THE USE OF COMPUTERS IN DESIGN AND CONSTRUCTION OF KENTUCKY HIGHWAYS

by

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Some 8 years ago, when the Kentucky Department of Highways was getting ready to enter the computer and photogrammetry field, you may have heard a talk describing how the Department would make a flight over the proposed corridor, feed the pictures from this flight into auxiliary equipment connected with the computer, from which a set of finished plans would be produced. Needless to say, this did not happen, but, it was no more far-fetched than the Buck Rogers comic strip was thirty years ago, and, today most of us have seen on television an astronaut doing many of the things depicted in the Buck Rogers cartoons. However, today I am to tell you of the services that are available to you now from the Electronic Computer Section and Bridge Division. These services have been in operation for several years. Many of you have availed yourself of some of these programs; however, it is believed that very few of you are familiar with all of them.

We have many programs that might be referred to as satellite programs. These print and edit data, reduce cross section notes, reduce and compile traffic counts, compute the pounds of reinforcing steel per structure, classify soils, and handle other data of this type; however, we have some dozen programs that furnish the main output for highway design. For description purposes, these will be divided into Structural and Roadway Design.

Under the Structural Group, we have an Analysis of Continuous Beams for Highway Bridges. This program computes the moments, shears, reactions and deflections produced by each type of dead load and the maximum for these values imposed by the live loads for steel, concrete or composite type continuous bridges from two to five spans in length.

The second program evaluates reinforced concrete beam sections. This program computes the location of the neutral axis, the moment of inertia, and the resisting moments of RC beam, either T or rectangular in section. This is used in designing either simple or continuous RC beams.

The next program provides Analysis of Eccentrically Loaded RC Column Sections. It determines the maximum concrete and steel stresses imposed on a RC column section by an eccentric loading condition. The column section may be rectangular, circular or irregular in shape. The general flexure formula is used to solve successive iterations until the neutral axis is located, then the stresses are computed.

The fourth structural program Composite Beam Design, is used to compute the steel girder size and other factors needed to complete the design of a simple span composite beam of steel and concrete.

The last program of this group is the Retrieval of Structural and Quantities Data. This provides conveniently indexed listings of engineering design decisions and pertinent structural and quantities data. This enables the Bridge Division to more fully utilize the inherent values of the files of completed plans and provides a data base and procedures for producing periodic reports, evaluations and estimates.

First under the Roadway Design is the Traverse Program that will compute a closed traverse or an open traverse that is tied into the State Coordinate System. This program will accept distances and bearings, or a beginning azimuth with distances and deflections. After computing the traverse, the program determines the error of closure and adjusts this error by the compass rule and recomputes the traverse with these adjusted values. It will compute the average traverse by the time you look up the trigonometric functions of the first course's bearing. This program can be used to advantage for centerline survey on major projects or for the determination of areas in land acquisition.

The second of these programs is for the purpose of providing for perfect geometric closure for a ramp or a loop of an interchange-type intersection. To obtain the maximum benefit from this program, the designer should draw the proposed intersection as accurately as possible, defining the degree of curvature and the length of the curves and tangents for all but three contiguous parts of the ramp or loop. These three unknown parts may be three curves, two curves with a tangent in the middle, or on either end, or a curve with a tangent on each end. The designer defines the amount of curvature by specifying either the degree of curvature or the length of the radius. The computer program will determine the three unknown parts to provide for perfect geometric closure. We have experienced no trouble with this program because of the requirement of having three unknown parts; however, it is sometimes necessary on a simple diamond-type interchange to use a dummy part in order to obtain the three contiguous unknown parts. The reason for using three unknowns is that there is one, and only one, solution that will meet these requirements. The ramps and loops may take off or join the two highways at any distance offset to the right or to the left, thus providing for directional-type ramps. They may also take off and join at any angle from one second to 90 degrees. This program may be used to calculate the exits and entrances to roadside parks, truck weighing stations and other facilities of this type by providing a dummy crossroad at some convenient station. The output from this program supplies the coordinates at all points where there is a change of alignment and at the center and PI's of all curves. It also prints out the length and bearings of the tangents, the curve's degree of curvature, length, radius, tangent, external distance and central angle. It is possible, if one of the intersecting highways is a tangent, to set its bearing equal to true north and, in this solution, all of the coordinates for the complete interchange would be offset distances from this north-south line and axis perpendicular to it. This, in some cases, should be of considerable value to the field people when they lay out the interchange.

The third of these programs is for the computation of profile grade. The input is the station and elevation of the Vertical PI and the length of the associated vertical curve. The output is the elevation at any desired station interval, plus any special stations, and the percent grade carried to four decimal places. This program, as originally written, was not designed to handle non-symmetrical vertical curves; however, this problem is much easier to program than the handling of line equations, which may occur at any point along the vertical curve. The output from this program is used as input to the fourth of our major programs, that of Template Generation.

