Design Studies
Indiana Toll Road

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“Design Studies” for the Indiana Toll Road will be in progress during the Engineering Report stage and also at the beginning of the construction stage during the period of preparing plans for construction purposes. At the present time, “Design Studies” for the Engineering Report are just beginning, so that discussions on specific problems would be premature. For that reason, this discussion will be confined to “Design Studies” of a general nature, and will not include specific problems.

Design studies, of a general nature, necessary in the preliminary stage of the Toll Road development, can be grouped under four headings as follows:

1. Selection of a route. The selection of a route, will be in sufficient detail to serve as the basis of a sound Engineering Report.

2. Geologic and Soil Studies. These studies, in the preliminary stage, will not include all such studies necessary for the construction of the Toll Road, but, will be in sufficient detail for the Engineering report.

3. Design Criteria or Design Standards. These studies, in the Engineering Report stage, will be in considerable detail, as they will be the standards which will control the Engineering Estimate, and will govern the preparation of construction plans.

4. Facilities for Maintenance and Operation. Studies that will be made during the Report Stage for Maintenance and Operation Facilities, will be in sufficient detail to describe what will be necessary for Operating the Toll Roads and will form a basis for further detailed planning during the preparation of construction plans.

SELECTION OF ROUTE

The initial step in the selection of a route for the Indiana Toll Road will be done in close cooperation with the Traffic Engineers. They will fix the extent over which location studies will be made, and
from a traffic service standpoint, will fix the direction and general location of the Toll Road. Traffic generators and the termini of the road, one of which is the Ohio Turnpike, together with topographic features, such as river crossings, railroad crossings and the necessity for interchanging traffic with existing and proposed state highways will more closely delineate the route.

At this stage in the route selection, it will be necessary to study various locations to avoid adverse topographic features and towns, and to compare construction costs of the various locations, with estimates of traffic service and revenue, so as to determine the most economical location. It may well turn out that routes having relatively high construction costs with high traffic potentials, and consequently high revenues, are more economical than routes having lower construction cost with low traffic potentials, which will produce low revenues. It can readily be seen that economics play a big part in route selection.

After this stage in the studies, the route location will have been narrowed down to a band about one mile wide. Aerial photographs will be taken, covering the mile wide band, and the location can be further refined and traced on the photographs. Where existing aerial photography is available, it may be used, but more often it is desirable and economical to fly special photography for the project. This permits control over the flight line layout, the camera focal length, photo scale, the season of the year best suited for photography, horizontal control, and other factors. After the photography has been obtained, field reconnaissance to study structure sites, interchange locations, and other topographic features, will be made to refine the location. The line traced on the photographs, will make a band about 2,000 feet wide. From this photography, photogrammetric maps covering the 2,000 foot band will be plotted to a scale of 1 inch to 200 feet, and with contour intervals of 5 feet. Over much of the northern part of Indiana, where the terrain is very flat, 5 foot contour intervals will have little or no significance. In these instances, special photography will be taken so that maps can be plotted with spot elevations along the drainage canals and at other significant locations. These photogrammetric maps will be used to further pin-point and develop the Toll Road Route.

GEOLOGIC AND SOIL STUDIES

After the route has been delineated within a 2,000 foot band, contact prints of the aerial photographs will be made to serve as a basis on which to record all pertinent soil and geologic data. All available information in the form of Agricultural Soil Maps, Engineering Soils
Maps, Geological Survey Maps and related information, will be collected and reviewed for pertinent data to be used in the Design Studies.

I would like to take this opportunity to express our sincere appreciation of the cooperation and courtesy shown us by Professor Woods. Professor Woods, and his department, have done a magnificent piece of work of assembling and correlating geologic and soils information and publishing it in the form of engineering soils maps. This information has been made available to us, and it will be of great value for the design studies and construction of the Indiana Toll Road.

