

Supercritical Flows – Design and Reality

IAHR UK Section Technical Meeting, “From Theory to Practice”,
16th September 2010, Birmingham

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Plan Design Enable

Supercritical Flows – Design and Reality

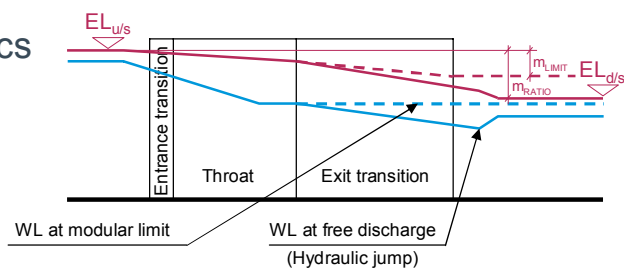
- Modular Limit of Flumes
- Hydraulic Jump Downstream of Weirs
- Ventilation of Weirs

Modular Limit of Flumes

Modular Limit of Flumes

Brief overview of flume hydraulics

- Flume structure
- Hydraulic operation
- Modular limit/ratio
- Submergence criteria



Modular Limit of Flumes

The Reality

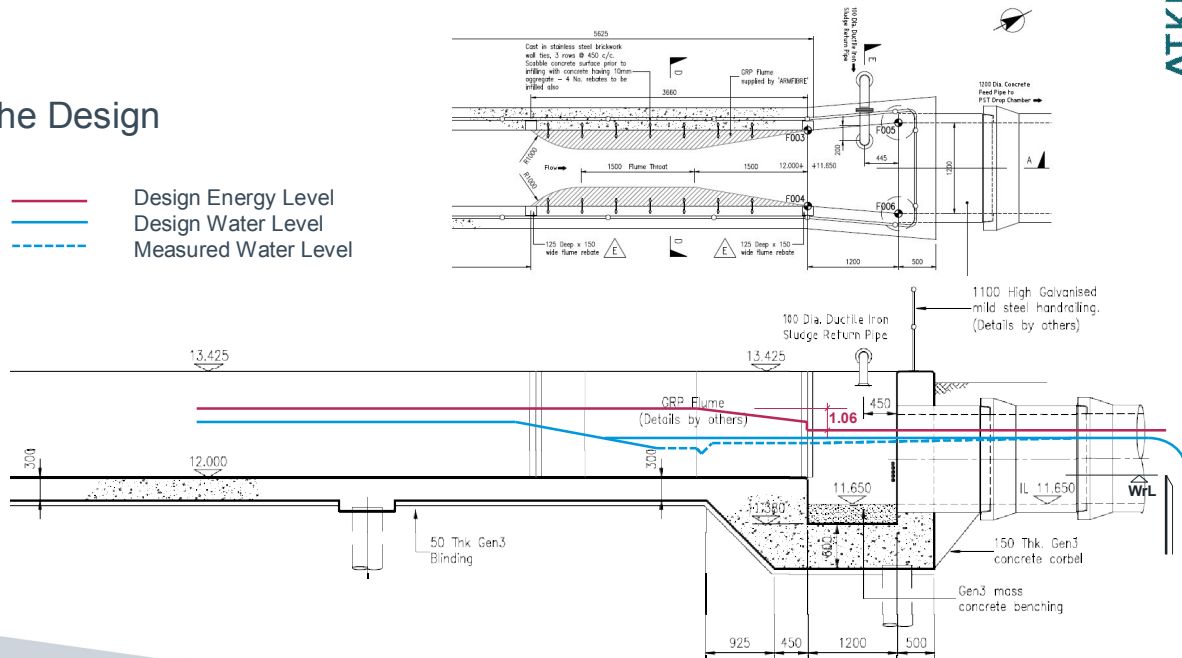
- Long-throated rectangular flume
- Level invert
- Expansion – 1 in 6
- Flow at the modular limit
- Measured u/s WL – good agreement with the design
- Measured d/s WL – 40mm lower
- Modular ratio = $1.06 \ll 1.25$ (BS)



