

AUTOMATION OF DECK BRIDGE REPRESENTATIONS

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ABSTRACT

The bridge deck has a apparent simple shape, but it is the result of an adequate combination of two longitudinal geometric components: the deck shape evolution along de longitudinal section the layout of the road, that acts in simultaneous over a cross section, defining the deck exact shape. A geometric modelling computer programme was developed for box girder decks, allowing the generation of cross sections along the deck, defined with correct shape and location.

In the elaboration of the deck plan drawings, the geometric information of the real deck shape is required. This information is not managed in an integrated and automatic way. On the creation of these drawings, directly executed over a graphic system, the time consumed is considerable and it is easy to comet errors.

This paper describes the drawing module included in the computer program refereed. The deck plan projections are obtained, in DXF format drawing files, using the geometric information obtained from 3D-deck model. Using the drawing module it is possible to generate the usual deck drawings required in bridge design process. Then, this module is a great support for the design process within its geometric design stage.

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1. The deck configuration

The surface shape of the deck can be seen as generated by one cross section that crosses the longitudinal direction. In that trajectory, the cross section configuration is modified in function of the two longitudinal morphologies:

- the morphologic evolution established by the bridge designer;
- the layout of the road, where the bridge is inserted, geometry that the deck must adapted.

The concept sweeping representation of the deck ([Anand,93], [Woodwark,86]) by means of a cross section shape that crosses a longitudinal trajectory, analytically defined, was implemented in a computer programme oriented to box girder decks [SampaioA,98]. This programme was developed in the ambit of the PhD thesis effectuated by the author [Sampaio,98].

1.1 The deck shape database

The deck geometric modelling programme allows the definition of the exact deck shape by the geometric description of the three morphologic components of deck configuration. A representative deck shape database is, then, created (Figure 1). This database allows the integration and automation of bridge design stages, based on the deck shape geometric information.

The programme generates cross sections along the deck, manipulating directly the data of the geometric database.

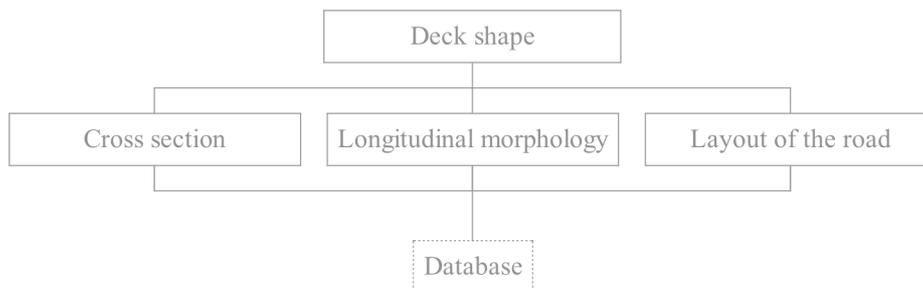


Figure 1: Creation of the deck shape database.

1.2 The deck geometric model

The longitudinal morphologic components referred act in simultaneous over an initial cross sections when it crosses the longitudinal direction of the deck. This is executed in two sequential phases:

The cross sections are generated along the deck only in function of the longitudinal analytical laws of variation established by the bridge designer. Those laws are refereed to the deck depth variation and to the flanges thickness variation (upper and low flanges and webs). In these phase it is admitted that the deck is straight and horizontal;

Then, each generated cross section is submitted to geometric transformations in its own support plan. Its forms are adapted to the required superwidth and superelevation in the kilometric point corresponding to the cross section

location. Later on, the cross section is transformed as a rigid body in order to be localised and oriented in correct way in a spatial trajectory defined by the horizontal and vertical alignments.

Then, the computer programme allows the creation of a geometric model of the deck formed by a series of consecutive cross sections, correctly defined in configuration and spatial position (Figure 2).

Each cross section is defined in vertices spatial co-ordinates format file.



Figure 2: Deck geometric model formed by a series of consecutive cross sections.

2. The drawing module

The drawing module, included in the computer programme, can allow automatically the deck drawings and the 3D face model usually required in bridge design. The geometric information of the cross section series, generated along the deck, is required.