With continuous stereoscopic study of the photographs as the soils data are recorded on them, the variation of pattern of the soil types will become apparent. Concurrently, pertinent geologic data, such as sand and gravel pits and other information of engineering importance, will be marked on the photographs. The character of the drainage and erosion patterns in the different soils areas will be studied, and a preliminary estimate of drainage problems will be possible. With the recognition of recurring land forms, such as swamp areas, muck and peat deposits, kames, eskars, former shorelines and lakebeds of glacial lakes, and moraine and outwash deposits, certain tentative conclusions can be made. For example, opinions can be formed regarding drainage and probable subgrade conditions, and likely sources of granular materials for construction purposes. Many topographic features such as possible peat and muck deposits, or marsh areas can be marked for field check. Those areas where field examination and sampling most likely will be required, can also be marked.

After all available information has been recorded on the photographs, the reference data and photographs will be taken into the field for verification and direct examination of all features previously marked for examination. A limited number of soil samples will be taken from each horizon of the several soil types traversed by the route selected for the Toll Road. These samples will be taken to a laboratory for testing and engineering classification. The soil samples will be obtained by hand auger borings in the areas where cuts and fills will be light and at this time the ground water elevations will be recorded. The larger muck and peat deposits will be sounded, to determine the depth to a firm bottom, for estimating purposes. During the construction stage while construction plans are being prepared, a more detailed study of soils and foundations will be made. At this time rig borings will be taken at all structure sites, and in areas where the cuts and fills may require subsurface explorations that cannot be readily made by hand auger methods.

Examination of the performance of existing pavements, as they
appear to be related to the various horizons in the soil profile, may lead to the determination that in certain soil areas, materials should be removed for a depth of several feet below the pavement, and be replaced with a suitable material.

The terrain data thus collected will be used for the preliminary design which will form the basis of the cost estimated accompanying the Engineering Report, and also, for the final design prepared during the construction stage.

One final advantage of the use of aerial photographs, for terrain studies, bears mention. Under the stereoscope, a pair of annotated photographs becomes, in effect, an approximate scale model of the terrain which has been studied in the field. They serve to refresh the memory on endless points of detail, and can furnish a wealth of data which could not be covered by the most voluminous field notes, or any conceivable type of map.

DESIGN CRITERIA OR DESIGN STANDARDS

The design criteria or design standards, which will be set up for the Indiana Toll Road, can be visualized as a list of rules or specifications, establishing minimum requirements to be met in preparing preliminary and final designs for the highway. Design criteria can be put into three classes, those for the roadway, those for structures and appurtenances, and those for drainage, and will form the basis upon which the estimate of construction costs in the Engineering Report will be made. They will cover conditions that are associated only with toll roads. The underlying objective in the formulation of the design criteria, is to build a facility that will provide safe, rapid, uninterrupted, and comfortable means of traveling under all weather conditions; by individuals who are willing to pay a toll for this service. In the development of this criteria consideration will be given to certain features that will minimize maintenance problems.

ROADWAY

Toll roads and expressways have been developed on the basis of safety features designed to make these highways as safe as possible, engineering wise. These safety features are:

1. The separation of grades at all cross traffic intersections.
2. Limiting access to the super highway, to specifically designated points where facilities are constructed to afford an interchange of traffic between the toll road and other important highways.
3. The elimination of left-hand turning movements at points of ingress and egress.

4. Separation of the traffic moving in opposite directions by a medial divider.

5. The use of long sight distances and the elimination of sharp horizontal curves.

Highways constructed with all of these features have proven to be safer highways than those constructed without them, or with only some of them. The degree of safety of a super highway which has all of these features, depends upon the standards adopted to control these features.

In the selection of a typical cross section, attention will be given to economy, appearance, safety and maintenance operations. Basic lane widths of twelve feet, together with shoulders of adequate width for emergency use, will be provided. Gutters or side ditches will be provided to remove quickly storm water from the roadway. The treatment of type of medial divider will be studied from the standpoint of drainage, storage for snow removal, other maintenance operations and safety.

