TEACHING STRUCTURAL MASONRY IN CLASSICAL AND INNOVATIVE VIRTUAL ENVIRONMENTS

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ABSTRACT

Brick masonry is widely used in Peru for walls in many low rise buildings, such as dwellings, offices, schools, and alike. Also, partition walls in medium and high-rise buildings are made usually of brick or block masonry. The design and construction of such walls is regulated by the Peruvian Masonry Code issued in 2006. However, technical literature in masonry is still quite limited, and significant efforts are needed to teach seismic structural design and construction practices correctly.

In Peru, the courses of structural masonry for civil engineers students are limited to a few universities. The Pontifical Catholic University of Peru (PUCP) has developed most of the experimental research in masonry in Peru, and offers such courses in undergraduate and graduate level, in the classical way of lectures in classrooms and laboratory tests.

A relatively new approach to disseminate knowledge in this field is the use of virtual environment. The blog of masonry (http://blog.pucp.edu.pe/albanileria in Spanish) developed by Angel San Bartolomé has passed its first year offering a new way to communicate recent research reports to masonry users all over Peru and beyond. Nowadays, the graduate course is being offered for the first time in a virtual way for master students and it looks as a promising virtual course for students in Peru and other Latin American countries.

KEYWORDS: teaching, education, blog, masonry, virtual education, Internet

INTRODUCTION

This paper deals with two approaches used in the Pontifical Catholic University of Peru (PUCP) for teaching structural masonry to civil engineering students. The first one is the classical course offered to the final year undergraduate students, and also used for graduate students (Masters

course). In 2008, a new approach was developed, offering a virtual course for graduate students. These two approaches are supported by a significant number of research studies carried out at the University, mainly as thesis, most of which are published on Internet in the blog of Angel San Bartolome [1] (http://blog.pucp.edu.pe/albanileria in Spanish).

USE OF MASONRY IN PERU

The most popular masonry units are clay bricks, followed by concrete blocks and bricks, and silica lime blocks and bricks. These units are used for structural and nonstructural wall construction. Confined masonry construction with brick masonry walls is widely used in Peru for low-rise buildings, such as dwellings, offices, schools, and others (Figure 1). Block masonry construction is less popular, but there are several medium-rise buildings with block masonry walls in Lima (Figure 2); in this case, walls are of internal reinforced masonry. Also, brick or block masonry is used for the construction of nonstructural walls, such as partition walls in medium- and high-rise buildings (see Figure 3), and perimeter walls and parapets (see Figure 4).

Figure 1: Typical brick masonry loadbearing wall buildings in Peru

Figure 2: Typical block masonry loadbearing wall buildings in Peru

Figure 3: Typical masonry partition walls in Peruvian RC buildings

Figure 4: Perimeter walls and parapet walls in Peruvian masonry construction

The design and construction of masonry walls is regulated by the new Peruvian Masonry Code issued in 2006 [2], which replaced the previous 1982 edition. The new Code updated the construction and design provisions for masonry structures [3]. Specially, changes in the in-plane seismic design provisions have been introduced with performance-based design for two levels of earthquakes, which have been discussed in a previous paper [4].

However, technical literature in masonry is still quite limited especially in Spanish ([5], [6]), and significant efforts are needed to teach seismic structural design and construction practices correctly. Bad constructions practices and non-engineered construction are widely observed. The recent earthquakes that hit Peru (Atico 2001, Mw=8.4; Pisco 2007, Mw=8.0) caused significant damage in poorly built masonry constructions [7], [8] (Figure 5).

The 2005 Peruvian housing census carried out by INEI (Peru National Institute of Statistics and Informatics) showed that for residential buildings, brick or block masonry walls were most prevalent, corresponding to 46% of the total building stock, followed by adobe (37% of the building stock), and other materials such as wood, cane and stone [9]. Therefore, teaching masonry design and construction is a must for the civil engineering educators in Peru, especially

due to the high earthquake hazard in the country. However, this effort has to be sustainable and consider national economic problems.

Figure 5: Damage to masonry constructions after the 2001 Atico (top) and the 2007 Pisco earthquakes (bottom)

UNIVERSITY COURSES IN MASONRY

The teaching of structural masonry in Peru started in 1980 through an elective course at the PUCP, for the final year civil engineering undergraduate students ("Albañileria Estructural" in Spanish). Since 2000, this course has been offered as a compulsory course in the undergraduate program. This course is delivered in the form of 3 hours/week lectures in classroom, plus a 2 hour biweekly lab sessions. Usually, there are two exams: a mid-term and the final exam. Around 30 to 45 students are enrolled every semester.

