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# Computer Aided Design for Slab Bridge Decks

Conception assistée par ordinateur pour des tabliers de ponts-dalles

Computergestützter Entwurf von Fahrbahnen auf Plattenbrücken

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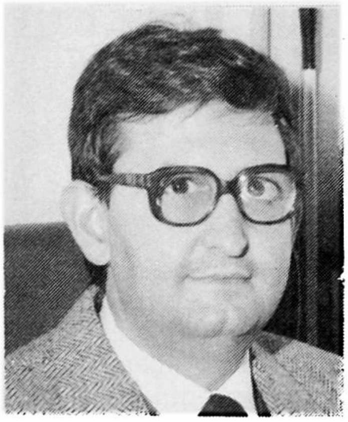

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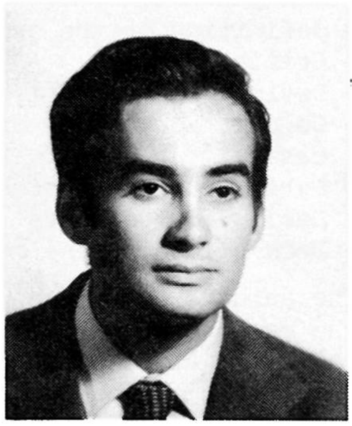

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**SUMMARY**
This paper presents the main characteristics of a CAD Program for the analysis of continuous multispan slab bridge decks. It allows the definition and drafting of the deck and produces all the data – geometrical, topological, mechanical and load cases including pre-stress forces – for a plane grillage used as the structural model for the bridge.

**RÉSUMÉ**
Cette étude présente les principales caractéristiques d'un programme CAO pour l'analyse des tabliers de pont de travées continues. Elle comporte la définition et le tracé du tablier et indique toutes les données – géométrique, topologique, mécanique et les cas de charges y compris l'action de la précontrainte – pour un grillage utilisé comme modèle structural du pont.

**ZUSAMMENFASSUNG**
In dieser Studie werden die wichtigsten Merkmale eines CAD-Programms für die Untersuchung durchgehender Fahrbahnen auf Plattenbrücken dargestellt. Dieses ermöglicht es, den Belag zu bestimmen und zu entwerfen, und es stellt alle Daten (die geometrischen, topologischen und mechanischen sowie die Belastungen, einschliesslich der Vorspannkräfte) für einen ebenen Trägerrost, der als Strukturmodell für die Brücke verwendet wird, zur Verfügung.

## 1. INTRODUCTION

The customary approaches for designing short or medium span bridges are either solid or hollow slab decks and precast girder bridges. The deck design is always done by the engineer when the option chosen is a slab bridge while for the precast girder option it is generally the girder manufacturer who supplies the design calculations. Slab decks, because of their "in situ" casting, can be more readily adapted to any layout arrangement, both in plant and elevation and they offer a more varied cross-section range. Furthermore, they make it possible to build continuous span bridges and provide greater freedom for pier location. All this requires that every bridge is studied carefully and treated individually and, for this reason, it is advisable that specific CAD programs are available for this type of bridge to help the engineer, not only in defining the type of bridge, but also to produce an adequate calculation model which, in most cases, would be a plane grillage.

The stages in the design of a slab deck can be summarised as follows:

- definition of the geometrical shape both in plant and cross-section
- Grillage layout
- Definition of the loads involved
- Calculation of the displacements or load effects corresponding to the above cases
- Determination of prestress forces
- Design load effects
- Deck reinforcement design.

The authors of this paper are working in the Instituto Eduardo Torroja (within the research project PR84/0199, with the financial support of CAICYT) on the development of a package covering all the above stages for straight slab span, multiple span and symmetrical slab bridge decks. These bridge types include a significant percentage of all highway bridges. This paper discusses the work carried out on Stages 1 to 5, where generally accepted criteria are recognised to exist.

## 2. DEFINITION OF GEOMETRICAL DECK CONFIGURATION

This program only deals with straight skew bridges where support lines may not be parallel to each other and have either a solid or hollow constant symmetrical cross-section which becomes solid along the support lines. This type does not allow direct treatment of curved plant bridges or of bridges with unsymmetrical cross sections or where the cross-section varies either in width or depth. But it is nevertheless possible to modify the grillage data provided by the program not using the computer in order to handle some of these cases.

