The matrix of coefficients of settlement

La matrice des coefficients de tassement

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SYNOPSIS A detailed analysis of differences between real and calculated settlements of building foundations leads to a statement that the differences are caused by many different factors / Fig. 1./ which may be arranged into a matrix with four columns and seven or more rows / Fig. 4 /.

INTRODUCTION

The differencies between the calculated and subsequently in situ measured foundation settlements are very great often. When seeking the causes of this disharmony we must necessarily come to the conclusion that the calculations of building settlements are much too simplified and that their input parameters do not cover the whole scope of the problem.

At present, generally speaking, two traditional calculation procedures are used /Giroud, Cordary, 1975/, consisting in the ascertainment of the compressibility of the soil, selecting numerical values of two to four coefficients in the respective tables or instructions, taking over the load applied in the foundation base from the structural analysis, determining the size of the foundation and finding the result by substituting all of these values in the respective formula. It can be proved easily that the existing traditional calculation procedures cannot be improved by a change of numerical values of existing coefficients used in calculations, / Pruška, 1983 /.

If the settlement calculation is verified by subsequent measurements on building sites, it is usually ascertained that the calculated settlements are higher, often even considerably higher, than the actual settlements.

The described state is well known. Its improvement is endeavoured by a number of top specialists, /e.g. by Széchy, 1957 or Giroud and Cordary, 1976/, who studied various factors influencing the settlement and who pointed out various methods to be used for the improvement of the present state. Let us try to find all the causes influencing the disharmony of the calculated and measured settlement, and ascertain how which factor can contribute to the above mentioned disharmony.

RELATIONSHIP BETWEEN THE CALCULATED AND ACTUAL SETTLEMENTS

An analysis of the nature of both types of settlement results in the conclusion that the difference between both results can be exhaustively analysed in two directions: in the horizontal direction and in the vertical direction /as shown in Fig. 1/.

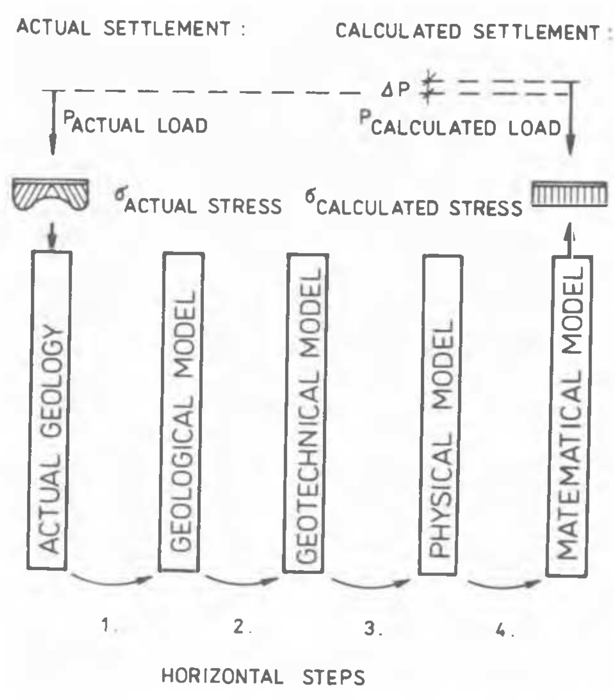

Fig.1 The Relationship Between a Calculated and Actual Settlement

The process in the horizontal direction involves the successive modelling of the transition from the actual geology to the mathematical model. In the vertical direction it involves the transformation of forces, loads and stresses in actual geological conditions /in situ/ into the calculation equations /in design office/.

Horizontal direction

The horizontal direction comprises four steps / Fig. 1 /.
The first step means the transformation of actual geological conditions into the geological model. This step may be very accurate in simple and regular geological conditions, but almost negligibly approximate in erratic geological conditions.

The second step represents the construction of a geotechnical model. It involves the supplementing of the geological model with geotechnical data. In this process various mean values are selected as geotechnical representatives, sharply differentiated, as a rule. In the majority of cases this step represent a marked simplification of reality.

The third step represents the transformation of the geotechnical model into a physical model. In this step one of the main, so far only incompletely solved problems appears, which is pointed out in literature, for example by de Beer, Graßhoff and Kany, 1966, or Zhaohua and Cook, 1983, or Kolář, 1979. This problem consists in the fundamental question, whether a model of the elastic half-space type /de Beer, 1973, Pruška, 1983/, or the modification of Winkler sub-base should be used.