In 1997 a more advanced elective graduate course on structural masonry was developed for students in the masters program ("Estructuras de Mampostería" in Spanish). The course is delivered in the form of 4 hours/week classroom sessions. In addition, students have assignments throughout the semester which consists of numerical calculations and laboratory testing of small specimens. Also, two exams are taken, usually a mid-term and the final exam. Students enrolled vary from 8 to 25, as the course is offered with a two to four semester interval.

The topics covered in both courses are: 1) introduction, history, types of masonry and types of walls; 2) masonry components (units, mortars, grout, prisms); 3) seismic behaviour of walls in real earthquakes and laboratory tests, and interaction between non structural masonry walls and frames; 4) structural analysis; 5) design of confined masonry and reinforced masonry structures, design for out-of-plane seismic forces; 6) construction procedures and usual construction faults;

7) adobe and earthen constructions; 8) other masonry systems. The graduate course also includes a chapter on repair and retrofitting of masonry walls.

In the graduate course the chapter devoted to adobe structures is expanded, and discusses Peruvian research studies performed at the PUCP. These studies include static and dynamic (seismic simulation) lab tests, reinforcing of new and existing adobe constructions, field applications of new technologies and associated challenges.

Some other Peruvian universities offer similar courses, either as compulsory or elective, following the PUCP pioneering effort and leadership.

In the practical portion of the course, students are given the task of analysing a sample building for gravity and seismic loads. After the analysis is completed, the students are required to perform structural design for the masonry walls. Students in the undergraduate course are divided into groups of 4. Each group designs a variation of the basic sample building. For example, the building has confined walls or reinforced walls, walls are connected by lintel beams or only the floor slab, soil type, floor systems consisting of one or two-way slabs, etc. The graduate course has fewer students and only a few of the above mentioned variations are studied.

Besides the design work, experimental labs are an important component of the practical portion of the course. Brick and mortar material properties are not tested in the course due to time constraints, but these tests are usual tests are usually performed through the thesis work. Each semester a different variable is chosen for study and comparison. These variables include: masonry units, mortar, grout, type of masonry (confined or reinforced), joint size, presence and amount of horizontal reinforcement, etc.

Small size masonry specimens are built and tested at the Structures Laboratory. These specimens are 3 to 6 layers high prisms, and small walls assemblies (usually 600 mm square). A laboratory technician demonstrates the use of the construction tools and builds a sample prisms and a wall specimen. Then, the students are required to build their prisms and small wall specimens on their own, under the technicians' guidance (Figure 6). This session takes about two hours.

Axial compression testing for the prisms and diagonal compression of the small wall specimens is performed at the age of 28 days (Figure 7). Depending to the availability, the specimens are made of clay bricks, concrete bricks or blocks and silica lime bricks or blocks. Sometimes, in the graduate course, testing of adobe specimens is also included to show their peculiar components and to compare the resistance to that of brick specimens.

THE MASONRY BLOG

PUCP professor Angel San Bartolomé has developed the masonry blog [1], in which most of his research studies in this field since 1979 are posted. Updated research studies are uploaded almost every month. Also, a free space is available for other researchers who wish to contribute to the blog. Most of the experimental research studies are profusely and graphically illustrated with drawings and colour photographs. Some videos are also available showing different lab

tests, such as cyclic lateral load of full masonry walls at final stages and some shaking table tests simulating seismic excitations on full scale specimens.

The blog contains many summaries of the theses of the undergraduate and some graduate students advised by Professor San Bartolomé, and also other professors. As a part of the masonry courses, the students are requested to review specific papers from the blog. Papers and reports related to the examples of building analysis and design, according to the new Peruvian Masonry Code are particularly useful.

Figure 6: Students performing the construction of prisms and small-size walls specimens

Figure 7: Tests of masonry prisms constructed by the students

The contents of the blog are divided into several sections, as follows: 1) introduction to masonry research; 2) adhesion (bond) between masonry units and mortar; 3) masonry prisms; 4) partition walls and parapets; 5) confined masonry; 6) reinforced masonry; 7) mortarless masonry; 8) repair and retrofitting; 9) control of sliding failure; 10) comments on the Masonry Code; 11)

structural design of masonry buildings; 12) earthen masonry construction; 13) unconventional housing systems; and 14) free space for other contributors.

Figure 8 displays the front page and other sample screenshots of this blog. When a user double clicks is performed over a highlighted item, a a paper can be viewed in an Adobe Acrobat (PDF) format. Similarly, a video clips can be viewed upon clicking on the play button.

It is also important to mention that users have a possibility of posing questions or making comments, and the responses are prepared by Professor San Bartolomé. Questions and answers are available in the blog.

