Application of a method of assigned displacements (MAD) at mechanical testing in-situ

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In modern conditions the building companies aspire to use modern, scientifically justified, industrial technologies permitting economically effective and in oblate terms to use inserted material and financial resources at construction. The important role in this case is played with a problem on a regularity of the definition of initial parameters of projection.

The mistakes in an evaluation of calculated values of mechanical properties of grounds, can reduce in noticeable inaccuracies at acceptance of design solutions and in a series of cases to violation of a stability of raised buildings. The greatest distortions arise already on a stage of approbation of dispersible grounds possessing, as a rule, high sensitivity and variability of properties. Even the insignificant force actions of a type "loading - unloading" reduce in violation of the stress-deformed condition and structure of researched grounds and as a consequence to irreparable distortions of an information, obtained in experiences. The monoliths selected from slits, also are subject to imperfections, that substantially limits application of soils research with laboratory methods. Therefore modern russian normative documents prefer field methods of the definition of soils mechanical properties.

Now, at realisation of field researches of grounds the connection between stresses and movements is established and thus as a rule the method of assigned loadings (MAL) is used. The essence of the given approach is known - on a researched ground act by gains, further measure the second parameter (movements), as a consequence of force loading. It is obvious, that for an establishment of correlation between stresses and movements, the researcher can use the opposite approach - method of assigned displacements (MAD), when the ground is deformed by the given transitions and thus the second parameter (gain), as a consequence of the deformed action is registered. In the theoretical approach the described above schemes of action on a ground are completely equivalent, because majority of physical models establish between stresses and movements the univalent correspondence.

The experimental researches whenever possible uses MAD at realisation of field researches of grounds within several years are fulfilled in JSC "Stroiizyskania Geoengineering" (Novosibirsk, Russia).

TRIAL OF PILES BY STATIC PRESSING LOADINGS

The experiments were carried out at a trial of control and real piles. For security of cleanliness of experiment and reduction of conditions of comparative trials to relative monotony (identical geological conditions and conditions of piles immersing), the parallel trials were fulfilled on the same experimental piles. Each experimental pile was tested with use of a method of assigned loadings MAL (standard approach regulated by the normative documents) and a method of assigned displacements MAD (of the prospective approach).

For elimination of influence of tixotropic properties of grounds of a research were carried out without "rest" of piles, with identical intervals of time after completion of the previous trial, or with "rest" of a pile, when before the next trial for any technique the pile was withstanded during time stipulated by the operating normative documents.

TRIAL OF CONTROL PILES

The experiments were fulfilled with use of metal control piles I types. The researches were carried out on a site, which is located in a rightcoastal part of Novosibirsk and is dated in a geomorphological ratio for a Priobsk plateau. The geomorphological slit of a site was submitted by aeolio-delluvial sand clays saturated by water softly and very plastic consistence (vdQ_{III}). The ground waters were on depth of 5,5 m.

Three parallel trials on three piles installed in limits of a researched site up to depth 10 м in total were carried out and one pair of comparative dates is obtained for a control pile of length 8 м (see tab. 1).

The particular values of limiting resistances of piles are close among themselves. The average values of a piles resistance of length 10 м have made 147 and 137 kN, deviations for piles of length 8 м - 12,5 %, for piles of length 10 м - 6,8 %. The settlements of control piles at the appropriate loadings have insignificant deviations (see fig.1) and are mainly in limits 1 ... 17 % achieving on the first steps of loading at small common settlements 24 ... 33 %.

