SUMMARY REPORT OF THE
EGOLF ROUND-ROBIN NR. TC2 14-1
IN FIRE RESISTANCE TESTING

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1. INTRODUCTION

In 2014, EGOLF organised a round robin (RR) on fire resistance tests according to EN 1365-3 with 16 participating labs. This round robin enables the participating laboratories to demonstrate their ability to perform this test method, to obtain regular results, and to express their trueness, precision and uncertainty of measurement.

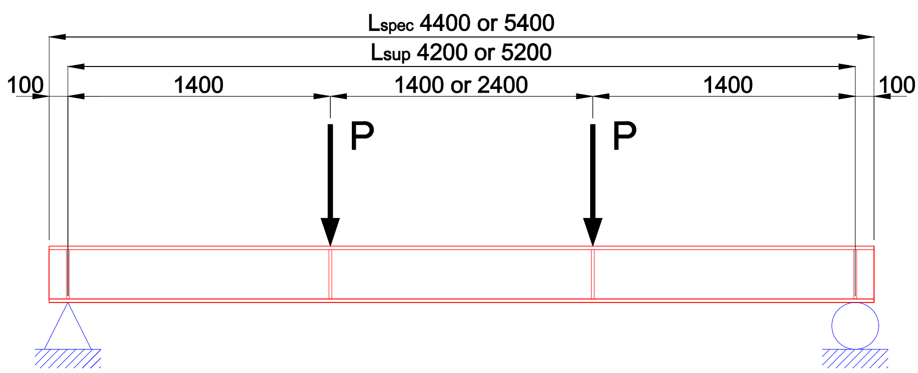
The present document is a summary of the full report of the round robin (TC2 14-1 round-robin).

1.1 SCOPE

1.1.1 Test specimen

The test specimen is a HEB 300 hot rolled beam, with a nominal steel grade of S355, reinforced by 8 welded stiffeners. The real elastic limit has been determined by tensile tests at an average value of 448 MPa. The stiffeners are provided at the supports and at the load application points on both sides of the web.

Each lab chose to test one of these two specimen lengths:



(all dimensions in mm)

1.1.2 Test method

The fire tests shall be performed according to the fire resistance standards EN 1363-1 and EN 1365-3. The performance to measure is the loadbearing capacity, through the limiting deflection criterion and the limiting rate of deflection criterion.

The test configuration is as follows:

- fire exposition: the beam shall be exposed to the fire on 3 sides (3 sided exposure)
- fire scenario: the fire scenario shall be the EN 1363-1 standard of fire curve (ISO 834)
- installation: the beam shall be simply supported
- loading: the test loads “P” alone shall produce a 140 kNm bending moment which is uniform between the two central stiffeners

1.1.3 Calculated setpoint values

The participating labs were asked to calculate and report the value of the load to apply at each application point “P”, as well as the limiting values of the deflection and rate of deflection criteria.

1.1.3.1 Load

The component of the bending moment generated by the own weight of the beam, as well as the component of the bending moment generated by the dead load of the associated construction, were expected to be disregarded from the calculation. Applying the formula $M_{max,uniform} = P \cdot x$, the value of the load to apply at each application point "P" was thus $P = 100kN$.

Four labs considered the own weight of the beam and the dead load of the associated construction in the bending moment calculation. In consequence, they reported a calculated loading setpoint slightly below 100 kN, fortunately without any consequences for the validity of their results. All the other labs reported $P = 100kN$ as expected.

1.1.3.2 Limiting criteria

Following the standard EN 1363-1 § 11.1, the limiting values to report were:

- limiting deflection:
  - 147 mm for L_{sup}=4200 mm, and
  - 225 mm for L_{sup}=5200 mm
- limiting rate of deflection:
  - 6,53 mm/min for L_{sup}=4200 mm, and
  - 10,0 mm/min for L_{sup}=5200 mm

All the labs correctly reported these values.

1.1.4 Laboratories experience

All participating laboratories are EGOLF members and are accredited against ISO 17025.

