13th International Brick and
Block Masonry Conference
Amsterdam, July 4-7, 2004

ESECMASE – EUROPEAN RESEARCH PROJECT ON SHEAR STRENGTH OF MASONRY STRUCTURES

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Abstract

The paper gives an overview of the scientific aims of the ESECMaSE project, which was initiated by several European Masonry Producers associations and is being funded by the European Commission within the 6th Framework programme. The research project intends to supply basic knowledge about the relevant material parameters for the shear strength of masonry and to develop suitable test methods for their determination, as a basis for future European standards. Furthermore suitable design methods for masonry subjected to in plane shear shall be evolved for future standards.

Key Words

shear, structural design, testing, research

1 Introduction

Masonry is the most common type of construction in Europe. For load bearing purposes in some European regions it is mainly used in combination with other construction types (e.g. reinforced concrete frames) as infill or confined masonry. In central and parts of southern Europe however masonry itself is still the most common construction type for load bearing purposes in housing, not only for vertical but also for shear loads.

The state-of-the-art in shear design of masonry walls in the German standard (design code) DIN 1053-1 dates back to the mid 70s. The shear design method in DIN 1053-1 was developed by Mann/Müller and still forms the basis for shear design in Eurocode 6. The design method in prEN 1996 (Eurocode 6) consists of two equations, describing two failure modes: bond failure (between mortar and unit) and unit failure (cracking of unit due to tensile failure). The criteria for bond failure are identical in Eurocode 6 (EC 6) and DIN 1053-1, whereas the criteria for unit failure were simplified for EC 6.

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When Mann/Müller developed the design method for DIN 1053-1 they took into consideration the boundary conditions given at that time: masonry was generally composed of units and general purpose mortar, the head joints where filled, units overlapped by half their lengths, unit sizes were comparably small and (in the case of clay unit and lightweight aggregate concrete units) they had not been optimised for thermal insulation reasons to today 's extent. Some of these given boundary conditions allowed some simplifications, but Mann/Müller were as well forced to simplify their approach due to the theoretical investigation methods and the technical (numerical) facilities given at that time and also in order to allow a simple design of shear walls. The simplifications in the design equations of DIN 1053-1 and EC 6 - in combination with the increased loads - are one of the reasons, why stability analysis for masonry members subjected to lateral loads (shear loads) in many cases is no longer possible, even for buildings that have been raised years ago and have proven their stability in practice. The discrepancy is obvious: the calculated shear resistance of masonry structures is significantly lower than the one observed in practice.
In the mean time the boundary conditions have significantly changed, also because units, mortars and the way of constructing masonry have been further developed: units in general are larger, units for thermal insulation purposes are higher perforated, head joints in general are not filled and thin layer as well as light weight mortars has become common. These (new) developments have so far not been considered in the design methods.
Beside the simplicity of the method, the input parameters in EC 6 (and DIN 1053-1) for the shear design of masonry are inexact, since it is insufficiently known which masonry material properties are relevant for shear failure. For one of the input parameters - the tensile strength of masonry units - there doesn't even exist an European test method. As comparative investigations show, the present test method in EN 1052-3 for the determination of the second input parameter, the initial shear strength between unit and mortar f_{vo}, results rd. 50 % lower values of f_{vo} as the German test method does. Just due to the definition of a new test method for the determination of f_{vo} the design shear resistance of masonry in case of bond failure decreases between 30% to 50 %. The German test results of f_{vo} have at least been verified based upon masonry shear tests, although the masonry shear test method itself is disputed. Such a verification of the input parameter or a correlation between the design value of masonry shear resistance according to EC 6 and the effective masonry shear strength is not possible at present, since an European masonry shear strength test method does not exist. The lacking of an European (harmonised) test method for the determination of masonry shear strength, which covers the full range of possible failure modes of masonry in shear is also the reason why potentials can not be utilized, even though EC 6 allows and encourages to determine the characteristic shear strength of masonry from the result of tests.
As a summary of the developments in the masonry field since the mid 70s and the lacking knowledge concerning the input parameters for the shear design of masonry, it has to be stated, that the state-of-the-art in shear design of masonry does not describe the state-of-the-art in masonry construction. For modern masonry resp. modern masonry construction materials, which have been optimised regarding thermal insulation properties as well as economic workability, the knowledge about the load bearing reserves for lateral loads (shear loads) is therefore widely lacking.
In order to safeguard competitiveness of load bearing masonry structures and of course the competitiveness of the connected industries, it has become a must to tap the full potential of masonry shear strength in structural design. As small and medium-sized enterprises (SMEs) are strongly represented in masonry producing and processing industries, they are particularly economically affected by the afore described present state. This was the motivation to submit a proposal addressing the Collective Research scheme within the 6th Framework Program of the European

