

# Length Calibration Quality Assessment through Interlaboratories Comparison

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**Abstract** – Year by year, laboratories has to demonstrate their competence to accreditation bodies and clients, as well.

In order to give confidence of their measurement results, participation in interlaboratories comparisons is an important key. Laboratories, through interlaboratories comparison, check the reliability of their measurement results in comparison with assigned values, either reference values or consensus value.

In this interlaboratories comparison, a number of 11 laboratories, using own procedures, had participated for a time period in which they determined the corrections [1] of callipers.

The main goal of this intercomparison[2] was the assessment of laboratories capabilities that perform calibrations in the length field and a travelling measurement standard which was used.

**Keywords** – proficiency testing, interlaboratories comparison, length, calliper

## I. INTRODUCTION

The measurement of length has its origin in ancient time. Today, in our society, dimensional metrology plays an important role.

In accordance with predetermined conditions, using the same item, laboratories performance and evaluation of their measurement results is assessed through interlaboratories comparison.

At national level, an external laboratories' assessment of their technical performance [3] is required, as a proof of quality.

Prior to participate in PT, laboratories must assure that the interlaboratories comparison is fit for purpose or not.

Measurement results of PT scheme is an objective evaluation of laboratory's performance, as individual and in comparison, with results of others. Participating in an interlaboratories comparison can help laboratories to identify their own measurement problems, such as inadequate test or measurement processes and procedures, and can give them the opportunity to improve their

activity.

PT scheme results requests a correct use and interpretation.

### TRAVELING MEASURING STANDARD

Type of proficiency testing scheme was quantitative sequential participation scheme, which had involved the proficiency test item being circulated successively from the one participant, circulated back to the proficiency testing provider for rechecking, to the next.

Proficiency test item, having documented traceability, was a calliper having the following characteristics:

- measuring range (0...150) mm,
- resolution 0.01 mm,
- coefficient of thermal expansion  $(11.5 \pm 1.0) \times 10^{-6} \times K^{-1}$ ,
- digital display.

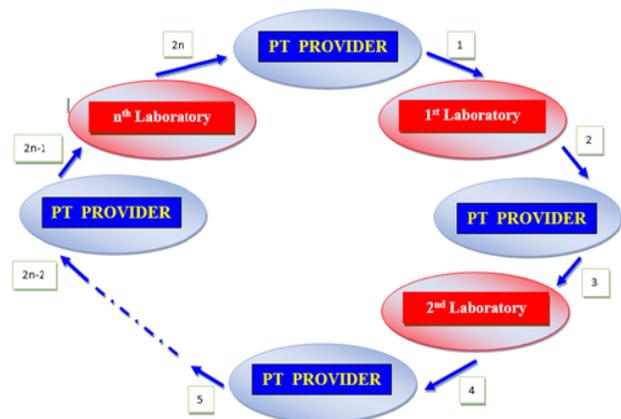


Fig. 1. Route of traveling measurement standard

According to technical protocol, the reference calliper – micrometer had been calibrated, as follows:

- for external measurements: 1.45; 15.50; 60.00; 90.00 and 140.00 mm,
- for internal measurements: 20.00 mm
- for depth measurements: 19.50 and 140.00 mm.

Rated operating conditions:

- temperature:  $(20 \pm 2) ^\circ C$ ,
- relative humidity:  $< 80 \%$ ,
- atmospheric pressure:  $(960 \pm 100)$  mbar
- measuring force had been limited to 3 clicks of mechanism.

## II. RESULTS & DISCUSSION

The reference laboratory of provider performed the characterization of traveling measurement standard. The reference values were calculated as a mean of obtained values by reference laboratory. The stability of travelling measuring standard is given by the corrections presented in the table 1.

