fib Symposium 2021
Lisbon · Portugal

Students' Competition

Prediction of the behaviour of reinforced recycled aggregates concrete (RAC) beams

Rules, schedule and prizes

Lisbon , 2020

Students' Competition

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1. INTRODUCTION

The present document describes the rules of the competition and the corresponding schedule. The participants are encouraged to read it carefully. The failure to comply with these rules will result in the disqualification of the team. This competition aims to evaluate the current knowledge on predicting the behaviour of reinforced RAC beams accurately. In the next sections, you will find all the details about this competition.

2. OBJECTIVE

The objective of this competition is to predict the load-deflection response of two equal beams. To participate in this contest, each team should propose a mechanical model to describe the nonlinear behaviour of the beams. 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 response, the innovative character of the proposed model, the creativity and the theoretical soundness of the model principles described will be an object of evaluation.

3. TEAMS

Each team must comply with the following rules:

- Each team must consist of two or three students currently enrolled in an MSc or a 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 cannot be a member of more than one team.

- Each team must have a Supervising Institution Advisor (SIA), who will verify that the students' team complies with the rules of the competition. The SIA is permitted to supervise no more than one team.

- At least one individual (team member or SIA) shall be designated to represent each team during the session of the *fib Symposium 2021* dedicated to the competition. During this session, will be presented the experimental results of the tested beams, and the winners of the contest will be announced. The winner teams will give a presentation about their work (in person or remotely), 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 *fib Symposium 2021* and are not presenting a paper.

- Members of the *fib Symposium 2021* scientific committee or other conference participants may be a SIA. Organizing committee members and jury members of this competition cannot be a SIA.

- Each team must submit the following three documents:

  i. The <u>registration form</u> (included in this document);

  ii. The <u>report-paper</u> with the description of the mechanical model used to simulate the beam's nonlinear behaviour up to failure. The principles and the theoretical background supporting the proposed global models should be described objectively, using a formal and scientific style. This report must follow the paper format and rules used in the *fib Symposium 2021*.

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iii. The <u>PPT presentation</u> of the work carried out. The presentation has a free format. However, it should be able to be presented in the session of the *fib Symposium 2021* dedicated to the competition. Each presentation will last 10 minutes.

After sending the registration form and receiving the confirmation of registration acceptance by e-mail, the team must submit the report-paper and the presentation up to **9th May 2021**.

4. MATERIALS

A concrete class of C30/37 with 25% recycled aggregates and steel bars of A500 NR SD are used to produce the two beams.

5. SPECIMEN GEOMETRY

Figure 1 depicts the geometry, load's location and support conditions of the beams. The beams are 3800 mm × 150 mm × 300 mm, with two spans of 1800 mm and, each one loaded at mid-span.
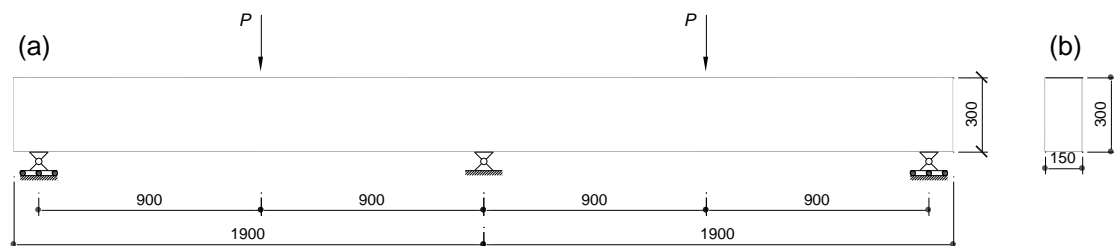
Figure 1. Geometry of the beams: (a) Front view; (b) Cross-section. All units in [mm].

