Problem of communication between design engineers and computers

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Problem of Communication Between Design Engineers and Computers

Probleme de communication entre les ingenieurs projeteurs et les ordinateurs

Verbindungsprobleme der Entwurfsbearbeiter mit den Rechenanlagen

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Summary
It is easy for design-engineers to use a big computer for the calculation of standard bridges and a small office computer for elementary calculations. On the contrary, when using program for checking a bridge built by cantilever constructuion method or Eugène system for special bridges, there were some problems; most of them are now solved.

Résumé
Il est facile pour les ingénieurs projeteurs d'utiliser un gros ordinateur pour le calcul de ponts-types et un petit ordinateur de bureau pour des calculs élémentaires. L'utilisation d'un programme pour la vérification d'un pont construit par encorbellement ou du système Eugène pour l'étude des ponts spéciaux a posé par contre quelques problèmes; le plus grand nombre de ceux-ci sont maintenant résolus.

Zusammenfassung
Für die Entwurfsbearbeiter ist es leicht eine grosse elektronische Rechenanlage für die Berechnung der standardisierten Brücken anzuwenden und eine kleine für teilweise Berechnungen. Einige Probleme sind dagagen aufgetaucht bei der Anwendung eines Programmes entweder für die Beurteilung einer durch Segmente ausgeführten Brücke, oder bei Berechnungen einer speziellen Brücke. Jetzt sind die meisten solchen Probleme gelöst.

1. INTRODUCTION

We shall be dealing with the problems raised by communication between designers and computers based upon the experience of SETRA (highway and motorway research department of Franch Ministry of Equipment), examining sucessively the following points which fall roughly into a historical order :

- programs for standard bridges
- use of an office computer
- V.E.P.program allowing the checking of prestressed concrete bridges of cantilever construction
- EUGENE system (which has several modules).

It should be pointed out that communication between designers and computers is facilitated by the fact that today's programs are written and documented by engineers who have learnt about bridge construction technique during their studies and who,subsequently, have become familiar with date processing. I say "today's programs" because about 10 years ago programs were written by IBM programmers, with analysis being carried out by specialized bridge engineers.

2. PROGRAMS FOR STANDARD BRIDGES

The first use of computers by SETRA (or rather by SSAR which does not exist now but the engineer of which work at SETRA) was for the design of standard bridges. During the 1960s, France initiated a motorway construction programme which was to progress at the rate of 175 km of motorway annually.

The bridges necessary for the connection of secondary roads were then standardized. For example, reinforced concrete overpasses had four spans of two to six beams, the number of beams depending on the width of the road carried, these beams being connected by cross-girders inside the spans and on supports.

Moreover, this standardization included the definition of a calculation method for design of the different elements (slabs, braces, main beams) and, of course, also for their justification.

Because the calculation method was well defined, it was possible to have the computer perform the material part of the calculation. It should be noted that above-described standardization greatly facilitates the preparation of computer data by the designer. In fact, as the bridge is standardized, it is defined by a small number of parameters.All these parameters can generally be provided on a data sheet prepared on a double-size 21 x 29.7 cm page.

We should speak here of the pilot documents which accompany each program. Among these documents, mention may be made of the following :

- a document describing the standardized structure,
- information enabling the predimensioning of the structure, using nomograms where applicable,
- the date sheet,
- comments on the date sheet.

To go back to the example of the reinforced concrete overpass, the designer will find that, considering the spans, provision should normally be made for a beam height of 0.71 metre and a thickness of 0.30 m.The designer will also have information on the strict minimum height. Having made his choice, the designer will be able to easily fill out the date sheet guided by the date sheet comments.

As regards the results, it should be pointed out first that the design calculation note printed by the computer has titles and subtitles in plain language. However, these titles and subtitles are necessarily of a limited length. To complete the explanations they give, the pilot documents include, among other documents :

- a model of a design calculation note giving supplementary information (including figures) added by hand,
- a note indicating the calculation mode used.

However, the essential task of the designer is the preparation of working drawings on the basis of data provided by the computer. To accomplish this :

- certain programs make it possible to obtain schematic drawings of reinforcements and/or cabling (case of prestressed concrete),
- the pilot documents always include a model showing how working drawings are drafted on the basis of documents furnished by the computer,
- finally, the working drawings include some general rules of determining certain reinforcements which cannot be obtained by specific computer calculations : for example, the reinforcements for the built-in header-girder of a slab bridge resting on a limited number of supports or minimum reinforcements in the span of a slab bridge.

