areas. For the relevant seismicity refer to the Basis for Design.

Table 8 Maximum permitted aspect ratio per area of seismicity (ASCE 41-13, masonry chimneys).

Surface acceleration from hazard map	Maximum permitted aspect ratio h/b (see figure 19)
Surface acceleration < 0.1g	3.00
0.1g < Surface acceleration < 0.2g	3.00
0.2g < Surface acceleration < 0.3g	3.00
Surface acceleration >0.3g	2.00

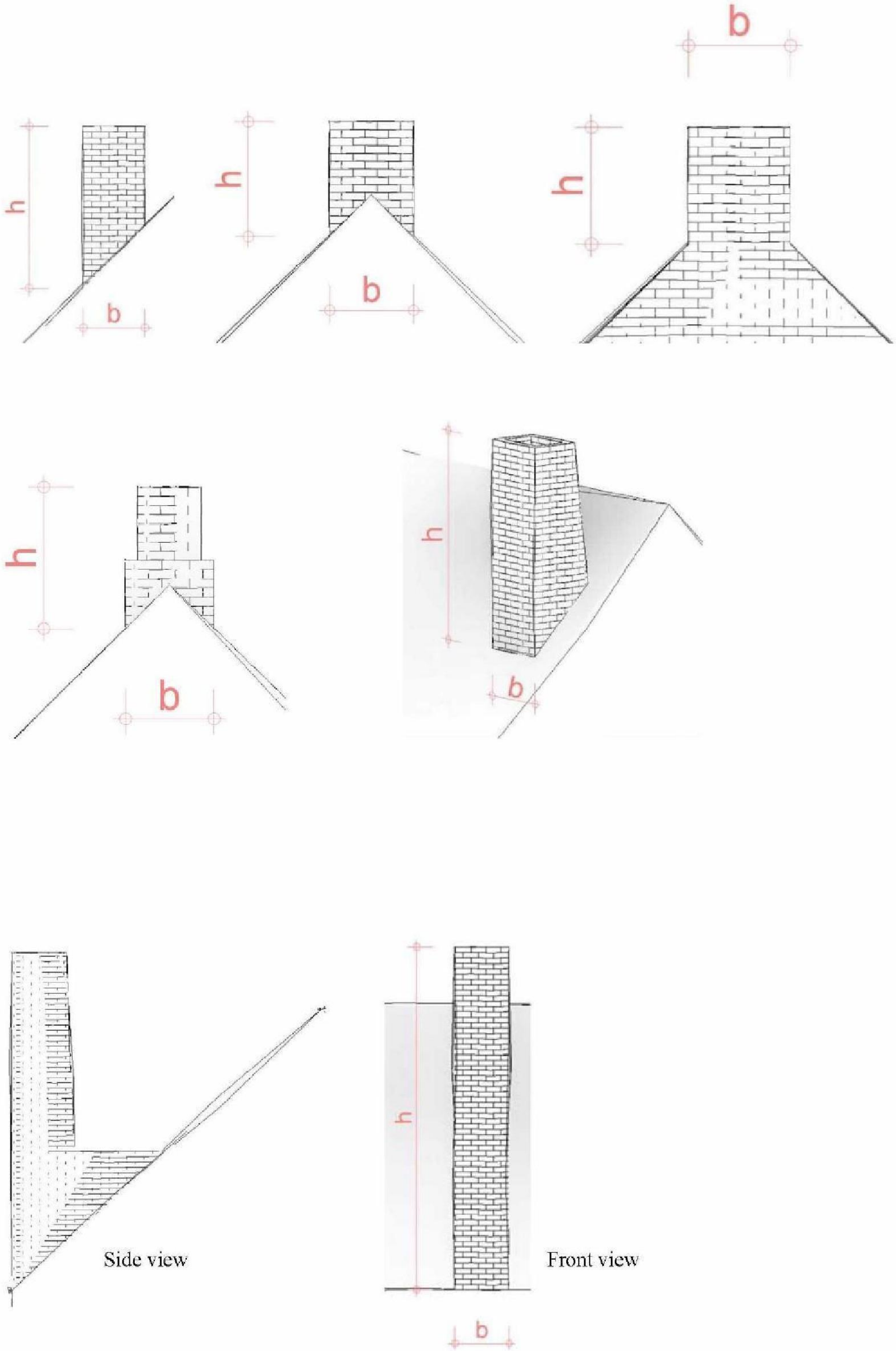


Figure 19 Types of chimneys with definition of height (h) and width (b).

The slenderness ratio of the chimney should be reported as follow:

- Ratio < 1.00
- Ratio ≥ 1.00 to < 1.50
- Ratio ≥ 1.50 to < 2.00
- Ratio ≥ 2.00 to < 2.50
- Ratio ≥ 2.50 to < 3.00
- Ratio ≥ 3.00 to < 3.50
- Ratio ≥ 3.50 to < 4.00
- Ratio ≥ 4.00 to < 4.50
- Ratio ≥ 4.50 to < 5.00
- Ratio ≥ 5.00 to < 5.50
- Ratio ≥ 5.50 to < 6.00
- Ratio > 6.00

Recommendation

a) URGENT ACTIONS: This should be recommended:
(i) if the h/b ratio exceeds the ratio > 6 (1:6) limits, the chimney posing a possible falling hazard and the recommendation an "Urgent Action" is required.
(ii) If the h/b ratio is 4 < ratio < 6 (1:4 - 1:6) an engineering judgment decide if an "Urgent Action", otherwise a "Further Investigation" is required.

b) FURTHER INVESTIGATION: This should be recommended:
(i) If the h/b ratio is: 2[1] < ratio < 4 (1:2 - 1:4)
(ii) If the slenderness issue is not clear and the maintenance level needs to be examined more closely.

c) NO ACTIONS: Potential HRBE not confirmed because h/d ratio is less than the limits given in Table 8.

[1]Ratio depends on the Surface acceleration, see Table 8.

Urgent Action should be required for any situation that appears as an immediate risk from engineering judgment. In case of damage the above mentioned limits do not apply, and each case should be assessed individually.

3.4.8 HRBE 8_Deformed or damaged chimneys

This item is to be selected when inspectors notice damage to, or deformation of, chimneys and/or where there are signs of rotation (even if they are not slender). Another category within this item is formed by the type of support of the chimney.

Background
This hazard is defined, because a chimney with a questionable equilibrium condition could become a falling hazard even with small ground peak acceleration, independent on the slenderness ratio (HRBE 7). The condition could be influenced by either damage or deformations, or by the type of support of the chimney.

- Deformed and damaged chimneys

Recommendations

a) URGENT ACTIONS: When chimneys have a clearly deformed/rotated shape and/or they are clearly heavily damaged, an "Urgent Action" is required because part or entire elements of the building may not be structurally stable.

b) FURTHER INVESTATION: If chimneys have a deformed/rotated shape and are damaged it should be reported as requiring "Further Investigation".

c) NO ACTIONS: Potential HRBE not confirmed when there is no deformed/rotated shape is evident and when the chimneys are clearly located upon a load bearing wall (for example they are located upon a lateral wall or flue, viewable from the street).

Every masonry chimney should be reported by taking a picture. If the chimney or roof construction is not damaged/deformed a command should be given: "No damage or deformation observed".

- Chimney supported by timber beams

Background
When chimneys are not securely standing on load bearing walls (for example they are positioned in the middle of the roof), they might be supported on timber joists.

Assessment
Chimneys supported by timber beams could be addressed as free standing or inadequately anchored, so therefore classified as a HRBE. During a RVS the inspector cannot screen the support of the chimney structure; this will only be evident from the EVS or as reported by previous damage inspections.

It is important to report such cases within this category. The pictures shown, Figures 20 to 24, are some examples (grouped in subcategories A, B and C) that have been reported. It is recognised that these will require Further Investigation within the property, and that it will not be possible to eliminate the risk from external inspection alone in a significant number of cases.

Recommendation

A - Chimney (fully) supported by timber beams

In the case of a chimney most likely supported by timber beams, where no visible damage is observed to the chimney and where no deflection is visible on the supporting roof structure, no further action is required. However, where damage and/or deflection is observed, then further investigation must be proposed as the final recommendation.

Figure 20 Example of a chimney likely to be supported by timber beams; No (or negligible) deflection of the roof structure visible and no damage visible on chimney.

Figure 21 Example of a chimney likely to be supported by timber beams, with some deflection of the roof structure visible and no damage visible on chimney.

Figure 22 Example of a skew standing chimney likely to be supported by timber beams.

B - Chimney partly supported by timber beams

In the case of a chimney partly supported by timber beams and partly supported by masonry, where there is no damage visible on the chimney and no visible deflection of or damage to the supporting roof structure (and the supporting masonry) is visible, no further action is proposed as a recommendation.

However, where damage and/or deflection is observed, then further investigation is proposed as the final recommendation.

Figure 23 Example of a chimney partly supported by timber beams, with damage (horizontal cracks) of the masonry.

C - Chimney (fully) supported by masonry flue

In the case of a chimney supported by masonry flue where no damage is visible on the chimney and no deflection or damage to the supporting roof structure (and the supporting masonry) is visible, then no further action is proposed as final recommendation.

In cases where damage and/or deflection is observed, then further investigation is proposed as the final recommendation.

Figure 24 Example of a chimney supported by masonry flue, with no damage or deflection of the roof structure visible and no damage visible in the masonry channel.

3.4.9 HRBE 9_Missing roof cladding or loose bricks

The inspectors must confirm that the roof cladding is in good condition. Missing, damaged, unstable or unsafe roof cladding should be reported as HRBE 9 (Figure 25).

The inspectors also should identify loose bricks on gable walls. These unstable bricks form a risk of falling and should be reported as HRBE 9 (Figure 26).

Background
Missing or loose elements on the roof pose a falling hazard, even at low seismic activity.

The examples shown in Figure 25 and Figure 26 illustrate such cases:

Figure 25 Examples of missing or loose roof tiles.

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Figure 26 Example of loose bricks on gable walls.

Recommendation

a) URGENT ACTIONS: When the stability of significant roof parts is not secured because of clearly unstable or misplaced elements, an "Urgent Action" is required as this would be a falling hazard.

b) FURTHER INVESTIGATION: If inspectors identify that there are relevant missing and or loose parts this should be reported as needing further investigation.

c) NO ACTIONS: This item is not a HRBE because no issues can be seen on the roof cladding.

In case of very local unsafe, unstable or just some loose roof tiles the recommendation should be "No Action". Where such 'roof cladding' is identified a maintenance letter should be sent to the owner to inform them on the possible hazard.

3.4.10 HRBE 10_Lack of mortar between bricks

With missing mortar the wall itself becomes weakened and may be more vulnerable to collapse in the event of an earthquake. This HBRE generally arises as a consequence of poor maintenance in connection with weathering and not by seismic related activity.

Background

The following types of mortar joints are typically found in the region:

- Mortar with a thickness of around 4-10 mm, based on calcareous/lime mortar, white colour, soft and more elastic than the cement-based mortar;
- Mortar with a thickness of around 10-12 mm, based on cement mortar, grey in colour and harder than the lime mortar.

The calcareous/lime mortar was used up to Second World War. The mortar was often of poor and probably variable quality (for economic reasons). It was made by grinding and burning shells, so basically it is a non-hydraulic lime mortar. This poor lime mortar, when exposed to weathering, degrades over time and crumbles. The use of this mortar can be identified by the presence of partially open joints.

Furthermore, it could often be observed that after years of deterioration of the external lime mortar, re-pointing may have been carried out with a cement based mortar. Inspectors should therefore be aware that, in these cases, the mortar will not be visible due to the re-pointing. This re-pointing itself could cause damage on (historic) brickwork because of the higher stiffness (problem for vertical loads and concentration of stresses, which could cause the bricks to be damaged) and the greater water resistance compared to the lime mortar (the water cannot get out of the mortar layers, so water moves to the inner side of the wall or possibly results in damage by frost to the mortar on the outside etc.).

During repointing of the mortar joints, damage on the masonry skin can appear (Figure 27). Most of times this damage is because of the differences in stiffness of the several used types of materials. A situation can be that the material of the mortar joint is stiffere than the bricks. The mortar joint(s) expands and when the stiffness of the brick is lower than the stiffness of the joint, the skin of the masonry can collapse/fall off (delaminate).

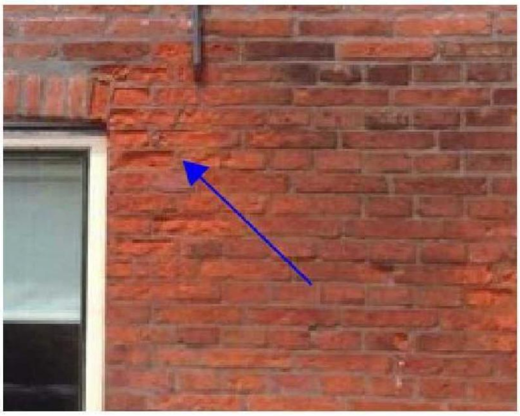

Figure 27 Masonry deterioration. Most of times it appears locally as shown on the picture.

Assessment

Inspectors must pay attention to those cases in which the lack of mortar in the outer face can be observed. The extent of missing mortar should be recorded. In such cases, repointing of the mortar may be required, with a lime mortar or a mortar with the same characteristics.

Recommendations

a) URGENT ACTIONS: When the wall is clearly unstable because of the lack of stable mortar between bricks, "Urgent Action" is required in order to renew the pointing.

b) FURTHER INVESTIGATION: If the inspectors identify a lack of mortar between bricks as described above, it should be reported as requiring "Further Investigation".

c) NO ACTIONS: Potential HRBE not confirmed because no issues with the mortar between bricks are identified.

3.4.11 HRBE 11_Masonry Dormer

A dormer can be identified as a HRBE if it is made of masonry. It is also possible that masonry dormers with an out of plane failure mechanism are found.

Figure 28 An example of masonry dormer.

Background

A masonry dormer could be a potential falling hazard.

Assessment

Even if there is no potential out-of-plane mechanism observed, the masonry dormer must be reported as a HRBE and must be followed up by inspection from the inside during an EVS in order to understand if it constitutes a falling hazard.

Recommendation

a) URGENT ACTIONS: If the masonry dormer clearly has issues such as masonry with significant cracks, damaged masonry, out of plane movement and when the safety of the masonry dormer is compromised (falling hazard); an "Urgent Action" is required.

b) FURTHER INVESTIGATION: If it is unclear that the masonry dormer is not securely situated upon load bearing walls (the dormer possible wood supported), the walls may have out of plane issues. In addition the maintenance level will likely need closer inspection.

c) NO ACTIONS: Potential HRBE not confirmed because the masonry dormer is located upon load bearing walls, the walls do not show out of plane movement and the maintenance level is good.

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3.4.12 HRBE 12_Lack of ties in cavity walls

The outer leaf of a cavity wall construction can typically be considered inadequate to independently resist the out-of-plane load generated by its own mass in a seismic event, therefore it could pose a falling hazard.