Commission (FP6). The research project “Enhanced Safety and Efficient Construction of Masonry Structures in Europe” (ESECMaSE) was submitted in February 2003 and was finally granted in Mai/June 2004 after passing two evaluation steps and the final contract negotiations.
This paper focuses on the scientific aims of ESECMaSE, of which the overall aim is the fundamental investigation of the mechanisms of masonry shear resistance, in order to evaluate and exploit the shear resistance potential of load bearing masonry structures. The intention of it is to improve the knowledge in this field in order to amend the design method in EC 6.

2 Scientific objectives

With the state-of-the-art in design of masonry structures subjected to lateral loads (shear walls) in many cases it will become impossible to prove the structural stability of common masonry structures for the future wind and earthquake design loads in Eurocode 1 resp. 8. Often these common structures are proven in practice, since they are built and in use for many years. This obvious discrepancy between calculation and observation might be related to the assumptions behind the new design loads, but it is basically expected to be related with the assumptions and methods of design. ESECMaSE is therefore targeted on the enhancement of the state-of-the-art in shear design of masonry walls, including relevant material properties. Hence ESECMaSE aims at a fundamental and accurate investigation and verification of the mechanisms involved in in-plane lateral loading and resistance of masonry. In the sense of an integral approach, masonry structures subjected to in-plane lateral (shear) loads will be investigated as a whole, including load distribution, stress states, etc.
In detail ESECMaSE will cover:

- theoretical investigations on the static and dynamic stress states of masonry members subjected to lateral (shear) loads, as basic input for the following steps of the project,
- the development of an accurate design model covering both static and dynamic loads, that covers the possible failure modes and takes into account the dimensions of the shear wall (stress states),
- the development of (an) test method(s) for the shear resistance of masonry members that represent(s) the stress states occurring in masonry members an allow(s) a correlation between calculated and observed failure loads.
- the detection of the relevant material properties leading to
  - o the development of test methods that represent the stresses occurring in a masonry shear wall and allow an evaluation of the materials (units, mortars) without extended test on masonry walls,
  - o an improvement of existing masonry construction material (e.g. improvement of perforation patterns, solid unit’s materials)
- tests to verify the theoretical results of the project at every step of it’s process and ending with a final verification of the whole projects results in a full scale test

The intention of the integral approach of the project and the transparency and availability of results throughout the whole project is to minimise early stage simplifications. The target is a realistic and highly accurate theoretical description of the shear resistance of masonry structures to help clear the discrepancy between calculated and observed shear resistance of masonry structures. The needed simplifications to achieve (a) manageable design method(s) shall therefore be put at the end of the investigations.
The integral approach of ESECMaSE also covers the investigation of the relevant material properties. To start off, the participating SMEs (all of them being masonry unit producers) will supply common masonry products, which will be investigated and tested. In a later step, once the relevant material properties have been identified and

possible ways of optimising these properties have been concluded, the participating SMEs will implements the knowledge in production and supply optimised masonry units (unit with optimised perforation patterns, higher tensile strength of the solid unit's material, etc.). In this way it will be possible to check the predicted influence of material properties within the duration of the project.