The cross section data files of the are used on deck drawing elaboration. The drawing module manipulates directly the vertices co-ordinates of each cross section outlines, in order to obtain the required deck geometric models. Each representation type presents the deck shape in a particular way.

The drawing module creates the deck representation in DXF format file drawing [Jones,91]. It is, then, possible to visualise the respective drawing, when the file is inserted in compatible graphic systems (for instances the AutoCAD system [AutoCAD,97]).

3. DXF format

The DXF (Drawing eXchange Format) files were defined to allow the transference of drawings between AutoCAD and others CAD (Computer Added Design) systems or data process programmes. The graphic systems usually used have the capacity to generate and to interpret DXF files. The DXF format is an ASCII (American Standard Code for Information Interchange) text format, of easy interpretation by the user and others computational programmes.

A drawing file in DXF format can be defined in complete way, composed by four types of graphic characteristics, or it can be formed only with the graphic entities definition. When complete, the tree first sections define: the drawing ambience (HEADER SECTION); the layers characteristics, type lines, styles, etc. (TABLES SECTION) and the blocks definition eventually used in the drawing (BLOCKS SECTION). The entities definition of the drawing is include in the last file section, the ENTITIES SECTION.

Then is, exclusively, the last section that contains the information needed to visualise the representation include in the drawing file. The entities section

describes, in DXF format, all the graphic entities of the drawing. One entity can be a line, an arc, a polygonal line, a text, etc.

The drawing module creates deck 2D and 3D models defined in DXF format files composed, only, by the entities section. There are established schemes of execution of the specified models based on the selection of several entities that in conjunct define the refereed drawings. In each case the entities are concretised with the data include in the cross sections files needed on the execution of those models.

4. Algorithms of deck models automatic execution

Based on the observation of box girder deck drawings included in several bridge designs, was possible detect some uniformity on the presentation of the principal deck plan projections and deck 3D model. The common characteristics founded, are included on the definition of the programmed drawing-standard established for each representation type.

To execute a cross section representation, the cross sections transformed only by the incorporation of the superwidth and the superelevation, is needed; on the definition of the deck longitudinal section, over those cross sections is needed to impose the vertical alignment geometry.

The bridge is a structure that interferes on its landscape, having style and particular characteristics that must be in harmony with the local environment. Then, its appearance and insertion in the existent ambient must be considered of the aesthetic point of view, since the first design stage. The bridge is a 3D-structure and, then, the aesthetic conceits must be contemplated from any point of view.

One of the most used process to create deck 3D models, is to generate cross sections along a spatial longitudinal trajectory (defined with the horizontal and vertical alignments of the road geometry information), by interpolation between control cross sections, using B-Spline surfaces. The generated cross shapes are, however, approximation of the deck cross section shapes, its orientation is normal to the trajectory and only the exterior view is allowed.

With the drawing module, here presented, is possible to visualise the deck 3D shape, composed with cross sections of correct shape, location and orientation. The deck 3D model is formed by a sequence of plan surface elements (3DFACE). This model can be submitted in graphic system to a several realistic algorithms (faces and edges elimination and colour application), conferring the model a solid aspect.

4.1 Cross section representation

Next is described how to create the DXF file drawing of a cross section. As only the entities section forms the drawing file, the first data to put into the file drawing corresponds to the beginning of a section definition.

```
0
SECTION    the beginning of a section definition
2
ENTITIES   section identification
```

The DXF format of an entity has a constant structure. Only the numeric values are different between concrete cases. Then the drawing module has one

routine for each entity used in any programmed representation. The routine of an entity defines the geometric parameters with the numeric values and places this information, in the DXF format [Jones,91], into the drawing file.

To define the outlines of cross section the graphic entity used is polygonal line entity (POLYLINE, in AutoCAD [AutoCAD,97]). It was established that the outline of a cross section should be formed by four open polygonal lines defined with the vertices plan co-ordinates included in the respective cross section file.