Background

Typical wall ties used in construction are as summarised in Figure 29. The shape of wall ties, used in construction before 1980, includes a kink in the middle in order to limit the accumulation of condensation or water that penetrates the cavity. These ties were made of galvanized iron and have poor corrosion protection. It is to be assumed that these older ties are neither stiff enough nor in good enough condition, or do not have adequate strength to resist seismic loads. For new buildings (after 1980), the inspectors can assume that ties have a higher axial stiffness, and generally they also have better corrosion protection. Even without signs of deterioration (most likely indirect signs as cracks and bulging) visible, an action must be taken to assess the seismic strength.

Visual indication of insufficient or corroding wall ties are:

- Deformed masonry walls (distortion)
- Breaking free of masonry (cracks)
- Loss of jointing (flushed/ weathered)

Cavity anchors in facades subject to moisture exposure from rain particularly on south-west and west facades, and these corrode more quickly than anchors in a north or east facade.

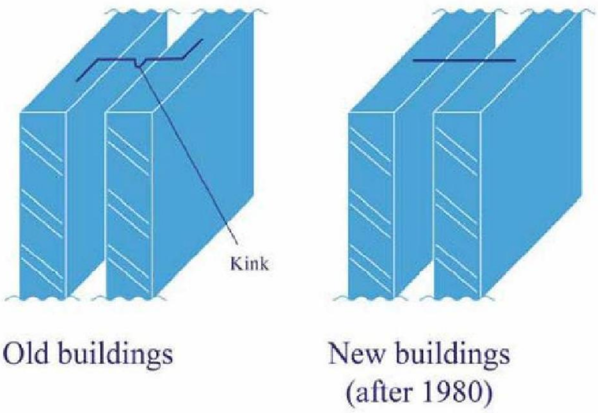


Figure 29 Wall ties.

Assessment

The presence of a cavity wall can be assessed from the brick bonding pattern (see Figure 30) – the wall may be assumed to be of solid construction where headers are visible.

The likelihood of the presence of cavity wall should be evaluated as follows:

- Buildings built before 1920: predominantly solid walls;

- Buildings built between1920 to 1965: both solid walls and cavity walls were typically built in the region. Check bond patterns and ventilation openings, they may provide clues on type of wall;
- Buildings built after 1965: assume that all walls are cavity walls unless observed as otherwise.

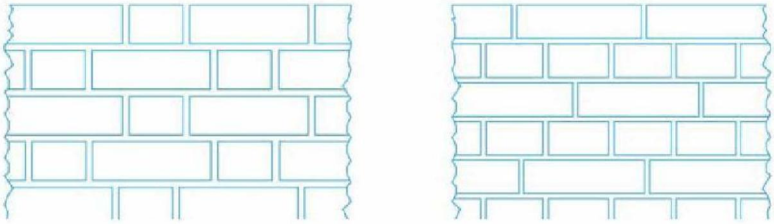


Figure 30 Bond patterns suggests solid wall construction (headers visible).

Recommendation

a) URGENT ACTIONS: An "Urgent Action" is not applicable. The visual indication of insufficient or possible corroding wall ties are being observed by other HRBEs (bulging or out of plumb walls, cracks, lack of mortar).

b) FURTHER INVESTIGATION: When a cavity wall is present or the presence of a cavity wall for the entire building is unclear, a "Further Investigation" is required.

c) NO ACTIONS: Potential HRBE not confirmed because the building has a solid wall construction.

3.4.13 HRBE 13 – Other

In addition to the HRBEs as described above in this document, other potential hazards may exist due to building elements or other objects related to the building - these elements may not be specifically described in this document. This is a category that requires the inspectors to be generally alert to any exceptional features or areas of concern on or around the building. A conservative approach to inspection to identify such elements is therefore advised.

For example: masonry cantilevered (vertical) wall elements (see figure 31), which could be found connected to buildings should be reported as "HRBE 13", since they pose an adverse effect on the behaviour of the wall it is connected to during a seismic event. Instead of identify these as "Parapets" or "Cantilevered Elements (vertical cantilevered elements)", to avoid confusion it is advised to put those elements at HRBE 13 "Other".

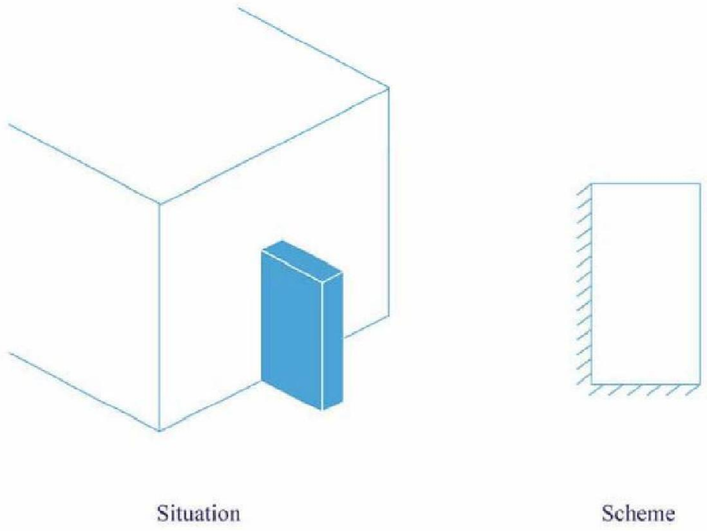


Figure 29 Masonry wall element.

Recommendation
The recommendations should be completed at the own discretion of the inspector. Pictures of the elements should always be taken and the recommendation can be "No Action" or if needed "Further investigation" or in the worst case "Urgent Action". Such on engineering judgment of the inspector.

4 S-score

4.1 S-score calculation process

This chapter gives a description of which inspected aspects are taken into account in the calculation of the Structural Hazard Score “S-Score”.

From earlier studies some particularly vulnerable building types have been identified e.g. those buildings with a high percentage of openings in walls. In cases such as these there is likely to be no adequate system in place to provide sufficient lateral stability.

To identify these buildings in the field, the RVS process ranks buildings for further (internal) assessment, in relation to other assessed buildings, by calculating a Structural Hazard score, known as the S-score. This S-score relates to the probability of collapse in the ‘Maximum Considered Earthquake’. However, in the context of current inspections it is used only as a score to compare relative vulnerability and not be explicit as to the vulnerability of an individual building. Within the S-score calculation it is assumed that only the outer walls provide resistance to the (horizontal) seismic loads. The S-score calculation is therefore only applicable to objects where the main stabilizing structure consists of the outer walls or facades with piers. The S-score is related to the in-plane shear stress capacity of outer walls and the out-of-plane shear behaviour of walls. There are, therefore, two S-scores for each building.

The basis for the S-score calculation is the following:

- Response spectrum according to EC8;
- Calculation based on Lateral Force Analysis according to EC8;
- Fundamental period based on EC8;
- Number of floors is equal to number of storeys minus 1;
- Roof area assumed to be equal to floor area (note: could give unrealistic results for extensions and additions);
- Length of shear walls determined by dividing wall area by average height;
- Shear area of walls determined by multiplying length of wall with thickness and average opening percentage; in case of cavity walls, shear area is calculated based on the inner leaf only. In cases where the wall ties are adequate, shear area is multiplied by 1.2.

In addition to the basis for the S-score, the following key assumption are applicable:

- Geometric parameters calculated based on estimated dimensions of the house;
- Assumption of unknown data based on known data from observation (unseen back façade is assumed to be equal to visible front façade); and
- Information from RVS assumed to be accurate and reliable.

The table in appendix 5 describes the information gathered for the S-score calculation and the process of defining the score.

4.2 S-score restrictions and boundaries

The suitability of the S-score calculation is restricted by the following aspects:

- If an inspection is not possible, there will be no input information for the S-score calculation. (see appendix 4, ID 1.5 Is inspection possible);
- S-score calculation is applicable to a building with less than 5 storeys. If higher numbers are introduced in the RVS application, the S-score calculation will take the maximum number of 5 storeys into account in the calculation. For buildings higher than 5 storeys, it is expected that there will be an internal stabilizing system. (see appendix 4, ID 5.4 Number of storeys);
- If "Other" is selected, the roof is treated as a flat concrete roof (since this is the heaviest type of roof structure and thus will produce the most conservative results). (see appendix 4, ID 6.4 Roof type);
- The S-score calculation is developed for masonry buildings and uses the average shear stress as a main indicator for the vulnerability of the building. The S-score calculation will therefore only be relevant when the main wall materials are masonry and calcium silicate (the reference wall shear stress is based on masonry buildings only). The S-score calculation could be used for buildings with concrete as the main wall material, but the S-score is too conservative for concrete buildings, since the shear strength of concrete is higher when compared to masonry. The S-score calculation is not relevant for wooden and steel structures, since the average base shear stress in the walls is not considered as a reliable indicator for failure for these buildings. (see appendix 4, ID 7.1 Main wall material)
- The S-score calculation is developed for masonry buildings. It is expected that only wooden floors, concrete floors and Nehobo floors are used for masonry buildings. If "Steel" or "Other" is selected in the application, the seismic weight of the building is calculated without the weight of the floors and will thus produce unreliable results. (see appendix 4, ID 7.3 Higher floor materials)
- At least two orthogonal facades need to be inspected for the S-score calculation. If in total only one facade is inspected, the S-score calculation will not run. If no information is available from the inspection for the left facade it is assumed that the information from the right facade also applies for the left facade and vice versa. This assumption also holds for the front and back facade. (see appendix 4, ID 10 Facade information)

5 The RVS report

The RVS report should be an effective summary of the information obtained from the screening. It will contain the following information:

- The gathered building data;
- Identified external High Risk Building Elements which could pose a life safety risk during a seismic event with recommendations; and
- Building information for prioritisation of the subsequent Extended Visual Screening.

The main conclusions and recommendations are:

- The identified HRBEs and the recommendations.

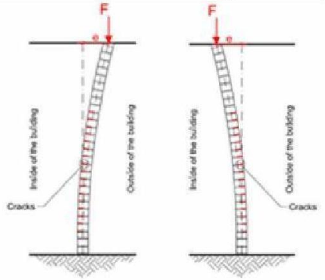
6 Reference documents

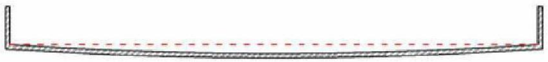
- ASCE 41-13 (American Society of Civil Engineers) "Seismic evaluation and retrofit of existing buildings";
- ATC 20 (Applied Technology Council) "Rapid Evaluation Safety Assessment";
- FEMA 154 (Federal Emergency Management Agency) "Rapid Visual Screening of Buildings for Potential Seismic Hazards";
- Eurocode 8; "Design of structures for earthquake resistance";
- Basis for Design, NAM Report Number EP201403208456, Rev 2 16 October 2014.
- GESU Report; Engineering Inspection Protocol RVS for CC1b buildings V0.3

Appendix 1 Examples of real cases HRBEs with recommendations

HRBE 1 Walls showing out of plane issues

Walls out of plumb





Walls out of plumb	√	Further investigation
Bulging wall	x	-
Gable wall	x	-

Data Characteristics:

If a wall leans inwards or outwards, we should report it as an out of plumb wall.

The recommendation depends on the deviation and damage.

No action: deviation	< 20mm/storey or < 50mm of total building height
Further investigation:	Deviation exceed the mentioned limits
Urgent action:	Deviation exceed the mentioned limits and/or the number/size of the cracks are clearly showing a danger for the entire building or part of the building.

Inspector Comment:

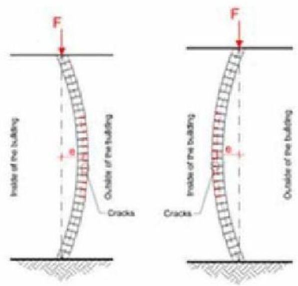
Left façade is approx. 5cm deforming outwards

Engineer Comment to inspector:

Assess each facades separately, each façade should have comments about estimated geometric deviations and observed damage. Common reasons for this type of damage are: problems in roof construction or lack of floor/wall connections.

This is **not a bulging wall**; we should consider the vertical cross section. In this situation the wall is out of plumb with a maximum deviation at the top of the wall in correspondence of the wall middle horizontal section.

Bulging wall



Walls out of plumb	x	-
Bulging wall	√	Further investigation
Gable wall	x	-

Data Characteristics:

If a wall is bulging **(vertical cross section)** either to the inside or to the outside, we should report it as a Bulging wall.
The recommendation depends on the deviation and damage.

No action: deviation	< 10mm per meter (vertical) < 50mm for 10 meter (vertical)
Further investigation:	Deviation exceeds the mentioned limits
Urgent action:	Deviation exceeds the mentioned limits and/or the number/size of the cracks are clearly showing a danger for the entire building or part of the building.

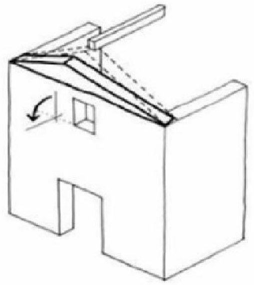
Inspector Comment:

Left façade is approx. 5cm bulging outwards

Engineer Comment to inspector:

Assess each facades separately, each façade should have comments about estimated geometric deviations and observed damage.
Common reasons for this type of damage are; bearing, movement in the building (pushing elements), lack of wall to floor connections, a possible foundation issues.

Gable wall



Walls out of plumb	x	-
Bulging wall	x	-
Gable wall	√	Further investigation

Data Characteristics:
If a gable wall is showing signs of a rotational mechanism, horizontal cracks along the gable and/or deviation, should be reported as HRBE (gable wall).
The recommendation depends on the deviation and damage.

No action:	-
Further investigation:	Observed cracks indicates a rotating mechanism.
Urgent action:	Observed cracks are significant (>5mm approx.) and/or the gable wall is quite deformed. If just a small horizontal force is introduced, the gable wall could collapse.

Inspector Comment:
Horizontal crack observed at the front gable near floor level. No deformation observed.

Engineer Comment to inspector:
Assess each gable wall separately, each gable wall with visible issues (as above) should be reported with comments about estimated geometric deformations and observed damage.
Common reasons for this type of damage are: lack of connection between roof/gable, lack of wall ties.
Vertical cracks, which are formed between the gable and the roof, are other indicators of detachment of the gable.

HRBE 2 - Slender columns or cracks in concrete/masonry columns

Slender columns or cracks in concrete/masonry columns


Crack

Slender columns or cracks in concrete/masonry columns √ Urgent action

Data Characteristics:
All **structural columns** that are damaged or could have a potential slenderness issue should be reported as HRBE 2. During the inspection at least further investigation should be selected for every structural column, the slenderness should be calculated in the engineer check.

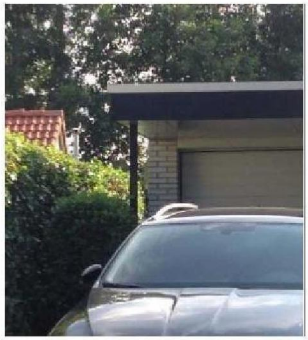
No action:	structural column is not slender and/or not damaged
Further investigation:	structural column is slender and/or damaged
Urgent action:	damaged structural column is clearly showing a danger for the entire building or part of the building.

Inspector Comment:
Masonry column, horizontal cracked near connection tie bar. Also cracks observed near the arch.

