Supervised by

River Improvement Division,

River Bureau, Ministry of Construction

Technical Standard of Rubberized Fabric Inflatable Weirs

(Second Draft)

August, 1983

Land Development Technical Research Center

Preface

Weirs installed across rivers are classified into separation weirs, tidal barriers, and intake weirs functionally. With regard to construction, concrete-made fixed weirs and steel-made movable wiers have been popularly seen.

Introduced into Japan ten-odd years ago, rubberized fabric inflatable weirs are increasing its applications in recent years because of their advantages such as sure blocking/passing of water, easy installation requiring short term, easy maintenance and control, and cheap construction cost.

Technical standard of rubberized fabric inflatable weirs was primarily drafted in 1978 as "Technical Standard of Rubberized Fabric Inflatable Weirs (Primary Draft)", which was to be reviewed as new records of installation would be added because of then insufficient survey and study due to a short history.

On this background, this book constitutes the second draft of the technical standard that offers materials to understand features of rubberized fabric inflatable wiers in details by reviewing and adding to the primary draft data obtained on selected subjects by surveys and studies carried out with cooperation with makers as well as insallation records supposed to be readers' reference.

This book is expected to be a good reference for those who are concerned to rubberized fabric inflatable wiers as well as general river engineers.

For preparing this book, reviews have been carried out by the ad hoc committee, "Committee for preparation of technical standard of rubberized fabric inflatable wiers (second draft)" composed of relating researchers and experts. The Center is thankful to the Chairman, the committee members, persons of makers who submitted materials and others who cooperated.

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Land Development Technical Research Center

List of the Committee Members

Hirotsugu Nakagawa	Chairmnan, Prof., Tech. Fac., Kyoto Univ.
Kunihiro Ogihara	Member, Prof., Tech. Fac., Toyo Univ.
Gyozo Suga	Member, Prof., Tech. Fac., Utsunomiya Univ.
Shin-ichi Ishida	Member, Specialist, River Impr. Div., River Bureau, Ministry of Construction
Masamichi Shirahase	Member, Assit. to Manager, Riv. Impr. Div., Riv. Bur., M. of Construction
Takashi Yamaguchi	Member, Manager of River Div., Public Works Research Inst., M. of Construction
Hiroshi Hashimoto	Member, Manager of River Research Lab., Riv. Div., Public Works Res. Inst., M. of Const.
Gosei Ito	Member, Manager of Mech. Res. Lab., Machine & Construction Div., P.W.R.I., M. of Const.
Kushuo Yasuoka	Secretary, Director, Land Development Technical Research Center
Takayuki Inoue	Secretary, Senior Member, Survey 1st Div., L.D.T.R.C.
Katsumi Wakugawa	Secretary, Researcher, Sur. 1. Div., L.D.T.R.C.
Cooperating Companies :	Sumitomo Electric Industries, Ltd. Bridgestone Tire Co. NipponJido Kiko Co. Fukoku Kogyo Co. The Yokohama Rubber Co.

= GENERALS =

= GENERALS =

= CONSTRUCTION WORK AND MANAGEMENT =

= GENERALS =

Section 1 Generals

1.1 Construction

This standard, consisting of three parts of Generals, Design and Construction and maintenance, covers standard technical issues to be considered in installation of rubberized fabric inflatable weirs.

Explanation

Each part is composed of chapters, sections and paragraphs. "Explanation" gives explanations on the text of standard to readers so that they have correct understanding and make no incorrect judgment in application of contents of the text. And, "reference" gives data of experiments or the like backing up the explanation.

1.2 Definition

"Rubberized fabric inflatable weir" (hereinafter called as "a rubber weir") denotes a structure with a barrier of rubberized fabric tube (hereinafter called as "a tube"), which is raised or flattened by pressing in or withdrawing out water or air.

1.3 Scope

This standard is desirably to be applied for design, and installation and maintenance of a rubber weir.

Explanation

Most of existing rubber weirs are operated only in shallow portions of medium or small rivers. Applications for large rivers and portions of large flow rate are foreseen in future.

This standard should intended to be applied for all the cases where a rubber weir is used as a barrier.

1.4 Application

> In case where application of this standard is improper, no application of this standard can be permitted only with the limitation that technical level stipulated in this standard is preserved.

Explanation

Indicating current technical level, this standard constitutes no obstruction for adoption of a higher level. Hence, in a case where judgment is made that application of this standard is improper and technical level shown in this standard is secured, it is permitted not to adopt this standard.

1.5 Associating rules and standards

> In case where some stipulation of associating rules or standards exists relating to items of subject of this standard, such stipulation should be taken preferable if not otherwise mentioned.

Explanation

Associating rules indicate laws, ordinances of the government or Ministry of Construction and directives of Ministry of Construction. Actual examples:

1) Ordinance of construction of facilities controlling rivers
2) Technical standard of erosion control of rivers of Ministry of Construction (draft), Part of survey
3) - ditto - , Part of planning

1.6 Revision

This standard shall be revised according to necessity in such cases as improvement of technical level.

Explanation

With a short history of only 10-odd years, the rubber weir in Japan is expected to expand its application and raise its technical level in the future. Therefore, revisions will be necessary according to changes of situation including revisions and/or abolitions of associating rules.

= DESIGN =

Chapter 1 Generals of Design

Section 1 Characteristics of rubber weirs

1.1 Consideration on adoption of rubber weirs

For adoption of a rubber weir, purpose and place of installation should be made clear, characteristics of the rubber weir should be well understood, and comparison should be made with a steel barrier weir.

Explanation

Generally, rubber weirs are superior to steel barrier weirs in sureness of flattening, adaptability for large spans, simple substructure, installation easiness and short term, easiness of maintenance, cheap construction cost, resistance to uneven sinking, resistance to vibration, water-tightness, etc. Because of its flexible structure, a rubber weir may not function suitably depending on purpose and place of installation.

Among fundamental characteristics of rubber weirs, issues to be considered for their adoption are as follows:

1) Maximum overflow water depth

If depth of water overflowing a weir exceeds a limit, overflow pulsation may cause vibration in the tube. Hence, overflow depth for ordinary discharge should be set within the limit. (Refer to 1.6, Chapter 2, Part of design.)

2) V notch effect

In cases when air is used for inflation, difficulty of water level and flow rate control may be in the process flattening the tube by its local deformation called V notch. When it occurs, flow concentrates at the notched portion. This makes it necessary to take sufficient consideration on effect on the downstream river channel. (Refer to 1.7, Chapter 2, Part of design.)

3) Water level change and tube deformation

Change of upstream and downstream water levels deforms the tube and, consequently, changes the weir height. Especially in tide sensitive sections and at places affected by backwater of other structures, the change of weir height can be substantial. This characteristic, working against the weir function of controlling water level and flow rate, should be studied carefully in relation to requirements. (Refer to 1.10, Chapter 2, Part of design.)

4) Wave effect

In cases receiving wave effect, the effect produces tension fluctuation in the tube. Hence, the tension fluctuation and accompanying parts' fatigue must be investigated. (Refer to 1.3, Chapter 2, Part of design.)

5) Possibility of perfect flattening

Under the conditions of small water level difference between weir upstream and downstream and small flow velocity, the tube may be only imperfectly flattened disturbing weir functions, or causing the tube's wear or damage. (Refer to 3.5, Chapter 2, Part of design.)

6) Prevention of damage given to the tube

In a river with many rolling stones or flowing matters, the tube and fittings becomes vulnerable to wear and damage. In such a case, sufficient consideration should be taken on river channel conditions at the point of installation. (Refer to 3.5, Chapter 2, Part of design.)

7) Effect of silt

If much silt has accumulated on the tube during being flat, it may becomes impossible to be raised. (Refer to 4.3, Chapter 2, Part of installation and maintenance.)

8) Repair

It must be minded that repair in water is impossible when a rubber weir submerged at all times is damaged. (Refer to 4.3, Chapter 2, Part of installation and maintenance.)

Table 1.1 summarizes characteristics of rubber weirs and Table 1.2 compares their adaptability with that of steel barrier weirs.

Table 1.1 Rubber Weir Characteristics

(1) Hydraulics

1. Water blocking	Superb including the tube and fixing portion.
2. Passinng water flow	Installable without changing river channel cross section, and little reduction of river section by weir posts.
3. Securing water level	Satisfactory, if no high precision water level is needed, because of good water blocking.
4. Storing water	Suitable for storing water with good blocking function.
5. Controlling water level	Somewhat improper for accurate control of water level because weir height changes according to upstream and downstream water level changes. Control difficult with air type weirs in the range exceeding V notch occurring limit.
6. Controlling low flow rate	Flow rate control at an arbitrary value more difficult than with steek barrier weirs for the same reason.
7. Controlling high flow rate	- ditto -
8. Breaking water	Superb in that impulsive wave force action is moderated due to the rubber weir's flexible construction.
9. Barring tide	Superb because of good water blocking and overflow construction.

Comprehensive	Generally, funcrions required for movable weirs are more than one. Whereas rubber weirs have many superiorities to steel barrier weirs regarding to functions in cases fully open or completely closed, they have only unsatisfactory functions in cases when weir height should be controlled such as water level control and flow rate control due to the tube deformation associated with water level change, occurrence of V notch and other effect cause by their flexible construction. While some mechanisms can be built in as measures against these shortcomings, operation becomes complicated nullifying their advantages. These issues should be understood sufficiently and comparison with steel barrier weirs should be made for adoption of rubber weirs.

(2) Operation

1. Complete flattening	Only to open the inflating medium discharge valve, flattening operation uses a simple mechanism securing highly reliable performance. When the auxiliary device for perfect putting inflating medium out is used together, the tube can be flattened completely. But, under conditions of small upstream-downstream water level difference and low velocity after flattening, complete flattening may not be brought about. Hence, investigation should be made under some hydraulic conditions.
2. Complete raising	The operation, consisting of starting raising units such as the pump and the blower and operating the valve, is highly reliable. With some silt on the tube, however, complete raising may be difficult. Hence, some measure should be taken depending on the place of installation.

3. Controlling weir height	In many conventional constructions, no device for controlling weir height is provided. Although weir height can be controlled by inflation and deflation, the control is impossible once V notch takes place in a rubber weir of air type.
4. Raising/flattening rate	Although relatively easy is controlling raisinig/flattening rate under specific conditions such as controlling flattening rate in the initial stage, the apparatus becomes complicated for controlling at an arbitrary rate because raising/flattening rate is affected by upstream-downstream water level difference.
5. Multi-span operation	Although operations in individual spans are possible, complete flattening may be disturbed in a place where upstream-downstream level difference is small when flattening in a later span.
Comprehensive comments	Since full open and complete close operations are the fundamental for a rubber weir generally, sureness of these operation is secured by automation and simplification of operating devices. Though possible is control of weir height and raising/flattening rate, sufficient cares should be taken so as not to curtail advantages of the rubber weir.

(3) Maintenance

1. Inspection of tube	Whereas inspection of tube is possible from inside, that from outside is more difficult with a rubber weir than with a gate pulling up weir.
2. Inspection of operating apparatus	With a simple construction, the apparatus can be easily inspected. But, buried portions of feeding and discharging pipes are difficult to be inspected. Hence, such portions should be sufficiently investigated regarding strength to effects such as deterioration and uneven sinking.
3. Treating silt	Weir height can be secured to a considerable extent by removing silt on the tube using inflating pressure with rather high setting value of internal pressure. But, complete raising is difficult. Hence, for some purposes, mechanical removal of silt should also be adopted.
4. Repair	Repair of small damages is possible. For repair of large damages requiring vulcanization or adhesion, however, the tube or parts must be dried.
Comprehensive comments	Rubber weirs are superb because of no need of coating simple devices, and easy inspection. For sure silt treating, manpower and machine operation are the only means. Measures for a case when a big damage is given should be prepared at a place of very high water level.

(4) Safety

1. Tube	Designed with a safety factor of eight, tube strength is considered sufficient. At places of many matters flowing down, measures for preventing tube damage should be taken.
2. Fixing units	Since the units are exposed to running water at all times, measures for preventing their damages should be taken at a place with many matters flowing down.
3. Operating units	Operating units are highly reliable because of simple construction, only a few moving parts and easy multiplication.
4. River channel and bank	River channels and banks are preserved safe even with installation of rubber weirs because of no needs for channel section change, small section reduction and sureness of raising and flattening.
5. Human sensitivity	Persons may feel unstableness on rubber weirs, at a place where people come to, because of their flexible construction.
Comprehensive comments	Rubber weirs can be surely raised or flattened and, consequently, preserve safety of river channels and banks in case of high water. However, for the facts that the tube is a flexible structure and the fixing units are exposed to running water, sufficient measures should be taken to secure installation safety depending on the place of installation and river conditions.

(5) Durabilities

1. Deterioration of tube	Judging from the past records, no problems are foreseen for 20 year use.
2. Wear of tube	Whereas little wear is caused by flowing sands, local wear of tube can occur under incomplete flattening conditions by friction against sealing sheet.
3. Damage to tube	While measures are prepared for prevention of such damages as caused by rolling stones, sufficient care should be taken in selection of the measures.
4. Wear and damage of fixing units	Because fixing units are more vulnerable to wear and damage than rubbers, suitable measures should be taken at a place of many flowing sands or rolling stones.
5. Wear and damage of operation devices	Only little deterioration or wear occurs because of few movable parts composing the devices. Measures to uneven sinking should be taken, if necessary, for buried portions of feeding and discharging pipes.
Comprehensive comments	Whereas may things remain to be made clear about durability of rubberized fabric, durability of rubber weirs is supposed almost near that of steel barriers as judged from the past experiences and various test results. Durability of rubber weirs should especially be considered in cases where they are installed in a river of many flowing matters such as rolling stones or where effects of tidal change is large. In such cases, sufficient precautions should be made with regard to tube and fixing units.

Table 1.2 Adaptability of Rubber Weirs

1. Intake weir and river mouth weir

Application	Type of steel barrier	Adaptability of rubber weirs
Discharging high flood	Roller gate Turnover gage Long span gage	Suitable because only tube's raising and flattening are required and, moreover, safety secured in passing high water.
Discharging soil and sand	Roller gate Radial gate	Similar to discharging high flood functionally. However, investigation should be made about impossibility of underflow operation and resistance to wear.
Water level adjustment Flow rate adjustment	Roller gate Radial gate Turnover gate Two step gate, especially gate with flaps	Adjustment possible by water level detection and weir height control. Since, however, there are cases when weir height variation due to upstream and downstream water level change cannot be neglected, precision of the adjustment should be investigated. As inflating medium, water gives adjustment range wider than air.
Intake Setting basin Training dike	Roller gate Slide gate Turnover gate	Suitable as water barring weir for inspecting the structures listed in the column to the left.
Fish pass	Turnover gate	Unsuitable in some cases though with some records of application.
Lock gate	Roller gate Radial gate Miter gate Sector gate Crossing gate	May cause interference to tugging operation because outflow rate following gate operation is limited, large depth and, consequently, sometimes incomplete flattening.

2. Tidal barrier

Application	Type of steel barrier	Adaptability of rubber weirs
Salt blocking Fish blocking High tide blocking River mouth blocking	Roller gate Miter gate Visor gate Turnover gate Crossing gate	Suitable, though requiring consideration on wave pressure, because of no performance degradation caused by rust, etc. Method for flushing sand land quickly should be investigated for blocking a river mouth. Additionally, method for repair of tube without drying should be developed.

3. Weir for dam or power generation plant

Application	Type of steel barrier	Adaptability of rubber weirs
Discharge outlet Intake	Roller gate Radial gate Case with many flow-down matters Sector gate Drum gate Turnover gate Rolling gate	Consideration required for inspection and repair because weirs are under operation at all times. Some records of intake applications for power generating stations in Japan.

1.2 Economical comparison with steel gates

Economical comparison with steel gates should be made in designing rubber weirs taking considerations on construction cost, maintenance cost and durable years.

Explanation

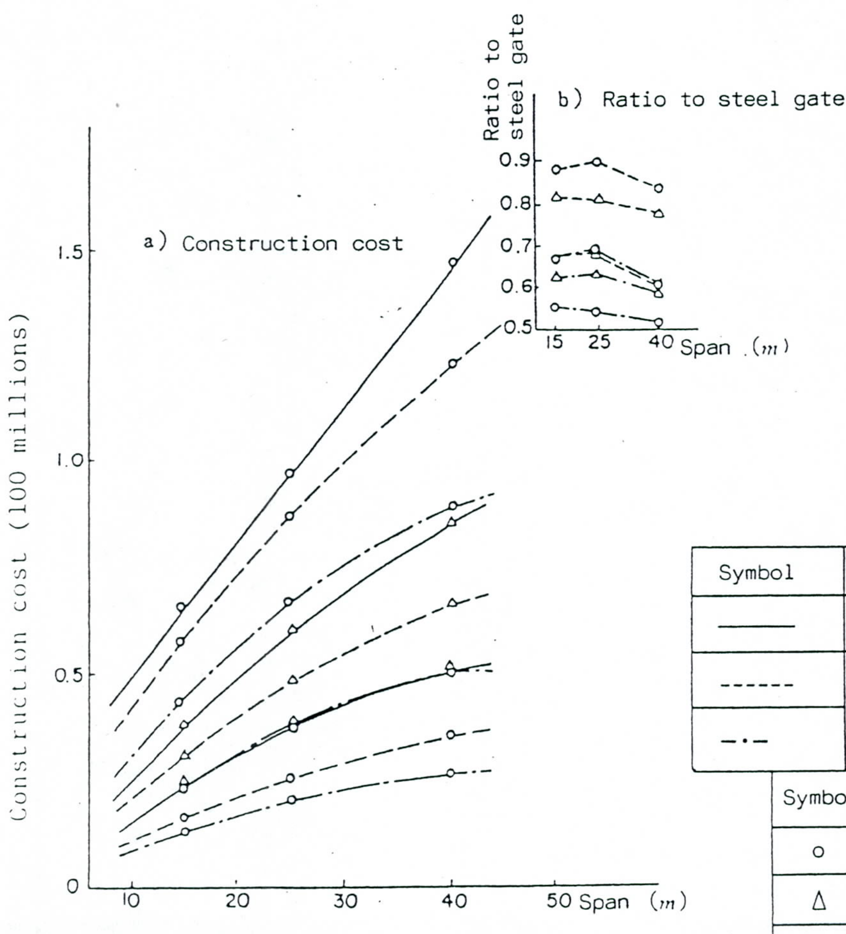
Construction cost depends on circumstances and river conditions such as river width, weir height, operation system, operation hours, and distance between weir location and operation room.

Maintenance cost of rubber weirs includes engine fuel or motor power as driving power source. But, no coating is required different from steel gate.

The first rubber weir was put to use in 1957 in the U.S.A. and 1964 in Japan.

Reference

An example of comparison of construction cost between rubber weir and steel turnover gate is shown in the figure below, consisted of rough estimation based on 1978 standard price. Actual comparison should be made under site conditions.



Nomenclature

Symbol	Gate type	
———	Steel turnover gate	
------	Rubber weir	Water inflation
—·—	Rubber weir	Air inflation

Symbol	Weir height (m)
o	3.0
Δ	2.0
◇	1.0

Fig. 1.1 Construction cost comparison with steel gate

Section 2 General design

2.1 Selection of installation location (Refer to Technical standard of erosion prevention of Ministry of Construction (draft) --- abbreviated as TSEP hereafter --- 11.1, Chapter 9, Part of planning.)

Location of rubber weir installation should be selected suitable for the purpose. Such places as river channel bend and small channel section should be avoided.

<u>Explanation</u>

1. For installing a rubber weir across a river, the location should be selected so as to meet the purpose of installation. A place of straight flow center, little flow velocity variation, stable flow center and little river bed change caused by water flow is preferable in order to produce no disturbance to river conditions by installation of the weir. If it is installed at a bend of river channel, possibility of silt accumulation on the tube will be great, whichis unsuitable for the rubber weir in constructional aspect. If a weir must inevitably be installed at a bend, measures such as revetment on side slope up to the top of bank should be taken besides consideration on treatment of silt. (Refer to 4.2, Chapter 1, Part of design.)

2. Whereas installation at a place of narrow river width is advantageous for reducing construction cost, this should be avoided as far as possible because special consideration must be taken for flowing down high water safely and the weir would constitute a restrictive condition for river channel in the future.

2.2 Shape and direction (Refer to 11.2, Chapter 9, Part of design, TSEP..)

Plan configuration of rubber weir should normally be straight. Direction of weir should ordinarily be normal to flow direction in downstream considering flow direction at high water.

Explanation

Water overriding the weir flows normal to it. When weir's plan configuration is improper, the flow can be a cause of local wash-cutting or accelerate water hammering action. For these reasons, plan configuration of the weir should be straight and its direction normal to flow in downstream.

2.3 Height of tube top and water storage level (Refer to 11.4, Chapter 9, Part of design, TSEP.)

1. Height of tube top should be determined for water depth corresponding to the purpose of weir installation. 2. Planned water storage level should be taken at 50 cm lower than the highest water level and not higher than the maximum ground level inside the bank including additional banking, if made.

Explanation

Generally, river banks are not designed so as to support water normally stored. When the ground level inside the bank is low, ordinary storage water may cause problems such as drain failure of the inside ground and rise of underground water level. When water is stored ordinarily at the highest water level, use of maintenance of the water level may be difficult. For determination of water storage level, these problems should carefully be considered. Special measures such as banking should be taken for inside ground level or the highest water level if necessary.

2.4 Construction

A rubber weir consists of superstructure, substructure and operation equipment defined below:

1. Superstructure: Includes tube, tube fixing fittings and bolts, and units appended to tube.
2. Substructure : Includes base plate mounting the tube, apron and banking works, foundation works and sealing sheet.
3. Operation equipment: Includes feeding/discharging equipment including piping to feed tube inflating medium, and maintenance equipment.

Explanation

1. The units appended to tube include tube protection unit, vibration prevention unit, ventilation unit against overflow pulsation, and auxiliary unit for complete discharge of tube inflating medium.

2. The substructure includes weir posts and side wall.

3. The foundation works indicate structures such as tube, base plate mounting the tube and others that transfer load imposed on weir to the ground. Foundation is roughly divided into direct foundation and pile foundation.

4. Configurations and scales of the base plate, the apron and the banking works depend on inflating medium, size of the rubber weir and ground quality of the foundation. The base plate mounting the tube should be provided with ports and pipes for feeding/discharging inflation medium.

5. Tube inflation medium can be water, air and combination of both. (Refer to 1.7, Chapter 2, Part of design.)

6. Tube flattening system includes one side system, both side system and direct flattening system. (Refer to 1.7, Chapter 2, Part of design.)

7. The operation equipment includes well, water tank and screen.

8. Facilities such as soil and sand outlet, lock gate and fish pass should be provided according to necessity.

2.5 Parts' names

Parts' names of rubber weir should be as shown in Fig. 1.2.

(1) Tube	(9) Maintenance bridge
(2) Weir post	(10) Fish pass
(3) Base plate mounting the tube	(11) Bridge mount
(4) Side wall	(12) Approach retaining wall
(5) Apron	(13) Approach bank
(6) Banking	(15) High water level protection works
(7) Sealing work	(16) Retaining bank
(8) Operation room	

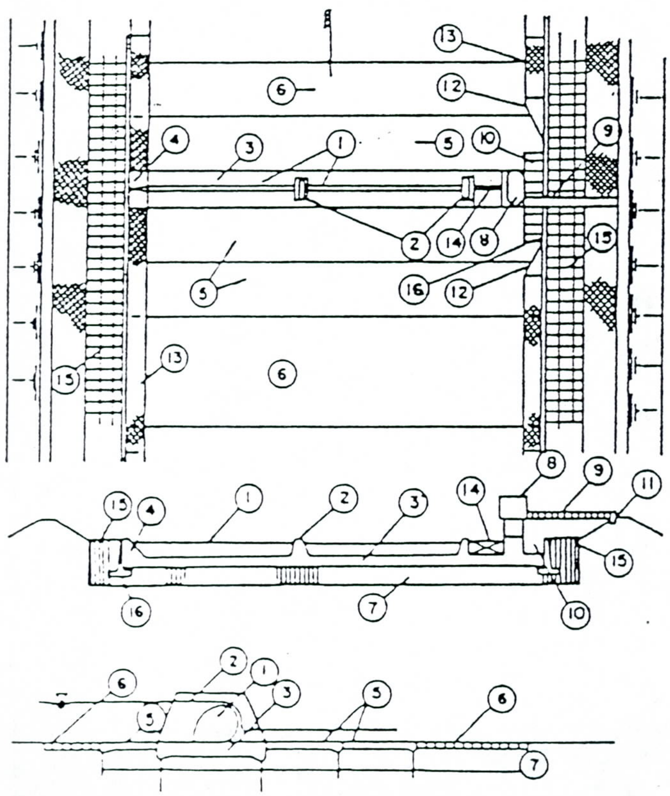


Fig. 1.2 Parts name

2.6 Definition of weir height and span

Weir height and span are defined as follows:

1. Standard conditions are defined with the full water level in upstream and zero level in downstream of the weir. The weir height and internal pressure under these conditions are defined as the standard weir height and standard internal pressure respectively.

2. Span should be defined as given in Fig. 1.3.

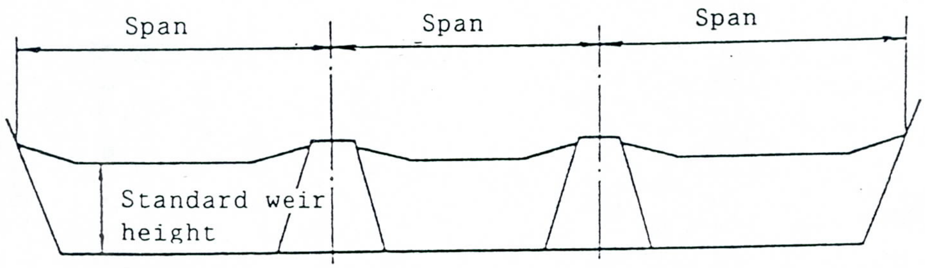


Fig. 1.3 Weir height and span

Explanation

Tube of rubber weir changes its form according to change of internal pressure and upstream and downstream water levels and, consequently, height of the weir changes also. While weir height used to be indicated under different conditions accordingly, this book establishes standard conditions shown above under which weir height is to be indicated.

As described in 1.10, Chapter 2, Part of design, change of form of the tube and change of weir height caused by flexible structure being proper to rubber weirs, it should be minded that concept of weir height is totally different from that for weirs with steel gate. For instance, in the process of change from the standard

conditions stated above to the flattening water level with an elevated water level, weir height decreases by change of tube form accompanying to change of water level. Therefore, to know overflow rate in the flattening process, change of weir height must be known that corresponds to upstream and downstream water level at every moment. This is the difference from the case of weirs with steel gate, whose height is constant. In such a case, comparison will become easy using the generalized data as presented in the reference of 1.10, Chapter 2, Part of design when weir height is gripped as ratio of change from the above-mentioned standard conditions and standard weir height.
According to the past records, many of the existing weirs were designed based exclusively on fixed set of hydraulic conditions such as upstream water level and overflow quantity when the weir is flattened or water storage level and overflow quantity in ordinary times, investigating only insufficiently into hydraulic characteristics outside the design conditions.
For weirs of importance or required to be operated in a complicated manner, sufficient studies should be made so that necessary weir height can be secured under all foreseen hydraulic conditions beyond considerations on purpose of installation and required functions. (Refer to 3.3, Chapter 1, Part of design.)
Span is defined as shown in the figure for the reason that concept of end span becomes different from the case of weirs with steel gates due to the fact that end weir posts are rarely installed in case of rubber weirs.
Definitions of weir height and span in this book have intention to unify indications of those items which based on conditions individually set up, Hence, be noted that the definitions give meanings of weir height and span different from those in the Construction Ordinance.

2.7 Safety factor

Proper safety factor should be taken in designing rubber weirs so as to make safe constructions.

2.8 Material test

JIS based materials used for manufacturing rubber weirs should be made sure that they meet the appropriate requirements. Materials not based on JIS should be inspected and tested in accordance with the general standards specified in JIS to assure satisfactory results of inspection and test.

Explanation

Materials not based on JIS should be tested in accordance with General rules of test of steel materials (JIS G 0303), General rules of test of nonferrous metal materials (JIS H 0321) and Rubber test (JIS K 6301, JIS K 6328, JIS L 1096). When the material's properties are made clear with results of material test conducted in the manufacturer's factory, these test results can be deemed as the weir maker's.

2.9 Survey

Necessary surveys should be selected among those listed below according to scale and importance of the rubber weir.

1. Ground survey
2. Water leakage survey of the bank
3. Water bed variation survey
4. Water quality survey
5. Ecology system survey

Explanation

Methods of survey should be in accordance with Part of survey, TSEP.

Section 3 Setting up of weir functions, etc.

3.1 Place of installation and functions

Purpose (functions) of rubber weirs should be as follows if shown in relation with place of installation:		
1. River mouth	:	Tidal barrier, measure for blocking river mouth, prevention of wave invasion
2. River channel	:	Branching flow, intake, prevention of inverse flow
3. Damp and reservoir	:	Barring water, raising the top level
4. Others		

Explanation

There can be a weir given with multiple purposes listed above.

1. Rubber weirs used for measures for blocking river mouth should prevent blocking of river mouth caused by drift sands. Rubber weirs, when used for prevention of wave invasion, absorb a large quantity of wave energy.

2. Rubber weirs for prevention of inverse flow adopted for discharging inside water should be provided with discharge pumps.

3. Application for raising the top level means to use rubber weirs to raise effective top of existing bank.

4. Possible other applications include use as a structure performing functions as both overflow bank and discharge channel gate of facilities such as spare gate, temporary floodgate, and retarding basin.

3.2 Co-installation of steel gate, etc.

Facilities with the following functions are sometimes installed with rubber weirs:

1. Flow rate adjusting gate

2. Lock gate
3. Soil and sand discharge port
4. Fish pass

Explanation

Operation of rubber weirs is more difficult than weirs with steel gate when high precision of water level and flow rate is required because of tube deformation caused by flaxible structure of rubber weirs. Whereas installation of adjusting units is possible when adjusting function is required, it is recommendable to install steel gates together because complification of equipment may upset advantages of rubber weirs. When rubber weirs are used as lock gate, with which water depth is great and upstream-downstream water level difference is small, incomplete flattening may easily occur. Impossible discharge water by underflow constructionally, rubber weirs may not be able to perform sufficiently for discharging soil and sands.

Steel gates should be designed in accordance with Ordinance of constructions of river controlling facilities, and Parts of survey and planning of TSEP.

3.3 Hydraulic quantities as objects of design

In designing rubber weirs, necessary hydraulic quantities should be set up as objects of design according to the place and purpose of installation.

Explanation

Hydraulic quantities should be set up as design objects in the following manner, according to necessity, from both aspects of river improvement safety and determination of construction of portions and scale of the weir.

1) Flow rate as design object

Design of parts relating to river improvement safety like determination of weir span should take planned high flow rate, determined by the person controlling the river, as objective flow rate. When the planned high flow rate is to be revised, value after revision should be taken. When no high flow rate is established, value calculated with the method to determine planned high flow rate described in Part of survey of TSEP should be taken as the object value.
For flow rate determined from purpose of weir installation like that of flow rate adjusting gate or flood discharging gate, range of flow rate determined by tube flattening value and raising value should be set up.

2) Water level as design object

To determine tube form, stress calculation and lift pressure, all combination of foreseen operations of the weir should be examined. The maximum and the minimum water levels in upstream and downstream of the weir should be established. Additionally, the maximum and the minimum tidal levels should also be estbalished as downstream water level when the weir is installed at the river mouth. The water level conditions with which tube tension becomes maximum should be set up as the value to calculate rubberized fabric stress with in order to determine calculated design tension. Upstream water level should not exceed planned high water level as a result of top raising with the weir.
Tube of the rubber weir deforms by water level change, changing weir height also. Hence, investigation relating to design water level is more important for rubber weirs than for weirs with steel gate. For example, tidal level for flattening should be determined with downstream water level besides upstream water level and overflow quantity in case

when the weir is installed near a river mouth. Since weir height increases with a raised downstream water level, overflow rate in flattening may not meet design flow rate because of weir height change if tidal level at the time of weir operation is different from design tidal level.
Therefore, in case when flattening is to be executed for a specific upstream water level and a specific overflow rate irrespective of downstream water level change, design water level should be determined taking measures such as selection of less deforming tube shape and installation of weir height adjusting devices into consideration.

3) Quantity of soil and sand transportation

For investigation of mud pressure on the weir, wear of the tube and necessity of silt treatment, quantity of soil and sand transportation should be set up at the place of installation according to periods of raising and flattening.

3.4 Operation conditions

Necessary raising and flattening conditions of a rubber weir should be set up based on purpose of its installation.

