Hydraulic Headloss in Plastic Drainage Pipes at Full and Partially Full Flow

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Abstract : Hydraulic headloss, expressed by the values of friction factor f and Manning's coefficient n, is an important parameter in designing drainage pipes. Their values normally are taken from manufacturer recommendations, many times without sufficient experimental support. To our knowledge, currently there is no standard procedure for hydraulically testing such pipes. As a result of research carried out at the Mexican Institute of Water Technology, a laboratory testing procedure was proposed and applied on 6 and 12 inches diameter polyvinyl chloride (PVC) and high-density dual wall polyethylene pipe (HDPE) drainage pipes. While the PVC pipe is characterized by naturally smooth interior and exterior walls, the dual wall HDPE pipe has corrugated exterior wall and, although considered smooth, a slightly wavy interior wall. The pipes were tested at full and partially full pipe flow conditions. The tests for full pipe flow were carried out on a 31.47 m long pipe at flow velocities between 0.11 and 4.61 m/s. Water was supplied by gravity from a 10 m-high tank in some of the tests, and from a 3.20 m-high tank in the rest of the tests. Pressure was measured independently with piezometer readings and pressure transducers. The flow rate was measured by an ultrasonic meter. For the partially full pipe flow the pipe was placed inside an existing 49.63 m long zero slope (horizontal) channel. The flow depth was measured by piezometers located along the pipe, for flow rates between 2.84 and 35.65 L/s, measured by a rectangular weir. The observed flow profiles were then compared to computer generated theoretical gradually varied flow profiles for different Manning's n values. It was found that Manning's n, that normally is assumed constant for a given pipe material, is in fact dependent on flow velocity and pipe diameter for full pipe flow, and on flow depth for partially full pipe flow. Contrary to the expected higher values of n and f for the HDPE pipe, virtually the same values were obtained for the smooth interior wall PVC pipe and the slightly wavy interior wall HDPE pipe. The explanation of this fact was found in Henry Morris' theory for smooth turbulent conduit flow over isolated roughness elements. Following Morris, three categories of the flow regimes are possible in a rough conduit: isolated roughness (or semi smooth turbulent) flow, wake interference (or hyper turbulent) flow, and skimming (or quasi-smooth) flow. Isolated roughness flow is characterized by friction drag turbulence over the wall between the roughness elements, independent vortex generation, and dissipation around each roughness element. In this regime, the wake and vortex generation zones at each element develop and dissipate before attaining the next element. The longitudinal spacing of the roughness elements and their height are important influencing agents. Given the slightly wavy form of the HDPE pipe interior wall, the flow for this type of pipe belongs to this category. Based on that theory, an equation for the hydraulic friction factor was obtained. The obtained coefficient values are going to be used in the Mexican design standards.

Keywords : drainage plastic pipes, hydraulic headloss, hydraulic friction factor, Manning's n
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