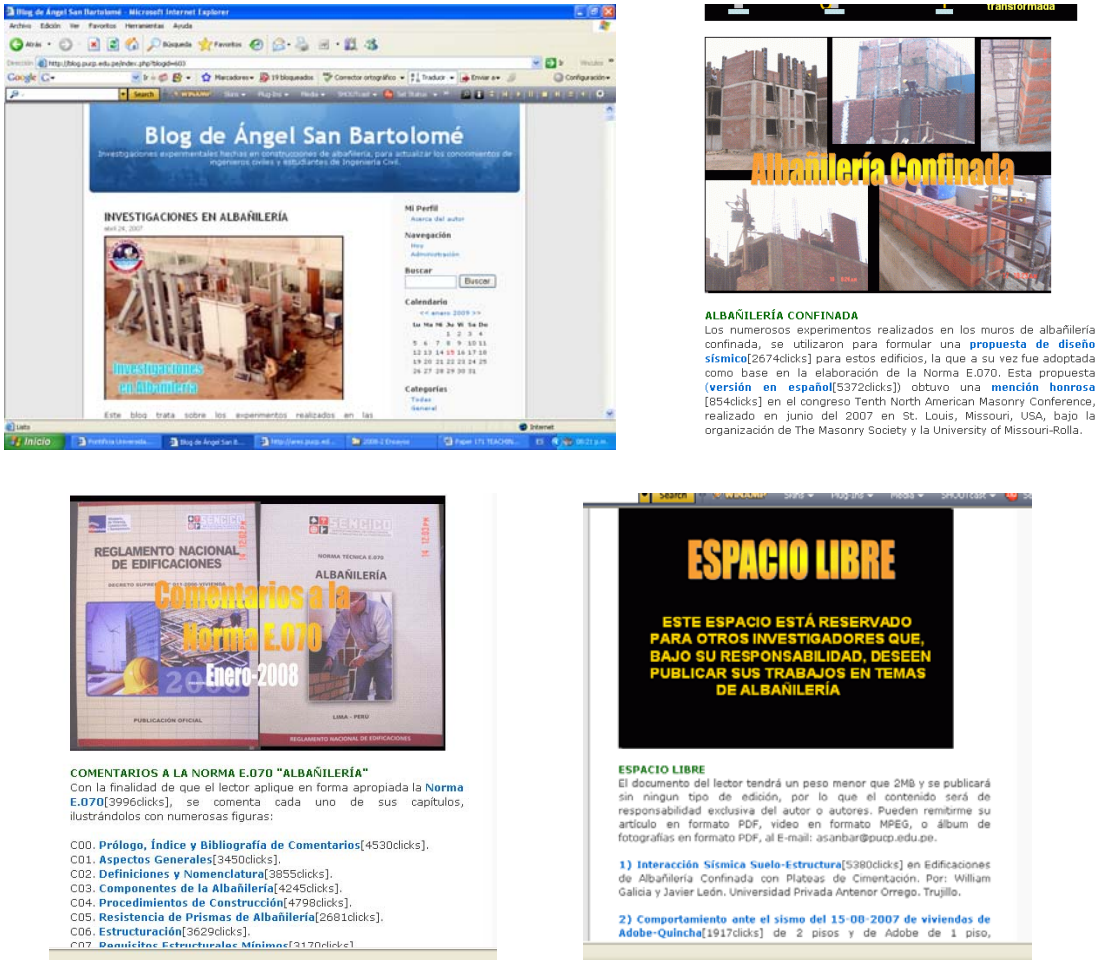

Figure 8: Masonry blog developed by Angel San Bartolome (in Spanish)

THE VIRTUAL COURSE IN MASONRY

Following innovative trends in the modern education, PUCP decided to develop and offer the Masters course in a virtual environment in 2008. In the first semester the course material was developed by the authors of this paper, and delivered for the first time in the second semester in a virtual way to eight students enrolled in the course. A maximum of 25 was expected. The authors prepared eight chapters with all the technical information in MS Word and eight

presentations containing a short overview of each chapter in MS Power Point, to be circulated to the students. The PUCP has a special office called PUCP Virtual, which receives the files containing the course information and prepares them for the virtual environment.

Each activity was programmed so that the system would inform the teachers and the students about the start and end of each session. For example, an e-mail is sent to inform the students that UNIT 3 had started and that documents are available at the virtual campus, etc.

The supervision of the course comprised of the automatic remainders (e-mails) sent by the computer system, and the tools such as "DOCUMENTS", "FORO", and "CHAT". Although these tools are available for any course (classroom-based or virtual), their use in the virtual course was made compulsory to share information and maintain the contact with the students. The students were required to be physically present at only two occasions: to perform the construction of small specimens, and to take the final exam.

All the technical documents and presentations were presented in the DOCUMENTS environment. The students had to download the contents of each chapter, and overview it through the corresponding presentation. An advantage of this approach recognized by the students is that they had flexibility related to the place and time they could assign for the study.