Figure 2 shows the details in terms of both longitudinal and transverse steel reinforcements: lower reinforcement is 2∅12 + 1∅16, upper reinforcement is 3∅12 near the intermediate support and 2∅8 in the remaining zones, and stirrups are ∅6@0,10 m. The concrete cover is 20 mm. The supports are materialized with steel plates with a width of 50 mm.

6. TESTING PROCEDURE

The beams under the three supported conditions, as shown in Figure 3, will be subjected to a point load P per span, located at mid-span. The test will be performed under displacement control at a rate of 33 μm/s, controlled by the internal LVDT of the actuator. The load (2P) will be recorded, as well as the mid-span vertical displacement at beam's mid-height at the point loads (LVDT1 and LVDT2) respected to the supports (P1, P2 and P3). A sequence of images will also document the crack pattern observed at zone Z1 of the beam's surface. The tests will stop when the deflection registered by LVDT1 or LVDT2 reaches 45 mm.

The beams will be tested on **week 10-14 of May 2021** at the Polytechnic Institute of Coimbra. All teams, are invited to follow tests in real-time by streaming session, created for this purpose.

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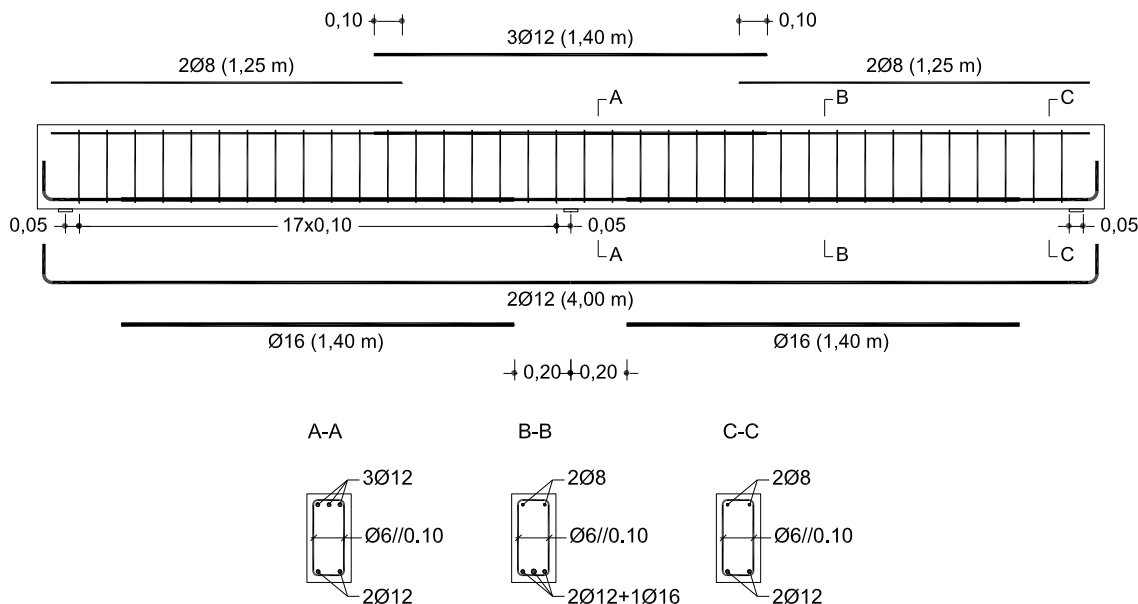*Prediction of the behaviour of reinforced recycled aggregates concrete (RAC) beams*