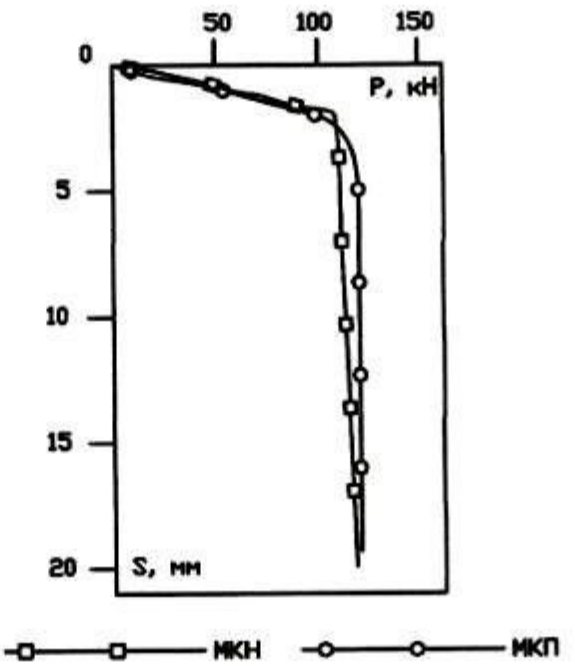

Fig.1. Graph of parallel trials of a control pile № 3
Line at the left - MAL, on the right – MAD.

Table 1. Particular values of limiting resistances of control piles on parallel trials

Range number	Number of a pile	Type of a pile	Length of a pile, m	Limiting resistance of piles P, кN		Deviation □P		Type of a ground under an edge of a pile
				MAL	MAD	kN	%	
1	1	CP-1	8. 0	80	70	10,0	12.5	water sand clays very plastic consistence
2	2	CP-1	10.0	190	190	0.0	0.0	
3	4	CP-1	10.0	130	105	25	19.2	
4	3	CP-1	10.0	120	122.5	-2,5	-2,1	

TRIALS OF REAL PILES

The experiments were carried out on real ferro-concrete piles by a cut 30x30 cm and 35x35 cm in length 12-18 м (integral - length 12-16 м and connected - 18 м). The trials were carried out on industrial platforms located in Central, October, Soviet, Kirov and Kalinin districts of Novosibirsk. The researched platforms are located on the various geomorphological elements: the Priobsk plateau, the valley of Kamenka river, I, II, III types of terraces of Ob river.

Such variety of geomorphological conditions has predetermined so wide variety of geological conditions: presence or lack of underground waters, variety of a slit - weak sand clays and clay sands, aeolian sands, eluvial sand clays etc. 12 real piles in total are tested, on which 12 pairs of comparative results in identical conditions are obtained.

For correct analysis of results the obtained dates are divided into two groups. First group included test dates of piles, which edge is immersed in dense soils, in the second group - pile with an edge immersed in weak soils.

In the first group 6 parallel trials which are carried out on MAL and MAD on two objects are included. The edge of piles was immersed in sand dense (dQ_{III}), plastic clay sand saturated by water with lenses of sand (aQ_{II-III}) and rigid eluvial sand clay (eK-P).

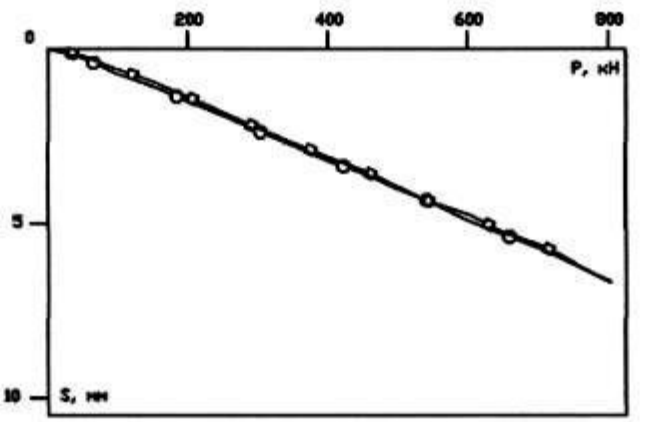

Fig.2. Results of parallel trials of real piles in dense soils

Length of real piles was 12 and 16 m. The trials were lead up to the max safe load at a loading of the metal stand by blocks up to 110 tons. The particular values of reached resistances of piles are reduced in tab. 2.