Engineer Comment to inspector:
Comment should be made about the material and the presence of damage. It is not required to make a comment about the slenderness.
In this situation the combination of horizontal crack in column and cracked arch require urgent action.

Structural slender, undamaged column	
	*Slender columns or cracks in concrete/masonry columns* √ Further investigation
	Data Characteristics: All **structural columns** that are damaged or could have a potential slenderness issue should be reported as HRBE 2. During the inspection at least further investigation should be selected for every structural column, the slenderness should be calculated in the engineer check. No action: structural column is not slender and/or not damaged Further investigation: structural column is slender and/or damaged Urgent action: damaged structural column is clearly showing a danger for the entire building or part of the building.
	Inspector Comment: Structural masonry column, no damage observed.
	Engineer Comment to inspector: Comment should be made about the material and the presence of damage. It is not required to make a comment about the slenderness.

Post supporting canopy



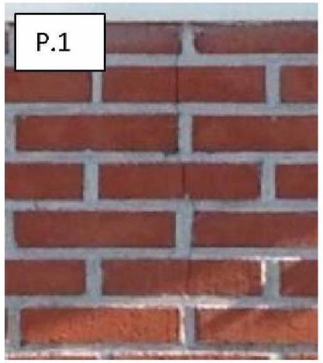

Slender columns or cracks in concrete/masonry columns	**x**	-
Data Characteristics: Post supporting the canopy.		
Inspector Comment:		
Engineer Comment to inspector: The post only supports the canopy and should be reported as HRBE 6 canopy.		

Timber post at corner window


Slender columns or cracks in concrete/masonry columns	**x**	-
Data Characteristics: Timber post at corner window		
Inspector Comment:		
Engineer Comment to inspector: The corner timber post is not to be considered as a column and doesn't have be reported as HRBE unless they extend a full storey and/or appear to support a significant load and/or appear damaged/cracked.		

HRBE 3 Wall cracks

Wall cracks



Wall cracks √ No Action

Data Characteristics:

If there is damage present in the form of cracks in masonry this should be reported as HRBE 3.

The recommendation depends on the deformation and damage.

No action: The crack is categorized as a local hairline (P.1) or the crack(s) have been sealed (P.2). The damage or repair work which is present is likely to be not severe enough to need further investigation.

Further investigation: Generally relevant structural cracks or a large amount of sealed damage can be reported as further investigation.

Urgent action: When the width of the crack is significant (>approx. 5 mm) and/or the element is quite deformed, an "Urgent Action" is required. Also when one or more cracks are present which compromise the safety of the entire building or a part of the building.

Inspector Comment:

P1: Hairline crack(s) observed,

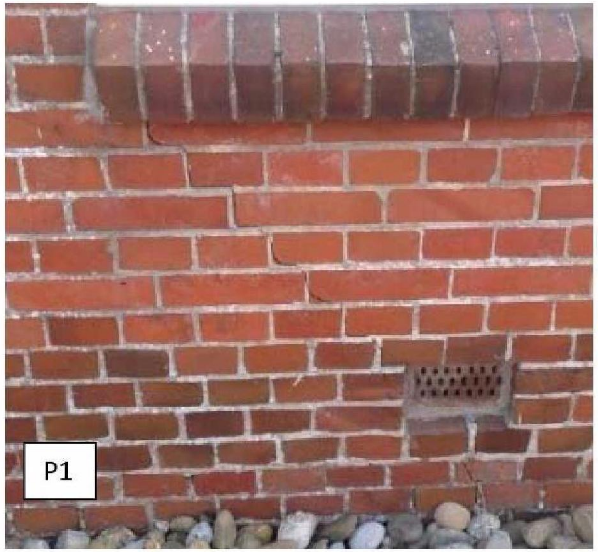
P2: Observed cracks/joints have been sealed.

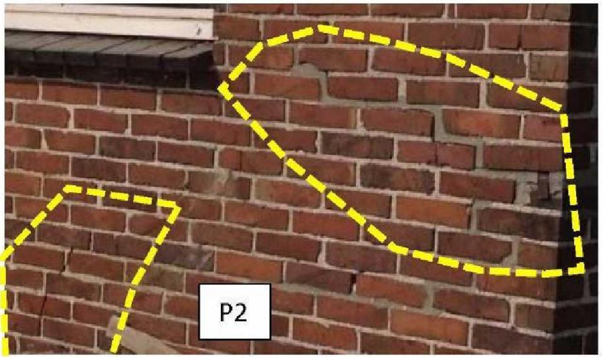
Engineer Comment to inspector:

P1: The observed damage is assumed to be not significant.

P2: Because of the low amount or not significant location of the observed damage, it is assumed to be not significant.

Wall cracks





Wall cracks	√	Further investigation

Data Characteristics:

If there is damage present in the form of cracks in masonry this should be reported as wall cracks.
The recommendation depends on the deformation and damage.

No action: The crack is categorized as hairline or the crack(s) have been sealed.

Further investigation: Generally relevant structural cracks (P.1&2) will be reported as further investigation also a large amount of sealed damage could require further investigation, because of the location, the amount, or the nature of the sealed crack. The need for further investigation is due to determine if a building is significantly affected in its seismic performance. When there is a large amount of repair work observed this could be an indication of high vulnerability.

Urgent action: When the width of the crack is significant (>approx. 5 mm) and/or the element is quite deformed, an "Urgent Action" is required. Also when one or more cracks are present which compromise the safety of the entire building or a part of the building.

Inspector Comment:

P1 No comment required (in case of structural cracks).
P2 Large amounts of sealed joints observed.

Engineer Comment to inspector:

The cause of cracks can be; soil subsidence, horizontal actions, overloading, lack of robustness of wall constrains, others.

Wall cracks

Wall cracks √	Urgent Action

Data Characteristics:

If there is damage present in the form of cracks in masonry this should be reported as wall cracks.

The recommendation depends on the deformation and damage.

- No action: The crack is categorized as hairline or the crack(s) have been sealed.
- Further investigation: Generally relevant structural cracks or a large amount of sealed damage can be reported as further investigation.
- Urgent action: When the width of the crack is significant (>approx. 5 mm) and/or the element is quite deformed, an "Urgent Action" is required. Also when one or more cracks are present which compromise the safety of the entire building or a part of the building (P.1)When cracks are encountered which require an urgent action, there is an increased risk for the total or partial collapse of walls. When large cracks are encountered also out of plane issues could be present.

Inspector Comment:

Severe crack observed in the front façade in combination with out of plane movement of the right façade.

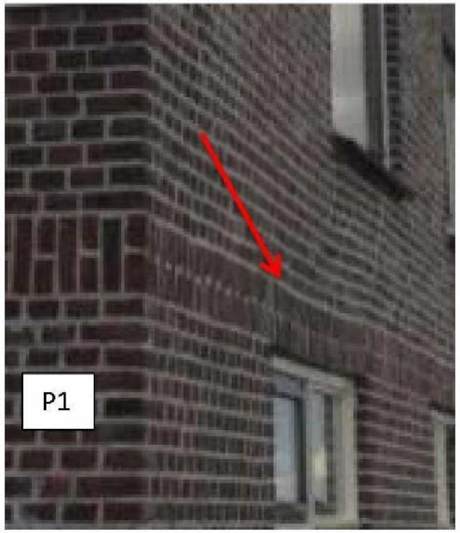
Engineer Comment to inspector:

A detailed description of encountered situation should be given. The cause of cracks can be; soil subsidence, horizontal actions, overloading, lack of robustness of wall constrains, others.

HRBE 4 Deflected/cracked lintel(s)

Deflected/cracked lintel/spandrels		
 	*Deflected or cracked lintel/spandrels* √	No action
	Data Characteristics: Signs of damage observed in spandrels (above openings) and lintels. The recommendation depends on the deformation and/or damage. No action: The crack is categorized as a hairline or the crack(s) have been sealed (P.1). The damage or repair work which is present is likely to be not severe enough to need further investigation. Further investigation: If inspectors identify deflection or some cracks in spandrels above openings or in lintels and or this should be reported as further investigation. Urgent action: When the width of the crack is significant (>approx. 5 mm) and/or the element is quite deformed, an "Urgent Action" is required. Also when one or more cracks are present which compromise the safety of the entire building or a part of the building.	
	Inspector Comment: Hairline crack(s) observed, observed cracks/joints have been sealed.	
	Engineer Comment to inspector: The observed damage is assumed to be not significant. Because of the low amount or not significant location of the observed damage, it is assumed to be not significant.	

Deflected/cracked lintel/spandrel



Deflected or cracked lintel/spandrels	√	Further investigation

Data Characteristics:

Signs of damage observed in spandrels (above openings) and lintels. The recommendation depends on the deformation and/or damage.

No action: The crack is categorized as a hairline or the crack(s) have been sealed. The damage or repair work which is present is likely to be not severe enough to need further investigation.

Further investigation: If inspectors identify deflection (P1) or some cracks in spandrels above openings or in lintels (P2) this should be reported as further investigation

Urgent action: When the width of the crack is significant (>approx. 5 mm) and/or the element is quite deformed,an "Urgent Action" is required. Also when one or more cracks are present which compromise the safety of the entire building or a part of the building.

Inspector Comment:

P1: Sealed joints in lintel observed.
P2: No comment required (in case of general structural cracks).

Engineer Comment to inspector:

When there are a large amount of repaired lintels observed this could be an indication of high vulnerability.

Deflected/cracked lintel/spandrel

Deflected or cracked lintel/spandrels √	Urgent action

Data Characteristics:

Signs of damage observed in spandrels (above openings) and lintels. The recommendation depends on the deformation and/or damage.

No action: The crack is categorized as a hairline or the crack(s) have been sealed. The damage or repair work which is present is likely to be not severe enough to need further investigation.

Further investigation: If inspectors identify deflection or some cracks in spandrels above openings or in lintels and or this should be reported as further investigation.

Urgent action: When the width of the crack is significant (>approx. 5 mm) and/or the element is quite deformed, an “Urgent Action” is required. Also an urgent action may be justified when one or more cracks are present which compromise the safety of a larger part of the building or to people below (P1).

Inspector Comment:

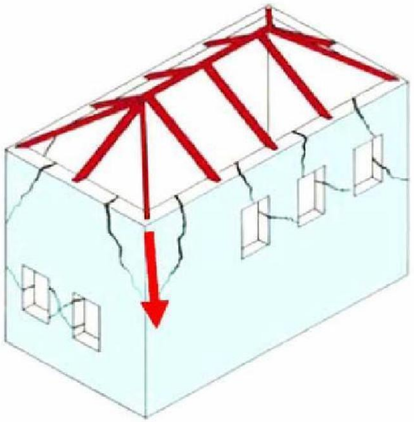
Severe deformation and cracks observed above the windows of the front façade.

Engineer Comment to inspector:

A detailed description of encountered situation should be given.

HRBE 5 Wall damage caused by lack of wall-floor-roof ties

Wall damage caused by lack of wall-floor-roof ties



"Typical cracks for HRBE 5 (pushing elements from for example the Roof structure)."

Damage caused by lack Of wall-floor-roof ties	√	Further investigation

Data Characteristics:

Wall damaged because of (assumed) lack of ties (floor connections), walls damaged because of pushing elements (roof, floor etc.). It is possible that some out-of-plane movement might also be observed here.

The recommendation depends on the deviation and damage.

<u>No action</u>: No crack has been identified or the crack is categorized as hairline

<u>Further investigation</u>: The crack width is relevant (< 1-2 mm - and no rotational mechanism is recognized)

<u>Urgent action</u>: The crack width is significant (>approx. 5 mm, and a rotational mechanism (out of plane overturning) is triggered), it might be recognised by several cracks, an "Urgent Action" is required. The safety of entire or a part of the building is not secured.

Inspector Comment:

Relevant crack(s), located at the left top corner of the front façade, have been observed and require further investigation.

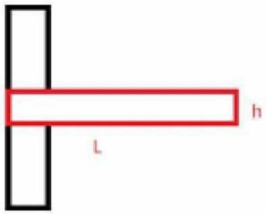
Engineer comment:

Always make clear descriptions of the exact location of the damage been observed.

HRBE 6 Parapet(s)-Balcony(s)-Cantilevered element(s)-Canopy(s)

Parapet(s)-Balcony(s)- Cantilevered Element(s)- Canopy(s)	
	*Parapet(s)* √ Urgent Action
	Data Characteristics: Parapets are assessed as high risk building elements when the limit of slenderness is exceeded or if the stability is comprised or when deterioration of the connections are visible. The recommendation depends on the deviation from dimensional guideline limits and damage. No action: no crack(s)/ stability issues are visible and the h/d ratio is within limits for the material and seismicity considered. Further investigation: h/d ratio is exceeding the limit for masonry/concrete parapets or corrosion of the connections is an issue (steel). Urgent action: the h/d ratio is exceeding the limit for Masonry/concrete parapets and the deterioration of building materials is clearly visible (steel corrosion, severe cracks in masonry, cracks and corrosion in reinforced concrete parapets).
	Inspector Comment: Significant cracks in the parapet(s) have been observed, h/d ratio = 2 and the stability possibly compromised by low level of maintenance.
	Engineer Comment: -

Parapet(s)-**Balcony(s)**-Cantilevered Element(s)-Canopy(s)



Example of scheme for a balcony, cantilever or canopy.

Balcony(s) √ Further investigation

Data Characteristics:

Balconies are building appendices usually supported by columns/ brackets or cantilevered beams. Balconies are usually providing external habitable floor area and are located typically above ground floor.
When the ratio L/h > 1,5 (balcony and cantilevered element) the slenderness should be evaluated. When L/h>5, this element could be an issue under seismic load.

The recommendation depends on the deviation from given dimensional limits and damage.

No action: The observed balcony is not slender (L/h < 1,5) or damaged.

Further investigation: The structural support system is not clear, there could be a slenderness issue (L/h > 1,5) and the degradation of the building materials needs to be looked at more closely.

Urgent action: When cracks are observed in (masonry or) reinforced concrete balcony (near the intersection with the wall), when the (L/h) ratio is clearly exceeding the limit (slenderness issue) or when the degradation of the building materials needs to be looked at more closely (steel corrosion, cracks and corrosion in reinforced concrete slabs).

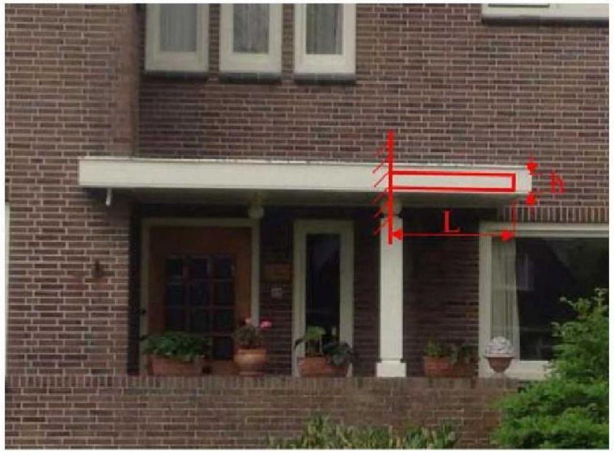
Inspector Comment:

Ratio (L/h) of the balcony is above 1,5. Also the structural support system is not clear. Maintenance level is quite bad.

Engineer Comment:

-

Parapet(s)-Balcony(s)- **Cantilevered Element(s)**- Canopy(s)	
	*Cantilevered Element(s)* √ Further investigation *Data Characteristics:* Cantilevered Elements are structural or non-structural elements anchored at only one end. The element carries the load to the support where it is forced against by a fixed restraint. When the ratio L/h > 1,5 (balcony and cantilevered element) the slenderness should be evaluated. When L/h>5, this element could be an issue under seismic load. The recommendation depends on the deviation and damage. No action: The observed balcony is not slender (L/h < 1,5) or damaged. Further investigation: The structural support system is not clear, there could be a slenderness issue (L/h > 1,5) and the degradation of the building materials needs to be looked at more closely. Urgent action: When cracks are observed in (The beam carries the load to the support where it is forced against by a moment and shear stress masonry or) reinforced concrete cantilevers (near the intersection with the wall), when the (L/h) ratio is clearly exceeding the limit (slenderness issue) or when the degradation of the building materials needs to be looked at more closely (steel corrosion, cracks and corrosion in reinforced concrete slabs).
	Inspector Comment: Further investigation: Ratio (L/h) of the cantilever is above 1,5.
	Engineer Comment: -

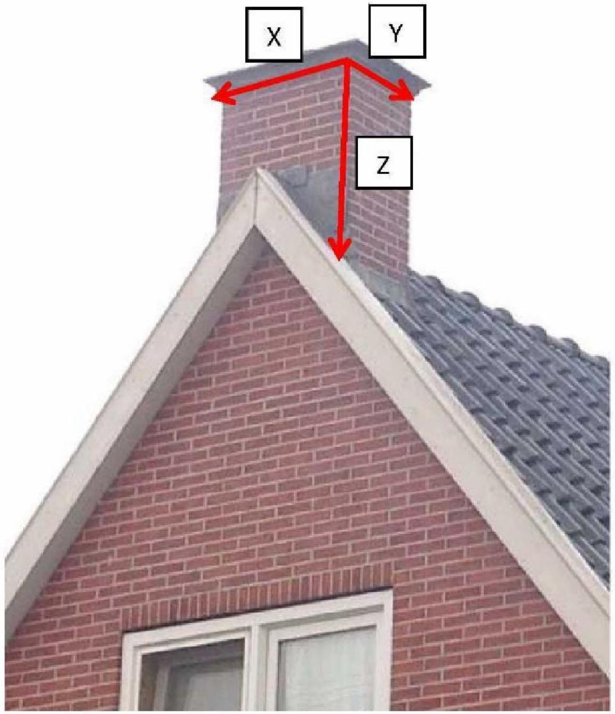
Parapet(s)-Balcony(s)- Cantilevered Element(s)- **Canopy(s)**	
 	*Canopy(s)* √ Further investigation *Data Characteristics:* Canopies (overhead roof able to provide shade or shelter) are secondary structural elements which are typically supported by columns/ brackets or cantilevers (only supported on one side). When the ratio L/h > 2,0 (canopy) the slenderness should be evaluated. When L/h>5, this element could be an issue under seismic load. The recommendation depends on the deviation and damage. No action: the observed canopy is not slender (L/h < 2,0) or damaged. Further investigation: structural support system is not clear, there could be a slenderness issue (L/h > 2,0) or the maintenance level needs to be looked more closely. Urgent action: when cracks are observed in (masonry or) reinforced concrete canopies (near the intersection with the wall), when the L/h ratio is clearly exceeding the limit (slenderness issue) or when the maintenance level is clearly bad (steel corrosion, cracks and corrosion in reinforced concrete slabs). *Inspector Comment:* Ratio (L/h) of the canopy is above 2,0. Also the structural support system is not clear. *Engineer Comment to inspector:* If damage to the posts supporting the canopy is visible it should be reported in this HRBE.

Parapet(s)-Balcony(s)- Cantilevered Element(s)- **Canopy(s)**	
	*Canopy(s)* √ No action *Data Characteristics:* Canopies (overhead roof able to provide shade or shelter) are secondary structural elements which are typically supported by columns/ brackets or cantilevers (only supported on one side). When the ratio L/h > 2,0 (canopy) the slenderness should be evaluated. When L/h>5, this element could be an issue under seismic load The recommendation depends on the deviation and damage. No action: the observed canopy is not slender (L/h < 2,0) or damaged. Further investigation: structural support system is not clear, there could be a slenderness issue (L/h > 2,0) or the maintenance level needs to be looked more closely. Urgent action: when cracks are observed in (masonry or) reinforced concrete canopies (near the intersection with the wall), when the L/h ratio is clearly exceeding the limit (slenderness issue) or when the maintenance level is clearly bad (steel corrosion, cracks and corrosion in reinforced concrete slabs). *Inspector Comment:* The front canopy is part of the building roof structure above the entrance. No damage or deflection observed. *Engineer Comment to inspector:* Self-supporting canopy. Slenderness is not a criteria in this situation because the canopy is not cantilevering from a fixed restraint but it has a large back span.

Parapet(s)-Balcony(s)- Cantilevered Element(s)- **Canopy(s)**	
	*Canopy(s)* √ No action *Data Characteristics:* Canopies (overhead roof able to provide shade or shelter) are secondary structural elements which are typically supported by columns/ brackets or cantilevers (only supported on one side). When the ratio L/h > 2,0 (canopy) the slenderness should be evaluated. When L/h>5, this element could be an issue under seismic load. The recommendation depends on the deviation and damage. No action: the observed canopy is not damaged. Further investigation: structural support system is not clear, there could be a slenderness issue (L/h > 2,0) or the maintenance level needs to be looked more closely. Urgent action: when cracks are observed in (masonry or) reinforced concrete canopies (near the intersection with the wall), when the L/h ratio is clearly exceeding the limit (slenderness issue) or when the maintenance level is clearly bad (steel corrosion, cracks and corrosion in reinforced concrete slabs). *Inspector Comment:* Light weigh canopy without damage or deflection observed. *Engineer Comment to inspector:* Because the canopy is light weight no further investigation is needed. As a rule of thumb, if the weight <0.5 kN/m^2 the frame could be considered light weight construction.

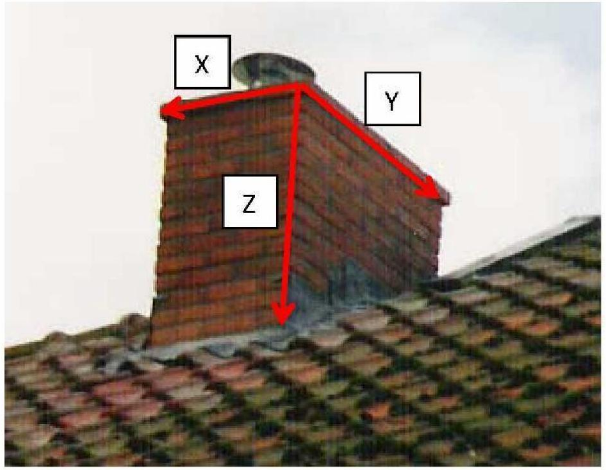
HRBE 7 Slender masonry chimneys

Slender masonry chimneys



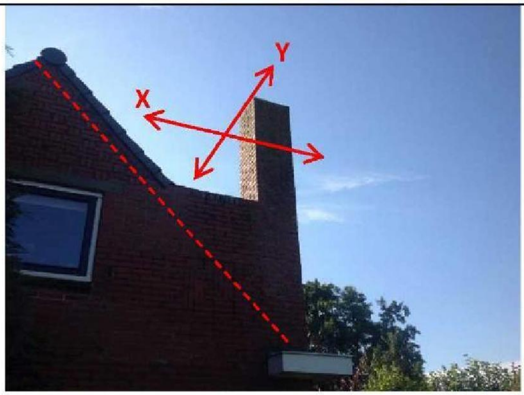
Slender Chimney √	Further investigation
Data Characteristics:	
X direction:	4 stretchers are visible: 4*220 – 10 = 870mm
Y direction:	2 stretchers and 1 header are visible: 2*220 + 110 - 10 = 540mm
Z direction:	17 layers are visible. 2 extra layers are added to account for the layers below the surface of the roof tiles, 19 layers. 19*62.5 = 1188mm
Z is divided by the least horizontal dimension:	1188 / 540 = **2.2**
Recommendation:	N/A
No action:	Slenderness is within the limits:
Further investigation:	2 < ratio < 4 **or** 4 < ratio < 6 Slenderness within the limits:
Urgent action:	ratio > 6 **or** 4 < ratio < 6
Inspector Comment: Ratio 2-2.5	
Engineer Comment to inspector: The assumed height of 1 stretcher is 62.5mm for standardization purpose	

Slender masonry chimneys



Slender Chimney	**x**	N/A
Data Characteristics:		
X direction:	2 stretchers and 1 header are visible: 2*220 + 110 - 10 = 540mm	
Y direction:	3 stretchers and 1 header are visible: 3*220 + 110 - 10 = 760mm	
Z direction:	13 layers are visible. 2 extra layers are added to account for the layers below the surface of the roof tiles, 15 layers. 15*62.5 = 938mm	
Z is divided by the least horizontal dimension:	938 / 540 = **1.7**	
Recommendation: Not applicable		
Inspector Comment: Ratio 1.5-2, No damage or deformation observed.		
Engineer Comment to inspector: The chimney is not reported as HRBE7.		

From where to measure?



Slender chimney	√	Further investigation

Data Characteristics:
In case a chimney is supported on 1 side by masonry connected to the gable wall (see picture) the slenderness ratio can differ based on the different directions considered. In this case, the most conservative assumption should be made:
The ratio of the chimney should be determined by measuring the height of the chimney to the nearest floor/roof structure supporting it.

In case a chimney is attached to a dormer, the height of the chimney should be measured either to the roof structure of the dormer, or to the main roof. Judgment should depend on whether the dormer can provide support to the chimney in both directions.

Recommendations:
See slender chimney

Inspector Comment:
-

Engineer Comment to inspector:
Comment on the slenderness ratio.

HRBE 8 Chimneys with deformed and/or rotated shape, or otherwise damaged /chimneys likely to be supported by timber beams

Chimneys with deformed and/or rotated shape

Deformed chimney	x	-
Rotated chimney	x	-
Chimney standing skew	√	Further investigation
Wood supported		

Data Characteristics:
Chimneys are classified as a high risk building element when they are damaged in a way that could increase the falling hazard due to horizontal actions.

Recommendation:
No action: If there is minor or no damage/deformation/rotation observed to the chimney.
Further investigation: If the chimney is deformed, rotated or otherwise damaged.
Urgent action: When chimneys have a severely deformed/rotated shape and/or they are clearly heavily damaged.

Inspector Comment:
Chimney is leaning to the left side. Ratio 1.5-2

Engineer Comment to inspector:
-

<table>
<tr><td colspan="3">Chimneys with deformed and/or rotated shape</td></tr>
<tr><td rowspan="4"></td><td>Deformed chimney</td><td>√ Further investigation</td></tr>
<tr><td>Rotated chimney</td><td>x -</td></tr>
<tr><td>Chimney standing skew</td><td>x -</td></tr>
<tr><td colspan="2">Wood supported

Data Characteristics:
Chimneys are classified as a high risk building element when they are damaged in a way that could increase the falling hazard due to horizontal actions.

Recommendation:
<u>No action:</u> If there is minor or no damage/deformation/rotation observed to the chimney.
<u>Further investigation</u>: If the chimney is deformed, rotated or otherwise damaged.
<u>Urgent action:</u> When chimneys have a severely deformed/rotated shape and/or they are clearly heavily damaged.

Inspector Comment:
Deformation and damage observed. Ratio 1.5-2

Engineer Comment to inspector:
-</td></tr>
</table>

Chimneys with deformed and/or rotated shape

Deformed chimney	x	-
Rotated chimney	√	Further investigation
Chimney standing skew	x	-
Wood supported		

Data Characteristics:
Chimneys are classified as a high risk building element when they are damaged in a way that could increase the falling hazard due to horizontal actions.

Recommendation:
No action: If there is minor or no damage/deformation/rotation observed to the chimney.
Further investigation: If the chimney is deformed, rotated or otherwise damaged.
Urgent action: When chimneys have a severely deformed/rotated shape and/or they are clearly heavily damaged.

Inspector Comment:
-

Engineer Comment to inspector:
Make a comment on the damage observed. A comment about the ratio of the chimney should also be added.

Roof deformation near chimneys			
	*Deformed chimney*	x	-
	Rotated chimney	x	-
	Chimney standing skew	√	Further investigation
	Wood supported	x	
	Data Characteristics: Roof deformation can be affecting the chimney if the chimney is supported by wooden beams. If roof deformation is observed which compromises the support of the chimney, this should be reported by HRBE8. Recommendation: <u>No action:</u> Minor or no roof deformation observed near the chimney. <u>Further investigation</u>: Clearly visible roof deformation is observed which could compromise the support of the chimney. <u>Urgent action:</u> The support and stability of the chimney are clearly in danger and could form a falling hazard even in case of small dynamic forces.		
	Inspector Comment: Roof deformation observed which could affect the support of the chimney.		
	Engineer Comment to inspector: -		

HRBE 9 - Roof cladding locally missing, unstable or unsafe (misplaced / missing / damaged tiles)

Unsafe roof cladding

Unsafe roof cladding	√	No action (not relevant)

Description:
If the roof cladding of a building is unsafe, unstable or roof tiles are loose this should be reported as HRBE 9. For example when the roof cladding is presumably a falling hazard.

No action (not relevant): Roof tiles are missing but there is no falling hazard (anymore). A maintenance letter does **not** have to be send.

No action (relevant): Roof tiles are unsafe, unstable or loose. The Project Team needs to be informed that a maintenance letter needs to be send.

Further investigation or Urgent action should never be selected.

Inspector Comment:
Roof tiles are missing, but no direct falling hazard present.

Engineer Comment to inspector:
N/A

Unsafe roof cladding

Unsafe roof cladding √ No action (relevant)

Description:
If the roof cladding of a building is unsafe, unstable or roof tiles are loose this should be reported as HRBE 9. For example when the roof cladding is presumably a falling hazard.

No action (not relevant): Roof tiles are missing but there is no falling hazard (anymore). A maintenance letter does **not** has to be send.

No action (relevant): Roof tiles are unsafe, unstable or loose. The Project Team needs to be informed that a maintenance letter needs to be send.

Further investigation or Urgent action should never be selected.

Inspector Comment:
Loose roof tiles observed. Letter to the owner requested and processed by management (roof tile letter).

Engineer Comment to inspector:
N/A

HRBE 10 – Extensive lack of mortar between bricks

Extensive lack of mortar	
 	*Extensive lack of mortar* √ Further investigation *Data characteristics:* If lack of mortar is observed or large amounts of mortar joints are damaged/ missing this should be reported at HRBE 10. No action: Small parts of the wall joints are missing or renovation work is in progress. Further investigation: If large parts of the wall joints are missing. Urgent action: When the wall is clearly unstable because of the lack of mortar. *Inspector Comment:* Large parts of the wall joints are missing. *Engineer Comment to inspector:* The lack of mortar could reduce the bearing/shear capacity of the wall. See the manual for a description of the different types of mortar.

