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THE INFLUENCE OF FOUNDATION BODY MOVEMENTS AND DEFORMATIONS IN QUALITY OF BUILDING CONSTRUCTION

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Abstract

The consequences of 'inherent deviations' (displacements, deformations and dimensional changes) of building materials are due to the effect of additional (physico-chemical) factors, influence of the assembly and position of structural elements, the outlook of the building and also the feasibility of the whole building tasks.

The Department of Surveying of the Technical University of Budapest performed planning, testing and controlling work for quality control of geometric parameters on several buildings. These commissions concentrated primarily on test of movements, deformations and dimensional changes – due to the effect of additional factors – and also on their determination and elimination of their injurious effects.

From the results measured by the Department, the experience, regarding to foundation body movement and deformation test, as well as the effect mechanism of structural dead load and payload to the vertical meant movements and deformations, is reported with the help of examples. These serve as basis for determination of forming foundation body deformations and regularities of their changes.

Keywords: quality control in the building industry, test of movement, deformation and dimensional change, *inherent deviations* caused by physico-chemical effects.

Introduction

The values of geometric parameters according to the project (size, form, position) have to be guaranteed with a specified accuracy. The values of geometric parameters in the period of construction and operation must not change beyond the permissible measure. For the sake of meeting these requirements, it has to be provided that the value of '*induced deviation*' created by manufacturing, setting out, building process (technology of assembly) and the value of '*inherent deviations*' due to movements, dimensional changes and deformations of building materials which arise from extrinsic and intrinsic physico-chemical causes (further additional factors) will not exceed together the rated permissible value.

The induced deviations can be planned exactly, it is merely a question of adherence to technological discipline and of suitable controls. The inherent deviations cannot be planned exactly. Empirical data of other establishments and the purposeful movement and deformation test of the fixed establishment can serve as base material when planning.

In every case the procedure causes, the effect mechanism of inherent deviations and the way of determining, considering estimated effects (displacements, size and form changes) and their elimination must be tested. The produced reversible or enduring building material movements which arise practically because of every physico and exterior–interior chemical causes are regarded as inherent deviations such as structural dimensional changes formed by the effect of temperature variation, structural displacements arising by mounting constraints, the foundation body movements, settings and deformations caused by the effect of structural dead load and payload.

In order to enlarge the empirical base material planning, test results of vertical valued foundation body movements are reported.

Testing Experience of Vertical Meant Foundation Body Movements and Deformations Formed by Structural Dead Load and Payload

The setting of the building foundation bodies is influenced by several facts, for example:

a) Geological, physical and mechanical bases of the underground

b) The movements of the underground:
   - movements in consequence of seismological effects,
   - movements because of water table changes,
   - movements due to the effect of change in natural state and environment of soil (easing of soil, guidance of rain and day water to the foundation body, change in environmental load distribution with establishing of trenches and spoil areas),
   - movements because of daily and annual change of temperature and air pressure,
   - movements in consequence of shrinking of the material of the foundation body,
   - movements caused by the effect of foundation body and underground loading.

c) Shaping of the foundation body.

As a result of the different factors, the resultant value of movements and deformations is experienced in testing measurements and also these are considered in planning. However, successful planning, the building direction and the controlling work, the behaviour of foundation body caused by detached effects need to be known.

Because of this, in the following examples the test of foundation body movements is evaluated primarily in respect of the structural loading and payload.

The Department of Surveying of the Technical University of Budapest took part in projecting, testing and controlling quality assurance at more establishments. In these works, in the period of building construction and, occasionally, also in operation, the Department was dealing with the test of movements, deformations and dimensional changes coming into being as an effect of additional factors. Among these, the following examples will be reported:

test of – the Budapest-City-Shopping-Business Centre, 16. Váci Street, in building process,
– the Nuclear Power Station, Paks, in building process and in operation.

Test of Foundation Body Movements and Deformations in Building Process at the Budapest-City-Shopping-Business Centre, 16. Váci Street

The ground plan of the group of buildings can be seen on diagrams 1, 3, 5. The A,B,C signed building parts have got basement +(9–10) floors while the part of the Department Store, among the building parts, has got basement + 3 floors.

The base plate and the basement are made of monolithic reinforced concrete structure. The ascensional structure of the building is steel-pillar framed one with reinforced concrete walls and mounted frontal walls. The structure of staircases and lift flaws is reinforced concrete.

The concrete walls of basement monolithic structure serve for the fixation of base plate and distribution of loading of pillars. Their positions are given in the ground plans. The base plate and basement belonging to the group of buildings was constructed in 1977, 1978, 1979. The ascensional structure was assembled in 1979, 1980, 1981. The planning tasks of the guidance of steel structure assembly of the group of the buildings was already reported in [2]. The foundation body movement test measurement was carried out parallel with the structure construction from 31.08.1979 to 10.12.1981.

The structural construction in different building parts was performed with 3 floors delay from each other.