Table 1 – Reference values

$x_{ref}$ mm		$c_i$		$c_f$	$c_i - c_f$	$c_m$
				□m		
1.45	c	$c_{Ref}$	3.3	0.0	3.3	1.7
		$U_{Ref}$		8.4		
15.50	r	$c_{Ref}$	6.7	3.3	3.3	5.0
		$U_{Ref}$		8.5		
60.00	c	$c_{Ref}$	6.7	6.7	0.0	6.7
		$U_{Ref}$		8.9		
90.00	o	$c_{Ref}$	-6.7	-10.0	3.3	-8.3
		$U_{Ref}$		9.4		
140.00	s,	$c_{Ref}$	-15.0	-14.3	-0.7	-14.7
		$U_{Ref}$		9.9		
20.00	□m	$c_{Ref}$	10.0	3.3	6.7	6.7
		$U_{Ref}$		9.4		
19.50		$c_{Ref}$	3.3	0.0	3.3	1.7
		$U_{Ref}$		9.7		
140.00		$c_{Ref}$	-6.7	-3.3	-3.3	-5.0
		$U_{Ref}$		9.9		

Evaluation of laboratories' performance by the PT provider give plus value to the measurement results of participants. The purpose of PT provider is to make a correct evaluation of measurement results, provided by participating laboratories, and to make all PT results comparable. Significance of evaluation can be

immediately observed by participants and, subsequently, can give the possibility to take action for improvement.

Measurement uncertainties used in evaluation of laboratories performance requests a certain degree of understanding.

Two types of measurement uncertainty [4] can be taken into account:

- Measurement uncertainty of the assigned value.
- Measurement uncertainty of the participant result.

The evaluation of acceptance criteria for each laboratory was made using the following formula

$$E_n = \frac{x - X}{\sqrt{U_x^2 + U_{ref}^2}} \quad (1)$$

where

- $x$  - measurement result of  $i$  laboratory, for each measurement point;
- $X$  - assigned value of PT object;
- $U_x$  - expanded uncertainty of the participant's result  $x$ ;
- $U_{ref}$  - expanded uncertainty of the assigned value  $X$  determined in a reference laboratory.

$E_n$  Numbers criteria:

- $|E_n| \leq 1.0$ ; the score indicates "satisfactory" performance
- $|E_n| > 1.0$ ; the score indicates "unsatisfactory" performance.

In table 2 are presented the corrections of measurement results reported by laboratories and uncertainties associated of measurement results and in the table3 are presented the deviations of measurement results reported by laboratories and the  $E_n$  numbers. Figures from 2 to 9 show the representation of  $E_n$  numbers.

Reported results presented within tables 2 and 3 show that the laboratories [5] proved their capabilities in the field of length calibration. As an exception laboratories, having numbers 2 and 5, have to take correction actions.

## III. CONCLUSIONS

The measurement results of this inter-laboratories comparison proved that all participants meet the acceptance criteria of competence with the exception of only two, which has to take actions for improvement.

Laboratory having number 2 obtained 3 values of  $E_n$  numbers from 8 values (37.5 %) which exceeded the range  $[-1;+1]$ , as follows: 1.76, 1.63 and 1.16.

Laboratory having number 5 obtained 1 value of  $E_n$  number (1.35) from 8 values (12.5 %) which exceeded the range [-1:+1], as well.

#### REFERENCES

[1] *International Vocabulary of Metrology, Basic and General Concepts and Associated Terms VIM, 3rd edition*, JCGM 200:2008 (2008)

[2] *ISO/IEC 17043:2010, Conformity assessment – General requirements for proficiency testing*, (2010)

[3] *Springer “Handbook of Metrology and Testing”, Czichos & others, 2011*

[4] *Eurachem Guide, The fitness for purpose of analytical methods*, 2nd edition, (2014)

*ISO 13528:2005, Statistical Methods for Use in Proficiency Testing by Interlaboratory Comparisons*, (2005)