The selection of a wide medial divider, has advantages worthy of mention. It suggests the possibility of fitting the highway more closely to the surrounding terrain, by using separate grade lines for opposing lanes of traffic. It makes it possible to design for steeper descending grades than ascending grades, where this procedure may prove economical. For a highway like the Indiana Toll Road, descending grades should be no steeper than four percent, and ascending grades should be limited to two percent.

In selecting standards for the control of horizontal and vertical alignment of the highway, particular attention must be given to the possibility of rear-end collisions and the easy negotiation of curves at high speeds. At present, it is the practice to provide clear sight distances such that a driver may see a four inch high object on the road a sufficient distance ahead that he may come to a complete stop, at a comfortable rate of deceleration, before reaching the object. The sight distances required for this depends on several variables, one of them is the speed at which the driver is traveling. The speed selected to govern this minimum requirement is designated as the design speed, and for existing turnpikes the design speed varies from 70 to 80 miles per hour, which is from 20 to 30 percent faster than the average person drives. This has been done to make the road comfortable for the average driver, and safe for those drivers who drive faster than the ma-
The majority of people. A design speed, therefore, should be selected which is expected to be from 20 to 30 percent faster than the average driver is expected to travel, but it should not be so fast as to invite disaster.

The selection of the design speed for the highway, also, sets one of the standards for horizontal alignment. The design speed, together with permissible rates of superelevation and allowable tire friction factors, determines the sharpest curves that can be used. It has become standard practice except where severe winters occur to set the maximum rate of superelevation at 10 percent. It is not unusual, in some localities where winters are severe, to set the maximum rate of superelevation as low as 5 percent, on the theory that vehicles stalled on curves under icy conditions, or slowly moving vehicles negotiating curves on a grade under icy conditions, would not slide toward the inside of the curve. Another approach to this problem, is to limit the superelevation on curves, to such a rate that it will just balance the centrifugal force of the vehicle at a speed of 45 to 50 miles per hour, thus reducing the likelihood of moving vehicles skidding under icy conditions. Also, to limit the resulting tire friction factor on vehicles traveling at the design speed, so that it will not exceed 0.10. With these limitations in mind, satisfactory rates of superelevation may be established for various degrees of curvature, and the maximum degree of curvature permitted for the design speed, can be readily determined.

Another criterion for alignment that is desirable from an esthetic point of view, is to establish a desirable minimum length for curves, so that they will not appear merely as kinks in the highway. The desirable minimum length of curves that has been set for other toll roads, including transitions, is 1,000 feet. Also a desirable minimum distance of 2,500 feet between curves in the same direction, has been used on other roads.

Minimum radius curves should be used at all interchanges that are consistent with a design speed of from 20 to 30 miles per hour. The basic lane width of 12 feet will require widening in the sharp curves, so that trucks will be able to stay on the paved surfaces while traveling at the design speed for the interchange.

Maximum upgrades of 4 percent and maximum downgrades of 5 percent, with superelevation limited to 8 percent, is desirable on all interchange ramps. In order to preserve safe, comfortable, riding qualities on the interchange ramps, it is desirable to limit the rate of change of cross slope in the pavement so as not to exceed 2 percent per second of time for the appropriate design speed.

At all interchanges, and at all other points of ingress and egress from the toll road, acceleration and deceleration lanes of sufficient
length to permit acceleration to and deceleration from the toll road design speed, should be provided. For a design speed of 70 miles per hour, lengths of 1,200 feet and 1,050 feet respectively, will be sufficient. For higher design speeds these lengths should be adjusted proportionately.

**STRUCTURES**

Horizontal and vertical clearances for structures crossing over the toll road should be such that they will not present hazards to the motorist, either mental or actual. On highways with narrow medial dividers, consideration should be given to spanning both lanes of opposing traffic without using a central support. Where the medial divider is wide, central supports may be used but consideration should be given to maintaining a clear distance between the edge of the pavement and the face of the supports of at least twelve feet. Where abutments and piers are placed closer than this to the edge of the roadway, mental hazards are introduced. Vertical underclearances of 15 feet have become standard practice.

