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TG1 Module 1 - PvA

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TG1 – Sub-group for Module 1: Out-of-plane failure of URM walls

Plan of Approach for phase 3

As presented during the meeting of the TG1 on 08 October 2019, the work of "Module 1: Out-of-plane failure of URM walls" is divided into three main topics:

1. Two-way bending resistance of three- and four-side restrained walls.
2. Definition of the secondary spectra.
3. Interaction between in-plane and out-of-plane behaviour of the walls.

Following the discussion, two more topics has been added:

4. Definition of the out-of-plane capacity of gables.
5. Calibration of NLKA for one-way bending walls against experimental shake table tests.

It should be noted that these topics are partially related one to each other and that the classification of a task or action into a specific topic is arbitrary. However, for each topic position papers or other documents can be produced at different stages of the process without the need of waiting for the eventual release of the updated version of NPR 9998.

A preliminary list of references classified for topic is included in [1]. More details about the sub-modules 1-3 are provided in [2].

In the following sections, a concise plan of approach inclusive of expected elapsed time and expected costs is described for each sub-module.

1. TWO-WAY BENDING RESISTANCE OF THREE- AND FOUR-SIDE RESTRAINED WALLS

The work for this sub-module aims at the formulation of a consistent procedure to assess the out-of-plane capacity of walls restrained on three or four sides. The current version of NPR 9998 [3] already allows to compute the resistance of the walls based on two-way bending mechanisms, but it does not provide any specific recommendation. It is then suggested to adopt a virtual work approach as presented in the Australian standard AS 3700 [4], and further refined by later works [5], [6].

The approach requires some additional studies to be adapted for the specific case of Groningen. Besides, experimental data are used to validate the proposed formulation and to compare the accuracy of the results obtained following it with those following the formulation recommended in NPR 9998:2018 for one-way walls. Finally, tables and/or plots that facilitate the application of the proposed formulation as well as a calculation example are produced.

Tasks, expected deliverables, elapsed time and parties involved are summarised in Table 1. A summary timetable is presented in Table 2. It should be noted that "month 1" in the timetable starts after that the project is approved by the minister and a contract with NEN is signed. The total number of hours expected to complete the sub-module 1 is presented in Table 3, with a division of the number of hours for each task.

It should be noted that the work of task 5 (Elaboration of virtual tests to provide benchmarks) will be partially re-used in other sub-modules.

Table 1. Summary of the tasks of sub-module 1. For each task the expected deliverable, the elapsed time and the parties involved are listed.

#	Task	Deliverable	Elapsed time	Parties involved
1	Review available literature	Reference list	2 months	TU Delft, BORG
2	Definition tensile strength masonry bricks and elements	Memorandum	1 month	TU Delft
3	Assessment of the EUCENTRE proposal on the change of boundary conditions during earthquakes	Memorandum	1 month	TU Delft, BORG
4	Intermediate report on applicability method proposed by Eucentre	Report	2 months	TU Delft, BORG
5	Elaboration outcomes of virtual tests to provide benchmarks*	Memorandum	3 months	ARUP, TNO
6	Comparison proposed formulation against experimental data and *virtual tests*	Memorandum	3 months	TU Delft, BORG, ARUP, TNO
7	Definition limits of applicability of proposed procedure	Memorandum	1 month	TU Delft, BORG, ARUP, TNO
8	Experimental determination of torsional strength of masonry	Report	4 months	TU Delft
9	Create tables/plots for application of the proposed formulation	Tables/Plots	1 months	TU Delft, BORG
10	Draft a calculation example	Calculation example	1 month	TU Delft, BORG
11	Draft a proposal to update Annex H	Report	2 months	TU Delft, BORG

12	Draft the background report	Report	2 months	TU Delft, BORG

* partially performed in tasks of the other sub-modules

Table 2. Timetable for sub-module 1. The red line indicates the start of Phase 3 of the project.