Extensive lack of mortar	
 	*Extensive lack of mortar* √ Further investigation
	Data characteristics: If lack of mortar is observed or large amounts of mortar joints are damaged/ missing this should be reported at HRBE 10. <u>No action</u>: Small parts of the wall joints are missing or renovation work is in progress. <u>Further investigation</u>: If large parts of the wall joints are missing. <u>Urgent action</u>: When the wall is clearly unstable because of the lack of mortar.
	Inspector Comment: Large part of the wall joints are missing
	Engineer Comment to inspector: The lack of mortar could reduce the bearing/shear capacity of the wall. See the manual for a description of the different types of mortar.

Extensive lack of mortar

Extensive lack of mortar √	Further investigation

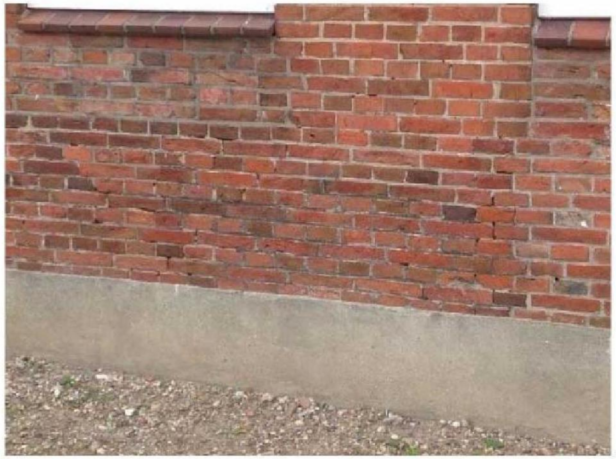
Data characteristics:
If lack of mortar is observed or large amounts of mortar joints are damaged/ missing this should be reported at HRBE 10.

No action: Small parts of the wall joints are missing or renovation work is in progress.
Further investigation: If large parts of the wall joints are missing.
Urgent action: When the wall is clearly unstable because of the lack of mortar.

Inspector Comment:
Joints are missing in the left facade at ground level

Engineer Comment to inspector:
The lack of mortar could reduce the bearing/shear capacity of the wall. See the manual for a description of the different types of mortar.

Extensive lack of mortar



Extensive lack of mortar √ No action

Data characteristics:
If lack of mortar is observed or large amounts of mortar joints are damaged/ missing this should be reported at HRBE 10.

No action: Small parts of the wall joints are missing or renovation work is in progress.
Further investigation: If large parts of the wall joints are missing.
Urgent action: When the wall is clearly unstable because of the lack of mortar.

Inspector Comment:
Small parts of the wall joints are missing

Engineer Comment to inspector:
The lack of mortar could reduce the bearing/shear capacity of the wall. See the manual for a description of the different types of mortar.

Extensive lack of mortar

Extensive lack of mortar √ No action

Data characteristics:
If lack of mortar is observed or large amounts of mortar joints are damaged/ missing this should be reported at HRBE 10.

No action: Small parts of the wall joints are missing or renovation work is in progress.
Further investigation: If large parts of the wall joints are missing.
Urgent action: When the wall is clearly unstable because of the lack of mortar.

Inspector Comment:
Wall joints are probably removed because of renovation work.

Engineer Comment to inspector:
The lack of mortar could reduce the bearing/shear capacity of the wall. See the manual for a description of the different types of mortar.

HRBE 11 – Masonry Dormers

HRBE 11 - Masonry Dormers

Masonry Dormer	√	Further investigation

Data Characteristics:

If the sidewalls (sometimes also the front wall) of a dormer are made of masonry, we should report it as HRBE 11 – masonry dormer.

No action: Never

Further investigation: This should be recommended if it is unclear that the masonry dormer is not securely located upon load bearing walls, the walls might have out-of-plane issues or the maintenance level needs closer inspection.

Urgent action: When the masonry dormer has visible issues such as masonry with relevant cracks, damaged masonry, out-of-plane movement and the safety of the masonry dormer is compromised (falling hazard); an "Urgent action" is required.

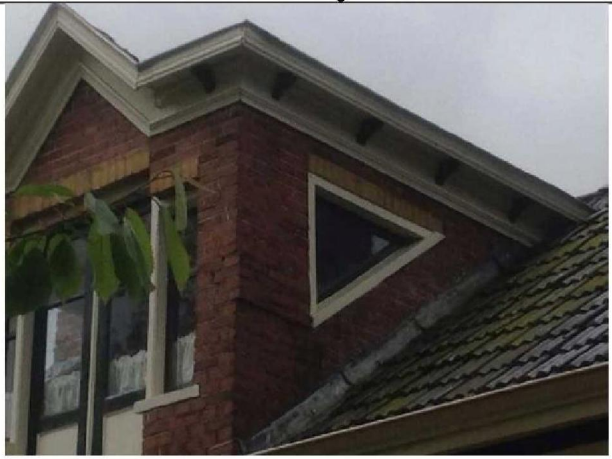
Inspector Comment:

Masonry dormer observed, possibly supported on timber frame. There is no damage observed on the dormer.

Engineer Comment:

Further investigation is required to establish the bearing frame of the masonry dormer.

HRBE 11 - Masonry Dormers



Masonry Dormer √ Urgent action

Data Characteristics:

If the sidewalls (sometimes also the front wall) of a dormer are made of masonry, we should report it as HRBE 11 – masonry dormer.

<u>No action</u>: Never

<u>Further investigation:</u> This should be recommended if it is unclear that the masonry dormer is not securely located upon load bearing walls, the walls might have out-of-plane issues or the maintenance level needs closer inspection.

<u>Urgent action</u>: When the masonry dormer has visible issues such as masonry with relevant cracks, damaged masonry, out-of-plane movement and the safety of the masonry dormer is compromised (falling hazard); an "Urgent action" is required.

Inspector Comment:

There are large cracks observed on both sides of the masonry dormer.

Engineer Comment:

Further investigation is required to establish the bearing frame and the vulnerability of the masonry dormer.

HRBE 11 - Masonry Dormers

Masonry Dormer √ Urgent action

Data Characteristics:
If the sidewalls (sometimes also the front wall) of a dormer are made of masonry, we should report it as HRBE 11 – masonry dormer.

No action: Never

Further investigation: This should be recommended if it is unclear that the masonry dormer is not securely located upon load bearing walls, the walls might have out-of-plane issues or the maintenance level needs closer inspection.

Urgent action: When the masonry dormer has visible issues such as masonry with relevant cracks, damaged masonry, out-of-plane movement and the safety of the masonry dormer is compromised (falling hazard); an "Urgent action" is required.

Inspector Comment:
Major out-of-plane issues observed on masonry dormer. The dormer is approximately 5 cm out of plane.

Engineer Comment:
Further investigation is required to establish the bearing frame and the vulnerability of the masonry dormer.

HRBE 11 – Not Masonry Dormers

Masonry Dormer	x	-
Roof/building extension	√	-

Data Characteristics:

In the pictures we see a larger building extension. This shouldn't be called a masonry dormer, but just a building extension. In this case, the loads of sidewalls are probably distributed to the foundation by bearing walls.

This building element should not be reported as a masonry dormer. If there is damage observed (for example wall cracks in one of the sidewalls), this can be reported under HRBE 3: Wall cracks.

Inspector Comment:

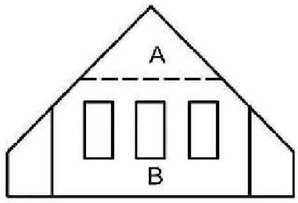
Report any observed damage in the corresponding HRBE chapter with the required comment.

Engineer Comment:

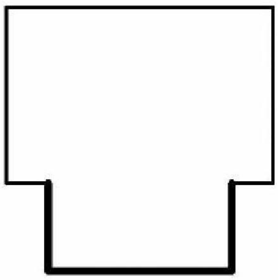
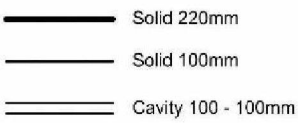
N/A

Appendix 2 Selecting wall types

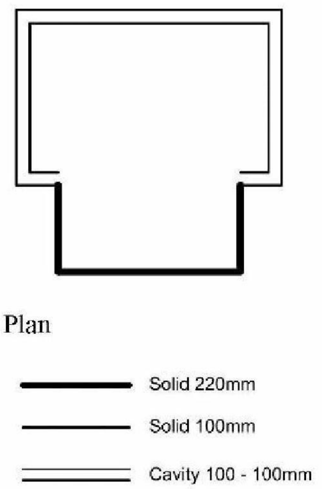
1.1 Difference between ground level and first floor level.

Solid 220mm / Solid 100mm			
	Cavity wall present	x	-
	Total wall thickness	220	-
	Wall ties	N/A	-
 Front view A: Solid 100mm B: Solid 220mm	*Data Characteristics:* The masonry bond visible on the ground floor shows a masonry bond which indicates the presence of a solid wall with a thickness of 220mm. The masonry bond visible on the first floor (gable wall) shows only stretchers.		
	Inspector Comment: -		
	Note for inspector: The section which is used to calculate the in-plane S-score is always at ground floor level. Weight of the façade is overestimated.		

1.2 Typical combinations

Solid 220mm / Solid 100mm			
	Cavity wall present	√	-
	Inner leaf	100	-
	Outer leaf	100	-
	Total wall thickness	250	-
	Wall ties	x	-
 Plan 	*Data Characteristics:* Common for typical T4 buildings (labourers cottage). The front part of the building has walls with a thickness of 220 and the back part has walls with a thickness of 100mm.		
	Inspector Comment: Due to differences in masonry patterns, cavity wall has been selected as the most conservative.		
	Note for inspector: The weight of structure is not underestimated by adopting 100mm walls and the shear area of the masonry is not overestimated.		

Solid 220mm / Cavity



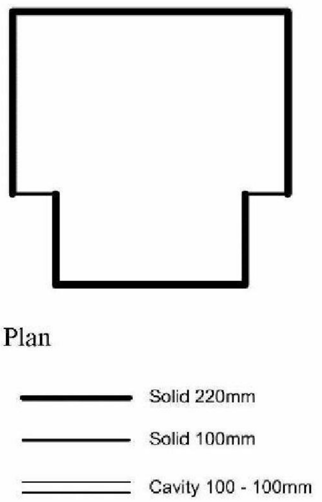
Cavity wall present	√	-
Inner leaf	100	-
Outer leaf	100	-
Total wall thickness	estimate	-
Wall ties	after 1980	-

Data Characteristics:
The front part of the building has walls with a thickness of 220mm and the back part consists of cavity walls. Usually a part of the façades has been rebuild if this combination is present.

Inspector Comment:
Due to differences in masonry patterns, cavity wall has been selected as the most conservative.

Note for inspector:
Cavity wall is the most conservative assumption for both the in-plane and out-of-plane S-score.

Solid 220mm / Solid 100mm



Cavity wall present	x	-
Total wall thickness	220mm	-
Wall ties	N/A	-

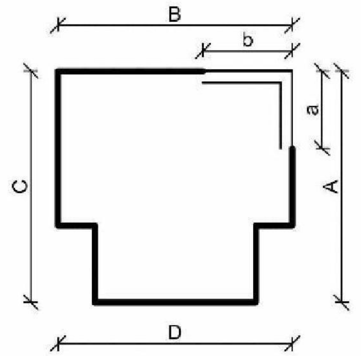
Data Characteristics:
The front majority of the external walls are walls with a thickness of 220, but the walls which connect the front part and the back part of the building consist of solid walls 100mm.

Inspector Comment:
-

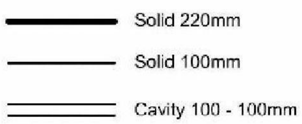
Note for inspector:
The majority of the walls in X- and Y- direction of the in-plane S-score is Solid 220mm. To select a different wall type would be over conservative.

1.3 Partially different wall types.

Solid 220mm / Cavity



Plan



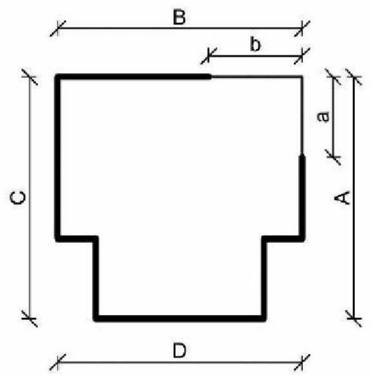
<u>Option 1:</u> a < 0.25 * (A + C) **and** b < 0.25 * (B + D)		
Cavity wall present	x	-
Total wall thickness	220	-
Wall ties	N/A	-
<u>Option 2:</u> a > 0.25 * (A + C) **or** b > 0.25 * (B + D)		
Cavity wall present	√	-
Inner leaf	100	-
Outer leaf	100	-
Total wall thickness	estimate	-
Wall ties	after 1980	-

Data Characteristics:
The majority of the external walls are walls with a thickness of 220mm, but a small part of the walls consist of cavity walls.

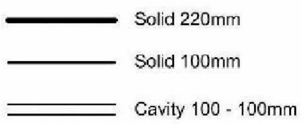
Inspector Comment:
Option 1:
-
Option 2:
Due to differences in masonry patterns, cavity wall has been selected as the most conservative.

Note for inspector:
It has been assumed that the threshold value to be conservative is when 25% of the walls in any direction are cavity walls.

Solid 220mm / Solid 100mm



Plan



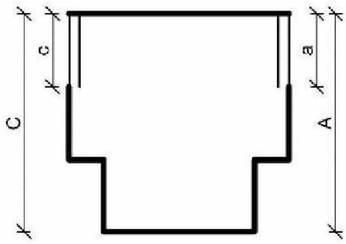
<u>Option 1:</u> a < 0.25 * (A + C) **and** b < 0.25 * (B + D)		
Cavity wall present	x	-
Total wall thickness	220	-
Wall ties	N/A	-
<u>Option 2:</u> a > 0.25 * (A + C) **or** b > 0.25 * (B + D)		
Cavity wall present	√	-
Inner leaf	100	-
Outer leaf	100	-
Total wall thickness	250	-
Wall ties	x	-

Data Characteristics:
The majority of the external walls are walls with a thickness of 220mm, but a small part of the walls consist of solid walls with a thickness of 100mm.

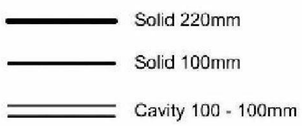
Inspector Comment:
<u>Option 1:</u>
-
<u>Option 2:</u>
Due to differences in masonry patterns, cavity wall has been selected as the most conservative.

Note for inspector:
It has been assumed that the threshold value to be conservative is when 25% of the walls in any direction are solid 100mm walls. The weight of structure is not underestimated by adopting 100mm walls and the shear area of the masonry is not overestimated.

Solid 220mm / Cavity



Plan



Option 1: (a + c) < 0.25 * (A + C)		
Cavity wall present	x	-
Total wall thickness	220	-
Wall ties	N/A	-
Option 2: (a + c) > 0.25 * (A + C)		
Cavity wall present	√	-
Inner leaf	100	-
Outer leaf	100	-
Total wall thickness	estimate	-
Wall ties	After 1980	-
Data Characteristics: The majority of the external walls have a thickness of 220mm, but a small part of the walls consist of cavity walls.		
Inspector Comment: Option 1: - Option 2: Due to differences in masonry patterns, cavity wall has been selected as the most conservative.		
Note for inspector: It has been assumed that the threshold value to be conservative is when 25% of the walls in any direction are cavity walls.		