Figure 2. Longitudinal and transverse reinforcements of the beams. Notes: all units in [m].
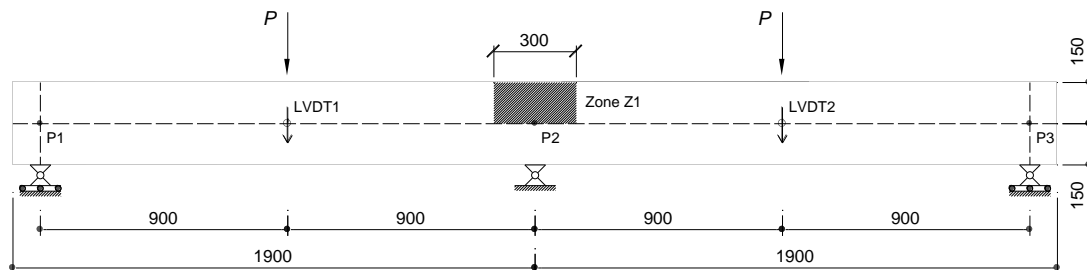

Figure 3. Instrumentation. All units in [mm].

7. INFORMATION TO BE PROVIDED.

The beams characteristics, including the properties of the materials employed in the beams, will be provided to the participating teams, namely:

- Photos about the manufacturing and curing of the beams;
- Details about the composition of the concrete mixture;
- Curing conditions of the beam specimens, including temperature and relative humidity up to 2.5 months;
- Concrete compressive strength at the age of 7 and 28 days according to the EN 12390-3 – normalized curing conditions and curing conditions similar to the beams (3 cubes with 150 mm of edge per age and per curing condition);

- Concrete flexural strength at the age of 7 and 28 days according to the EN 12390-5 – normalized curing conditions and curing conditions similar to the beams (3 prismatic specimens of 100 mm x 100 mm x 500 mm per age and per curing condition);
- Concrete E-modulus at the age of 28 days, under similar curing conditions to the beams, according to the LNEC specification E 397-1993 (3 prismatic specimens of 150 mm x 150 mm x 600 mm);
- Shrinkage of the concrete under similar curing conditions of the beam specimens up to the testing day, according to the LNEC specification E 398-1993 (2 prismatic specimens of 150 mm x 150 mm x 600 mm);
- Creep of the concrete under similar curing conditions of the beam specimens up to the testing day, for specimens loaded at 28 days, at 30% and 60% of the compressive strength, according to E 398-1993 (2 prismatic specimens of 150 mm x 150 mm x 600 mm per creep load);
- The density of dry concrete at 28 days;
- The stress-strain response under the tension of the steel bars.

8. CHRONOGRAM

The chronogram for the competition is the following:

- Reception of the registration forms: up to **1st February 2021**;
- Confirmation of registration acceptance: **5th February 2021**;
- Production of the two beams and concrete specimens: **8-19 of February 2021**;
- Announcement of detailed information (see Section 7): **15th March 2021**;
- Publication of the remaining details (see Section 7): **1st May 2021**;
- Delivery of report-paper and the presentation up to **9th May 2021**;
- Test of the beams: **10-21 of May 2021**;
- Announcement of the winners: **16th June 2021**.

Precise dates about the production of the two beams and concrete specimens and the test of the beams will be provided to the teams in due time.

9. REPORTING

The challenge is that each participant predicts the load mid-span deflection response of the two similar beams. The participants should, therefore, submit their estimation of the entire load mid-span deflection behaviour of the beams, together with the concise description of the theoretical background and principles used to estimate the response.

The report-paper must include, as an appendix, a separate file containing the results of the estimated load-deflection response. The EXCEL file template available at the webpage must be used to report the estimated load mid-span deflection response. Note: the maximum load difference between consecutive points of the load mid-span deflection response must not exceed 0.01×P (peak load); the maximum deflection difference between consecutive points of the load-deflection response must not exceed 0.01×(mid-span deflection at peak load).

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The report-paper must adopt the template available in the menu of the webpage of the *fib Symposium 2021*. The presentation should contain the most relevant figures, results and model aspects, either already included in the paper or not.

The report-paper should include the following sections:

- Theoretical concepts and background;

- Model formulation;

- Model calculations (including load-mid span deflection) and prediction of the load at L/250 deflection and peak load

- Failure mechanism;

- Conclusions.