The FORO tool was used in two ways. Firstly, FORO was an open environment during the semester. The students were able to pose questions, and the teachers could respond to these questions anytime. All the students had access to the questions and answers during the course. At the beginning of the semester, another FORO was set, with the purpose of welcoming all the students and asking them about their views, background and expectations.

The CHAT tool was used especially after the students had finished an assignment (usually during the daytime). During the evening hours of the same day (6 to 9 pm), the students were able to use this tool to comment their results. Using the CHAT tool, the students and the teachers remained in touch in a virtual environment and had useful discussions. Each student was required to explain his/her homework, while the others could give comments, share their doubts or seek answers to any inquiry related to the topic under discussion. At the end, the students commented on the chatting tool, which they found to be very useful and requested more opportunities for this type of communication.

The grading of the course had three components as shown in Table 1. Also, the laboratory work had four parts displayed in Table 2. The four individual assignments are described in Table 3. Each assignment had a report which students had to deliver virtually by uploading it to the DOCUMENTS environment.

For Assignment 1, the students were required to choose any construction site in Lima. They were requested to take the role of an inspector, indicating good and bad construction practices according to the Code and the recommendations presented in the course. Both materials quality and construction had to be inspected and a critical discussion had to be presented in the form of a written report.

Assignment 2 consisted of selecting a paper from the blog, summarizing it and offering a students' own views on the importance of the research reported, and offering his/her recommendations.

Table 1: Virtual Course Components and Grading

Laboratory work	25%	Presence and virtual
Individual assignments	50%	Virtual
Final exam	25%	Presence

Table 2: Laboratory Work Components and Grading

Construction of specimens	20%	Presence
Test of the specimens	20%	Virtual
Report with lab results	40%	Virtual
CHAT discussion	20%	Virtual

Table 3: Individual Assignments

Visit to a real site construction	20%
Read and summarize a paper of the blog	10%
Structural analysis of a masonry building	40%
Structural design of the masonry walls	30%

Assignments 3 and 4 were related to the same four-story building (Figure 9). Material specifications, cross sections, loads, seismic parameters and other required information were given, along with a guide on how to proceed and obtain the results.

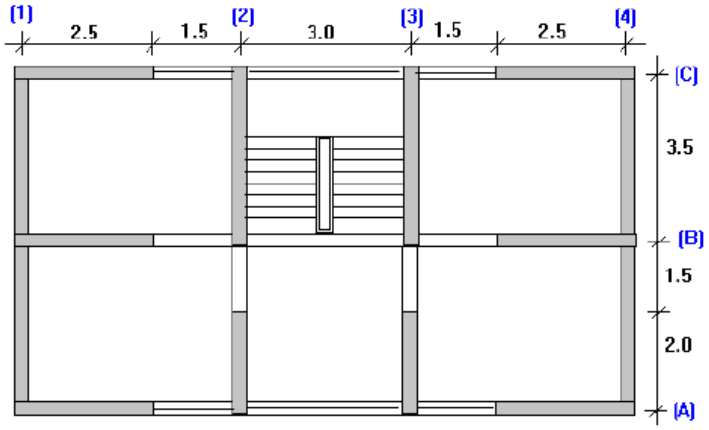

Figure 9: Building used for Assignments 3 and 4

The students who completed the course showed their satisfaction for the system used (virtual) and the written material. They are demanding that more courses in the Masters program use this virtual approach in the future, because of its multiple advantages. Special attention must be

given to this, because most of the students enrolled in the Masters program are part-time students, and during daytime they have different activities and work either for various firms or are self-employed. Therefore, their schedule is very tight and they find the classical classroom-based approach of graduate studies challenging due to the fixed schedule and other constraints.

CONCLUSIONS

The teaching of structural masonry in Peru started at the PUCP, and it is at the forefront of the civil engineering education related to this construction system in the country. The final year undergraduate students have a compulsory course on structural masonry while Masters degree students can take it as an elective course. The classical classroom-based approach and a new virtual course approach are currently available for teaching these subjects. The virtual approach overcomes the time constraints of part-time students, and Masters students have found it to be adequate for their needs.

The recent Peruvian Masonry Code and its numerous updates require a special focus on explanation and dissemination of code provisions, especially after poorly constructed masonry buildings and elements have collapsed or had suffered heavy damage in recent Peruvian earthquakes. There is a huge need for teaching good design and construction practice to civil engineer students. Also, guidelines and appropriate practices are needed for technical construction workers. Such effort has significant importance due to the high earthquake hazard in Peru. However, the population has economic problems and many prefer to use self construction, cheap and inadequate quality materials, and avoid hiring a structural engineer in order to save money. As limited textbooks are available in Spanish, the approach of using the Masonry blog and the virtual course is suitable for the education of civil engineers and others, not only in Peru but also in other Latin American countries.

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