- If only one façade is observable in one of the directions, the inspector copies this wall to the other wall. (in this case the assumed threshold value is 25% of the observable façade)

- If the majority of the walls consists of cavity walls, we select cavity walls.

1.4 Only stretchers observed, building year before ~1920

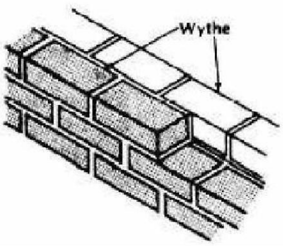
Cavity walls are not likely before the building year ~1920. Some small buildings before this year have the masonry pattern with only stretchers (see example below).

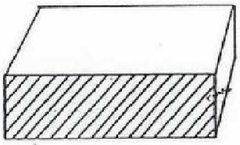
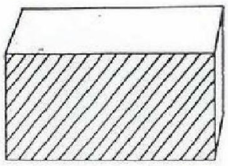
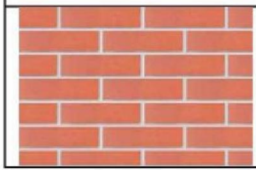
If the masonry observed is original, we can assume that the masonry visible from outside is the bearing wall, consisting of only a single wythe. If we see a significant space between the front of the façade and the front of the window frame (reveal depth/in dutch: "negge"), we assume that a backwall of shiners is present to connect the window frame. We select cavity wall as conservative assumption (without wall ties)

<table>
<tr><td>Walls with stretchers only, building year before 1920</td><td></td></tr>
<tr><td rowspan="4"></td><td>Cavity wall present √ -
Inner leaf 100mm -
Outer leaf 100mm -
Total wall thickness 250mm -
Wall ties x -</td></tr>
<tr><td>Data Characteristics:
Building year older than 1920
A significant space between the front of the façade and the front of the window frame is observed ~50mm.
The masonry observed on all facades is running bond (only stretchers) and this is assumed to be original.</td></tr>
<tr><td>Inspector Comment:
-</td></tr>
<tr><td>Note for inspector:
We assume that a backwall of shiners is present. The weight of the rowlock backwall is taken into account by selecting a cavity wall.</td></tr>
</table>

<table>
<tr><td>Walls with stretchers only, building year before 1920</td><td></td></tr>
<tr><td rowspan="4"></td><td>Cavity wall present x -
Total wall thickness 100mm -
Wall ties N/A -</td></tr>
<tr><td>Data Characteristics:
Building year older than 1920
The front of the window frame is in line with the front of the masonry.
The masonry observed on <u>all facades</u> is running bond (only stretchers) and this is assumed to be original.</td></tr>
<tr><td>Inspector Comment:
-</td></tr>
<tr><td>Note for inspector:
Make sure all facades have a running bond and all window frames are in line with the front of the masonry before selecting this wall type. This situations is very rare.</td></tr>
</table>

Walls with stretchers only, building year before 1920	
	*Cavity wall present* √ - *Inner leaf* 100mm - *Outer leaf* 100mm - *Total wall thickness* 250mm - *Wall ties* x -
	Data Characteristics: • Building year older than 1920 • The masonry observed on all facades is running bond (only stretchers). This is assumed to be **not** original.
	Inspector Comment: Possible there has been a rebuild process of the facades.
	Note for inspector: Possible there has been a rebuild process of the facades. Cavity wall and year of construction (1900), to be further investigated.

Definitions	
	**Reveal depth** Space between the front of the façade and the front of the windowframe: (see picture) Dutch: (negge /neggemaat)
	**Wythe:** Single brick wall of only stretchers, running bond. Thickness: 100mm.
	Shiner backwall: Not bearing wall consisting of shiners (Stretchers placed on the side) Thickness: 50mm.

 STRETCHER  SHINER	
	**Running bond**

Appendix 3 Recommendation for chimneys with caps or ornaments

Recommendations for chimneys with caps or ornaments

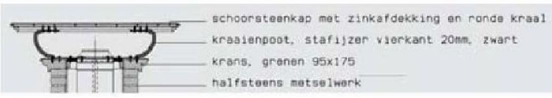
Chimneys with caps

During the inspection caps of various types and materials maybe found over masonry chimneys. If the weight of the caps is comparable to the weight of two or more layers of masonry, it maybe be un-conservative to ignore the presence of the cap when calculating the slenderness ratio of the chimney during the assessment of HRBE 7.

The following approach has been therefore suggested:

- Assess the construction material of the cap, assume an overall weight and if possible observe the connection details to the masonry below.
- If the weight of the cap is believed to exceed the equivalent weight of two masonry layers (in a typical 430mm square chimney this equates to approximately 31kg), an increase in the overall height of the chimney can be considered when checking the slenderness ratio. This extra height shall be taken equal to the height of an equivalent section of chimney with the same weight of the cap been assessed.
- If the weight of the cap is believed to be less than the equivalent weight of two masonry layers (in a typical 430mm square chimney this equates to approximately 31kg), the height of the chimney (excluding the cap) shall be taken when calculating the slenderness ratio of the chimney.
- If concerns exist in relation the weight of the cap and its connections to the masonry and it is believed that the cap may constitute an HRBE (unclear or doubtful connections to resist horizontal actions), the inspector should report the above cap in the comments accompanying the recommendation for further investigations, if this is the final recommendation for HRBE 7 or HRBE 8, otherwise the cap should be recorded under HRBE13 as heavy ornament.

The following are a few summary tables providing the assessment of some chimneys with caps been encountered to date during RVS screenings for reference and guide:

<table>
<tr><td>Chimney with caps</td><td></td></tr>
<tr><td rowspan="4">


Extracted from "Schoorstenen met kap" by Joop Wijnsema</td>
<td>HRBE 7 √ Further investigations
HRBE 13_ornament x -
None x -</td></tr>
<tr><td>Data Characteristics:
The cap of the chimney appears to be made of timber plates connected to the masonry via small diameter metal rods possibly anchored to the masonry below.
Estimated weight of cap = 0.60 KN (>2 layers)
Estimated linear density of chimney = 3.4KN/m
Equiv. extra height of chimney 0.6/3.4 = 0.18m
Chimney slenderness ratio:
x = y = 2*220 + 110 - 10 = 540mm,
z =15 (layers)*62.5 + 180 (cap) = 1117mm

<u>No action</u>: ratio < 2 (3 for ag<0.2)
<u>Further investigation</u>: Slenderness is within the limits: 2 (3 for a_g<0.2) < ratio < 4 or 4 < ratio < 6 (engineering judgment)
<u>Urgent action</u>: Slenderness within the limits: ratio > 6 or 4 < ratio < 6 (engineering judgment)</td></tr>
<tr><td>Inspector Comment:
Chimney ratio 2.0-2.5 (including cap)
Also review connections of cap frame to the chimney.</td></tr>
<tr><td>Engineer Comment to inspector:
-</td></tr>
</table>

Chimney with caps

HRBE 7	x	-
HRBE 13_ornament	√	Further investigations
None	x	-

Data Characteristics:

The cap of the chimney appears to be made of two large metal plates (the top one pyramid shaped) connected together via small diameter metal rods. The connection between the metal cap and the chimney is not clear.

Estimated weight of cap =1.0 KN (>2 layers)

Estimated linear density of chimney = 3.4KN/m

Equiv. extra height of chimney 1.0/3.4 = 0.295m

x = y = 2*220 + 110 - 10 = 540mm,

z =12 (layers)*62.5 + 295 (cap) = 1045mm

No action: ratio < 2 (3 for ag<0.2)

Further investigation: Slenderness is within the limits:
2 (3 for a_g<0.2) < ratio < 4 or
4 < ratio < 6 (engineering judgment)

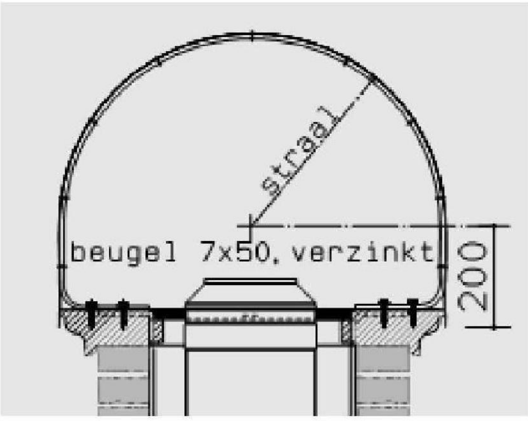
Urgent action: Slenderness within the limits:
ratio > 6 or 4 < ratio < 6 (engineering judgment)

Inspector Comment:

Chimney ratio 1.5-2.0. (including cap)

Engineer Comment to inspector:

Given the likely total weight of the cap and the uncertainty around the connections to the masonry it is recommended to record this element in HRBE13 Building ornaments with further investigations specifically to assess its connection to the masonry.

Chimney with caps			
  *Extracted from "Schoorstenen met kap" by Joop Wijnsema*	*HRBE 7*	x	-
	HRBE 13_ornament	x	-
	None	x	-
	Data Characteristics: The cap of the chimney appears to be made of a thin folded metal plate, possibly zinc. The connections are not visible. Estimated weight of cap = 0.25 KN (< 2 layers) x = y = 2*220 - 10 = 430mm, z =12 (layers)*62.5 =750mm No action: ratio < 2 (3 for ag<0.2) Further investigation: Slenderness is within the limits: 2 (3 for a_g<0.2) < ratio < 4 or 4 < ratio < 6 (engineering judgment) Urgent action: Slenderness within the limits: ratio > 6 or 4 < ratio < 6 (engineering judgment)		
	Inspector Comment: Chimney ratio 1.74 (cap not included) This cap is not believed to pose particularly higher risk than any other non-structural elements of the building.		
	Engineer Comment to inspector: -		

Chimneys with side ornaments

If there are concerns in relation the weight of the ornament and its connections to the masonry and it is believed that the ornament may constitute an HRBE (unclear or doubtful connections to resist horizontal actions), the RVS report should include the ornament in the further investigations for the chimney, if recommended for HRBE 7 or HRBE 8, or otherwise the ornament should be recorded under HRBE13 as heavy ornament.

The following table provides a proposed assessment of one chimney with an ornament for reference:

Chimney with ornaments	
	*HRBE 7* √ Urgent action *HRBE 13_ornament* x - *None* x -
	Data Characteristics: The chimney is clearly exceeding the slenderness ratio. The chimney's ornament (concrete sphere) appears heavy and the anchoring connections to the masonry unclear. No action: ratio < 2 (3 for ag<0.2) Further investigation: Slenderness is within the limits: 2 (3 for a_g<0.2) < ratio < 4 or 4 < ratio < 6 (engineering judgment) Urgent action: Slenderness within the limits: ratio > 6 or 4 < ratio < 6 (engineering judgment)
	Inspector Comment: Chimney ratio > 6. Heavy ornament present (concrete sphere).
	Engineer Comment to inspector: Also important to assess anchoring details of the ornament if a strengthening solution is required for the chimney, unnecessary if the chimney is replaced with a lightweight specimen and the ornament removed.

Appendix 4 RVS application

SECTION 1: INSPECTION INFORMATION		
ID	**Topic**	**Explanation**
1.1	Inspection reference	Provides a unique reference for the inspection and related documents (automated)
1.2	Planned inspection date	Provides the planned date for the inspection
1.3	Damage report ID (GIS)	Provides reference to NAM damage report (if available)
1.4	Date of inspection	Space to provide the date of the inspection
1.5	Is inspection possible	Space to indicate whether the object can be inspected
1.5.1 (no)	Reason if not possible	Select the reason (if present) from the list in the application: - No cooperation from user - Vision obstructed - Too far away from public realm - Private property - Continuous to other objects - Health and Safety issue - Building demolished - Other
1.6	Abandoned?	Space to indicate whether the object is abandoned • Yes • No
1.7	Situational photo(s)	Space to provide (at least) one situational photograph of the object
1.8	Comments related to inspection	Space to provide general comments about the inspection and description of the building, like the following aspects: - Terraced house, numbers: … are connected - Semi-detached house, connected to nr…. - Residential building with extension connected to the ….side - Residential building with garage connected to the ….side - Major adjoin attached to the residential building - Residential building with connection part to the barn - Due to differences in masonry patterns, cavity wall has been selected as the most conservative
1.9	Comments from owner/resident	Space to provide general comments and complaints from owner/resident

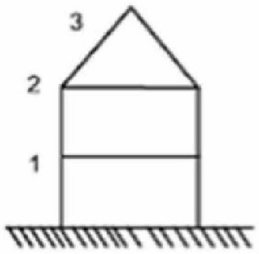
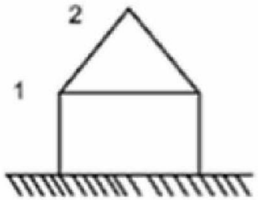
SECTION 2: EMERGENCY SITUATION		
ID	**Topic**	**Explanation**
2.1	Safety label	Select safety label from the list in the application: - Inspected (green) - Restricted use (yellow) - Unsafe (red)
2.2	Emergency situation?	Space to indicate whether there is an emergency situation regarding the current state of the object and the safety of the owner/residents. Select information from the list in the application: • Yes • No
2.2.1 (yes)	Date of emergency call	Space to fill in the date of the emergency call
2.2.2 (yes)	Time of emergency call	Space to fill in the time of the emergency call
2.2.3 (yes)	Contacted person	Space to fill in the time of the name of the contacted person
2.2.4 (yes)	Emergency protocol followed	Select information from the list in the application: • Yes • No
2.2.5 (yes)	Comments emergency situation	Space to provide comments that describe the emergency situation
2.2.6 (yes)	Photo's emergency situation	Take (at least) one picture of the current state of the object
2.2.7 (yes)	Planned timeframe for emergency interventions	Space to fill in the timeframe for emergency interventions: • < 24 hours • < 14 days

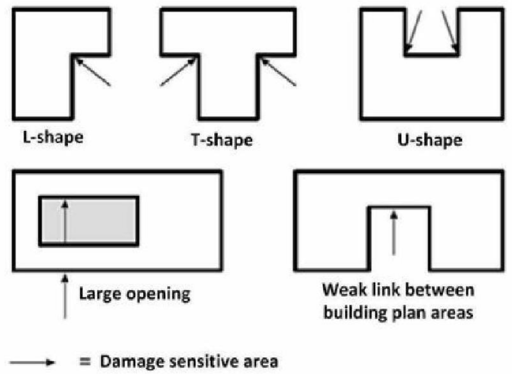
SECTION 3: ADDRESS INFORMATION		
ID	**Topic**	**Explanation**
3.1	Street	Provides street name taken from GIS
3.2	House number	Provides house number taken from GIS
3.3	Additional house number	Provides additional house number taken from GIS
3.4	Postal code	Provides postal code taken from GIS

3.5	City	Provides city name taken from GIS
3.6	Update address	Space to update address information (GIS data validation by inspector)
3.6.1	Street	Space to fill in the street name
3.6.2	House number	Space to fill in the house number
3.6.3	Additional house number	Space to fill in the additional house number
3.6.4	Postal code	Space to fill in the postal code
3.6.5	City	Space to fill in the city

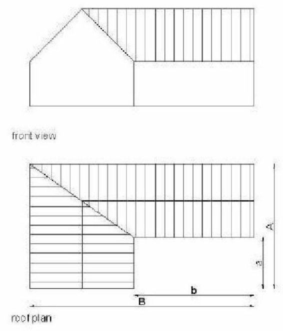
SECTION 4: OBJECT DESCRIPTION		
ID	**Topic**	**Explanation**
4.1	Address use 1	Provides information about type of object taken from GIS
4.2	BAG address use	Provides information about function of the object taken from GIS
4.3	Status of premise	Provides information about the status of the object taken from GIS
4.4	Building year	Provides information about the building year taken from GIS
4.5	Eurocode (importance) class	Provides Eurocode 8 importance class of object taken from GIS
4.6	Occupancy class	Provides occupancy class of object taken from GIS
4.7	Update object description	Space to update object description (GIS data validation by inspector)
4.7.1	Address use 1	Select type of object from the list in the application.
4.7.2	BAG address use	Select function from the list in the application
4.7.3	Status of premise	Select status from the list in the application
4.7.4	Building year	Fill in the year of construction
4.7.5	Eurocode (importance) class	Select Eurocode 8 importance class from the list in the application
4.7.6	Occupancy class	Select occupancy class from the list in the application

SECTION 5: OBJECT DIMENSIONS		
ID	**Topic**	**Explanation**
5.1	Storey height	Space to provide the (estimated) storey height of the object
5.2	Building footprint area	Provides foot print area of the object taken from GIS
5.3	Building height	Provides height of the object taken from GIS
5.4	Number of storeys	Provides the (calculated) number of storeys of the object taken from GIS The number of storeys can be determined on the basis of the figure below.