3. USE OF AN OFFICE COMPUTER

It is not possible to standardize all bridge designs. For bridges which cannot be standardized, use may be made of stress calculation programs (e.g. a continuous beam) but this does not solve all the problems especially if a computer or a terminal is not available (which, in 1967, was the case of SCET, another department set up whithin SETRA). In fact :

- if one is to avoid significant manual calculations, it is necessary to provide the calculation of the moments of inertia of the sections and these can be highly varied,
- the response time is too long (of the order of a week) and this is troublesome when a sucessive approximation procedure is used.

To relieve engineers of tedious calculations without the above-mentioned drawbacks, we purchased an office computer : the Olivetti Programma 101 (this machine is presently obsolete but others of more modern design can replace it, for example, the Hewlett Packard 97).It would obviously take a very long time to calculate the complete envelope lines of a continuous beam using such a computer but it is adequate for a preliminary approach during which only the bending moments at the middle of the span and on the supports are calculated.

Such a computer can be used only by engineers or technicians familiar with bridge design. Consequently, the program writer does not provide the user with explanations as detailed as those appearing in the pilot documents.

A computer of this type is not able to print titles and subtitles in plain language ; it can only print results one after the other. It should however be noted that there is a small number of these results. In the simple example of the calculation of the characteristics of a section, the computer provides four results, namely :

- the area of the section,
- the moment of inertia with respect to a datum line,

- the location of the centre of gravity,
- the moment of inertia in relation to the line parallel to the datum line going through the centre of gravity.

It is hence sufficient to indicate to the user the order in which the results are furnished. More precisely, for each program, two or three pages of directions go over the computation principle and show how to furnish the data and the order in which the results are printed out by the computer.

I should like to point out that not only have the programs been used by engineers and technicians at SETRA in charge of preparing and checking design schemes after these programs have been written and after the directions for use have been finalized, but also that there was such a need that, firstly, the handwritten directions for use were requested from the programme writers before final typing and secondly, programs of more limited range were requested by users, for example for the calculation of the permissible shearing stress of concrete as a function of the normal stress and the permissible compressive and tensile strength of the concrete (in France we use the formula of Chalos and Bêteille).

These programs are presently less used because we have a small terminal connected to a computer working on a time-sharing basis. First of all, this allows an engineer to request more complex calculations, for example the calculation of stresses in a reinforced concrete section subjected to compound and oblique bending.

Secondly, as soon as an engineer specializing in bridges has acquired some familiarity with data processing (in particular the notion of data set) he can modify and hence correct the data he has introduced into the terminal.However, the Olivetti Programma 101 continues to be used.

4. DESING CALCULATIONS FOR PRESTRESSED CONCRETE BRIDGES BUILT BY CANTILEVER CONTRUCTION METHOD

To check such bridges, we have written a check program. This program is applied only to straight (rectilinear and not skewed) box-section bridges. No account is taken of the horizontal deviations of cables. In other words, the bridge may be regarded as a medium -plane beam loaded in its medium-plane and prestressed by cables located in this plane. The data define the shuttering and the cabling in particular. The program indicated whether the structure meets requirements of the french rules in the different construction phases and in service.

There are many data and it is these data which raise the greatest problem. It should be mentioned that a first version of this program was written for the IBM 7094 computer which had only 32K words of core memory. The configuration used was that of the IBM service bureau in Paris which included eight tape units but no disks. The program was written on the basis of the small capacity of the main memory, i.e. so that it could facilitate the work of the computer. The type of data introduced were the following :

- shuttering of a cantilever arm (two contilevers),
- corresponding cabling or, more precisely, the definition of cables going through this cantilever arm.

Precautions were nevertheless taken to avoid duplicating the input of data on the continuity cables (they go through two cantiliver arms) and to avoid the repeated descriptions of a symmetrical cantilever or one identical to another. Another precaution was taken to obviate the complete redefinition of all sections.

Without going into details, let us simply point out that we entered only whatever varied in relation to the first section, essentially total height and thickness of the lower slab.

Moreover, the cables could be :

- either defined by points,
- or defined as standard cables composed of a middle line flanked by two parabolas with vertical axes extended by line segments to the vicinity of the anchors.

Under these conditions, a continuity cable located in the lower slab and raised in the span could be defined only by points, thus leading to a large number of data (see figure 1).

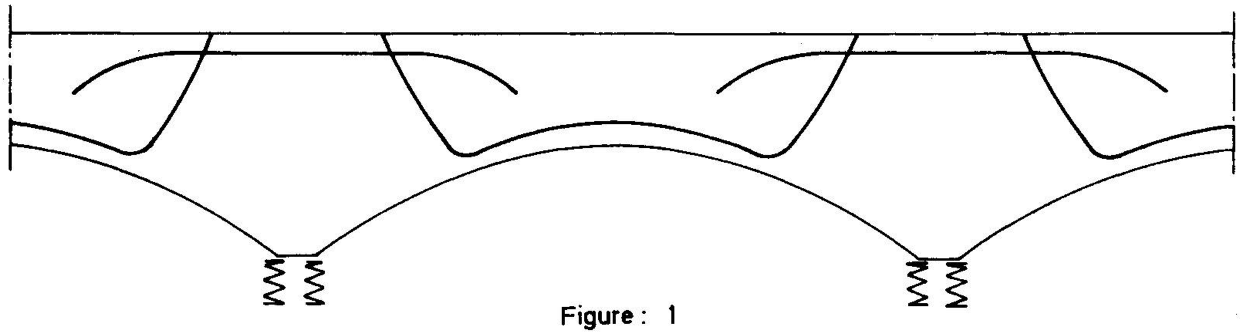

Figure : 1

A preprocessor was hence subsequently written and makes it possible in particular :

- to enter, as simply as for standard cables, the data on continuity cables raised in the span ; the preprocessor then generates cables by points,
- to enter data on shuttering and cabling in a logical order : entering first all the date defining the sections and then those defining the cables.

We did not consider it useful to create a special language allowing the formulation of all data in a plain language as in the case of the STRESS and STRUDL programs. No users have indicated to us that such a language would be useful and, quite the contrary, a user pointed out that he preferred to be guided by the data sheet and its comments. In fact, it is not every day that an engineer has to have design calculations for a prestressed concrete bridge of cantilever construction and hecannot know by heart the rules governing the formulation of the data.Accessorily, this choice made it possible to reduce the programming time. We nevertheless introduced some key words which are very useful for the checking of data by the preprocessor as indicated below.

The preprocessor in fact has two other functions :

- data checking,
- recall of all data in plain language and in logical order.

This logical order corresponds to the order in which they have been introduced into the preprocessor where as they are recalled by the program in a somewhat special manner. The program carries out the calculation of losses in the cables of a cantilever arm then recalls the data relative to these cables, calculates the properties of the cantilever arm design sections and then recalls the data relative to the shuttering of this cantilever arm. It then goes on to the next cantilever arm and so forth.

As regards the checking of data, a first group of checks carried out by the preprocessor consists in ensuring the coherence of data. A first example is provided by the lengths of spans : they are furnished by the user and the preprocessor checks that the length of each span is indeed equal to the sum of the lengths of the different segments (key segment, running segment, pier segment). Another example is provided by the number of cables of a given type in a given cantilever arm this number is defined by the user and amidst the data read by the preprocessor. Further, there are key words which occupy a card. One of them announces that the preprocessor will have to read the cables of a given cantilever arm, while another announces that the precompiler will have to read standard cables. The number of cards defining the standard cables is thus equal to the number of cards between the key-word card and the next key-word card. If this number is not equal to the number of standard cables previouly announced, the preprocessor detects a data error.

A second group of checks consists in having examined, by an engineer, drawings made automatically on the basis of the date furnished : we consider unnecessary to have all the sections drafted ; we drafted only :

- the first section entirely (note that it is on the basis of this section that all the others are defined),
- the section on the first pier,
- a longitudinal section of the shuttering (the preprocessor notes the highest point and the lowest point of the outer contour and then the internal hollow at each section and drafts the curve obtained by joining the projections of these points onto the same vertical plane),
- a plan view obtained by taking the points farthest to the right and farthest to the left in each section,
- and, of course, a longitudinal section defining the cabling.

These drawings are sufficient for checking the data in simple cases, but they are inadequate in certain complex cases. In the latter cases, we thinks of drafting all the sections.

As concerns the outputs, this program raised much fewer problems. From the outset, they included titles and subtitles in plain language and, moreover, a presentation document giving additional information. After a certain number of operations, explanations were drawn up again so that they were clearer and more complete. It should also be noted that it was found necessary to have numbered pages. The results are examined by the program manager before being sent to the engineer in charge of preparing and checking the design scheme who required the calculations. And, it is interesting for the manager to be able to tell when there is excessive stress in a given section indicated on a given page of the outputs. To obtain thise page numbering, we have written a small post-processor program which re-reads from the data set the formated results, notes the pages skipped and can then increment the number of the page and write it.

I should also like to point out that the outputs are of course voluminous. In a similar program which we wrote for curved bridges, we are considering selective outputs : the user will specify during each operation the results he wishes to obtain.

5. DESIGN CALCULATIONS FOR SPECIAL BRIDGES BY MEANS OF THE EUGENE SYSTEM

For the calculation of special bridges, such as those encountered in particular in motorway interchanges, we have developed a system called the EUGENE system composed of several modules. The first calculates the influence areas ; the second calculates the envelope lines, i.e. the extreme values of the action effects under dead load and live loads ; the third determines a cabling diagram using the techniques of operational research.

The data of these modules obviously include the results of the modules used before, but they also include data specific to each module and furnished on cards which are broken down into two parts :

- operation cards,
- numerical and alphanumerical list cards.

An operation cad indicates, for example, that there is a link between a plate and a beam at a certain number of points constituting a field. A numerical list specifies, for example, the coordinates of the points of a field.

This imput method has two main advantages :

- it is very flexible ; the engineer using the EUGENE system builds his model,
- it allows many check by the computer.

On the other hand, it has a major drawback : its esoteric nature. The result is that these data cannot be prepared by the engineer in charge of establishing a design scheme. A few years ago, this engineer had to contact a specialist of the EUGENE system to outline his problem to him. This specialist prepared the data.

We have sought to facilitate the use of the system for current models (skewed beams, skew bridges with beams connected by a slab, bridges with leg frame supports). To achieve this, we first drew data sheets which would enable the design engineer to enter in the proper zones of the cards the numerical data regarding, for example, the inertia of beams and the abcissas of supports. As the operation cards do not vary greatly for a given current model, the same deck of cards was used with some modifications where necessary. However, this procedure came up against various difficulties :

- the volume of the data sheet can become significant ; for example, a simple skewed beam can be made up of several parts, each part beeing an elementary beam (beam on which the inverse of the inertia is expressed as a function of the abscissa by means a second-degree trinomial) and for each part a page of data is necessary,
- fairly significant modifications are however necessary to the deck of operating cards. In fact, a "current model" can encompass quite different structures for example, a bridge with leg frame supports may or may not have counter-leg ; the leg frame supports may be full fixed or hinged on the foundation (see fig. 2) ; major modifications to the deck of operation card were thus required for each operation, thereby bringing about the risk of error,
- the recall of data was of course carried out by the EUGENE system, but in the manner in which it would have been carried out for any structure, whatever its complexity ; it was thus difficults to understand for relatively simple structures which can be calculated by using the library of current models.

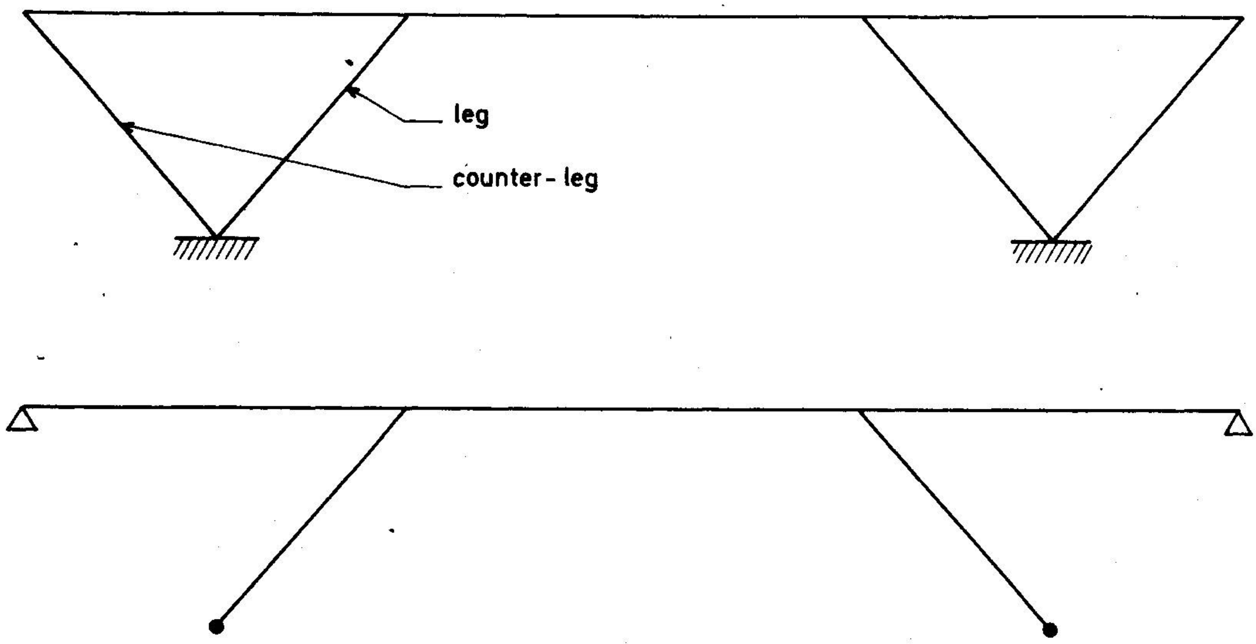

Figure : 2

To avoid these difficulties, we have written preprocessors for each module and for the different curent models. To keep engineering costs down and to facilitate the portability we have written them in PL 1. This allows the plain-language introduction of data. More precisely, the data are provided in the form of qualitative or numerical constants or of numerical lists. In every case, a key-word makes it possible to specify the nature of the information. An example of a qualitative constant is furnished by the bridge with a leg frame support mentioned earlier. To indicate that there is no counter-leg, one need only write :

CONTRE-BEQUILLES-CHOIX = ' NON '

That is to say :

COUNTER-LEG-CHOICE = ' NO '

As this data introduction mode is more flexible and the data are prepared on any type of paper, the paper volume for a given problem remains limited. Moreover, the precompiler generates operation cards a well as numerical data cards. Finally, one need only have the computer list the cards introduced in order to obtain a recall of data in plain language. Another advantage : the limited number of data can be typed by specialist engineers or technicians on a simple terminal connected to the computer working on a time sharing basis. Errors of syntax and the absence of data are immediately pointed out by the computer.

It is to be noted that design engineers using the EUGENE system for the first time encounter certain difficulties in formulating their data in this manner : in France, engineers are accustomed to filling out data sheets for standard bridges. This observation seems to confirm the opinion of the user consulted with regard to the formulation of data for bridge built by cantilever construction method : a special language appeared to him to be unnecessary. Coming back to EUGENE, it should be noted that at the second time the design engineers are able to formulate their data by means of the preprocessor.

As concerns the interpretation of the results of the EUGENE system, difficulties still come from the generality of this system. For example, a table printed by the EUGENE-STRUCTURE module hase the title :

"Composante de la déformation Moment.1 (lignes du tableau)
Composante de l'action Force 3 (colonnes du tableau)".

That is to say :

"Component of deformation Moment 1 (lines of table)
Component of action Force 3 (columns of table)".

Explanatory documents include :

- a calculation note on which is added information ; in the given example : "torsional moment",
- comments on the calculation note which constitute another document and can be more detailed.

These comments also indicate how cross-checks and verifications can be made, thereby allowing the reader to understand the meaning of the results obtained.

As regards the EUGENE-ENVELOPPE module, the adopted solution is different : comment cards are introduced with the data and listed at the output with the titles ; for example, under the title printed by the EUGENE-ENVELOPPE module "Lignes enveloppes intermédiaires relatives à l'enveloppe spécifique n° 2" (that is to say : "Intermediate envelope lines relative to specific envelope n° 2" can be made to oppear the comment "Moment fléchissant sous charge d'exploitation" (that is to say : "Bending moment under live load"). Let us specify that, in the case of current models, the comment cards are generated by the preprocessor

The EUGENE-B.P. module does not raise any particular problem because it furnisches a cabling diagram for a beam of the structure (it is sufficient to spécify which) and titles and subtitles clearly indicate the content of the different tables printed by the computer

It must be acknowledgedthat certain difficulties remain which appear to be due to the fact that in France design office engineers are used to design calculation notes for standard bridges for which, on the one hand the computer prints all the results required without it being necessary to specify to it the desired results and, on the other, it sends out a warning message in plain language if the geometrical dimensions of the concrete are insufficient. On the oter hand, when the EUGENE system is used, it is necessary for example :

- to specify that one wishes to know the shearing stress at a given point of a beam under torsional moment and shear force,
- to check that this shear stress does not exceed the limit stress (taking into account the normal stress).

The solution will probably consist in giving additional information for each of the current models.

6. CONCLUSION

Problems of communication between design engineers and the computer have generally been solved, with different solutions depending on the problems involved.

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