The curb to curb width for structures, which carry the toll road over streams and other roads, should be consistent with safe practice. For short structures, consideration should be given to carrying the shoulder width across the structure so as not to introduce a mental hazard. For long structures, the shoulder width may be reduced safely, without introducing a mental hazard. The reduction of shoulder width on long structures has proven to be proper and is dictated by economical considerations. The amount of reduction in shoulder width will vary with the length of the structure, but the minimum width from curb to curb for long bridges should be not less than 30 feet for two lanes of traffic.

**PAVEMENT AND APPURTENANCES**

Other criteria or standards that will be established in the preliminary stage, is the type of pavements and shoulders to be used, as well as the selection of appurtenances, such as striping to delineate traffic lanes, standards for guard rails, reflectorized delineators, and types of curbs to be used at interchanges and toll plazas, and also regulatory and directional signs.

Several types of pavements and shoulders that will adequately support the traffic loads to which they are to be subjected, will be designed and studied. In the study of pavements consideration will be given to the effect of climate, soil conditions, and the availability of construction materials, as well as the economical construction cost
of each type. Consideration will be given to the durability of the various types of pavements, as well as safety aspects.

**DRAINAGE**

Drainage of a major highway such as the Indiana Toll Road must be provided so as to insure safe driving conditions at all times. The dangers to high speed traffic resulting from ponded water, eroded materials washed on to the roadway and shoulders, washouts and settlements due to erosion at culverts and bridges and other unsafe or hazardous conditions resulting from inadequate drainage must be guarded against for all conditions of storms and floods. Moreover, the toll road must continue to provide uninterrupted service at times when local highways may be obstructed at various locations by high water or washouts.

A complete system of highway drainage provides for the collection and disposal of all surface water from the highway itself as well as the surface water from the surrounding terrain that may affect the highway. It also provides for the collection and disposal of ground water that may contribute to unstable foundations for the roadway, or embankments, and that may cause landslides in cut sections, or hillside sections, and also that may contribute to damage of pavements by the action of freezing and thawing or by frost heaving.

Surface drainage for a major highway falls into several general classifications, each of which is considered separately in the design of the drainage system. These general classifications are: (1) roadway surface drainage; (2) minor streams and small drainage areas having watersheds less than 400 acres; and, (3) major streams and drainage areas having watersheds of 400 acres or more.

Roadway surface drainage comprises the collection and disposal of all surface water that may fall within the limits of the roadway and its slopes, or that may reach the system of gutters, ditches or storm sewers. Inlets should be spaced so as to control the amount of water that flows to the drainage system from the surrounding terrain. The spacing of inlets is also dependent upon the capacity of the gutters and ditches to carry the water without flooding or eroding. Consideration should be given to the depth of water to be permitted in the drainage ditches, the economical protection against erosion, and the desirability of quickly removing the surface water from the highway. Through long cut sections, longitudinal sewers will be necessary to collect and carry storm water to a suitable outlet. In order to provide adequate capacity for the roadway drainage systems, storm sewers should be designed for a rainfall frequency of 25 years with a maxi-
mum surcharge not higher than the bottom of the inlet grate, and also for a rainfall frequency of 10 years with the pipe flowing full with no surcharge. Storm sewers, serving depressed areas where ponding is likely to occur, such as at low points in vertical curves, should be designed for a rainfall frequency of 100 years, with a maximum surcharge not higher than the bottom of the inlet grates. Ditches and gutters should be designed with sufficient capacity for a 10 year frequency rainfall, and when inlets are required in the shoulder ditches they should be spaced so that the flow of water will be kept well below the edge of the shoulders.

Minor streams and small drainage areas comprise watersheds beyond the limits of the roadway, from the smallest drainage area requiring an 18 inch pipe to drainage areas as large as 400 acres. This classification falls into two catagories.

