BEARING CAPACITY OBJECTIFICATION OF THE EARTH STRUCTURES OF AIRFIELDS USING IN LABO AND IN SITU CBR MEASUREMENTS

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ABSTRACT

The article shows the results of the earth structures bearing capacity evaluation objectification for airfields by means of CBR (California Bearing Ratio). This test is one of the most used laboratory tests of the quality of the earth structures. In labo CBR values were determined according to STN 72 1016 Laboratory determination of the California Bearing Ratio of soils. Within the frame of author´s research activities were made an objectification of the correlation between CBR values and moisture of the fill material in a cut of the earth structure of the RWY. The CBR tests were performed on the clay gravel specimens, which were prepared in the test cylinders used for a modified Proctor test. The found correlation allows to determine the moisture level to meet requirements of the RWY recommended by Aerodrome Design Manual.

In the contribution, there are presented the newest results CBR in situ measurements on the objective aero-drome earth structures too. CBR in situ values were objectified by the device WS 32830 according to CLEGG. This device quantifies the value of rate of compaction on the basis in situ tests of CIV values (Clegg Impact Value).

Keywords: *earth structures, airfields, in situ CBR, Clegg impact value, compaction*

INTRODUCTION

The Earth structures should be designed, built, maintained at a reasonable cost, within a reasonable quality, taking into account relevant user requirements and principles of sustainable development throughout their entire life cycle [1]. The Aerodrome Design Manual, Part 1 (Aerodrome Design, 2006) [9] is the relevant documents for quality control of the earth structures of the airfield areas. A runway shoulder should be prepared or constructed so as to be capable, in the event of an aeroplane running off the runway, of supporting the aeroplane without inducing structural damage to the aeroplane and of supporting ground vehicles which may operate on the shoulder. In the part "Strength of runway strips" the portion of a strip containing a non-instrument runway within a distance of at least:

- 75 m where the code number is 3 or 4,
- 40 m where the code number is 2,
- 30 m where the code number is 1,

from the centre line of the runway and its extended centre line should be so prepared or constructed as to minimize hazards arising from differences in load-bearing capacity to aeroplanes which the runway is intended to serve in the event of an aeroplane running off the runway. The value of CBR between 15 and 20 % is recommended.

Figure 1. The aeroplane confined in non-bearing shoulder part of RWY for 500 days

The CBR test is one of the most used laboratory tests of the quality of the earth structures. At first the Laboratory determination of earth compatibility test according Slovak standard STN 72 1015 is necessary to perform. The requirement involved should protect the problems incurred in airport Bratislava in 2012 (Fig.1).

METHODS AND TEST RESULTS

The main aim of earth compatibility test according STN 72 1015, 1988 (Proctor test) is to determine an optimum moisture wopt and maximum bulk density of dry soil ρmax. The evaluated results of earth construction of backfilling material of shoulder of RWY (Fig.2) are showed in next table 1 and figure 3.

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Figure 2. days The figures of earth construction under consideration from 16. 10. 2012 (up) and 24.4.2015 (down)

Table I. The results of the Proctor test modified

Number	Mass of moist soil [g]	Bulk density of moist soil [g.cm^{-3}]	Data for moisture w							
			Bowl number	Mass of bowl and moist soil [g]	Mass of bowl and dry soil [g]	Mass of water [g]	Mass of bowl [g]	Mass of dry soil [g]	Moisture [%]	Bulk density of dry soil [g.cm^{-3}]
	2	2/cylinder volume	3	4	5	6=4-5	7	8=5-7	9=100.6/8	10
1	4283	1,83	K1	414,5	404,8	9,7	158	246,8	3,93	1,761
2	4449	1,942	K4	459	442,8	16,2	144,6	298,2	5,43	1,842
3	4649	2,029	K3	429,7	408,2	21,5	144,2	264	8,14	1,876
4	4810	2,143	K6	432,9	403,4	29,5	151,1	252,3	11,69	1,919
5	4810	2,099	K2	468,3	430,8	37,5	151,7	279,1	13,44	1,850

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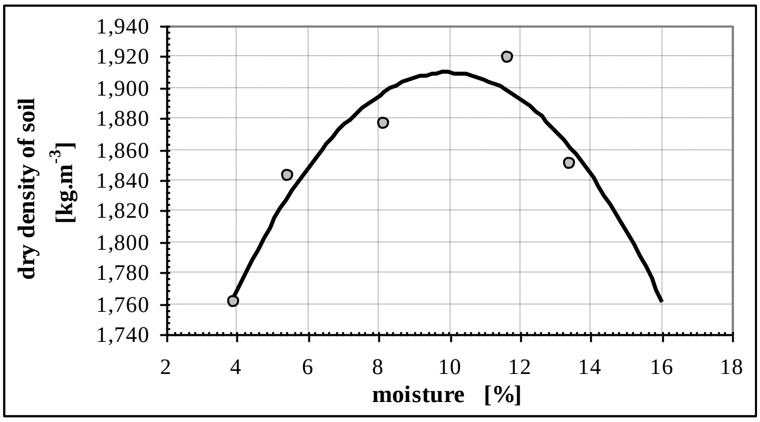

Figure 3. The results of the Proctor test modified.