#	Task	Phase 3: Month								
		0	1	2	3	4	5	6	7	8
1	Review available literature									
2	Definition tensile strength masonry...									
3	Assessment of the EUCENTRE...									
4	Intermediate report on applicability...									
5	Elaboration outcomes of virtual...*									
6	Validation of the formulation...									
7	Definition limits of applicability...									
8	Experimental determination of...									
9	Create tables/plots for application...									
10	Draft a calculation example									
11	Draft a proposal to update Annex H									
12	Draft the background report									

* partially performed in tasks of the other sub-modules

Table 3. Expected no. of working hours for each party involved in sub-module 1.

#	Task	Party			
		TU Delft	BORG	ARUP	TNO
1	Review available literature	? hours	? hours	-	-
2	Definition tensile strength masonry...	? hours	-	-	-
3	Assessment of the EUCENTRE...	? hours	? hours	-	-
4	Intermediate report on applicability...	? hours	? hours	-	-
5	Elaboration outcomes of virtual ...*	-	-	? hours	? hours
6	Validation of the formulation...	? hours	? hours	? hours	? hours
7	Definition limits of applicability...	? hours	? hours	? hours	? hours
8	Experimental determination of...	? hours	? hours	-	-
9	Create tables/plots for application...	? hours	? hours	-	-
10	Draft a calculation example	? hours	? hours	-	-
11	Draft a proposal to update Annex H	? hours	? hours	-	-
12	Draft the background report	? hours	? hours	-	-
-	**TOTAL**	**Tot no. hours**	**Tot no. hours**	**Tot no. hours**	**Tot no. hours**

* partially performed in tasks of the other sub-modules

2. DEFINITION OF THE SECONDARY SPECTRA

The work for this sub-module aims at the formulation of a consistent definition of the secondary spectra. The formulation currently included in Annex H is in accordance with Eurocode 8 - part 3 [7]. In a commentary provided by EUCENTRE [6], the elastic floor response spectra derived according to Annex H was compared with the response of full-scale house experiments and numerical models of index buildings. The comparison highlighted large discrepancies between predictions and experimental/numerical outcomes. BORG recently proposed a revision of the formulation recommended in the NZ standard [8]. The revision was based on the numerical investigation carried out by a TU Delft MSc student for the final thesis in collaboration with BORG [9]. The MSc thesis introduces an adjustment of the NZ standard to the specific ground motions and buildings in the province of Groningen.

In this sub-module the work proposed in [9] will be validated and extended to different building typologies.

Tasks, expected deliverables, elapsed time and parties involved are summarised in Table 4. A summary timetable is presented in Table 5. Once more, it should be noted that "month 1" in the timetable starts after that the project is approved by the minister and a contract with NEN is signed.

The total number of hours expected to complete the sub-module 2 is presented in Table 6, with a division of the number of hours for each task.

It should be noted that part of the work planned for task 3 is also used for task 5 of sub-module 1.

Table 4. Summary of the tasks of sub-module 1. For each task the expected deliverable, the elapsed time and the parties involved are listed.

#	Task	Deliverable	Elapsed time	Parties involved
1	Review available literature	Reference list	2 months	TU Delft, BORG
2	Adaptation of the study of N. Galanakis	Memorandum	2 months	BORG
3	Elaboration outcomes of virtual tests to provide benchmarks*	Memorandum	3 months	ARUP, TNO
4	Development secondary spectra based on the proposed method	Memorandum	2 months	BORG
5	Validation of the proposed method against the benchmarks	Memorandum	2 months	BORG
6	Extension to MDOF for rigid floors	Report	3 months	TU Delft, BORG
7	Extension to MDOF for flexible floors	Report	3 months	TU Delft, BORG
8	Create tables/plots for application of the proposed formulation	Tables/Plots	3 months	BORG
9	Draft a calculation example	Calculation example	2 months	TU Delft, BORG
10	Draft a proposal to update Annex H	Report	2 months	TU Delft, BORG
11	Draft the background report	Report	2 months	TU Delft, BORG

* partially performed in tasks of the other sub-modules

Table 5. Timetable for sub-module 1. The red line indicates the start of Phase 3 of the project.