To define the plant it is only necessary to provide the length of each span, the deck width and, for each support line, the angle it forms relative to a line perpendicular to the bridge axis and the width of the solid area over the support lines.

The most complicated exterior profile of the cross-section can be a trapezoid with two wings varying in depth linearly. The cross-section can be solid or hollow; in the latter case, hollows may be either circular or rectangular. Two hollow sizes can be considered, depending on whether they are located in the centre or at an end. The program requires a minimum number of geometrical data that are necessary for obtaining a cross-section shape in which the number and position of hollows are determined.

The program allows the bridge plant and cross-section to be drafted, either on the screen or on a plotter and both correctly dimensioned. Figure 1 shows the plant and cross-section of a two-span bridge whose cross-section has wings and circular hollows. The program also supplies a number of additional data on the

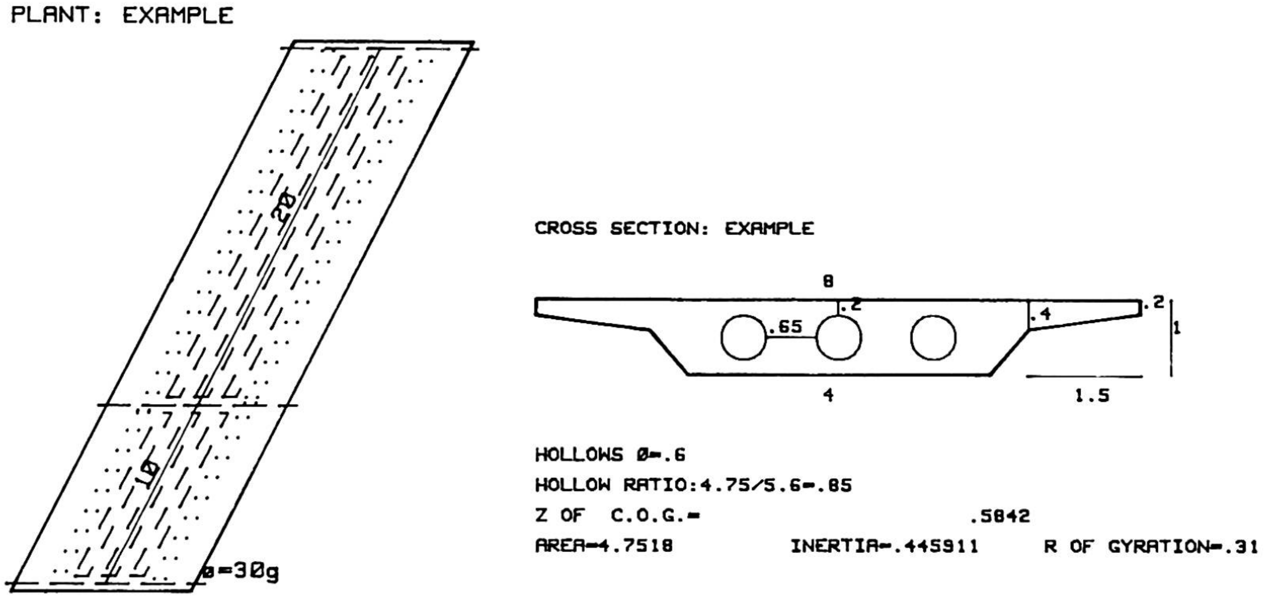


Fig. 1 Plant and cross-section of a two-span bridge

cross-section such as cross area, depth of centre of gravity, the moment of inertia relative to the horizontal axis crossing this centre of gravity, the turning radius, and the hollowing ratio. The designer may decide, in view of these data and of the cross-section and/or plant draft, to change the specifications in an interactive fashion and will immediately obtain the results of the modifications.

## 3. GRILLAGE DESIGN

The structural model selected to represent the behaviour of this type of structure is a plane grillage with longitudinal members parallel to the bridge axis and cross members that can be perpendicular to the longitudinal members or parallel to the support lines if these are parallel to each other (1, 2, 3). A further set condition is that longitudinal members must be uneven in number and symmetrical to the bridge axis.