- By the time of the 1. test measurement, the steel structure assembly of the first 3 floors and the concreting of their slabs in building 'A' were finished and the structure assembly in the other parts of the group of buildings was started also.
- During the 2. test measurement, the structural weight of buildings 'B' and 'C' already loaded the foundation body.
- Longer more the structure construction in the 3 building parts were made almost in the same rate.
- At time of the 4. test measurement, also building 'C' has already got 6 floors.
- In the 5. test measurement, the steel structure assembly in all the 3 building parts was already finished.

The test points were placed at the pillars on the ± 0.00 level. Three first-order benchmarks of Budapest served as relative control points in the test measurements. During the construction process several test points disappeared. In evaluation, the test data – given in *Table 1* – of the points usable during the whole structural construction are used. The position of the test points can be identified on the ground plans with the help of building module system. In the 1. column of *Table 1* the identification marks of module system serve as identification marks of the points. In the 2. column of the *Table 1* the Baltic-height of the test points determined by the base measurement are given. In the case of test measurement the displacement value between 2 test measurements, one after the other, is given in 'Δ' column, the displacement value since the time of base measurement is indicated in '$\sum \Delta$' column, both in mm.

The explanation of displacement values is as follows:

+2 means: the height of the point became higher with 2 mm,
the test point rose 2 mm,

−2 means: the height of the point decreased 2 mm,
the test point sank 2 mm.

The test measurements were carried out with the technology and instrument set of higher-order levelling. The degree of accuracy of the relative height of the test points can be characterized by ±0.4 mm standard deviation, while the degree of accuracy of the absolute height of the test points, compared with the height of the base points, can be characterized by ±0.7 mm standard deviation.

Because of the measured low vertical displacement values it has to primarily be tested whether they refer to measurement error or movement. The method of these measurements is reported in [1].

Table 1
Testing dates of foundation body movements and deformations of the Budapest City-Shopping-Business-Centre

Test point identifier	Base measure ment	Testing measurements											
	0.	1.		2.		3.		4.		5.		6.	
	1979.08.31.	1980.04.12.		1980.08.29.		1980.11.20.		1981.03.13.		1981.09.15.		1981.12.10.	
	m	Δ	ΣΔ	Δ	ΣΔ	Δ	ΣΔ	Δ	ΣΔ	Δ	ΣΔ	Δ	ΣΔ
		mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
H 2	103,957				-5	+2	-4	-1	-6	+1	-5	-1	-6
J 3	103,887	0	0	-1	-1	-1	-2	-3	-4	0	-4	-1	-5
0 3	103,885	+1	+1	-2	-1	0	-1	-2	-3	+1	-2		
E 4	103,691				-3	-1	-4	-2	-6	+1	-5	-1	-6
G 4	103,715	-1	-1	-2	-3	-1	-4	-2	-6	+1	-5		
I 4	103,694				+2	-1	+1	-2	-1	+1	0	-1	-1
K 4	103,688	0	0	-1	-1	-1	-2	-2	-4	+1	-3	0	-3
N 4	103,714	+1	+1	-1	0	-2	-2	-3	-4				-5
The medium value of "B" building		+0,2	+0,2	-1,5	-1,0	-1,0	-2,0	-2,0	-4,0	+1,0	-3,8	-0,7	-3,8
B 5	103,718	-1	-1	-1	-2	-1	-3	-2	-5	0	-5	0	-5
C 6	103,690	-2	-2	-1	-3	-1	-4	-2	-6	0	-6	-2	-8
E 6	103,687	-2	-2	-2	-4	-1	-5	-1	-6	-1	-7	0	-7
The medium value of "C" building		-1,7	-1,7	-1,3	-3,0	-1,0	-4,0	-1,7	-5,7	-0,3	-6,0	-0,7	-6,7
K 6	103,688	-1	-1	-1	-2	-1	-3	-2	-5	+1	-4	0	-4
N 6	103,688	0	0	-1	-1	-1	-2	-1	-3	+1	-2	0	-2
G 7	103,687	-3	-3	+1	-2	-2	-4	-2	-6	0	-6		
I 7	103,678	0	0	-1	-1	-2	-3	-2	-5				
Shopping building		-1,0	-1,0	-0,5	-1,5	-1,5	-3,0	-1,8	-4,8	+0,7	-4,0	0	-3,0
H 8	103,692	-5	-5	+2	-3	-2	-5	-2	-7	0	-7	0	-7
K 8	103,695	+1	+1	-2	-1	-1	-2	-3	-5	+2	-3	-1	-4
E 9	103,583	-1	-1	0	-1	-2	-3	-1	-4	-1	-5	+1	-4
G 9	103,588	-4	-4	+2	-2	-2	-4	-2	-6	-1	-7	0	-7
I 9	103,692	+2	+2	-3	-1	-2	-3	-1	-4	-1	-5	0	-5
L 9	103,686	-1	-1	0	-1	-2	-3	-1	-4	+1	-3		
K 10	103,593	-2	-2	+1	-1	-2	-3	-1	-4	0	-4		
K 12	103,619	-2	-2	+1	-1	-1	-2	-2	-4				
G 13	103,592	-5	-5	+3	-2	-2	-4	-2	-6	0	-6	+1	-5
E 14	103,591	-1	-1	+1	0	-1	-1	-2	-3				
The medium value of "A" building		-1,9	-1,9	+0,5	-1,3	-1,7	-3,0	-1,7	-4,7	0	-5,0	+0,2	-5,3
P 15	103,887	0	0	-2	-2	+1	-1	-2	-3	+2	-1		
R 15	103,885	+1	+1	-3	-2	-1	-1	-1	-2	0	-2	0	-2
S 15	103,890	-1	-1	-1	-2	-1	-3	-1	-4	0	-4	-1	-5
T 15	103,890						-4	-1	-5	-1	-6	0	-6
S 16	103,850				-2	-2	-4	-2	-6	0	-6	-1	-7
		0	0	-2,0	-2,0	-0,8	-2,6	-1,4	-4,0	+0,2	-3,8	-0,5	-5,0