Tabelul 2– Participating Laboratory's Reported Results

Reference value, mm	Corrections& Uncertanties, $\mu\text{m}$											
	Lab, no	1	2	3	4	5	6	7	8	9	10	11
1.45	$c_{\text{lab}}$	3.27	10.07	10.00	10.00	17.00	7.00	0.00	3.47	0.00	0.00	10.00
	$U_{\text{lab}}$	<b>15.05</b>	<b>10.74</b>	<b>18.70</b>	<b>15.00</b>	<b>13.00</b>	<b>12.00</b>	<b>9.00</b>	<b>17.32</b>	<b>18.00</b>	<b>13.00</b>	<b>23.00</b>
15.50	$c_{\text{lab}}$	-0.08	9.92	10.00	10.00	17.00	-3.00	0.00	-3.21	7.00	15.00	10.00
	$U_{\text{lab}}$	<b>13.49</b>	10.74	<b>19.20</b>	<b>15.00</b>	<b>13.00</b>	<b>12.00</b>	<b>9.00</b>	<b>17.32</b>	<b>20.00</b>	<b>14.00</b>	<b>23.00</b>
60.00	$c_{\text{lab}}$	10.10	20.15	10.00	10.00	17.00	-3.00	-3.00	-3.11	10.00	11.00	10.00
	$U_{\text{lab}}$	<b>13.49</b>	<b>10.74</b>	<b>21.00</b>	<b>15.00</b>	<b>13.00</b>	<b>12.00</b>	<b>9.00</b>	<b>17.33</b>	<b>18.00</b>	<b>18.00</b>	<b>23.00</b>
90.00	$c_{\text{lab}}$	-10.14	6.30	-10.00	-10.00	3.00	-10.00	-7.00	-13.23	-7.00	8.00	0.00
	$U_{\text{lab}}$	<b>13.49</b>	<b>11.81</b>	<b>21.60</b>	<b>15.00</b>	<b>13.00</b>	<b>12.00</b>	<b>9.00</b>	<b>17.33</b>	<b>20.00</b>	<b>16.00</b>	<b>23.00</b>
140.00	$c_{\text{lab}}$	-19.72	-16.18	-20.00	-17.00	-17.00	-20.00	-3.00	-16.08	-23.00	-8.00	-10.00
	$U_{\text{lab}}$	<b>13.49</b>	<b>11.81</b>	<b>23.30</b>	<b>15.00</b>	<b>13.00</b>	<b>12.00</b>	<b>9.00</b>	<b>17.35</b>	<b>20.00</b>	<b>14.00</b>	<b>24.00</b>
20.00	$c_{\text{lab}}$	0.06	33.22	10.00	17.00	15.00	3.00	-3.00	23.38	10.00	-4.33	21.00
	$U_{\text{lab}}$	<b>13.49</b>	<b>11.81</b>	<b>19.30</b>	<b>16.00</b>	<b>10.00</b>	<b>12.00</b>	<b>9.00</b>	<b>17.32</b>	<b>18.00</b>	<b>13.00</b>	<b>28.00</b>
19.50	$c_{\text{lab}}$	-0.07	26.57	0.00	13.00	13.00	14.00	-3.00	-6.63	10.00	-10.00	20.00
	$U_{\text{lab}}$	<b>13.49</b>	<b>11.81</b>	<b>19.30</b>	<b>16.00</b>	<b>13.00</b>	<b>12.00</b>	<b>9.00</b>	<b>17.32</b>	<b>18.00</b>	<b>13.00</b>	<b>35.00</b>
140.00	$c_{\text{lab}}$	-13.61	12.85	-23.00	-13.00	17.00	-20.00	-7.00	-16.08	-10.00	-10.00	-10.00
	$U_{\text{lab}}$	<b>15.05</b>	<b>11.81</b>	<b>23.30</b>	<b>17.00</b>	<b>13.00</b>	<b>12.00</b>	<b>9.00</b>	<b>17.35</b>	<b>18.00</b>	<b>13.00</b>	<b>36.00</b>