Half-spaces do not exist in reality; consequently, the settlement calculation are based on integrations from zero to infinity and results therefore in higher values, /Pruška, 1983/. Also the problems of horizontal stresses /Pruška, Fessl, 1982/, depth of the compressed layer, /Altes, 1976/ and the influence of stratification on the stress distribution in the sub-base have not been fully solved so far. The influence of horizontal stresses appears fundamental and is being studied both theoretically and experimentally at present /e.g. by Krivorotov and Babello, 1981, Pruška and Fessl, 1983, Stefanoff, 1982, etc/.

The fourth step means the expression of physical model by mathematical equations, i.g. the construction of the mathematical model. In homogeneous sub-bases this step can be made fairly accurate with the exceptions mentioned in the third step. The accuracy in the case of strafied sub-base has few exact data at its disposal, particularly if a system of more than two strata is involved.

Vertical direction

There are the following problems in the vertical direction / Fig. 1 /:

1. The magnitude of the load.
2. The contact pressure distribution under foundation.
3. The foundation size and form.
4. The foundation depth.
5. Local problems of actual geology.
6. The stress distribution in the sub-base.
7. Different particular problems.

Principally we begin with the force /load/ transferred by the foundation to the sub-base. This force is considered constant by the settlement calculations. Actually it is more or less variable in accordance with the type and purpose of the building or structure. In the majority of cases, however, this variability is small and does not influences the calculation results. Its magnitude, however, is not entirely reliable. That is the value given by the structural designer who always considers a certain safety margin and standard values of loads in his work. Individual measurements and analyses of structural design indicate that the calculated force is higher about by 10 - 20% than the actual force usually.

The second problem presents the question of the distribution of contact stress. In the majority of cases it is assumed that the contact stress is distributed either uniformly /in the case of yielding foundation/ or markedly ridged with plastic saddles on the edges /in the case of rigid foundation/. The difference in the settlement of centres of such two foundation is approximately 20%.

The presented results have been deduced in the theory of elasticity. The transition of an elastic sub-base into its limit state is accompagnied by redistribution of sub-base stress, as it is described e.g. by Skormin and Malyshev, 1970. It can be proved that this transition can increase the settlement by as much as 50%. Consequently, the second step is not only the function of the rigidity of the foundation and the sub-base, but also it represents the extent to which the load approaches its limit state.

The third problem represents the influence of the foundation size and form. It is maintained often that the influence of the size is negligible, but the exact analysis reveals that the increase of the contact size reduces the settlement /Bobe, 1958/. The influence of the foundation form has been generally well investigated so that it is possible to take into account data given anywhere in literature. Other factors appaering due to construction and construction activities on the building site are small and need not be considered with the exception of special cases of sub-base treatement by gravel cushions, groutings, etc.

The fourth problem is the foundation depth. This problem has been afforded little attention so far /Poulos, Davis, 1973/ and its reducing effect is being silently overlocked, the equations in use being those valid for surface loads.

There is a difference between increases of stresses as they are introduced in settlement calculation methods and as they exist in the subbase. It must be stated that the traditional strip /indirect/ methods do not include horizontal stresses or they calculate with the constant ratio of the horizontal to the vertical pressure as it exists in a oedometer apparatus.

The horizontal stress in a semi-infinite elastic mass in the axis of superficial uniform loads has been studied by Pruška and Fessl, 1982. An example of changes in horizontal stress in the axis of a load uniformly distributed on a square area is presented in Fig. 2. We see, that the horizontal stress is always pressure just below the surface of the half-space. The pressure decreases speedily towards the depth and changes into tension. The tension attains speedily its maximum, from which it decreases towards further depth, nearing assymptotically zero.

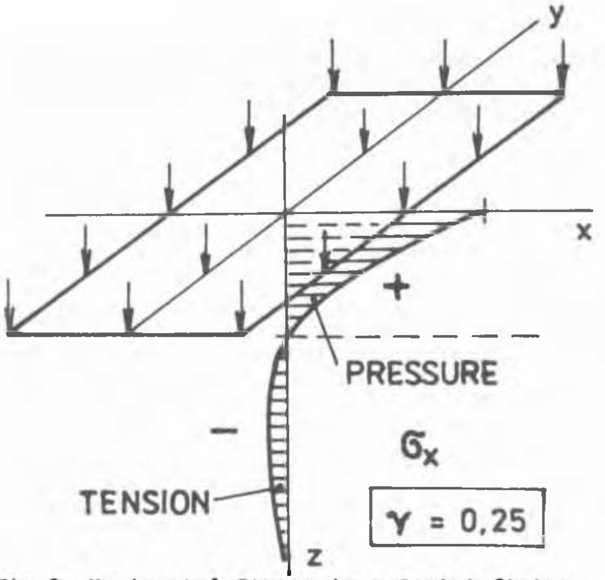

Fig.2 Horizontal Stress in a Semi-infinite Elastic Mass in the Axis of the Superficial Uniform Vertical Load on a Square Area