3 Consortium and Work Plan

In general, according to the rules of FP6 and the Collective Research scheme, the ESECMaSE consortium consists of Research & Technological Development (RTD) partners, SME partners and partners from Industrial Associations and Groupings (IAGs). The participants are listed below according to their corresponding group:

<u>RTD partners:</u>

- University of Kassel (Germany)
- Dipartimento di Meccanica Strutturale - Università degli Studi di Pavia (Italy)
- National Technical University of Athens Laboratory for Earthquake Engineering (Greece)
- Netherlands Organisation for Applied Scientific Research (Nethelands)
- Technische Universität Darmstadt - Institut für Massivbau (Germany)
- Dresden University of Technology (Germany)
- Technische Universität München - Lehrstuhl für Massivbau (Germany)
- Ingenieurkonsulent für Bauwesen Dipl.-Ing. Dr. Anton Pech (Austria)
- Joint Research Centre (Italy)
- Forschungsvereinigung Kalk-Sand e.V. (Germany)
- Institut für Ziegelforschung Essen e.V. (Germany)

<u>SME partners:</u>

- Peter GmbH Kalksandsteinwerk KG (Germany)
- Zapfwerke GmbH & Co. KG (Germany)
- Cirkel GmbH & Co. KG (Germany)
- Ziegelwerk Bellenberg Wiest GmbH & Co. KG (Germany)
- Herbert Pexider GmbH (Austria)
- RIL Rondi Industria Laterizi S.p.A. (Italy)
- LIAS Vinitrov, Lehky Stavebni Material K.S. (Czech Republic)
- SEPA SARL (France)

<u>IAG partners:</u>

- Deutsche Gesellschaft für Mauerwerksbau e.V. (Germany)
- Bundesverband Kalksandsteinindustrie e.V. (Germany)
- Arbeitsgemeinschaft Mau-erziegel e.V. im Bundesverband der Deutschen Ziegelindustrie e.V. (Germany)
- Verband Österreichischer Beton- und Fertigteilwerke (Austria)
- Verband Österreichischer Ziegelwerke (Austria)
- ANDIL Assolaterizi (Italy)
- European Autoclaved Aerated Concrete Association (seated in Germany)

The described objectives and others (e.g. training and dissemination) are closely linked to the work packages into which the ESECMaSE was subdivided and timed in order to achieve the goals. Figure 1 shows the interdependencies of the work packages (WP) resp. the deliverables and their timing. The duration of the whole project will be 36 months and it will start in June 2004.