Tabelul 3 – Participating Laboratory's En number

Reference value. mm	Deviations, $\mu\text{m}$ & $E_n$ Number											
	Lab, no	1	2	3	4	5	6	7	8	9	10	11
1.45	$c_{\text{lab}} - c_{\text{ref}}$	1.57	8.37	8.30	8.30	15.30	5.30	-1.70	1.77	-1.70	-1.70	8.30
	$ E_n \text{ Number} $	<b>0.09</b>	<b>0.61</b>	<b>0.40</b>	<b>0.48</b>	<b>0.99</b>	<b>0.36</b>	<b>0.14</b>	<b>0.09</b>	<b>0.09</b>	<b>0.11</b>	<b>0.34</b>
15.50	$c_{\text{lab}} - c_{\text{ref}}$	-5.08	4.93	5.01	5.01	12.01	-8.00	-5.00	-8.21	2.01	10.01	5.01
	$ E_n \text{ Number} $	<b>0.32</b>	<b>0.36</b>	<b>0.24</b>	<b>0.29</b>	<b>0.77</b>	<b>0.54</b>	<b>0.40</b>	<b>0.43</b>	<b>0.09</b>	<b>0.61</b>	<b>0.20</b>
60.00	$c_{\text{lab}} - c_{\text{ref}}$	3.44	13.49	3.34	3.34	10.34	-9.66	-9.66	-9.77	3.34	4.34	3.34
	$ E_n \text{ Number} $	<b>0.21</b>	<b>0.97</b>	<b>0.15</b>	<b>0.19</b>	<b>0.66</b>	<b>0.65</b>	<b>0.76</b>	<b>0.50</b>	<b>0.17</b>	<b>0.22</b>	<b>0.14</b>
90.00	$c_{\text{lab}} - c_{\text{ref}}$	-1.81	14.63	-1.67	-1.67	11.33	-1.67	1.33	-4.90	1.33	16.33	8.33
	$ E_n \text{ Number} $	<b>0.11</b>	<b>0.97</b>	<b>0.07</b>	<b>0.09</b>	<b>0.71</b>	<b>0.11</b>	<b>0.10</b>	<b>0.25</b>	<b>0.06</b>	<b>0.88</b>	<b>0.34</b>
140.00	$c_{\text{lab}} - c_{\text{ref}}$	-5.06	-1.52	-5.34	-2.34	-2.34	-5.34	11.67	-1.42	-8.34	6.67	4.67
	$ E_n \text{ Number} $	<b>0.30</b>	<b>0.10</b>	<b>0.21</b>	<b>0.13</b>	<b>0.14</b>	<b>0.34</b>	<b>0.87</b>	<b>0.07</b>	<b>0.37</b>	<b>0.39</b>	<b>0.18</b>
	$c_{\text{lab}} - c_{\text{ref}}$	-6.61	26.56	3.34	10.34	8.34	7.34	-9.67	16.72	3.34	-11.00	14.34

<b>20.00</b>	E <sub>n</sub> Number	<b>0.40</b>	<b>1.76</b>	<b>0.16</b>	<b>0.56</b>	<b>0.61</b>	<b>0.48</b>	<b>0.74</b>	<b>0.85</b>	<b>0.16</b>	<b>0.69</b>	<b>0.49</b>
<b>19.50</b>	c <sub>lab</sub> - c <sub>ref</sub>	-1.74	24.91	-1.67	11.34	11.34	12.34	-4.67	-8.30	8.34	-11.67	18.34
	E <sub>n</sub> Number	<b>0.10</b>	<b>1.63</b>	<b>0.08</b>	<b>0.61</b>	<b>0.70</b>	<b>0.80</b>	<b>0.35</b>	<b>0.42</b>	<b>0.41</b>	<b>0.72</b>	<b>0.51</b>
<b>140.00</b>	c <sub>lab</sub> - c <sub>ref</sub>	-8.61	17.85	-18.00	-8.00	22.00	-15.00	-2.00	-11.08	-5.00	-5.00	-5.00
	E <sub>n</sub> Number	<b>0.48</b>	<b>1.16</b>	<b>0.71</b>	<b>0.41</b>	<b>1.35</b>	<b>0.96</b>	<b>0.15</b>	<b>0.55</b>	<b>0.24</b>	<b>0.31</b>	<b>0.13</b>