Stefanoff and Jellev, 1982, meassured the horizontal stress in the field in the loose and the compacted sandy sub-base in the axis of the

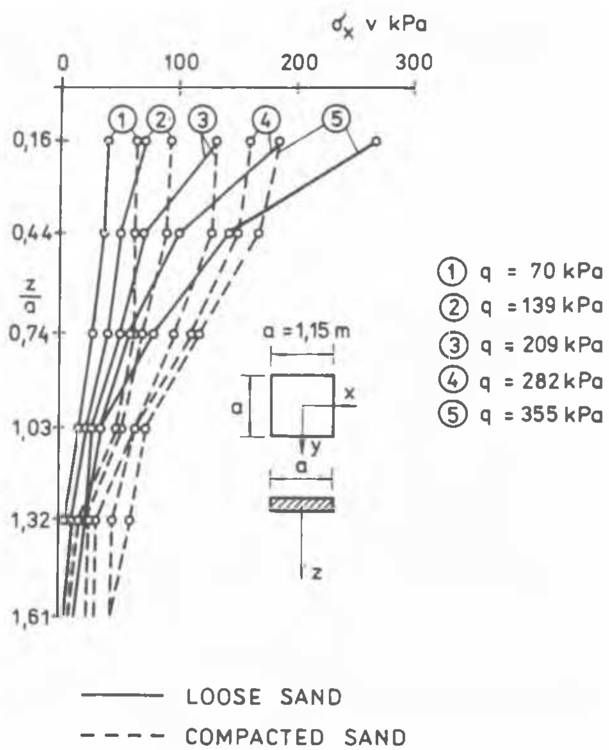

Fig.3 Horizontal Stress in the Subbase in the Axis of a Tested Concrete Plate /after Stefanoff and Jellev/

differently loaded square concrete plate. The results are presented in Fig. 3. Both the Fig.2 and 3 demonstrate that the horizontal stress plays a role by settlement process. The comparison of both the Figgures 2 and 3 shows the difference between the semi-infinite elastic mass and the sandy subsoil. It is possible to take instructions from these studies how to incorporate this problematics into the settlement calculation procedures.

Many local problems of actual geology are not incorporated in settlement calculation methods although they significantly influence the settlement rate often, e.g. the anisotropy which in a homogeneous sub-base influences the settlement up to 40% /Eftimie, 1968/. The horizontal stratification is supposed only, borders of individual geological strata are considered to be sharp only, gr·ud water regime is supposed to be constant, etc. All these effects are always individual and necessitate, consequently, always individual assesment.

MATRIX OF CORRECTION COEFFICIENTS

The described relations in the vertical and horizontal directions can be incorporated into a matrix of four columns and seven or more lines / Fig. 4 /.

P	a_{11}	a_{12}	a_{13}	a_{14}
p	a_{21}	a_{22}	a_{23}	a_{24}
Size & Form	a_{31}	a_{32}	a_{33}	a_{34}
H	a_{41}	a_{42}	a_{43}	a_{44}
σ_{ij}	a_{51}	a_{52}	a_{53}	a_{54}
Geol.	a_{61}	a_{62}	a_{63}	a_{64}
Part.	a_{71}	a_{72}	a_{73}	a_{74}
⋮	⋮	⋮	⋮	⋮
Al	a_{n1}	a_{n2}	a_{n3}	a_{n4}
Σ	a_1	a_2	a_3	a_4

Fig.4 Matrix of Settlement Coefficients

Some members of the matrix are unitary, which means that the factor of safety they represent plays no role in the given step. All other members must be assessed individually by common endeavour of engineers and geologist. Some can be determined with relativly high accuracy, other - due to the contemporary standard of science - must be still eastimated. However, the estimate of this members should be credible.

CONCLUSION

The application of the described matrix to the determination of settlement coefficient values by traditional calculation methods will increase the accuracy and markadly extend the values of settlement coefficients. Particularly advantageous is the application of partial multiplications in columns and thus arriving in conclusion at four basic settlement coefficients which should be then considered in every calculation of building settlements. The task of the design engineer is to evaluate by each settlement calculation which coefficient plays a role by this problem and which is without importance.

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