DESCRIPTION OF APPARATUS AND PROCEDURE FOR TESTING FLOW IN GUTTERS AND STORM DRAIN INLETS

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The Highway Drainage Research Project was undertaken by the University of Illinois at the request of the State of Illinois Division of Highways and the Public Roads Administration. Design engineers in the Illinois Highway Department have long realized that the data for design of highway drainage facilities is far from adequate. The State Division of Highways, faced with the task of building hundreds of miles of express highways upon which traffic stoppage, due to high or ponded water would be extremely costly, decided to undertake a study and to accumulate data for the proper design of drainage facilities for these high-speed roadways.

This project financed jointly by the State of Illinois and the Public Roads Administration, provides for fundamental research to develop improved designs of the various pertinent hydraulic features of such a high-speed roadway. The actual investigation will be carried out by the University of Illinois under an agreement between the University and State of Illinois, Division of Highways. The purpose of the study is "to compile information and to make investigations and tests relating to hydraulics and hydrology as involved in highway design, construction and maintenance with the objective of improving efficiency, ecomony and safety."

This objective directs that the studies be not only analytical, but that to a large extent they involve the construction and testing of hydraulic models of proposed designs and the development of new designs. The features of greatest concern ~~to~~ the ~~Highway~~ Department are, flow in gutters, flow through gutter inlets of various designs and flow through a collection system to the point where the collection system enters the main drain. In addition to this laboratory work, an analytical study ~~is to be~~ made of hydrology as it affects run-off on the highway project. It ~~will~~ includes the study of storm paths and patterns relative to the drainage area shape, including a comprehensive review and analysis of existing rainfall data. A model reproducing any given rainfall hydrograph ~~will~~ be used in the laboratory in connection with these hydrologic studies.

The superhighway project facing the Illinois State Highway Department in the future is the Congress Street Superhighway, officially known as the West Route, in the city of Chicago. By directing all immediate laboratory study to the Congress Street Superhighway and obtaining results before the actual final design is completed on the project, it will be possible to use the Congress Street roadway as a 'pilot' project. An extensive study can then be made of such problems as driver behavior and psychology and other variables not readily adaptable to either laboratory or purely analytical study.

The Congress Street project is of the divided highway type with each directional roadway consisting of four 12-ft. lanes for high-speed traffic and one emergency parking lane. Each directional roadway is symetrical about its center line except that the emergency parking lane is provided on the right side of the roadway. The emergency parking lane is separated from the high-speed roadway by a mountable-type curb. The purpose of this curb and gutter is to channelize traffic and remove light precipitation run-off from the roadway without its first passing over the emergency parking lane. On the extreme right hand side of the emergency parking lane is a large circular section gutter which is designed to carry the bulk of the run-off to the collection system. On the other, or left side of the directional roadway is a barrier-type curb and gutter which carries the water from that half of the roadway to the collecting system. The collection system then carries the water from the three inlet boxes to a junction and thence to the main drain.

Because of the broad scope of the laboratory investigations, several types of hydraulic models will be employed in the study. First a 1:3 model of a portion of the Congress Street project will be built. This model will extend from the center line of the roadway to the outside edge of the toe-of-slope gutter in width, and in length will reproduce a prototype distance of 140 feet. By varying the amount of water supplied to the toe-of-slope gutter at the up-stream end of the model any gutter inlet spacing may be simulated. That is, the model will always represent the down-stream 140 feet of the inlet spacing distance. This 1:3 model will be used initially to study such design features of the Congress Street Superhighway as velocity distribution in gutters, efficiency of inlet gratings, sheet flow across the highway slab and a study of the intersection pattern of the sheet flow with the gutter flow. The model will be of the adjustable slope type capable of longitudinal slopes varying between zero and six percent and transverse slopes varying between zero and ten percent.

The model itself will rest upon a trussed model support frame which in turn will be supported by hydraulic jacks at alternate panel points. The model is of simple design, to facilitate remodeling and consists essentially of 2-by 10-in. transverse templates with a plywood surface. It has been decided to use molded Lucite sheets for the gutter portions of the model to facilitate observation in the velocity distribution phase of the work. The rest of the model area, representing the roadway lanes, will be covered with 3/8-in. thick Marine plywood. The plywood will be treated so as to obtain the proper roughness for hydraulic similitude. The lucite is naturally of the required roughness.