Explanation

Fundamental conditions for raising and flattening include operation rate and water level and flow rate at the time of operation start. Raising rate should be determined considering operation frequency, capacity of the raising devices and operation time required for control. Flattening rate should be determined so as to satisfy purpose of installation considering effects to downstream besides upstream water level change brought about by discharge. (Refer to 1.4, Chapter 4, Part of design.)

Setting up of water level and flow rate is relatively easy for a weir with which ordinary operation includes only complete closing and full opening and flattening is executed only when upstream water level exceeds a specific value. However, setting up of operation conditions is complicated in cases such as design water level and flow rate are to be determined for flattening period and for ordinary times each, down stream changes irrespective of weir operation like in backwater section or tide sensitive section, or as flow rate is to be adjusted without co-installation of steel gate.

Regarding to tube deformation characteristics of rubber weirs which is described in 1.10, Chapter 2, Part of design, weir height should be adjusted by feeding or discharging inflating medium according to conditions in cases when design water level and flow rate combination becomes complicated. This is similar to downstream water level change. And, when actions by means of cross-section shape change and internal pressure change cannot meet the requirement, installation of adjusting devices becomes necessary.

In case of use of rubber weirs of air type for flow rate adjustment, V notch effect should be considered besides tube deformation by water level change. (Refer to 1.7, Chapter 2, Part of design.) Since weir height becomes difficult to know once V notch occurs, suitable operation conditions should be set up including adoption of weirs of water type in cases of wide adjustment range and co-installation of steel gates.

Section 4 Design conditions

4.1 Principle of construction (Refer to Art. 36 of Ordinance of construction of river controlling facilities.)

A rubber weir should satisfy the following principles of construction.

1. To be safe to action of running water of a level lower than the planned high water level (or planned tidal level in a section of high tide).
2. To let flow safely flood of a water level less than the planned high water level without giving any harmful effect to nearby river banks and river controlling facilities, and take suitable consideration for prevention of wash-cutting of connected river bed and high water bed.

4.2 Relation with river profile and section configuration

1. Floor level of a weir should be determined so that top of the flattened tube be not higher than planned river bed level or current level whichever the lower.
2. Shape of weir section normal to the river should fit to upstream and downstream low water revetment or bank side slope at the place of installation if no steel gate is co-installed.

<u>Explanation</u>

1. Weir floor level should be determined so that height of flattened weir including the total thickness of rubberized fabric and tube damage preventive device be not more than the height of planned or current river bed level whichever the lower. Sufficient survey should be made on river bed variation at the place of weir installation. And, silt accumulation when raised and tube berial when flattened should be avoided.

2. A slope portion should be provided as shown in the Fig. 14 between the level of tube mounting bed plate, the apron and the bed protection face and the level of the planned or current river bed.

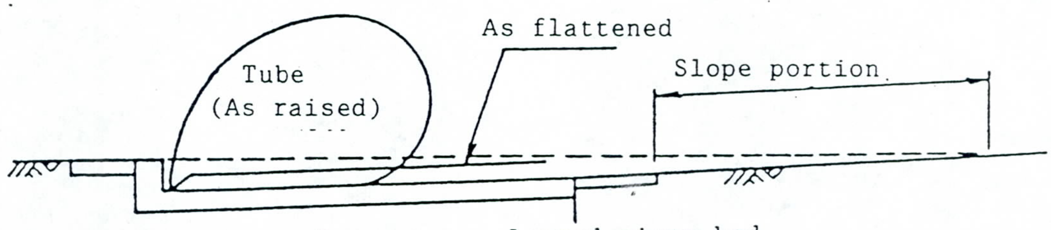


Fig. 1.4 Relation in river profile configuration

3. One of rubber weir's features is that it is attachable to any slope on both sides. Hence, side slope walls on which ends of the tube are attached should be matched to side slope of low water revetments in upstream and downstream of the weir or that of the bank. And, consideration should be taken so that tube height be not so large as to give a great disturbance to water flow along the side slope, when the tube is flattened, by its attachment.

4.3 Loads

The loads used for design of weirs should be as follows:

1. Self weight	:	To be calculated with weight per unit volume.
2. Static hydraulic pressure	:	To be considered with combinations of water levels possible to occur in weir operation.
3. Dynamic hydraulic pressure	:	To be studied by Westergaard's approximation. If inflating medium is water, its action on the tube caused by earthquake should be considered.

4. Ice pressure	:	To be 20 t/m^2 for portions contacting frozen water only in cases of ice thickness not less than 10 cm in cold areas.
5. Wave pressure	:	To be determined considering wave force caused by wind and earthquake.
6. Mud pressure	:	To be considered when soil and sand accumulation is expected.
7. Residual water pressure	:	To be considered when a water level difference is produced between the front and the back of walls such as side wall and retaining wall of tube attachment by combinations of water levels foreseen in weir operation.
8. Soil pressure	:	To use Rankine's or Coulomb's formula of soil pressure for ordinary soil pressure and Monobe and Okabe's formula for earthquake soil pressure, using data of soil quality tests such as soil unit volume, weight, internal friction angle and adhesion.
9. Lift pressure	:	To assume 100% of weir upstream-downstream water level difference at the start point of percolation path by combinations of water levels foreseen in weir operation and be gradually reduced as the percolation proceeds.
10. Wind load	:	To assume 300 kg/m^2 on vertical projected area of the structure.
11. Snow load	:	To assume 100 kg/m^2 on snow face. The value, however, should be increased or decreased according to the locality.
12. Car load	:	To consider TL-14 (2nd class load) or TL-20 (1st class load) according to necessity.
13. Temperature load	:	To consider load caused by temperature change. A temperature change of ± 15°C and a coefficient of thermal expansion of 1×10^{-5} per °C should be adopted.

14. Earthquake force	:	To adopt the seismic intensity method. Design intensity of earthquake should be calculated by the formula given below, neglecting vertical intensity:

$$Kh = \gamma_1 \times \gamma_2 \times \gamma_3 \times K_0$$

Kh	:	Design horizontal seismic intensity
K_0	:	0.2 for standard design horizontal seismic intensity
γ_1	:	Local correction factor given in the table in Explanation below.
γ_2	:	Local correction factor given in the table in Explanation below.
γ_3	:	Correction factor by importance of 1.0. For an earthquake of extremely large scale and with large effects, however, this factor can be assumed as 1.25.

Explanation

1. It has been concluded that Westergaard's approximation formula should be adopted for calculation of dynamic hydraulic pressure at times of earthquake. Because of the tube's flexible structure, however, this formula may give results larger than the actual values. Dynamic hydraulic pressure working on a flexible structure at times of earthquake remains to be analyzed in the future.

2. For wave pressure, assumed are waves caused by wind and earthquake, whose height can be determined by the methods described below:

1) Wave height by wind

SMB method is generally used for calculation of the height.

$$hw = 0.00086V^{1.1} \cdot F^{0.45}$$

where, hw : Total wave height (significant wave) (m)

F : Distance to shore (m)

V : Wind velocity (mean for 10 min) (m/s)

2) Wave height by earthquake

$$he = \frac{Kh \cdot \tau}{\pi} \cdot \sqrt{gH}$$

where, he : Total wave height (m)

Kh : Design horizontal seismic intensity

τ : Earthquake's vibration period (s)

H : Depth from design water level to tube mounting bed plate level (m)

3. Horizontal mud pressure should be calculated by the equation given below taking vertical mud weight in water:

$$Pe = Ce \cdot W_1 \cdot d$$

where, Pe : Horizontal mud pressure (t/m^2)

Ce : Mud pressure coefficient

w_1 : Mud weight in water (t/m^2)

d : Depth from design water level to an arbitrary point on the contact face (m)

Mud represents the state that voids in the mud particles are perfectly filled with water, not the state that mud particles are suspended in water. Hence, the equation below gives its weight:

$$w_1 = w - (1 - \nu) \cdot W_0$$

where, W : Apparent unit weight of mud (t/m^2)

ν : Void ratio in mud

W_0 : Unit weight of water

As approximation of these variables, the following are conventionally adopted:

$w = 1.5 \sim 1.8t/m^2$, $\nu = 0.3 \sim 0.45$, $w_0 = 1.0t/m^2$, $Ce = 0.4 \sim 0.6$

4. Residual water pressure represents, with regard to a structure consisted of water tight wall or whose back-filling permiates little water, water pressure caused by water level difference generated by time lag of backfill water level change to the front water level change. For tide sensitive portions, 2/3 of the front tidal change is assumed.

5. For determining design horizontal seismic intensity, correction factor of locality γ_1 and that of ground construction γ_2 are obtained from the figure and the table below:

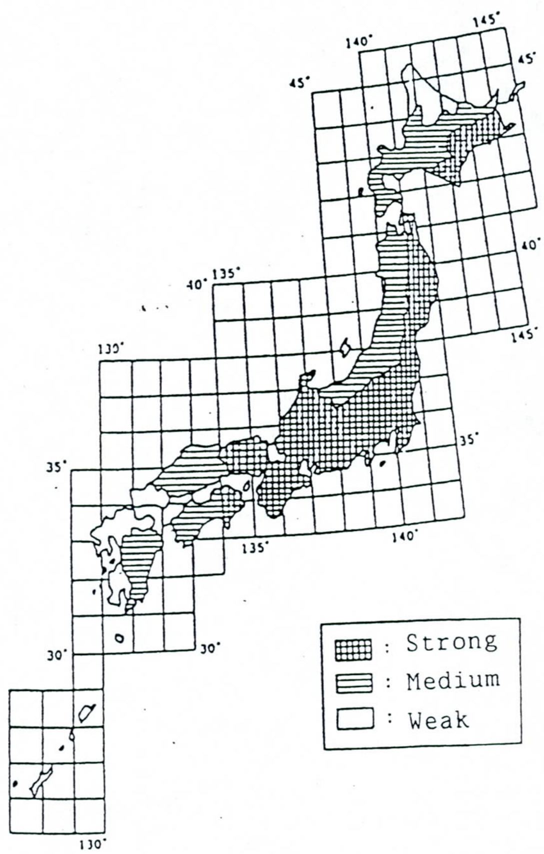


Fig. 1.5 Localities of seismic intensity

Table 1.3 Correction Factor by Localities

Relative intensity	Correction factor γ_1	Appropriate areas

Relative intensity	Correction factor γ_1	Appropriate areas

Relative intensity	Correction factor γ_1	Appropriate areas

Table 1.4 Correction Factor by Ground Construction (γ_2)

Classification	Ground construction	Factor
1	(1) Stratum generated prior to Tertiary period (termed as rock-bed hereinafter) (2) Diluvium of a thickness less than 10 m to rock-bed	0.9
2	(1) Diluvium of a thickness not less than 10 m to rock-bed (2) Alluvium of a thickness less than 10 m to rock-bed	1.0
3	Alluvium of a thickness less than 25 m and soft stratum of a thickness less than 5 m	1.1
4	Others	1.2

Section 5 Model test

5.1 Application of the test

When reliable judgment cannot be obtained about effects given to river channel by tube installation and weir construction, tube behavior and overflow coefficient based on this standard and past materials, a model test should be made.

5.2 Method of the test

Similarity should be made sure for conducting a model test. Model materials and modelling range should carefully be investigated, and boundary conditions and measuring method should be suitably selected.

Explanation

Generally in model tests, precision of models and boundary conditions give effects on results, and method of measurement and personality of operator also produce differences in results.

Hence, verification tests and similarity of the model should be carefully examined. And, results of the test should be backed up by calculation as far as possible.

With regard to weirs of air type, compressibility of air in tube gives rise to difference between the model and the actual structure. This requires sufficient attention.

5.3 Judgment of results

Test results should be judged taking into consideration factors such as items omitted in similarity setup, difference of boundary conditions between the test and the actual, and accuracy of measurement.

Explanation

Since some results of test are incompatible with quantitative discussion, sufficient care should be taken on this point in judgment.

Chapter 2 Superstructure Design

Section 1 Generals

1.1 Definitions

Part names and states are defined as follows:

1. Tube attachment fittings	:	Consisting of bed plate and fittings.
2. Tube fixing bolts	:	Consisting of attachment bolts and anchor bolts.
3. Tube shrinkage and flattening	:	Terming the state that tube inflating medium is taken out as shrinkage, and the state that tube touches the bed plate or the apron directly as complete flattening.
4. Tube inflating medium	:	Indicating medium for inflating and raising the tube. Air or water is generally used, or both are co-used in some cases.
5. Rubberized fabric	:	Indicating woven cloth, reinforcing material, covered with various rubbers.

1.2 Design conditions

Tube should satisfy the following requirements:

1. Necessary weir height should be secured for combination of design water levels and design flow rates.
2. Tube should be safe to foreseen loads.
3. Tube's airtightness and watertightness and weir's watertightness should be secured.
4. Weir should easily and surely be raised and flattened. Its construction should, in particular, be such one as bringing about complete flattening in shrinkage.

5. Weir should be sufficiently durable.

6. Weir should not generate harmful vibration.

7. Weir should be convenient for maintenance.

Explanation

These are fundamentals to be considered in designing rubber weirs.

1) Tube deformation caused by water level change should not disturb purpose of weir installation for foreseen combinations of water level and flow rate. If tube deformation exceeds tolerable limits, weirs should be so designed as to satisfy required functions considering measures such as weir height adjusting devices and co-installation of steel gates. (Refer to 1.10, Chapter 2, Part of design.)

2) For designing tubes, the loads described in 1.3 of this section should be considered.

3) In designing fixing of rubberized fabric on bed plate, side slope and weir post, consideration should be taken so that no inflating medium leaks or no upstream water flows down to downstream in a form other than overflow. Consideration should also be taken so that "wrinkles" generated in the attachment to side walls do not cause water leakage. (Refer to 1.5, Chapter 2, Part of design.)

4) Devices for raising and flattening should be provided with sufficient capability and perform easily and securely. Weir construction should be such that incomplete flattening, when tube is shrinked, projects tube top above design river bed level as caused by remaining medium in the tube or soil and sand accumulation downside the tube. (Refer to 1.5, Chapter 2, Part of design.)

5) Since a weir is used for a long period, durability should be carefully studied in designing tube and fixing units.

6) When overflow depth is large, vibration may take place in tube. Efficient countermeasures to vibration should be provided when it must be avoided. (Refer to 1.6, Chapter 2, Part of design.)

7) The greatest advantage of weirs of this type is the fact that they are surer in flattening and easier in maintenance than weirs with steel gate. This advantage must be preserved in design.

1.3 Design load

> For design of tube, static hydraulic pressure, dynamic hydraulic pressure and seismic dynamic hydraulic pressure should be considered among the loads in 4.3, Chapter 1. Additionally, mud pressure, wave pressure, wind pressure, ice pressure, snow load and temperature change should also be considered according to site conditions.

Reference

Fig. 1.6 shows investigation results of horizontal wave force acting on tube measured on a model of air type weir 0.2 m high and 2.0 m long under the conditions of wave height of 1.5 cm to 7.0 cm and period of 0.93 sec to 1.29 sec. In the figure, positive wave force shows action of wave peak and negative force action of wave bottom. But, in application of these data, consideration should be taken on the fact that a part of wave passed over to upstream side in this experiment.

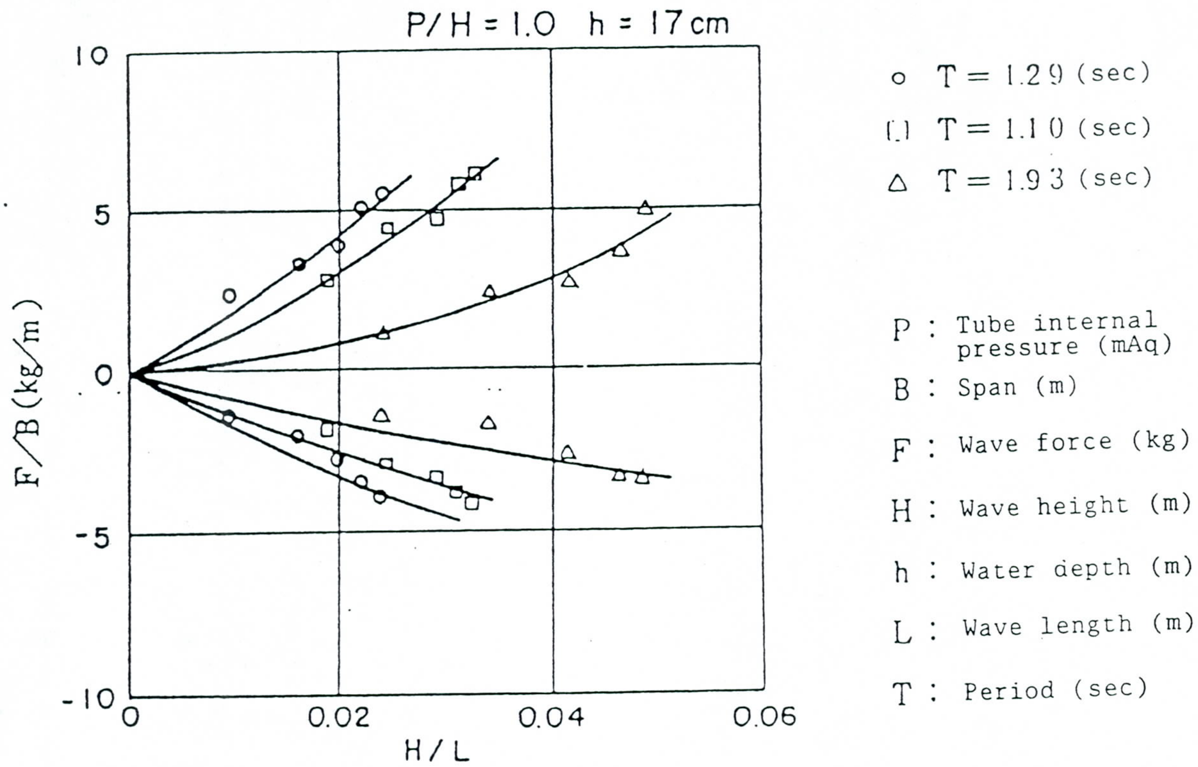


Fig. 1.6 Horizontal wave force acting on tube

Reference

Fig. 1.7 shows investigation results of tube internal pressure and tension variation measured using a weir models 0.15 m high, 3.47 m long and 0.3 m high, 3.47 m long. The larger the wave length and the lower the internal pressure, the greater the tension variation. With the same internal pressure, a weir of water type shows larger tension variation than air type.

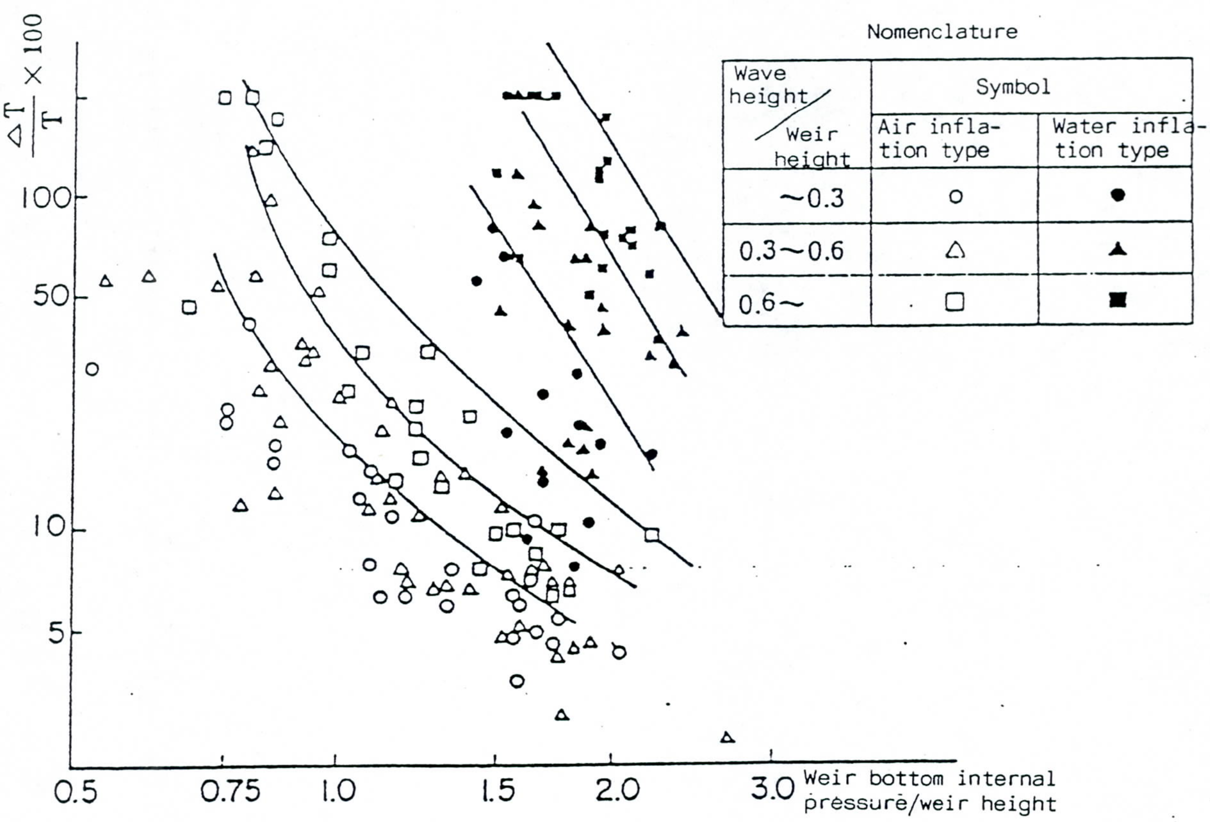


Fig. 1.7 Tension variation due to wave

1.4 Safety factor

Safety factor should be determined suitably within the range securing weir safety for tube after rubberization and adhesion, attachment unit and tube fixing bolts.

Explanation

Safety factor is currently taken at 8 or more to calculated design tension for tube and 3 or more for attachment unit and tube fixing bolts. Safety factor for earthquake should be 8/1.5 for 3/1.5 for tube fixing bolts.

1.5 Height of attachment to side wall

For ensuring water storage with tube, height of attachment to side wall should be determined larger than weir height.

Explanation

Though dependent on method of tube raising/flattening, height of attachment to side wall should be determined as shown in Fig. 1.8.

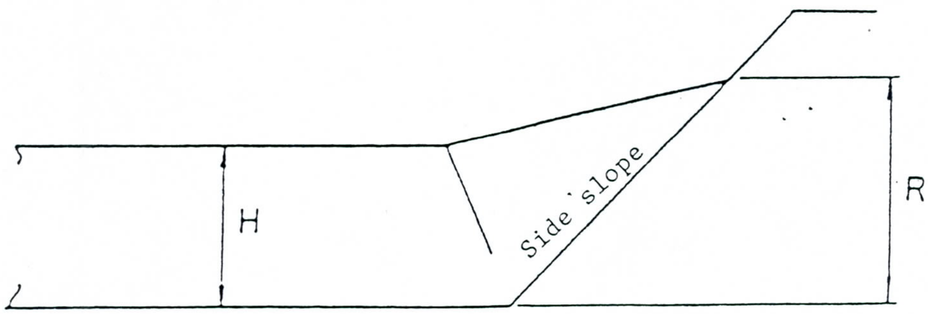


Fig. 1.8 Attachment of tube to side wall

In this drawing,

H: height of raised tube above bed plate, and

R: height of tube hanging-up when raised.

1. One side flattening type

Table 1.5 Table of Tube Attachment to Side Wall

Side slope	R Unit: mm
1:00 ∿ 1:0.5	(1.15 ∿ 1.20) H or H + 150
1:0.5 ≦	1.10H or H + 150

2. Both sides flattening type, and direct flattening type

R=16.0' × 1.2 = 19.2'

$R \doteqdot 1.20 \times H$

Though different by the type, whether raising/flattening or fixed type, angle of attachment ot side wall should be selected suitably in relation with design hydraulic quantity so that no stress concentration does not occur near the attachment.

1.6 Maximum overflow water depth

Standard overflow depth over tube at normal times should be taken not more than the following values:

1. Air inflation type: 0.2H   .2(16) = 3.2'
2. Water inflation type:
   - When downstream is exposed jet flow; 0.5H
   - When downstream water level is higher; 0.4H (P/H = 2.5 ∿ 3.0)
     - 0.3H (P/H = 2.0 ∿ 2.5)
     - 0.2H (P/H = 1.5 ∿ 2.0)

where, H: Weir height at time of overflow (m)

P: Weir bottom internal pressure (mAq)

Explanation

Due to flexible structure of rubber weir, vibration takes place in tube when overflow water dpeth is large. While the vibration starting limit value depends on downstream water depth, internal pressure, tube shape, material, etc., the values listed above give the limit overflow water depth based on experiments on standard rubber weirs.

Effect of downstream water depth is small for weirs of air inflation type. But, weirs of water inflating type easily produce vibration when downstream water level is high. Therefore, for such cases, the maximum overflow depth is determined for each internal pressure range of tube.

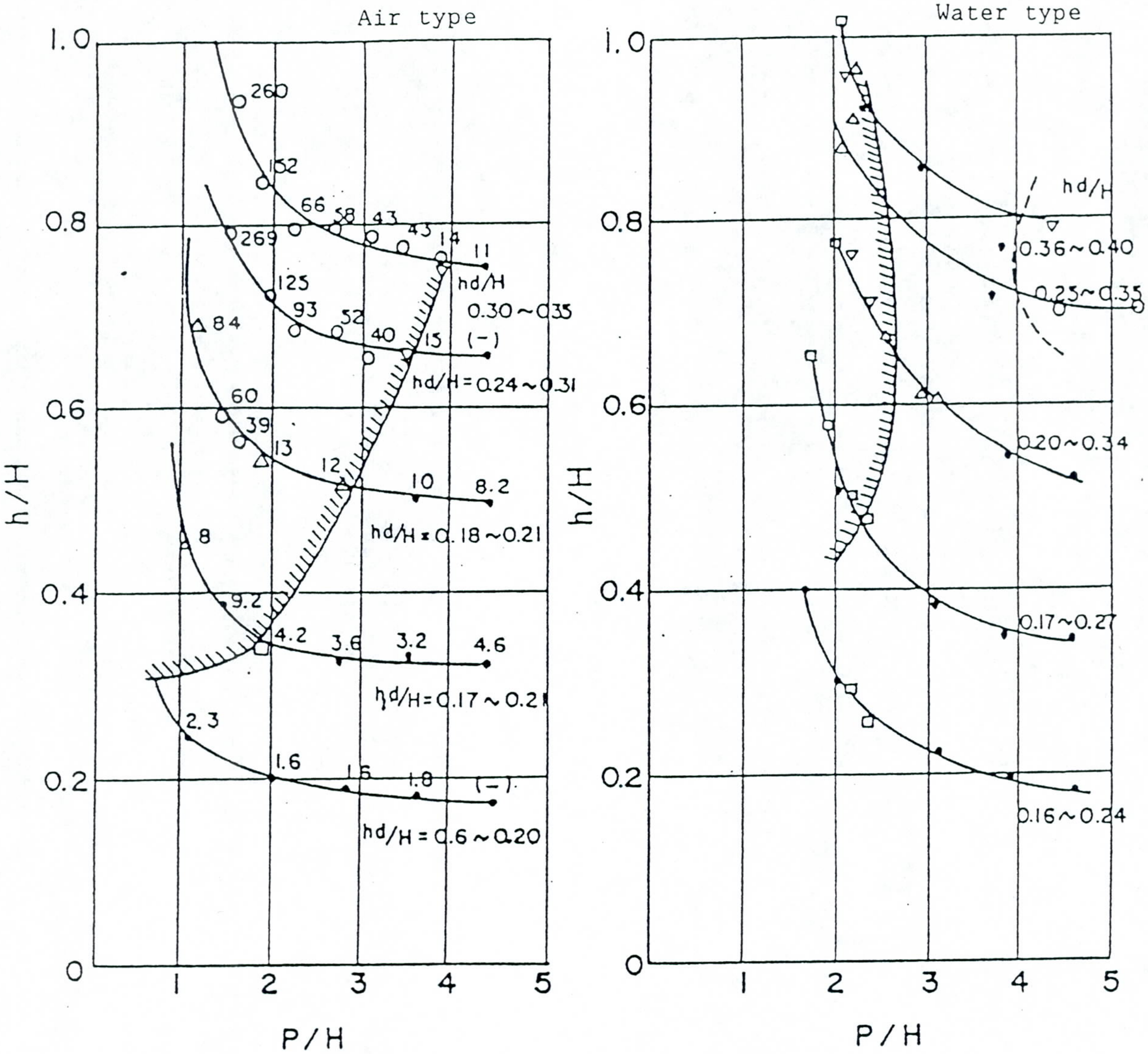
If the expected maximum overflow depth exceeds the above-mentioned maximum leading to possibility of vibration, effective measures such as installation of a damper should be taken and the effect should be verified.

Reference: Vibration starting limit

Fig. 1.9 shows experimental values obtained with a weir model 0.2 m high and 4.0 m long. Generally speaking, raising internal pressure makes vibration hard to occur. But, with weirs of water inflation type, too great an internal pressure ($P/H = 4 \sim 5$) causes a very strong vibration. Care should be taken against this.

From this figure, a tension variation rate of approx. 10% may be the limit of vibration occurrence.

When to present data in relation with downstream water depth, Fig. 1.10 is obtained showing the fact that weirs of water inflation type easily vibrate when downstream depth is large. Vibration starting limit can be raised by increasing fixture interval of tube and making its cross-section near semi-circle. And, increasing stiffness of tube's rubberized fabric also suppresses vibration start. Fig. 1.11 shows these effects based on experimental results.



Note) Figures indicate tension variation rate.