1.1.5 Scheme of the experiment

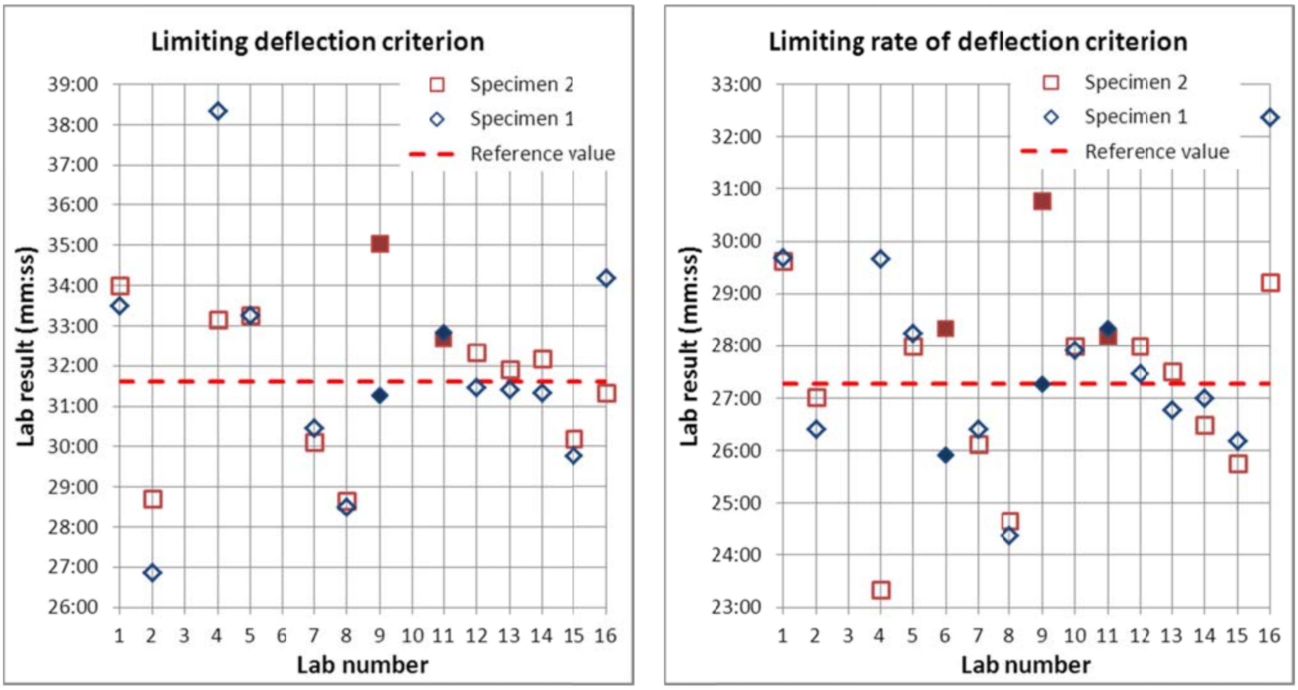
Sixteen laboratories participated to this RR (*p=16*). Since about 20 laboratories declare to use this test method, it can be assumed that the number of laboratories participating to this RR is large enough to be a reasonable cross-section of the population of qualified laboratories.

Each laboratory was requested to conduct two identical tests, on identical replicates, under repeatability conditions.

1.2 ORIGINAL DATA

The raw data for the limiting deflection criterion and the limiting rate of deflection criterion are presented in charts below. The wording "raw data" refers to "the data as they've been submitted by the participants", meaning that those data may possibly contain errors.

Missing data are due to tests stopped either before the occurrence of the corresponding mode of failure, or because of technical problems.



(Filled markers locates test on L_{sup}=5200 mm)

2. GENERAL ACCURACY EVALUATION

2.1 PURPOSE

The test specimen, the laboratories, the number of replicates, the instructions and the protocol of this experiment have been chosen to fully comply with the ISO 5725 prescriptions. As a result, the data processing tools presented in the ISO 5725 could also be implemented.

The first aim of the analysis is to work out as accurate as possible the best estimates of the fire resistance results of the specimen (reference values *m*) and quantitative measurements of the spread of the lab results (repeatability standard deviations s_r and reproducibility standard deviations s_R).
As it is useful to include as many correct results as possible in the estimations, all the necessary and possible corrections of the data are allowed for this purpose.

2.2 SELECTION OF REGULAR DATA

As the accepted reference values are produced from the raw data submitted by the participating laboratories, the presence of irregular data could distort the estimates. Irregular data refers to:

- results incorrectly reported: results too rounded, results badly captured from the spreadsheets, rate of deflection incorrectly computed…
- results arising from tests not carried out under repeatability conditions
- results arising from tests non-complying with standards requirements and instructions
- results identified as outliers, as detected by specific statistical tests (Mandel, Grubbs and Cochran).

A deep inspection of the data has been carried out, lab by lab and test by test, to detect such deviations. As a result, the whole data of 3 tests have been discarded because of unrecoverable non-compliant data, as well as the deflection criterion results of one lab because of outlier data.