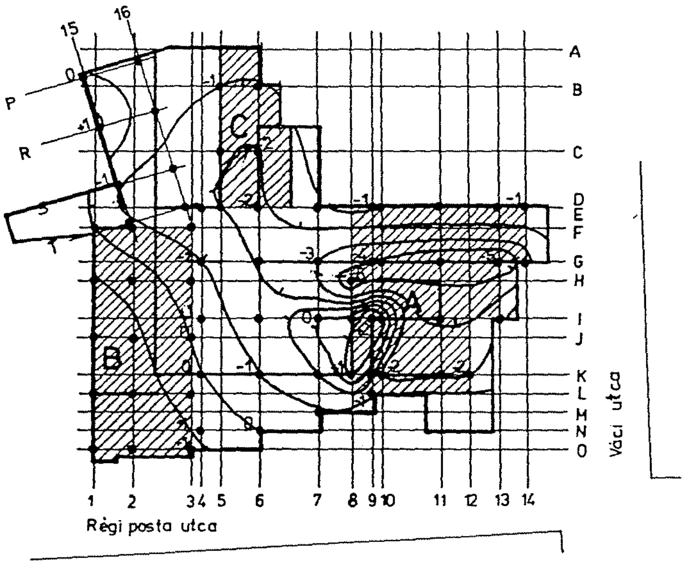

Fig. 1. The values of foundation body movements and deformations given in elevations numbers, determined at the 1. testing measurement of the Budapest-City-Shopping-Business-Centre as well as the presentation of their lines of levels

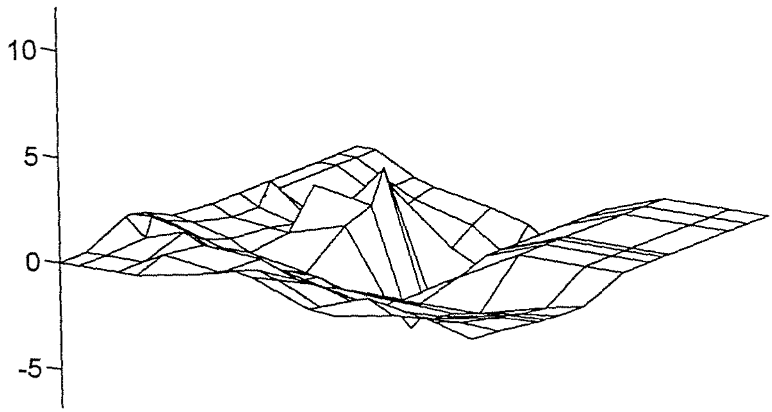

Fig. 2. The scenography of the values of foundation body movements and deformations determined at the 1. testing measurement of the Budapest-City-Shopping-Business-Centre

Applying tests of mathematical statistics, taking 0.90 probability level into consideration

$$\alpha = u_p \frac{\sigma}{\sqrt{n}} = 1.65 \frac{0.7}{\sqrt{2}} = 0.82\,\text{mm},$$

1 mm valued vertical displacement already refers to movements.

The vertical displacement of the test point groups in the different building parts are similarly marked, and their domination can be determined in every case, therefore, according to the rules of regular movements, the test data regarding movement and deformation are informative.

For evaluation of the regularities of foundation body movements and, deformations, the displacement values of each test point, and the line of levels regarding to the vertical displacements and deformations of the foundation body are given in diagrams 1,3,5. In diagrams 2, 4, 6, the deformations of the foundation body, vertical displacements are represented with scenography. The medium displacements of the test points at the building parts, in function of time, are shown in diagram 7.

Based on the test data and the upper diagrams, the following regularities can be stated:

1) The foundation body under influence of the building structure weight and payload makes vertical movement, it sinks.
   Note: The medium sinking value is not important here.
2) Sinking is proportional to loading.
3) Certain points of the foundation body do not move in the same measure.
4) In consequence of the uneven measured movements of certain points or point groups of the foundation body, this or its parts tilt.
5) Because of the uneven measured movements of the earlier mentioned certain points, the foundation body deforms. It does not make function as a rigid body but the ascensional structure dips at the places of maximum load.
6) The foundation body's deformation changes with the transfer of loading. Several dipping points can be presented also on the foundation body.
7) In consequence of the growth of environmental loading, places with constant loading elevate.
8) Along the reinforced concrete walls of the basement the movement values show almost the same. This effect appears presumably because of reinforcing and load distribution capacity of these walls on the basement.

The uneven foundation body movements and the deleterious effect of foundation body tiltings and deformations are bigger than their regular sinking. In spite of this their consideration is not general because in this area less experience is available.

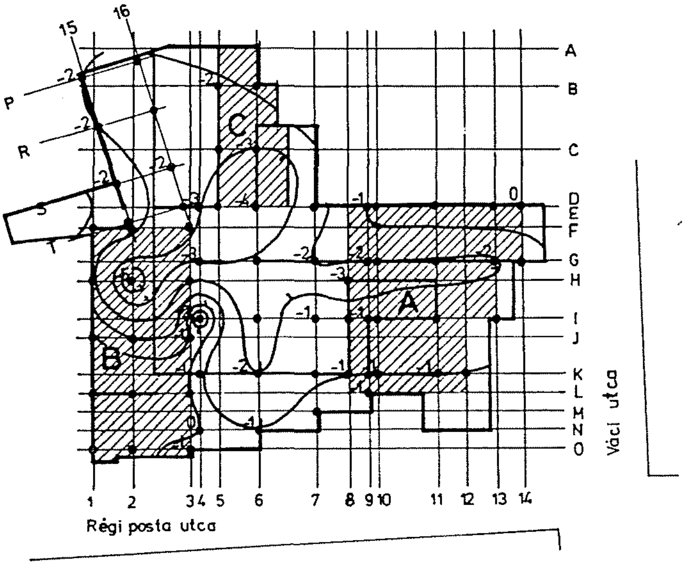

Fig. 3. The values of foundation body movements and deformations given in elevation numbers, determined at the 2. testing measurements of the Budapest-City-Shopping-Business-Centre as well as the prezentation of their lines of levels

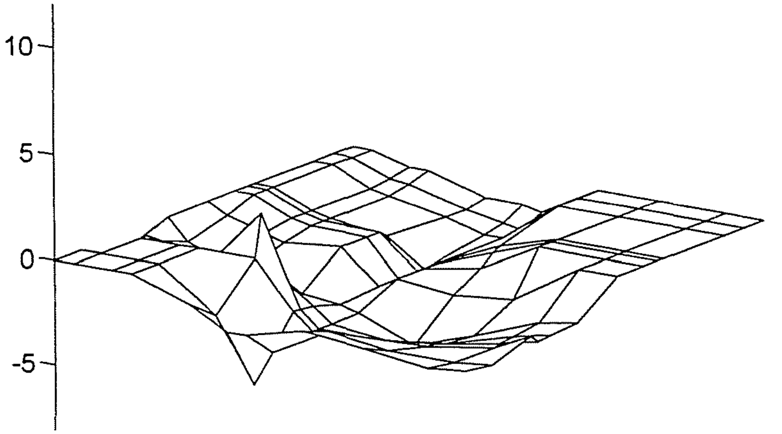

Fig. 4. The scenography of the values of foundation body movements and deformations determined at the 1. and 2. testing measurements of the Budapest-City-Shopping-Business-Centre

Therefore from the measured results – under construction and operation – of the Nuclear Power Station, Paks, examples are given for foundation body deformation and tilting test.

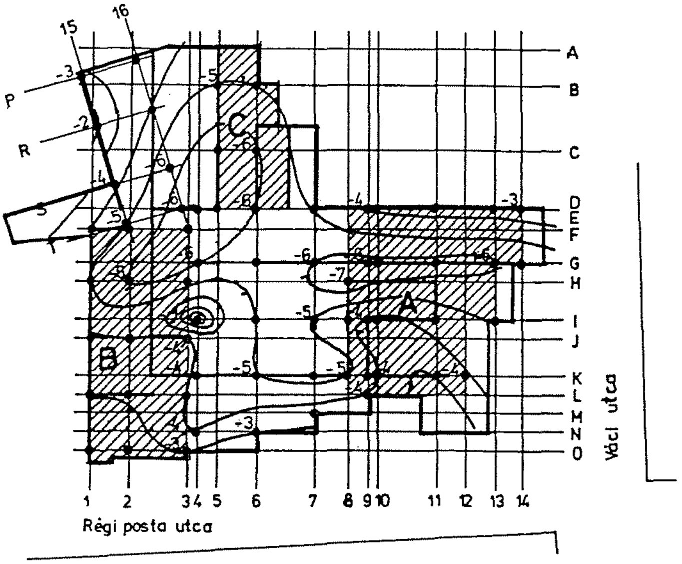

Fig. 5. The values of foundation body movements and deformations given in elevation numbers, determined at the 4. testing measurement of the Budapest-City-Shopping-Business-Centre as well as the presentation of their lines of levels