		 Number of storeys = 3  Number of storeys = 2 The number of storey is required to determine the correct mass of the building. A building consisting of one storey means a building in which only the ground floor provides habitable space, e.g. a bungalow with a flat roof. Note; a basement is not considered a storey.
5.4	Update object dimensions	Space to update object dimensions (if required).
5.4.1	Building footprint area	Space to fill in the (estimated) building footprint area
5.4.2	Building height	Space to fill in the (estimated) building height
5.4.3	Number of storeys	Space to fill in the number of storeys

SECTION 6: FORM ASPECTS		
ID	**Topic**	**Explanation**
6.1	Horizontal irregularities	Select the type of horizontal irregularity (if present) from the list in the application: • L-shape • T-shape • U-shape • Large opening • Weak link between larger building plan areas • Other If not visible this can be obtained from Aerial photos when checking the imported data. Some aspects may not be identifiable until there is access within the property boundary.  Some practical case studies of these irregularities, these are for internal use only:

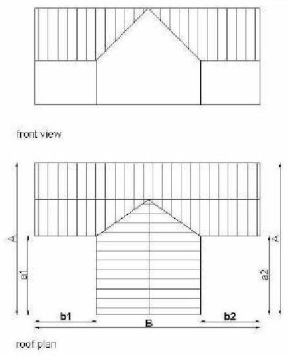
G_{H-1}



H Irregularity	√	L-shape
V Irregularity	x	-
S Irregularity	x	-

Data Characteristics:
a/A, b/B ≥ 20% (<80%)

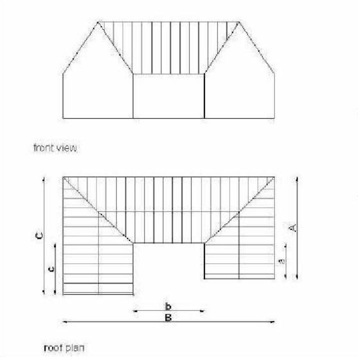
G_{H-2}



H Irregularity	√	T-shape
V Irregularity	x	-
S Irregularity	x	-

Data Characteristics:
$a_{1,2}$/A, $b_{1,2}$/B ≥ 20% (<80%)

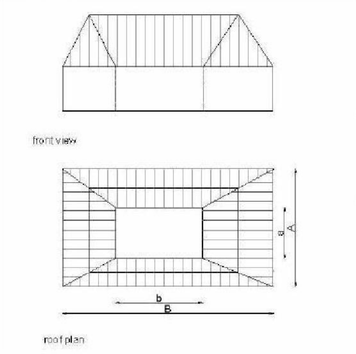
$G_{H\text{-}3}$



H Irregularity	√	U-shape
V Irregularity	x	-
S Irregularity	x	-

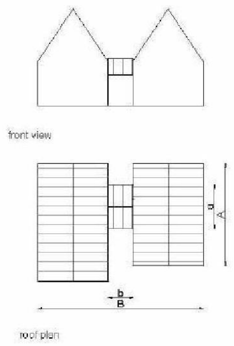
Data Characteristics:
a/A, b/B, c/C ≥ 20% (<80%)

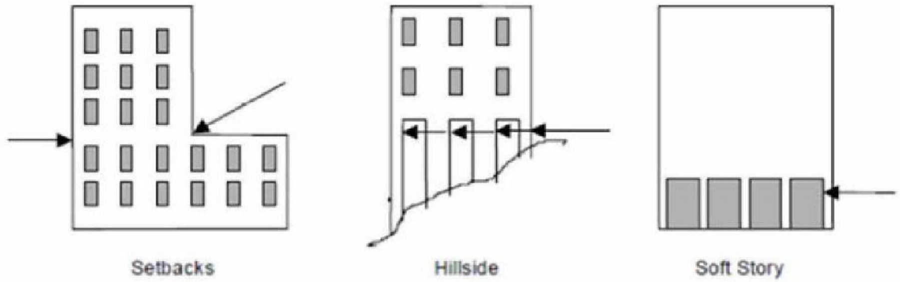
$G_{H\text{-}4}$



H Irregularity	√	Large Opening
V Irregularity	x	-
S Irregularity	x	-

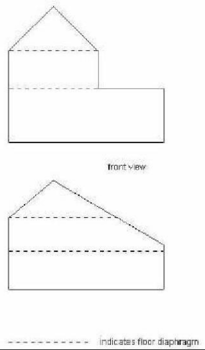
Data Characteristics:
a/A, b/B ≥ 20% (<80%)

<table>
<tr><td></td><td></td><td>
<table>
<tr><td>GH-5</td><td></td><td></td></tr>
<tr><td rowspan="3">
</td><td>H Irregularity √ Weak link
V Irregularity x -
S Irregularity x -</td></tr>
<tr><td>Data Characteristics:
a/A≤80%, b/B ≥ 10% & b/B<40%</td></tr>
<tr><td></td></tr>
</table>
<table>
<tr><td>GH-6</td><td></td></tr>
<tr><td rowspan="3"></td><td>H Irregularity √ Other
V Irregularity x -
S Irregularity x -</td></tr>
<tr><td>Data Characteristics:
-</td></tr>
<tr><td></td></tr>
</table>
</td></tr>
<tr><td>6.2</td><td>Vertical irregularities</td><td>Select the type of vertical irregularity (if present) from the list in the application:
• Setbacks
• Hill side (e.g. dike)
• Soft-storey
• Other</td></tr>
</table>



Some practical case studies of these irregularities, these are for internal use only:

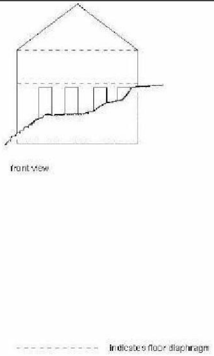
G_{V-1}



H Irregularity	x	-
V Irregularity	√	Set-back
S Irregularity	x	-

Data Characteristics:
Storey high measured at floor level

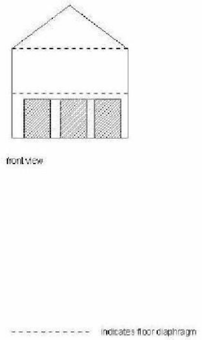
G_{V-2}



H Irregularity	x	-
V Irregularity	√	Hill-side
S Irregularity	x	-

Data Characteristics:
Storey high measured at floor level

G_{V-3}



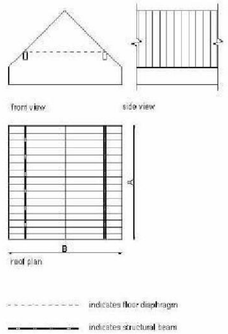
H Irregularity	x	-
V Irregularity	√	Soft-storey
S Irregularity	x	-

Data Characteristics:
-

		G_{V-4} H Irregularity x - V Irregularity √ Other S Irregularity x - Data Characteristics: -
6.3	Basement present	If there is a basement which extends the ground floor footprint or in a very relevant manner, this should be noted. For all other cases in which the basement is present, a limited extension is expected and implicit in the comment. Select information from the list in the application: • Yes • No
6.3.1	Basement photographs	Take a picture of the visible part of the basement
6.4	Roof type	Select the roof type of the object from the list in the application: • Inclined – wood structure (to be selected for all inclined roofs with roof tiles, corrugated sheet or thatch) • Flat – wood structure • Flat – concrete structure • Other (if other is selected, the S-score calculation will not run)
	Shape Irregularity	The following categories are taken from specific case studies encountered during the RVS and found to be frequent in the study area. Some examples of these irregularities are shown below:

			See sub-tables S_{I-1} and S_{I-2} below

S_{I-1}



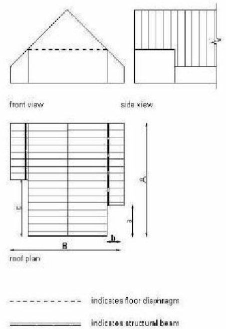
H Irregularity	x	-
V Irregularity	√	Others
S Irregularity	x	-

Data Characteristics:
- Full building lengths
- Storey high measured at floor level

Surveyor Comment:
*comments on the data measured are expected

Engineer Comment:
Potential vulnerability:
Possible differences in the resisting structural systems.

S_{I-2}



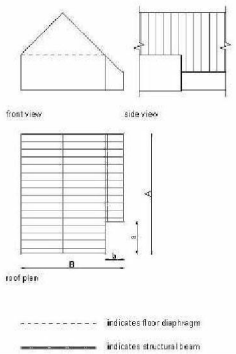
H Irregularity	√	T-shape
V Irregularity	√	Others
S Irregularity	x	-

Data Characteristics:
a,c/A, b/B ≥ 20%
- Full building lengths
- Storey high measured at floor level

Surveyor Comment:
*comments on the data measured are expected

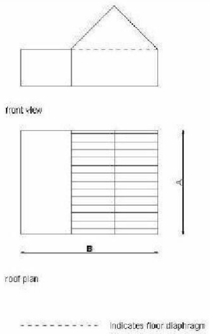
Engineer Comment:
Potential vulnerability:
Possible differences in the resisting structural systems.

S_{I-3}



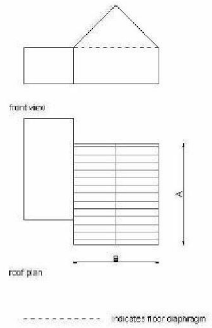
H Irregularity	√	L-shape
V Irregularity	√	Others
S Irregularity	x	-
Data Characteristics: -		
Surveyor Comment: *comments on the data measured are expected		
Engineer Comment: Potential vulnerability: Possible differences in the resisting structural systems.		

S_{I-4}



H Irregularity	x	-
V Irregularity	x	-
S Irregularity	x	-
Data Characteristics: - Full building lengths		
Surveyor Comment: *comments on the data measured are expected		
Engineer Comment: Potential vulnerability: Possible interaction of adjacent structures.		

S_{I-5}



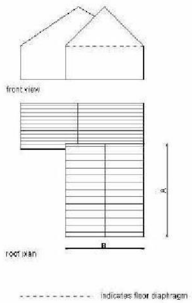
H Irregularity	x	Others
V Irregularity	x	Others
S Irregularity	√	-

Data Characteristics:
- Main building lengths only

Surveyor Comment:
*comments on the data measured are expected

Engineer Comment:
Potential vulnerability:
Possible interaction of adjacent structures.

S_{I-6}

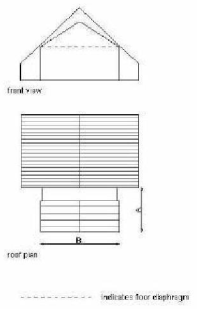


H Irregularity	x	Others
V Irregularity	x	Others
S Irregularity	√	-

Data Characteristics:
- Main building lengths only

Surveyor Comment:
Major adjoin attached to the residential building
*comments on the data measured are expected

Engineer Comment:
Potential vulnerability:
The presence of a major adjoin may determine a structural irregularity.

		$S_{I\text{-}7}$  H Irregularity: x — Weak link V Irregularity: x — Others S Irregularity: √ — - Data Characteristics: - Main building lengths only Surveyor Comment: Major adjoin attached to the residential building *comments on the residential function of the link *comments on the data measured are expected Engineer Comment: Potential vulnerability: The presence of a major adjoin may determine a structural irregularity.

