CAVITATION IN HYDRAULIC STRUCTURES

WITH SPECIAL REFERENCE TO

HOLLOW JET VALVE TYPE ENERGY DISSIPATORS

AND

UKUWELA OUTLET WORKS

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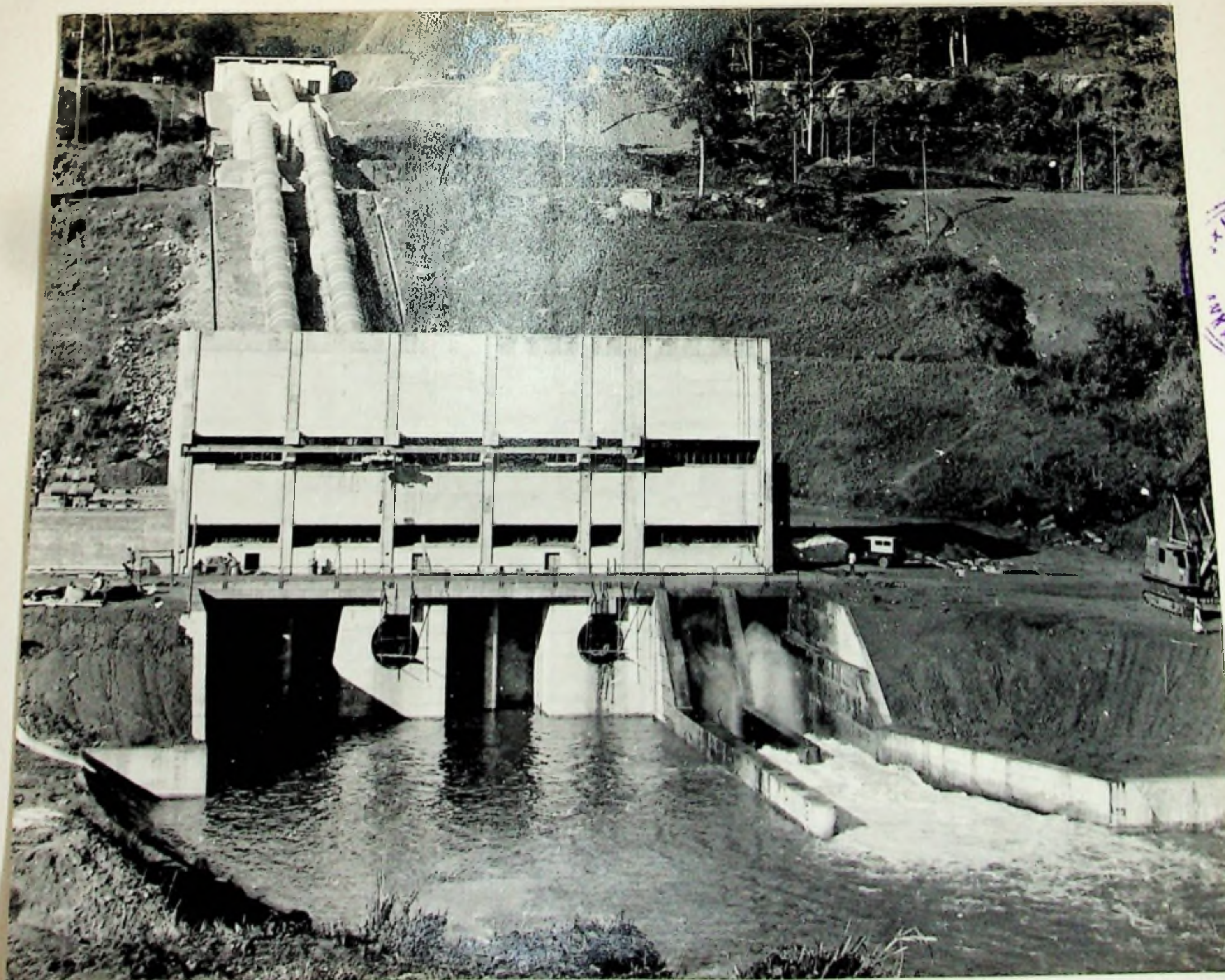

UKUWELA POWER HOUSE
Downstream view

Frontispiece

SYNOPSIS

Cavitation is a major source of damage to hydraulic structures and hydraulic machinery and leads to failure of function. In all forms of cavitation (fixed, travelling, vortex and vibratory) low ambient pressures and high velocities are conducive to cavitation. Low pressures can be caused by narrowing down or abrupt change of curvature of flow passages, separation of flow from wall surface, vorticity or pulsation and stable cavities are formed when local pressures drop close to vapour pressure. Cavities thus formed, collapse when they move into high pressure zones with tremendous implosive violence causing the damage to guiding surfaces.