Table 2. Particular values of reached resistances of real piles on parallel trials in dense grounds

Range number	Number of a pile	Type of a pile	Length of a pile, m	Limiting resistance of piles P, kN		Deviation □P		Type of a ground under an edge of a pile
				MAL	MAD	kN	%	
1.	3	P-16-35	11.97	900	910	-10	-1.1	dense dusty sand
2.	2	P-16-35	16.00	835	835	00	0.0	dense sand clay
3.	4	P-16-35	16.00	740	895	-155	-20.9	dense sand clay
4.	4	P-16-35	16.00	800	800	0.0	0.00	dense sand clay
5.	6	P-12-30	12.0	800	720	80	10	plastic clay sand with lenses of sand
6.	5	P-12-30	12.0	880	820	60	6.8	plastic clay sand with lenses of sand

The average values of piles resistances on parallel trials are close among themselves and make 826 and 830 kN at factor of safety 1.034 and 1.040 accordingly. The deviation between particular values of resistances changes from + 10.0 % up to -20.9 %, the average values differ on -0.5 %.

The average values of piles settlement are calculated for the appropriate loadings, in limits of each technique of trials (fig.2). A deviation of piles settlements obtained at a trial by a MAD method from results on a MAL method insignificant and varies basically in limits 0.0 ...4.2 %.

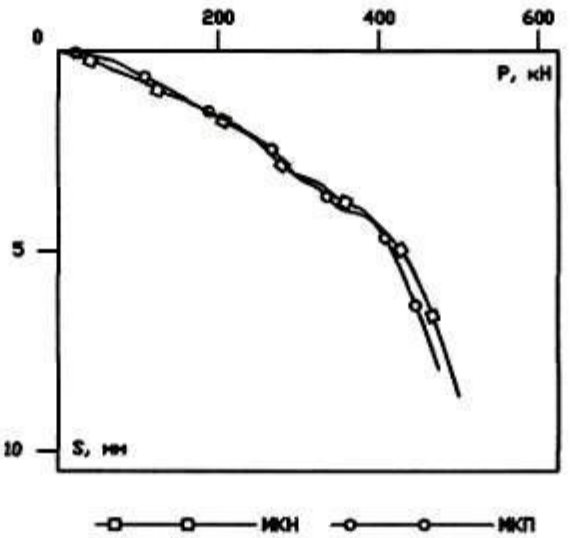

Fig.3. Results of parallel trials of real piles in weak soils
Line at the left - MAL, on the right – MAD.

The second group unites results 6 parallel trials of piles which are carried out on four objects. The ferro-concrete piles by a cut 30x30 cm and 35x35 cm, length 12, 14 and 18 м, integral (12 and 14 м) and connected (18 m) were tested, which edge was immersed in a weak plastic clay sand saturated by water and weak sand clay saturated by water softly and very plastic consistence (vd Q_{II} kd).

The particular values of piles limiting resistances on both techniques are reduced in tab. 3. For a comparison of results the values of piles limiting resistances appropriate to a point of inflection on the graph a settlement - loading of each pile were used.

Table 3. Particular values of limiting resistances of real piles on parallel trials in weak soils

Range number	Number of a pile	Type of a pile	Length of a pile, m	Limiting resistance of piles P, kN		Deviation ΔP		Type of a ground under an edge of a pile
				MAL	MAD	kN	%	
1.	2	P-14-35	12.46	330	320	10	3.0	weak softly plastic sand clay
2.	2	P-12-30 + P-6-30	18	290	250	40	13.8	weak plastic clay sand
3.	1	P-12-30 + P-6-30	18	300	300	00	00	weak plastic clay sand
4.	14	P-12-30	12	230	240	-10	-4.3	weak softly plastic sand clay
5.	4	P-12-30	12	275	260	15	5.5	weak very plastic sand clay
6.	3	P-12-30	12	375	310	65	17.3	weak very plastic sand clay

The average values of piles limiting resistances have made 300 kN - for trials on MAL and 280 kN - on MAD, at factors of safety 1.082 and 1.060 accordingly. The deviation of average values has made + 6.7%.

The comparison of average settlements of piles at different loadings calculated on both techniques, gives an insignificant deviation (fig.3). The magnitude of deviations varies basically in limits from -5.3 % to + 11.5 %, achieving maximum values (-16.9 ... -118.8 %) at the first steps of loading, where the settlements of piles have insignificant magnitudes.