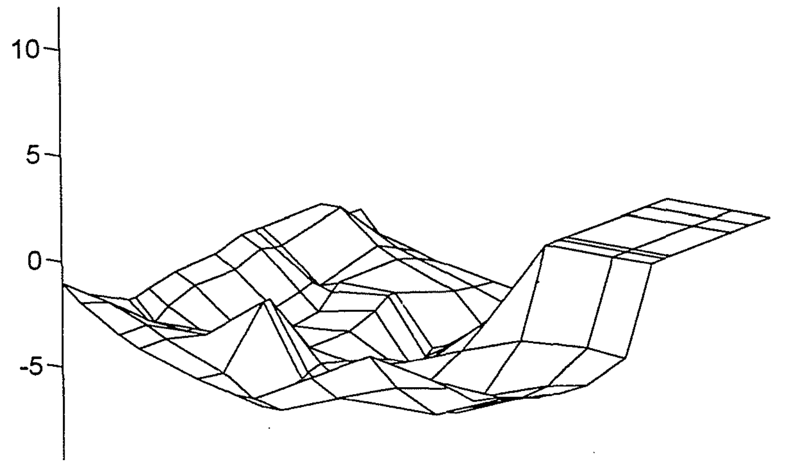

Fig. 6. The scenography of the values of foundation body movements and deformations determined at the 4. testing measurement of the Budapest-City-Shopping-Business-Centre as well as the presentation of their lines of levels

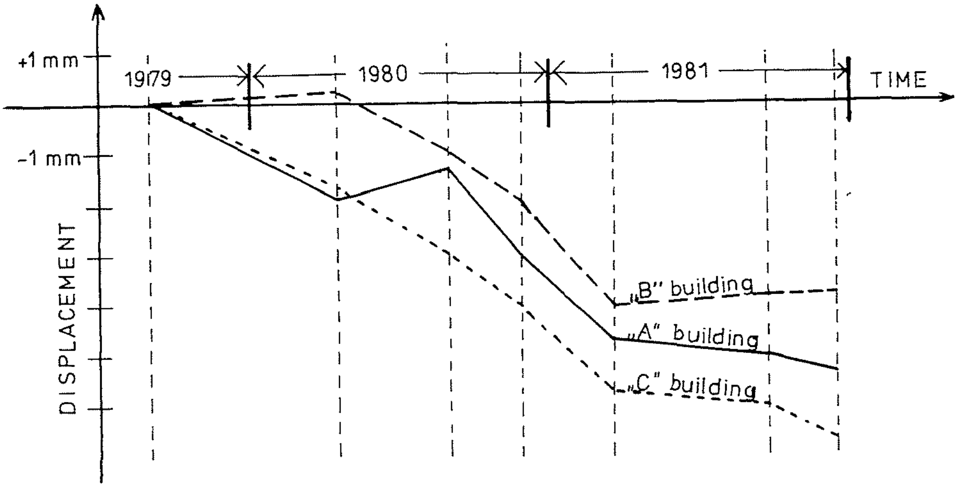

Fig. 7. Average displacements of the testing points at the building parts of the Budapest-City-Shopping-Business-Centre in function of time

The Test of Foundation Body Movement and Deformation in the IV. Block of the II. Main Building of the Nuclear Power Station, Paks

The foundation body movement and deformation tests of the reinforced concrete structured IV. block were performed during the building process. The data measured during base testing in March, 1981 and in March and in June, 1985 are given in *Table 2.* The interpretation is the same as for *Table 1.* As test points the origin of height on −6.50 m level and ±0.00 m level were mentioned. The situation of the test points can be seen on diagram 8. As base points in measurement tests the four deeply founded base points of the Nuclear Power Station were used.

The measurement tests were made with the instrument set and technology of higher-order levelling. The degree of accuracy of the determination can be characterized with standard deviation:

- at relative height on each floor with ±0.22 mm
- at absolute heights, compared to the deeply founded origin of heights of the establishment, with ±0.56 mm.

For the clear evaluation of the foundation body movements and deformations the displacement values of each test point are reported and also the contour line of the foundation body deformations are given on diagram 8.