Nomenclature

Symbol	Vibration
•	None
□	Extremely small
△	Small
▽	Medium
○	Large
\\\\\\\\\\\\	Vibration range

H : Weir height (m)

h : Overflow depth (m)

p : Internal pressure (mAq)

hd : Downstream water depth

Fig. 1.9 Vibration starting limit with exposed jet flow in downstream

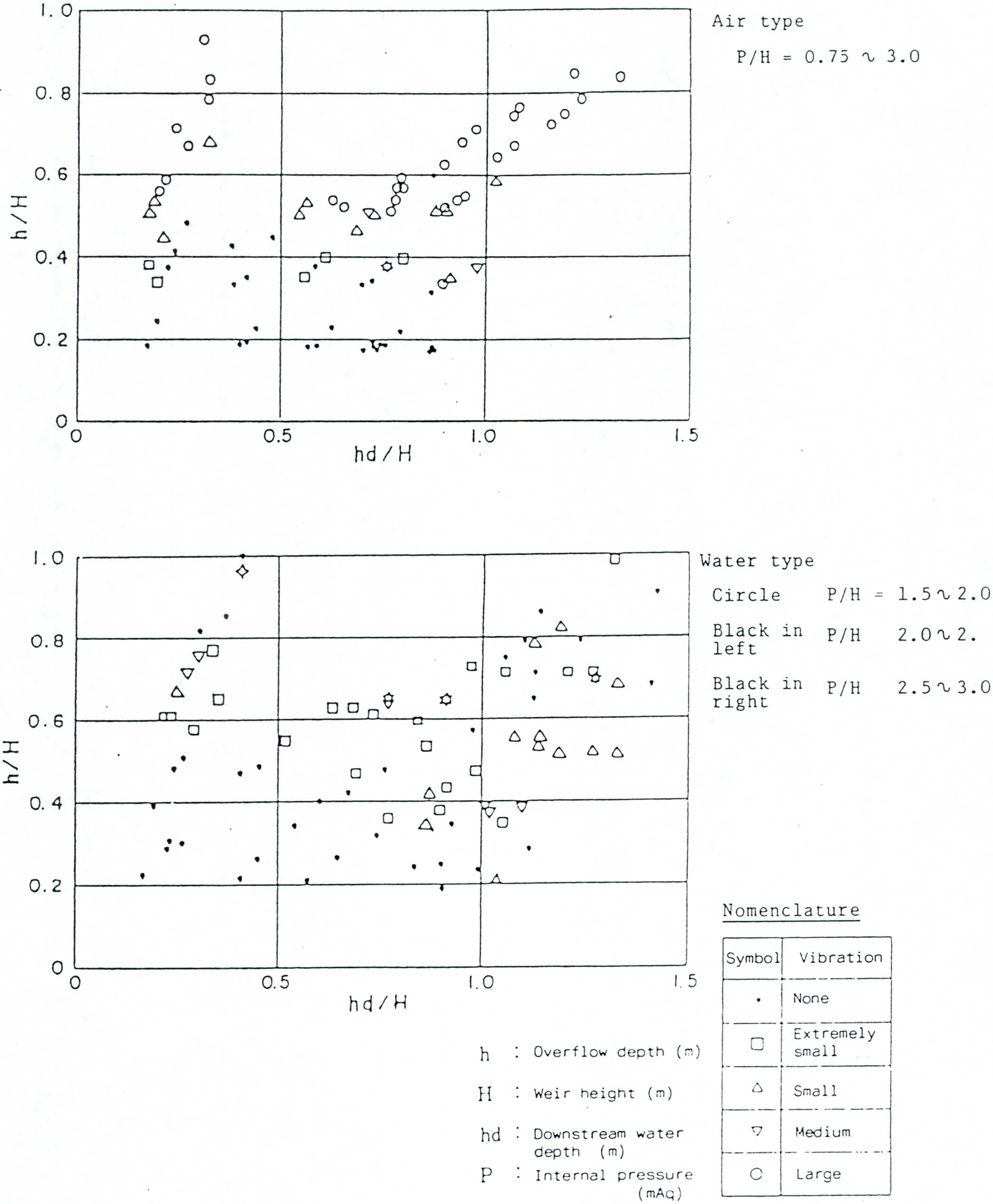


Fig. 1.10 Downstream water depth and vibration starting limit

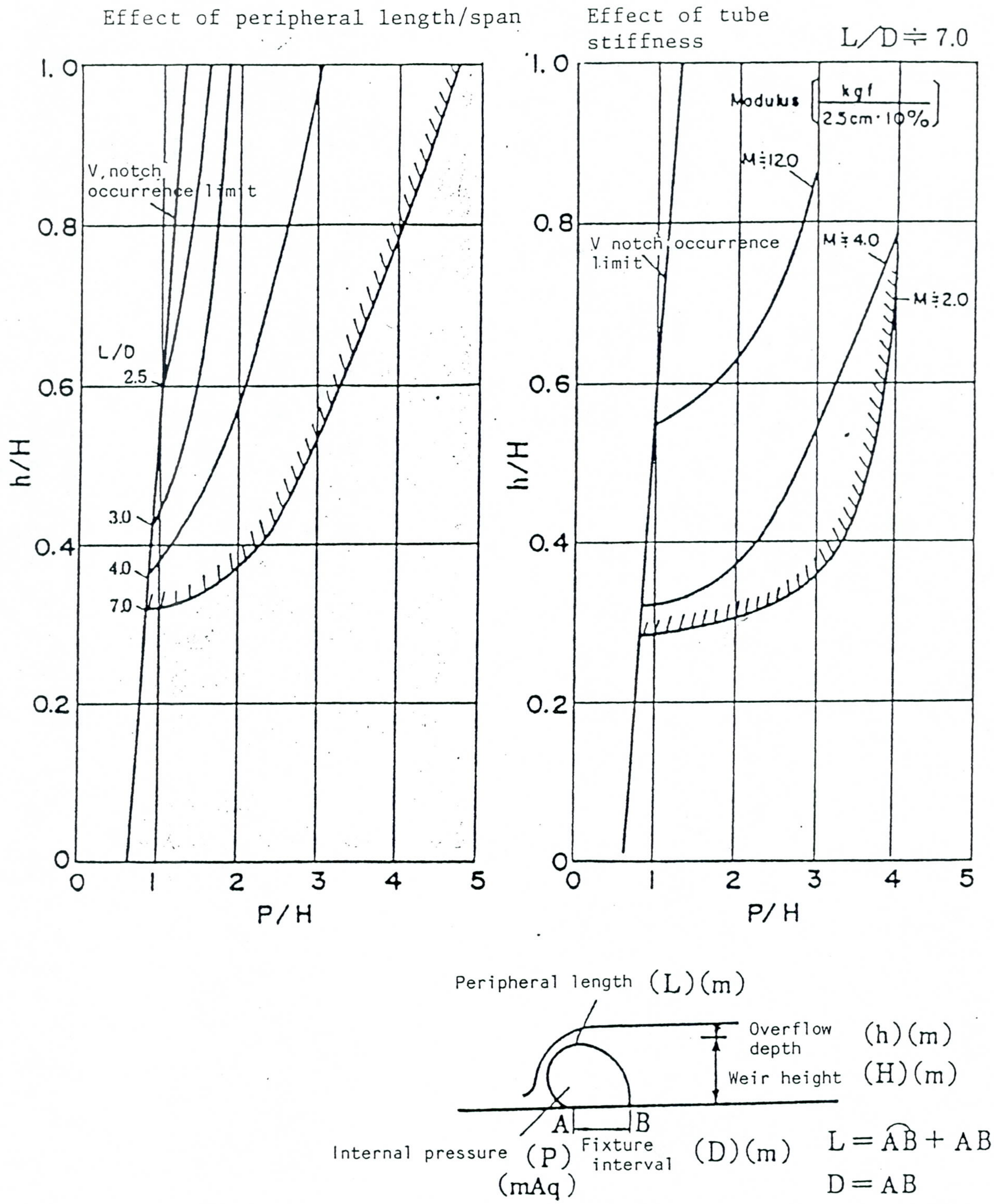


Fig. 1.11 Shape and stiffness of tube and vibration limit

Reference: Vibration suppressing devices

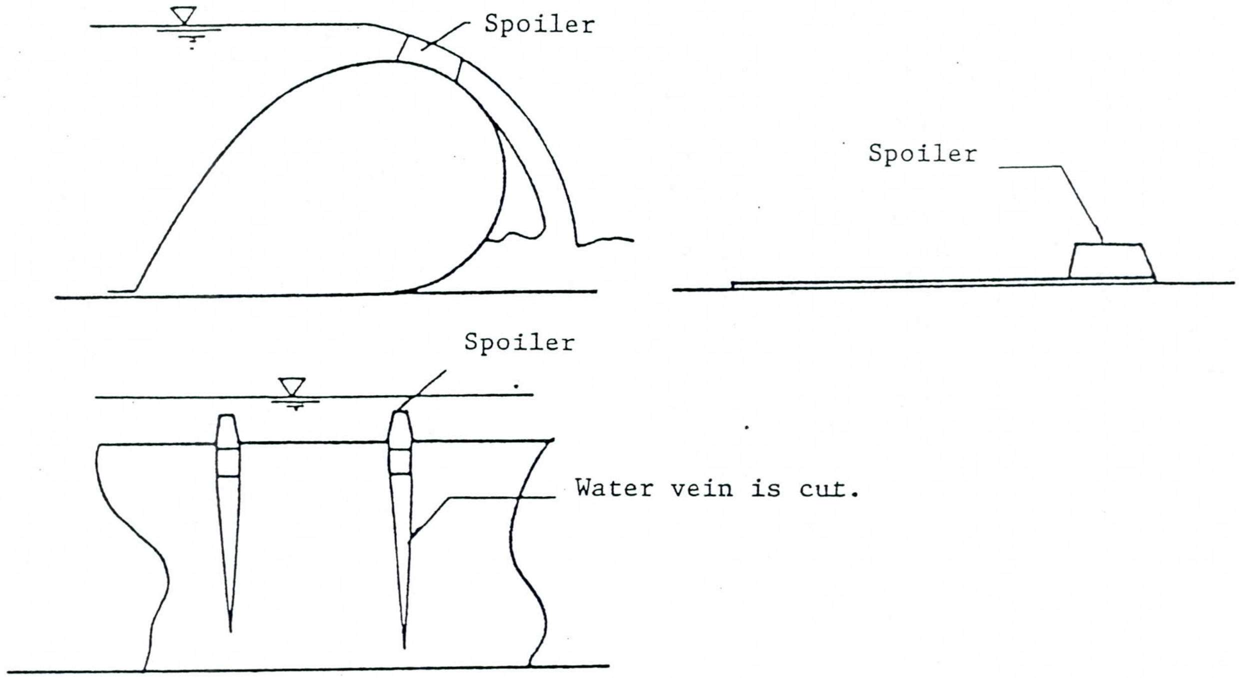
As vibration suppressing devices, those such as spoiler and deflector shown in Fig. 1.12 have been developed. Devices of two or more devices can be used together. All of these secure sufficient ventilation between overflow water and tube, which makes overflow water burble off the tube reducing tube vibration as a result.

Hence, the effect may be limited depending on relation between device dimensions and shape and overflow depth. A large depth of overflow requires a large device. Since some materials and shapes of vibration suppressing device may capture flowing-down matters so as to cause damages to the tube, considerations should be taken so that strength of the device be not higher than the tube itself.

Fig. 1.13 shows an experiment result obtained on a model weir of a height of 0.2m and a span of 3.0m attached with a deflector of a width of 2cm.

Overflow vibration characteristics depend on overflow depth, downstream water depth, span and material. Therefore, investigation by experiment on individual models should be done for determining shape and dimensions of vibration suppressing devices.

a) Spoiler method



b) Deflector method

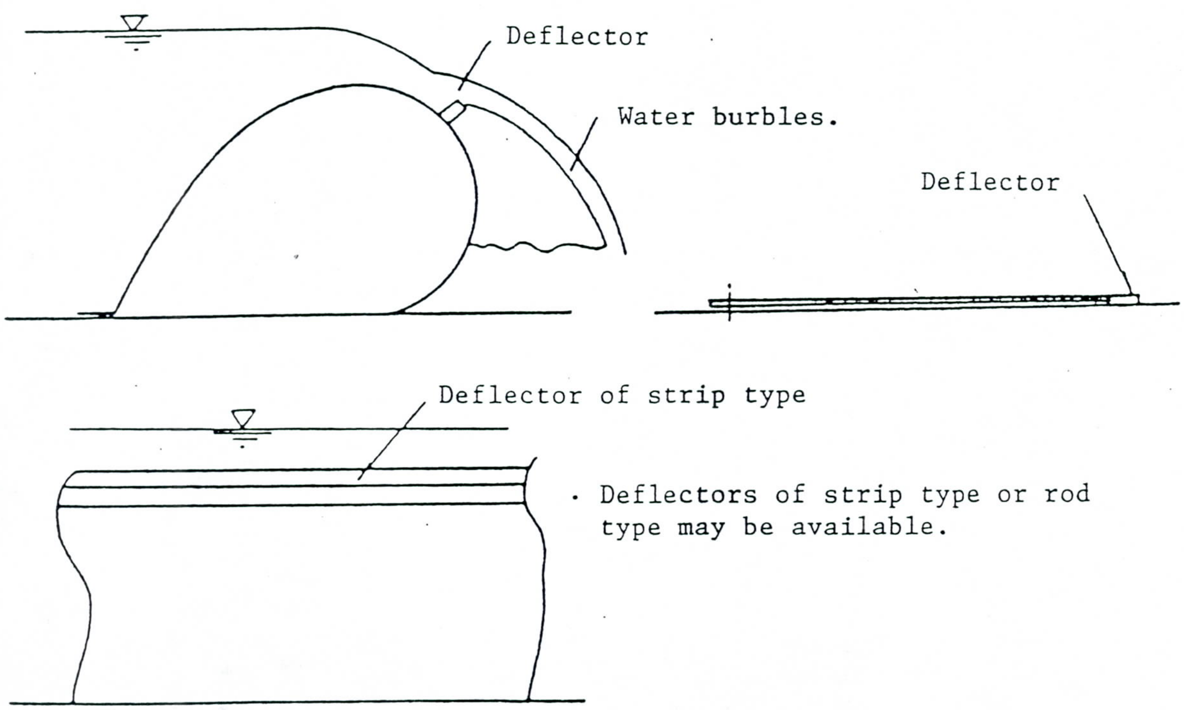
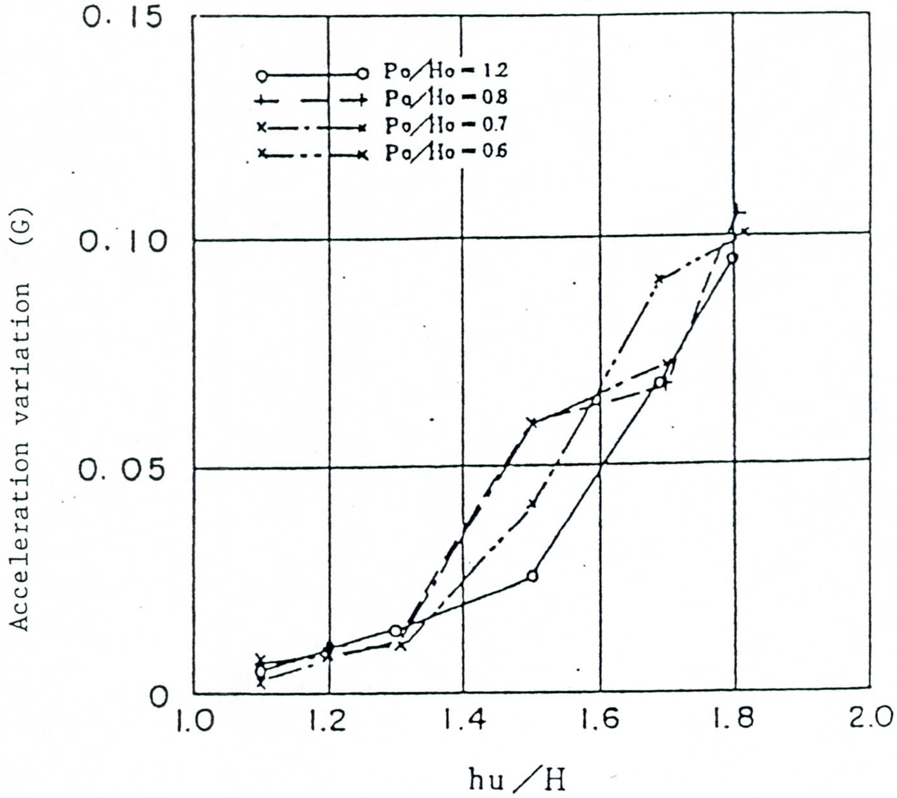


Fig. 1.12 Examples of vibration suppressing devices

Without deflector   Exposed jet flow in downstream



H : Weir height (m)

Ho : Initial weir height (m)

hu : Upstream water depth (m)

Po : Initial internal pressure (mAq)

With deflector   Exposed jet flow in downstream

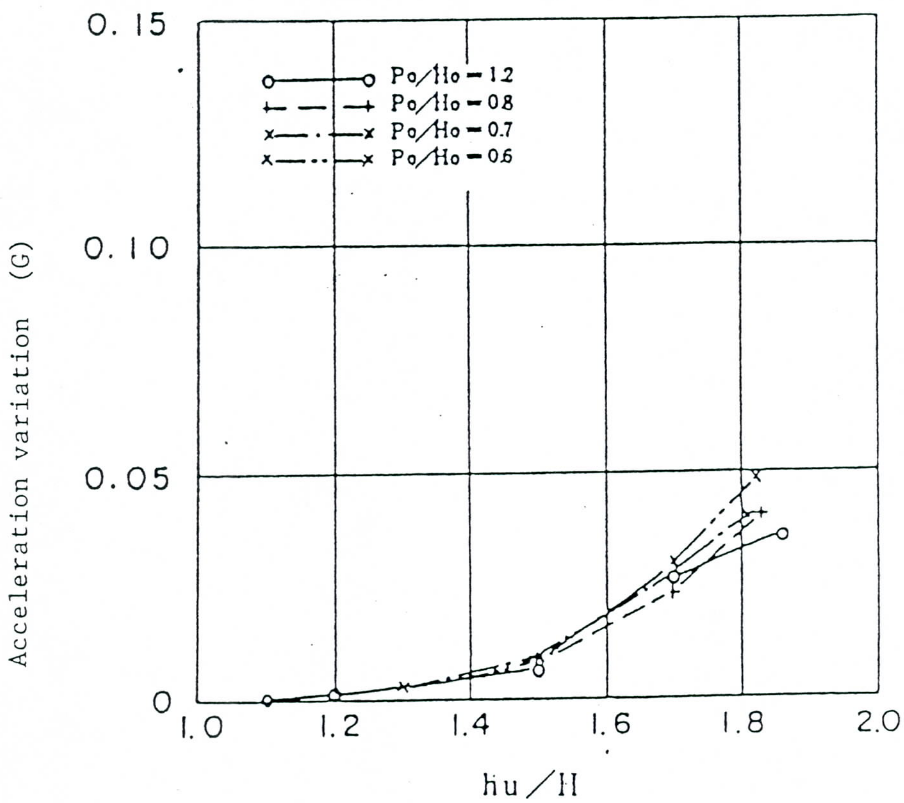


Fig. 1.13 Example of vibration suppressor application

Reference: Flow rate coefficient

Flow rate coefficient of a weir depends on upstream and downstream water levels, internal pressure, inflating medium and fixture interval. In addition, since tube attaching portion to side wall is made higher than the tube height, width of overflow in case of trapezoidal river section increases as overflow depth increases while no overflow portion is formed when overflow depth is small.

In this book, experimental formulas have been prepared to get rough estimation of general flow rate coefficient for rubber weirs as shown in Figs. 1.14 and 1.15. Those formulas are based on past experiences and experiment data under conditions of $P/H = 1.0 \sim 2.0$ for air type and $P/H = 1.5 \sim 2.5$ for water type. Because flow rate coefficient in case of imperfect overflow and diving overflow fits to Homma's formula for trapezoidal weirs, the same expression has been adopted.

Flow rate coefficient's experimental expressions of rubber weirs:

1) Perfect overflow

$$Q = C \cdot B \cdot h^{3/2}$$

For air type, $C = 1.77 \cdot h/H + 1.05 \quad (0 < h/H < 0.6)$

For water type, $C = 1.37 \cdot h/H + 0.96 \quad (0 < h/H < 1.0)$

2) Imperfect overflow

$$Q = C' \cdot B \cdot h^{3/2}$$

$$C' = (-0.2 \cdot \frac{hd-H}{h} + 1.1) \cdot C \quad (0.5 \leqq \frac{hd-H}{h} < 0.85)$$

3) Diving overflow

$$Q = C'' \cdot B \cdot h^{3/2}$$

$$C'' = (2.82 \cdot \frac{hd-H}{h} \cdot \sqrt{1-\frac{hd-H}{h}}) \cdot C \quad (0.85 \leqq \frac{hd-H}{h} < 1.0)$$

where, Q: Flow rate

C, C', C'': Flow rate coefficient

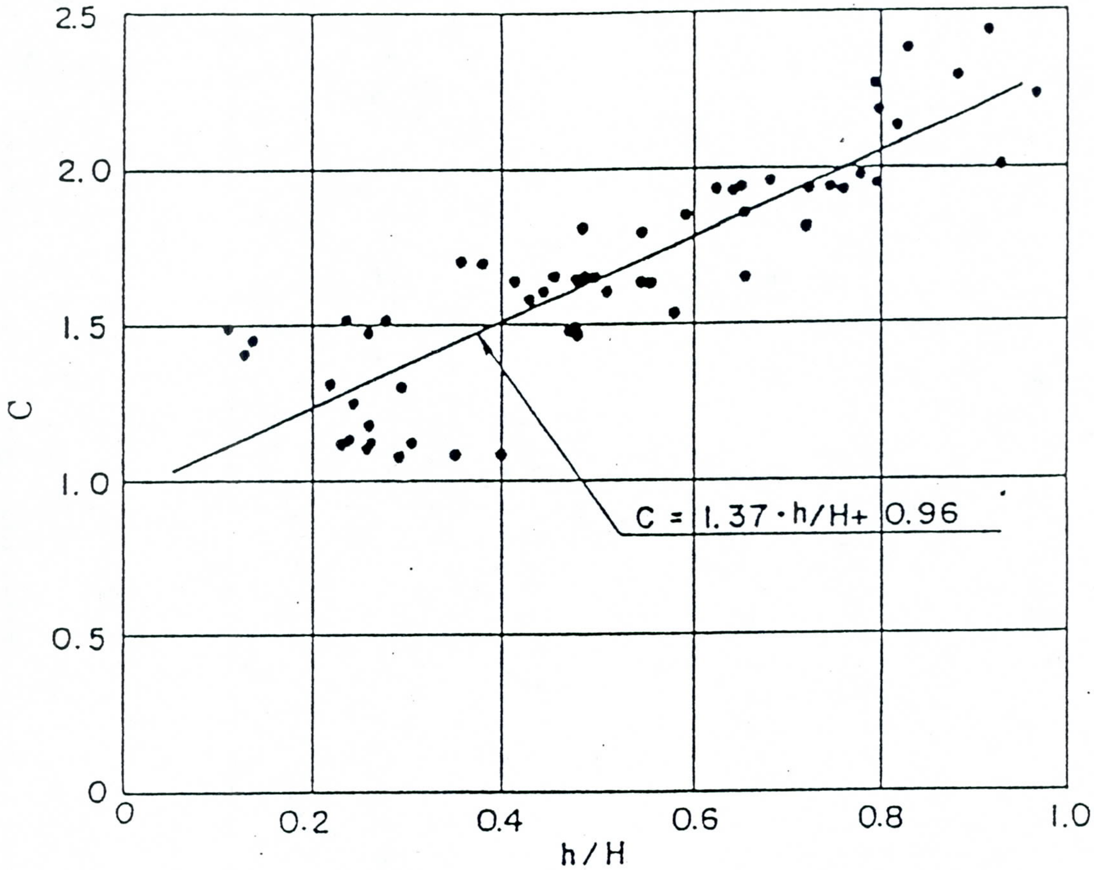
B: Span

h: Overflow depth

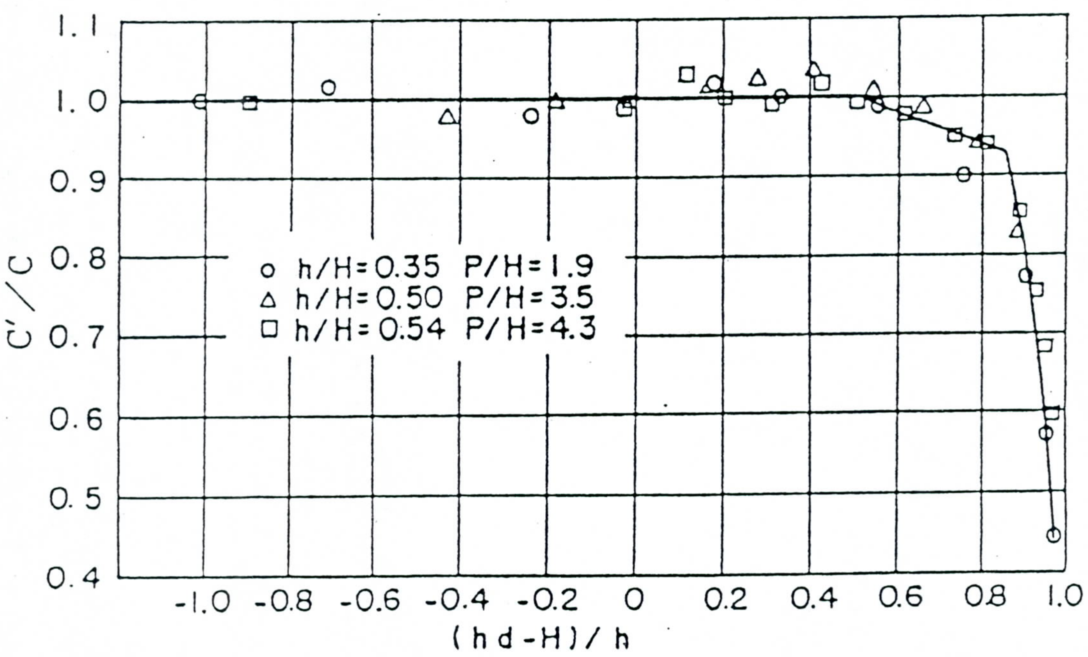
H: Weir height

hd: Downstream water depth

Case of perfect overflow



Case of imperfect and diving overflow



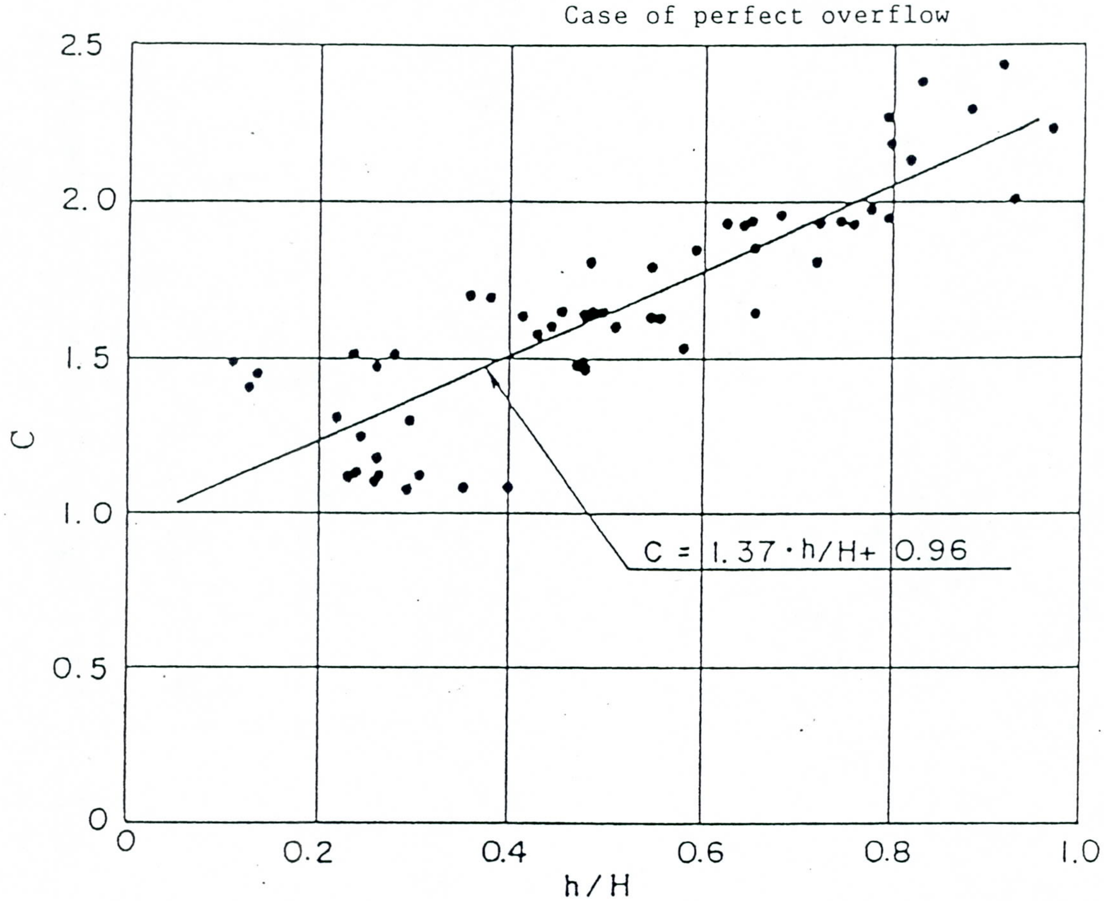
C,C' : Flow rate coefficients

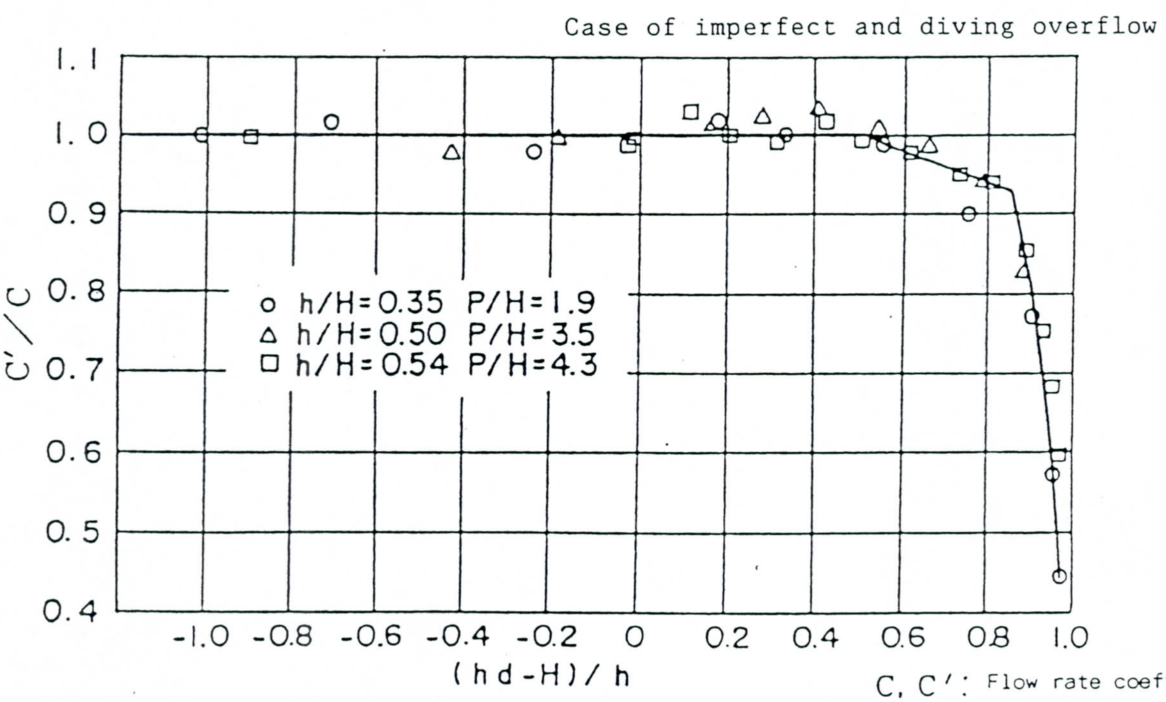
H : Weir height (m)

h : Overflow (m)

hd : Downstream water depth (m)

Fig. 1.4 Flow rate coefficient of weir of air type





C, C′ : Flow rate coefficients
H : Weir height (m)
h : Overflow depth (m)
hd : Downstream water dpeth (m)

Fig. 1.15 Flow rate coefficient of weir of water type

1.7 Selection of tube inflating medium

Tube inflating medium should be selected among water, air and co-use of both considering the following comprehensively:

1. Natural conditions of installation site (ambient temperature, ground quality, hydraulic quantity, etc.)
2. Purpose and operation policy (required function, operation frequency)
3. Easiness of maintenance and control
4. Constant securability of inflating medium
5. Economy

Explanation

Available tube inflating media are water, air and co-use of both, each of which has features as follows:

Table 1.6 Comparison of features of tube inflating medius

Item \ Type	Water type	Air type
Ambient temperature	Inflating water may freeze in an extremely cold area.	In an area of large temperature variation, tube internal pressure varies.
Ground quality		More advantageous at a place of soft ground.
Medium securability		Easy.
Tube peripheral length	Longer because tube becomes oval.	
Tube mounting bed plate	Longer for the same reason as above.	
Overflow depth	Bearing larger overflow depth than air type when downstream water depth is small.	

Tube shape stability in operation	Uniform overflow with a rather constant depth.	V notch produced at a low internal pressure.
Water level adjustment	Adjustment range wider than air type.	Adjustment difficult under a condition of V notch occurrence.
Tube deformation	Small deformation caused by water level change.	
Performance to wave		Small tension variation and tube oscillation caused by waves.
Feeding/ discharging time	Discharge time gets longer, with natural discharging, if downstream water level rises.	
Feeding/ discharging pipe	Possible soil and sand accumulation in pipe according to method for taking water in.	Possible to use smaller pipe than water type.
Other structures	Requiring sand settling basin and water tank in many cases.	

Weirs of air type is generally more advantageous in operatability and economy than water type because of feeding/discharging installations of smaller scale. A proper problem of weirs of air type is V notch effect, which makes flow rate adjustment difficult and produces a large flow rate per unit width. Therefore, careful consideration should be paid on this problem. Weirs of water type bear larger overflow depth than air type when downstream water depth is small. They are also superior to air type in keeping and adjusting weir height because of no V notch occurrence in flattening and smaller deformation of tube caused by water level changes in upstream and downstream.

No problem for securing inflating medium with weirs of air type whereas some problems may exist with water type depending on what water is to be used. For example, when to use river water, a screen and a settling basin are required as well as a difficulty may take place in case of water shortage. And, in case when to use underground water, pumping facilities are required as well as a well or a tank of sufficient pumping capacity. If supply water is used alternately, a reservoir is required depending on operation frequency because of expensive cost. Additionally in case of weirs of water type, care should be taken on the fact that tube weight, when raised, is considerably large when weir scale is large.

Reference: Example of water and air co-use

An example of water and air co-use is given in Fig. 1.16. With this system, air is put in the internal tube and river water is let into the external tube making use of buoyancy of the internal tube.

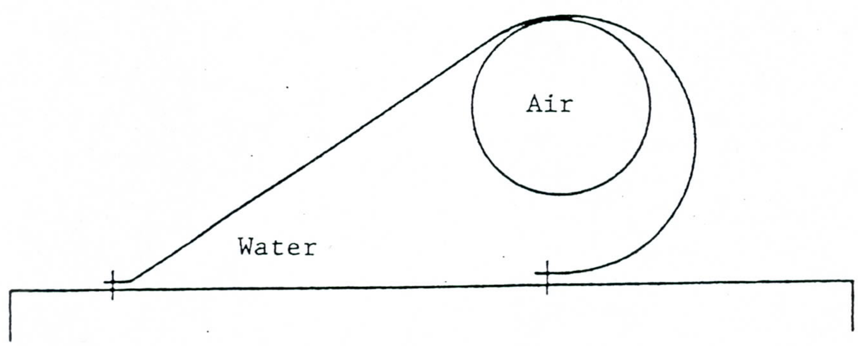


Fig. 1.16 Water and air co-use system

Reference: V notch occurrence limit

Fig. 1.17 compares Ogiwara's theoretical formula of V notch occurrence limit and results of a model test. P/H at V notch occurrence and h/H are in almost linear relation.