RESEARCH OF DEFORMATION PROPERTIES OF SOILS

For the definition of deformation performances of grounds, as well as in case of a trial of piles, is required to receive an association loading - settlement, which can be defined with the help of two approaches - using a method of assigned loadings (MAL) and method of assigned displacements (MAD).

The experiments were carried out with the help of stamps and with the help of wedge dilatometer.

TRIAL OF SOILS BY STAMPS

The experiments were fulfilled in field conditions on two platforms of Novosibirsk with use of round stamps by square 600 cm^2 of two types: III - flat and IV - screw. The platforms were located in limits of the I-st geological terrace of the Ob river and in a valley of the Kamenka river.

The researches were carried out in slits on depths 2.1 ... 7.5 m in river sands, ashes grounds and peat clays. The parallel trials were fulfilled in the same slits and in case of insufficiency of a potency of researched soils, in the additionally drilled slits.

The works were fulfilled with the help of device KRU-600 or special system of beams and hydraulic jack.

On dates, obtained during trials, for investigated intervals the deformation modules of soils were calculated which are shown in tab. 4.

Table 4. Test dates of grounds by stamps on different techniques

Range number	Type of a ground	Depth of researches, m	Technique of a trial	Deformation module E, MPa
1.	softly plastic saturated by water peat clay	6.7 7.2	MAL MAD	1.6 2.9
2.	ashes ground saturated by water	2.1 2.7	MAL MAD	2.0 1.5
3.	shallow average denseness river sand (average size)	4.7 6.2 6.8	MAL MAL MAD	24.0 30.0 26.0
4.	shallow average denseness river sand (small size)	5.5 6.2 7.5	MAD MAL MAD	11.0 14.5 15.5

From reduced dates obtained on different techniques, it is possible to see, that the values of the deformation module of soils are close among themselves. And the scatter of values has not expressed regularity.

TRIAL OF SOILS BY WEDGE DILATOMETER (WD-100)

For the definition of the deformation module of dispersible soils in field conditions in the company "Stroiizyskania Geoengineering" the wedge dilatometer WD-100 is used. Wedge dilatometer realises in practice a method of assigned displacements (MAD).

The kinematical scheme of the devices realising loading by displacements, has appeared more simple, than for a traditional way of loading - method of assigned loadings (MAL). The realisation of relaxation method in field conditions result in a very simple design of a loading appliance (indentor which body while pressing in a ground and receiving definite displacements, serves simultaneously registrar of the pressure that arises in ground).

As shown in the researches (Lavrov, Nuzhdin et al., 2000a), (Lavrov, Nuzhdin et al., 2000b), (Pisanenko, Karaulov et al., 1991), the form of indentor essentially influences the strain condition of an environmental ground.

The more concrete conclusion was made that the task of the direct definition of the deformation module of grounds can be fulfilled with indentors having an extended cutting edge. Most simples for manufacture with such requirements is the indentor with a symmetric rectilinear wedge.

The wedge dilatometer WD-100 was developed and successfully used in practice by JSC «Stroiizyskania» («ZapSibTISIZ» Trust, Novosibirsk, Russia). The basic working body of WD-100 is an indentor, executed as a wedge. (Pisanenko and Gogolev, 1991). The WD-100 realises loading variant of a researching ground massive by acting purposeful deforms and passive measurement of unguided contact pressure arising in ground.

In presence, this device is made under the mark «WD-100» and serves for direct definition of the deformation module of soils in field conditions.

The general view of the dilatometer mounted on the chassis of static sounding self-propelled device is shown in fig.4.

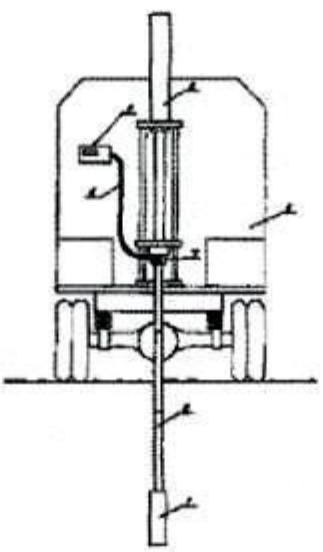

Fig.4. The dilatometer device
1-indentor, 2-sounding poles, 3-hydrocylinder, 4-cable, 5-registrar,
6-automachine, 7-special pole cup.