In consequence of bigger loading and longer testing period, the movement values are essentially bigger than in the mounted steel structured

Table 2

Testing dates of foundation body movements and deformations of the IV. block of the Nuclear Power Station in Paks

Test point identifier	Base measurement (m)	Testing measurement 1985.03 ΣΔ (mm)	1985.06. ΣΔ (mm)	Comment
M016	91,1843	-59,2		on -6,5 m
M019	91,1225	-55,1		on -6,5 m
M020	91,1675	-48,4		on -6,5 m
M021	91,1419	-48,1		on -6,5 m
M022	91,1767	-54,2		on -6,5 m
R4-1	90,4301		-63,3	on -6,5 m
R4-2	90,3871	-54,6	-53,6	on -6,5 m
R4-3	90,4457	-56,3	-59,2	on -6,5 m
R4-4	90,4092	-55,3	-59,2	on -6,5 m
R4-5	90,4261	-60,3	-64,3	on -6,5 m
M209	97,0224	-57,1		on ± 0,0 m
M210	97,8853	-51,6		on ± 0,0 m

Budapest City-Shopping-Business-Centre buildings. The foundation body deformation and bending hint to the fact that even in the case of this extremely safely planned foundation body, deformations have to be also calculated. The position – North-South from reactor axis – of the deep point of bending is presumably due to the big eccentric loadings of the localization tower. This means that the foundation body part around the reactor axis makes tilting and its measure can be perfectly characterized with the parameters of the adjusted plane calculated with the help of the displacement values of the reactor network main control points. Measurement tests could be organized in each of the 5 points of the reactor network in 06. 1985. So the parameters of the adjusted plane displacement values are given from 03. 1981. to 06. 1985.

The parameters of the fitting plane:

- bedding angle −60"
- speed of bedding angle changes 1,2"/month
- reliability of bedding angle ±18"
- directional angle of bedding angle 306 (N-W)
- barycentric height of the plane −59.9 mm

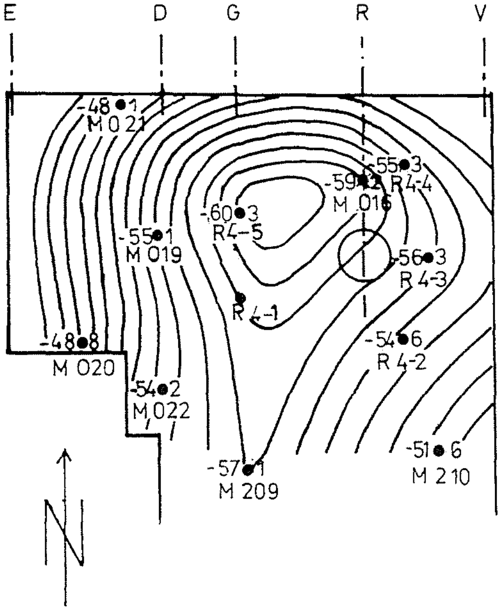

Fig. 8. The displacement values of the testing points of foundation body given in elevation numbers at the IV. block of the Nuclear Power Station in Paks as well as the presentation of their lines of levels

– medium movement speed 1.2 mm/month

The detailed test of the IV. reactor box movements is reported in [4].

The foundation body movements under operation, especially of those, which belong to technological units, can also be dangerous. So at this establishment the turbine table movements were also tested during the operation. The test results – in 1984 – of turbine tables, belonging to the I. and II. reactor blocks, are given in *Tables 3* and *4*. The position of test points and bedding vectors of turbine tables are shown in diagram 10. The degree of accuracy of determination is ± 0.56 mm at the absolute height of the test points and ± 0.22 mm at the relative heights of the test points on certain turbine tables.

Evaluating the movement test data regarding to the turbine tables – contained in *Tables 3* and *4* – it can be seen that the medium height change is −1.3 mm in the 2. quarter of the year and +0.6 mm in the 3. quarter of the year. The different sign of the height deviations is due to movements or thermal agitation. The medium difference of the two movements is −0.7

Table 3
Testing dates of turbine table tilting of the I. and II. reactor blocks

Test point indentifier	Base measurement 1984.01. (m)	Testing measurement 1984.03. (m)	Δ (mm)
III/I	106,6985	106,6997	1,2
III/II			
III/III	106,6801	106,6815	1,4
III/IV	106,6898	106,6913	1,4
III/V	106,6918	106,6929	1,1
III/VI	106,6827	106,6836	0,9
III/VII	106,6841	106,6854	0,9
III/VIII	106,6858	106,6871	1,4
III/IX	106,6889	106,6893	0,4
III/X	106,6805	106,6813	0,8
III/XI	106,6845	106,6848	0,4

mm, that gives the resultant movement of the 2 quarters of the year, not eliminating the possibility of simultaneous sinking.

The uniformly presented foundation body movement, in the case of the 4 tested turbine tables, cannot be proved. Low rate simultaneous sinking can occur, but the separate movements (sinking, tilting) of turbine tables are stronger than the former one.

For testing each turbine table movement, the adjusted planes of surfaces, which are determined with the height changes, were calculated for the whole period of 2. and 2.+3. quarters of the year. The parameters of the adjusted planes are presented in *Table 5.* The parameters of adjusted planes, the grid bearings of the planes rise, regarding to the North, and their bedding angles are shown in diagram 9 with such a graphic performance where the drawn fingers are in proportional length with the value of bedding angle.

Because of the low values (giving 0.5 mm and 0.3 mm height differences in 10 m) and the relatively big reliability measuring numbers of bedding angles, in the case of turbine table 1, separately do not prove bedding.