In addition to the grade values, the horizontal curve information, including curve widening - as desired - is used as input to this program. The output is a record on magnetic tape defining the template at each station, with up to 17 sets of X and Y coordinates. The number 17 was selected to properly identify a roadbed similar to that of the Interstate where trenching is used. Actually, this part of our major programs consists of some half-dozen separate programs. One for Federal Aid projects with low class surfacing; one for two-lane with or without truck lanes; one for 4-lane, depressed median; and one for non-uniform median Interstate and one for standard 60' depressed median Interstate. This tape and cards containing the cross section and another set of cards containing the rock information are used as the input to the fifth program, that of Earthwork.

This program classifies the rock excavations from the earth and punches into cards these quantities, together with the embankment quantities, the slopes and the accumulated quantities adjusted for shrinkage and swell, for each station. At the same time, the printer produces a copy showing the section output, which includes the elevations and distances to the slope stake points, the rock intercept points, the ditch and shoulder points and the finished grade elevation. This program will provide for a widened ditch where pre-splitting is used, one bench in the rock at any pre-determined elevation and an overburden bench. After the top of the cuts and the toe of the fills have been determined, the limits of the right of way are sufficiently defined that the area of each tract may be computed by two programs. One of these accepts the highway alignment described as a series of tangents, spirals (if used) and curves. The coordinates of these break points are computed, either using the State Coordinate System or one of your own choosing. Each area that is to be computed is described as station points of with offsets from station along the centerline. Depending on the input, the output from this program consists of the coordinates of all the points defining a piece of property. This output is used as the input to a second program that performs an inversion of these coordinates, thus supplying the course lengths, bearings, and area. This program can store in the computer memory, the length, bearings and coordinates for any course and these can be recalled for later use in computing other adjacent courses. The stored bearing can be rotated in either direction for 0 to 180 degrees. This program will also compute a closed traverse or an open traverse that is tied into the State Coordinate System. It will compute any two unknowns in a traverse of this type. These two unknowns may be the length of bearing of one course, the length of one course and the bearing of another course, the length of two courses, or the bearing of two courses. Some of these have two solutions, and, in general, which one you use will be left to your decision. It should be noted that in a computation of this type, that the program assumes all the data furnished is correct and if this is not true, all the errors will appear in the missing parts. Under some conditions, this might prove embarrasing.

The use of the computer and associated equipment on some projects may cost more than it would to do the same work by conventional means; however, if the data is correct, it is possible to make many trials with the computer and thus obtain the optium in design, whereas, it is doubtful in the use of the conventional method if many of you will erase or destroy your first template and make additional trials until you obtain perfect balance.

In addition to these main programs for design, we have several of the major type programs that should be of use - especially during the construction period - for Interstate projects. The first of these programs is that of Bridge Elevations. This produces a complete grid system of elevations that are required for the construction control of bridge beams and slabs. The table of elevations is machine printed on the bridge plans.

The second of these programs provides Circular Curve Offsets. This program computes offsets for the construction of bridge curbs on curved bridges.

The third of these - the so-called Blue Top Program - uses the grade elevations and the horizontal curve data, together with template identification to provide an output showing the elevation and distance from centerline of the break points for construction of the grade and drain.

The fourth program, using practically the same input, furnishes the finished elevations for each edge and the centerline of the Interstate pavement.

The last of these programs, when furnished the original cross sections and the final cross sections, will compute the excavation that has been performed by the contractor. This output requires manual corrections for excess breakage, undercutting and some channel changes, if provision is not made for them in the final cross sections.

From our viewpoint, none of the programs I have discussed today are perfect. In fact, it is almost impossible to anticipate all the contingencies that will arise when these programs are first written. Most of them have been modified, improved, and in general, have had many additions. We appreciate any criticisms that point out the weaknesses of these programs and look forward to any suggested methods that may be used to improve them. All but the most simple programs have a certain format for the input data. It is absolutely essential that the data be in this form. I wish to stress that any mistakes you find are due to the input data or to an oversight on the part of the programmer or operator. In other words, the computer, when supplied with the correct program data will give us a very, very reliable answer.

Computers have been used in the highway industry during the last decade. I am convinced that within the next generation, the more progressive highway departments will be designing their highways, not by pushing one or two buttons, but by pushing many buttons. The old methods that we know today will practically all disappear and the description given in the talk mentioned at the beginning of this paper of the method the department would use to produce plans, will, in effect, be in operation.

The programs that have been described are for your use now and if you are not able to take advantage of some of these, it is probably already past time when you should tell your boss that you wish to retire. Whether you do or do not use these programs in the immediate future will not affect the technological revolution in the highway industry very much. The students in our major high schools and on our college and university campuses are working with these computers (There are 4 computers on this campus) and they regard them much as you and I, of the first and second generation back did the slide rule and the calculating machine - a most useful and necessary tool.