ROAD DESIGN WITH 3D SOFTWARE

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Abstract

In the current era of powerful computers and well-developed technical and engineering drawing software, road designing is slow and sure moving into the domain of 3D computer graphics. This paper considers the basic concepts of road design with this type of software. In addition to the design concept we would like to mention the key advantages and disadvantages of this type of work.
Concept:
· Design development procedure remains conventional: alignment of the route and of the level line and definition of standard cross section
· With the aid of the computer the standard cross section becomes a dynamic object that can be logically adjusted to the given situation (cutting, embankment, position with respect to the level line, etc.)
· Based on input parameters (route, level line and standard cross section) the computer is dynamically developing the 3D road structure and from this corridor generates all the 3D planes required.
· Change of any element of designed road results in a dynamic update of other parameters (screwing (warping) change generates changes on the 3D corridor and cross sections)
· This significantly simplifies and accelerates the work of design engineers, which mostly comes down to the proper alignment of the centre line and level line of the road. The rest is up to the computer.

Keywords: road design, computer graphics, 3D modelling

1 Historical Background

Road design is an old engineering activity and is mostly reduced to route alignment, level line determination and definition of normal cross section. These three components have always represented the basis of this work, and the implementation method has to date developed in several phases.
Drawing Accessories: Various drawing accessories have been used, including triangles, T-squares, pair of compasses and French curve (both circular and chlotoide). Such method of work was not only slow, but its preciseness was questionable, as a great deal depended on the good eyesight of the designer. All necessary point coordinates have been provided from respective tables.
Drawing Accessories combined with computer: As soon as the first personal computers (PCs) were introduced, they have been used for computing purposes in road design. Specifically, the points of individual road elements have been entered into the software as input data, and the output were the detailed coordinates of all route and level line elements. Based on this information the route and the level line were then drawn manually.
Computer Aided Design: This was actually the most significant step in the use of computer for designing. Computer now did all the tasks that were previously done manually. Drawing

accessories became redundant. Everything was displayed on the screen in front of the design engineer. Computers not only conducted all necessary calculations, but they also completed plan view drawings, longitudinal profiles and cross sections and prepared them for plotting. Cross sections were generated based on the code programmed by the design engineer and the entire process was accelerated, allowing the design engineer to take his/her time to provide optimal route alignment and level line definition. This phase is still in application nowadays.

3D modelling: In the present age of powerful computers and highly sophisticated software for technical and engineering drawing, road design is slowly but steadily entering the domain of 3D computer graphics. As opposed to the previous phase, the 3D modelling method includes a continuous work with the 3D construct of the entire route. All elements of the route, of level line and of cross sections are permanently and inseparably connected, so that any changes of one segment will automatically affect other segments. This method of work allows the design engineer the insight into the realistic situation of the future road, so that the problems can be identified realistically. So, the topic of this presentation is 3D modelling in road design.

2 3D modelling

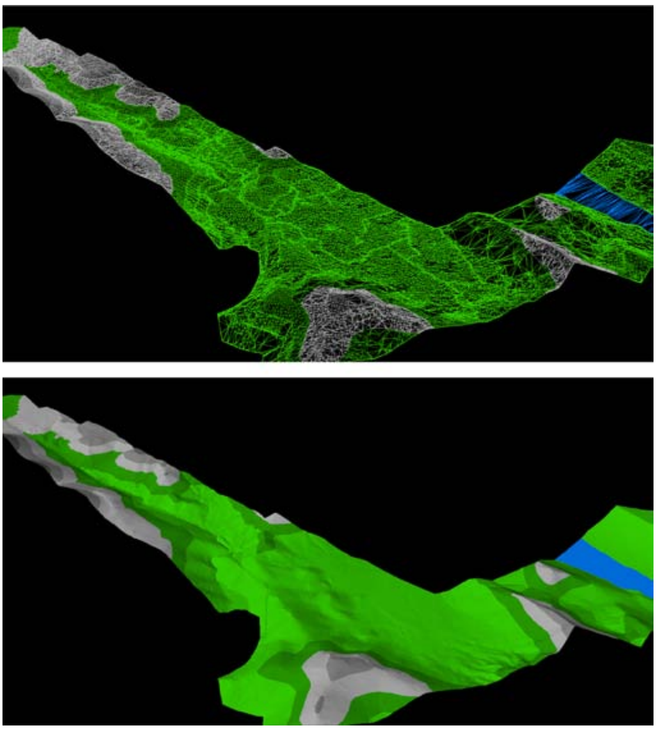

Figure 1 3D terrain model

We have already mentioned that this method of work is the cutting edge of designing. It goes without saying that the designer must get acquainted with this method in order to use it. As 3D modelling is still not as represented in the design practice as it should be, we will try to make our presentation as relevant as possible, hoping to additionally motivate the engineers to use this method.