#	Task	Phase 3: Month									
		0	1	2	3	4	5	6	7	8	9
1	Review available literature										
2	Adaptation of the study of Galanakis										
3	Elaboration outcomes of virtual...*										
4	Development secondary spectra...										
5	Validation of the proposed method...										
6	Extension to MDOF for rigid floors										
7	Extension to MDOF for flexible floors										
8	Create tables/plots for application of...										
9	Draft a calculation example										
10	Draft a proposal to update Annex H										
11	Draft the background report										

* partially performed in tasks of the other sub-modules

Table 6. Expected no. of working hours for each party involved in sub-module 1.

#	Task	Party			
		TU Delft	BORG	ARUP	TNO
1	Review available literature	? hours	? hours	-	-
2	Adaptation of the study of Galanakis	-	-	? hours	? hours
3	Elaboration outcomes of virtual...*	-	? hours	-	-
4	Development secondary spectra...	-	? hours	-	-
5	Validation of the proposed method...	-	? hours	-	-
6	Extension to MDOF for rigid floors	? hours	? hours	-	-
7	Extension to MDOF for flexible floors	? hours	? hours	-	-
8	Create tables/plots for application of...	-	? hours	-	-
9	Draft a calculation example	? hours	? hours	-	-
10	Draft a proposal to update Annex H	? hours	? hours	-	-
11	Draft the background report	? hours	? hours	-	-
-	**TOTAL**	**Tot no. hours**	**Tot no. hours**	**Tot no. hours**	**Tot no. hours**

* partially performed in tasks of the other sub-modules

3. INTERACTION BETWEEN IN-PLANE AND OUT-OF-PLANE BEHAVIOUR OF THE WALLS

The work for this sub-module aims at identifying when the interaction between the in-plane and the out-of-plane mechanisms may lead to unconservative results if NLPO and NLKA methods are used to assess the seismic vulnerability of the structure. The goal can be achieved by considering numerical nonlinear time-history analyses of complete URM buildings, with the models used in these numerical simulations being validated against a number of experimental tests. The numerical simulations are then considered as *virtual tests*. The analysis and interpretation of these virtual tests can allow then to determine in what conditions the in-plane / out-of-plane interaction cannot be neglected.

Tasks, expected deliverables, elapsed time and parties involved are summarised in Table 7. A summary timetable is presented in Table 8. Once more, it should be noted that "month 1" in the timetable starts after that the project is approved by the minister and a contract with NEN is signed. The total number of hours expected to complete the sub-module 2 is presented in Table 9, with a division of the number of hours for each task.

It should be noted that the elaboration of the outcomes of the virtual tests is partially used also in the other sub-modules.

Table 7. Summary of the tasks of sub-module 1. For each task the expected deliverable, the elapsed time and the parties involved are listed.

#	Task	Deliverable	Elapsed time	Parties involved
1	Review available literature	Reference list	1 month	TU Delft, BORG, ARUP, TNO
2	Elaboration outcomes of virtual tests*	Memorandum	3 months	ARUP, TNO
3	Interpretation study	Memorandum	2 months	TU Delft, BORG, ARUP, TNO
4	Report of conclusions	Report	1 months	TU Delft, BORG, ARUP, TNO

* partially performed in tasks of the other sub-modules

Table 8. Timetable for sub-module 1. The red line indicates the start of Phase 3 of the project.

#	Task	Phase 3: Month					
		0	1	2	3	4	5
1	Review available literature						
2	Elaboration outcomes of virtual tests*						
3	Interpretation study						
4	Report of conclusions						

* partially performed in tasks of the other sub-modules

Table 9. Expected no. of working hours for each party involved in sub-module 1.

#	Task	Party			
		TU Delft	BORG	ARUP	TNO
1	Review available literature	? hours	? hours	? hours	? hours
2	Elaboration outcomes of virtual tests*	-	-	? hours	? hours
3	Interpretation study	? hours	? hours	? hours	? hours
4	Report of conclusions	? hours	? hours	? hours	? hours
-	**TOTAL**	**Tot no. hours**	**Tot no. hours**	**Tot no. hours**	**Tot no. hours**

* partially performed in tasks of the other sub-modules

4. OUT-OF-PLANE CAPACITY OF GABLES

The work for this sub-module aims at identifying the capacity of gables. Both experimental and numerical tests will be considered in the task. Similar to the previous sub-module, once more the virtual tests will be used, along with the few experimental tests performed specifically for gables.