Weir height in V notch occurrence depends on initial internal pressure, peripheral length/fixture interval ratio, etc., and is roughly 70 to 80% of the initial height in general cases.

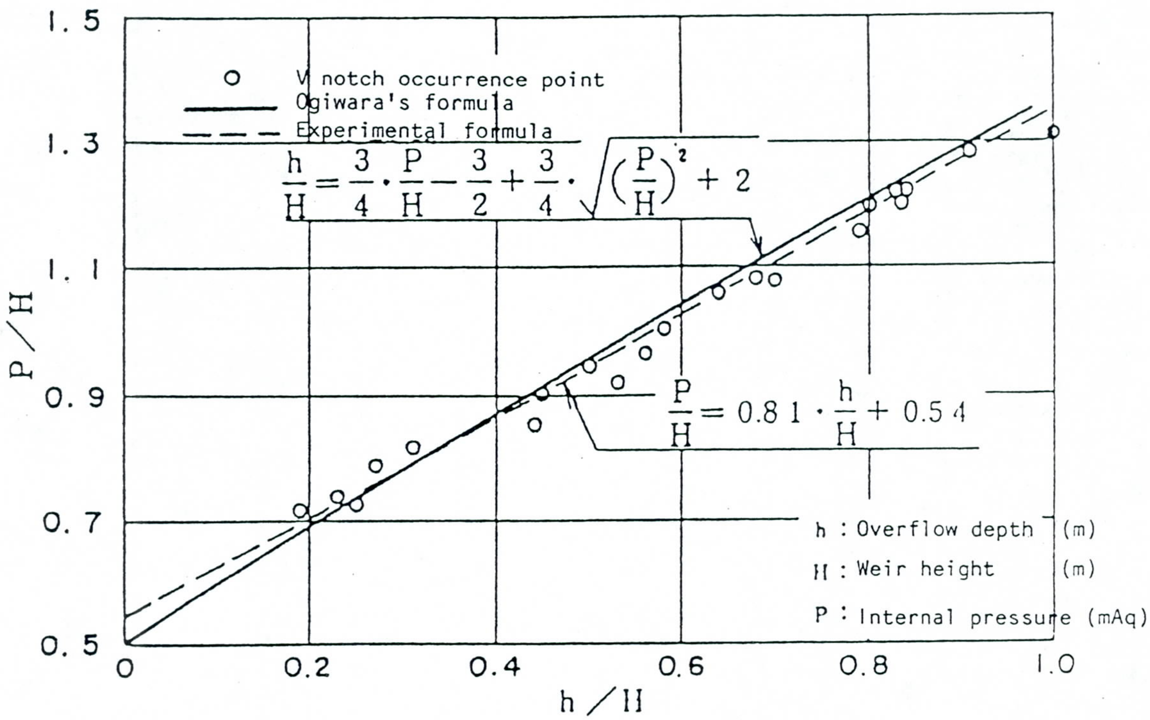


Fig. 17 Internal pressure and overflow depth at V notch occurrence

1.8 Selection of tube flattening system

Tube flattening system should be selected depending on flow characteristics at installation site among one side falttening, both sides flattening and direct flattening.

Explanation

Fig. 1.18 shows outlines of each flattening system. Each system should generally be selected by the following standard:

1) One side flattening system

This system should be applied to a case where flattening direction is constant such as water flows to downstream at all times. This is the most typical application and includes most of the past records. Since tube attachment to side wall is inclined to downstream in this sytem, if the flow were reversed as a result of reversal of water level difference between upstream and downstream, stress concentration would be produced at the attachment portion according to tube shape.

2) Both sides flattening system

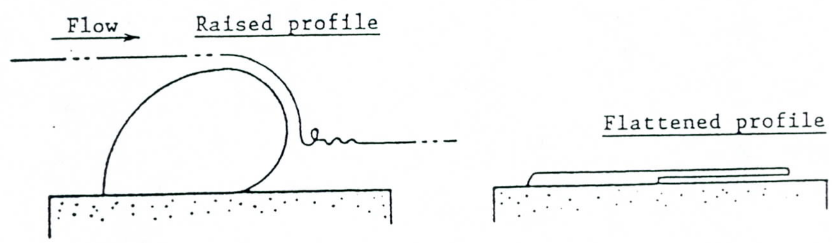
This system should be applied to a case where one side flattening system cannot be applied with possibility of reversed water level difference at times when tube is raised or where flattening direction cannot be fixed at a place with possibility of reversal of flow direction.

3) Direct flattening system

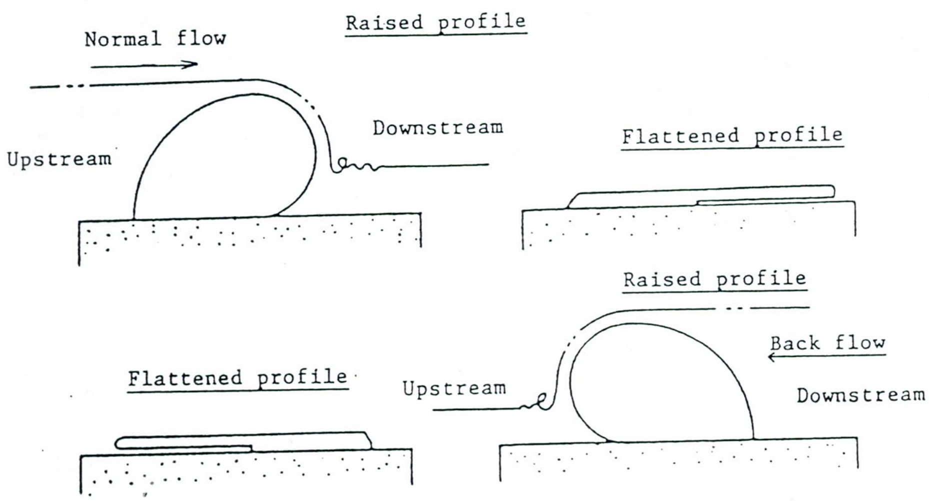
In this system, many auxiliary air chambers are provided inside the tube which are inflated in flattening in order to hold the tube in the cavity between two lines of fixing apparatus. This system is effective as a measure for avoidance of imperfect flattening caused by accumulated soil and sands as well as protection of tube. Tube construction and operation units become complicated.

Construction of rubber weir tube includes single chamber type and multiple chamber type. Design of a tube of multiple chamber type can include varieties of concepts such as providing separating walls inside and multiplying the tube in accordance with actual application. The direct flattening system is an example of multiple chamber type. Whereas tube performance can be improved by multiple chamber concept, some loss of weir advantage is inevitable. Hence, weirs of multiple chamber type should not be employed except special cases.

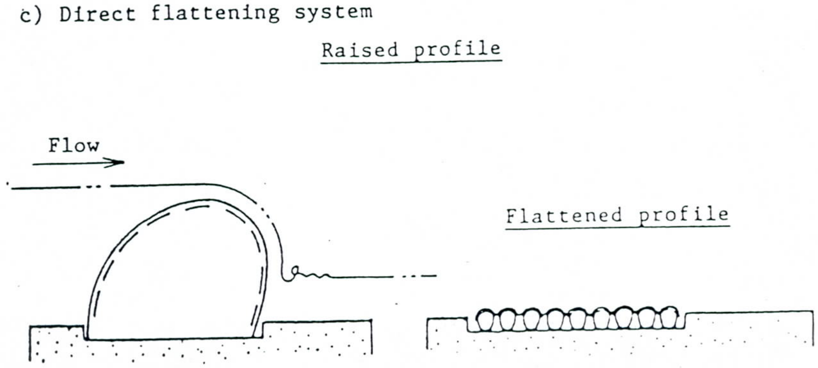
a) One side flattening system



b) Both sides flattening system



c) Direct flattening system



1.9 Selection of tube fixing system

Tube fixing system should be selected as either one of one line fixing system and two line fixing system.

Explanation

Tube fixing system includes one line system that fixes tube with fixtures in one line on upstream side and two line system that fixes tube with fixtures in two lines, one line on upstream side and the other on downstream side. The latter is advantageous in cases where force may be applied from downstream side by change of upstream and downstream water levels or waves. With regard to relation with flattening system, while both one and two line fixing methods are available for one side flättening system, both sides flattening system and direct flattening system must employ two line fixing system for the reason of, respectively, feeding/discharging pipe affixing and mechanism construction.

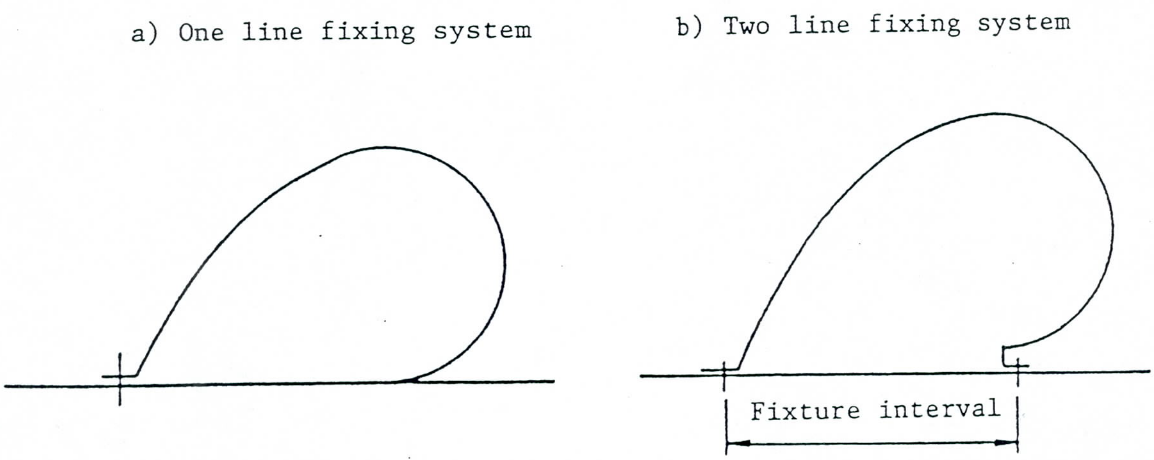


Fig. 1.19 Tube fixing systems

1.10 Water level change and tube deformation

Tube deformation caused by water level change at the place of weir installation should not disturb weir function.

Explanation

Rubber weir tube deforms accompanying to water level changes in upstream and downstream because of its flexible structure. Since this deformation, if large, may interfere the weir functions required for design water level and flow rate, investigation should be made by calculation and experiment to take efficient measures according to necessity.
Tube deformation characteristics accompanying to water level changes include the following:

1) Upstream water level

With high upstream water level, height of a weir of air type decreases. As for a weir of water type, the height either increases or decreases depending on its internal pressure.

2) Downstream water level

With high downstream water level, height of a weir increases.

3) Internal pressure

With a weir of air type, the higher the internal pressure, the smaller change of weir height.

4) Inflating medium

Water results in smaller rate of change of weir height than air as inflating medium. With weirs of air type, those of large height produce higher rate of weir height change than those of small height under condition of the same ratio of internal pressure to weir height because of compressibility of air.

5) Tube section shape

In case of two line fixing system, small ratio of peripheral length to fixture interval and semi-circular cross section of tube decrease rate of weir height change.

Conclusively, it is effective to decrease tube deformation caused by water level change to adopt a weir of nearly a semi-circular tube section with water type, and to set internal pressure rather high with air type.
If deformation exceeds tolerable value even with such measures described above, action should be taken like co-installation of steel gate or installation of weir height adjusting device by feeding or discharging inflating medium.

Reference: Internal pressure and cross-sectional shape (with full upstream water level and zero downstream water depth)

Fig. 1.20 shows cross-sectional shapes of tube of air and water type by values of internal pressure. Abscissas and ordinates of these drawings are scaled dimensionless by division by weir height. Because shapes of water type are generally oval, their peripheral lengths are larger than air type.

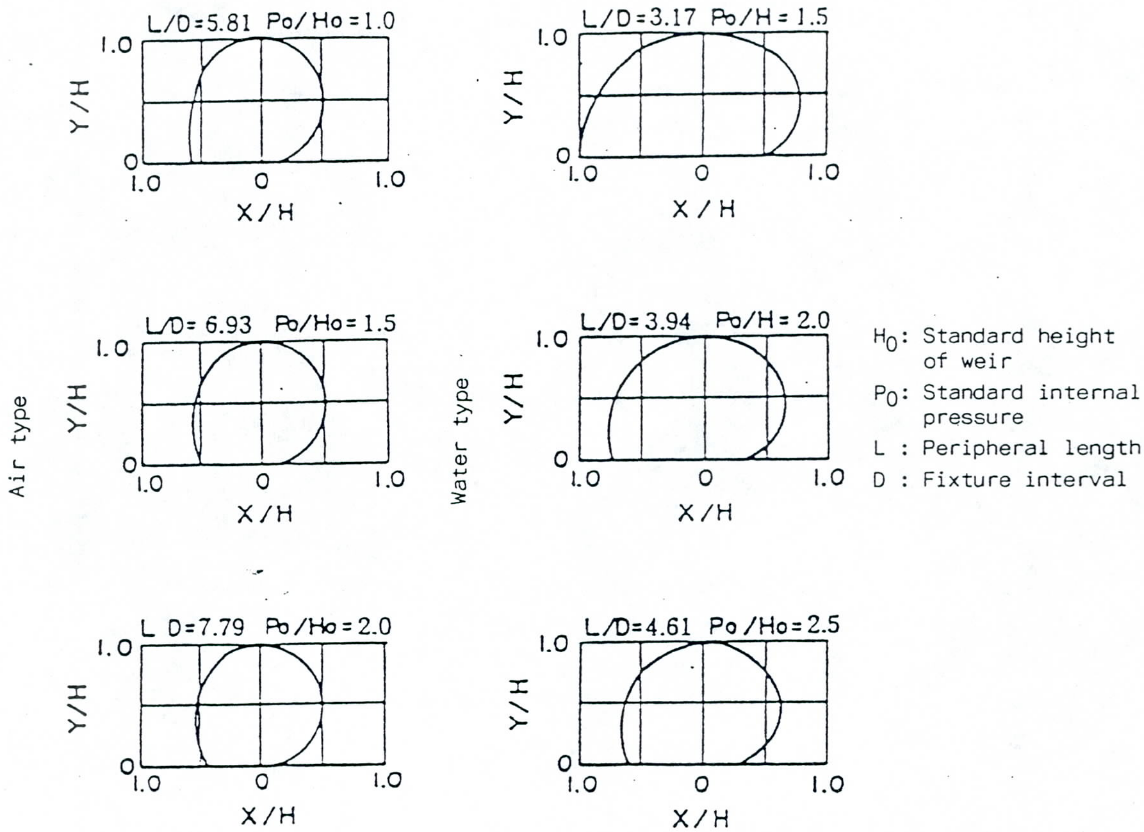


Fig. 1.20 Internal pressure and cross-sectional shape

Reference: Peripheral length/fixture interval and cross-sectional shape (with full upstream water level and zero downstream water depth)

Fig. 1.21 shows tube cross-sectional shapes of air type for various values of peripheral length/fixture interval. Abscissas and ordinates of these drawings are scaled dimensionless by division by weir height.

By records, most of weirs of air type employ values of $L/D \geqq 6.5$ and those of water type $L/D \geqq 4.0$.

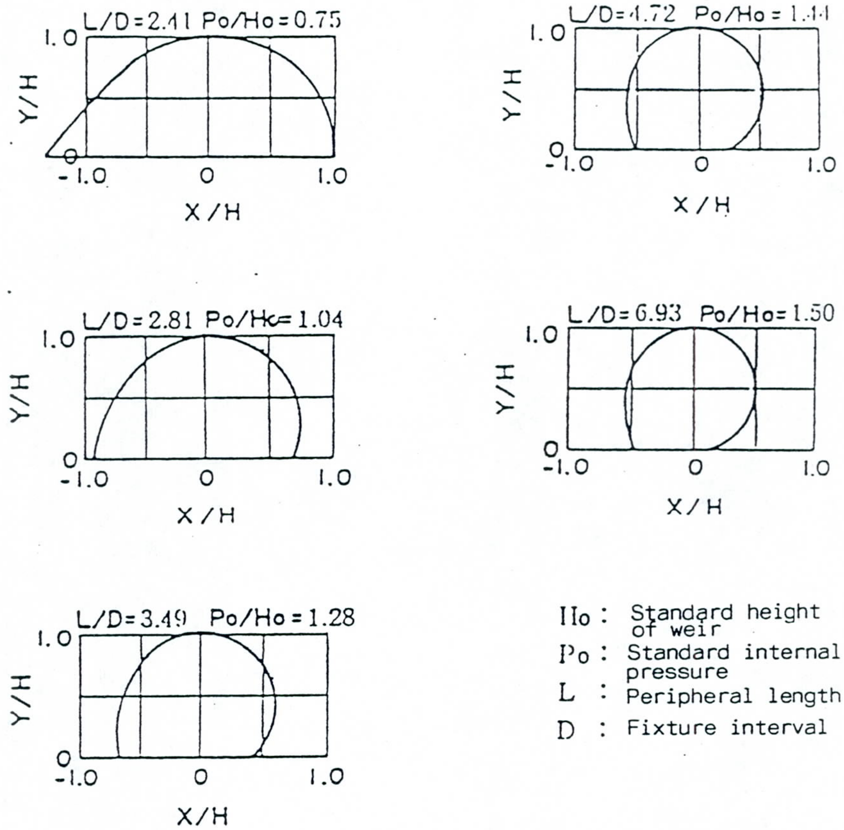


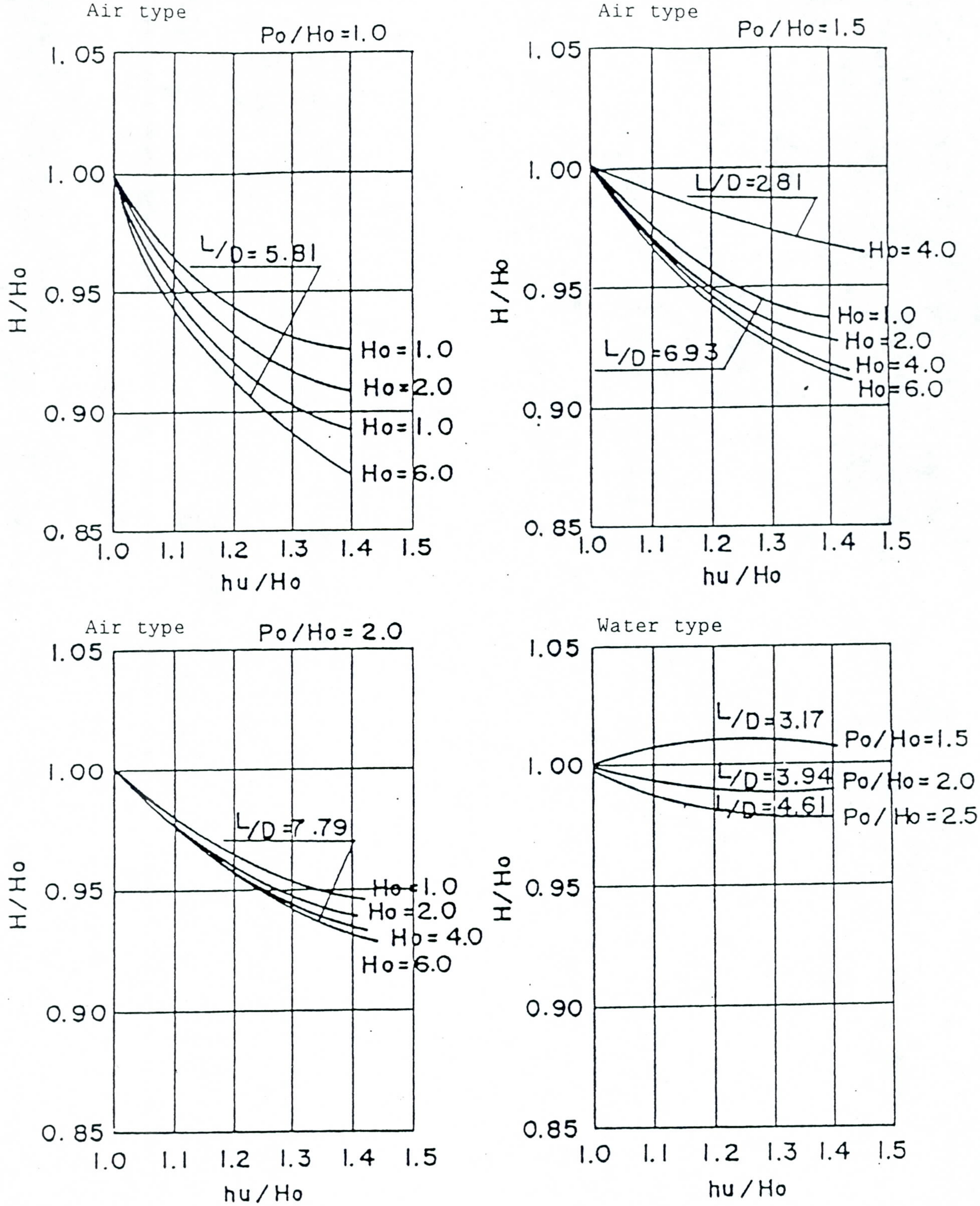
Fig. 1.21 Peripheral length/fixture interval and cross-sectional shape (Air type)

<u>Reference</u>: Upstream water depth and weir height

Fig. 1.22 gives calculation results of internal pressure, weir height, and peripheral length/fixture interval that affect weir height change for both air and water types.

With air type, a higher internal pressure leads to a smaller change of weir height and a smaller effect of standard weir height. And, by reducing peripheral length/fixture interval ratio, rate of weir height change can be considerably reduced.

With water type, weir height change and effect of internal pressure are smaller than air type.



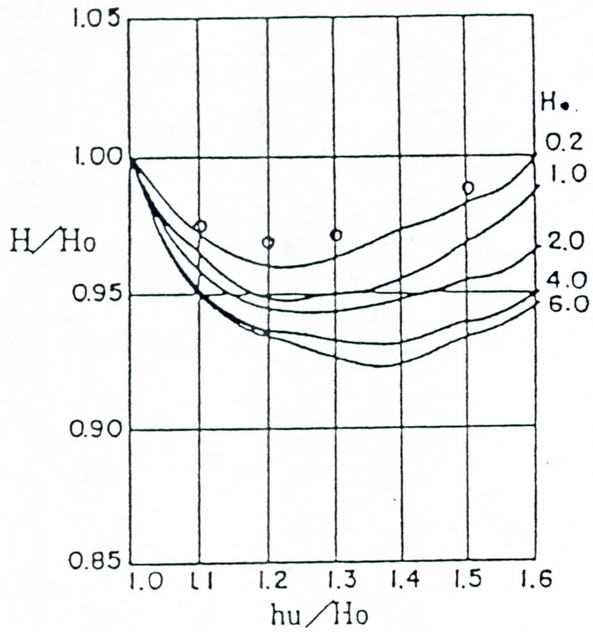
H :	Weir height	L :	Peripheral length
hu:	Upstream water depth	D :	Fixture interval
po:	Standard internal pressure		
Ho:	Standard weir height		

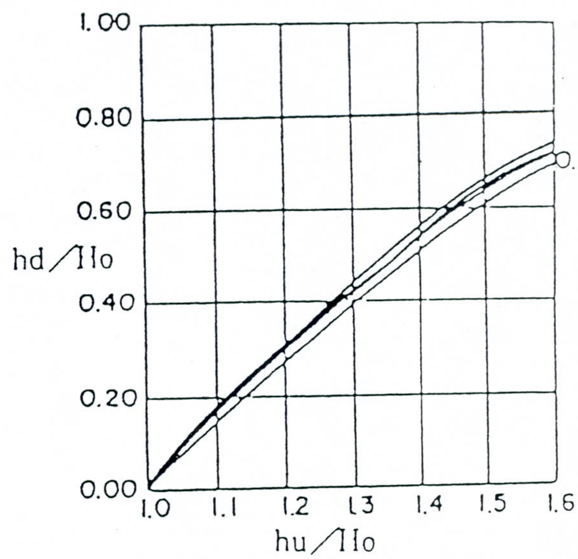
Fig. 1.22 Upstream water depth and weir height

Reference: Upstream water depth and weir height

Fig. 1.23 shows calculation results of weir height in case when downstream water depth changes accompanying to upstream depth. The figure also includes water depth relation between upstream and downstream.

Weir height decreases gradually as upstream water level increases in initial stage. But, it turns to increase by effect of increased downstream water level pushing the tube. The circle plots in the figure represent measured values obtained with a model 0.2 m high.



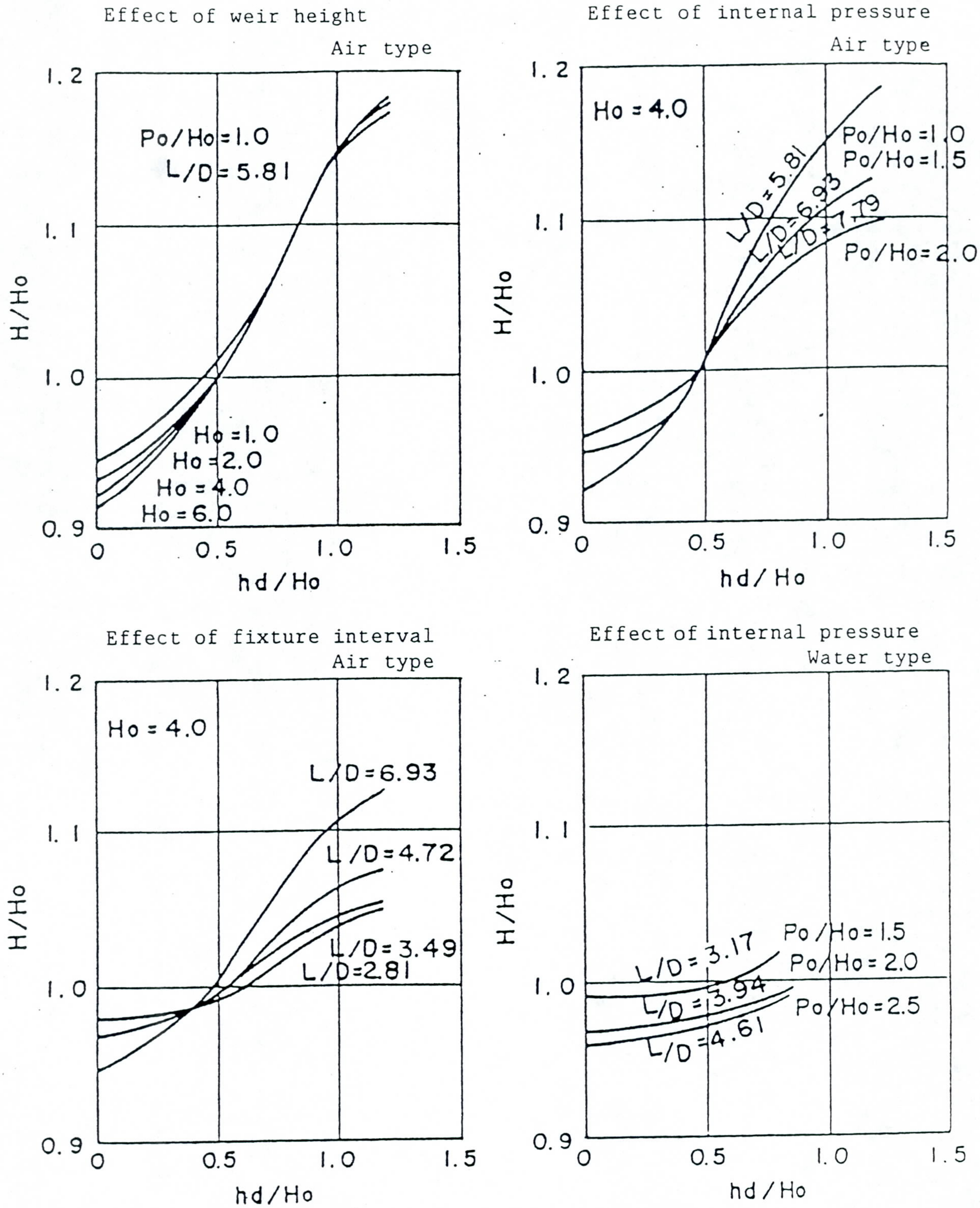


Ho: Standard weir height
H : Weir height
hu: Upstream water depth
hd: Downstream water depth

Fig. 1.23 Relation between upstream water depth and weir height

Reference: Downstream water depth and weir height

Fig. 1.24 gives calculation results showing effects of standard weir height, internal pressure, peripheral length/fixture interval and inflating medium on changes of downstream water depth and weir height for a fixed upstream water depth (hu/Ho = 1.2). Generally, weir height becomes large as downstream water depth increases. With regard to weirs of air type, change of weir height becomes large as the standard weir height increases, internal pressure decreases and peripheral length/fixture interval ratio increases. For weirs of water type also, change of weir height tends to increase as internal pressure decreases. Rate of change, however, is smaller than air type.



hd:	Downstream water depth	L :	Peripheral length
H :	Weir height	D :	Fixture interval
Po:	Standard internal pressure		
Ho:	Standard weir height		

Fig. 1.24 Downstream water depth and weir height

Section 2 Materials of parts

2.1 Specification of rubberized fabric

Rubberized fabric for rubber weirs should satisfy the specification summarized in Table 1.7.

Table 1.7 Summarized Specification of Rubberized Fabric

<table>
<tr><th colspan="2">Material</th><th>Test item</th><th>Specification value</th><th>Test method</th></tr>
<tr><td rowspan="7">Rubberized fabric for tube</td><td rowspan="5">Rubber (external, intermediate, internal)</td><td>Initial properties</td><td>TB : Not less than 120 kg/cm^2
EB : Not less than 400%</td><td>JIS K 6301. 3
3 speciment (JIS #3 dumb-bell)</td></tr>
<tr><td>Thermal deterioration, 100°C, 4 days</td><td>TB : Not less than 100 kg/cm^2
EB : Not less than 300%</td><td>JIS K 6301. 6</td></tr>
<tr><td>Resistance to water, 70°C, 4 days</td><td>ΔV : Not more than 20%
TB : Not less than 100 kg/cm^2
EB : Not less than 350%</td><td>JIS K 6301. 12</td></tr>
<tr><td>Resistance to ozone</td><td>100 pphm, 40°C, 50%, 96 hrs
No abnormality</td><td>JIS K 6301. 16</td></tr>
<tr><td>Resistance to coldness</td><td>Embrittle temperature
Not higher than -25°C</td><td>JIS K 6301. 14</td></tr>
<tr><td>Outer layer rubber</td><td>Resistance to wear</td><td>Tapered wear ring
H18 1000g load, 1000 cyc.
Not more than 0.5mℓ</td><td>In accordance with C method, 15.3, 6., JIS L 1096</td></tr>
<tr><td>Rubberized fabric</td><td>Tensile strength</td><td>(Longitudinal)
Not less than design calc. tension x 8
(Lateral)
Not less than 2/3 of the longitudinal</td><td>In accordance with JIS K 6328, 6., 3.5(1) or JIS L 1068 (strip method)</td></tr>
</table>

Rubberized fabric for tube	Rubberized fabric	Thermal deterioration of tensile strength 100°C, 4 days	(Longitudinal) Not less than 80% of the initial property Not less than design calc. tension x 8	In accordance with JIS K 6328, 6., 3.5(1) or JIS L 1068 (strip method)
		Resistance to water of tensile strength 70°C water, 4 days	- ditto -	- ditto -
		Rubber to fabric adhesion	(Longitudinal & lateral) Initial: Not less than 6 kg/cm^2 After 4 days in 70°C water: Not less than 4 kg/cm^2	JIS K 6301. 7 (Tanzawa)
Watertight/airtight sheet	Rubber	Initial property	TB : Not less than 120 kg/cm^2 EB : Not less than 400%	JIS K 6301. 3 3 specimens (JIS #3 dumb-bell)
		Thermal deterioration 1002C, 4 days	TB : Not less than 70 kg/cm^2 EB : Not less than 250%	JIS K 6301. 6
		Resistance to water 70°C, 4 days	ΔV : Not more than 20% TB : Not less than 70 kg/cm EB : Not less than 250%	JIS K 6301. 12
	Rubberized fabric	Tensile strength	(Longitudinal & lateral) Not less than 80 kg/cm^2	In accordance with JIS K 6328, 6., 3.5(1) or JIS L 1068 (Strip method)
		Rubber to fabric adhesion	(Longitudinal & lateral) Initial: Not less than 6 kg/cm^2 After 4 days in 70°C water: Not less than 4 kg/cm^2	JIS K 6301. 7 (Tanzawa)

where, TB : Tensile strength

EB : Elongation

ΔV : Volume change

Explanation

Rubberized fabric for tube and watertight/airtight sheet indicate the tube's parts as shown in Fig. 1.25. No need for these materials for a weir of one line fixture design.