Modular Limit of Flumes

The Design

- Design Energy Level
- Design Water Level
- - - Measured Water Level



Modular Limit of Flumes

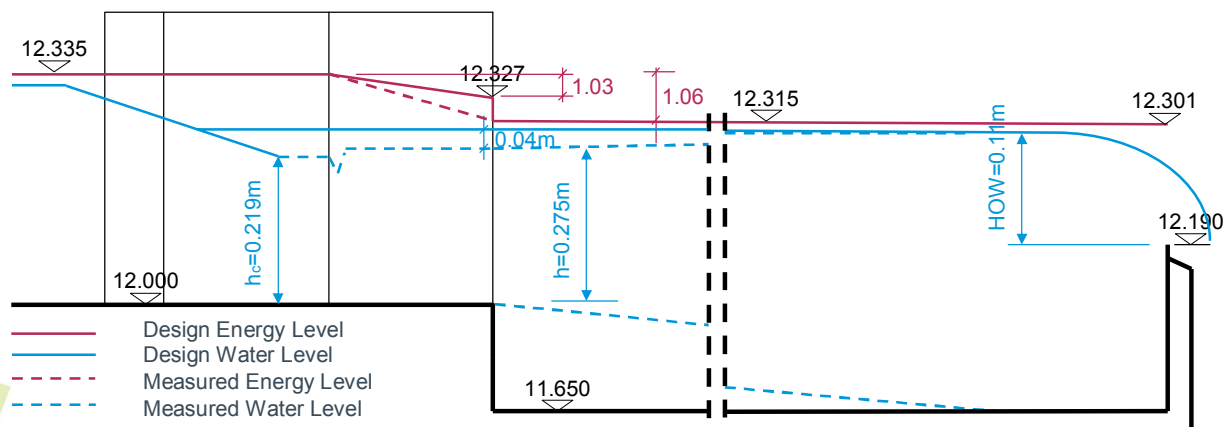
Possible explanations

- Hydraulic model being too conservative ?
- BS ISO 4359:1983 being too conservative ?

Modular Limit of Flumes

Possible explanations

- Hydraulic model being too conservative ?



Modular Limit of Flumes

Possible explanations

- BS ISO 4359:1983 being too conservative ?
 - Main principles and requirements of BS ISO 4359:1983 ;
 - Based on critical depth theory augmented by experimental data;
 - Required modular ratio depends on expansion only (1.25 required for 1 in 6 expansion);
 - Allows reduce of modular ratio provided that the free discharge is confirmed
 - Total head to be measured just d/s of exit transition (no account taken for d/s conditions)?;
 - USBR Water Measurement Manual features;
 - Submergence limit depends on exit transition and exit channel energy conditions;
 - Modular limit from 1.05 (Q max) and 1.22 (Q min) for similar size d/s channel;
 - Modular limit from 1.25 (Q max) and 1.54 (Q min) when discharging into a lake;
 - ILRI Publication 20, “Discharge Measurement Structures”;
 - Methodology for estimation of the modular limit of flumes.

Modular Limit of Flumes

Conclusions :

- BS ISO 4359:1983
 - Modular ratio required allows for the flume headloss and exit headloss;
 - Allows lower modular ratios when free discharge is confirmed;
 - Conservative at small exit loss may not be with large exit loss !
- Hydraulic modelling
 - D/s EL to be taken “just beyond” the exit transition (section 11.3.2);
 - The required modular ratio could be estimated (ILRI Publication 20 augmented by the exit loss) and compared to BS requirement.
- Design
 - Reducing the energy loss d/s of the flume reduces the modular limit;

Hydraulic Jump Downstream of Weirs



Hydraulic Jump Downstream of Weirs

The Reality

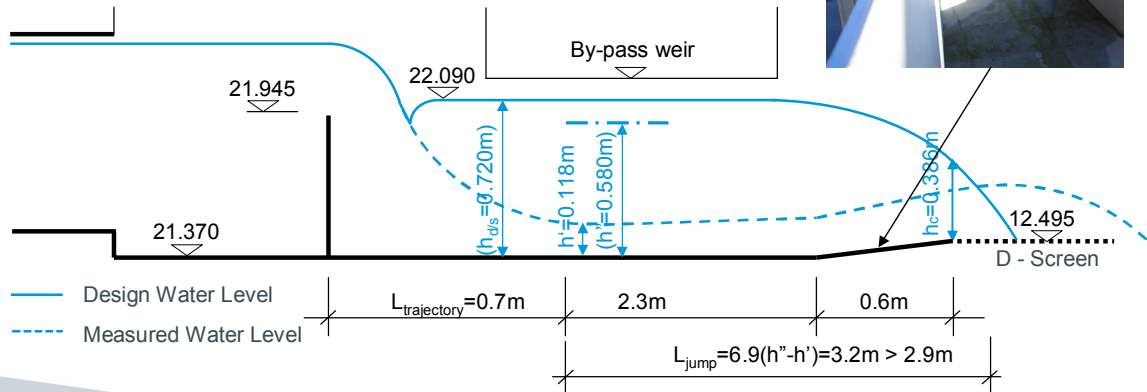
- Sharp crested weir - $h_{\text{weir}}=0.575\text{m}$
- D/s depth - $h_{d/s}=0.720\text{m}$
- Contracted depth - $h_c=0.118\text{m}$
- Conjugate depth - $h_c'=0.580\text{m}$
- Displaced hydraulic jump ?