Tasks, expected deliverables, elapsed time and parties involved are summarised in Table 10. A summary timetable is presented in Table 11. Once more, it should be noted that "month 1" in the timetable starts after that the project is approved by the minister and a contract with NEN is signed.

The total number of hours expected to complete the sub-module 4 is presented in Table 12, with a division of the number of hours for each task.

Table 10. Summary of the tasks of sub-module 1. For each task the expected deliverable, the elapsed time and the parties involved are listed.

#	Task	Deliverable	Elapsed time	Parties involved
1	Review available literature	Reference list	1 month	TU Delft, BORG, ARUP, TNO
2	Elaboration outcomes of virtual tests*	Memorandum	3 months	ARUP, TNO
3	Interpretation study	Memorandum	1 months	TU Delft, BORG, ARUP, TNO
4	Report of conclusions	Report	1 months	TU Delft, BORG, ARUP, TNO

* partially performed in tasks of the other sub-modules

Table 11. Timetable for sub-module 1. The red line indicates the start of Phase 3 of the project.

#	Task	Phase 3: Month					
		0	1	2	3	4	5
1	Review available literature						
2	Elaboration outcomes of virtual tests*						
3	Interpretation study						
4	Report of conclusions						

* partially performed in tasks of the other sub-modules

Table 12. Expected no. of working hours for each party involved in sub-module 1.

#	Task	Party			
		TU Delft	BORG	ARUP	TNO
1	Review available literature	? hours	? hours	? hours	? hours
2	Elaboration outcomes of virtual tests*	-	-	? hours	? hours
3	Interpretation study	? hours	? hours	? hours	? hours
4	Report of conclusions	? hours	? hours	? hours	? hours
-	**TOTAL**	**Tot no. hours**	**Tot no. hours**	**Tot no. hours**	**Tot no. hours**

* partially performed in tasks of the other sub-modules

5. CALIBRATION OF NLKA FOR ONE-WAY BENDING WALLS AGAINST EXPERIMENTAL SHAKE TABLE TESTS

The work for this sub-module aims at studying the dynamic instability displacement and assess whether the formulation currently provided for one-way bending walls is appropriate or should be revised. Once more, both experimental and virtual numerical tests will be considered in the task.

Tasks, expected deliverables, elapsed time and parties involved are summarised in Table 13. A summary timetable is presented in Table 14. Once more, it should be noted that "month 1" in the timetable starts after that the project is approved by the minister and a contract with NEN is signed.

The total number of hours expected to complete the sub-module 4 is presented in Table 15, with a division of the number of hours for each task.

Table 13. Summary of the tasks of sub-module 1. For each task the expected deliverable, the elapsed time and the parties involved are listed.

#	Task	Deliverable	Elapsed time	Parties involved
1	Review available literature	Reference list	2 months	TU Delft, BORG
2	Elaboration outcomes of virtual tests*	Memorandum	3 months	ARUP, TNO
3	Comparison of NLKA results against experiments and virtual tests	Memorandum	1 months	TU Delft, BORG, ARUP, TNO
4	Report of conclusions	Report	1 months	TU Delft, BORG, ARUP, TNO

* partially performed in tasks of the other sub-modules

Table 14. Timetable for sub-module 1. The red line indicates the start of Phase 3 of the project.

#	Task	Phase 3: Month					
		0	1	2	3	4	5
1	Review available literature						
2	Elaboration outcomes of virtual tests*						
3	Comparison of NLKA results against...						
4	Report of conclusions						

* partially performed in tasks of the other sub-modules

Table 15. Expected no. of working hours for each party involved in sub-module 1.

#	Task	Party			
		TU Delft	BORG	ARUP	TNO
1	Review available literature	? hours	? hours	-	-
2	Elaboration outcomes of virtual tests*	-	-	? hours	? hours
3	Comparison of NLKA results against...	? hours	? hours	? hours	? hours
4	Report of conclusions	? hours	? hours	? hours	? hours
-	**TOTAL**	**Tot no. hours**	**Tot no. hours**	**Tot no. hours**	**Tot no. hours**

* partially performed in tasks of the other sub-modules

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