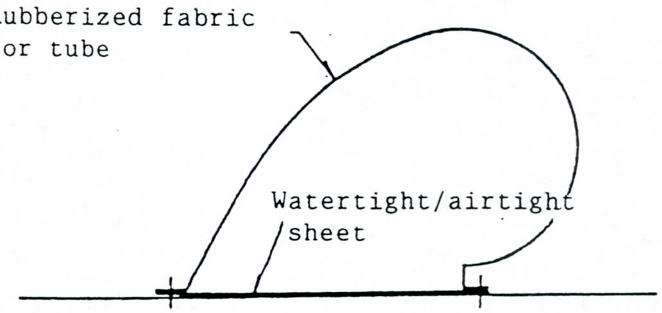


Fig. 1.25 Names of rubberized fabric

Rubberized fabric consists of reinforcing fibers bearing tube tension and three rubber layers protecting the fabric and securing airtightness. The rubber recipe is different for each of outer, intermediate and inner layers in order to construct the layers so as to develop required functions securely. The functions required for each layer rubber:

1) Outer layer rubber

The rubber should be provided with a sufficient resistance to wear against flowing-down matters because outer tube is exposed to water flow at all times. Further, resistances to insolation, heat and ozone are also required.

2) Intermediate layer rubber

For the rubber, important functions are adhesion to fiber and rubber, and resistance to water because the rubber should protect fibers directly. The intermediate layer rubber is not required to have so strong a resistance to ozone as outer and inner layers because it is not directly exposed to air.

3) Inner layer rubber

The rubber should be sufficiently watertight and airtight as well as protective for fiber. It requires consideration for resistance to ozone, while not so much as outer layer rubber, because some air comes to inside the tube.

"Longitudinal" means the same direction as river flow. The reason why requirement for lateral tensile strength is set as not less than 2/3 of the longitudinal is the fact that it was revealed in a measurement with an actual product (for a case with zero water depth in both upstream and downstream) that a tension of approx. 2/3 of the longitudinal is induced in attachment to wall. Design tension can be calculated by 3.1 of this chapter.
A safety factor of 8 has been adopted for rubberized fabric from consideration on use conditions of weirs installed in rivers and expected durability.
Moreover, rubberized fabric for tube should satisfy specification values in any part including a joint.

2.2 Thickness of outer layer rubber

Outer layer rubber of rubberized fabric should have such a thickness that develops sufficient durability.

Explanation

Outer layer rubber is a key part for tube protection in that it should ensure water and air-tightness of tube and prevent deterioration of reinforcing fabric, the strength member.
Durability of tube depends in a large part on deterioration of outer layer rubber and wear and damage given to it by flowing-down matters.

Thickness of outer layer rubber should be determined to be sufficient from consideration on river conditions at the place of installation, use conditions and durability of the weir.

Reference: Tube wear

Fig. 1.26 shows results of investigation of 17 rubber weirs 6 to 14 years after installation about wear of rubberized fabric of tubes. The maximum wear rate in this investigation was 0.013 mm per year. Sufficient consideration should be taken on river conditions at the place of installation because wear is largely affected by river bed material, quantity of traction sands, flow velocity, flood frequency, etc.

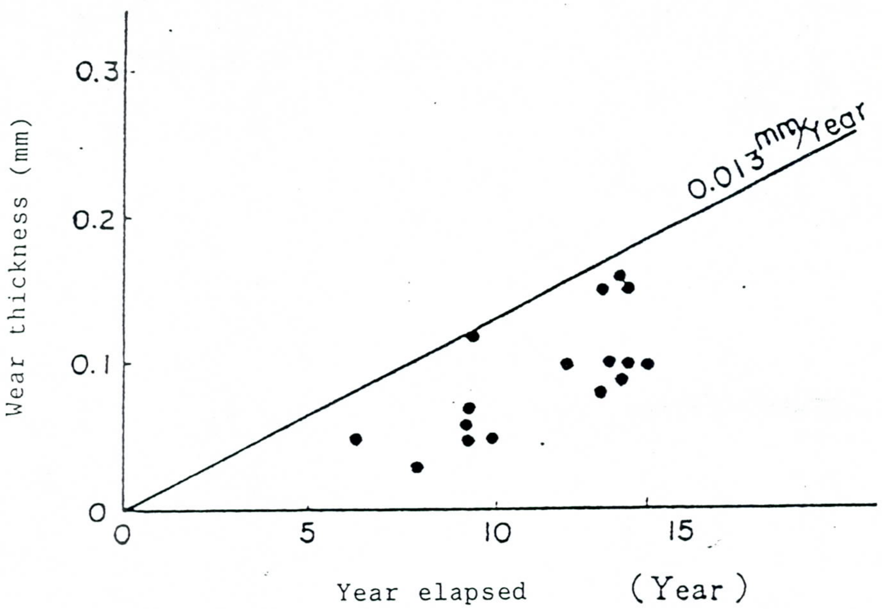


Fig. 1.26 Wear quantity

2.3 Material of tube attachment fittings

Material of tube attachment fittings should be determined from sufficient consideration on strength and durability required at the place of installation.

2.4 Material of tube fixing bolts

Material of tube fixing bolts should be determined from sufficient consideration on strength and durability required at the place of installation.

Section 3   Design

3.1 Tube shape and tension calculation

Tube shape and tension should be determined depending on external pressure, internal pressure and weir height using the equation below:

$$T = \Delta P \times R$$

where, T: Tube tension

ΔP: Pressure difference between inside and outside of tube

R: Radius of curvature in portions of tube

<u>Explanation</u>

1. Fundamental equation

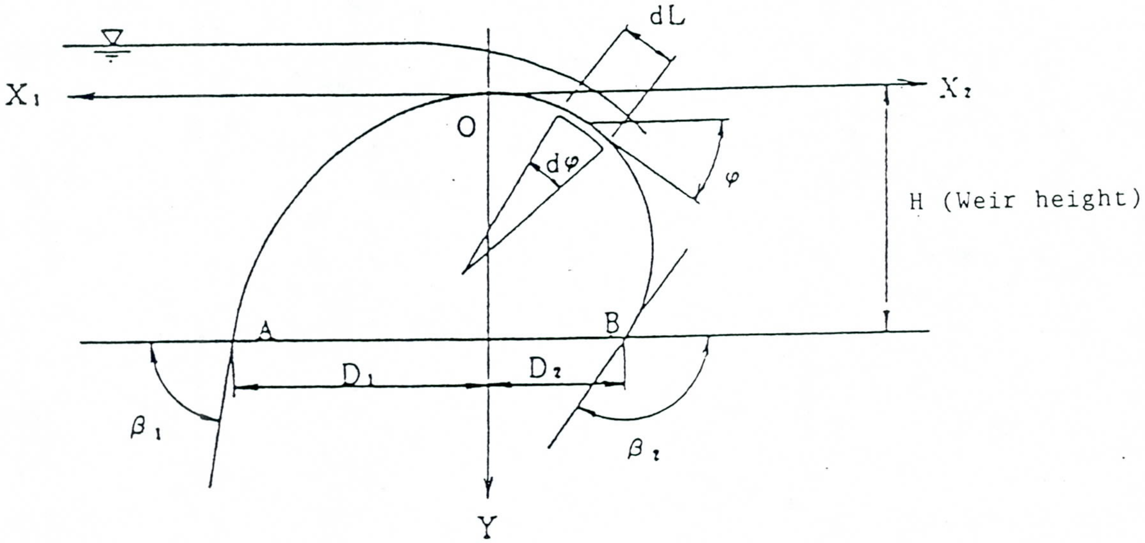


Fig. 1.27 Figure for equation definition

$$T = \Delta P \cdot R \text{ ---------------- } (1)$$

From Fig. 1.27,

$$dL = R \cdot d\varphi \text{ ---------------- } (2)$$

$$dX = dL \cdot \cos\varphi \text{ ---------------- } (3)$$

$$dY = dL \cdot \sin\varphi \text{ ---------------- } (4)$$

1) Tube tension (T)

Because tension is constant along periphery of tube, from equations (1), (2) and (4),

$$T \cdot \sin\varphi \cdot d\varphi = \Delta P(Y) \cdot dY \quad \cdots\cdots \quad (5)$$

Integrating equation (5) from 0 to B on downstream side,

$$T = \frac{\int_0^H \Delta P_2(Y) \cdot dY}{\int_0^{\beta_2} \sin\varphi_2 \cdot d\varphi_2} \quad \cdots\cdots \quad (6)$$

2) Grounding point on downstream side (B)

From equations (3) and (4),

$$dX_2 = \frac{\cos\varphi_2}{\sin\varphi_2} \cdot dY \quad \cdots\cdots \quad (7)$$

Equation (5) gives the relation between φ_2 and Y. Put it as

$$\frac{\cos\varphi_2}{\sin\varphi_2} = f_2(Y) \quad \cdots\cdots \quad (8)$$

where $\Delta P(Y) = \Delta P_2(Y)$.

Hence, $dX_2 = f_2(Y) \cdot dY$ ---------------- (9)

giving an expression of D_2 as below:

$$D_2 = \int_0^H f_2(Y) \cdot dY \quad \cdots\cdots \quad (10)$$

3) Peripheral length on downstream side (L_2)

From equations (3), (4) and (8),

$$dL_2 = \sqrt{1 + \left(\frac{dX_2}{dY}\right)^2} \cdot dY$$

$$= \sqrt{1 + f_2(Y)^2} \cdot dY \quad \cdots\cdots \quad (11)$$

Integrating this equation along the arc OB, peripheral length on downstream side is given by

$$L_2 = \int_0^H \sqrt{1 + f_2(Y)^2} \cdot dY \quad \cdots\cdots\cdots\cdots\cdots (12)$$

4) Cross-sectional area on downstream side (S_2)

Differential cross-sectional area dS_2 is expressed as

$$dS_2 = X_2 \cdot dY \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (13)$$

Hence, S_2 is calculated as

$$S_2 = \int_0^H X_2 \cdot dY \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (14)$$

5) Coordinates of downstream side (X_2, Y)

Integrating equation (9), X_2 is given as a function of Y as

$$X_2 = \int_0^{X_2} dX_2 = \int_0^Y f_2(Y) \cdot dY \quad \cdots\cdots\cdots (15)$$

6) Rising angle on upstream side (β_2)

B_2 can be calculated with the following equation derived from equations (1), (2) and (4):

$$\int_0^{\beta_1} T \sin\varphi_1 \cdot d\varphi_1 = \int_0^H \Delta P_1(Y) \cdot dY \quad \cdots\cdots (16)$$

7) Grounding point on upstream side (A)

Similarly to downstream side, from equations (3) and (4),

$$dX_1 = \frac{\cos\varphi_1}{\sin\varphi_1} \cdot dY = f_1(Y) \cdot dY \quad \cdots\cdots (17)$$

$$D_1 = \int_0^H f_1(Y) \cdot dY \quad \cdots\cdots\cdots\cdots\cdots\cdots\cdots\cdots (18)$$

This gives the point A provided that $f_1(Y)$ is given as a function of ϕ_1 which is derived from equation (5) ($\Delta P(Y) = \Delta P_1(Y)$):

$$\frac{\cos\varphi_1}{\sin\varphi_1} = f_1(Y) \quad \cdots\cdots \quad (19)$$

8) Peripheral length on upstream side (L_1)

Similarly to downstream side,

$$L_1 = \int_0^H \sqrt{1 + f_1(Y)^2} \cdot dY \quad \cdots\cdots \quad (20)$$

9) Cross-sectional area on upstream side (S_1)

Similarly to downstream side.

$$S_1 = \int_0^H X_1 \cdot dY \quad \cdots\cdots \quad (21)$$

10) Coordinates on upstream side (X_1, Y)

Similarly to downstream side, (X_1, Y) can be calculated as below by integrating equation (17):

$$Y_1 = \int_0^{X_1} dX_1 = \int_0^Y f_1(Y) \cdot dY \quad \cdots\cdots \quad (22)$$

Hitherto, equations have been prepared for calculations on downstream side and upstream side separately. Using these, distance between grounding points, peripheral length and cross-sectional area of tube are expressed as follows:

11) Distance between grounding points of tube (D)

The distance AB is obtained from equations (10) and (18):

$$D = D_1 + D_2 = \int_0^H f_1(Y)\,dY + \int_0^H f_2(Y)\,dY \quad \cdots\cdots \quad (23)$$

12) Peripheral length of tube (L)

The peripheral length AOB is obtained from equations (12) and (20):

$$L = L_1 + L_2$$

$$= \int_0^H \sqrt{1 + f_1(Y)^2} \cdot dY + \int_0^H \sqrt{1 + f_2(Y)^2} \cdot dY \cdots \quad (24)$$

13) Tube cross-sectional area (S)

The cross-sectional area S is obtained from equations (14) and (21):

$$S = S_1 + S_2$$

$$= \int_0^H X_1 \, dY + \int_0^H X_2 \, dY \quad \cdots\cdots\cdots \quad (25)$$

2. Tube tension at times of no overflow

Tube tension at times of no overflow (i.e. a rising angle of 180 deg.) can be calculated as follows:

1) Air inflating type

Tube internal pressure Pi is given by

$$Pi = \alpha \rho g H$$

where, α: Internal pressure coefficient

ρ: Water density

H: Weir height

Hence, tube tension T is given as below using equation (6):

$$T = \frac{1}{2} \alpha \rho g H^2 \quad \cdots\cdots\cdots \quad (26)$$

2) Water inflating type

Tube internal pressure Pi is given by

$$Pi = \alpha\rho gH + \rho gY$$

Hence, tube tension T is given as below using equation (6):

$$T = \frac{1}{4}(1 + 2\alpha)\rho gH^2 \quad \cdots\cdots\cdots\cdots \quad (7)$$

3. Nomograph

An example of calculation of tube tension by means of equations in the previous paragraph is presented in this paragraph. Fig. 1.28 is the calculation result under the condition of a tube rubberized fabric's rising angle of 180 deg. on down-stream side assuming zero water level there. In this figure, equivalent overflow depth indicates overflow depth plus velocity head.

ρ: Water density (kg/cm^3)
H: Weir height (cm)
T: Tube tension (kg/cm)

4. Approximate design calculation

Under general conditions of overflow, numerical calculation of the equations described in the previous section must be carried out because external pressure acting on the tube distributes through the tube in a complex way according to upstream and downstream water dpeths and overflow water veins. In this paragraph, an approximated design calculation is described simplifying external conditions.

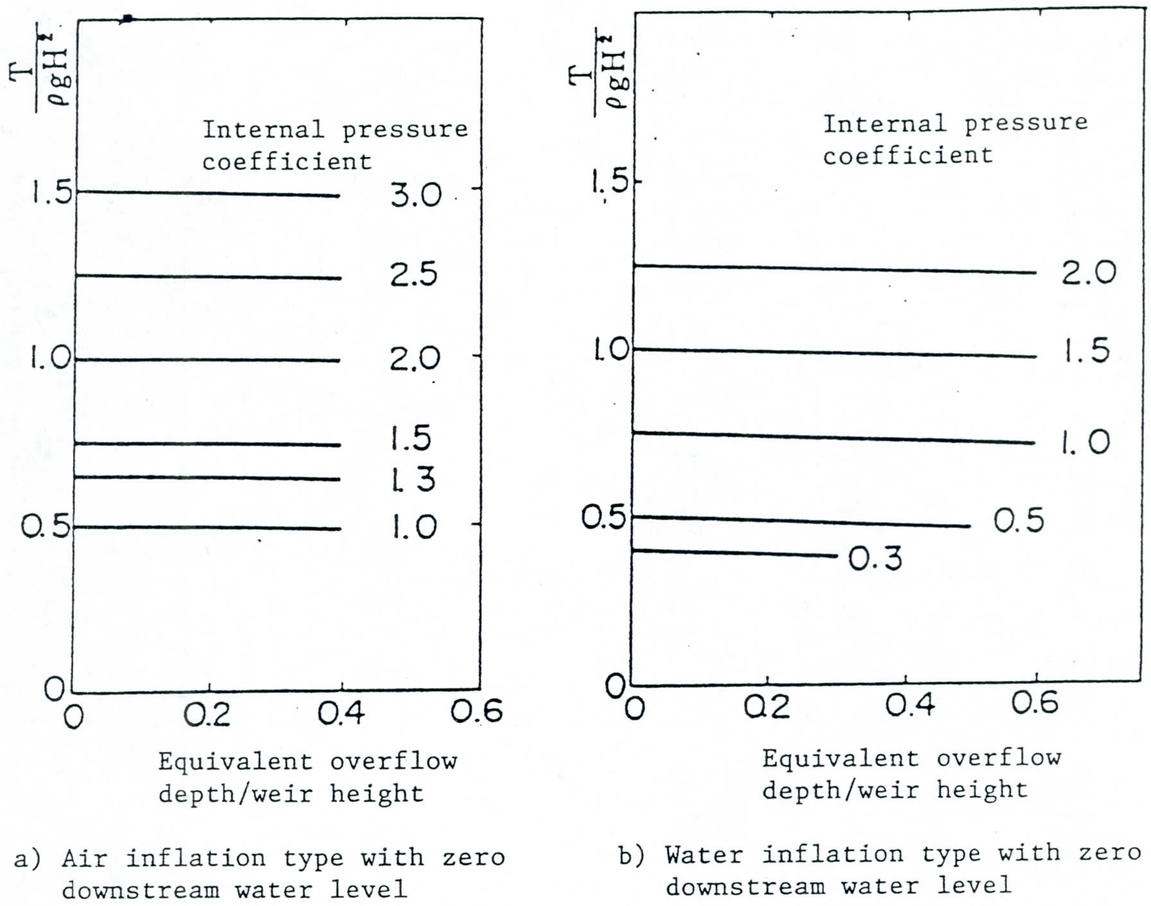


Fig. 1.28 Relation, tension vs. overflow depth

1) External pressure conditions

Let's assume that upstream water level is constant from infinity to the weir and gives no effect on downstream side, and that hydraulic pressure acting on the tube on both upstream and downstream sides distributes statically.

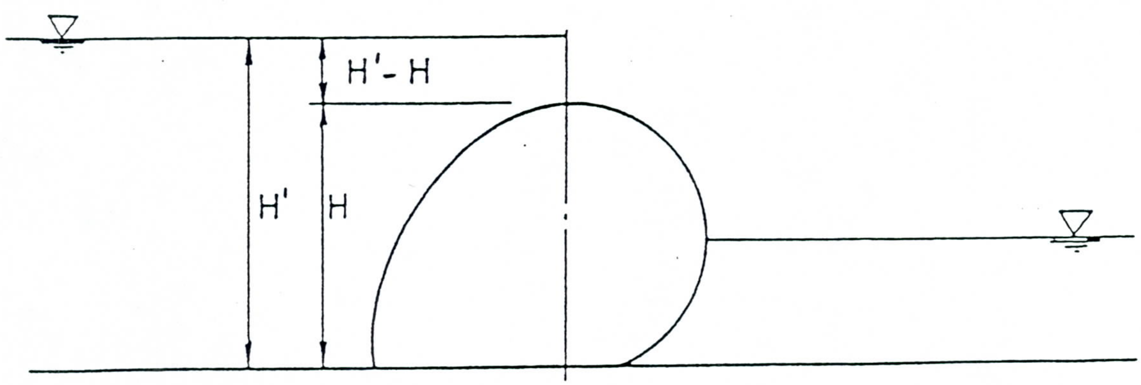
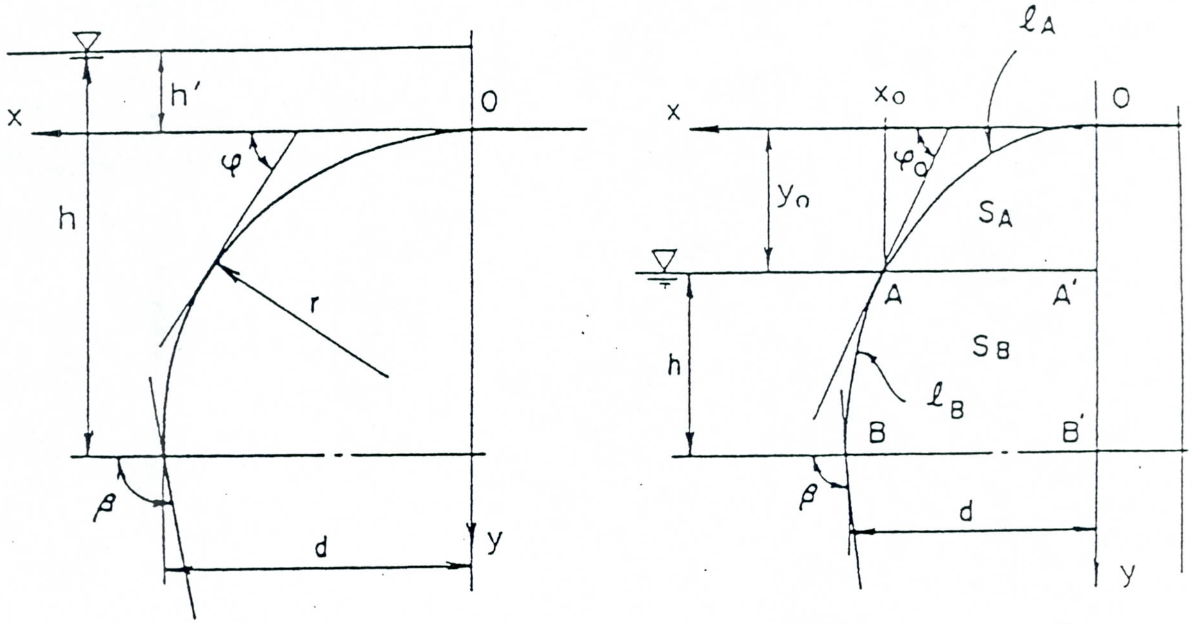


Fig. 1.29 External pressure conditions for calculation

2) Coordinates

Coordinates and symbols of dimensions and angles are as shown in Fig. 1.30.



a) Case of h ≧ 1 b) Case of h < 1

Fig. 1.30 Coordinates and symbols

Table 1.8 Symbols for calculation and conversion equations

Symbol	Dimension	Substance	Dimensionless expression
H	cm	Weir height	$1 = H / H$
H′	cm	Water depth	$h = H' / H$
R	cm	Weir peripheral radius of curvature	$r = R / H$
Pin	kg/cm²	Internal pressure	$\alpha = Pin / \rho g H$
D	cm	Distance between grounding points ($d_0 = d_1 + d_2$)	$d = D / H$
L	cm	Weir periphery length ($\ell_0 = \ell_1 + \ell_2$)	$\ell = L / H$
β	radian	Rising angle	β
T	kg/cm	Tension	$t = T / \rho g H^2$
S	cm²	Cross-sectional area ($s_0 = s_1 + s_2$)	$s = S / H^2$
φ	radian	Angle between tangent to weir periphery and X axis	φ
X	cm	Horizontal coordinate	$x = X / H$
Y	cm	Vertical coordinate	$y = Y / H$

Here, the following should be noted:

i) Suffixes 1 and 2 indicate upstream and downstream respectively.

ii) α indicates weir internal pressure for air type and weir top internal pressure for water type.

iii) Definitions in case of $h < 1$: point $A(x_0, y_0)$, and

$$S_A = \text{▱}OAA' \qquad S_B = \square ABB'A'$$

$$\ell_A = \overset{\frown}{OA} \qquad \ell_B = \overset{\frown}{AB}$$

3) Approximation equations

The fundamental equations are (1) to (4) in the previous paragraph, and the boundary conditions are:

at $x = 0$, $y = 0$; $\phi = 0$ (Weir top)

at $x = d$, $y = 1$; $\phi = \beta$ (Grounding point)

Using assumptions of external pressure conditions, calculations are conducted for upstream side and downstream side separately. And, from relations

$t_1 = t_2$ equal tension on upstream side and downstream side

$\alpha_1 = \alpha_2$ equal internal pressure on upstream side and downstream side

and,

$d_0 = d_1 + d_2$

$\ell_0 = \ell_1 + \ell_2$

$S_0 = S_1 + S_2$,

various values of entire tube can be determined.
Hereunder, approximation equations of tension, rising angle, grounding point, peripheral length, cross-sectional area and coordinate are described by combinations of inflating medium (water or air) and water depth ($h \geq 1$ and $h < 1$).

(1) In case of water inflating type

① If $h \geqq 1$

a) Tension and rising angle

$$t = \frac{\alpha - h'}{1 - \cos\beta} \qquad \alpha - h' \geqq 0 \qquad \text{(where, } h' = h - 1\text{)} \qquad \cdots\cdots (1)$$

b) Grounding point

$$d = \sin\beta \cdot \frac{t}{\alpha - h'} \qquad \cdots\cdots (2)$$

c) Peripheral length

$$\ell = \beta \cdot \frac{t}{\alpha - h'} \qquad \cdots\cdots (3)$$

d) Cross-sectional area

$$S = \frac{1}{2} (\beta - \sin\beta \cdot \cos\beta) \cdot (\frac{t}{\alpha - h'})^2 \qquad \cdots\cdots (4)$$

e) Coordinates

$$x^2 + (y - \frac{t}{\alpha - h'})^2 = (\frac{t}{\alpha - h'})^2 \qquad x,\ y \geqq 0 \qquad \cdots\cdots (5)$$

② If $h < 1$

a) Tension

$$t = \frac{\alpha y_0 + \frac{1}{2} y_0^2}{1 - \cos\varphi_0} \qquad \cdots\cdots (6)$$

b) Rising angle

$$\cos\beta = \cos\varphi_0 - \frac{(\alpha + y_0)\ h}{t} \qquad \cdots\cdots (7)$$

c) Grounding point

$$d = x_0 + \frac{t}{\alpha + y_0} \cdot (\sin\beta - \sin\varphi_0) \qquad \cdots\cdots (8)$$

where

$$x_0 = \frac{2t}{\sqrt{\alpha^2 + 4t}} \left[F(\frac{\pi - \varphi_0}{2}, k) - F(\frac{\pi}{2}, k) - \frac{2}{k^2} \right.$$

$$\left. (F(\frac{\pi - \varphi_0}{2}, k) - E(\frac{\pi - \varphi_0}{2}, k) - \{ F(\frac{\pi}{2}, k) - E(\frac{\pi}{2}, k) \}) \right]$$

where, $k^2 = \dfrac{4t}{\alpha^2 + 4t}$, F: 1st kind elliptic integral,
E: 2nd kind elliptic integral

d) Peripheral length

$$\ell = \ell_A + \ell_B$$

$$= \frac{2t}{\sqrt{\alpha^2 + 4t}} \{ F(\frac{\pi}{2}, k) - F(\frac{\pi - \varphi_0}{2}, k) \} + \frac{t}{\alpha + y_0} (\beta - \varphi_0) \qquad \cdots\cdots\cdots\cdots (9)$$

e) Cross-sectional area

$$S = S_A + S_B$$

$$= x_0 (\alpha + y_0) - \sin\varphi_0 \cdot t + \frac{t^2}{(\alpha + y_0)^2} \{ (\frac{1}{2}\beta - \frac{\sin 2\beta}{4})$$

$$- (\frac{1}{2}\varphi_0 - \frac{\sin 2\varphi_0}{4}) \} + \{ \frac{t^2}{(\alpha + y_0)^2} \sin\varphi_0 - \frac{t\, x_0}{\alpha + y_0} \} (\cos\beta - \cos\varphi_0) \qquad \cdots\cdots\cdots\cdots (10)$$

f) Coordinates

If $0 \leqq y \leqq y_0$

$$x = \frac{2t}{\sqrt{\alpha^2 + 4t}} [F(\frac{\pi - \varphi}{2}, k) - F(\frac{\pi}{2}, k) - \frac{2}{k^2} [F(\frac{\pi - \varphi}{2}, k)$$

$$- E(\frac{\pi - \varphi}{2}, k) - \{ F(\frac{\pi}{2}, k) - E(\frac{\pi}{2}, k) \}]] \qquad \cdots\cdots\cdots\cdots (11)$$

$$y = \sqrt{\alpha^2 + 2t(1 - \cos\varphi)} - \alpha$$

If $y_0 \leqq y \leqq 1$

$$x = x_0 + \frac{t}{\alpha + y_0} (\sin\varphi - \sin\varphi_0)$$

$$\cdots\cdots\cdots\cdots (11)'$$

$$y = y_0 + \frac{t}{\alpha + y_0} (\cos\varphi_0 - \cos\varphi)$$

(2) In case of air inflation type

① If $h \geqq 1$

a) Tension

$$t = \frac{\alpha - h' - \frac{1}{2}}{1 - \cos\beta} \qquad \cdots\cdots\cdots\cdots\cdots (12)$$

b) Grounding point

If $k^2 = \dfrac{4t}{(\alpha - h')^2} > 1$

$$d = \sqrt{t}\,\{\,2E(\theta, \frac{1}{k}) - F(\theta, \frac{1}{k})\}$$

$$\theta = \cos^{-1}(1 - \frac{1}{\alpha - h'}) \qquad \cdots\cdots\cdots\cdots\cdots (13)$$

If $k^2 = \dfrac{4t}{(\alpha - h')^2} \leqq 1$

$$d = \frac{2t}{\alpha - h'}\,[\,F(\frac{\beta}{2}, k) - (\alpha - h')\{F(\frac{\beta}{2}, k)$$

$$- E(\frac{\beta}{2}, k)\}\,] \qquad \cdots\cdots\cdots\cdots\cdots (13)'$$

c) Peripheral length

If $k^2 = \dfrac{4t}{(\alpha - h')^2} > 1$

$$\ell = \sqrt{t}\,F(\theta, \frac{1}{k}) \qquad \cdots\cdots\cdots\cdots\cdots (14)$$

θ : Defined previously

If $k^2 = \dfrac{4t}{(\alpha - h')^2} \leqq 1$

$$\ell = \frac{2t}{\alpha - h'}\,F(\frac{\beta}{2}, k) \qquad \cdots\cdots\cdots\cdots\cdots (14)'$$

d) Cross-sectional area

$$S = (1 - \alpha + h')\, d + t \sin\beta$$

e) Coordinates

If $k^2 = \dfrac{4t}{(\alpha - h')^2} > 1$

$$x = \sqrt{t}\,\left[2E(\phi, \frac{1}{k}) - F(\phi, \frac{1}{k}) \right] \quad \cdots\cdots\cdots\cdots\cdots (16)$$

$$\phi = \cos^{-1}\left(1 - \frac{y}{\alpha - h'}\right)$$

If $k^2 = \dfrac{4t}{(\alpha - h')^2} \leqq 1$

$$x = \frac{2t}{\alpha - h'} F(\frac{\varphi}{2}, k) - (\alpha - h')\left\{ F(\frac{\varphi}{2}, k) - E(\frac{\varphi}{2}, k) \right\} \cdots\cdots (16)'$$

$$\sin\frac{\varphi}{2} = \sqrt{\frac{2(\alpha - h')\,y - y^2}{4t}}$$

② If $h < 1$

a) Tension

$$t = \frac{y_0\,\alpha}{1 - \cos\varphi_0} \quad \cdots\cdots\cdots\cdots\cdots (17)$$

b) Rising angle

$$\cos\beta = \cos\varphi_0 - \frac{\frac{1}{2} - h(1 - \alpha) - \frac{1}{2} y_0^2}{t} \quad \cdots\cdots\cdots\cdots\cdots (18)$$

c) Grounding point

If $k^2 = \dfrac{4t}{\alpha^2 + 2\alpha y_0} < 1$

$$d = \frac{t}{\alpha}\sin\varphi_0 + \frac{2t}{\sqrt{\alpha^2 + 2\alpha y_0}}\left[F(\frac{\beta}{2}, k) - F(\frac{\varphi_0}{2}, k) - \frac{2}{k^2} \right.$$

$$\left. \left\{ F(\frac{\beta}{2}, k) - E(\frac{\beta}{2}, k) - F(\frac{\varphi_0}{2}, k) - E(\frac{\varphi_0}{2}, k) \right\} \right] \cdots\cdots (19)$$

If $k^2 = \dfrac{4t}{\alpha^2 + 2\alpha y_0} \geqq 1$

$$d = \frac{t}{\alpha}\sin\varphi_0 + \sqrt{t}\,[\,-F(b,\frac{1}{k}) + F(a,\frac{1}{k}) + 2\{E(b,\frac{1}{k}) - E(a,\frac{1}{k})\}\,] \quad \cdots\cdots \quad (19)'$$

$$\sin b = k\sin\frac{\beta}{2} \qquad \sin a = k\sin\frac{\varphi_0}{2}$$

d) Peripheral length

If $k^2 = \dfrac{4t}{\alpha^2 + 2\alpha y_0} \leqq 1$

$$\ell = \ell_A + \ell_B$$

$$= \frac{t}{\alpha}\varphi_0 + \frac{2t}{\sqrt{\alpha^2 + 2\alpha y_0}}\{F(\frac{\beta}{2}, k) - F(\frac{\varphi_0}{2}, k)\} \quad \cdots\cdots\cdots \quad (20)$$

If $k^2 = \dfrac{4t}{\alpha^2 + 2\alpha y_0} > 1$

$$\ell = \ell_A + \ell_B$$

$$= \frac{t}{\alpha}\varphi_0 + \sqrt{t}\,[\,F(b,\frac{1}{k}) - F(a,\frac{1}{k})\,] \quad \cdots\cdots\cdots\cdots\cdots \quad (20)'$$

b, a .... Defined previously

e) Cross-sectional area

$$S = S_A + S_B$$

$$= \frac{1}{2}(\frac{t}{\alpha})^2(\varphi_0 - \sin\varphi_0\cos\varphi_0) + d(h - \alpha) + t\sin\beta \quad \cdots\cdots\cdots \quad (21)$$

f) Coordinates

If $0 \leqq y \leqq y_0$

$$x^2 + \left(y - \frac{t}{\alpha}\right)^2 = \left(\frac{t}{\alpha}\right)^2 \qquad \text{.................} \quad (22)$$

$$x\ ,\ y \geqq 0$$

If $y_0 \leqq y \leqq 1$

If $k^2 = \dfrac{4t}{\alpha^2 + 2\alpha y_0} \leqq 1$

$$x = \frac{t}{\alpha}\sin\varphi_0 + \frac{2t}{\sqrt{\alpha^2 + 2\alpha y_0}}\left[F\left(\frac{\varphi}{2}, k\right) - F\left(\frac{\varphi_0}{2}, k\right) - \frac{2}{k^2}\right.$$

$$\left.\left\{F\left(\frac{\varphi}{2}, k\right) - E\left(\frac{\varphi}{2}, k\right) - \left(F\left(\frac{\varphi_0}{2}, k\right) - E\left(\frac{\varphi_0}{2}, k\right)\right)\right\}\right] \quad \cdots \quad (23)$$

where,

$$t(\cos\varphi_0 - \cos\varphi) = (\alpha + y_0)y - \frac{1}{2}y^2 - \left(\alpha + \frac{1}{2}y_0\right)y_0$$

If $k^2 = \dfrac{4t}{\alpha^2 + 2\alpha y_0} > 1$

$$x = \frac{t}{\alpha}\sin\varphi_0 + \frac{2t}{\sqrt{\alpha^2 + 2\alpha y_0}}\left[\frac{1}{k}\left\{F\left(b, \frac{1}{k}\right) - F\left(a, \frac{1}{k}\right)\right\}\right.$$

$$\left.- \frac{2}{k}\left\{F\left(b, \frac{1}{k}\right) - E\left(b, \frac{1}{k}\right) - \left(F\left(a, \frac{1}{k}\right) - E\left(a, \frac{1}{k}\right)\right)\right\}\right] \quad \cdots \quad (23)'$$

$$\sin b = k \sin\frac{\varphi}{2}\ , \qquad \sin a = k \sin\frac{\varphi_0}{2}$$

Relation of y vs. φ : Defined previously

4) Determination of weir fundamentals

Relation between the approximation equations in the previous paragraphs and unknowns are summarized as below:

Table 1.9 Equations for Weir Fundamentals vs. Unknowns

Inflating medium		Equations	Unknowns
Water type	$h \geqq 1$	(1), (2), (3), (4)	t, α, α', β, d, ℓ, S
	$h < 1$	(7), (8), (9), (10)	t, α, h, β, d, ℓ, S
Air type	$h \geqq 1$	(12), (13), (14), (15)	t, α, α', β, d, ℓ, S
	$h < 1$	(18), (19), (20), (21)	t, α, h, β, d, ℓ, S

In the table above, (13)', (14)', (19)' and (20)' are sometimes used instead of (13), (14), (19) and (20) respectively.
To determine weir fundamentals, select a combination of equations satisfying conditions of inflating medium and water depth from the table above and solve them simultaneously.
When suffixes 1 and 2 are assigned to variables representing upstream and downstream respectively, relations hold as below besides the eight equations and 14 unknowns in the table:

$t_1 = t_2$ Tension is equal in both upstream and downstream.