Hydraulic Jump Downstream of Weirs

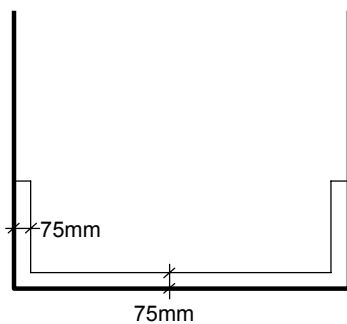
The design and possible explanations

- Channel shorter than the length of hydraulic jump ?
- Non submerged “Ski jump” ?



Hydraulic Jump Downstream of Weirs

The solution



Existing baffle (weir) cut out to leave 75mm wide strip at sides and base



View of the submerged weir



View of the submerged jump

Hydraulic Jump Downstream of Weirs

Conclusions :

- Hydraulic jump may occur d/s of weirs (including submerged ones);
- Jump may be displaced if insufficient length is provided d/s of weirs irrespective of the d/s depth being greater than the conjugate depth;
- Jump length cannot be calculated precisely – safety margin;
- “Ski jump” effect – rare occurrence.

Ventilation of Weirs

Ventilation of Weirs

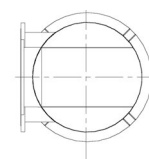
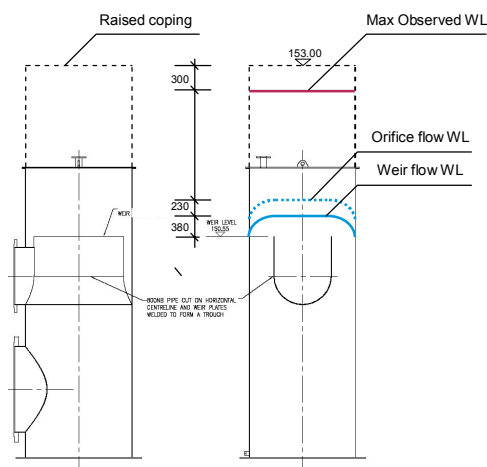
The Reality

- Sharp crested double sided weir in a U-shaped channel
- High inlet pipe velocity – 2.08m/s
- Air entrainment at the pipe walls
- Weir submergence
- Pressurisation of air underneath the weir
- Intermittent release of large volumes of air
- Turbulent oscillating water level u/s of weir



Ventilation of Weirs

The Design



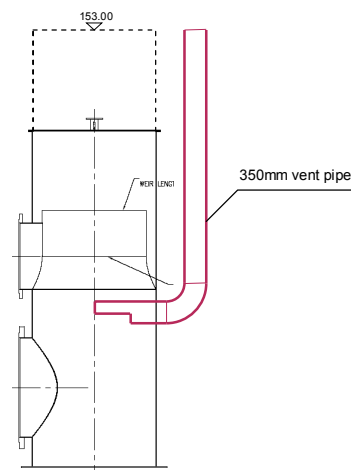
SECTION 'A-A'

Ventilation of Weirs

The solution



Test of venting the space under the weir using 2x225mm pipes



Proposed solution

Ventilation of Weirs

Conclusions :

- Air movement
 - Air entrained in vertical pipes tends to escape back at low downward velocities and obstruct the inlet;
- Flow over the weir is affected by upstream velocity;
- Sufficient area is required to achieve weir flow rather than orifice flow
- Sufficient ventilation is required to guarantee free discharge
 - Nappe not to impinge onto the opposite wall or;
 - Notches to be provided on the weir sides;
 - Provision of separate venting back of any entrained air in case of orifice flow.

Supercritical Flows – Design and Reality

Summary of Conclusions :

- Modular Limit of Flumes
 - BS may be conservative when energy loss at flume exit is minimised;
 - Lower modular ratio could be used if free discharge (displaced jump) is confirmed;
- Hydraulic Jump Downstream of Weirs;
 - Hydraulic jump may occur downstream of weirs;
 - Jump may be displaced if insufficient length is provided downstream;
- Ventilation of Weirs
 - Sufficient ventilation of weirs has to be provided in order to prevent air entrained in vertical pipes/shafts from obstructing the inlet when escaping in upward direction;