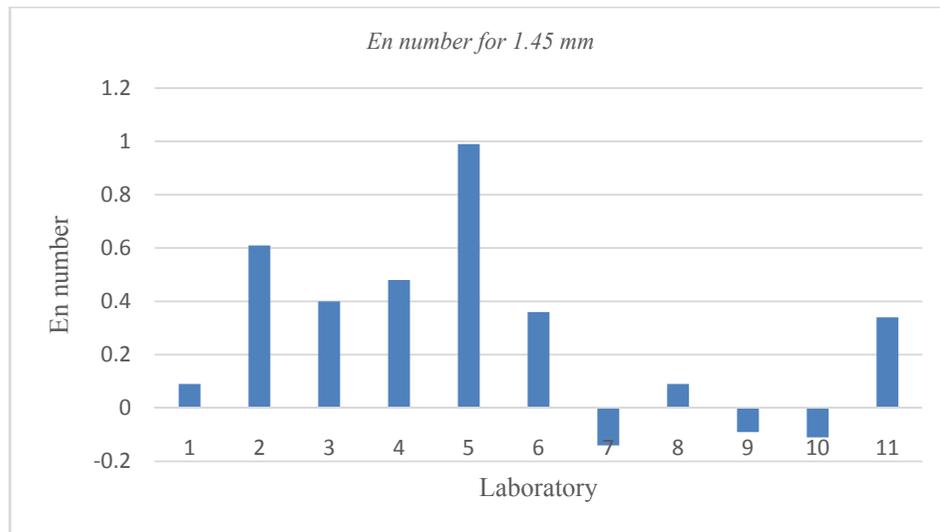


Fig. 2. E<sub>n</sub> number for 1.45 mm

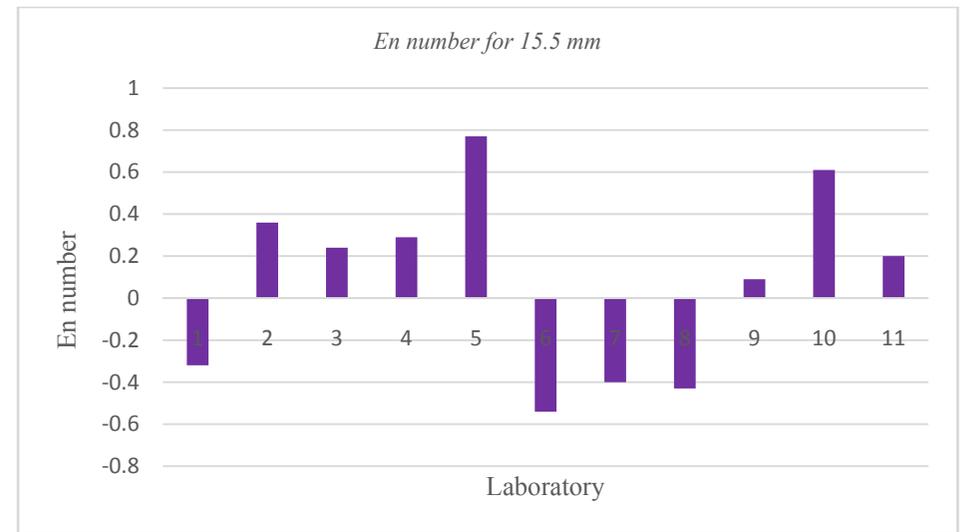
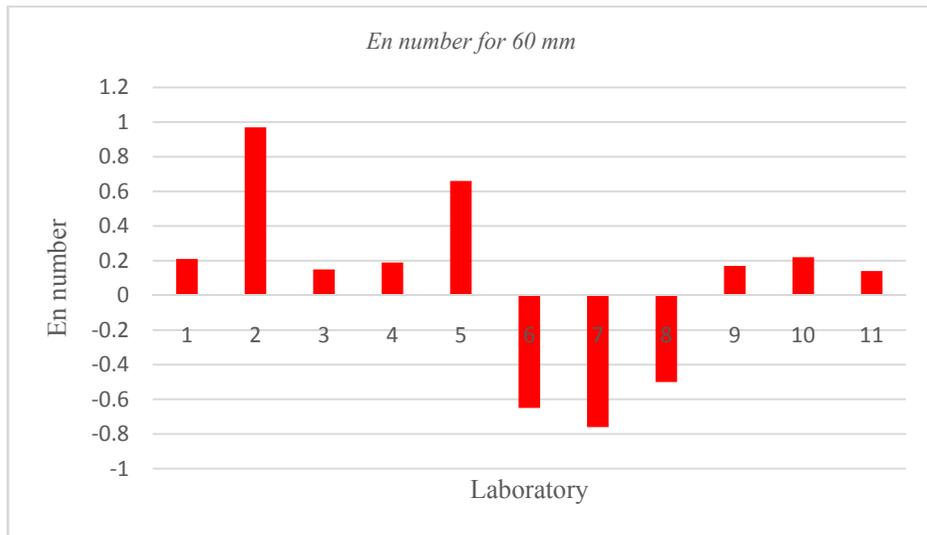
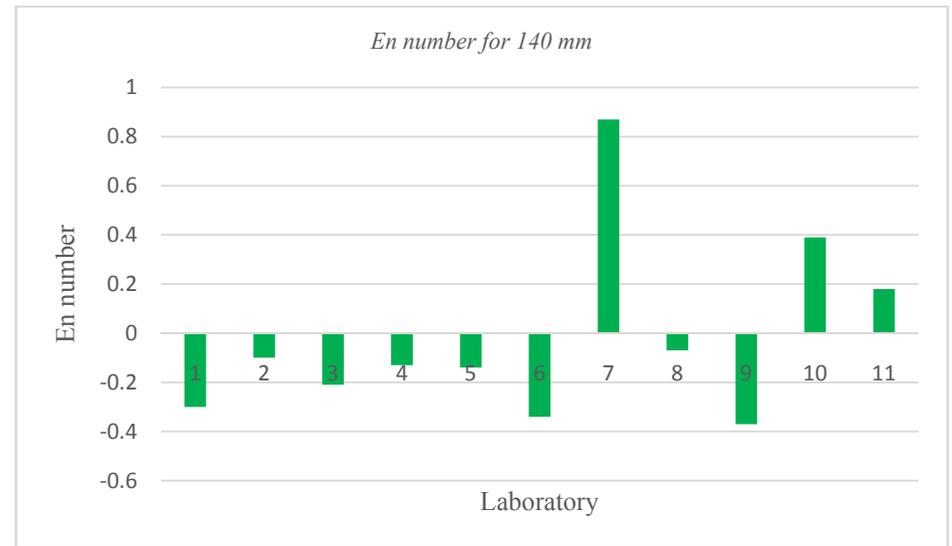