$\alpha_1 = \alpha_2$ Internal pressure (at weir top) is equal in both upstream and downstream.

and

$$d_0 = d_1 + d_2$$
$$\ell_0 = \ell_1 + \ell_2$$
$$S_0 = S_1 + S_2$$

There are 17 unknowns for 13 equations. Hence, weir fundamentals are settled if arbitrary four independent unknowns are set. As the group of mutually independent unknowns, (α, h_1, h_2, t) or (α, h_1, h_2, β_2) is popularly used for the reason of easiness of calculation.

With regard to tube deformation accompanying to change of water levels in upstream and downstream, convergence calculation of the described equations holding the conditions below gives the solution. The conditions:

i) Constant periphery length (at no tension)

ii) Constant fixture interval

iii) For air type : Constant air quantity in weir

$$(\text{atm. pressure} + Pi) \cdot S_0 = \text{const}$$

For water type : Constant water quantity in weir

$$S_0 = \text{const}$$

5) Examples of calculation

Examples of calculation using the approximation equations described in the previous paragraph are presented.

As known from assumption for the approximation calculation, these equations yield precise solution in case of no overflow.

Even in case of overflow, they can be properly used if internal pressure and overflow depth remain in ordinary range.

Table 1.10 Examples of Calculation

Type	Water inflation type				Air inflation type										
Given unknowns group	α, h_1, h_2, β_2				α, h_1, h_2, β_2							α, h_1 h_2, t			
Internal pressure	0.5	1.0	1.5	1.0	0.75	1.0	1.5	2.0	2.5	3.0	2.0	1.443	1.280	1.038	0.75
Upstream water level h_1	1.0	1.0	1.0	1.2	1.0	1.0	1.0	1.0	1.0	1.0	1.2	1.0	1.0	1.0	1.0
Downstream water level h_2	0	0	0	0.5	0	0	0	0	0	0	0.5	0	0	0	0
Downstream side rising angle β_2	π	π	π	π	π	π	π	π	π	π	π	0.875π	0.750π	0.625π	$\frac{\pi}{2}$
Tension t	0.5	0.75	1.0	0.6875	0.375	0.5	0.75	1.0	1.25	1.5	0.9375	0.75	0.75	0.75	0.75
Upstream side rising angle β_1	$\frac{\pi}{2}$	0.608π	$\frac{2}{3}\pi$	0.552π	0.392π	0.5π	0.608π	$\frac{2}{3}\pi$	0.705π	0.732π	0.626π	0.583π	0.513π	0.409π	0.268π
Interval d_0	1.438	0.981	0.779	1.020	0.722	0.599	0.479	0.415	0.373	0.342	0.371	0.729	1.093	1.592	2.375
Peripheral length l_0	3.258	3.051	2.993	3.119	2.909	2.882	2.879	2.888	2.897	2.907	2.930	2.746	2.741	2.896	3.317
Cross-sectional area S_0	1.443	1.174	1.064	1.196	0.927	0.893	0.860	0.844	0.833	0.827	0.833	0.909	1.050	1.290	1.688

3.2 Design of tube fixing bolts

> Tube fixing bolts should be designed taking tension in tube's rubberized fabric and nut tightening forces into account. Bolt strength should be stronger not less than three (3) times stress induced therein.

Explanation

Investigation should be made on damage and wear if weir is to be installed at a place of many flowing-down matters such as rolling stones.

3.3 Design of buried unit for fixing bolts

> Buried units for fixing bolts should be designed so as to secure sufficient strength of tube fixing bolts taking strength of burying concrete into consideration.

Explanation

In case when the unit is separated from the bolt before being buried in order to bury the bolt afterwards, strength of bolt affixing portion should be carefully examined.

3.4 Design of tube affixing fittings

> Strength of tube affixing fittings should be determined taking tension in tube's rubberized fabric and tightening force of nuts into consideration. Safety factor of the strength should not be less than three (3). The tube affixing fittings should be constructed so that force in the tube's rubberized fabric is evenly held.

Explanation

In case when thickness of rubberized fabric jointing portion is uneven locally, it is important to clamp it to foundation uniformly.

The fittings should be provided with sifficient holding capability despite stress relaxation in rubberized fabric caused by temporal change after tightening.

Consideration should be made against damage and wear at a place with many flowing-down matters such as rolling stones.

Reference: Affixing fittings and fixing bolts

Fig. 1.31 shows examples of actual design of tube affixing fittings and fixing bolts.

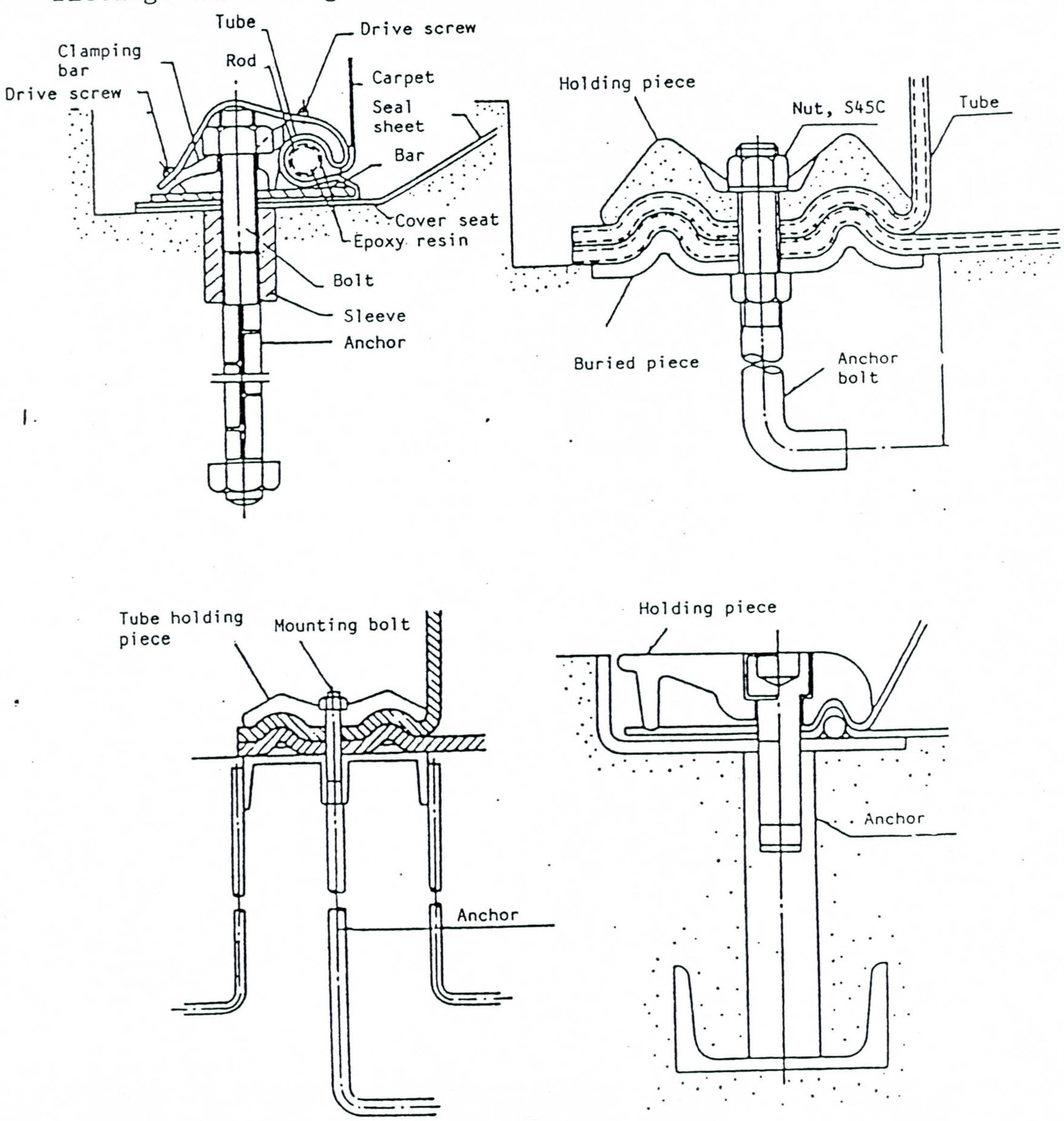


Fig. 1.31 Examples of tube affixing fittings and fixing bolts

3.5 Complete discharge of inflating medium

Suitable measures should be taken so that tube flattens completely when shrinked.

Explanation

If tube blocks feeding/discharging port in flattening process, complete flattening is disturbed. Hence, construction should be designed so that inflating medium be perfectly discharged. Besides, in such a case that upstream-downstream water level difference is small and flow rate in flattening is low, shrinked tube may drift in water without falling onto bed even if inflating medium is perfectly discharged. In this situation, possibility that tube is damaged as caused by friction to bed or by flowing-down matters increases. Hence, countermeasures should be taken against such effects.

Reference

Auxiliary apparatus for perfect discharging includes drain-board like cover (drain pad) to be put on each feeding/discharging port and vent pipe through into tube (spacer). Both methods intend to discharge inflating medium via the path they provide even when tube blocks feeding/discharging port. Fig. 1.32 shows examples of the auxiliary apparatus.

3.6 Measures to prevent damages of tube

Suitable measures should be taken in cases when tube and fixture unit may be damaged by rolling stones or the like.

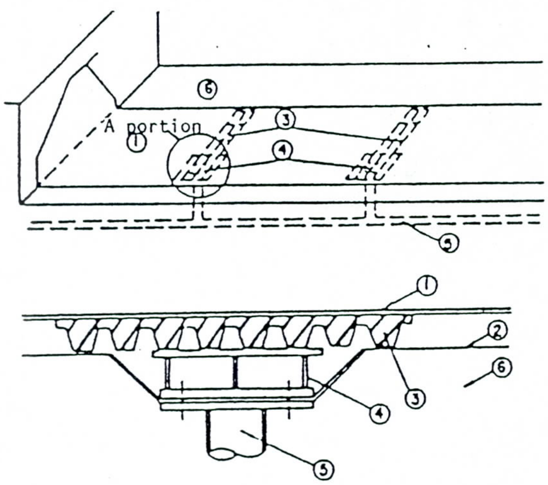
Explanation

In design of the measures, sufficient investigation should be made so that damaging energy is absorbed taking flow velocity at place of installation and shape of flowing-down matters into account.

Reference: Measures to prevent damages

Measures to prevent damages of tube against flowing-down matters such as rolling stones include buffer installation inside tube, increased thickness of outer layer rubber and addition of re-inforcing cloth (breaker) to outer layer rubber. Examples are shown in Fig. 1.33.

a) Drain pad system



1 : Tube
2 : Water and air-tight sheet
3 : Drain pad
4 : Special flange on feeding/discharging port
5 : Feeding/discharging pipe
6 : foundation river bed

Details of A portion (Cross-section)

b) Spacer system

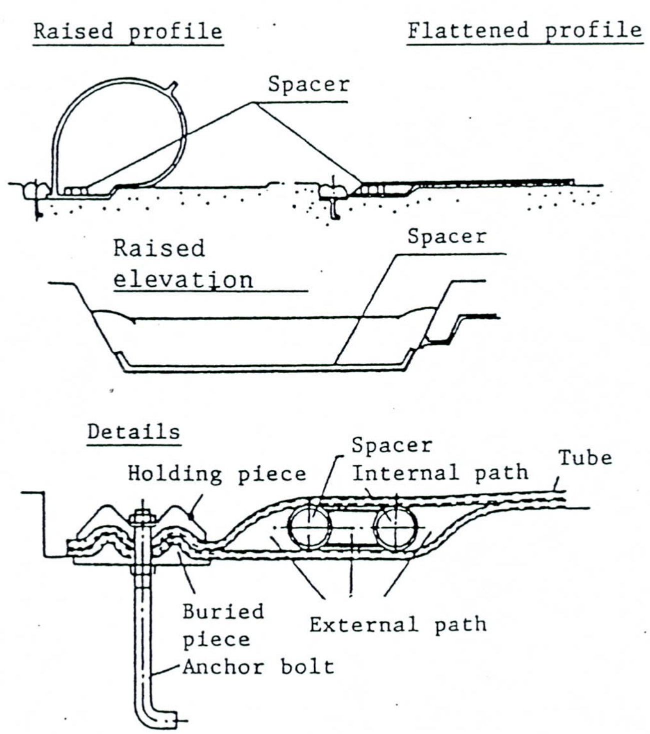
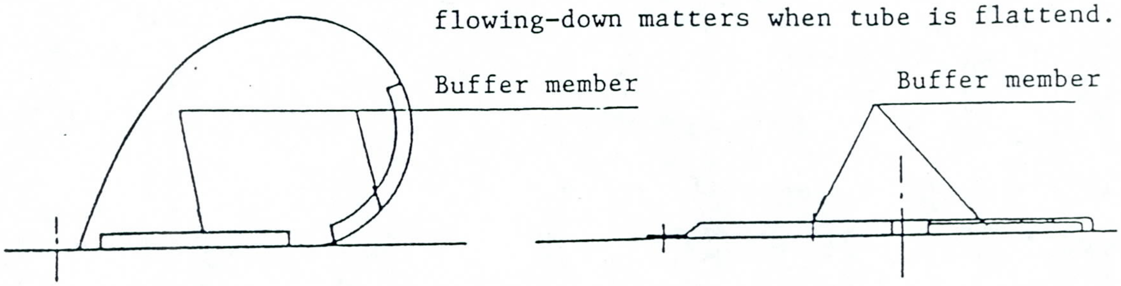
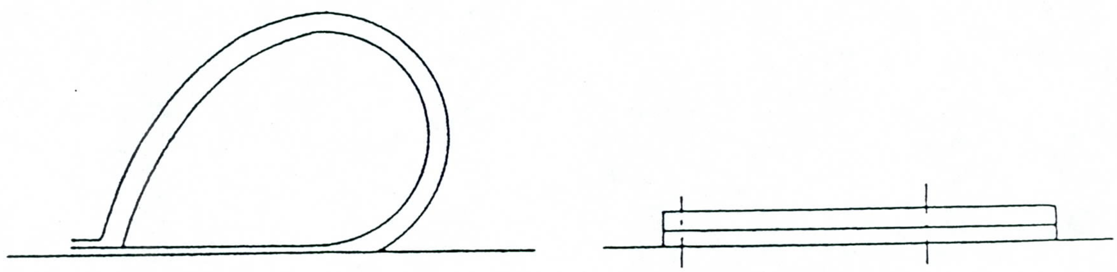


Fig. 1.32 Examples of auxiliary apparatus for perfect discharge of inflating medium

a) Buffer method ----- Elastic buffer members are lined inside tube in order to absorb shock exerted by flowing-down matters when tube is flattend.



b) Thick outer layer rubber method ---- Outer layer rubber thicker than usual provides a measure against external damage. Flattened shape must be plane without elongation strain.



c) Breaker method ------ Breaker is placed in the outermost layer to prevent extension of a damage.

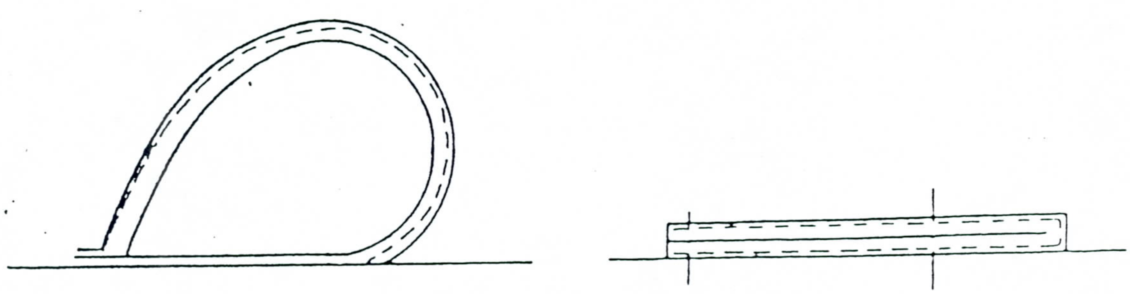


Fig. 1.33 Examples of measures for tube protection

Chapter 3 Substructure Design

Section 1 Generals

1.1 Design conditions

Substructure of rubber weir should meet the conditions listed below:

1. Construction of substructure portions should be safe to expected loads.
2. Substructure should secure watertightness as required by weir.
3. Substructure should have superb durability.

Explanation

While rubber weirs are more advantageous than steel gates with smaller superstructure load, they need sufficient cautions for watertightness and airtightness.

1.2 Design loads

Substructure should be designed based on the loads described in 4.3, Chapter 1.

Explanation

Whereas load values should be determined by the method described in 4.3, Chapter 1, Part of design, the items of load to be considered in design should be selected depending on conditions of installation point and structure type.

1.3 Unit volume weights of materials

Unit volume weights of materials should be determined referring to the values listed in Table 1.11.

Table 1.11 Unit Volume Weights of Materials

Material name	Unit volume weights kg/m^3
Reinforced concrete	2,500
plain concrete	2,350
Soil (in air)	1,800
Soil (in water)	1,000
Steel, cast steel, forged steel	7,850
Cast iron	7,250
Sand, gravel, crushed stone	1,900
Cement, mortar	2,150
Stone	2,600
Timber	800
Bituminous material (for waterproofing)	1,100
Bituminous pavement	2,300

Explanation

The weight of soil in the table is a representative value.

If any soil test data is available, that value should be adopted.

1.4 Stress values tolerable for materials

Stress values tolerable for materials should be as listed below:

Ordinary round steel bar	SR24	Tensible	1,400 kg/cm^2
"	SR30	"	1,600 "
Specially formed round steel bar	SD24	"	1,400 "
"	SD30	"	1,600 "
"	SD35	"	1,800 "
Steel pipe pile	STK41	"	1,400 "
Steel sheet pile	(SY30)	"	1,800 "
Ready-made pile			In accordance with JIS
Tie rod	SS41		900 kg/cm^2
	SS50	16mm < dia. ≦40mm	1,100 "
	"	40mm < dia.	1,000 "
	HT70		1,800 "
	HT75		2,200 "
Steel member	SS41	Tensible	1,400 "

Concrete (kg/cm^2)

Stress type \ Design standard strength		210	240	270	300
Compressive stress	By bending	70	80	90	100
	By axial load	55	65	75	85
Shearing stress	Born only by concrete (τa_1)	3.6	3.9	4.2	4.5
	Born by concrete with diagonal tension bar (τa_2)	16	17	18	19

Stress increase rates for short term load are as given in the table below:

Table 1.12 Stress Increase Rates

Type of short time load	Increase rate (%)
Temperature change	15
Earthquake	50
Temperature change and earthquake	65

Explanation

When to consider a load other than those in the table, stress increase rate tolerable for short term load should be in accordance with an appropriate standard.

1.5 Safety factor

Safety factor relating to foundation of rubber weir should be determined properly in the range securing weir safety.

Explanation

For design of foundation, safety factors listed in the table below can be generally used.

Table 1.13 Safety Factors

			In ordinary times	In earthquake
Overturn			Resultant force to act in within 2/3 from the center	Resultant force to act in within 2/3 from the center
Slide			1.5	1.2
Supporting force	Direct foundation	Vertical bearing force	3	2
		Horizontal bearing force	1.5	1.1
	Pile foundation	Axial press-in bearing force	Bearing pile 3 Friction pile 4	Bearing pile 2 Friction pile 3
		Axial draw-out force	6	3
		Bearing force in normal direction	Bearing portion stress and pile head displacement not to exceed specification values.	
	Caisson foundation	Vertical bearing force	3	2
		Horizontal bearing force	1.5	1.1

Tolerable pile head displacement is taken as approx. 10 mm in ordinary times and approx. 15mm in earthquake in many cases for a fixed pile.

1.6 Minimum member dimension and others

1. The minimum member dimension should be 35 cm except operation room, etc.
2. Permissible corrosion depth of steel pile should be 2 mm on outer face.
3. Covering for reinforcing bar should not be less than 7.5 cm except operation room, etc. (not less than 10 cm for bed plate).

Explanation

The permissible corrosion depth of 2 mm is a general value. Therefore, in case where severe corrosion is foreseen as an effect of water from sea or of bad quality, measures such as adopting larger allowance for corrosion or execution of anti-corrosion treatment should be taken.

Section 2 Construction of substracture portions

2.1 Weir post

1. Weir post width should be such that minimizes river area blocking ratio.
2. Weir post shapes; all the plan, the front and the side elevations; should be less resistant to both water flow and flowing-down matters.
3. Weir post height should be the minimum needed for fixing tube edge, except for cases where the a maintenance bridge, an entrance and/or an exit of inspection corridor for maintenance and inflation medium feeding/discharging devices are installed.

Explanation

1. While no problem is ordinarily caused by width of weir posts when using rubber weirs, consideration should be taken so as to minimize the width as far as no technical difficulties arise.
   Explanation is given in Ordinance for river control facilities construction that river area blocking ratio by weir posts should not exceed 10%.

2. In case when structures such as operation room is installed on weir posts, the posts should be so constructed as to transfer upper loads safely to bed plate.

2.2 Side wall

Construction of side wall should be determined taking the following into consideration:

1. Tube top height on side wall in tube flattening
2. Flow stability along side wall in tube flattening
3. Range of revetment

Explanation

1. Design effort should be taken so that tube end side wall be not beyond low water revetment in upstream and downstream of weir or levee's side slope unless no steel gates are co-installed. And, any projection of tube face above upstream and downstream water levels near side wall is undesirable because it gives turbulance to water flow thereabout. Hence, it is recommended to provide a cavity in the side wall in the range relating to tube flattening so that wall face is finished lower by thickness of flattened tube.

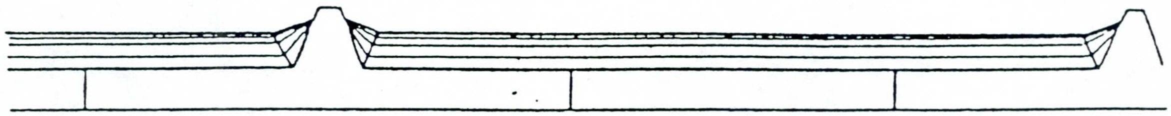
2. Nearby weirs, revetment shoulder or portions around structures (such as fish pass) in high water facilities are often wash-cut by flow turbulance in floods. As a provision to this, side wall edge should be extended into high water facilities or bank well observing stipulations in Ordinance of river control facilities construction.

2.3 Tube mounting bed plate

Construction of tube mounting bed plate should be such that supports upper load and ensures tube watertightness and airtightness.

Explanation

Joints are often provided in tube mounting bed plate as shown in Fig. 1.34. Bed plates should be so constructed as to prevent uneven sinking since parts such as feeding/discharging pipes are embedded therein. Joint construction should be such that ensures watertightness and allows treatment in uneven sinking. Joint construction includes dowel bar type and key type, and should be selected depending on conditions of foundation ground quality.



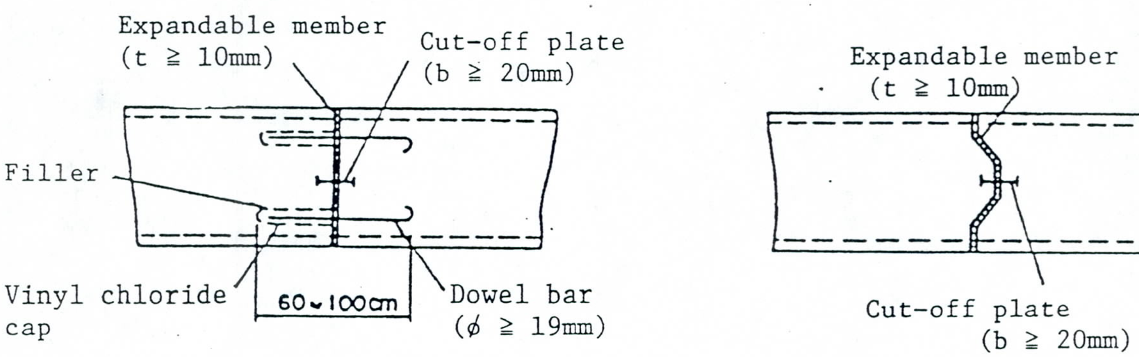


Fig. 1.34 Joint constructions

2.4 Apron

> Aprons of reinforced concrete should be provided in both upstream and downstream of weir. Range of apron installation should be determined by comprehensive consideration on safety with regard to overflow depth, flow rate, fall, downstream water depth, flow velocity, river bed material, river channel shape, river bed gradient and lift pressure.

<u>Explanation</u>

1. Upstream apron thickness can be thinner than downstream because of mounted water counter-weight against lift pressure, and is set at a thickness of 1/2 to 2/3 of that in downstream in many cases.

2. Downstream apron is a very important structure for weir protection since immediate downstream portion of weir is strongly affected by water flow overflowing the weir. For readers' reference, Ply's formula is shown below.

Ply's formula:

$$\ell = 0.67 \cdot C \cdot \sqrt{\Delta H \cdot q}$$

where

ℓ : Apron length + revetment length (m)

c : Ply's coefficient of percolation path

ΔH : Upstream-downstream water level difference (m)

q : Unit width flow rate ($m^3/s/m$)

3. With respect to weirs of air type, V notch effect, a featuring behavior in flattening, was described in 1.7, Chapter 2, Part of design. This effect should be investigated in determination of apron and revetment length because of large unit width flow rate in a V notch.

4. Joints should be watertight and allow treatment in uneven sinking because sealing is made in aprons. A flexible material should be employed for cut-off plate and elastic material for expansion member.

5. Apron should be designed considering hydraulic characteristics of discharge port for soil and sand, fish pass and lock gate if installed.

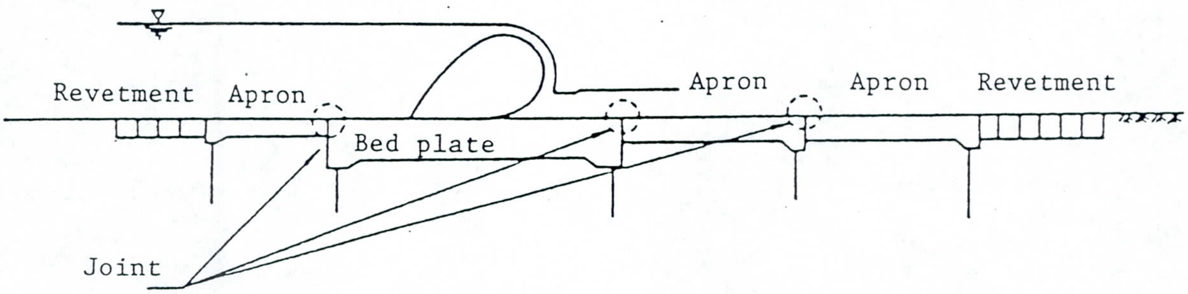


Fig. 1.35 Apron

2.5 Revetment

Revetment should be provided on upstream side and downstream side of tube mounting bed plate and apron. Type of revetment should be selected considering hydraulic characteristics, river bed material, construction easiness, and economy.

Explanation

1. Velocity of flow over tube mounting bed plate and apron, whose faces are made of concrete and slippy, is faster than that in upstream and downstream, where river bed is natural ground. From this reason, revetment must be provided for protection of bed plate and apron from danger of wash-cut.

2. Generally employed revetments are as below:

   ① Fascine mattress
   ② Timber mattress
   ③ Improvement mattress
   ④ Rubble mattress
   ⑤ Concrete block mattress

3. Cautions listed below should be taken in selection and location of revetment.

① Rigidness of revetment should become less as distance from weir gets larger.

② Roughness coefficient of revetment should become larger as distance from weir gets larger.

③ Revetment should preferably be flexible so as to fit naturally to river bed.

④ Flow velocity over the portion joining revetment with bed plate and apron is fast. Investigation on revetment should be made regarding its proper stability and prevention of sucking out river bed material.

⑤ Consideration should be taken on easiness of material procurement and required construction period.

2.6 Protection for high water level facilities

Shoulder of approach revetment in both upstream and downstream of rubber weir and proximities of high water facility structures in a suitable range should be protected with flexible structures.

Explanation

1. Shoulder of revetment or proximities of high water facility structures are vulnerable to wash-cut by turbulent flow of flood. Hence, these portions should be protected with structures such as concrete blocks and concrete bed plate.

2. The range where high water protective structures are to be provided should be extent where water flow is turbulent, and abrupt change of roughness coefficient should be avoided.

2.7 Approach revetment

Revetment should be provided in upstream and downstream of rubber weir in order to prevent wash-cut of river bank or levee accompanying change of water flow.

Explanation

Area where revetment is required for installation of rubber weir should be determined in accordance with Art. 16 of Ordinance of river control facilities construction.

2.8 Approach retaining wall

Approach retaining wall of construction safe to water flow turbulence should be provided in upstream and downstream of rubber weir.