The complete set of the dilatometer WD-100 consists of the working wedge indentor (1), sounding poles (2), cable (4), registrar (5) and special pole cap (7). At immersing the indentor (1) in a ground, the special pole cap (7) is established on the top end of sounding poles (2). The effort from the hydraulic cylinder (3) of static sounding device (6) is transferred to a cap (7), thus the cable (4) should be missed in an aperture of a cap (7).

The dilatometer WD-100 does not contain mobile parts and consequently is rather reliable and convenient at work. The complete work cycle becomes isolated on one static sounding device widely distributed in geoengineering practice. During immersing the indentor, a current parameter of the soil module is registered on a registrar digital panel that allows to receive the continuous information of meanings of the researched deformation module along the depth.

The experimental researches preceded introduction of the dilatometer WD-100 in practice. These researches were executed for comparison of the data received with the help of the dilatometer and similar devices already known.

The comparison of results of the definition of the deformation module was produced on platforms of realisation of geological researches for construction in Novosibirsk. By comparison of results was not made of any restrictions in a ratio of ground conditions monotony. It is enough to tell, that in comparative samples have come even technogrounds (ashes).

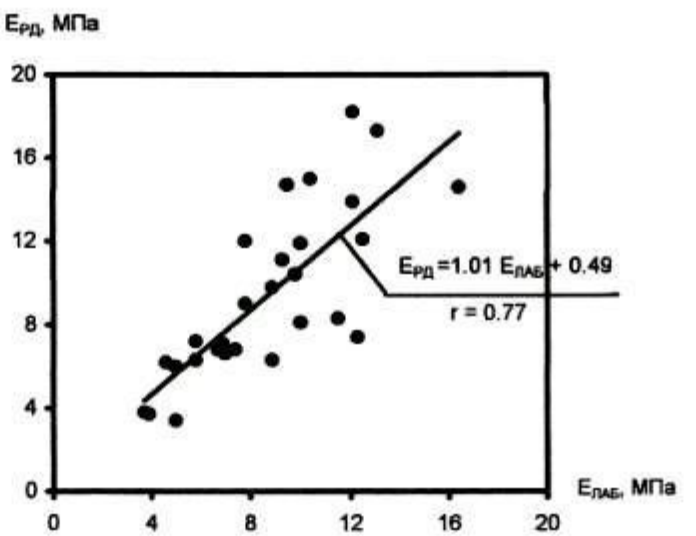

Fig.5. Results of comparison and statistical handling of values of the deformation module (E, MPa), obtained on trials by a WD-100 (axes of ordinates) and laboratory compressive device (axes of abscissas)

The statistical analysis of obtained dates was fulfilled in two stages. At the first stage the dot statistical analysis of particular values obtained by various modes in limits of the chosen geological element was carried out. The average level-by-level magnitude of the deformation module, in case of the correspondence of variability parameters (average quadratic deviation and factor of a variation) requirements of the federal standard (GOST 20522-96), was used at the further statistical analysis.

At the second stage the two-dimensional statistical analysis for an establishment of reliability and proximity of correlation of compared magnitudes (average level-by-level value of the deformation module obtained on dates of dilatometrical researches and one of traditional methods of researches) was fulfilled.

In total by comparison were used:

- laboratory values of the deformation module received in compression devices (CD-1) – 200 definitions;

- the values of soil researches received by blade pressiometer (BP-15) – 118 definitions;
- results of ground tests received by 2 stamps (the area of stamps is 600 and 2500 cm^2) – 215 definitions;
- results of ground approbation received by the wedge dilatometer (WD-100) – 1847 definitions;

As a result of statistical processing of private values sets such linear dependencies were received:

- the comparison of the dilatometrical values with the lab compressive values has resulted in the following linear expression (correlation factor – 0,77) $E_{WD}=1,01E_{lab}+0,49MPa$ (see fig.5);
- the comparison between the dilatometrical and pressiometrical research values (correlation factor – 0,96) $E_{WD}=1,06E_{BP}+0,09MPa$ (see fig.6);
- the comparison between the dilatometrical values and the stamp values (correlation factor – 0,81) $E_{WD}=0,94E_S+2,12MPa$ (see fig.7);