We will take you through all aspects of work with the conceptual review of the work process.

2.1 Creating 3D Terrain Models

The only supporting data for design is the 3D terrain model, created through the design application based on the input data. The input data may be points, break lines or contour lines. It should be mentioned that each and every input data must be defined by all three spatial coordinates (X, Y, Z). The model is generated by placing a large number of triangular planes that connect the input data in all three dimensions. Such a model may be subsequently altered. An example of the 3D terrain model generated in this way is shown in the Figure 1.

2.2 Route Alignment

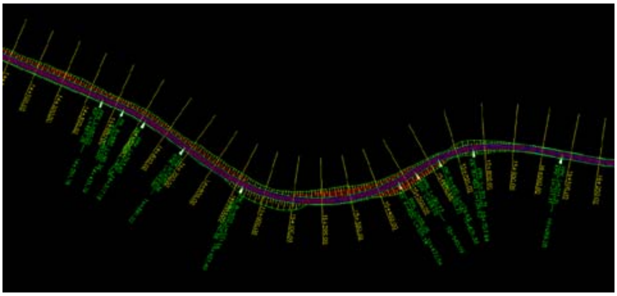

Figure 2 Route alignment

To the previously generated 3D terrain model the route of the road is aligned using standard alignment elements (straight lines, circular curves, transition curves) and their respective combinations. The designing application may warn us if some of the chosen elements are not allowed, for instance, if the curve radius is too small or if the transition curve is too small for the specified computed speed. Once the route is aligned, it can be re-aligned and altered at any time. All changes are accepted and transferred to other road defining elements (level line, cross section). In addition to these controls, the application automatically defines any necessary widening in curves and screwing for a given centre line of the road.

2.3 Level Line Design

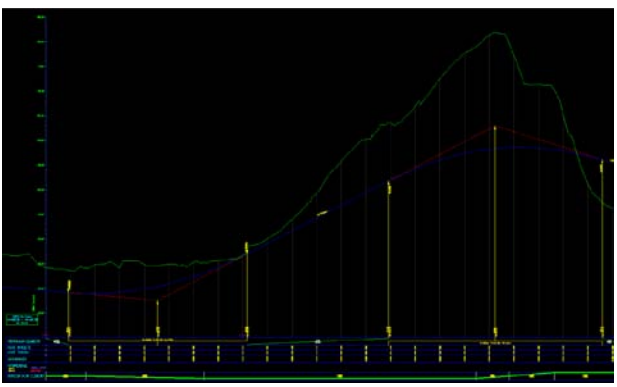

Figure 3 Level line design

Basically very similar to route design. The elements of tangents and vertical curves are applied to the previously developed tentative longitudinal profile containing the longitudinal section of the 3D terrain model along the centre line of the road. The application checks whether the chosen elements are within the allowed scope and provides the respective information to the design engineer. In addition to the cross section of the terrain, it is possible to display the level line of some other centre lines as the projection to the current level line. This option is especially interesting when the pavement connections with various centre lines are defined (grade-separated junctions, at-grade intersections).

2.4 Defining Normal Cross Sections

This particular phase has always been a challenge to design engineers. The purpose of normal cross section is to provide the best possible definition of all possible scenarios that can occur in defining the 3D road model. It is also possible that several different normal cross sections are applied on individual segments of one route.
Such normal cross sections can be defined by programming the profile elements, taking into account the logics of behaviour in various conditions (embankment, excavation...) or the profiles can be aligned over the so-called intelligent blocks. Each of these blocks represents one segment of the normal cross section (pavement, shoulder, slope) and is acting accordingly (the shoulder changes the fall and the width, the pavement is changing the width and the courses, the slope is defined as either embankment or cut). Proper material types are assigned to such blocks, so that subsequently the quantities may be calculated. The precision of 3D model defining increases proportionately with the skills of the design engineer and with the number and elaboration level of these intelligent blocks.