The next results were obtained by evaluation of proctor test modified:

- optimum moisture .... w_{opt} = 9,9 %,
- maximum bulk density of dry soil .... $\rho_{d,max}$ = 1,910 g.cm^{-3}.

The test moisture w_{sk} in % is determined (for soils with Ip > l) according:

$$w_{sk} = w_{opt} + \Delta w_{sk} \qquad (1)$$

where: w_{opt} is optimum moisture specified according to STN 72 1015 [%],
Δw_{sk} moisture increase with regard to table 2 [%].

During CBR test the penetration into soil and implied strength are followed (Fig. 4). The device must develop strength 50 kN and has got moveable upper and lower plate which is able to move with penetration rate 1,00 mm.min-1.

Table II. Moisture increases with regard to STN 72 1016

Type of soil	Δ w_{sk} [%]
Silty sand, clayey sand	1,0
Sandy silt, silt	2,0
Clayey silt sandy, clayey silt, clay, sandy clay	3,0

The strength at penetrations 2,5 mm a 5,0 mm from corrected (aligned) curve are divided by standardized strength 13,2 kN (2,5 mm) a 20,0 kN (5,0 mm). The CBR value in % is calculated according:

$$CBR = \frac{F}{F_s} \cdot 100 \qquad (2)$$

where: F is measured strength [kN],
F_s standardized strength [kN].

Figure 4. CBR test device.

The California Bearing Ratio (CBR) is generally a ratio appertaining penetration 2,5 mm. The test result is value of California Bearing Ratio CBR in % as average of two measurements rounding-off according to Table 3.

Table III. Table Type Styles

Interval of CBR according to STN	< 30	30 - 100	>100
Rounding-off	1 %	5%	10%

The bearing capacity of tested earth structure is markedly determined by soil moisture. From this reason the CBR measurements were performed at all moistures used during Proctor test modified. The figures 5, 6 and 7 and table 4 present test results.