The definition of each polygonal line in DXF format is placed in the drawing file by means of the respective routine. The DXF format of a POLYLINE is as follow [Jones,91]:

```

0
POLYLINE  entity identification
8
0          layer identification where the entity is located
66
1          vertices definition is following
70
0          definition of a open polygonal line
0
VERTEX    element identification
8
0          layer identification where the vertex is located
10
xp(1)    x co-ordinate value of the first vertex
20
yp(1)    y co-ordinate value of the first vertex
0
VERTEX
8
0
10
xp(2)    x co-ordinate value of the second vertex
20
yp(2)    y co-ordinate value of the second vertex
...
0
SEQEND    end of vertices definition
8
0          layer identification where the element is located

```

The x and y co-ordinates of each POLYLINE vertices were defined, in the routine, as variables $x_p()$ and $y_p()$. The co-ordinates of the cross section to represent assume in each case the values of the variables. The location order of the vertices in file indicates the vertices topology.

The definition of all graphic entities, that identifies the cross-section shape, is followed by the end section and the end file information.

Is possible now to visualise the cross section representation. For that, the drawing file in DXF format should be inserted into a compatible graphic system.

The module of cross-section drawing definition also places into the DXF file the definition of the symmetric symbol and inserts the kilometric location over the cross section representation (Figure 3). The LINE entity (of AutoCAD) represents the symmetric axe. The drawing module includes a routine with the definition of the entity LINE in DXF format [Jones,91]. The upper symmetric symbol is defined by two open polygonal lines composed with four vertices each one. The kilometric value (that locates the cross section into the road) is represented by the TEXT entity (of AutoCAD).

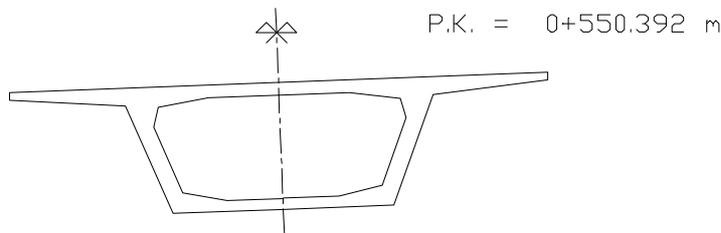


Figure 3: A cross section representation.

4.2 Longitudinal section

The longitudinal representation is another usual deck plan projection included in a bridge design. In the representation the longitudinal outlines are complemented with the information of cross section kilometric location, the elevation value related to the deck axe and the dimensions of the flanges thickness and deck height, in each cross section used to form the drawing (Figure. 4).

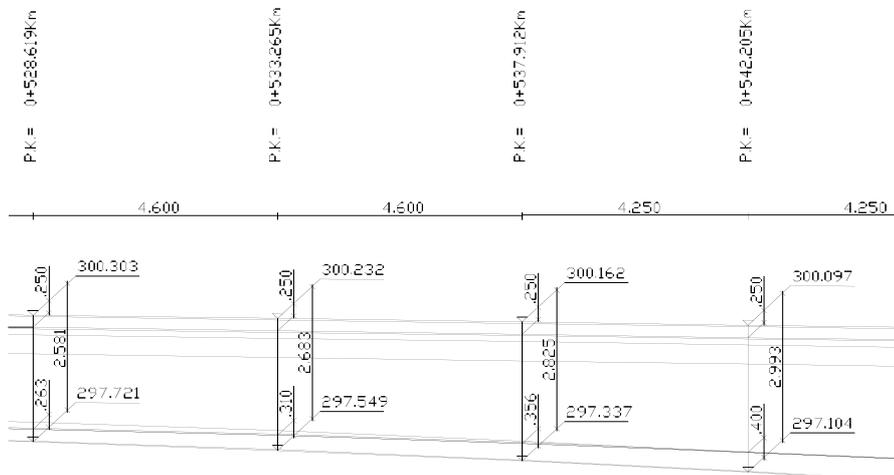


Figure 4: Longitudinal section detail.

The longitudinal representation drawing file includes two parts: the longitudinal outline definition and the text dimensions.