Explanation

1. While the extent where the retaining wall is installed is generally set up to apron, studies should be made on weir construction, shape of side slope, revetment type, fish pass, port of soil and sand discharge and presence or absence and place of gate.

2. Approach retaining wall should be so configurated as to expand or contract river sectional area gradually.

2.9 Water sealing

Water sealing should be provided in order to prevent flow and suck-out of soil and sand by curtailing hydraulic gradient to foundation face of percolation water. Sealing should be effectuated with concrete wall or steel sheet pile wall.

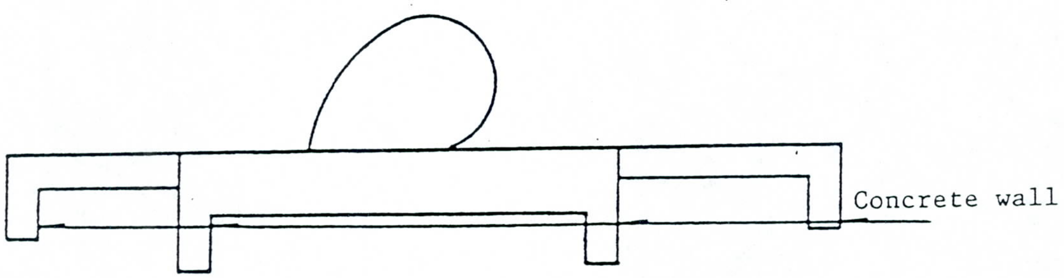
Explanation

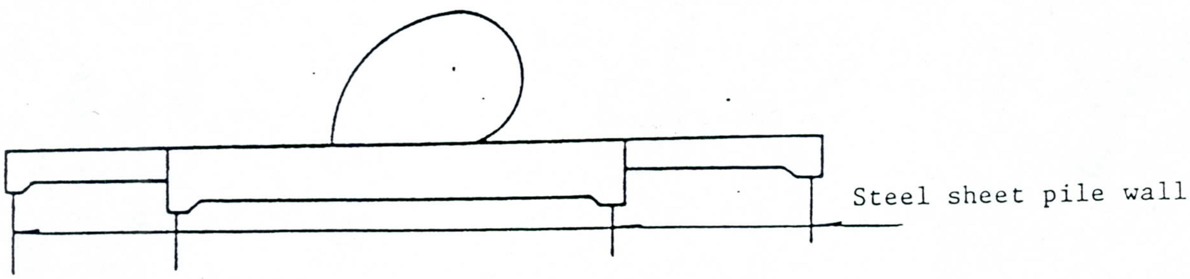
1. Location of water sealing includes underside of tube mounting bed plate and apron, weir attachment to levee, and underside of approach retaining wall bed plate, for all of which sealing should be installed continuously.

2. With regard to weir attachment to levee, sufficient investigation should be made on percolation so that the levee be not the weak point.

3. In case using steel sheet pile for sealing, sheet pile of a grade upper than II type should be used for reasons of strength to corrosion and construction easiness.

4. Sealing length should be studied for the purposes of curtailing lift pressure and thinning tube mounting bed plate and apron.





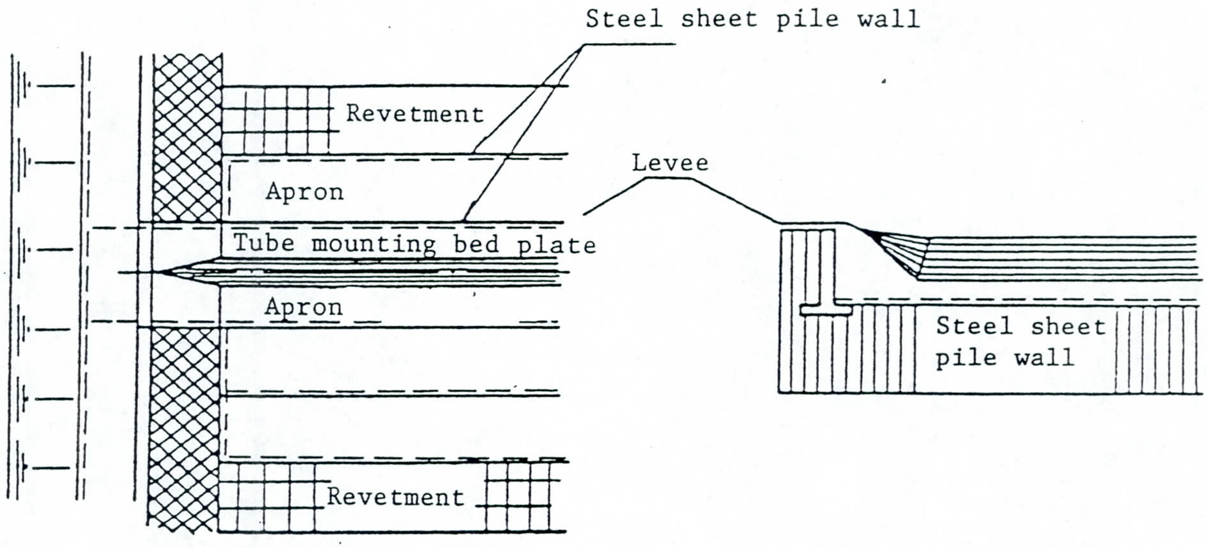


Fig. 1.36 Water sealing

2.10 Selection of foundation type

> Type of foundation should be selected considering load, effect of water flow, ground quality conditions, construction work, environmental conditions, safety and economy.

Explanation

1. Types of foundation are roughly divided into direct foundation, pile foundation and caisson foundation. Type of foundation should be carefully selected based on detailed studies on the above-stated conditions becuase the selection gives great effect on construction cost and change of selection in a midway point of work procedures wastes immense manpower and time.

2. Regarding foundation of rubber weir, conditions to be satisfied are as below:

   ① Foundation itself must have sufficient rigidity for ground reaction and deformation.

② Foundation should not displace to a harmful extent. Foundation type for all structures should be same since uneven sinking, if it occurs, gives great effect to matters embedded in tube mounting bed plate like feeding/discharging pipes.

2.11 Appended equipment

Appended equipment should be provided as required for operation and maintenance of rubber weir.

Explanation

Alarming equipment should be provided in case when great effect is foreseen by flattening rubber weir.

Section 3 Stability calculation

3.1 Stability calculation

> Rubber weir should be designed so as to have stability against overturning, sliding and bearing loads.

Explanation

An example of a set of loading conditions for stability calculation is shown below. Design should be made so as to be safe foreseen combinations of hydraulic conditions besides loading conditions mentioned above.

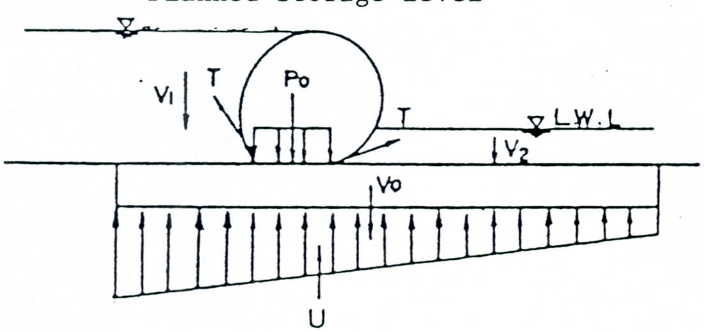
Among combinations of loads, assumed is no action of simultaneous combinations such as following: flood and earthquake wave pressure and earthquake, and wind load and earthquake.

1. Tube mounting bed plate

   1) In direction of water flow

      a) In ordinary times (with planned water storage)

Planned storage level



V_0 : Self weight

T : Tube tension

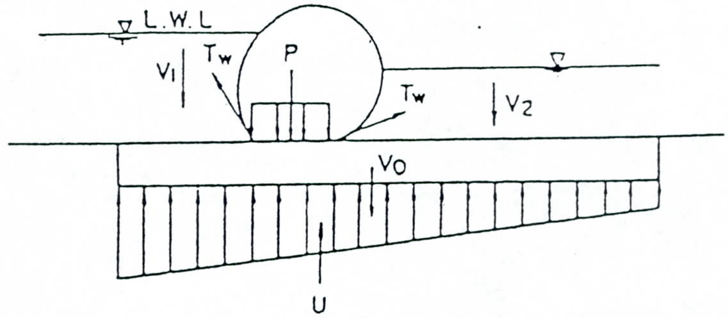
P_0 : Vertical force by tube's internal pressure

V_1 : Upstream water weight

V_2 : Downstream water weight

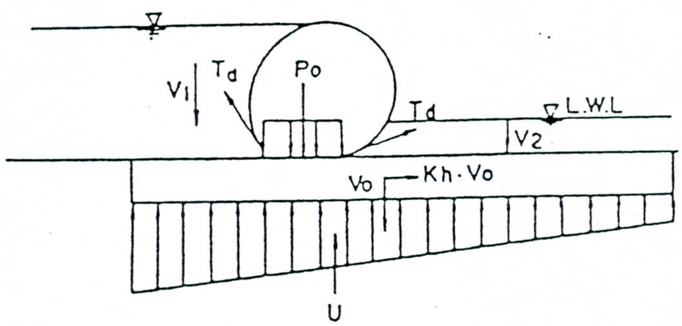
U : Lift pressure

b) In ordinary times (at high tide)



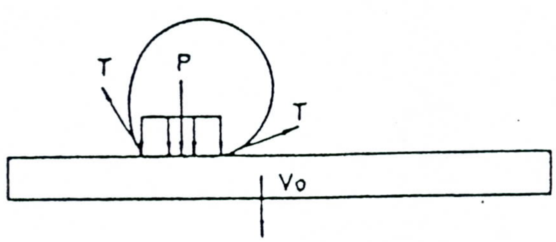
Tw : Tube tension (Take tension for design wave.)

c) At earthquake (with planned water storage)



Td : Tube tension (Take tension for dynamic hydraulic pressure at earthquake. For water inflation type, take tension by inflating water at earthquake into account additionally.)

d) In installation work



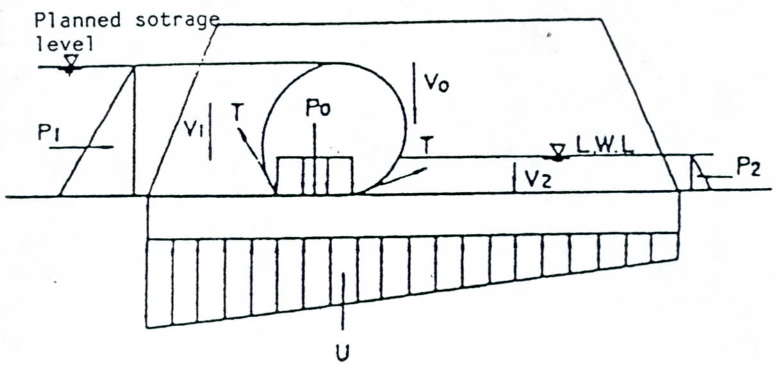
2) In direction normal to water flow

Omitted

2. Weir post

1) In direction of water flow

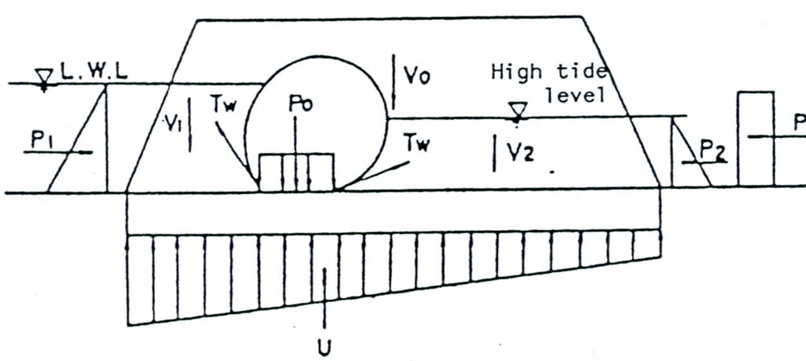
a) In ordinary times (with planned storage water level)



P_1 : Upstream hydraulic pressure applied on post

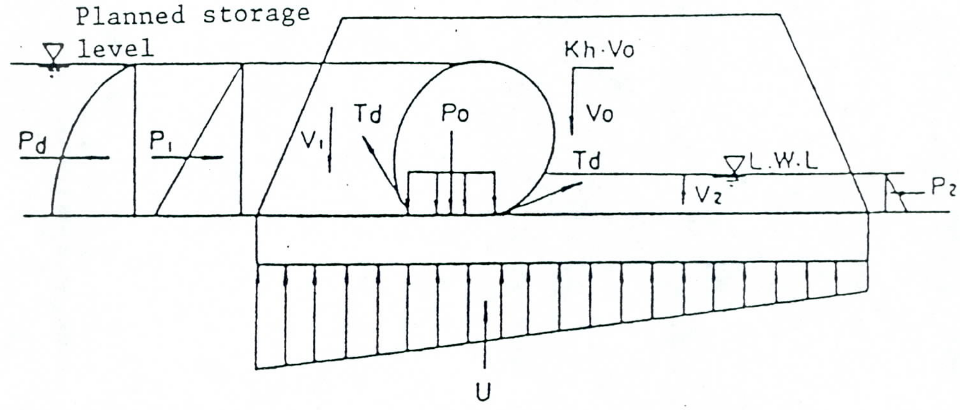
P_2 : Downstream hydraulic pressure applied on post

b) In ordinary times (at high tide)



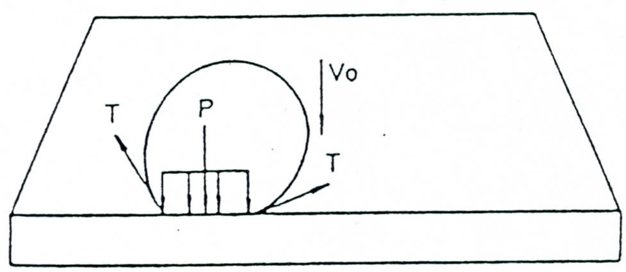
Pw : Wave pressure acting on post (Take tension for design wave.)

c) At earthquake (with planned water storage level)



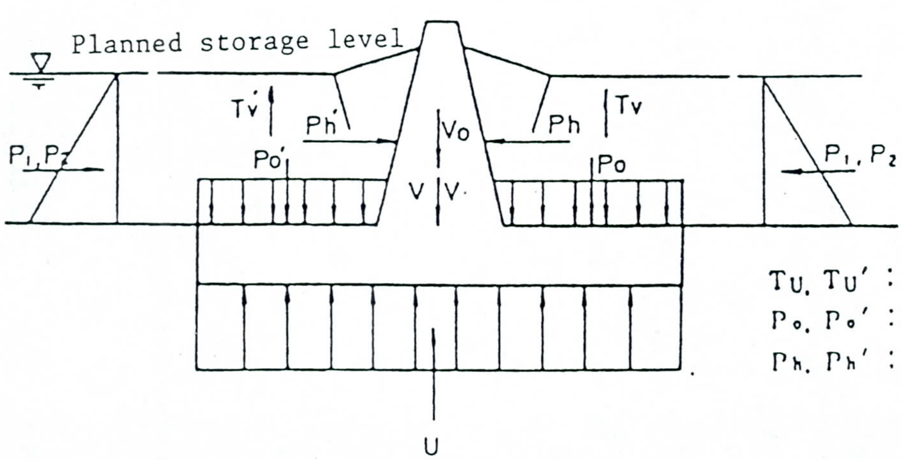
Pd: Earthquake dynamic hydraulic pressure acting on post

d) In installation work



2) In direction normal to water flow

a) In ordinary times (with planned water storage level)

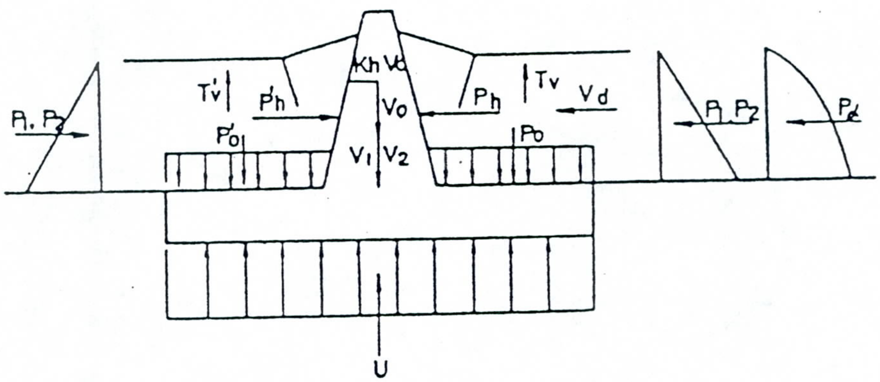


Tu, Tu' : Vertical component of tube tension

Po, Po' : Vertical force by tube's internal tension

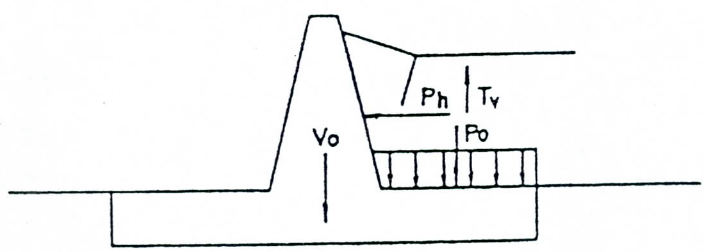
Ph, Ph' : Horizontal force by tube's internal tension

b) At earthquake (with planned water storage level)

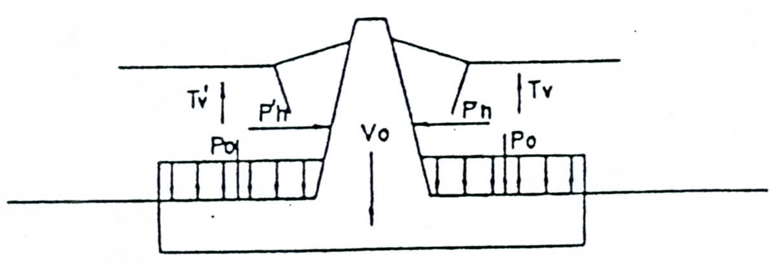


Vd : Earthquake force of tube inflating medium (only in case of water inflation type)

c) In installation work (in case when one side only is raised)



d) In installation work (in case when both sides are raised)



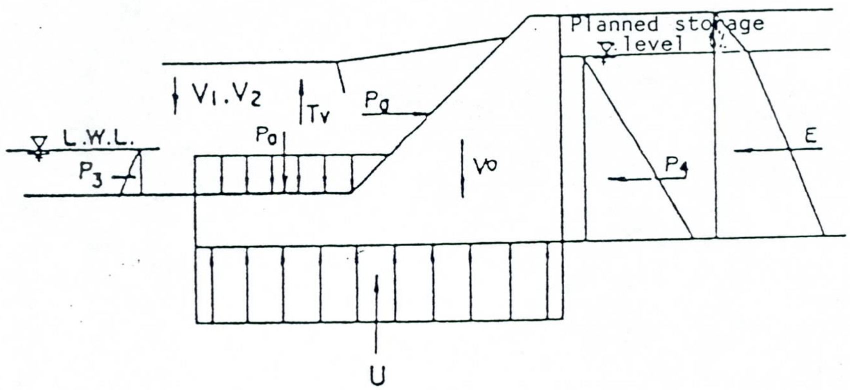
3. Side wall

1) In direction of water flow

Make calculation under the same condition as weir post.

2) In direction normal to water flow

a) In ordinary times (with planned water storage level)

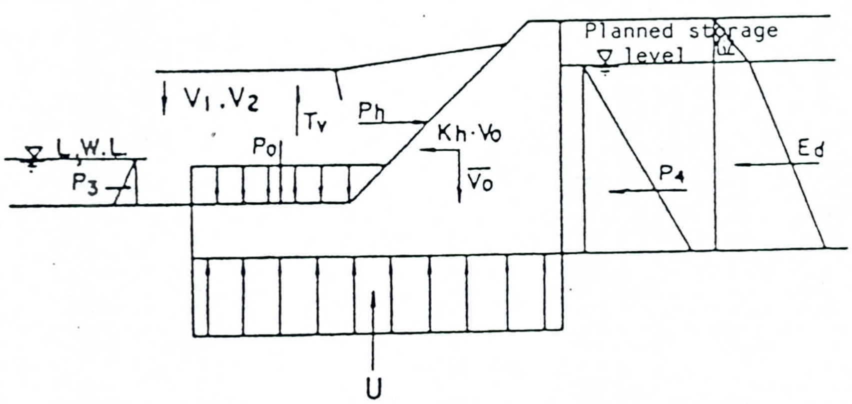


P_3 : Front water pressure

P_4 : Back water pressure

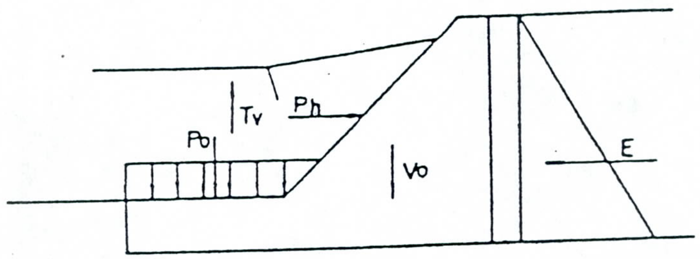
E : Back soil pressure

b) At earthquake (with planned water storage level)

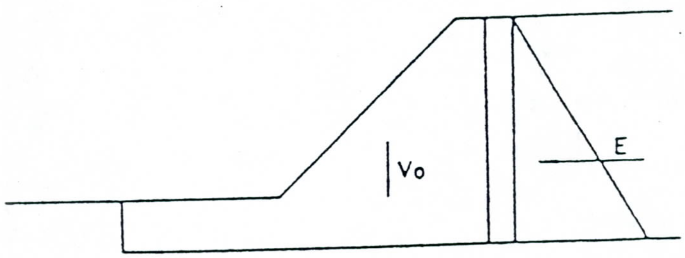


Ed : Back soil pressure at earthquake

c) In installation work (when raised)



d) In installation work (when flattened)



Section 4 Design of substructure portions

4.1 Tube mounting bed plate

> Stress of tube mounting bed plate shall be calculated as a beam on elastic floor or a cantilever fixed on post or side wall depending on its construction.

Explanation

1. Take the same load conditions as for stability calculation.

2. Ground reaction coefficient for calculation should be determined based on careful studies on results of soil quality test.

4.2 Weir post

> Weir port stress should be calculated as a cantilever fixed on tube mounting bed plate.

Explanation

1. Take the same load conditions as for stability calculation.

2. In most cases, weir post has great length in direction of water flow and, therefore, its stress in this direction is rarely a problem. Thus, reinforcing bar determined only by stress check in direction normal to water flow is satisfactory in most cases.

3. Effective cross-sectional area of weir post should exclude round edge portions.

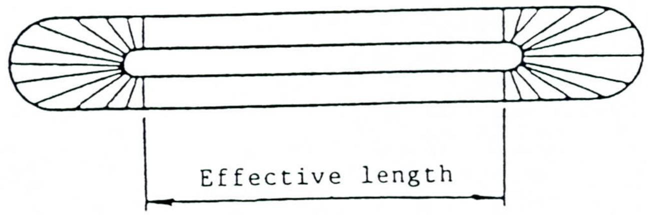


Fig. 1.37 Effective length

4.3 Side wall

Side wall stress should be calculated as a cantilever fixed on tube mounting bed plate.

Explanation

1. Take the same load conditions as for stability calculation.

2. In most cases, side wall length is determined same as tube mounting bed plate, posing no stress problem in direction of water flow. Hence, reinforcing bar determined only by stress calculation in direction normal to water flow is satisfactory in most cases.

4.4 Apron

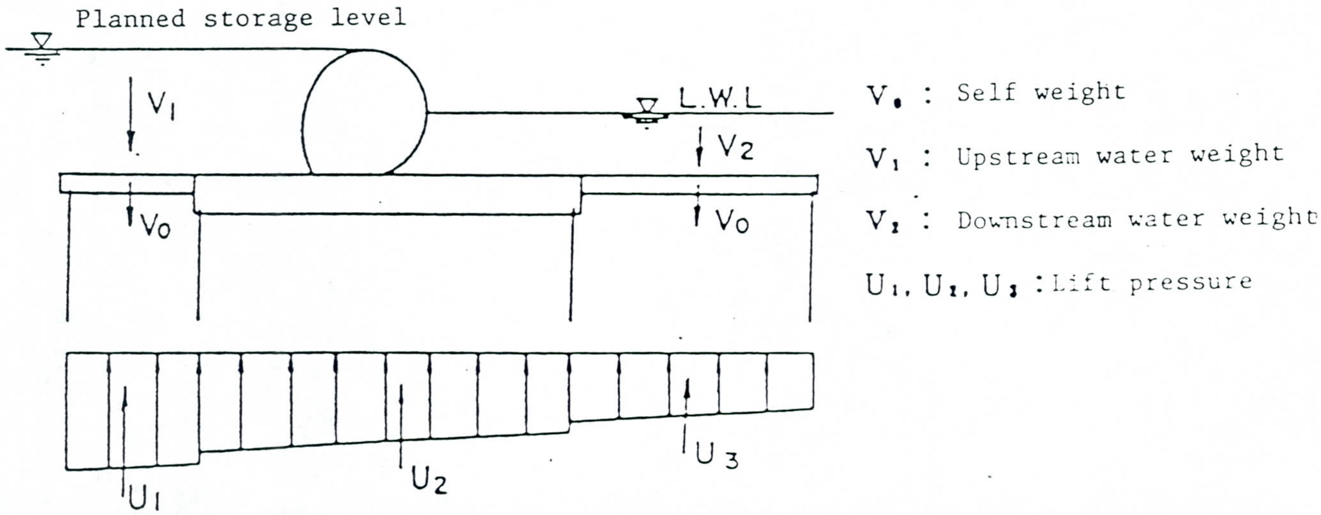
Apron should be constructed safe to loads such as water weight and lift pressure.

Explanation

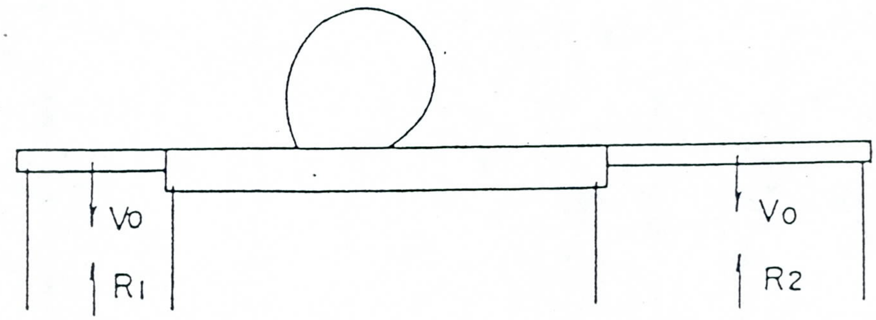
1. An example of a set of loading conditions for apron stability calculation is shown below.

   1) In direction of water flow

      a) In ordinary times (with planned water storage level)



b) In installation work



R_1, R_2 : Foundation reaction

2. Member's thickness should be calculated block by block using the following equation:

$$t = \frac{4}{3} \cdot \frac{Hp - \omega}{\gamma c - 1}$$

where
- t : Member thickness
- Hp : Lift pressure larger in each block
- γc : Concrete weight
- ω : Weight of mounted water

3. Apron should be assumed having flat slab construction for stress calculation in case of pile foundation.

4.5 Water sealing

> Penetration length of water sealing should be determined based on values obtained by Reyn's formula or Ply's formula and past records.

<u>Explanation</u>

1. With recognition that resistance to percolation is smaller in horizontal portion than in vertical portion, Reyn's formula assumes the former at 1/3 of the latter to determine effective length.

Reyn's formula

$$C \leqq \frac{L/3 + \Sigma \ell}{\Delta H}$$

where
- C : Creep ratio
- L : Entire weir length (m)
- $\Sigma \ell$: Total percolation path length of water sealing (m)
- ΔH : Upstream-downstream water level difference

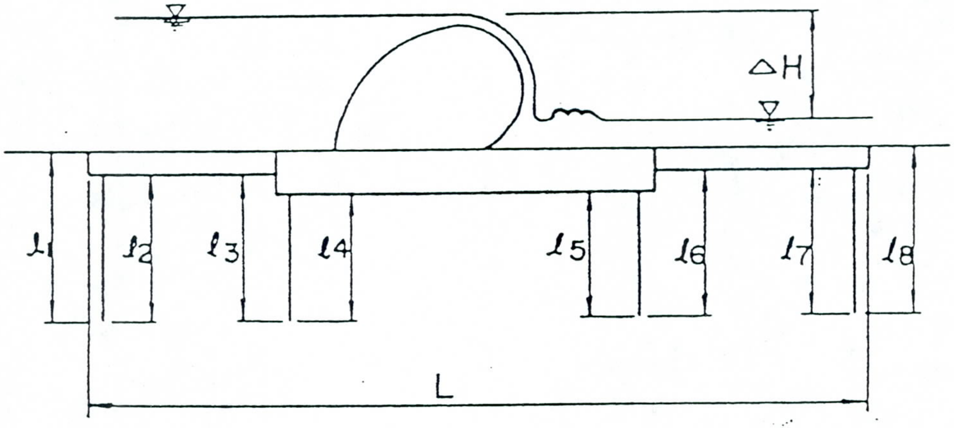


Table 1.14 Creep Ratio

Foundation ground quality	C
Very fine sand or silt	8.5
Fine sand	7.0
Medium sand	6.0
Coarse sand	5.0
Small gravel	4.0
Medium gravel	3.5
Coarse gravel including cobble stones	3.0
Stones including a little quantity of cobble stones and gravel	2.0

2. According to relation between water sealing length and its interval, water sealing may not work effectively because percolating water passes along a route of smaller resistance.

Hence, water sealing length should be taken not longer than 1/2 of water sealing interval. If it gets longer than this limit, extend apron length.

3. In case using steel sheet pile as water sealing, it should not be shorter than 2 m.

4. Cautions should be taken on percolation path detouring towards high water facilities or levee.

Chapter 4 Design of Operation Equipment

Section 1 Generals

1.1 Definition

1. Raising equipment means engine or motor driven pump in weir of water inflation type, and engine or motor driven blower or compressor in weir of air inflation type.
2. Flattening equipment means apparatus for flattening tube.
3. Safety equipment means apparatus for preventing damage of tube caused by excessive internal pressure and apparatus for ensuring flattening of tube even in case of flattening equipment trouble.
4. External water level detector means apparatus for detecting upstream and downstream water levels.
5. Tube internal pressure detector means apparatus for detecting hydraulic or pneumatic pressure in tube.

1.2 Preparatory power equipment

1. Preparatory power equipment should be provided for important or necessary weir.
2. Capacity of auxiliary power equipment should be sufficient for sure operation of planned performance of weir.

Explanation

For weir to let flood down safely, preparatory power equipment should be provided so that no interference be brought about even when a trouble occurs in power equipment for ordinary use. In case when power equipment is driven by electric motor, an engine is generally installed as preparatory power source.

Some small weirs receive power branched directly from transmission or distribution lines. In such a case, power should be received from other power transmission system which is not cut off simultaneously with ordinary power. Preparatory power equipment must surely perform its fundamental functions. Capacity of preparatory power equipment should be determined based on investigation results of aggregation of required loads, which should include power for illumination. In case where multiple weirs are installed, the necessary capacity depends on starting procedures and number of weirs operated simultaneously as well as motor type. Output of the engine for driving preparatory power equipment should be sufficient taking output, power factor and efficiency of generator into consideration.

1.3 Safety equipment

Safety equipment should be provided for rubber weirs.

Explanation

Safety equipment should be provided in order to prevent tube damage caused by excessive supply of inflating medium and to ensure flattening of tube even when flattening equipment is in trouble.

1) Overfeed preventing apparatus

Overfeed preventing apparatus includes siphon (water type), water seal tube or U-figured tube (air type), pressure adjusting valve and excessive pressure preventive blower (air type).

2) Flattening safety apparatus

Rubber weirs are often provided with automatic flattening apparatus linked with upstream water level. Although tube can be flattened using manual valves when automatic flattening apparatus is in failure, automatic flattening can also be performed using siphon (water type) or U-figured tube (air type), that is, on the principle of excessive pressure preventive apparatus. Water seal tube, however, may not be suitable for complete flattening for its constructional reasons.

It is desirable to raise safety of an important weir by parallel installation of flattening apparatus of different principles with independent piping. And, consideration such as to install no valves between safety apparatus and tube would be required so as to prevent an event that a mis-operations disturb performance of safety apparatus.

Reference: Example of safety apparatus

Inflating medium feeding/discharging system depends on weir type, water or air, to some extent. In Fig. 1.38, siphon (water type), water seal tube and U-figure tube (air type) are apparatus not to increase tube internal pressure over a specific value. They have inflating medium discharging function when tube internal pressure becomes high as a result of overfeeding of inflating medium or rising of upstream water level.