The program automatically proposes a grillage where the longitudinal members correspond to a central hollow, the member axis coinciding with the hollow axis when the number of the latter is uneven or with the solid area between hollows when these are even in number. The remaining parts of the cross-section up to each end are carried by two members with their axes placed at 0.3 times the depth from the point where the wings start or, if no wings are provided, from the bridge edges. Cross members are perpendicular to longitudinal ones, intersecting them on the support lines and at regular intervals in each span; in addition, when a support line is not perpendicular to the bridge axis other members are then arranged representing such a line. As support conditions, the program proposes that all nodes falling on a support line are restrained in their vertical displacements and free in both rotations. The structural nodes are numbered according to cross members. Figure 2 presents the grillage proposed by the program for the bridge in Figure 1.

The grillage proposed can be modified by the designer in the following respects:

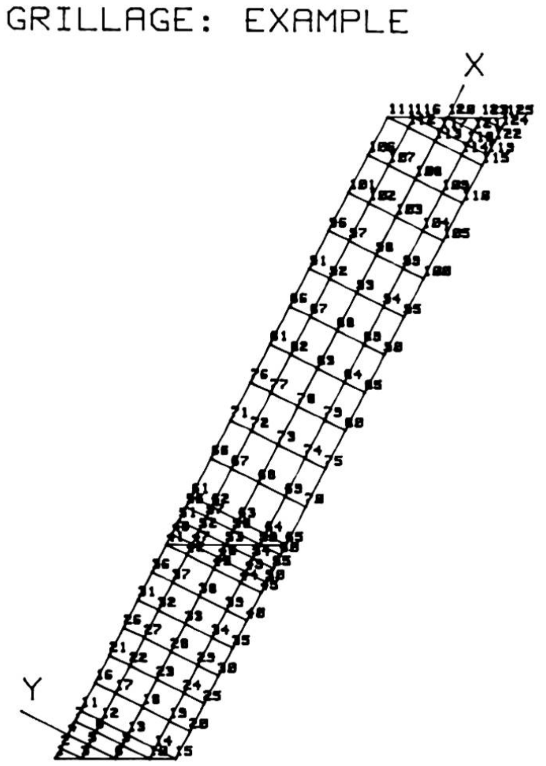


Fig. 2 Grillage

- changing the number and location of longitudinal members, i.e. grouping more than one hollow for each member
- if all support lines are parallel to each other placing cross members parallel to support lines
- changing the number of cross members for each span
- where cross members are perpendicular to longitudinal ones and support lines exist that are not perpendicular to the bridge axis, automatically eliminating alternating cross-member lines on support lines with the purpose of avoiding an excessive number of members where the skew angle is small
- numbering nodes lengthwise. This form of numbering, which may be advisable in some cases, gives a greater band width in the stiffness matrix, which is of no worth if the structural analysis program renumbers the nodes internally in order to reduce band width
- redefining support conditions for all grillage nodes, considering them as rigid supports or attributing to them elastic coefficients.

Figure 3 shows two grillage layouts for the bridge in Figure 1 where some of the abovementioned changes have been introduced.

The program produces all geometrical, topological and mechanical data of the grillage in accordance with accepted standards for this type of structure; it allows data to be listed and stored in a file directly available to a structural analysis program, and a grillage layout to be drafted on the CRT or on a plotter. Moments of inertia of members are given in respect of an axis placed at the same level as the centre of gravity of the cross-section. To calculate the cross-area and moment of inertia of longitudinal members, circular hollows are substituted by rectangular hollows of equal area and moment of inertia relative to the horizontal axis. This permits these constants to be accurately calculated when longitudinal members represent whole numbers of half hollows, as is normally the case,