2.3 EXPRESSION OF GENERAL ACCURACY RESULTS

Final accuracy results for the limiting deflection criterion

General mean = Reference value	m	**31:37**	
Repeatability standard deviation	s_r		**00:21**
Between-laboratory standard deviation	s_L		01:45
Reproducibility standard deviation	s_R		**01:47**
Ratio	$\gamma = s_R / s_r$		5,0
Repeatability limit	r		**01:00**
Reproducibility limit	R		**05:01**

Final accuracy results for the limiting rate of deflection criterion

General mean = Reference value	m	**27:17**	
Repeatability standard deviation	s_r		**00:53**
Between-laboratory standard deviation	s_L		01:10
Reproducibility standard deviation	s_R		**01:27**
Ratio	$\gamma = s_R / s_r$		1,7
Repeatability limit	r		**02:28**
Reproducibility limit	R		**04:05**

2.4 INTERPRETATION

The **general mean** *m* is the best estimation of the test result. This is the result that would be produced by a “perfect lab” performing a “perfect test”.

The **repeatability standard deviation** s_r is the standard deviation of test results – obtained under repeatability conditions – that may be expected on average in labs.

The **repeatability limit** *r* is the value below which the absolute difference between two test results obtained under repeatability conditions may be expected to lie with a probability of 95 %.

The **reproducibility standard deviation** s_R is the standard deviation of test results – obtained under reproducibility conditions – that may be expected on average in labs.

The **reproducibility limit** *R* is the value below which the absolute difference between two test results obtained under reproducibility conditions may be expected to lie with a probability of 95 %.

These amounts depict in what proportions the test results are spread because of all the factors encountered when testing a beam according to the standards EN 1363-1 and EN 1365-3 (differences in handling and positioning the test specimen, differences in instrumentations and calibrations, differences in furnaces and other equipment, differences in operators, differences in procedures and calculations, …).

3. PERFORMANCE EVALUATION

3.1 PURPOSE

In this Part 2, individual accuracy results are produced from the raw data submitted by the laboratories. These individual accuracy results consist of the bias (trueness) and the standard deviation (precision) for each lab. The performance of each lab can then be deduced by comparison of these values with the general accuracy results produced above.

This section implements some simple graphical and numerical criteria to these labs' individual accuracy results. Those methods, presented in the ISO 13528, allow deducing a clear picture of the performances of the laboratories.

3.2 STARTING DATA

For each laboratory, the within-lab mean ($\overline{y_i}$), the bias ($\Delta_i = \overline{y_i} - m$) and the within-lab standard deviation (s_i) are calculated. The bias and the standard deviation express the trueness and the precision of the labs respectively. Contrary to what has been done in accuracy evaluation, the performance assessment of the labs must be based on the original results submitted by the labs. So, no correction is allowed.