Please send all the information to jsena@civil.uminho.pt

10. EVALUATION

Experimental results of both beam specimens will be used as a reference in the evaluation of the reports submitted by the participants. This evaluation will consider two main aspects: (i) one related with the objective quantification of the degree of approximation achieved by the estimated load mid-span deflection responses, and (ii) the other related with the evaluation of the proposals (report-paper) by the Jury of the competition. Accordingly, the final classification of each team will be based on the following parameters:

- **Parameters C$P_{L/250}$, CP_{max}**: these parameters aim at grading the approximation of the estimated load corresponding to L/250 ($P_{L/250}$) and the peak load (P_{max}), respectively. For the case of C$P_{L/250}$, the grade is given by:

$$CP_{L/250} = \left(1,00 - \frac{\left|P_{L/250,pred} - P_{L/250,exp}\right|}{P_{L/250,exp}}\right) \times 5,00$$

where $P_{L/250,pred}$ is the predicted value of P$_{L/250}$ and, $P_{L/250,exp} = 0,5 \times \left(P_{L/250,Beam1} + P_{L/250,Beam2}\right)$, $P_{L/250,Beam1}$ and $P_{L/250,Beam2}$ are the values of $P_{L/250}$ for the beams 1 and 2, respectively. The other parameters of P_{max} will be graded similarly.

- **Parameter C$w_{L/250}$**: this parameter aims at grading the approximation of the estimated response mean value of the crack width near the mid support (150 mm from each side of the mid-support). The grade will be assessed using the estimated mean value of the crack width ($w_{L/250,pred}$) and the experimental mean value of the crack width of both beams ($w_{L/250,exp}$) and is given by:

$$Cw_{L/250} = \left(1,00 - \frac{\left|w_{L/250,pred} - w_{L/250,exp}\right|}{w_{L/250,exp}}\right) \times 5,00$$

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- **Parameter CP-$\delta_{\text{mid-span}}$**: this parameter aims at grading the approximation of the estimated response of the load mid-span deflection curve up to 45 mm of deformation. The grade will be assessed using the total area between the estimated curve (A_{pred}) and the mean experimental response of both beams (A_{exp}) up to the experimental peak load and is given by:

$$CP\delta_{\text{Mid-span}} = \left[1,00 - \frac{\left| A_{\text{pred}} - A_{\text{exp}} \right|}{A_{\text{exp}}} \right] \times 5,00$$

- **Parameter CModel**: The Jury of the competition will review the reports submitted by each team. The quality of the reports submitted will be evaluated, considering the following aspects:
    i. The accuracy of the predicted load-displacement responses, and the description of the expected failure mechanism;
    ii. The innovative character of the proposed model;
    iii. The creativity and the theoretical soundness of the model principles described;
    iv. 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 be on the scale [1-5].

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

$$C = 0,15 \times CP_{L/250} + 0,10 \times Cw_{L/250} + 0,20 \times CP_{\text{max}} + 0,35 \times CP - \delta_{\text{Mid-span}} + 0,20 \times CModel$$

11. PRIZES AND AWARDS

The competition results, winners and a summary of the proposals submitted will be published in the Newsletter of *fib*. 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 beams, as well as the analysis of the models adopted.

The winning teams will be awarded the following prizes:

- 1st prize: 1500€;
- 2nd prize: 750€;
- 3rd prize: 300€.

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

12. JURY

José Sena Cruz (chairman)	António Pinho Ramos	Aurelio Muttoni
Jan Vitek	João Almeida	Mário Pimentel

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REGISTRATION FORM

Team

Name of the team:

Acronym (10 characters max.):

Supervisor

Name:

Affiliation:

E-mail:

Participants

Name / Affiliation / Type of Student (MSc or PhD) / E-mail 1:

Name / Affiliation / Type of Student (MSc or PhD) / E-mail 2:

Name / Affiliation / Type of Student (MSc or PhD) / E-mail 3: