STRENGTHENING CFRP CHALLENGE at UM
Competition for the prediction of the behaviour of a CFRP strengthened reinforced concrete beam
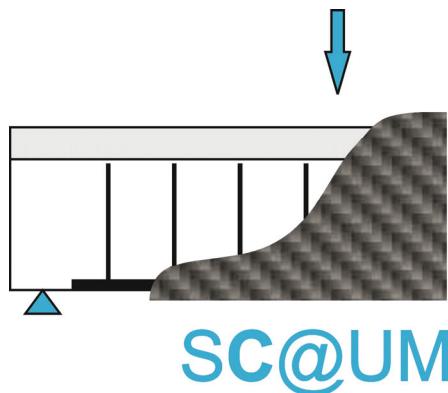
SC@UM

COMPETITION RULES
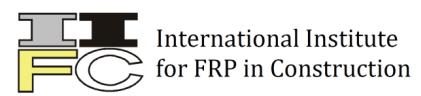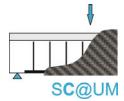
1. Introduction

This document describes the schedule and the rules of the competition. The participants are encouraged to read it carefully. The failure to comply with these rules will cause the disqualification of the team.

The object of this competition is a T-shaped reinforced concrete beam, shear and flexurally strengthened with carbon fibre reinforced polymer (CFRP) laminates according to the Near Surface Mounted (NSM) technique, which represents a hypothetical real case study. The T-beam will be subjected to an initial loading corresponding to a deflection at mid-span of L/350, which introduces an initial damaged state representative of service conditions. *The deflection corresponds, in general, to the vertical displacement at the loaded section, except when explicitly referred otherwise*. Subsequently, the T-beam will be strengthened using NSM CFRP laminates to increase its load carrying capacity. The detailed description of the geometry, of the steel reinforcement and of the CFRP strengthening will be provided to all participants, as well as all the relevant material properties.

2. Objectives

The objective of this competition is to predict the load-deflection response of the T-beam after strengthening. For this purpose, each team should propose a mechanical model to describe the non-linear behaviour of the T-beam up to failure. The principles and the theoretical background supporting the proposed global models should be described objectively, using a formal and scientific style. The accuracy of the predicted load-displacement responses, the innovative character of the proposed model, the creativity and the theoretical soundness of the model principles described will be object of evaluation.

3. Teams

- Each team must consist of not more than three students currently enrolled in an MsC or PhD program. At least one team member must be a PhD student. All members of a given team must belong to the same institution. A student may not be a member of more than one team.
- Each team must have a supervising institution advisor, who will verify that the students' team complies with the rules of the competition. The institution advisor is permitted to supervise no more than one team.
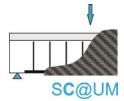
- At least one individual (team member or institution advisor) should be designated to represent each team and be present at the session of the FRPRCS-11 symposium dedicated to the SC@UM challenge. At this session the experimental results of the tested T-beam will be presented and the winners of the challenge will be announced. The winner teams will give a presentation about their work, focusing on the most important aspects of their theoretical models. Participation by all team members is strongly encouraged. Reduced registration fees will be available to the team members who wish to attend the conference and are not presenting a paper.

- In total, each team must submit three documents: the registration form, the report-paper and the report-presentation. After sending the registration form and receiving the confirmation of registration acceptance by e-mail, the team must submit the report-paper and the report-presentation up to 10th of May 2013.

4. Materials

The properties of the materials employed in the T-beam will be provided to the participating teams, namely.

- The composition of the concrete mixture; the load versus the displacement between the extremities of the specimen recorded in compression tests of three concrete cylinder specimens tested at 7 and 28 days (the geometry of the specimens will be provided with the results);

- The stress-strain response in tension of the steel bars; the stress-strain response of the CFRP laminates;

- The elasticity modulus and the tensile strength of the adhesive.

5. Specimen geometry

The geometry of the T-beam cross-section is presented in Figure 1. The steel reinforcement arrangement is shown in Figure 1.a. Both the longitudinal (3 laminates with 1.4x20 mm^2 of cross section) and the transverse (2 laminates with 1.4x20 mm^2 of cross section spaced at 300 mm) CFRP reinforcements inserted on the T-beam for flexural and shear strengthening are shown in Figure 1.b. The file containing the detailed drawings of the T-beam will be forwarded to all participants after the production and strengthening of the T-beam specimen, so the exact measurements of all details can be verified by the participants.

6. Testing procedure

The T-beam, simply supported, will be subjected to a non-symmetrical descending load **P**. The geometry of the T-beam, positioning of the supports and load **P** are presented in Figure 2. To simulate the service conditions and the corresponding loading, the T-beam will be subjected to an imposed deflection of **L**/350 at mid-span, where **L** is the distance between supports, at a deflection rate of 20 µm/s. Subsequently, the T-beam will be instantly unloaded and the transverse and longitudinal CFRP laminates will be applied according to the NSM strengthening technique. No further measures to obliterate the produced cracking will be undertaken. Finally, the retrofitted T-beam will be tested under displacement control up to failure at a displacement rate of 20 µm/s. The load-deflection response will be recorded and the evolution of the deformation of the T-beam during testing will be documented. The crack patterns observed at the T-beam surface will be also documented by a sequence of images. The strengthened T-beam will be tested only after the deadline for receiving the proposals. As such, no restrictions are applied to the members of the FRPRCS-11 scientific committee or other conference participants who wish to supervise competing teams.
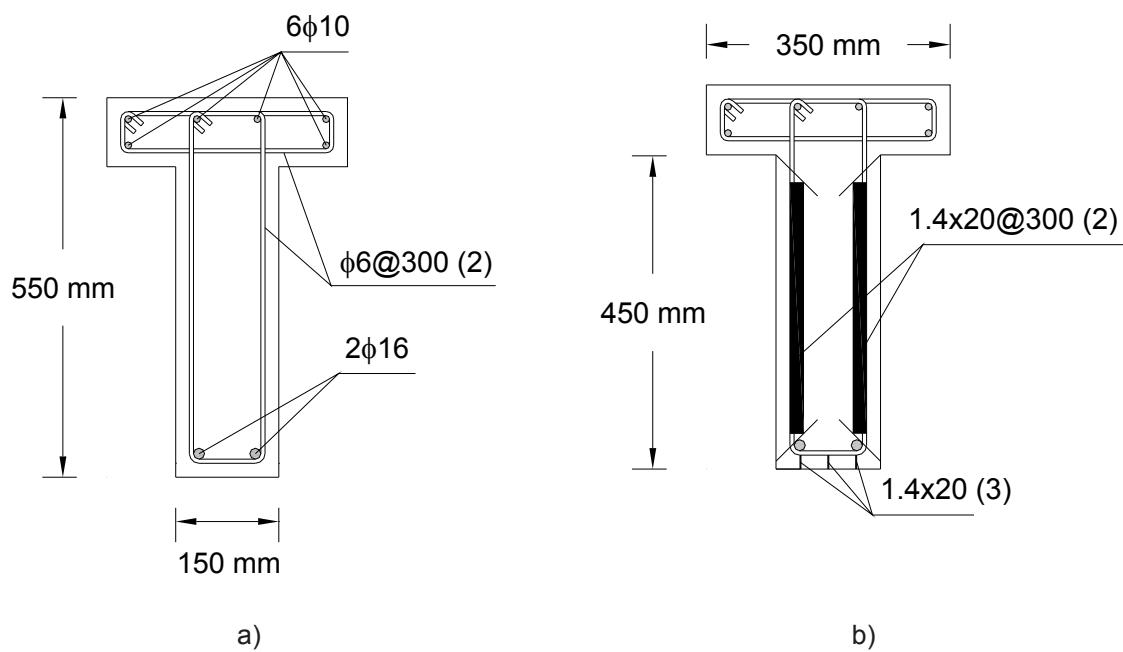

Figure 1. T-beam cross section geometry, a) before and b) after CFRP laminate strengthening.
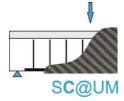
7. Chronogram

The chronogram for the competition, including the testing procedure, is the following:

- reception of the registration forms: up to the 1st of February (postponed to **the 1st of March**);
- production of the T-beam and concrete cylinder specimens; testing of the concrete cylinders at 7 and 28 days; loading of the T-beam up to a mid-span deflection of L/350 at 28 days; insertion of the CFRP laminates on the T-beam; forwarding of the final drawings of the retrofitted T-beam and of the results of the materials characterization to the participants up to the **1st of March**;
- reception of the report-paper and the report-presentation from the participating teams: up to the **10th of May**;
- testing of the retrofitted T-beam at 90 days after casting. Any requests to change the results or include corrections in the previously submitted reports by the participating teams after testing the T-beam are not acceptable.

8. Reporting

The participants are challenged to predict the load-deflection response of the T-shaped beam after strengthening. The deflection refers to the vertical displacement of the T-beam measured at the loading section. The participants should therefore submit their estimations of the entire load-deflection behaviour of the T-shaped beam after strengthening, together with the concise description of the theoretical background and principles used to estimate the T-beam response. The final report should be submitted using the format file provided by the organizing committee at the webpage of the symposium.