The first catagory is where the runoff is small and pipe culverts varying in size from 18 to 72 inches, can carry the storm water without danger of flooding adjacent lands, from high backwater, or, of erosion resulting from a great depth of flow and high velocities obtained in large pipes. The size of pipe should be selected so that it will carry the runoff resulting from a 10 year frequency rainfall, with the pipe running full but with no surcharge. The size of pipe should also be such that it can carry the runoff from a 100 year frequency rainfall, with a surcharge at the culvert entrance not greater than 2 feet.

The second catagory covers runoff from larger drainage areas, which is likely to carry a considerable amount of debris and is capable of causing more damage. Culverts for this catagory should be designed for more extreme conditions of flow and should be box culverts rather than pipes. The size of opening should be selected to carry the runoff resulting from a 25 year frequency rainfall with no surcharge at the culvert entrance. The opening should also be of such size that it can carry the runoff resulting from a 100 year frequency rainfall with a surcharge at the culvert entrance not greater than 2 feet.

Major streams and drainage areas over 400 acres, comprises all watersheds not included in the two former classifications. Structures requiring spans in excess of 24 feet normal to the abutments as a minimum condition, should be designed to provide adequate capacity for a flood which may be expected on an average of once every 25 years, with sufficient under clearance to pass floating ice and debris. Such under clearances will vary depending on the size of the span, nature of the stream and its watershed, and other factors which may influence the size and amount of debris carried by the flood. As a further condition of design, major structures should be of adequate capacity to carry a
flood equal to the maximum flood experienced in that stream, and at least, equal to a flood which may be expected on an average of once every 100 years.

The amount of flood flows used in the design of drainage structures is a determining factor in the size and type of structures which will be required. The prediction of these flood flows then becomes of primary importance. Therefore, it is necessary to establish detailed design standards covering all aspects of the drainage design. These standards will form the basis upon which the estimate of construction cost will be made, and also will govern the final design of all drainage facilities.

FACILITIES FOR MAINTENANCE AND OPERATION

Planning facilities for maintenance and operation of a Toll Road is a phase of highway engineering not generally considered by the average highway engineer. But, in planning for the modern turnpike, it is a phase of engineering that requires a considerable amount of study. It encompasses the study of all the elements of operation for the toll road, in order to plan facilities for each. It comprises the planning of facilities for general administration of the turnpike; facilities for the maintenance and repair of the roadway and appurtenances, structures, buildings and equipment; facilities for the collection of tolls; facilities for police patrol; and facilities for restaurants and the sale of gasoline and oil, etc. for the convenience of patrons. It requires a thorough knowledge of the functions of each element of operation.

These studies include determining the number, size, type and location of buildings necessary to accommodate personnel and house equipment for the orderly functioning of maintenance and operation. They include planning a system for communication that will insure contact between all administrative, maintenance and operating personnel, in all kinds of weather. This system should include telephone communication between buildings and also radio communication between buildings and patrol and maintenance vehicles, in order to provide an instant, dependable means of communication during emergencies.

The thoroughness required for these studies can be illustrated by enumerating the features to be studied in connection with toll collections. Providing facilities for toll collection requires detailed studies of many features such as, the method and mechanics of actual collection of the fare, the classification of the various types of vehicles and the assessment of appropriate rates to each classification, the proper recording of tickets issued and fares collected, the establishment of adequate controls and checks to guarantee the integrity of the
collectors, the formulation of a system for maintaining records for bookkeeping and statistical purposes, and the fixing of other procedures necessary to assure the proper receipt, handling and safekeeping of large sums of cash. These procedures must be so ordered and conducted as to cause no annoyance to the patrons of the toll road.

Time will not permit a detailed discussion of all Design Studies necessary in planning the Indiana Toll Road; nor is it known at the present time what specific problems may develop, since the design studies have just begun. In this discussion I have attempted to indicate, in a general way, some of the items that will be studied and their importance in the planning for the Indiana Toll Road.