To create the deck longitudinal section, the deck must be submitted to a longitudinal section executed by a surface that contains the deck longitudinal axis and symmetric axes of each cross section (Figure 5a). Later on, that surface is planed in order to obtain the pretended plan projection. The longitudinal section is represented with the longitudinal edges resulting of the intersection of the deck with the section surface and with the longitudinal edges that is possible to visualise over the section surface.

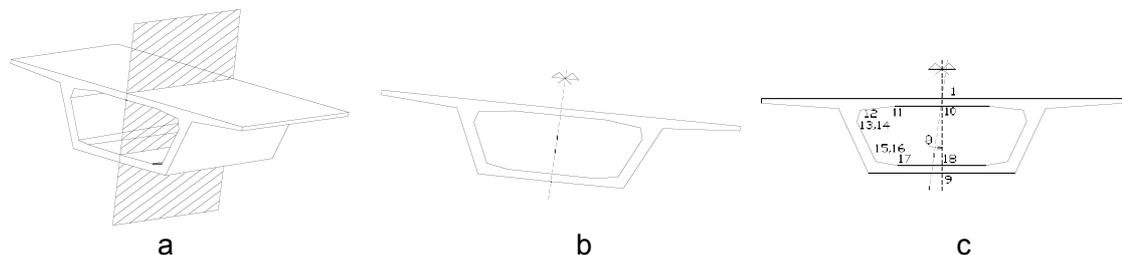


Figure 5: Process to obtain the longitudinal section of a deck segment.

The graphic entity used on longitudinal edge representation is, also, the polygonal line entity (POLYLINE). Each polygonal line is formed with the vertices in equal number of the cross section involved in the representation. The co-ordinates values included in the cross section files are used to define the required polygonal lines, in the DXF format.

The intersection zone is identified with its outlines detached from others lines of the drawing with different colours. In the DXF format of the used entities the group with the 62 code number (referred to the colour) is associated with distinct values for the definition of lines in intersection zone or lines visualised. In the definition of the longitudinal representation each cross section is represented by a LINE entity [AutoCAD,97], oriented in a vertical way. To put the text dimension in a drawing, include the definition of the dimension lines, the extension lines, dimension limits (donuts, arrows or oblique segments) and the dimension numeric value. The dimension values, included in the drawing represented in Figure 4, are calculated in function of the data of the respective cross section file.

4.3 3D surface model

Using the deck geometric modelling programme, several solutions and redefinition of the deck shape, can be visualised from any point of view and in a quickly way. Following the shape definition stage with a dynamic visualisation, anaesthetic forms can be avoided.

The graphic entity used to represent a plan surface is the 3DFACE entity (of AutoCAD [AutoCAD,97]). The co-ordinates of four vertices that define this entity must be in a spatial referential. The vertices sequence must follow a circular order. Two consecutive vertices, of equal number located in consecutive cross sections (Figure 6) limit each plan element 3DFACE.

Each entity, formed by four vertices, is included in sequential order in the drawing files, in DXF format [Jones,91].

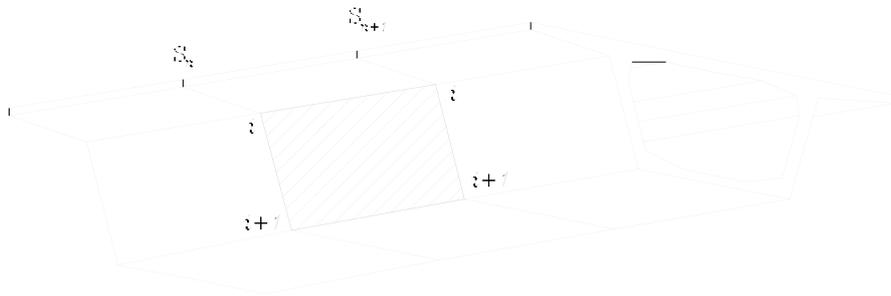


Figure 6: Definition of a 3DFACE entity between two consecutive cross section.

The model, defined with those plan elements, form two longitudinal tubular surfaces representing the exterior deck surface and the interior deck surface (Figure 7 a). It is necessary to define as surfaces the top cross sections in order to obtain a 3D model with a solid appearance (Figure 7 b).