The final report will consist of a report-paper and report-presentation. The report-paper must include, as an appendix, a separate file containing the results of the estimated load-deflection response. The .xls file template available at the webpage must be used to report the estimated load-deflection response. The maximum load difference between consecutive points of the load-deflection response must not exceed $0.01 \times P$ (peak load). The maximum deflection difference between consecutive points of the load-deflection response must not exceed $0.01 \times \delta$ (deflection at peak load). The report-paper and the report-presentation must adopt the templates available in the menu of the webpage of the FRPRCS-11. The presentation should contain the most relevant figures, results and model aspects, either included already in the paper or not.

The sections that should be included in the report-paper are:

- Theoretical concepts and background;
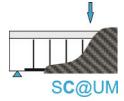
- Model formulation;

- Model calculations (including load versus deflection at loaded section), peak load, loaded section deflection at peak load, maximum strain reached by the longitudinal and transverse CFRP laminates;

- Failure mechanism;

- Conclusions.

9. Evaluation

The experimental results of the T-beam specimen will be used as reference to the evaluation of the reports submitted by the participants. This evaluation will consider two main aspects, one related with the objective quantification of the degree of approximation achieved by the estimated load-deflection responses, and the other related with the evaluation of the proposals by the scientific committee of the competition. Accordingly, the final classification of each team will be based in the following parameters:

Parameters $f_{L/250}$, $f_{\delta,ult}$ and $f_{P,ult}$:

After the submission process is closed and the retrofitted T-beam testing is finalized, the reports submitted will be listed in ascending order according to the degree of approximation achieved with the estimations, ending the list with the closest estimation of the parameter being evaluated. The f_i ($i = L/250$, δ,ult or P,ult suffixes) grade attributed to each team will consist of the sequence number obtained by each team. The $f_{L/250}$ parameter will evaluate the degree of approximation reached when estimating the load for a deflection at the loaded section of $L/250$. The $f_{P,ult}$ and $f_{\delta,ult}$ parameters will evaluate, respectively, the degree of approximation reached when estimating the peak load and the corresponding deflection at the loaded section.

Parameter $f_{P-\delta}$:

The reports submitted will also be listed in ascending order considering the degree of approximation reached by the estimation of the entire load-deflection response, ending the list with the closest estimation of the total load-displacement response. To evaluate the approximation of the estimated response, the total area between the estimated and the experimental responses will be calculated up to the experimental peak load. The smallest area will lead to the maximum classification in this item. The $f_{P-\delta}$ grade attributed to each team will correspond to the sequence number obtained by each team in this parameter.

Parameter f_{Model}:
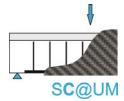
The reports submitted by the competition teams will be reviewed by the competition scientific committee. The quality of the reports submitted will be evaluated considering:

- the accuracy of the predicted load-displacement responses, and of the description of the expected failure mechanism;
- the innovative character of the proposed model;
- the creativity and the theoretical soundness of the model principles described;

The principles and the theoretical background supporting the proposed global models should be described objectively, using a formal and scientific style. The grade attributed to each team will correspond to the sequence number after listing all competing teams in ascending order, ending the list with the best quality proposal.

The final classification, **C**, of each team will be obtained by combining all the aforementioned parameters. These parameters will be combined using different relative weights, as follows:

$$C = 0.15f_{Model} + 0.1f_{L/250} + 0.20f_{\delta,ult} + 0.10f_{P,ult} + 0.35f_{P-\delta}$$
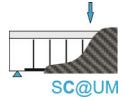
Prizes and awards

After the selection of the best proposals submitted by the participants, these proposals will be considered as candidates to be included in a special publication. The selected teams will be invited to revise their report-papers in the context of a subsequent peer reviewing process by the scientific committee of the competition. In addition, the results of the competition, winners and a brief summary of the proposals submitted will be published in the Newsletter of the International Institute for FRP in Construction (IIFC) and of the Institute for Sustainability and Innovation in Structural Engineering (ISISE). This publication will give visibility and emphasize the most creative and innovative aspects of the proposed models by the participating teams to predict the response of the strengthened T-beam, as well as the analysis of the effectiveness of the strengthening system adopted.

The winning teams will be awarded with the following prizes:

- 1st prize: 1000€;
- 2nd prize: 500€;
- 3rd prize: 250€.