The water supply for this model will be pumped from a below floor level reservoir, or chase, into a constant head tank and then to one of three outlets, first it may flow to the up-stream end of the model and be introduced as gutter flow, as from an up-stream pavement area which is not a part of the model. It will then flow down either the mountable-curb gutter or the toe-of-slope gutter to the inlet basins and thence return to the chase. Second, the water may leave the constant head tank in one of two horizontal pipes whose purpose it is to simulate, in one case, the rainfall on the highway slab, and in the other case, the run-off from the cut slope to the side of the prototype roadway. Both of these pipes are horizontal and directly above, in case one, the center line of the roadway and in case two, the toe-

of-slope gutter. Flow will take place through orifices in the sides of the pipe. The orifices will be about six inches on center for the entire length of the model. The water leaving an orifice will impinge upon a sheet of plastic screen material which will distribute the flow evenly as it flows down the sheet, and finally will release the water at the bottom edge of the screen to the model itself. Between the distribution pipes and the constant head tank the water will flow through valves which are operated by a pair of Selsyn motors so that any desired rainfall hydrograph may be reproduced in the model. By using continuous outflow measuring devices on the discharge lines from the catch basins it will be possible to accurately measure the dentention period or time lag which occurs between the change in rainfall intensity on the highway slab and the discharge rate at the catch basin outlets.

The second form of model which is to be employed in this investigation is of a large scale, probably 1:1½ or even 1:1. This model, actually three models in one, will consist of three gutters and catch basins complete with collection system. The only gutter sections that will be built on this model will be those necessary to accurately reproduce the entrance and tailwater condition at the inlet itself. This model, too, will be of the adjustable slope type. However, it will be subjected to a longitudinal slope change of only zero to four percent and will not be capable of any change in transverse slope. The gutters of this model will be constructed of light weight aggregate concrete to ease the change of slope problem. The grating inlet bars, catch basins and the junction boxes will all be made of Lucite of varying thicknesses. This again is done to facilitate the observation of flow characteristics.

This model is expected to yield data for the more efficient design of catch basins, junction boxes and grates, data for the elimination, or at least great reduction in the amount, of air entrained by the water in the catch basin. Finally a check test on the proper size and location of collecting system pipes which drain the catch basins or inlet boxes will be made. The piping in this model also, will be made of Lucite material artificially roughened for hydraulic similitude. In this study, too, a system of measuring devices will be used to show the time lag between the various points of inflow and outflow from the model. Design features developed in this model study will be reproduced at 1:3 scale and will then be inserted in the 1:3 model of the roadway itself. There they will be subjected to tests on the integrated structure to determine what effect any particular change may have on the general problem. By adhering to this procedure the 1:3 model will always be available for tests and demonstrations of the latest designs.

The third type of model to be employed in this study is not, strictly speaking, a hydraulic model. It is designed in accordance with the laws of hydraulic similitude but rather than use water for the testing medium a Bentonite solution will be used. Bentonite is actually a colloidal clay, which, when in proper suspension and subjected to stress, exhibits a remarkable birefringent characteristic. That is, when subjected to circularly polarized light, those portions of the suspension under different stresses show different colors. The difference in the stress and, therefore, the color, is caused by the existence of an acceleration gradient through the liquid at the point under question. This acceleration,

of course, is indicative of the change in velocity. Therefore, the color is a direct measure of the velocity at any point. The light supplied to this model is passed through a polaroid screen and then a quarter wave plate. This quarter wave plate causes the light leaving the quarter wave plate to be circularly polarized. The circularly polarized light encountering the different refractive stream-lines in the model suspension is transformed in such a way that the net result when observed through proper polaroid plates is a chromatic velocity picture.

This model is expected to yield data depicting exactly what flow conditions do exist between adjacent bars of the inlet grating. It will also show exactly what the flow condition is in the catch basin itself. From this data a much more efficient inlet grating and catch basin design may be developed. The importance of the hydraulics of the jet of water flowing between the bars of the inlet grate cannot be over emphasized when considering air entrainment in the catch basin and the discharge pipe. Air entrainment is probably one of the major problems in the proper design of catch basins and inlet boxes. With the aid of the Bentonite model the design of catch basins is expected to be greatly simplified.

The space provided for this project is on the campus of the University of Illinois, in Urbana. The main laboratory is on the first floor of the Sanitary Engineering Building and contains approximately 1500 square feet. It is in this room that all the 1:3 model studies will be carried on. Another laboratory, containing about 1800 square feet of floor space is being readied for construction of the large scale model tests. This new laboratory will also contain facilities for testing component parts of the project, without it being necessary to use either the 1:3 model, or the large scale model of the catch basins and collecting system. This arrangement will make it possible to study numerous design features simultaneously, and thus avoid costly delay while awaiting completion of a test already in progress.

The above studies are being carried out by the Engineering Experiment Station at the University of Illinois. Dean M. L. Enger is director of the Engineering Experiment Station. The personnel involved in this particular study is composed of students and members of the Civil Engineering staff in the College of Engineering. Professor W. C. Huntington is head of the Civil Engineering Department and is in charge of all Civil Engineering research. Professor J. J. Doland is in specific charge of the Highway Drainage Research Project as well as other hydraulic engineering research. Mr. John C. Guillou is in charge of the model tests and other laboratory studies. Several research graduate assistants are employed and work half time on the project. It is expected that the preliminary tests on the Congress Street Superhighway will be completed by May of 1948. The large scale model tests should begin by mid February, 1948 and the Bentonite model should be in operation by mid April, 1948.