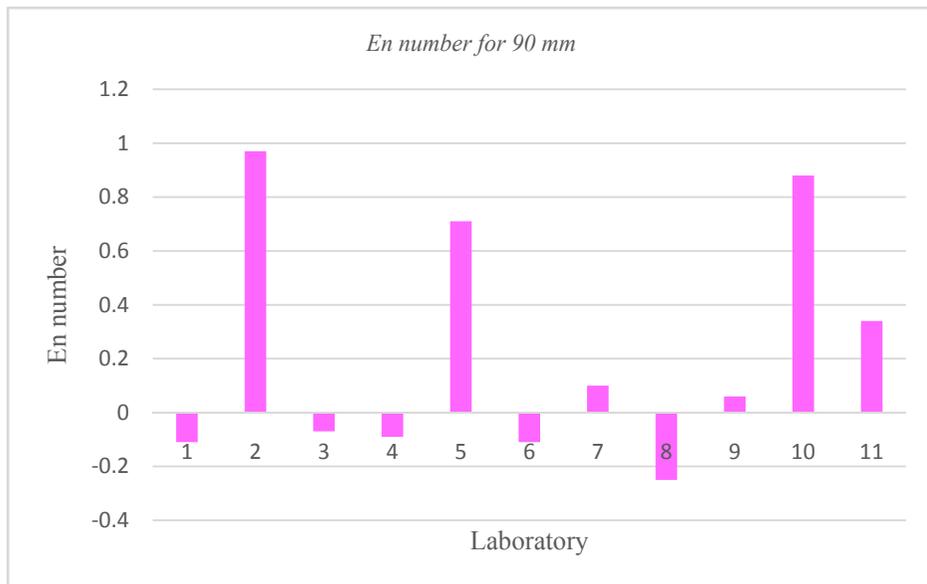
Fig. 3 -E<sub>n</sub> number for 15.5 mm