Testing the two periods together, it can be experienced that the direction of tilt angles differs 87° from each other, so the tendency for strengthening each other can be mentioned.

Table 4
Testing dates of turbine table tilting of the I. and II. reactor blocks

Test point identifier	Base measurement 1984.03. (m)	Testing measurement 1984.06. (m)	Δ (mm)	Testing measurement 1984.09. (m)	ΣΔ (mm)
I/I					
I/II		106,6885		106,6900	
I/III	106,6908	106,6889	-1,9	106,6904	-0,4
I/IV	106,6962	106,6948	-1,4	106,6960	-0,2
I/V	106,6960	106,6951	-0,6	106,6957	-0,3
I/VI	106,7007	106,6997	-0,9	106,7000	-0,6
I/VII	106,6987	106,6972	-1,6	106,6981	-0,6
I/VIII	106,6753	106,6738	-1,5	106,6748	-0,5
I/IX	106,6827	106,6812	-1,5	106,6822	-0,5
I/X	106,6889	106,6866	-2,3	106,6883	-0,6
I/XI	106,6814	106,6790	-2,3	106,6805	-0,9
II/I	106,6935	106,6933	-0,2	106,6941	0,6
II/II	106,6930				
II/III	106,6889	106,6880	-0,8	106,6883	-0,6
II/IV	106,6964	106,6951	-1,3	106,6955	-0,8
II/V	106,6881	106,6867	-1,5	106,6868	-1,4
II/VI	106,6893	106,6877	-1,6	106,6874	-1,9
II/VII	106,6841	106,6827	-1,4	106,6827	-1,4
II/VIII	106,6904	106,6892	-1,2	106,6895	-0,9
II/IX	106,6948	106,6935	-1,2	106,6938	-1,0
II/X	106,6969	106,6956	-1,3	106,6962	-0,7
II/XI	106,6871	106,6856	-1,5	106,6863	-0,8
III/I	106,6997	106,6984	-1,3	106,7006	0,9
III/II					
III/III	106,6815	106,6803	-1,2	106,6812	-0,3
III/IV	106,6913	106,6899	-1,3	106,6908	-0,5
III/V	106,6929	106,6910	-1,9	106,6918	-1,1
III/VI	106,6836	106,6817	-1,9	106,6824	-1,3
III/VII	106,6854	106,6840	-1,4	106,6848	-0,6
III/VIII	106,6871	106,6858	-1,4		
III/IX	106,6893	106,6880	-1,3	106,6892	-0,1
III/X	106,6813	106,6800	-1,3	106,6816	0,4
III/XI	106,6848	106,6831	-1,7	106,6852	0,3
IV/III	106,6815	106,6814	-0,1	106,6812	-0,3
IV/IV	106,6848	106,6844	-0,4	106,6842	-0,6
IV/V	106,6810	106,6799	-1,1	106,6793	-1,7
IV/VI	106,6823	106,6814	-0,9	106,6808	-1,5
IV/VII	106,6923	106,6916	-0,6	106,6914	-0,9
IV/VIII	106,6902	106,6895	-0,7	106,6896	-0,7
IV/IX	106,6882	106,6877	-0,5	106,6884	0,2
IV/X	106,6813	106,6812	-0,1	106,6816	0,3
IV/XI	106,6885	106,6879	-0,6	106,6886	0,2

Consequently, tilting cannot be supposed at turbine table 1 but the same sign of barycentric heights of planes refers to low measured sinking.

In the case of turbine table 2, the values of tilt angles (giving 0.6 mm and 1.0 mm height differences in 10 m) raise the possibility of tilting taking the reliability of determination into consideration.

Testing the two periods together reveals that the grid bearings differ only 11° from each other and the tilt angle increases. Accordingly, tilting can be supposed for turbine table 2, and the same sign of barycentric heights refers to low measured sinking.

At turbine table 3 the parameters of adjusted planes, the values of tilt angles give 0.2 mm, 0.7 mm, 1.2 mm height differences in 10 m. Considering the reliability measuring numbers of tilt angle values in the 2.+3. and 1.+2.+3. quarters of the year, those in themselves refer to tilting.

Examining the three periods together, it is found that grid bearings only differ from each other in a low measure and the value of tilt angle grows in function of time.

So in the case of turbine table 3 tilting can be assumed, but the different sign value of barycentric height of the fields does not prove constant tilting or growth.

At turbine table 4, taking the small values of tilt angles – giving 0.3 mm and 0.6 mm height differences in 10 m – and the great reliability of measuring numbers into consideration, tilting cannot be supposed.

Watching the two periods together, it is found that grid bearings differ 48° from each other, but tilt angle increases.

According to these facts, only the growth of tilt angle refers to tilting at turbine table 4, however, tilting cannot be proved. The same sign of barycentric heights of the planes can refer to sinking but their low values do not prove that either.

In connection with turbine tables such small movements were seen which are not important at the moment, but they direct the attention to the possibility of injurious processes.

