MODIFIED HAZEN-WILLIAMS FORMULA

THESIS

Submitted in partial fulfilment of the requirements

for the degree of

DOCTOR OF PHILOSOPHY

by ,

D.M. MOHAN

CENTRE FOR ENVIRONMENTAL SCIENCE AND ENGINEERING

. INDIAN INST ITUTE OF TECHNOLOGY , BOMBAY

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Abstract

A dimensionally homogeneous and accurate formula has been derived in this research for the estimation of surface resistance in pipes based on explicit friction factor relationship and Darcy-Weisbach equation. The new relationship has been de3ignated as Modified Hazen-Williams formula. The values of coefficient of roughness for commercial pipes have been estimated experimentally and a rational approach put forth to account for reduction in carrying capacity of pipes with age.

Chapter 1 delineates the goals of Government of India in water supply and sanitation sectors along with concomitant investments during the International Drinking Water Supply and Sanitation Decade. The need for and scope of present research are also brought out in this chapter.

Chapter 2 critically reviews pipe friction formulae in respect of their utility to-Environmental Engineers.

Chapter 3 brings forth the limitations of widely used Hazen-Williams and Manning's formulae and quantifies errors in the estimation of frictional resistance through these formulae.

Chapter 4 presents a dimensionally homogeneous and accurate Modified Hazen-Williams formula, similar in form to that of Hazen-Williams, based on explicit friction factor relationship and Darcy-Weisbach equation. A nomograph for the solution of water supply and wastewater systems design and analysis problems is also presented.

Chapter 5 demonstrates the applicability of Modified Hazen-Williams formula to the design and analysis of rural and urban water supply systems.

Chapter 6 deals with the application of Modified Hazen-Williams formula, through the development of hydraulic elements for partful conditions, to design and analysis of wastewater collection systems.

Chapter 7 presents the details of experimental estimation of C_R values for commonly used commercial pipes. A comparison of C and C_R values on f-R diagram is also provided.

Chapter 8 reviews prevalent practices for the reduction in carrying capacity of pipes with age. The data on existing systems in some cities is analysed alongwith experimental information gathered during this research to bring out a rational approach to the reduction in carrying capacity of pipes *over* design period.

Chapter 9 underscores salient conclusions and recommendations drawn from the present research.

Appendix I presents a rationale for ascertaining dimensional homogeneity of empirical formulae.

Appendix II provides the derivation for explicit equations for pipe diameter and velocity.

Appendix III presents a case study on the application of Modified Hazen-Williams formula to the design of a real-life rural water supply system.

Appendix IV presents the derivation of hydraulic elements for partful conditions in wastewater lines based on Modified Hazen-Williams formula.

Appendix V provides derivation of Modified Shields .equation for the estimation of self cleansing velocity in wastewater lines incorporating Modified Hazen-Williams formula.

Appendix VI describes the procedure adopted in this research for calibration of pitotmeters for experimental estimation of values for coefficient of roughness.

The thesis concludes., with a list of references on researches and articles relevant to the present research.

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THESIS APPROVAL SHEET

Thesis entitled 'MODIFIED HAZEN-WILLIAMS FORMULA' by D.M. MOHAN is approved for the degree of DOCTOR OF PHILOSOPHY.

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NOMENCLATURE

A	=	area of pipe
A_1	=	constant for power cost
a	=	partful area of pipe
a_r	=	constant dependent on depth of flow
B_r	=	constant for rough turbulent flow equation
b	=	multiplication factor in Hazen-Williams formula
C or C'	=	Chezys or Hazen-Williams constant
$\bar{C}$	=	constant for a pipe of known length, C_R and flow
C_i	=	consumption at node i
$\bar{C}_i$	=	constant $\bar{C}$ for ith pipe
C_R	=	coefficient of roughness
C_{Rf}	=	coefficient of roughness for full flow condition
C_{Rp}	=	coefficient of roughness for partful conditions
D	=	diameter of pipe
D/K	=	relative roughness
D_i	=	diameter of ith element
D_t	=	distance travelled
d	=	partful depth
d_p	=	diameter of grit particle
f	=	Darcys friction factor
f'	=	porosity ratio
f_f	=	friction factor at full flow condition
f_p	=	friction factor at part flow conditions

GL	=	ground level
g	=	acceleration due to gravity
H	=	head loss due to friction in pipe line
HGL	=	hydraulic grade line
H_j	=	head at node j
HW	=	Hazen-Williams
h	=	head measured in manometer
h_f	=	head lost due to friction in meters
h_j	=	head loss over j pipes
h_n	=	friction head loss in n pipes
h_o	=	input head
h_r	=	constant dependent on depth of flow
h_t	=	desired terminal head required at withdrawal point
I	=	Langeliers saturation index
K	=	roughness of pipe material
K'	=	peaking factor in wastewater flow
$\bar{K'}$, K_1 and K_2	=	regression analysis constants
K_o	=	initial roughness
K_s	=	sediment characteristic
K_T	=	roughness at end of T years
L	=	length of pipe line
MF	=	multiplication factor
MHW	=	Modified Hazen-Williams

m, m_1	=	regression analysis exponents
N	=	[1.8099/4.8099 + m]
n	=	Mannings coefficient
n_f	=	Mannings coefficient for full flow condition
n_p	=	Mannings coefficient for partful conditions
Q	=	flow in pipe
Q_{av}	=	average flow
Q_i	=	flow in ith element
Q_{peak}	=	peak flow in wastewater lines
q	=	partful flow in wastewater lines
R	=	Reynolds number
R_R	=	Reynolds number based on $(gDS)^{\frac{1}{2}}$ as velocity
r	=	hydraulic radius of pipe
r_f	=	hydraulic radius at full flow condition
r_p	=	hydraulic radius at partful conditions
S	=	slope of hydraulic gradient line
S_s	=	specific gravity of sediment
SGSW	=	salt glazed stoneware
T	=	time in years
t_t	=	time of travel
V	=	velocity of flow
V_A	=	actual velocity
V_c	=	centre velocity
V_f	=	velocity at full flow condition

V_m	=	mean velocity
V_p	=	velocity at partful conditions
V_{Th}	=	theoretical velocity
W	=	weight of sediment in water
*	=	subscript for nondimensional parameter
α	=	exponent of r in exponential formulae
α_f	=	friction angle of sediment
α_r	=	growth rate of roughness
β	=	exponent of s in exponential formulae
ρ	=	specific weight of water
ρ_s	=	specific weight of sediment
τ	=	intensity of tractive force
ν	=	kinematic viscosity