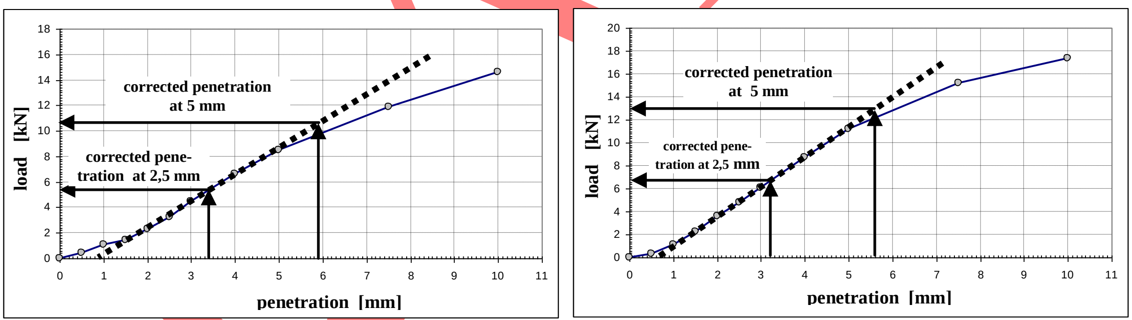

Figure 5. The corrections of CBR values for moisture w = 3,9% and 5,4%

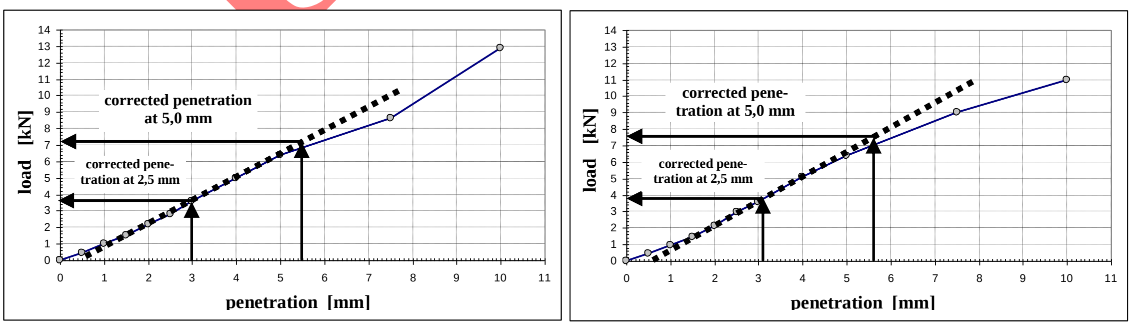

Figure 6. The corrections of CBR values for moisture w = 8,1% and 11,7%

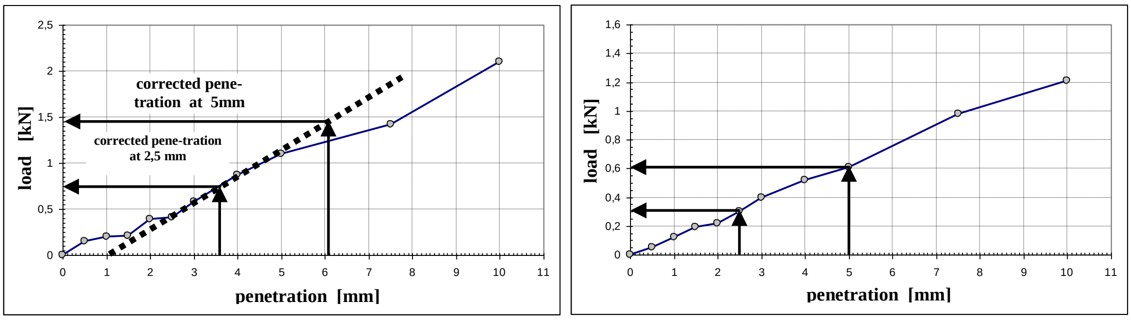

Figure 7. The corrections of CBR values for moisture w = 13,4% and 17,0%

The corrected reading of strength and CBR value are showed in table 4. Figure 8 presents correlation dependency of CBR values for penetration 2,5 a 5,0 mm and moisture of tested soil.

Table IV. Corrected readings of strength and CBR values

Moisture w [%]	Corrected strengths for penetration		CBR values			
			Calculated values of CBR		Rounding according STN	
	2,5 mm	5,0 mm	2,5 mm	5,0 mm	2,5 mm	5,0 mm
3,9	5,4	10,6	40,9	53,0	40	55
5,4	6,2	12,5	47,0	62,5	45	60
8,1	3,6	7,2	27,3	36,0	27	36
11,7	3,87	7,5	29,3	37,5	29	38
13,4	0,75	1,45	5,7	7,3	6	7
17,0	0,3	0,6	2,3	3,0	2	3

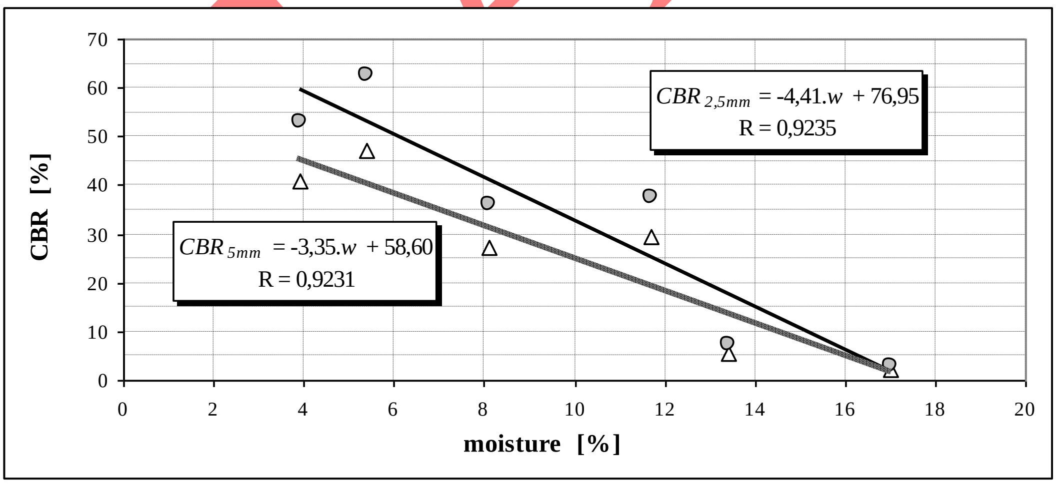

Figure 8. The correlation dependency of CBR values for penetration 2,5 mm and 5 mm

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COMPARISON OF CBR RESULTS WITH IN SITU MEASUREMENTS BY CLEGG

Clegg Impact Soil Tester model CIST/882 represents simple way of gauging the quality of features of surface and road base layers of constructions. It allows the control by the earthworks and detection of unified compaction of large-scale zones. Decký and Drusa [5] ascertained that, it is possible to use it for locating insufficiently compacted areas. Apparatus (Figure 9.) consist of:

- free falling mass with compaction built-in sensor,
- guide tube with integrated base plate and pull handle,
- control unit with digital display and connection cable.