SECTION 7: STRUCTURAL MATERIALS		
ID	**Topic**	**Explanation**
7.1	Main wall material	Provides the (assumed) main wall material of the object taken from GIS
7.2	Ground floor material	Provides the (assumed) ground floor material of the object taken from GIS
7.3	Higher floor material	Provides the (assumed) higher floor material of the object taken from GIS
7.4	Update building material	Space to update building materials (if required and when possible to estimate during the rapid visual screening) Select the main wall material of the object from the list in the application: • Wood • Concrete • Steel • Unreinforced masonry • Limestone (Calcium Silicate) • Other • Unknown S-score calculation only valid for concrete, unreinforced masonry and calcium silicate. Select the ground floor material of the object from the list in the application:

		• Wood • Concrete • Sand ground • Other Select the higher floor material of the object from the list in the application: • Wood • Concrete • Steel • Nehobo • Other S-score calculation only valid for wood, concrete and Nehobo

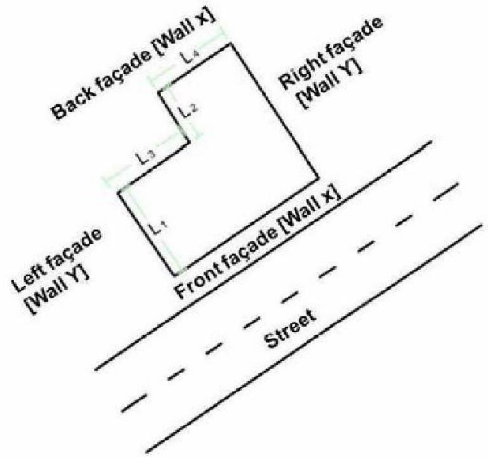
SECTION 8: STRUCTURAL CHARACTERISTICS		
ID	**Topic**	**Explanation**
8.1	Structural certainty	Space to provide information about the certainty of the information provided about the structure of the object Select the structural certainty of the object from the list in the application: • Observation • Assumption
8.2	Joint structure	Space to provide information whether the object is connected to another object through the wall in between both objects. Select whether the object is connected from the list in the application: • Yes • No
8.3	Foundation type	Space to provide information about the (estimated) type of foundation. Select type of foundation from the list in the application: • Wooden piles • Concrete piles • Masonry strip foundation • Concrete strip foundation • Masonry footings • Concrete footings • Unknown
8.4	Cavity walls	Space to provide information whether the main load bearing walls of the object consist of cavity walls. Select information from the list in the application:

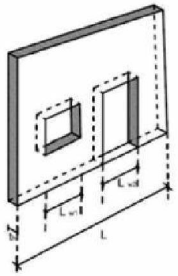
		• Yes • No • Unknown If "Yes" is selected the following information ID 8.4.1 to 8.4.3 is requested.
8.4.1	Thickness inner leaf	Space to fill in the thickness inner leaf
8.4.2	Thickness outer leaf	Space to fill in the thickness outer leaf
8.4.3	Presence of adequate wall ties	Space to select the presence of adequate wall ties. Select information from the list in the application: • Yes • No • Unknown
8.5	Total wall thickness	Space to fill in the total wall thickness (cavity or solid wall) *A masonry building can be composed with different wall types within the building layout. Considering that it is not possible to select more than one wall type for the same building, there should be at least a consistent approach for this screening. The following scenarios have been encountered:* • *Wall types can differ between ground level and first floor level.* • *Buildings can have a combination of Solid walls 220mm and cavity walls.* • *Buildings can have a combination of Solid walls 220mm and solid 100mm walls.* *Examples to approach the different wall types are included in appendix 2 and serve as input for the RVS report.*
8.6	Presence of wall-floor-roof ties	Space to select the presence of wall-floor ties, wall-roof ties and floor-roof ties. Select information from the list in the application: • Yes • No • Unknown

SECTION 9: MAINTENANCE LEVEL		
ID	**Topic**	**Explanation**
9.1	General maintenance level	Space to provide information about the general maintenance level of the object. Select information from the list in the application: • Very bad • Bad

		• Moderate • Good • Very good
9.2	Deterioration masonry	Space to provide information about deterioration of masonry. Select information from the list in the application: • Yes • No
9.3	Deterioration of mortar	Space to provide information about deterioration of the mortar. Select information from the list in the application: • None • Brittle • Eroded
9.4	Deterioration concrete	Space to provide information about deterioration of the concrete. Select information from the list in the application: • Yes • No
9.5	Deterioration steel	Space to provide information about deterioration of steel and steel elements. Select information from the list in the application: • None • Corrosion • Fractured • Loosened
9.6	Deterioration wood	Space to provide information about deterioration of wood and wooden elements. Select information from the list in the application: • None • Decay • Shrinkage • Fire damage • Sagging

SECTION 10: FACADE INSPECTION		
ID	**Topic**	**Explanation**
10.1	Front facade	Space to provide information about the front facade of the object: • Inspection possible (yes/no) ○ No

		- No cooperation from user - Vision obstructed - Too far away from public space - Private property - Continuous to other objects - Health and Safety issue - Building demolished - Other • Facade length (m)  • Average facade height (m) • Total area of facade (m^2) • Openings (%)

		 *Openings given as a percentage of the length of the wall.* *Percentage openings = 100 · [(L$_{w1}$ + L$_{w2}$) / L]* • Certainty (assumption/observation)
10.1.1	Photo facade	Take (at least) one picture of the facade

10.2	Right facade	Space to provide information about the right facade of the object:
		• Inspection possible (yes/no)
		   o No
		      - No cooperation from user
		      - Vision obstructed
		      - Too far away from public space
		      - Private property
		      - Continuous to other objects
		      - Health and Safety issue
		      - Building demolished
		      - Other
		• Facade length (m)
		• Average facade height (m)
		• Total area of facade (m^2)
		• Openings (%)
		• Certainty (assumption/observation)

10.2.1	Photo facade	Take (at least) one picture of the facade

10.3	Back facade	Space to provide information about the back facade of the object:
		• Inspection possible (yes/no)
		   o No
		      - No cooperation from user
		      - Vision obstructed
		      - Too far away from public space
		      - Private property

		- Continuous to other objects - Health and Safety issue - Building demolished - Other • Facade length (m). *Façade length back facade equal to* $L_3 + L_4$ • Average facade height (m) • Total area of facade (m^2) • Openings (%) • Certainty (assumption/observation)
10.3.1	Photo facade	Take (at least) one picture of the facade
10.4	Left facade	Space to provide information about the left facade of the object: • Inspection possible (yes/no) o No - No cooperation from user - Vision obstructed - Too far away from public space - Private property - Continuous to other objects - Health and Safety issue - Building demolished - Other • Facade length (m) *Facade length left facade equal to* $L_1 + L_2$ • Total area of facade (m^2) • Openings (%) • Certainty (assumption/observation)
10.4.1	Photo facade	Take (at least) one picture of the facade
10.5	Comments related to facades	Space to provide comments about the facade inspection

Table 3 – sections 1-10

SECTION 11: HIGH RISK BUILDING ELEMENTS (HRBE)		
ID	**Topic**	**Explanation**
11.1	HRBE 1: Gables & Walls out of plane	Space to provide information about presence of gable with visible rotation mechanism.

		Space to provide information about walls showing one of the following out of plane deficiencies (if present). Select information from the list in the application: • No • Wall out of plumb • Bulging wall • Gable wall Space to provide recommendations regarding HRBE. Select information from the list in the application: • Further investigation • No immediate/direct action required • Urgent actions
11.1.1	Comments (yes)	Space to provide comments
11.1.2	Photo (yes)	Take (at least) one picture of the element(s)
11.2	HRBE 2: Column slenderness issues & cracks	Space to provide information about presence of slender columns. Space to provide information about concrete columns showing cracks (if present). Select information from the list in the application: • Yes • No Space to provide recommendations regarding HRBE. Select information from the list in the application: • Further investigation • No immediate/direct action required • Urgent actions
11.2.1	Comments (yes)	Space to provide comments
11.2.2	Photo (yes)	Take (at least) one picture of the element(s)
11.3	HRBE 3: Wall cracks	Space to provide information about wall cracks (if present). Select information from the list in the application: • Yes • No Space to provide recommendations regarding HRBE. Select information from the list in the application: • Further investigation • No immediate/direct action required • Urgent actions
11.3.1	Comments (yes)	Space to provide comments
11.3.2	Photo (yes)	Take (at least) one picture of the element(s)
11.4	HRBE 4: Deflected/cracked lintels	Space to provide information about deflected/cracked lintels (if present). Select information from the list in the application: • Yes

		• No Space to provide recommendations regarding HRBE. Select information from the list in the application: • Further investigation • No action required • Urgent actions
11.4.1	Comments (yes)	Space to provide comments
11.4.2	Photo (yes)	Take (at least) one picture of the element(s)
11.5	HRBE 5: Damage caused by lack of ties	Space to provide information about damage caused by the lack of adequate floor-wall ties and wall-roof ties (if present). Select information from the list in the application: • Yes • No Space to provide recommendations regarding HRBE. Select information from the list in the application: • Further investigation • No action required • Urgent actions
11.5.1	Comments (yes)	Space to provide comments
11.5.2	Photo (yes)	Take (at least) one picture of the element(s)
11.6	HRBE 6: Parapet(s)-Balcony(s)-Cantilevered elements-Canopies	Space to provide information about presence of parapets, balconies, cantilevered elements and canopies. Select information from the list in the application: • HRBE 6.1: Parapets present (Yes/No) • HRBE 6.2: Balconies present (Yes/No) • HRBE 6.3: Cantilevered elements present (Yes/No) • HRBE 6.4: Canopies present (Yes/No) Space to provide recommendations regarding HRBE. Select information from the list in the application: • Further investigation • No action required • Urgent actions
11.6.1	Photo 6.1	Take (at least) one picture of the element(s)
11.6.2	Photo 6.2	Take (at least) one picture of the element(s)
11.6.3	Photo 6.3	Take (at least) one picture of the element(s)
11.6.4	Photo 6.4	Take (at least) one picture of the element(s)
11.6.5	Comments (yes)	Space to provide comments
11.7	HRBE 7: Slender chimney(s) present?	Space to provide information about presence of slender chimneys. Select information from the list in the application: • Yes • No Space to provide recommendations regarding HRBE. Select information from the list in the application:

		• Further investigation • No action required • Urgent actions
11.7.1	Comments (yes)	Space to provide comments (report the ratio)
11.7.2	Photo (yes)	Take (at least) one picture of the element(s)
11.8	HRBE 8: Damaged chimney present?	Space to provide information about damaged chimneys (if present). Select information from the list in the application: • Yes • No To provide recommendations regarding HRBE chimney likely to be (partly) supported by timber beams. Select information from the list in the application: • Further investigation • No action required • Urgent actions
11.8.1	Yes	Select information from the list in the application: • Deformed • Rotated • Standing skew • Wood supported
11.8.2	Comments (yes)	Space to provide comments
11.8.3	Photo (yes)	Take (at least) one picture of the element(s)
11.9	HRBE 9: Unsafe roof cladding or loose bricks on gable walls	Space to provide information about unsafe roof cladding or loose bricks on gable walls (if present). Select information from the list in the application: • Yes • No Space to provide recommendations regarding HRBE. Select information from the list in the application: • Further investigation • No action required • Urgent actions
11.9.1	Comments (yes)	Space to provide comments
11.9.2	Photo (yes)	Take (at least) one picture of the element(s)
11.10	HRBE 10: Damaged/lack of mortar	To provide information about damaged or lack of mortar between bricks in the masonry (if present). Select information from the list in the application: • Yes • No Space to provide recommendations regarding HRBE. Select information from the list in the application: • Further investigation

		• No action required • Urgent actions
11.10.1	Comments (yes)	Space to provide comments
11.10.2	Photo (yes)	Take (at least) one picture of the element(s)
11.11	HRBE 11: Masonry dormer(s)	Space to provide information about the presence of masonry dormer(s). Select information from the list in the application: • Yes • No To provide recommendations regarding HRBE. Select information from the list in the application: • Further investigation • No action required • Urgent actions
11.11.1	Comments (yes)	Space to provide comments
11.11.2	Photo (yes)	Take (at least) one picture of the element(s)
11.12	HRBE 12: Lack of ties in cavity walls	Space to provide information about the presence of visible damage to walls likely to be caused by the lack of adequate wall ties. Select information from the list in the application: • Yes • No Space to provide recommendations regarding HRBE. Select information from the list in the application: • Further investigation • No action required • Urgent actions
11.12.1	Comments (yes)	Space to provide comments
11.12.2	Photo (yes)	Take (at least) one picture of the element(s)
11.13	HRBE 13: Other damage	Space to provide information about the presence of other types of HRBE. Space to provide information about other damage to the object observed during the screening (if present). Select information from the list in the application: • Yes • No Space to provide recommendations regarding HRBE. Select information from the list in the application: • Further investigation • No action required • Urgent actions
11.13.1	Comments (yes)	Space to provide comments
11.13.2	Photo (yes)	Take (at least) one picture of the element(s)

Table 4 – section 11

SECTION 12: SOLAR CELLS PRESENT		
ID	**Topic**	**Explanation**
12.1	Solar cells present	Space to provide information about the presence of solar cells on the roof of the object. Select information from the list in the application: • Yes • No
12.1.1	Photo (yes)	Take (at least) one picture of the solar cells
12.2	Roof suitable for solar cells (optional)	Space to provide information whether the roof is suitable for the installation of solar cells. Select information from the list in the application: • Yes • No

SECTION 13: CONFIRMATION INSPECTOR		
ID	**Topic**	**Explanation**
13.1	Confirmation inspector	Confirm (by signing off the inspection application) that the inspection is complete: • Name inspector • Signature

Appendix 5 S-score calculations process

This table describes the information gathered for the S-score calculation and the process of defining the score.

No	Step	Explanation	Input from	Result
1	Geometry	Collect data from RVS inspection application regarding the geometry of the building. 1) Building footprint 2) Storey height 3) Main wall material 4) Higher floor material 5) Roof type 6) Year of construction 7) Number of storeys 8) Cavity walls - Wall thickness, thickness inner leaf, thickness outer leaf - Presence of adequate wall ties 9) Presence of wall-floor-roof ties 10) Facade information - Total area of facade, length of facade, openings percentage	ID 5.2 ID 5.1 ID 7.1 ID 7.3 ID 6.4 ID 4.4 ID 5.4 ID 8.4 ID 8.4.3 ID 8.6 ID 10.1, 10.2, 10.3, 10.4	Input information for in-plane and out-of-plane S-score calculation
2	Calculation shear wall area	Calculation of the average height of the walls and the minimum shear wall area available to withstand seismic loads on the object. Minimum shear wall area is calculated based on the facade length, wall thickness and openings percentage. For the wall thickness, only the load bearing part is considered. 11) Average height 12) Shear wall area	ID 5.3, 5.4.2 ID 10.1, 10.2, 10.3, 10.4	Minimum shear wall area
3	Calculation of the seismic weight of the object	The seismic weight of the object is calculated based on the information from the RVS inspection application 1) Building footprint 8) Cavity walls 10) Facade information	ID 5.2, 5.4.1 ID 8.4 ID 10.1, 10.2, 10.3, 10.4	Seismic weight of the building
4	Calculation of the seismic loads on the object	The seismic loads on the object and the average base shear stress is calculated based on the information from the RVS inspection application and GIS-database 13) Seismic hazard - Peak ground acceleration - Response spectrum 14) Eurocode Imprtance Class	11) average wall height 12) shear wall area ID 4.5	Fundamental period T Spectral acceleration $S_d(T)$ Base shear force Base shear stress
5	Determine adjustment factors (in-plane)	Adjustment factors are applied for the year of construction, seismic hazard and the irregularities 6) Year of construction 15) Reference wall shear stress and reference surface PGA 16) Vertical irregularities 17) Horizontal irregularities	ID 4.4 ID 6.2 ID 6.1	Adjusted median PGA for DS4 fragility curve (in-plane)
6	Determine S-score (in-plane)	Calculate in-plane S-score based on the adjusted median PGA for DS4 fragility curve and the raw standard deviation for the DS4 fragility curve		**In-plane S-score**
7	Wall out-of-plane S-score	Determine the height-to-thickness ratio of the walls 2) Storey height 8) Cavity walls - Wall thickness, thickness inner leaf, thickness outer leaf - Presence of adequate wall ties	ID 5.1 ID 8.4	H/T-ratio
8	Determine adjustment factors (out-of-plane)	Adjustment factors are applied for the number of storeys, the presence of wall ties, the presence of wall-floor-roof ties 7) Number of storeys 8) Cavity walls - Wall thickness, thickness inner leaf, thickness outer leaf - Presence of adequate wall ties 9) Presence of wall-floor-roof ties	ID 5.3 ID 8.4.1, 8.4.2, 8.4.3 ID 8.6	Adjusted median PGA for DS4 fragility curve (out-of-plane)
9	Determine S-score (out-of-plane)	Calculate out-of-plane S-score based on the adjusted median PGA for DS4 fragility curve and the raw standard deviation for the DS4 fragility curve		**Out-of-plane S-score**