Honour mention certificates will be granted by the IIFC to the participating teams that, although not winning, are selected for having submitted outstanding proposals considering the main evaluation parameters referred earlier.

Guimarães, November 2012.

by the organizing committee:

Joaquim António Oliveira de Barros
_____
(Chairman of FRPRCS-11)

0,35 m

0,55 m

a) BEFORE STRENGTHENING

P

3,60 m

2,10 m

0,35 m

0,45 m

0,15 m   0,35 m

b) AFTER STRENGTHENING

P
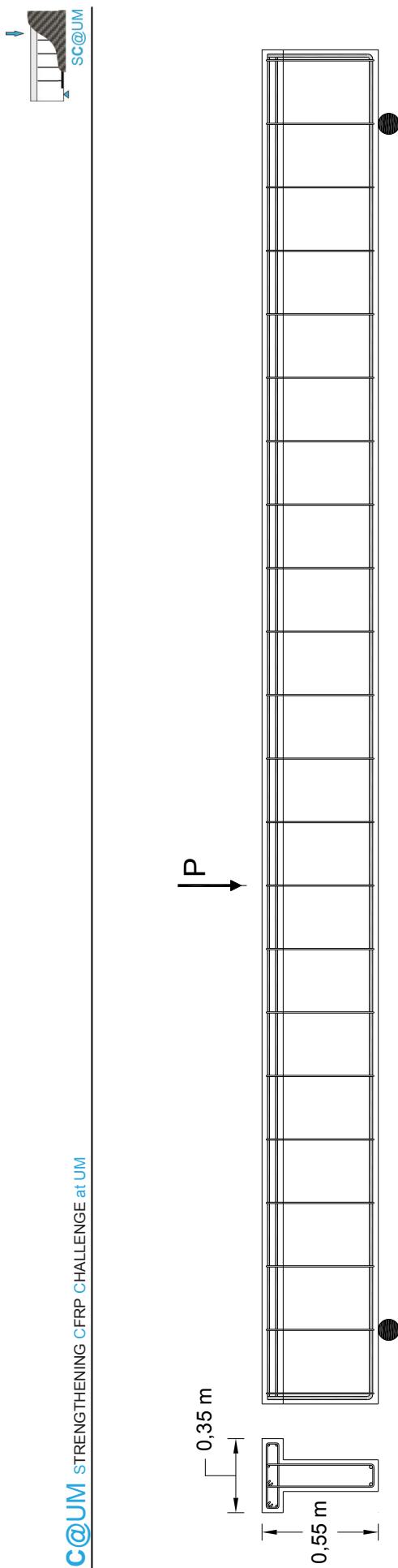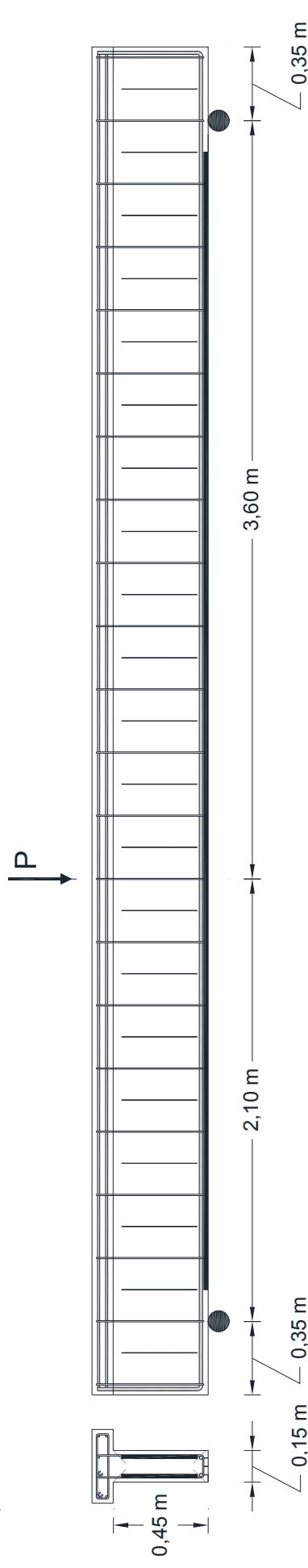
Figure 2. T-beam geometry, steel reinforcement and CFRP strengthening system: a) before and b) after strengthening.

SC@UM STRENGTHENING CFRP CHALLENGE at UM

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REGISTRATION FORM

TEAM

Name:	Acronym (8 characters max.):

SUPERVISOR

Name:	Affiliation:

PARTICIPANTS

Name:	Affiliation:
Name:	Affiliation:
Name:	Affiliation: