Computer aided bridges design

Computer Aided Bridges Design

Conception assistée d'ouvrages d'art

Computerunterstützter Brückenentwurf

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RÉSUMÉ
Un programme complet de CAO pour la modélisation de ponts permet à l'utilisateur de construire une maquette réaliste, à partir de laquelle seront extraits des données de calcul et permettant de même la génération partielle ou totale de plans nécessaires à la construction de l'ouvrage.

SUMMARY
An extensive CAD software for bridge design enables the user to produce a realistic model of the structure from which structural software data files and drawings are partly or totally generated automatically.

ZUSAMMENFASSUNG
Das vollständig computerunterstützte Programm ermöglicht dem Anwender ein realistisches Modell zu entwickeln, aus welchem Bemessungsdaten sowie Konstruktionspläne der Brücke automatisch produziert werden können.

INTRODUCTION

For **CAMPENON BERNARD**, a major French civil engineering contractor, the use of a CAD system was at first an answer to a drafting problem. Meanwhile the choice of a powerfull system was brought about by the wish to perform a smooth evolution to computer-aided design.
Drawings are nevertheless the main production from the design office. CAD system beeing mainly devoted to draftmen, the aim of the first developpement was to process data exchanges between drafting and design. Drawings, as a main data base for design, are transformed to a computer data base, easily and errorfree processed by structural analysis software. But there is some differences between a computing model and a drafting model. Many precise details must be drafted, while they are unnecessary for structural analysis.Sometimes inconsistant with software simplification, they are of no mechanical consequence.
The aim of our developpements was to have the design draftman responsible for the preparation of a common model, under the control of the design engineer.

I STRUCTURE LAY-OUT (Fig. 1)

The structure is positioned in space with the help of two plannar definitions, the site view and the profile line.
Site plan view is a projection of the reference axis of the structure upon an horizontal plane. Computations are very precised, the results are often to the millimeter even for radii of more than 1 kilometer.
The profile line gives the level of every point of the plan reference line. It usualy consists of straight lines and conics.
Construction lines are drafted in a 3D file, on two perpendicular planes. On each curve, particular points are defined as indications of the major geometrical changes of the deck.
A 3D curve is automatically generated. More than a curve, points are placed in space. Every point is the location of piers or represents changes of the structure which leads to section modification. These points often mark a discontinuity in the construction process or precast element fabrication.

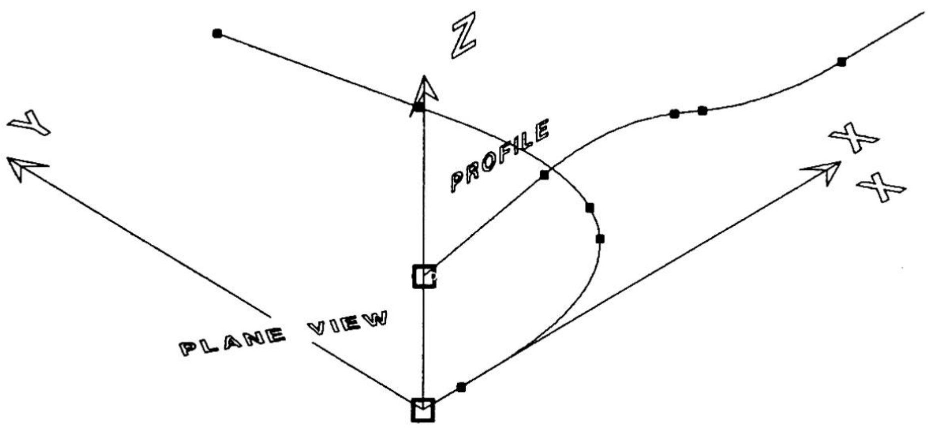
II SECTIONS DRAFTING

Bridge sections while varying a lot, always still have some common characteristics between them.
A bridge section consists of slabs and webs. It can be open or closed with one or more openings. Symetrical or not, its shape is directly linked to its behavioural properties. It is one of the variables in the calculations, and cannot be fixed at the beginning.
For these reasons, we had to imagine an evolutionary process, free enough to allow any particularity while offering practical tools for drafting usual shapes.
Before they are recorded, different mechanical properties are computed and listed. Modifications are easy and quick, especially if these modifications are the usual geometrical changes applied to sections to improve their behavourial properties such as thickening of slabs and webs. These sections are named and stored in a library. They can be recalled at any moment for any project.

III PLACING THE SECTIONS (fig. 2)

In addition to the mechanical and geometrical parameters, some more data linked to layout process are defined for each section. Attachment point to reference curve, superelevation points and theoretical mechanical axis for computation are defined. Some reference points can be added too, in order to identify, after the completion of the structural design process, the final coordinates of the different parts, which is usefull for

Fig. 1 - Layout curves



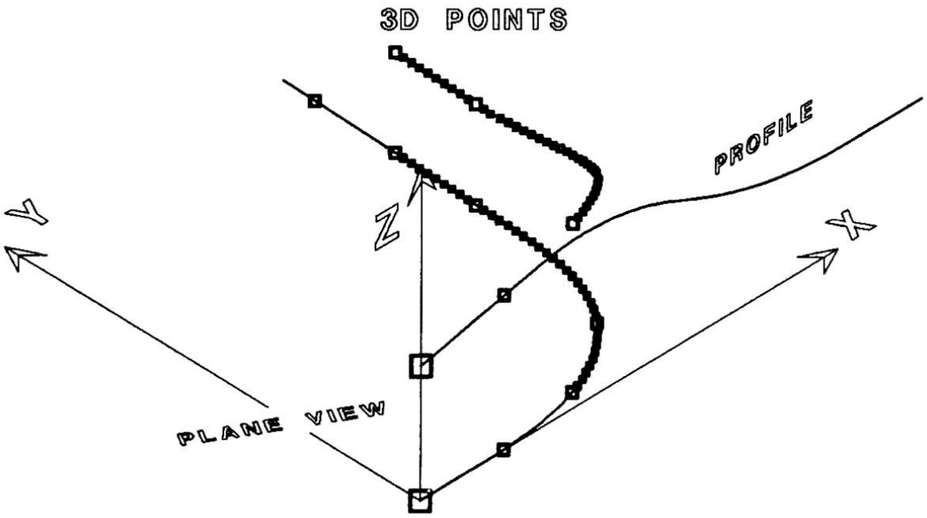
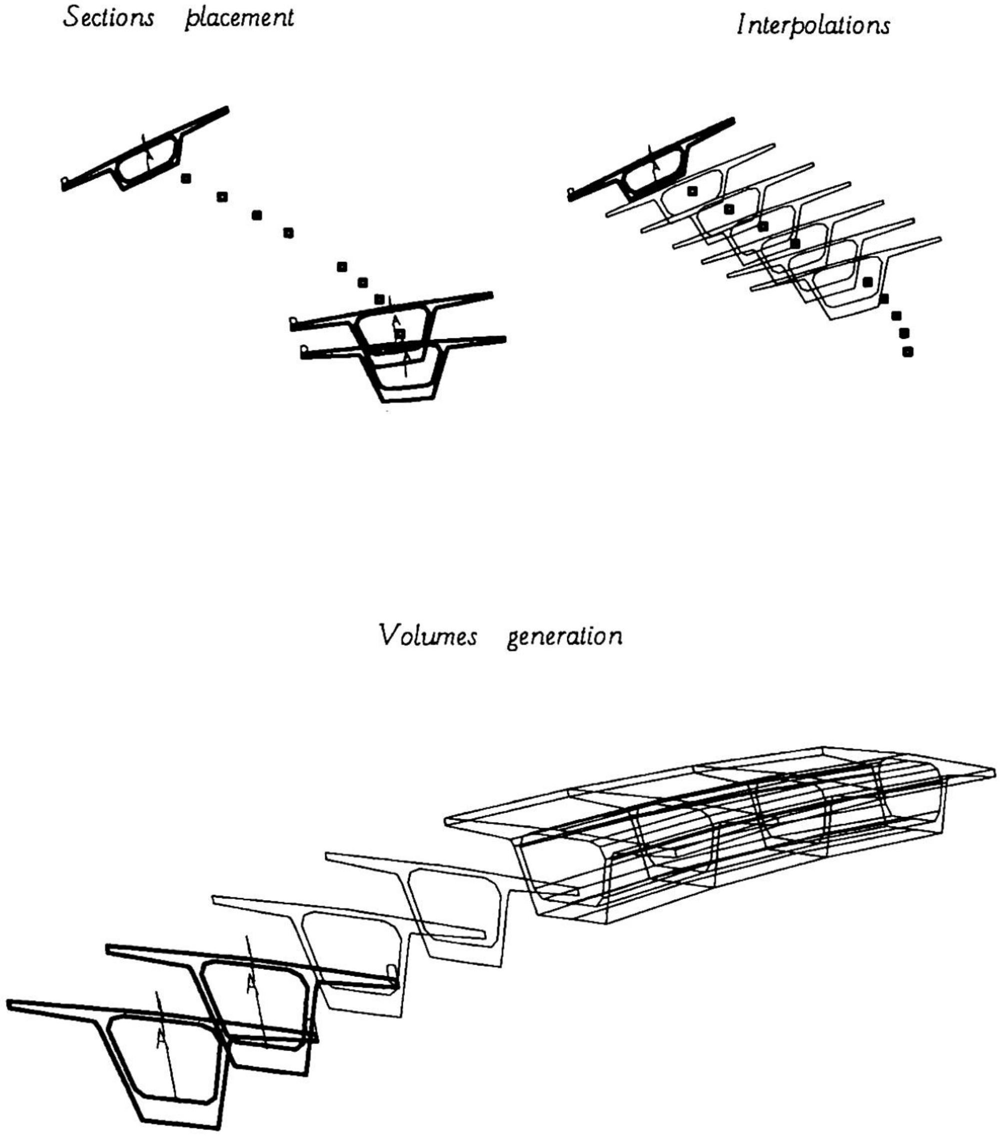


Fig. 2 - Sections and volumes



construction.