*Fig. 4.  $E_n$  number for 60 mm*



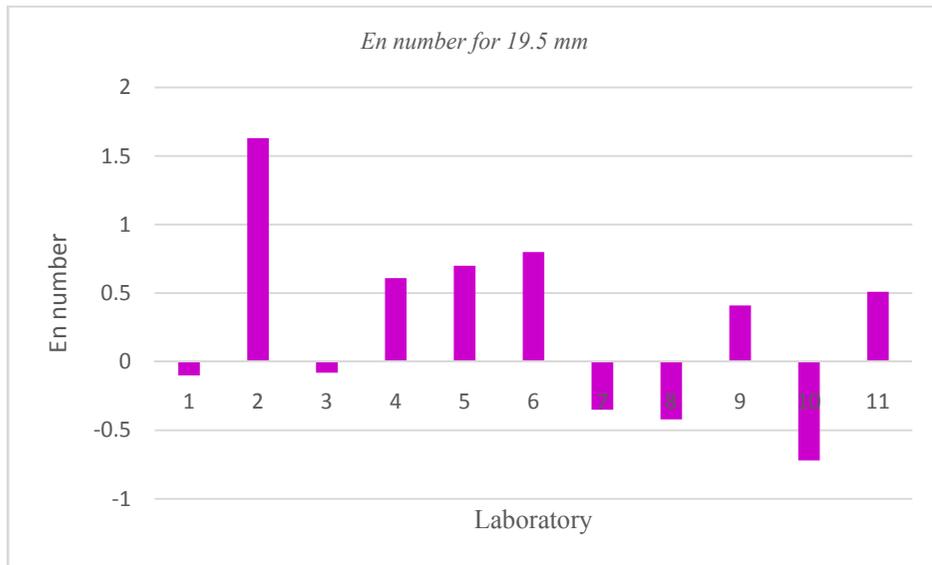
*Fig. 6 -  $E_n$  number for 140 mm*



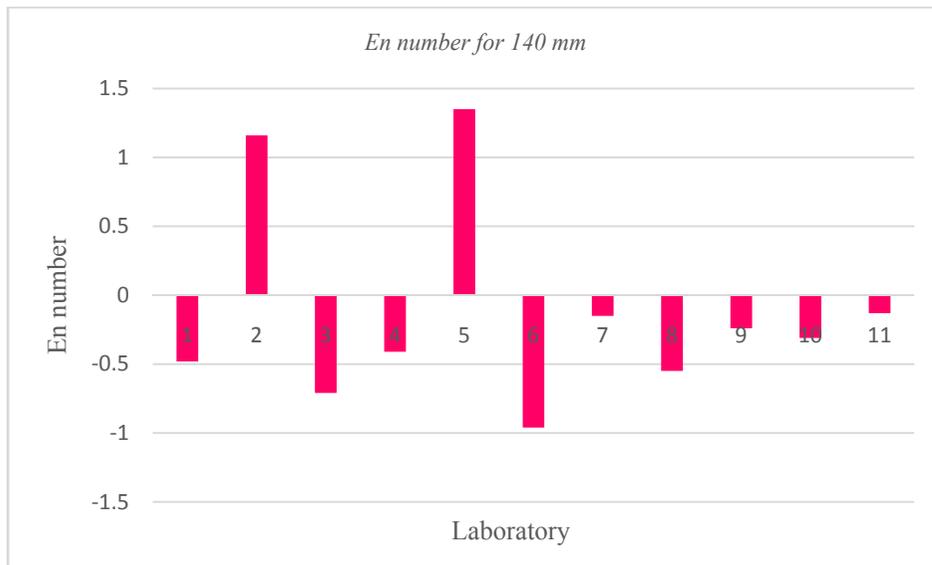
*Fig. 5 -  $E_n$  number for 90 mm*



*Fig. 7 -  $E_n$  number for 20 mm*



*Fig. 8 -  $E_n$  number for 19.5 mm*



*Fig. 9 -  $E_n$  number for 140 mm*