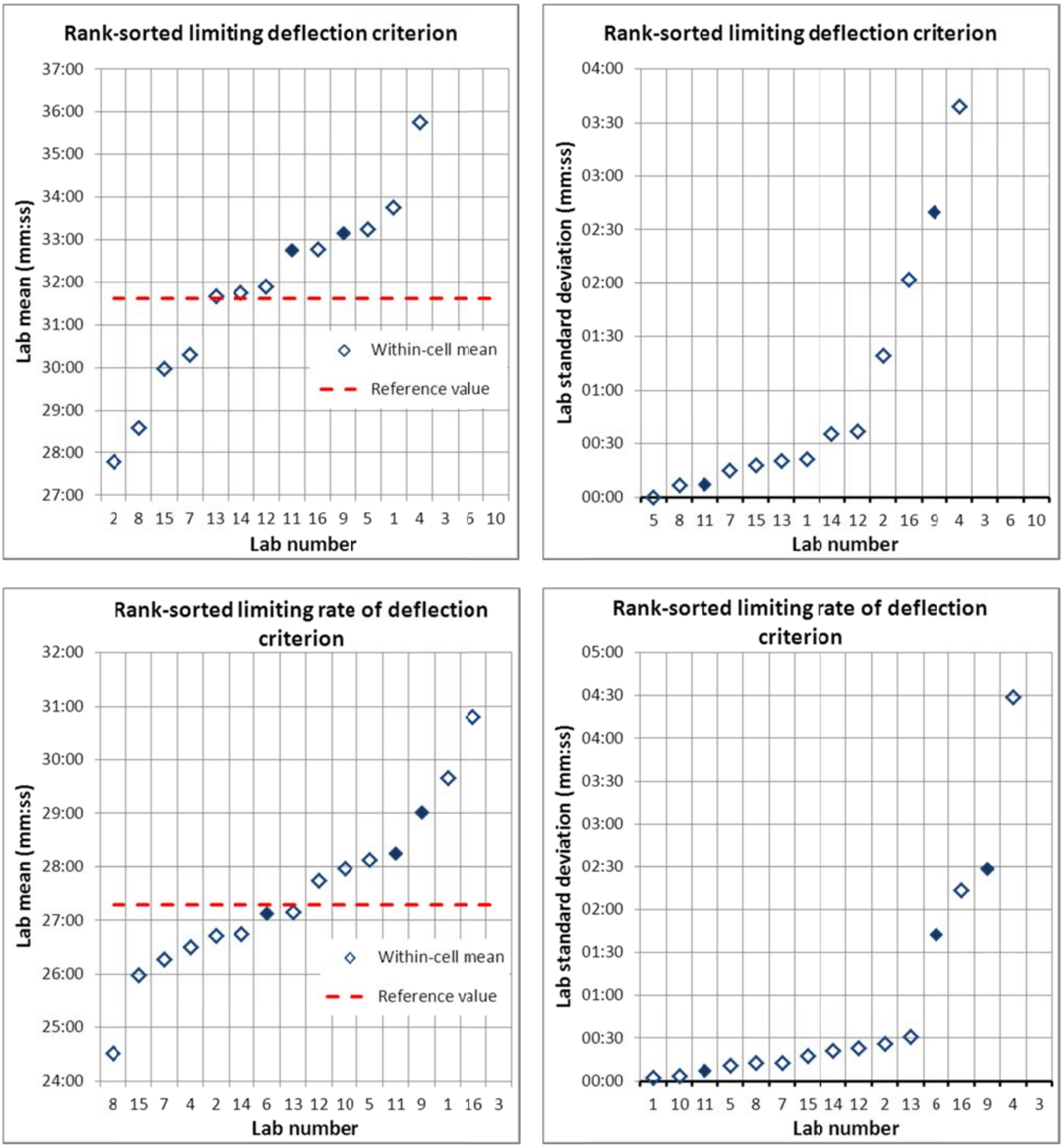
The closer to the reference value the within-laboratory mean is, the smaller the lab's bias is, the better the lab's trueness is. This will be quantified by the *z*-score below.
The smaller the within-laboratory standard deviation is, the smaller the lab's variability is, the better the lab's precision is. This will be quantified by the *k*-score below.
The global accuracy of a laboratory results from these two components.

3.3 RANKS

Ranks for the means are deduced from the mean result of each laboratory by assigning the rank 1 to the lab having the smallest mean, rank 2 to the lab having the next upper mean, … up to rank p to the lab having the highest mean. Similarly, ranks for the standard deviations can be deduced from the standard deviation of each laboratory.

The rank-sorting provides a simple method to identify the laboratories having the most extreme results. They are often used to identify the laboratories that would be the more likely to improve their performance.

Gauss plots of the rank-sorted laboratories are shown below.



(Filled markers locates test on L_{sup}=5200 mm)

3.4 Scores

- The z-score is a performance statistic that depicts the bias and thus the trueness of a laboratory. It is defined by

$$z_i = \frac{\overline{y_i} - m}{s}$$

where s is the proficiency testing standard deviation (standard deviation of the average results of the labs).

- The k-score is a performance statistic that depicts the variability and thus the precision of a laboratory. It is defined by

$$k_i = \frac{s_i}{s_r}$$

The interpretation of these scores is simple:

- $|score_i| \leq 2$: the trueness performance of the lab is satisfactory (the lab's mean is found to fall approximately in the 95% range of more probability occurrence values),
- $2 < |score_i| \leq 3$: warning signal, the trueness performance of the lab is questionable (the lab's mean is found to fall approximately in the 5% range of less probability occurrence values),
- $3 < |score_i|$: action signal, the trueness performance of the lab is unsatisfactory (the lab's mean is found to fall approximately in the 0,3% range of less probability occurrence values).

(Out of 16 participating labs)	*z*-score	
	Deflection	Rate of deflection
Warning signal	2 labs	2 labs
Action signal	-	-

(Out of 16 participating labs)	*k*-score	
	Deflection	Rate of deflection
Warning signal	-	2 labs
Action signal	4 labs	1 lab

4. MAIN CONCLUSIONS

When testing of a beam with a fire resistance of approximately 30 minutes, one could expect to reach a relative expanded uncertainty of 11% on the test result ($= \frac{2s_R}{m}$ at a confidence level of 95%, see tables in 2.3) for the limiting deflection criterion as well as for the limiting rate of deflection.