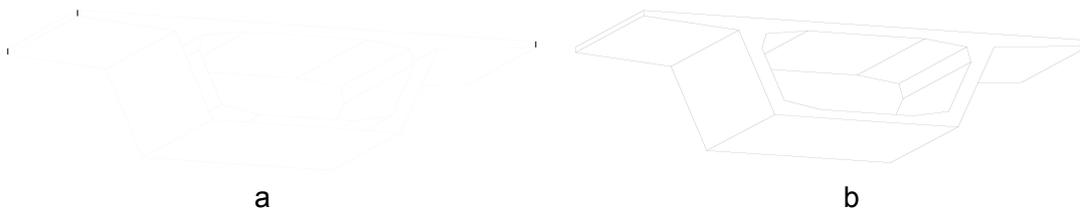


Figure 7: Deck segment 3D model without (a) and with (b) top cross sections defined as surfaces.

The 3DFACE entity also represents the top cross sections of the geometric model. Each surface is defined with an adequate triangulation formed by those plan elements. Defined both top cross sections as opaque surfaces, for any point of view established the created deck 3D model seems like a solid object, after insertion the respective DXF file into a compatible graphic system. The principal interest of this geometric model is, naturally, to allow the visualisation of the complete bridge with a real aspect. Generated the 3D model faces DXF file of the deck, using all the cross sections needed to the elaboration of all deck extension, it can be complemented in the graphic system, with other structural elements and bridge details (Figure 8). The abutments and the piles have usually specific shapes in each case.

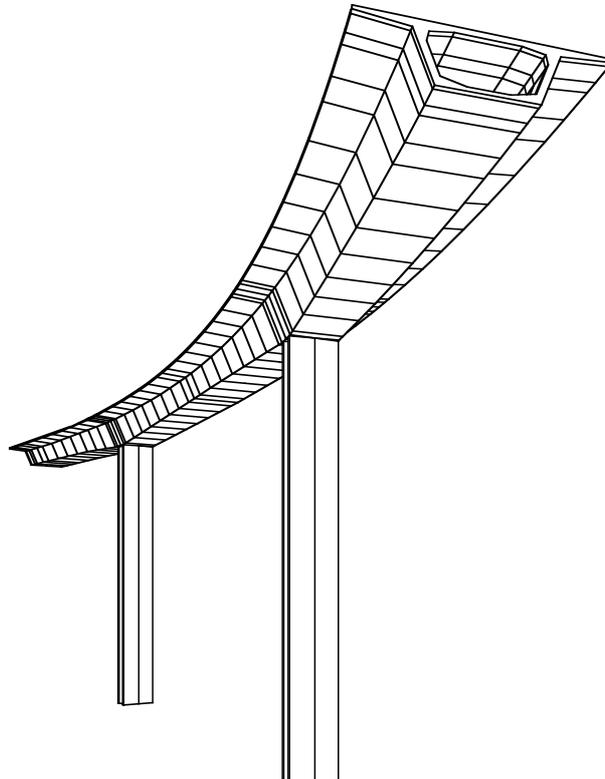


Figure 8: 3D face model of the deck and piles.

5. Conclusions

The purpose of this paper was to present the developed methodology to achieve the automation of the required deck models in a designed bridge. The algorithms presented use the graphic information related to cross sections generated along the deck with correct shape, location and orientation. With those algorithms is possible to create:

- deck cross sections representation;
- deck longitudinal section representation with the indication of dimensions, elevations and kilometric values;
- deck 3D face model

Using the deck geometric modelling programme (described in [SampaioA,98] and [Sampaio, 97]) is possible to obtain in a quickly and correct way the deck representation need in bridge design. With this programme is possible to reduce the time consumed in the execution of a bridge design. It is, then, a great contribution to the execution of the geometric stages included in a bridge design. It is also an incentive to do several iterations of the deck shape in an initial design stage, since the aesthetic aspect is a decisive factor on the selection of a solution for the deck configuration.

6. References

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