Figure 9. Control of compaction rate by Clegg Impact Soil Tester for on clayey gravel

These parts are able to be easily constructed to lightweight portable unit. A special compaction hammer at 4,5 kg is moving in vertical guide tube. The hammer is released allowing it to fall free in guide tube at certain height and strike on the surface of base plate, at the time the rate of deceleration is identified by the force depending on compaction of the material in the area of compaction. A signal from exact accelerometer, where is documented maximum speed decrease of the hammer, located on falling mass is transferred by the connection cable to digital display.

The in situ CBR measurement according to Clegg is, as well as the cone penetration testing, progressive indirect method for testing of soil and earthwork compaction. [6] Following the measurements accomplished during experimental activities of project "ITMS: 26220220112-Independent Research of Civil Engineering Construction.

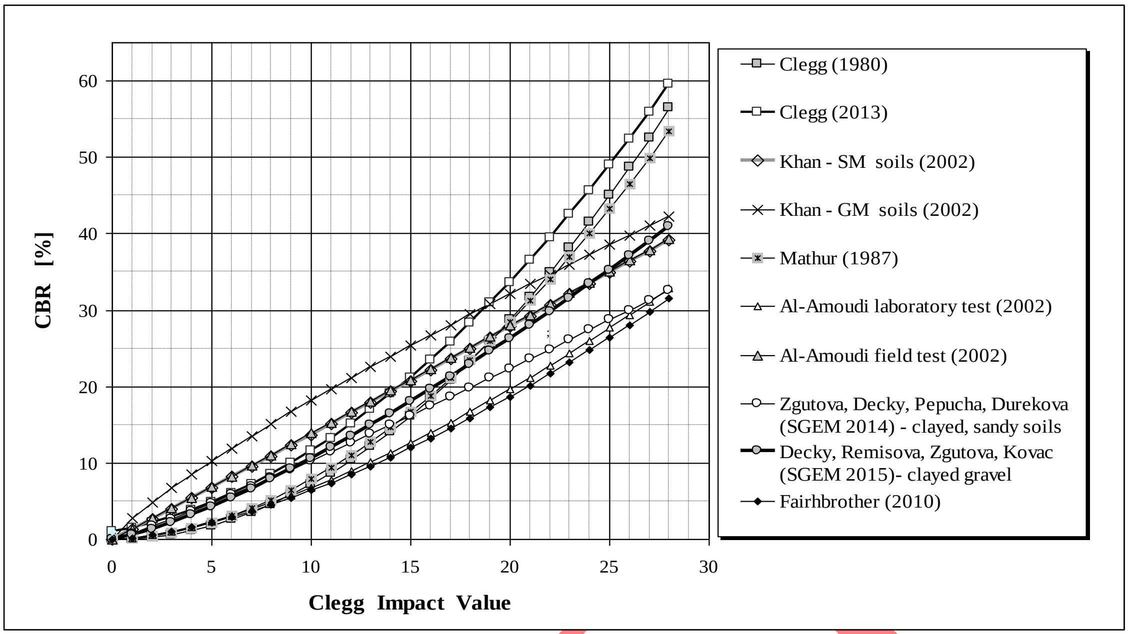

Figure 10. The comparison of CBR values and Clegg results [1]

SUMMARY

The CBR test is one of the most used laboratory tests of the quality of the earth structures. The article shows the results of the earth structures bearing capacity evaluation objectification for airfields by means of CBR (California Bearing Ratio). In labo CBR values were determined according to Slovak standard STN 721016 Laboratory determination of the California Bearing Ratio of soils. Within the frame of author´s research activities were made an objectification of the correlation between CBR values and moisture of the fill material in a cut of the earth structure of the RWY. The CBR tests were performed on the clay gravel specimens, which were prepared in the test cylinders used for a modified Proctor test. The values of the optimum moisture wopt = 9,9 % and maximum dry unit weight of soil □max = 1 910 kg.m-3 were evaluated by a modified Proctor test. The found correlation allows to determine the moisture level to meet requirements of the RWY recommended by Aerodrome Design Manual.

In the contribution, there are presented the newest results CBR in situ measurements on the objective aerodrome earth structures too. CBR in situ values were objectified by the device WS 32830 according to CLEGG. This device quantifies the value of rate of compaction on the basis in situ tests of CIV values (Clegg Impact Value). On the basis of performed laboratory and in situ tests of CBR values the applicability of author´s objectified correlation function for a quality control of the earth structures of the airfield areas according Aerodrome Design Manual, Part 1 was verified.

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