From movement and deformation tests of this establishment [3, 5] report further examples. [6] gives examples for geodetic methods of deformation tests.

Consequences of Foundation Body Movements and Deformations

The inherent deviations (like foundation body movements and deformations) come into being in consequence of additional factors, they also influence the values of induced deviations. The feasibility of the whole building

Table 5

Parameters of fitting plates determined with the height changes of turbine tables of the I. and II. reactor blocks of the Nuclear Power Station in Paks

	Turbine tables								
	1		2		3			4	
	2nd	2nd + 3rd	2nd	2nd + 3rd	2nd	2nd + 3rd	1st + 2nd + 3rd	2nd	2nd + 3rd
	quarter of the year		quarter of the year		quarter of the year			quarter of the year	
bedding angle	9,5"	6,4"	13,5"	20,0"	3,1"	14,4"	23,8"	5,9"	11,4"
veliability of bedding angle	±4,5"	±1,6"	±3,6"	±3,8"	±3,3"	±4,0"	±5,4"	±4,9"	±6,6"
directional angle of bedding angle	7°	280°	255°	244°	299°	323°	294°	306°	354°
barycentric height of the plane	-1,8mm	-0,5mm	-1,1mm	-0,6mm	-1,4mm	0,0mm	1,0mm	-0,4mm	-0,2mm

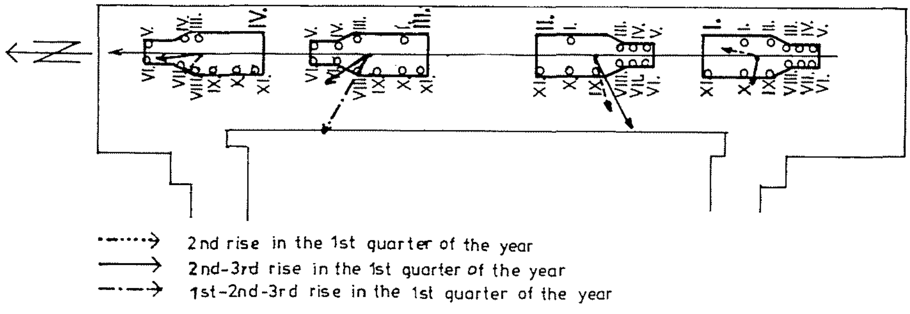

Fig. 9. The presentation of testing points and bedding vectors of the I. and II. reactor blocks of the Nuclear Power Station in Paks

task depends on their consequences. The facts mentioned also influence, within this, the position and assembly of structural elements, the forming of joints, the stability of structural elements and the exterior outlook of the buildings.

Determination, Elimination and Consideration of Foundation Body Movements

For determination of foundation body movements in building process and till finishing foundation body settlement, during the operation of the building purposeful movement and deformation tests need to be made. Their changes have to be forecasted.

The above mentioned effects can be partly eliminated with considering the values of foundation body movements and deformations expected and measured in building process, and forecasted (based on the former experience) at the setting out, assembly and the direction of assembly.

For example, the injurious effects of foundation body tilting influencing the vertical of pillars or any other structural elements can be decreased with the consideration of the forecasted tilting values in directing the assembly. Besides the adoption of corrections, also the previous methods can be put into practice. The injurious effect of foundation body sinking, influencing the setting out in height regarding to one building unit, can be eliminated with placing the height control points of the establishment to the already built up foundation body.

The expected values of foundation body movements and deformations can be taken into consideration when choosing operating and building tolerance values. The consideration of movement and deformation values is needed in test measurements and controls, too.

References

1. DETREKŐI, Á.: Kiegyenlítő számítások (Compensating Computations.) Tankönyvkiadó, Budapest, 1991.
2. KISS, A. (1983): Planirovanie geodezitcheskih rabot pri montage stalnych konstrukcii: *Periodica Polytechnica Ser. Civil Engineering*, Vol. 27. pp. 197–208.
3. KISS, A. (1984): Deformation Measurement of the Localizing Tower under Overpressure of a Nuclear Power Station. *RILEM ACI International Symposium, on Long-Term Observation of Concrete Structures.* Budapest.
4. KISS, A. (1990): Analiz rezultatov issledovania peremeshenia 4-ovo reaktora atomnoi elektrostancii "Paks" s tochki zrenia sostavlenia prognoza peremeshenia i sozdaniya diagnostitcheskoy systemy. *Periodica Polytechnica. Ser. Civil Engineering*, Vol. 34, pp. 47–67.
5. KÖRÖSI, M. – NÉMETH, A. (1987) : A Paksi Atomerőmű jelenlegi mozgásvizsgálati és távlati tervei. (Movement Tests in the Nuclear Power Station Paks at Present and in Future.) Mérnökgeodéziai mozgásvizsgálatok szeminárium kiadásában, Sopron, 1987. (In Hungarian).
6. THIERBACH, H. : Deformationsmessungen in Kraftwerken, *FIG III. International Symposium on Deformation Measurements by Geodetic Methods.* Budapest, 1982.