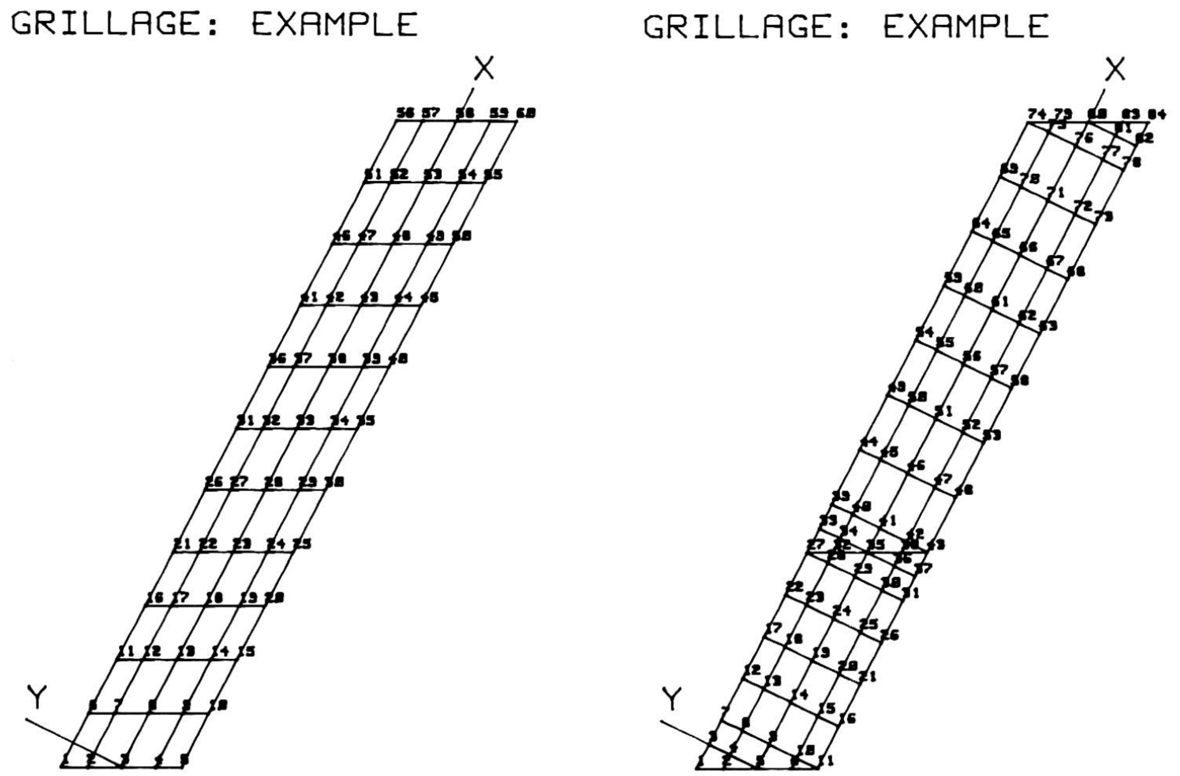


Fig. 3 Two grillage layouts for bridge

although when the opposite is true minor errors do occur. To calculate the moment of inertia of the cross-members only the upper and lower sub-slabs are considered, on both sides of a central hollow axis although, in the case of circular hollows these are changed for equal area square hollows. Members corresponding to support lines are assumed to be of solid square section.

For these calculations the width represented by each member is deemed to be up to the midpoint between adjacent members or up to the outer deck surface. Cross-members falling on nodes along the support line are assigned half the characteristics of the other members in the same line. Finally, the moment of inertia of the members is determined by a simplified procedure equal to twice the flexural moment of inertia.

## 4. DEFINITION OF LOAD CASES

The program automatically produces the most common load cases and provides for the manual introduction of new cases, at the designer's discretion, permitting changes to any of them.

The automatically produced load cases are:

- deck dead weight, as uniformly distributed load along longitudinal members
- dead weight of footpaths, pavings, parapets and guard rails
- service life loads at 400 kilograms per square metre, assumed to be uniformly distributed over each half carriageway on each span
- positions of the loading pattern, both centred at 40 cm from one of the carriageway edges, over the following lines: intermediate support lines; one depth away from the end support lines and on the centre line of each span. In addition, the following load types may be introduced at the designer's will:

- load distributed on a given deck area
- loading pattern placed at any point
- definition of pre-stress cable arrangement through calculation of vertical loads, loss of pre-stress and axial action effects, for a unit pre-stressing force.

## 5. CALCULATION OF DISPLACEMENTS AND LOAD EFFECTS

The program for calculating displacements and load effects in grillages takes its data from files storing grillage and load description, then calculates the displacements and load effects for each load case and stores them in the respective disk files. Later, the program allows the load cases to be classified as: permanent, those that must always be taken into account; variable, those that should only be taken into account when their effect is unfavourable; and exclusive, only one of which is to be so considered for each combination, that is the most unfavourable for the load effect being studied. The designer may decide the number of combinations to be carried out and the coefficients to be assigned to each case and with this the program determines the most unfavourable load effect combination for each cross-section.

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