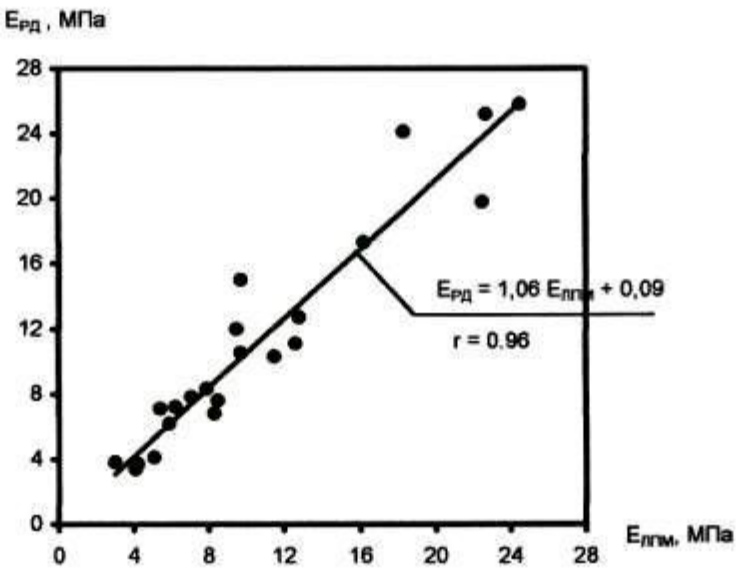

Fig.6. Results of comparison and statistical handling of values of the deformation module (E, MPa), obtained on trials by a WD-100 (axes of ordinates) and by blade pressiometer BP-15 (axes of abscissas)

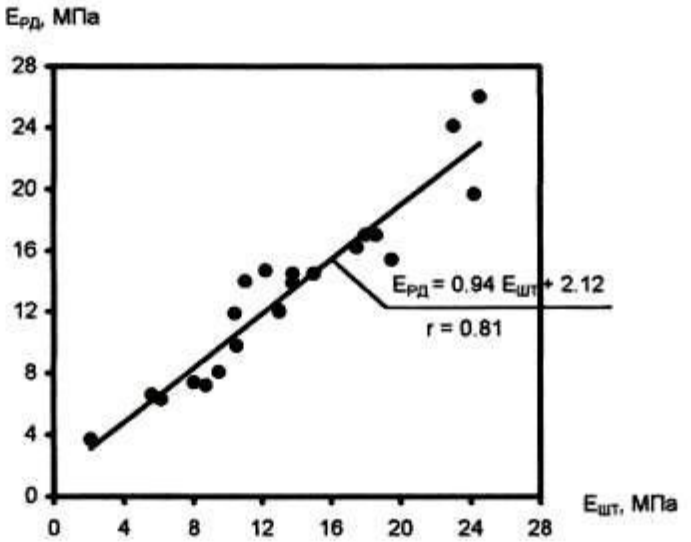

Fig.7. Results of comparison and statistical handling of values of the deformation module (E, MPa), obtained on trials by a WD-100 (axes of ordinates) and by stamp (axes of abscissas)

CONCLUSIONS

1. The carried out experimental researches confirm preliminary conclusions about the univalent correspondence of methods of assigned loadings (MAL) and displacements (MAD) and their use at a research of mechanical performances of soils in field conditions.
2. The carried out experiments not only have not revealed advantages of a MAL method above an offered MAD method, but even have designated a series of virtues of the offered approach. So, in particular, the duration of trials by a relaxation method noticeably is reduced (at a trial of control piles - in 2 ... 8 times; real piles in 5 ... 10 and more time, at a trial of stamps - in 10 and more time).
3. The realisation of a method of assigned transitions does not require manufacture of a special equipment at realisation of traditional trials.
4. The designs of an equipment realising loading of a ground by the assigned displacements, are simples and technologies in manufacture and operation.
5. The positive results of use of a MAD method in field conditions open extensive possibilities for development of an equipment of a new class for study of mechanical properties of grounds in field and laboratory conditions.

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