Statyba

ISSN: 1392-1525 (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tcem19

APPLICATION OF COMPUTER AIDED DESIGN SYSTEMS IN GEOTECHNICAL ENGINEERING

J. Amšiejus , L. Gabrielaitis & R. Gruodis

APPLICATION OF COMPUTER AIDED DESIGN SYSTEMS IN GEOTECHNICAL ENGINEERING

J. Amšiejus, L. Gabrielaitis, R. Gruodis

1. Introduction

An emergence of the latest computing technology and modern programming facilities has finally given rise to greater interest in the applications of computer-aided design in Lithuania. In civil engineering the major part of design documentation consists of graphic information presented in the form of engineering drawings. That is why nowadays among the most popular programming and technical aids are those which enable to rationalize the drawing work. However, such level of programming facilities can partly satisfy if only the needs of architects. For large-scale structural solutions, corresponding drawing aids constitute only the final and the simplest link in a general sequence of computer-aided design. This can be explained by the fact that a project is in itself a synthetic process which is not so simple as to be expressed by ordinary algorithms. In addition, nowadays projects involve such a large amount of data which are not always presented in a suitable enough form so as to be used in computer-aided work.

Naturally, with an introduction of such modern design techniques, quite a variety of problems arise in connection with the advantages and disadvantages of different computing systems, and the possibilities of acquiring them. On the other hand, even an ideal tool of computer-aided design could not evaluate the features peculiar to separate regions of the world as well as their traditions of design and construction established in course of time. The latter issue becomes still a greater concern in the case of rather specific ground and foundation design problems in which such completely separate spheres as selection of a locality for proposed construction, site investigation, design, construction and maintenance are to be integrated into one system. However, before making definite decisions, first of all, the available data and information have to be sorted, at least in general outline, and the very problem of computer-aided design has to be defined.

2. Objective and subjective factors influencing computer-aided design systems

In developing automated design systems, particular attention should be given to that portion of data and information which, owing to their peculiarities, cannot be unified. This could be most evidently illustrated by taking such an example as soil conditions which vary significantly in different regions of the world. As a result, sometimes even the very soils classification may differ. Similar situation has occurred in Lithuania where the range of some soil types appeared to be wider than that involved in soils classification systems of other states.

That is a sufficiently good reason why the programming aids developed in other countries cannot be used in Lithuania without corresponding modifications and supplements. Another not less important circumstance is that related to ground and foundation design principles which are traditionally established in Lithuania and non-existent in other countries, the design and construction of bored foundations being a good example. However, the greatest problems are, undoubtedly, likely to results from the soviet system of state standards and design codes, still currently valid in Lithuania, which are based on detailed and in many cases unreasonable statements and requirements. The system quite evidently represents the narrow interests of separate departments and organizations, and consequently, cannot promote the achievement of any advanced results. This can be well illustrated by an example taken from the area of site investigations. According to the currently existing building codes and specifications, largest borings spacing specified is for some reason 25 m. What does this figure mean ? For any rational design, borings spacing should provide for establishing accurate boundaries between different deposited soil layers. However, according to the above requirement, a geologist and his department are, clearly, indirectly obliged to be responsible for the data obtained at the location of a boring or probing, whereas to make decisions in the intermediate areas between borings is the responsibility of the designer who has no possibilities for additional investigations. In this case site investigations in the phase of making project working drawings would be of great help. Then, estimating the investigation results in the phase of technical-and-economic project evaluation, a certain expert system could be developed within a separate programming module. After processing the initial site investigation data, with the help of the expert system, a computer would indicate locations for additional boring or probing. In spite of the current site investigation code requirement to indicate on a plan only the boundaries of organic soil layers, the expert system mentioned would permit to apply this requirement to any type of soil or even for an engineering-and-geological element.

Moreover, it should be noted that an expert system of such a type would be very helpful in developing a numerical ground model. However, the fulfillment of this task is hindered, especially in establishing the boundaries of soil layers by a still widely spread subjective factor based on the I-think-so principle. Even with the same initial conditions, such an approach, as a rule, leads to different final results. Therefore, in a computer-aided design system a similar way of problem solution should not exist in principle. Far better results could be achieved if the problem could be expressed analytically. It is strange enough that this problem is not given any consideration in the world practice too [1, 2]. This is already well testified of the above problem is not included provided for the Swedish computerized probes, recently acquired by Lithuania.

Here is another example. Can any code requirement be considered correct if a variety of analysis methods involved in their recommendations yield absolutely different results. As a result, in computer-aided design a problem arises as to which methods should be given priority. Also, the codes include methods for designing various ground and foundation types according to different soil properties values, for instance, for shallow foundations c and a are recommended, while for bored foundations q is to be used. Besides, in determining design indices for the mechanical properties of the latter foundations, the prescribed values to be used are for some reasons specified 0.85 and 0.95, instead of being reasonably related to technically justified reliability of the ground and foundation being designed. Therefore, the universal disadvantage of the existing design codes lies in the fact that they are prevailed by the limit state method which are constant, irrespective even of the capability degree of structural materials to be tested, to say nothing of other factors. As a result, variations in reliability of different types of foundations are neglected in design. Therefore, the unification of technical-and-economic indices of foundations with an unequal degree of safety is absolutely incorrect. A proper solution of this problem can be achieved only by modern statistical structural analysis methods for which information only on the mean values of soil properties is insufficient, data on their variability with in a ground layer being required too. With not quite precisely determined values for soil properties indices used, higher values of safety factor are to be taken in the design of the ground and foundations. With a more detailed investigation of the ground, the value of its safety factor is reduced, what permits a more efficient utilization of its strength and, consequently, makes the structural foundations themselves more economical. To achieve this aim, in processing soil investigation results statistical methods are used for obtaining design values of soil properties.

The examples presented above lead to a conclusion that all the obstacles hindering the development of a computer-aided design system can be devided into two parts. The first part embraces the objective factors which cannot be changed (owing to existing specific soil conditions) or the changing of which is undesirable (because of a great influence of established but still progressive design and construction traditions). The second part thus includes all subjective factors the changing of which is not only possible but even desirable owing to their incapability of conforming to modern requirements (under the existence of an out of date system of state standards and design codes). Consequently, one more conclusion can be drawn: in developing a computer- aided design system, two ways of its improvement are possible. According to the first method, the system should include that part of data and information which, due to the above reasons, is unchangeable. That is, the very computer-aided design system is to be left open for a certain part of information. As to the second method, the available data and information system should be arranged in such a way as to be as much suitable for computer-aided work as possible. In this case it concerns an improvement of the system of state standards and design codes, with reference to the best world analogues in a creative application of new and efficient solutions.

In defining the very problem of automated design, first of all, in our opinion, it is necessary to integrate the spheres of site investigations, the ground and foundation design, construction and maintenance, which have been completely separated up to now. It means that in future all the work of site investigations, design and construction is performed by one organization, if only except that part of site investigations, which is conducted in the phase of the technical-and-economic project evaluation, which could be performed by organizations specializing in this area. The scale of investigations in this phase should provide for obtaining adequate enough information required for determining which type of foundation is most suitable for specific soil conditions. Further, in the phase of making project working drawings, an organization executing the construction should conduct the investigations. In this way, the zero cycle design work and construction would be carried out in complex and simultaneously, i.e. "from office to industry". Consequently, as to the very programming aids, they should consist of four parts: site investigations, ground and foundation design, construction and maintenance. A more detailed description of these parts would be the following:

Site investigations:
- processing of the collected investigation data and its storage in the database;
- establishing of the soil layers boundaries within the ground volume of the proposed construction site providing the mean values of soils properties and their dispersion.

Design:
- determining of stresses in a structure estimating the ground-structure interaction;
- structure interaction;
- selection of the ground and foundation;
- determining of optimum parameters;
- dimensioning of the structural foundation;
- making of working drawings, expenditure estimates of materials, labour and equipment as well as economic calculations;

Construction:
- collection and analysis of data on the ground control;
- making of the foundation execution photographs;

Maintenance:
- conclusions on the structure serviceability according to the foundation settlement data;
- collection of data on variations in the ground conditions.

This scheme can be regarded as an idealized variant of a computer-aided design problem which, when put into practice, could serve as a good guide. In this case, a system under development should be based upon such computer-aided design systems which are open for including separate modules. Then, in accordance with existing possibilities, on the basis of the presented scheme, the very automated foundation design system could be developed by joining separate modules into the system taking into account the above mentioned peculiarities of local conditions and design.

3. Proposed principles for implementation of computer-aided foundation design

The ways of implementing automated foundation design may vary widely, depending, primarily, on the design systems they are based on in each specific case.

In accordance with our current possibilities, the widely known programming packages which are available in the CAD system could be quite successfully used. These include the systems of the Autodesk firm AutoCAD, Key systems and DTM of the Softdesk firm [3]. Information in words and numerical data can be stored in the popular programming package EXCEL where it would be also possible to do uncomplicated calculations according to the algorithms presented in building codes. The data can be stored, supplemented and changed in such databases as dBASE III, dBASE IV, PARADOX, which are well connected with the latest versions of AutoCAD. The programming package of Key Systems is very handy. It embraces a data bank, provision for producing soil profiles as well as additional drawing in CAD environment.

In developing separate programming modules providing for estimating different features peculiar to the geotechnical problems mentioned above, one will inevitably have to use such algorithmic languages which are suitable for performing wide-scale arithmetic operations and which are connected with the programming packages of the CAD system (Fortran, C++, Pascal, est.). In the cases when more complicated calculations are to be performed (in estimating soils variability, influence of neighbouring foundations or buildings, soil-structure interaction, etc.) such finite element packages as GEOSLOPE, DIANA and others could be successfully used [4]. Working in this way, calculations will be performed and graphical results will be obtained within the CAD system. Additional data required for calculations are introduced interactively. When calculations are completed, foundation sections and all the information required for construction can be presented on the monitor screen. Further, foundations are rapidly introduced into the plan, specification tables are made and the amounts of the materials are calculated.

It may seem strange that nowadays, with such significant developments in this field achieved in the world, it is not worth the trouble of combining the programming aids which are already almost out of date. But it is not a secret that, owing to the well-known historical circumstances of Lithuania, the solution of similar problems in the country is often too complicated because of limited financial possibilities. As a result, one of the basic aims was to find an optimum solution providing for conforming the possibilities of he computer-aided design system and its cost. Because of the limited size of the paper it is impossible to outline in greater detail all the components of computer-aided foundation design and only the basic principles of the implementation of this system can be presented. Nevertheless, one of the principle items of this subject is discussed in greater detail.

4. Analytical method of determining ground layers boundaries

As it was written before, up to now the boundaries between ground layers are determined on the basis of subjective information of an engineering geologist. This can be accepted for ground layers which consist of different types of soil but is not acceptable for the layers of the same type of soil.

Estimation of ground layers is based on soil mechanical properties, their average values and variations. At the beginning an attempt was made to divide the ground using CPT results in such a way that variation coefficient of individual values of cone resistance should not exceed the prescribed value. But later it was proved that for some soils, when dividing the ground into layers, this coefficient decreases very slightly and, for example, if one is seeking to obtain the value 0.2, the ground needs to be divided into an infinite number of layers. In the next stage the method of the least squares was used. In this case first a given number of layers is prescribed. The position of the boundaries between layers is obtained at the least sum of squares of differences among individual values and of average values of cone resistance. Besides, it is necessary to calculate the main square deviation of q . Then, using the probability analysis, it is possible to check whether these values belong to the same general series or, in other words, to the same ground layer. On solving this problem, a unique value of the position of the boundaries is obtained, in contrast to the subjective opinion of geologists. This is shown in Fig 1, c where the boundaries established by a geologist do not coincide with those obtained by calculations.

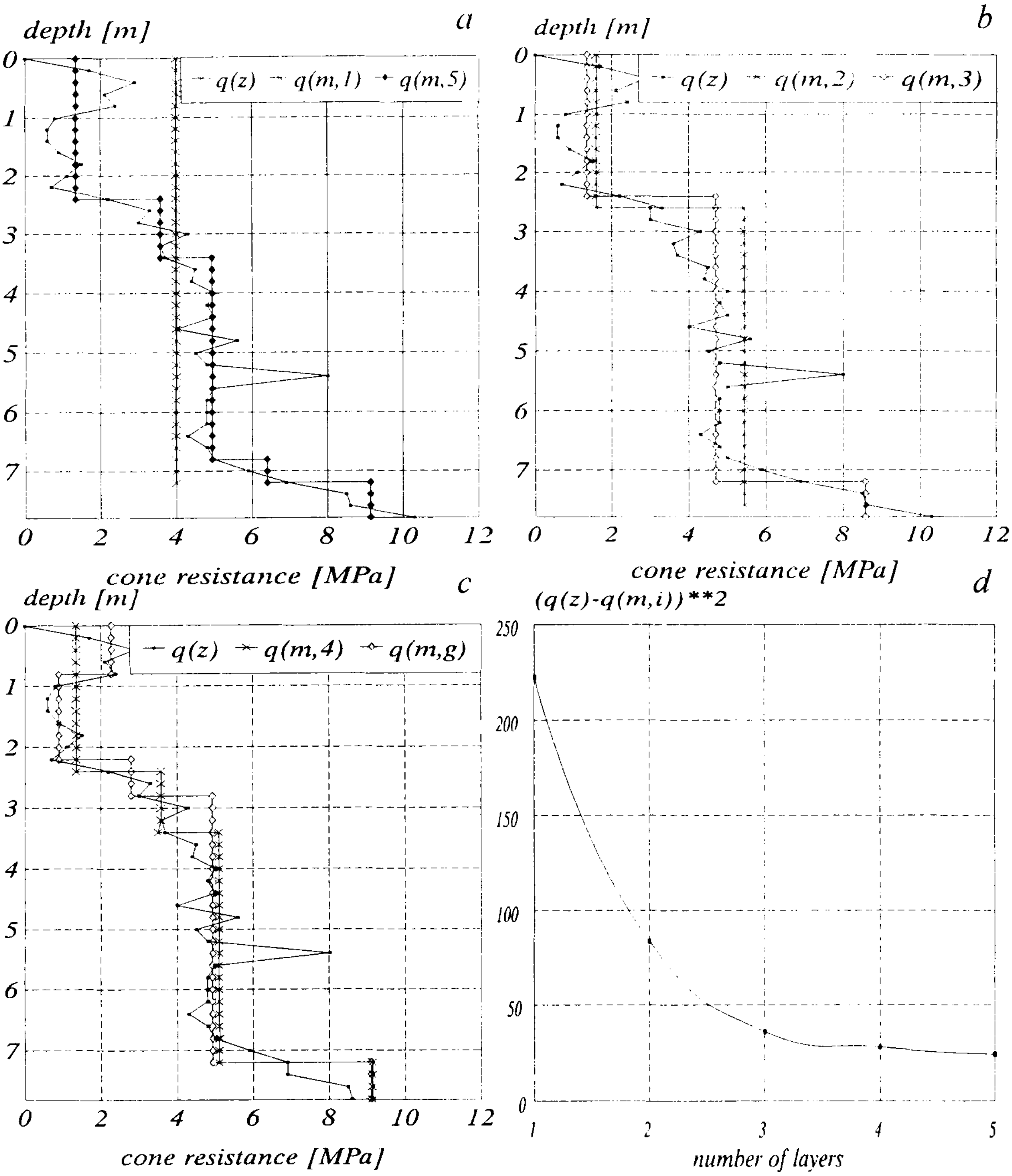

Fig 1. Assessment of ground layers according to results of CPT testing: *a* - number of layers 1 & 5; *b* - 2 & 3; *c* -4 & assessment by engineer geologist; *d* - sum of squares of differences between individual values and average values of the same layer

According to this technique, first of all, the number of layers should be prescribed. It can be easily found on the graph which shows that in this specific case the minimum number of layers is three (Fig 1, d). With a larger number of layers, the above-mentioned sum of differences changes significantly, it means that by increasing the number of layers, more accurate information on the ground cannot be obtained.

Here we have shown how easily one of the principal geotechnical problems can be solved. Besides, we have successfully solved one of the most important design problems for calculating specified ground reliability. At present we are developing a numerical ground model. These and other similar ways of solving geotechnical problems could, undoubtedly, constitute separate links of a computer-aided design system.

References

1. AutoCAD Map User's GUIDE / Autodesk, Inc. - 1996. - June 25.
2. Autodesk G/S Solutions: Mapping and G/S Software / Autodesk. - 1995.
3. Softdesk Civil/Survey' DTM Reference Manual / Softdesk, Inc. - 1996.
4. Diana word. - 1996. - N 2.

Įteikta 1997 02 10

AUTOMATIZUOTO PROJEKTAVIMO SISTEMŲ NAUDOJIMAS GEOTECHNIKOJE

J. Amšiejus, L. Gabrielaitis, R. Gruodis

Santrauka

Kuriant automatizuoto projektavimo sistemas ypač svarbu atkreipti dėmesį į tą duomenų bei informacijos dalį, kuri dėl jai būdingų savitumų negali būti unifikuota. Ryškiausias pavyzdys šiuo požiūriu galėtų būti inžinerinės-geologinės sąlygos, kurios įvairiuose pasaulio regionuose yra gana skirtingos. Pasitaiko ir taip, kad dėl to gali skirtis net pati gruntų klasifikacija. Panaši situacija yra ir Lietuvos teritorijoje, kur kai kurių grunto tipų spektras pasirodė platesnis, negu numato kitų valstybių gruntų klasifikacijos sistemos. Jau vien dėl šios priežasties kitose šalyse sukurtos programinės priemonės čia negali būti naudojamos neatlikus tam tikrų pakeitimų bei papildymų. Ne mažiau reikšminga ir kita aplinkybė, apimanti tradiciškai Lietuvoje susiklosčiusius pagrindų ir pamatų projektavimo principus, kurių neturi kitos šalys, kalbant, pavyzdžiui, apie gręžininių pamatų projektavimą ir statybą.

Formuluojant patį automatizuoto projektavimo uždavinį, autorių nuomone, pirmiausia reikėtų sujungti iki šiol visiškai atskirtas inžinerinių tyrinėjimų, pagrindų ir pamatų projektavimo, statybos bei eksploatacijos sritis. Kitaip sakant, reikėtų orientuotis į tai, kad ateityje visus tyrinėjimų, projektavimo bei statybos darbus turėtų atlikti viena organizacija, išskiriant nebent inžinerinių tyrinėjimų dalį projekto techninio-ekonominio pagrindimo stadijoje, kai galėtų dirbti šioje srityje besispecializuojančios organizacijos. Tyrinėjimų apimtis šioje stadijoje turėtų būti bent jau tokia, kad iš gautos medžiagos matytųsi, koks pamatų tipas labiausiai tinka konkrečioms gruntinėms sąlygoms. Tada projekto darbo brėžinių stadijoje tyrinėti turėtų jau pati pamatų statybos darbus atliekanti organizacija. Šitaip nulinio ciklo projektavimo bei statybos darbai vyktų kompleksiškai ir vienu metu, pagal principą "nuo stalo į gamybą".

Pamatų automatizuoto projektavimo diegimo būdai gali būti labai įvairūs ir pirmiausia priklauso nuo to, kokios projektavimo sistemos bus laikomasi kiekvienu konkrečiu atveju. Atsižvelgiant į mūsų dabarties galimybes, šiam tikslui visai neblogai gali būti naudojami plačiai žinomi ir labiausiai prieinami CAD sistemoje bei jos terpėje dirbantys programų paketai. Antra vertus, nemažai projektavimo uždavinių galima išspręsti ir savo jėgomis. Darbe parodyta, kaip remiantis matematinės statistikos dėsniais gali būti analitiškai nustatomos pagrindo sluoksnių ribos. Be šio klausimo, yra išspręstas, tik netilpęs į šio straipsnio rėmus, ir vienas svarbiausių projektavimo uždavinių - pagrindo normuotam patikimumui skaičiuoti. Dabartiniu metu dirbama ties pagrindo skaitmeninio modelio sukūrimo problema. Visi šie, o ir kiti panašūs geotechnikos problemų sprendimo būdai, vadovaujantis išdėstytais automatizuotos projektavimo sistemos kūrimo principais, neabejotinai gali sudaryti atskiras šios sistemos grandis.

Jonas AMŠIEJUS. Senior assistant. Department of Geotechnical Engineering. Vilnius Gediminas Technical University (VGTU, formerly VTU, VISI), 11 Saulėtekio Ave, 2040 Vilnius, Lithuania.

First degree in Civil Engineering, Kaunas Polytechnic Institute (KPI), 1966. Staff member of Department of Geotechnical Engineering, VGTU, 1971. Author of 2 inventions. Research interests: analysis of ground deformations and strength.

Linas GABRIELAITIS. Doctoral student. Vilnius Gediminas Technical University (VGTU, formerly VTU, VISI), 11 Saulėtekio Ave, 2040 Vilnius, Lithuania.

First degree in Civil Engineering, VTU, 1994. Doctoral student, VGTU, 1996. Master of Science, VTU, 1996. Research interests: application of computer-aided design systems in geotechnical engineering.

Rimantas GRUODIS. Doctor, Associate Professor. Department of Geotechnical Engineering. Vilnius Gediminas Technical University (VGTU, formerly VTU, VISI), 11 Saulėtekio Ave, 2040 Vilnius, Lithuania.

Staff member of Department of Geotechnical Engineering, VGTU, 1975. First degree in Civil Engineering, Vilnius Civil Engineering Institute (VISI, now VGTU), 1974. Doctor of Technical sciences (geotechnical engineering), 1981. Research visit: Prague Technical University 1989-90. Co-author of Construction Standards of Lithuania. Research interests: interaction between ground and foundations, and analysis of their design methods.