The following parameters have been identified as potential improvement. These topics could help the laboratories to improve the quality of their test process and results.

1. The total bending moment generated in a beam results of several components:
   - a bending moment component generated by the point loading system;
   - a bending moment component generated by the own weight of the beam;
   - a bending moment component generated by the dead load of the associated construction (aerated concrete slabs).

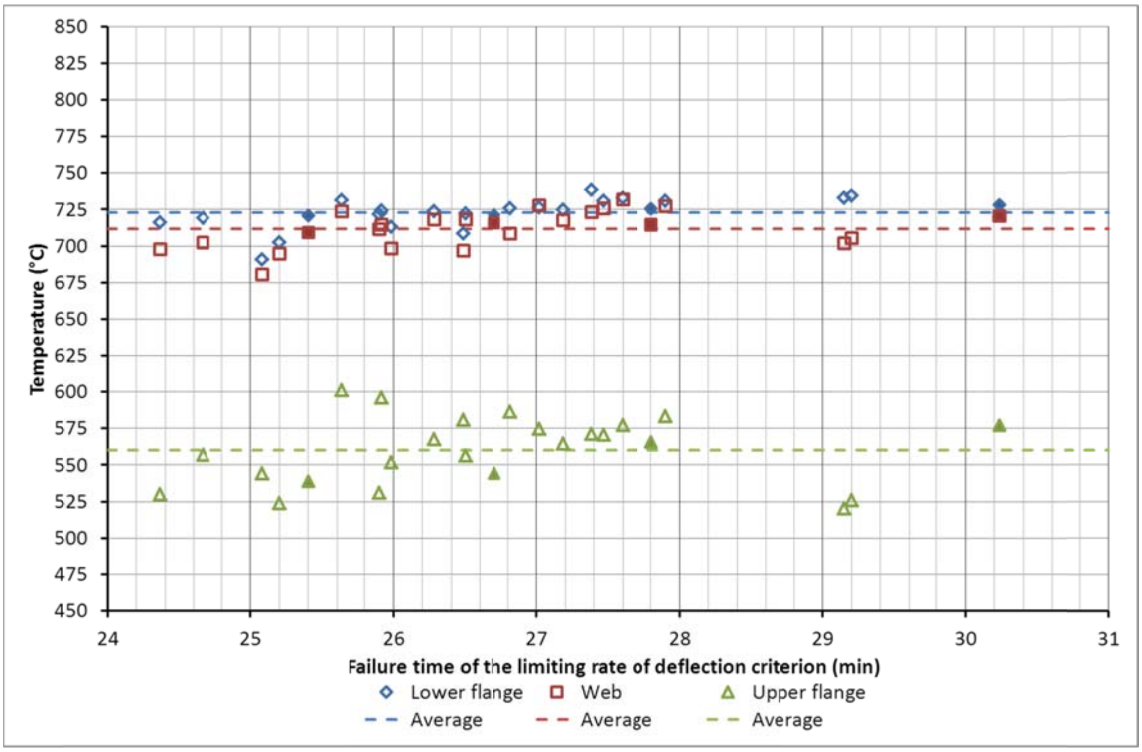
   The first component is uniform between the two central loading points. The second and the third components are not uniform but well quadratic along the beam.
   These components should be clearly differentiated when discussing with a client (setpoint of the load), and stated separately in any report.

2. The load shall be applied and held in-between the standard tolerances from at least 15 minutes before the commencement of the fire test. The load values shall be reported from the beginning of the loading.

3. The deflection measurements shall be reported from the beginning of the loading. They shall prove to be stabilised before commencing the fire test.

4. Since the currents standards do not provide any method to compute the rate of deflection from the deflection measurements, each laboratory is free to compute the rate of deflection by its own numerical differentiation method.
   A harmonized computation method for the rate of deflection could be proposed and adopted amongst the European labs.

5. The steel temperature has been measured and reported by most of the labs. These values are plotted below and show that the failure occurs at a rather specific steel temperature profile in the beam section.



This means that the test results are probably much more influenced by the heating conditions than by other causes. The labs should thus pay attention to:

- the closeness between the furnace temperature and the time-temperature curve,
- the deviation in the area of the furnace temperature curve from the area of the standard curve, and therefore the rate of heating in the furnace,
- the number, location and orientation of the plate thermometers,
- how confined is the area around the beam, depending on the geometry of the furnace cover slabs (this could affect the temperature fields which applies to the beam).