Research Problem Statement Title:
Energy Dissipation in Broken-back Culverts with Twelve-foot Drop using Laboratory Models

Problem Statement:
This project represents a continuation of three other projects funded by the OkTC-FWHA and ODOT. The funded projects include energy dissipation in broken-back culverts with 6, 18 and 24 foot drops. This project will study energy dissipation efficiency and appurtenance design for 12 foot drop using laboratory scale modeling techniques. A survey conducted by Oklahoma State University indicates that the broken-back culverts problem is a $6.6 billion problem for replacing them in the field by various DOTs and the FHWA. This research topic is on the national research list of Federal Highway Administration.

Proposed Research:
This research maximizes the energy loss within the culvert, and thus, minimizes the scour around the culvert. This will reduce the construction and rehabilitation costs of culverts in Oklahoma and the United States. A research study conducted by the Oklahoma Transportation Center (OTC) at Oklahoma State University indicates that there are 121 scour-critical culverts on the Interstate System (ISTAT), the National Highway System (NHS), and the State Transportation Program (STP) in Oklahoma. Replacement cost of these culverts is about $121M. This project is supported by the Bridge Division of ODOT. This research will build a laboratory scale model for 150 feet long, two barrels of 10 X 10 feet and a broken-back culvert with vertical drop of 12 feet. Simulate different flow conditions for 0.8, 1.0 and 1.2 times the hydraulic head in the scale model constructed and evaluate the broken-back culvert with sills and/or friction blocks of different sizes and shapes. Investigate the sill design for easy drainage of water from the broken-back culvert to observe in physical experiments the efficiency of hydraulic jump with and without friction blocks between upstream and downstream ends of the culvert and to identify the location of hydraulic jump from the toe to the drop in the culvert. The parameter for measuring success of the experiments includes total head loss between entrance and exit faces of the culvert, efficiency of the hydraulic jump formed, and exit velocity from downstream wingwall into the channel downstream.

Suggested Tasks (to include but not limited to):
- Perform literature search
- Perform necessary lab testing
- Evaluation of Climatic Data
- Statistical analysis of data
**Implementation:**
The Principal Investigator (PI) will provide an assessment of the results of the study which should include expected benefits and action needed for successful implementation. The PI should include draft specifications, if applicable, with final recommended implementation activities, methods or schedules to meet ODOT goals.

**Benefits:**
The results of this research will aid ODOT hydraulic and bridge engineers in designing bridge culverts to better dissipate energy within a culvert resulting in less scour at the outfall of the structure.

**Deliverables:**
All projects require the submission of the following reports:
- Monthly Progress Reports
- Multi-Year Projects require a Year-end Annual Report
- Copies of the project Draft Final Report in Microsoft Word and ADA accessible Adobe Acrobat pdf electronic formats
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The Year-end Annual Report, Draft Final Report, Final Report and Color Article should be submitted to satisfy all federal and state requirements pertaining to the accessibility of documents including but not limited to:
- Oklahoma State Statute 62 § 41.5e and the Americans with Disability Act (ADA) of 1990, 42 USC 12.01 et seq.

The PI must also participate in the following project meetings:
- New project initiation meeting
- Semi-annual project meeting
- Close-out project meeting
- Continuing project meeting

**Existing Research:**
The following information has been provided as a convenience only and does not constitute a thorough literature review.
Laboratory Modeling of Energy Dissipation in Broken-Back Culverts - Phase II
http://trid.trb.org/view/2010/P/978408 $210,175.00
Energy Dissipation in Eighteen-Foot Broken-Back Culverts using Laboratory Models
http://trid.trb.org/view/2011/P/1118276
Laboratory Modeling of Energy Dissipation in Broken-Back Culverts
http://trid.trb.org/view/2008/P/1117225
Laboratory Modeling of Energy Dissipation in Broken-back Culverts
Research Pays Off: "Analyze This!" Taking The Guesswork Out of Broken-Back Culvert Analysis

Hydraulic Jumps in Broken-Back Culverts

Hydraulic Analysis of Broken-Back Culverts