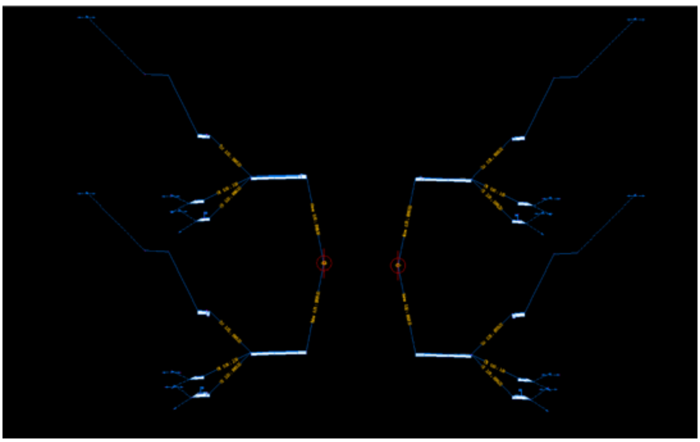

Figure 4 Defining The Normal Cross Section

2.5 Creating the 3D Road Model

Based on the previously defined parameters of route, level line and normal cross sections the computer is generating a 3D road model in interaction with the 3D terrain model. This procedure requires a high computing power and the computers today have such power. The result is the generation of all necessary 3D lines and planes that describe all parts of the road in any chosen point in space. This type of model may also be manually altered in case that some segments could not have been properly described through the logics of normal cross sections. From such model all necessary material quantities for construction may be deducted, as well as all cross sections necessary for roadway stakeout.

If there are any changes in parameters defining the 3D road model, the application will give the respective warning and automatically refresh such 3D model.

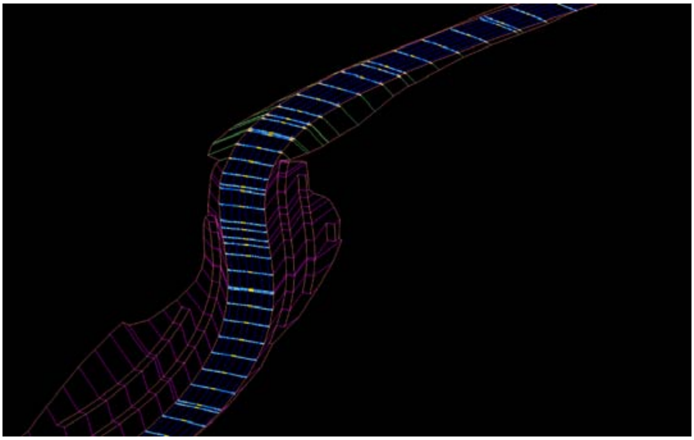

Figure 5 3D Road Model

2.6 Output Data

The so generated 3D road model can at any time provide all necessary output data for development of the design, as well as all the data required for precise stakeout of the facility. These data include precise cross profiles in all chainages of the centre line, the coordinates of any point in the roadbed, the exact quantities of specific road sections necessary for the Bill of Quantities, as well as many other data resulting from the 3D model.
One of the interesting outputs is certainly the visual presentation of the route, i.e. the realistic 3D presentation of the situation after the construction of the road in question. It is precisely the output that other designing methods cannot provide, and in the present era of comprehensive visualisation such realistic model becomes crucial.

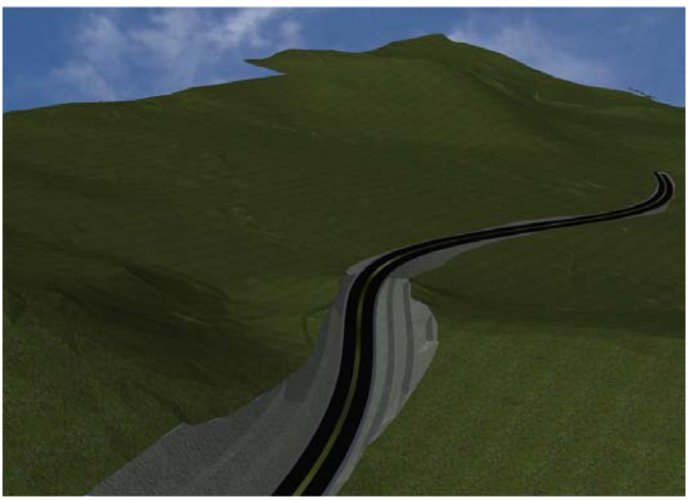

Figure 6 3D Realistic Model

3 Features of The Method

At the end of this presentation we should mention some positive and negative features – Pros and Cons - of this method.

Pros:

- Once the concept of working with computer is mastered, the work is significantly accelerated.
- The “human factor” errors are avoided in the process of calculating the cross sections and – more important – of calculating the material quantities.
- The design engineer needs not check whether an entered change has been applied to lower levels.
- The generation of all necessary drawings (layouts, longitudinal and cross profiles) and of numerical lists (axis calculation, list of quantities) is almost fully automated and the design engineer does not waste time preparing or checking such documents.
- Finalisation of drawings before they are inserted into the design is much less time- and work-consuming.

Cons:

- Design engineer will need a certain period of time to get accustomed with this method of work.
- Despite the fact that the modern computers are powerful, this type of software is still facing challenges in some more complex issues of designing, especially in terms of the speed of data processing.
- When defining the logics of generating cross sections, in some cases the design engineer must know one of the programming languages (e.g. VisualBasic or c).