Theoretical analyses of "Bubble Dynamics" have been made and the theories verified experimentally. The influence of factors such as surface tension, viscosity, tensile strength of liquids, solvates etc. have also been analysed.

Elaborate equipment such as water tunnels with facilities for observing cavitation on models, controlling and simulating influencing conditions such as velocity, pressure, temperature and measuring functions such as torque and thrust, while visually observing and "listening in" on cavitating components have been evolved. Stroboscopic lighting and high speed motion photography have been developed to record and study such phenomena. Equipment such as Rotating Disc and Drop Impact Device have been made to study cavitation resistance of various materials.

Study of cavitation through models and comparison of performance and ensuring dynamic similarity are achieved by use of a dimensionless coefficient - the Cavitation Parameter, which is a ratio of energy available to collapse a cavity to the energy available to produce it. The computation of this parameter takes a form appropriate to the hydrodynamic context. The Cavitation Parameter is also used as an index to demarcate cavitation inception, threshold, advanced stage, etc.

Stilling basins are structures under potential cavitation hazard. Ukuwela Power House Irrigation Outlet Stilling Basin of Jet Diffusion type with Twin Hollow Jet valve has been selected for case study, since the structure commissioned in 1976 suffered cavitation damage in several forms.

Model tests for this structure have been conducted by the Irrigation Department Hydraulic Laboratory earlier. The model test results and "Wet test" results on the Prototype are reviewed in the light of Cavitation Theory studied in depth.

Conclusions regarding situations conducive to cavitation and methods of preventing same by appropriate design and computation have been drawn from the above study. Thus recommendations for cavitation free design and construction of hydraulic structures (especially stilling basins) have been made for future guidance.

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The model tests described in this text were carried out at the Irrigation Department Hydraulics Laboratory under the direction of Mr. K.B.E. de S. Karunaratne, Deputy Director of Irrigation and Mr. N. Karunakaran, Chief Engineer (Hydraulics). The writer in his capacity as Chief Engineer(Structural Designs), was able to participate in the tests to make observations,and suggest probing of probable problem areas.

The prototype tests at Ukuwela were carried out by Technical staff from Mitsubishi Japan. Their work was monitored by Mr. K.L. Ariyananda, Deputy General Manager (E&M) as regards mechanical performance,and myself as regards structural safety. I am indebted to these personnel for carrying out additional tests and observations, and modifying certain test procedures as requested by me. During testing period, my interest was of course, safety and durability of structural components - but this experience later came to be material for presentation in a dissertation.

The first part of the text is largely an assimilation (and re-presentation in a condensed form) of theory obtained from text books, articles, research papers presented in Journals and Proceedings of Technical Institute Symposia etc. Acknowledgement for same is made throughout the text by cross reference to relevant sources serially numbered in the Bibliography.

C O N T E N T S

LIST OF PLATES

LIST OF ILLUSTRATIONS

LIST OF TABLES

LIST OF SYMBOLS

A	-	A Gas Constant Proportional to No. of Gas Molecules
b	-	Width
B	-	Width of Basin
c	-	Celerity
C	-	Constant
d	-	Depth
D	-	Diameter
E	-	Young's Modulus of Elasticity
g	-	Acceleration due to Gravity
h	-	Head
H	-	Static Draft Head
H	-	Frictional Head Loss
H	-	Atmospheric Pressure Head
H	-	Vapour Pressure Head
K	-	Cavitation Parameter
l	-	Length
L	-	Length (of Stilling Basin)
n	-	Number
N	-	RPM, Gas Constant
p	-	Pressure
p_v	-	Vapour Pressure
p_g	-	Partial Pressure of Gas
p_*	-	Critical Minimum Pressure
p_{crit}	-	Critical Pressure

p_0	-	Ambient Pressure
p_∞	-	Undisturbed Stream Pressure
Q	-	Initial Gas Pressure
r	-	Radius at a Point from Bubble Centre
R	-	Bubble Radius
R	-	Critical Bubble Radius
t	-	Time
T	-	Temperature
u	-	Velocity at a point
U	-	Cavity wall Velocity
w	-	Specific Weight
y, z	-	Height above Datum
z	-	Ratio R_0^3/R^3
α	-	Apex Angle
β	-	Ratio R/R_0
γ	-	Specific Weight
μ	-	Viscosity
ρ	-	Density
σ	-	Surface Tension
τ	-	Time Required for Bubble Collapse
ω	-	Angular Velocity