IV VOLUME GENERATION (fig. 2)

From the positioned sections, volumes are automatically generated from one section to another. The usual variation is linear but it can also be parabolic or user defined. One restriction is that sections must be defined with the same number of points all along the project, even if some points are geometrically at the same place.
Erection of piers is done in the same manner. They are in fact very similar to the deck, in their design process.

V PRESTRESS CABLES

Two types of prestressing techniques are used wich need totally different processes to be generated.
Cables placed externally to the structure are the easiest to design. Tendons are linked to concrete at some particular points, such as a deflacting block, wich modify their direction. The constitution of such a cable is made of lines linked by circular arcs at attachement points. It is often defined by theoretical points where lines cross, wich are also the points where loads concentrate. Circular arcs are determined as fillets between lines, with a given radius. The direction of the cable model is left to the draftman. Once the model is defined, all the different parts are linked together, and software is called upon to transform all this information into a coherent system. A facility is provided to the operator to perform difficult connections such as for non coplanar lines.
For internal cables, definition is totaly different. Some leading points are imposed. In sections, positions are often the same from cable to cable in the different sections. Geometrical interpolation between these points have to follow given rules. Ends near the anchorages are often the same too, in order to make design and construction easier and to reduce cost. For that reason, the user is helped as much as possible to easily define that kind of cable.
Tendons are then generated by a batch job. They are aproximated by cubic parabolae. Imposed points between sections or new ones can be defined, some can be suppressed or moved to another place.
For both types, additional parameters are defined for each cable. The type of the cable, the different mechanical properties and the initial stressing load are input in order to get the final tension and expected loss. After modification, these results can be obtained interactively allowing the best definition to be found.
Cables are modelled by their central axis only. For spare economy and minimized response time, it is useless to model the sheath. But in particular points, for interference checking, an overall dimension tube can be automatically generated giving two points on the cable.

VI ANCHOR BLOCK DEFINITION

Anchor block design has always been the most difficult part in bridge drafting, due to the complicated geometrical definition of these parts. If we try to simply define an anchor block, it is made of a dimension imposed face on wich rests the metal anchor plate, perpendicular to the axis of the cable. Pyramidal facets are the drawn to obtain the jonction with the surrounded concrete base. In order to simplify design and construction, shapes are often the sames for every anchor, even if the concrete base is different, leading to some simple geometrical modifications and adjustments. Variable facets are automatically adjusted to be linked to the existing concrete surface.

VII COMPUTING INPUT FILES GENERATION

Until then, the work performed by draftsmen has been identical to the one they should have done before, but much easier and quicker. As he is processing, much of the information is recorded for later use. With the help of the engineer, some parameters, directly linked to computation software as nodes and bars definition, sub-cutting and connections, internal as well as external, are defined.
The software will automatically generate input data files for structural analysis software.
The engineer will have only to define external loads and get the results of the computation.

VIII GRAPHICAL EXTENSION

All the informations collected can also be used for the graphics. First, form plans are drafted from different parts of the model, automatic references and titles are added. No more difficult geometrical calculation is needed for complex shapes, software simply uses coordinates data from the real sized model. Hidden lines removal and automatic perspective generation is often used to add detailed views wich make the plan more easily readable and understandable by everybody.
The drafting activity most aided by this facility is the preparation of prestress cables plans. On the longitudinal profile, for each point of the cable much information can be automatically written as name, local radius or slope. A set of section plans can be automatically generated to, giving for each defined section the position of the cables going through it with exact local coordinates.
Bench marks set on each sections can also be collected on setting plans in order to help the making and placement of segments.
The Model is also used as a reference for reinforcement placement. No 2D interpretation of the model is required. Bars are directly defined inside the concrete model using the INTERGRAPH CDP software. The aim of this software is to provide an automatic check of the major rules of rebars placement in accordance with several major standards (ACI,CP100,BAEL). Freed from this, the draftsman can design better reinforcement. At the end of the work, sections and detail views are automatically generated, for assisting quantity takeoffs.

Report and bending schedules are drawn automatically too .With the help of interference checking, the draftman is able to draw more realistic plan of reinforcement.(fig. 6 & 7)

CONCLUSION

This major development needed more than one and a half year-man of programming. However, that important work has been done in understanding the basic softwares.
The first use of that software showed an important saving of time and more consistency in design.
We had given consideration wether we have to go further in automation of modelling process, eg. prestress optimisation. In fact, the bridges studied at the design office are too different from each other to find a common calculation method for geometrical optimisation and get the best results.
As of now, this software with the help and speed it provides, allows the engeneer to design a greater number variant models to select the best one.