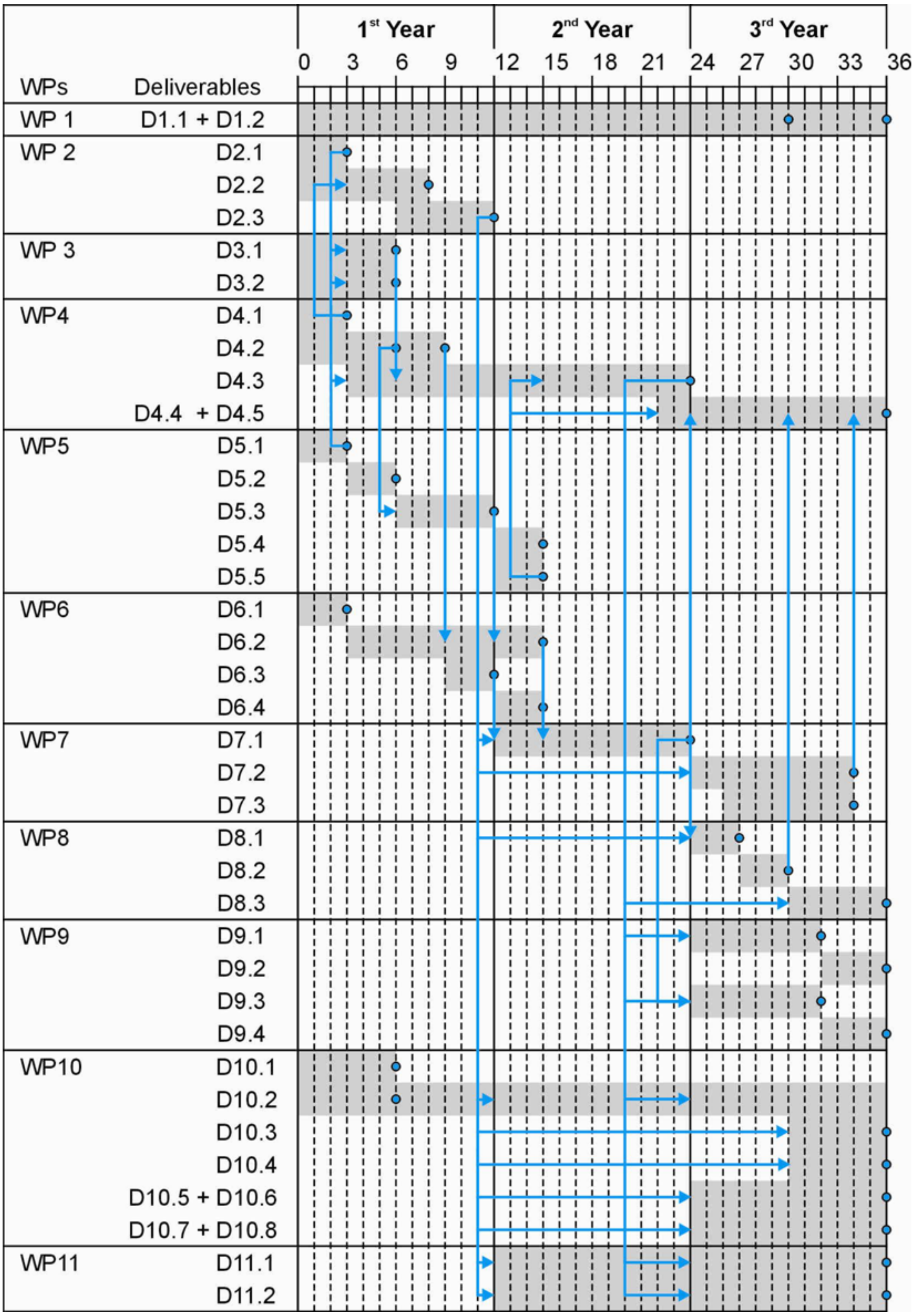

Figure 1 Detail of test arrangement

A brief description of the contents of the Workpackages and the deliverables (only for Workpackages with scientific character) is given in Table 1.

Table 1 Description of Workpackages (WP) and Deliverables (D)

WP 1	Project management
WP 2	Optimisation of Unit Properties
	D2.1 Definition of relevant material properties for WP 3
	D2.2 Proposals for improvement of masonry units
	D2.3 Production of improved masonry units for further steps in WP 7 & 8
WP 3	Theoretical Investigations on the Stress States of Masonry Structures Subjected to Static and Dynamic Shear Loads
	D3.1 Analysis of Terraced House
	D3.2 Analysis of Apartment House
WP 4	Design Model for the Resistance of Shear Loaded Masonry
	D4.1 Demands for the optimisation of masonry unit properties
	D4.2 Requirements for test methods
	D4.3 Shear design model for structural masonry members
	D4.4 + D4.5 Verification of the design model with results of WP 6, 7 & 8
WP 5	Theoretical Investigations on Relevant Material Properties and Test Methods for Material Properties
	D5.1 Material parameters as input for WP 3
	D5.2 Analysis and evaluation of test methods
	D5.3 Construction of suitable test set-ups
	D5.4 Proposal for test methods
	D5.5 Material properties for the tests in WP 7 & 8
WP 6	Theoretical Investigation of Shear Test Methods
	D6.1 Study on suitability of existing test methods
	D6.2 Development of test methods for European standardisation
	D6.3 Construction of test set-up
	D6.4 Shear tests for validation
WP 7	Static and Dynamic Shear Tests on Structural Members
	D7.1 Static tests
	D7.2 Dynamic tests
	D7.3 Identification of suitable behaviour factors
WP 8	Large Scale Earthquake Test on a Building
	D8.1 Definition and design of test specimen
	D8.2 Preliminary tests
	D8.3 Analysis of experimental results
WP 9	Development of Design Procedures for Standardisation and Simplified Rules for Application
	D9.1 Advanced design model for EC 6-1-1
	D9.2 Simplified rules for EC 6-1-1
	D9.3 Advanced design model for EC 8
	D9.4 Simplified rules for EC 8
WP 10	Dissemination of Knowledge
WP 11	Training of SME's and IAG's

Acknowledgements

The authors would like to thank Zenit GmbH, Mühlheim (Germany) and in particular Mr. Stefan Braun, for the support and good advise throughout the whole proposal steps.
The participants of ESECMaSE are grateful to the European Commission for granting this research project and generously funding it for the coming three years with around 70 % of the total eligible costs of around 3 million Euros.