Provided with construction preventing pressure rise over a specific pressure, excessive pressure preventive blower has function to prevent overfeeding inflating medium.

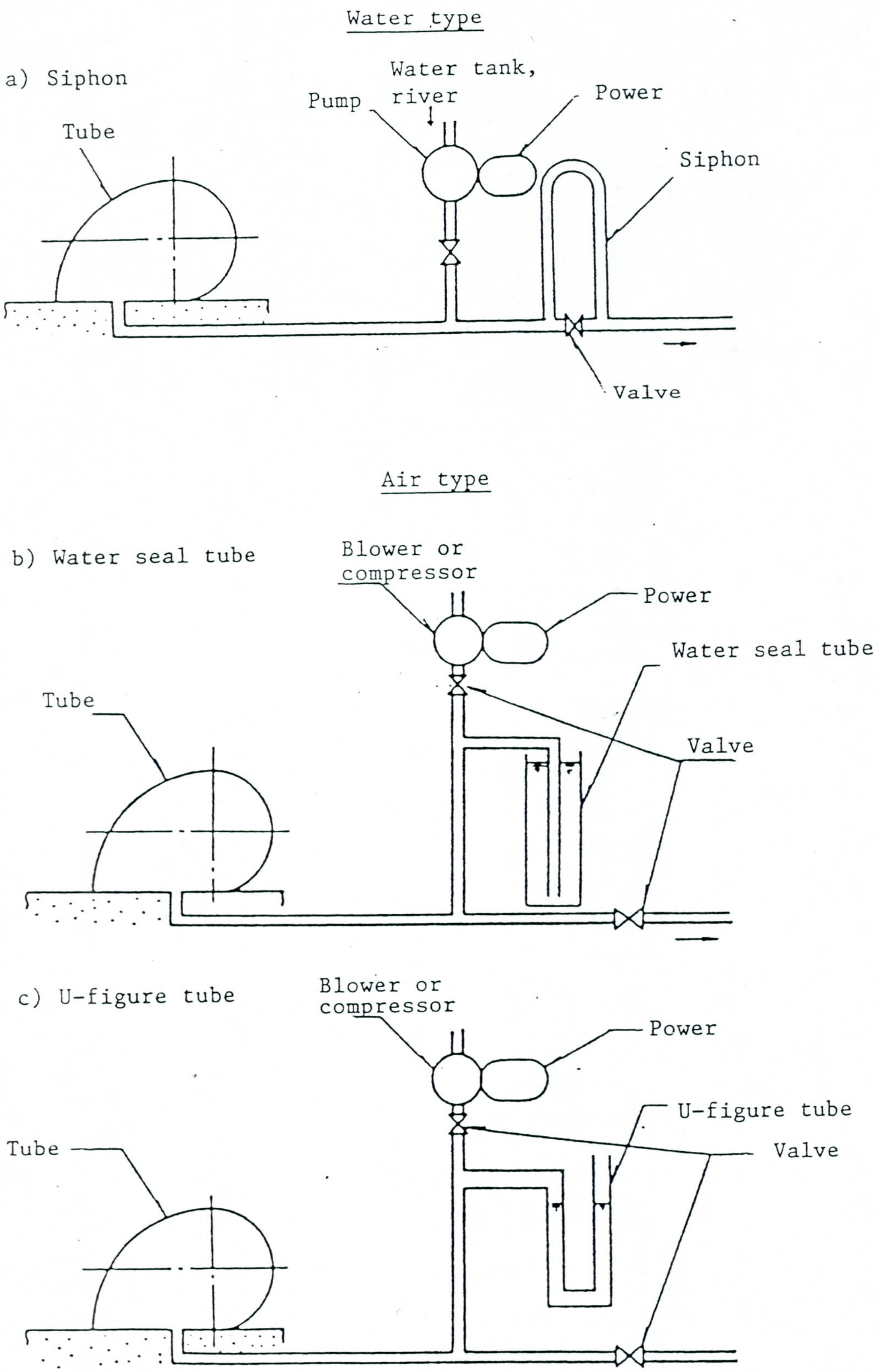


Fig. 1.38 Examples of safety apparatus

1.4 Raising and flattening speed

Raising and flattening speed of rubber weir should be suitable for the purpose of weir use.

Explanation

Capacities of pump, blower, etc. and diameter of feeding/discharging pipe for raising should be selected in accordance with performance speed required from operation frequency and management of weir.

Determined based on upstream and downstream water levels and internal pressure, flattening speed is not constant during performance because the conditions change from minute to the next.

When inflating medium is discharged naturally, rubber weir flattening speed is maximum immediately after start and then decreases gradually as upstream water level lowers. On the other hand, initial flattening speed should be suppressed for consideration of effect to downstream water level rising rate, which is maximum immediately after start of flattening. Given methods such as stepping change of openness ratio of discharge valves or number of open pipes, and adjustment of flattening speed watching upstream water level and downstream water level, sufficient investigation should be made for purpose of installation and downstream safety.

For a weir requiring complex operation, more detailed studies are required on response to estimated water level and flow rate change as operation speed and precision become higher.

Since rubber weir's raising and flattening speeds depend on upstream and downstream water level conditions, installation of feeding/discharging valve openness adjusting mechanism and sufficient capacity of raising apparatus are essential.

Section 2 Comparison of various systems of operating equipment

2.1 Discharging method of inflating medium

Discharging method of inflating medium should be selected out of natural method, forced method, and mixed method.

Explanation

Discharging method of inflating medium should be selected taking into consideration type of inflating medium, piping system, place for discharge of inflating medium, flattening time and the following:

1) Natural discharge: This is the method most commonly used in existing rubber weirs. Weirs of water type with natural discharge system should be selected for places where water level rise is not so great as to disturb natural draining.

2) Forced discharge : This system should be selected in such cases where flattening time is to be adjusted, draining pipe of water type is to be installed over tube mounting bed plate, or natural draining may become impracticable as caused by water level rise at discharging place.

3) Mixed discharge : This system is selected in a case where forced draining is necessary in times of flood. Whereas provided with advantages of both natural and forced discharge systems, equipment becomes complicated.

2.2 Raising and flattening sensors

Rubber weir raising and flattening sensors should be selected according to detection object such as river water level and tube internal pressure.

Explanation

Required for automatic operation of weirs, raising/flattening sensors detect upstream and downstream water levels and tube internal pressure. In many existing weirs, river water level detectors of mechanical type are installed. Whereas electric sensors are often used in weirs important or requiring complicated operation, it is recommendable to install highly reliable sensors of mechanical type together.

Table 1.15 Comparison of Raising/Flattening Sensors

Detection object	Sensor			
River water level	External water level detector	Mechanical type	Float type, bucket type	Used in cases when to detect water level mechanically for valve operation
		Electrical type	Float type, probe type, hydraulic pressure type, pneumatic pressure type, ultrasonic type, static capacitance type	Used in cases when to detect water level electrically for output amplification and then valve operation
Tube internal pressure	Tube internal pressure detector	Diaphragm type, Bourdon tube type, bellow type, liquid pressure type		Used in cases when to detect internal pressure electrically for output amplification and then valve operation

2.3 Feeding/discharging valve operating force

1. Operating force for feeding/discharging valves should be such that can surely open or close valves.

2. Operating force for feeding/discharging valves should be selected out of electric force, electromagnetic force, hydraulic pressure, pneumatic pressure, mechanical force and manual force considering type of driving power and scale of weir.

Explanation

Generally, it is recommended to select operation of feeding/discharging valves by the reference described below.
In weirs important or requiring complicated operation, many cases require large operating force and operation frequency is high. Hence, it is supposed that operation is often automatically done using electric force, electromagnetic force, hydraulic pressure and pneumatic pressure in combination with external water level detector and tube internal pressure detector. In such cases also, it is desirable to raise safety by co-installation of feeding/discharging valves and manual valves using mechanical force that allows sure valve operation without use of driving power. In many existing weirs, two systems of valves of automatic operation by mechanical force and manual valves are employed together.

Table 1.16 Table of Comparison of Various Forces for Operation of Feeding/Discharging valves

Operating force		
Electric power	Electric motors operate valves directly.	Case where electric power can be supplied at any time of operation, and case of remote operation.
Electro-megnetic force	Solenoids operate valves indirectly.	Case where electric power can be supplied at any time of operation, and case where remote operation or response are required; but if change-over flow quantity is large, the valves to be used as solenoid pilot changeover valves
Hydraulic pressure	Hydraulic pressure operates valves directly.	Case where power accumulation is necessary (accumulation less than pneumatic pressure), case where large output is required, and case where accuracy of speed control is required for continuous or intermittent movement or positioning
Pneumatic pressure	Pneumatic pressure operates valves directly.	Case where power accumulation is necessary, case where small output is allowed because of small working pressure, and case where simple circuit configuration is required as this force needs no return circuit
Mechanical force	Pneumatic pressure operates valves utilizing bucket tare weight or float buoyancy as power source.	Case where automatic valve operation is required without any use of driving power
Manual force		Case where operator is required to operate valve

2.4 Power equipment for raising and flattening

Power equipment for raising and flattening of rubber weirs should be selected out of electric motors and internal combustion engines. But, in some cases of natural discharge of inflating medium, power equipment can be omitted.

Explanation

Type, number and capacities of units composing power equipment of rubber weir should be selected taking weir scale, control sureness, operation frequency and cost into consideration.

1) Electric motor : The most popular power unit. It is easy in control, economical when operation frequency is high, and advantageous for automatic operation.

2) Internal combustion engine : Popular in small weirs. Economical when operation frequency is low, and advantageous in that it is not affected by electric power shutdowns in areas of frequent typhoon attacks.

① Gasoline engine : Commonly issuing small outputs. Cheaper than diesel engine.

② Diesel engine : Commonly issuing large outputs. Its fuel is cheaper than gasoline engine, and it has a superb torque characteristics.

Section 3 Design of operation equipment

3.1 Design of raising equipment

Design pressure and design capacity of pump, blower and compressor for raising apparatus should be taken less than 90% of rated quantity of discharge. Output of driving motor should be sufficient for performance of objective units.

3.2 Design of flattening equipment

Flattening equipment should perform surely.

Explanation

Flattening equipment should be desirably composed of simple units because, generally speaking, complicated mechanisms require large quantity of manpower, high maintenance cost and much time for maintenance. Whereas weirs needing complicated operation require sophisticated equipment, consideration should be taken so as not to interfere sure flattening by means such as duplication of flattening equipment by co-installation of simple mechanisms.

3.3 Design of safety equipment

Safety equipment should be designed in the following procedures: 1. Selection of type of safety equipment 2. Design of scale or capacity of equipment

Explanation

1. Type of safety equipment should be determined according to tube inflating medium and weir function.

2. Scale or capacity of safety equipment should be designed in accordance with pressing in rate of inflating medium. In case when safety equipment is to work also as flattening apparatus, its scale and capacity should be determined in accordance with flattening rate.

3.4 Design of external water level detector

Type, place of installation and working range of external water level detector should be determined according to purpose of detection.

Explanation

Whereas no sophisticated external water level detector is required when weir is used for simple purposes such as water cut-off or water intake, detector must naturally be sophisticated and work in a wide range when weir is used for water level or flow rate adjustment.

3.5 Design of tube internal pressure detector

Tube internal pressure detector should be designed with the substances as mentioned below: 1. Setting purpose of detection and selecting detector type 2. Design of mechanism and function of the detector

Explanation

1. Types of tube inflating medium make difference of tube internal pressure detector in some cases. Weir functions define detection purpose, and expand detection range if the weir requires complex operation.

2. Mechanism of detector should be designed only after setting the detector's type and working range. Then, design object should be extended to linkage with safety equipment or, in some cases, with raising/flattening equipment.

3.6 Design of inflating medium feeding/discharging pipe

Inflating medium feeding/discharging pipe should be provided with sufficient feeding/discharging capacity in accordance with raising/flattening rate. Additionally, durability should also be examined.
With regard to piping materials;

1. Materials used for piping should be equal or superior to JIS G 3452 SGP (white) "Carbon steel tubes for piping" or SUS 304 TP of JIS G 3459 "Stainless steel tubes for piping" depending on river water quality.

2. Flange joints of JIS 5 kg/cm^2 or more should normally be adopted.

Explanation

Pipings connecting rubber tube and operation room include the following:

① inflating medium feeding/discharging piping,

② tube internal pressure detecting piping, and

③ draining piping,

among which one may often work also as other.
Inflating medium feeding/discharging pipe may laid horizontally on river bed, installed on side slope or in-part laid horizontally and in-part on side slope. Weir of water inflating type requires horizontal piping. When to use pressurized water like supply water, piping should be designed in accordance with associating standards.

Linkage pipings from upstream and downstream to operation room include:

④ extenal water level detecting piping, and

⑤ discharging pipe (for water inflating type only).

The external water level detecting piping should be installed in such a manner as to avoid clogging by soil and sands, and the discharging pipe to drain water, the inflating medium, surely. Portions of the pipings ④ and ⑤ may be constructed with concrete.

These types of piping should be constructed safe to ground deformation such as uneven sinking.

Reference

Examples of feeding/discharging piping and raising/flattening equipment are given in Fig. 1.39 to Fig. 1.41.

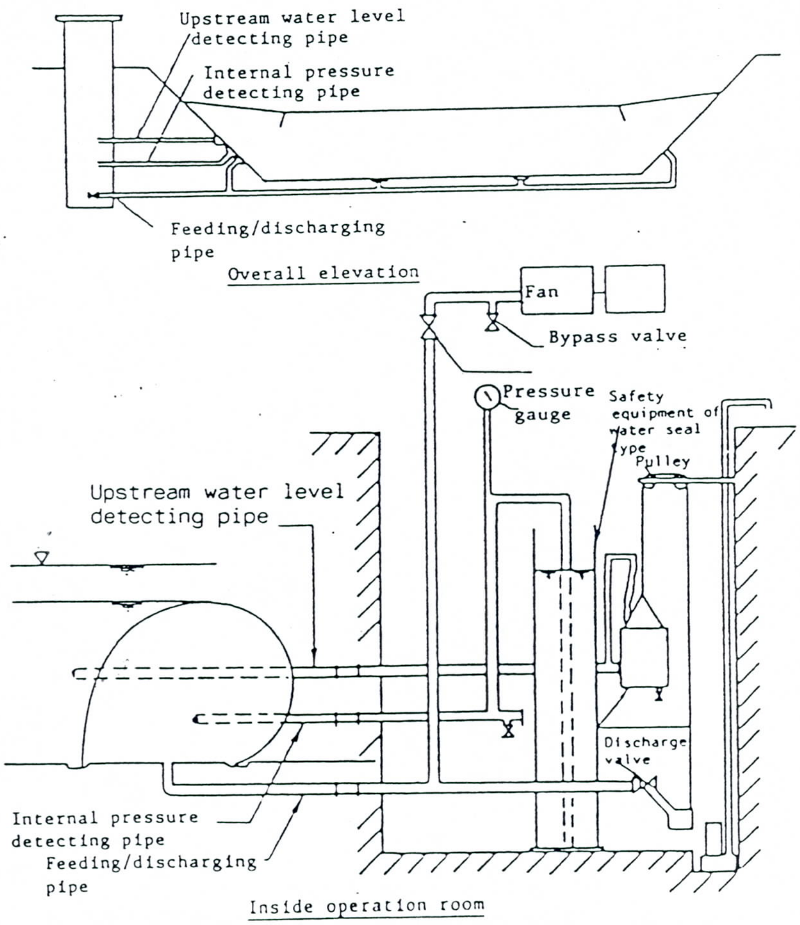


Fig. 1.39 Example of installation of feeding/discharging piping (Air type - 1)

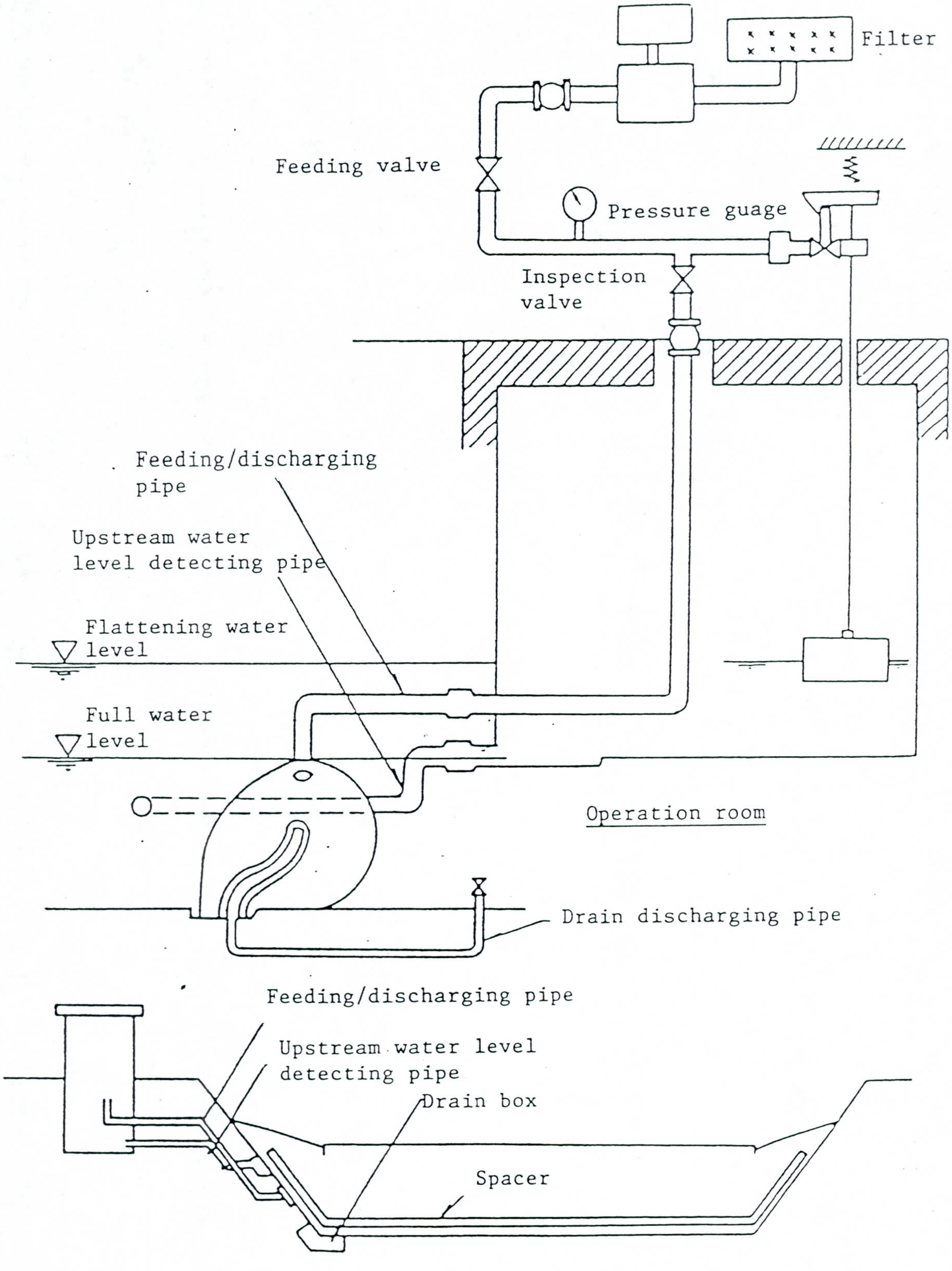
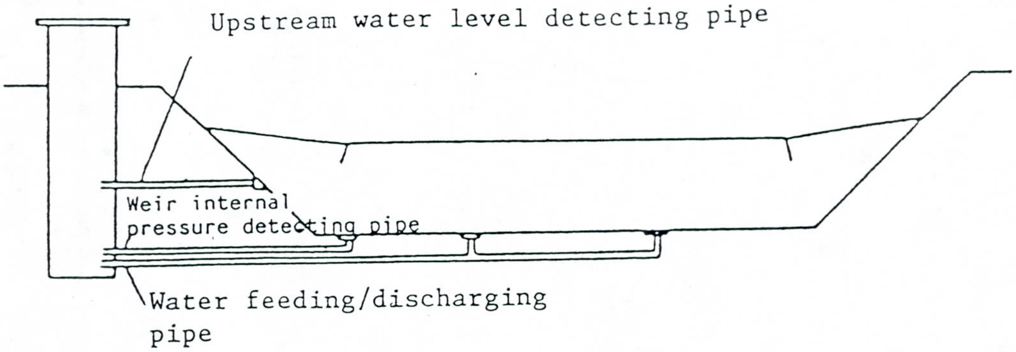
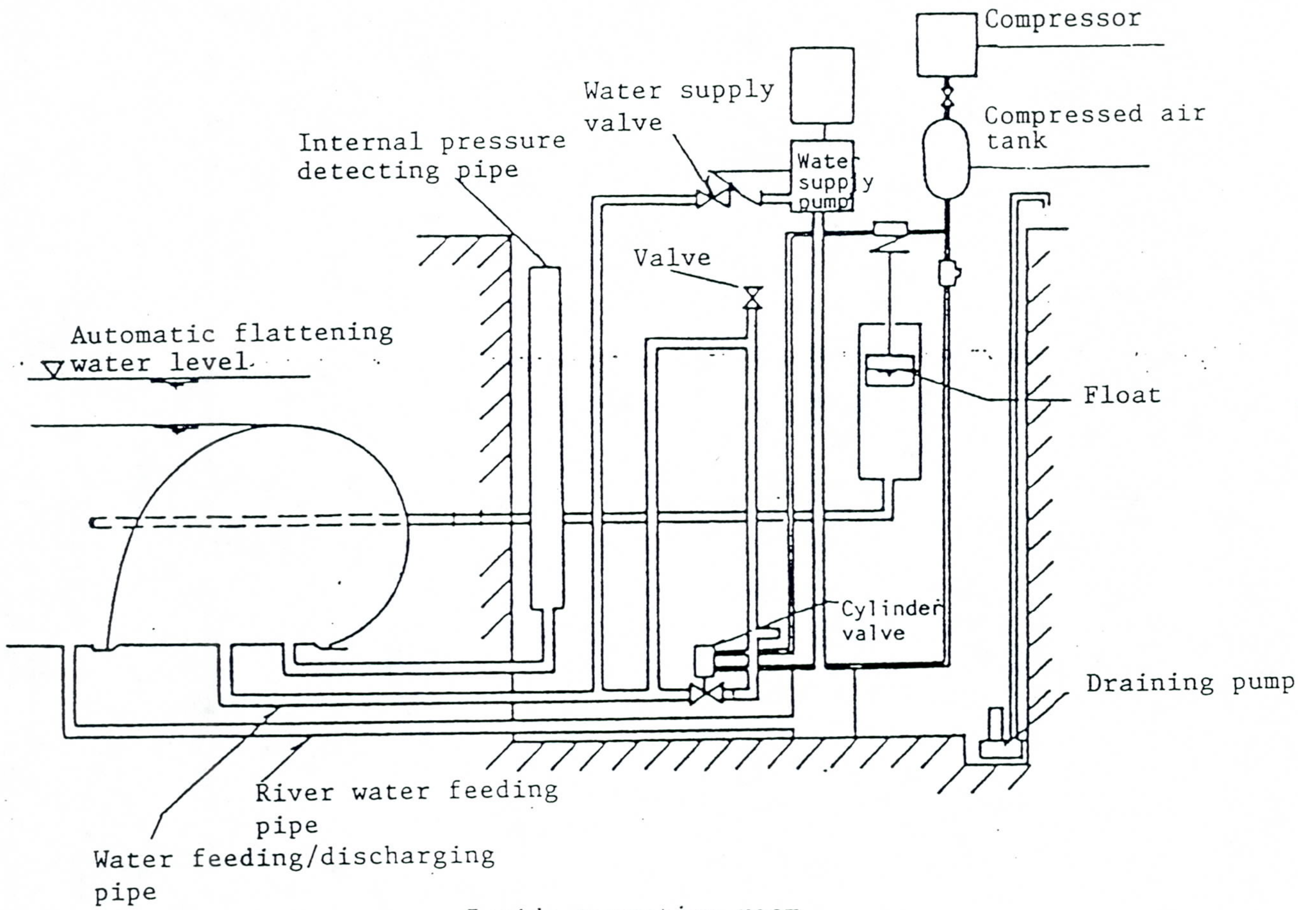


Fig. 1.40 Example of installation of feeding/discharging piping (Air type - 2)



Overall elevation



Inside operation room

Fig.1.41 Example of installation of feeding/discharging piping (Water type)

Section 4 Design of other facilities

4.1 Design of operation room

Operation room should satisfy the following conditions:

1. Equipment should be easily and safely operated.
2. External water invasion should be blocked.
3. Lighting and ventilation should be sufficiently taken care of.
4. Instruction board of operation procedures should be put at a suitable place in the room.

Explanation

Operation room, if placed outside levees, should be provided with watertight construction up to the height equal to levee allowance. When placed inside levees, the room should be so constructed as to prevent water invasion up to the foreseen internal water level. It is recommendable to install apparatus/units weak to water over planned high water level or equivalent water level.

4.2 Levee crossing of feeding/discharging piping

Cautions should be posed, if rubber weir's feeding/discharging piping crosses a levee, so that the crossing give no remarkable disturbing effect on nearby banks and river control facility structures.

Explanation

In some cases when operation room is placed inside levees, inflating medium feeding/discharging pipings, external water level detecting piping, tube internal pressure detecting piping, draining piping, etc. may laid crossing the levees.

Since diameter and number of lines of these piping increase as weir scale and number of spans increase, sufficient care should be taken on construction of these crossings so that they constitute no weak points in the levees.

4.3 Alarm equipment

If a remarkable effect is foreseen to be used by flattening of rubber weir, alarm equipment should be provided in necessary areas.

4.4 Installation of safety facilities

Sufficient consideration should be taken on safety.

Explanation

As for safety facilities for weir operation and disinterested people, it is advisable to install handrails and ladders, and danger preventing fences such as metallic net in a suitable area and sign boards attracting people's attention.

When to use an internal combustion engine as power equipment, sufficient care should be taken on measures to let exhaust gas out. Investigation should be made on illumination equipment for night operation.

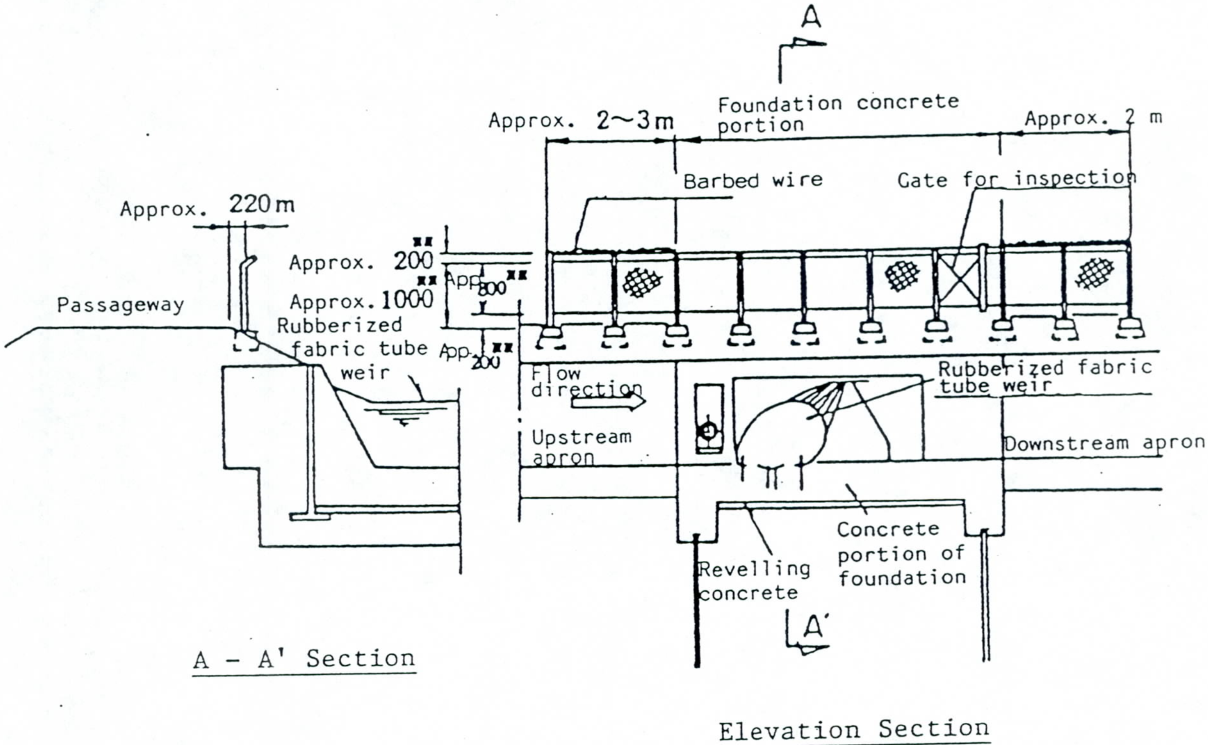


Fig. 1.42 Example of safety facilities

Chapter 1 Manufacturing and Construction Work

Section 1 Generals

1.1 Construction plan

Construction plan should ensure that construction work be surely implemented considering the following: 1. Site conditions 2. Construction conditions 3. Contents of construction works

Explanation

Construction plan should be established so that works proceed just as planned, on the base of preliminary studies of past construction records and estimation of possible problems on the site.

1) Site conditions include climatic conditions, river flow conditions and place of installation.

2) Construction conditions include work period, work implementation capacity and materials procurement.

3) Contents of construction works include scale of the works and easiness or difficulty of works.

1.2 Hauling road

Hauling road should be constructed after determining its scale and construction taking work efficiency and safety into consideration.

Explanation

Points to be cared for in construction plan of hauling road are as follows:

1) Road width should not be less than 4.0 m and profile gradient not more than 15% preferably.

2) Roadbed construction should be determined considering scale and period of construction works.

3) In case where slope is constructed on river side from level top, banking should be constructed outside levee section and downstream of weir.

4) In case where levee top, banquette or toe of slope is used as hauling road, measures such as reinforcement should be taken so as not to give damage to levee crossing structures and levee cross-section.

5) In case where hauling road is made by banking the side of high water base, it should be made as low as possible so as not to disturb water flow. If it is inevitable to make banking at a high level, measures should be taken such as removing it in freshet season.

6) In case where a temporary bridge is necessary, bridge fundamentals such as height, direction and construction should be determined taking river conditions, and scale and period of construction works into consideration.

1.3 Temporary coffering

Temporary coffering should be constructed so as not to block flood.

Explanation

For construction of a temporary coffering, consideration should be made on matters affected by sheet pile driving such as water level variation -- especially, flow velocity in flood, wash-cut effect, displacement of stream center line, weir raising quantitt -- rolling stones on river bed and mattress.

As self-standing temporary coffering, the following are design alternatives. Selection should be made considering the above-mentioned conditions.

① Soil levee

② Soil bags

③ Continuous frame

④ Single line sheet pile

⑤ Double line sheet pile

⑥ Steel pile cell

Temporary coffering should be determined based on Standard for construction of temporary cofferings (draft).

Section 2 Substructure construction works

2.1 Foundation

Foundation, which transfers load from upside safely to base ground, should be constructed with sufficient care.

Explanation

Weir foundation is constructed after constructing temporary coffering, draining and floor digging to a specific depth. Hence, working space becomes small. For this reason, detailed construction plan should be established on retaining, disposal of spring water and leaking water, excavation sequence, work schedule, etc. based on exact survey of site conditions.
In case of pile foundation, final bearing force should surely be checked. This check should assure that design bearing force is satisfactory taking static bearing force based on soil quality test data and dynamic bearing force based on final driving penetration quantity into consideration. In case of other foundation, bearing force should be checked by loading test or the like.

2.2 Bed plate and apron

Bed plate and apron should be constructed carefully with concrete of required strength, watertightness, wearproofness and uniform quality.

Explanation

Bed plate and apron are feared to be damaged via wash-cut by water flow and soil and sands suck-out by percolating water, and their repair is difficult after construction. Hence, their construction should be carried out with special cares.

Concrete strong, durable, resistant to wear and of superb and uniform quality is needed because it is continuously exposed to water flow. Before placing concrete, inspection should be made if reinforced molds are correctly assembled and cleaning is sufficient. In concrete placing, single block without construction joint should be made in each work section. Although concrete should not be placed at a cold temperature, sufficient care must be taken if cold temperature placing of concrete is inevitable.

2.3 Backfill

Backfill should carefully be carried out so that no damage is given to structures. And, after backfilling, soil should sufficiently be compacted.

<u>Explanation</u>

For backfill, suitable material should be used. Cleaning should be made before backfilling, and each layer should be sufficiently compacted. Backfilling and compacting that may affect structures should be carefully made so as to give no damage to them.

2.4 Piping

Piping should be examined, before embedding, on watertightness and airtightness of joints.

<u>Explanation</u>

Sufficient consideration should be taken on measures such as adoption of flexible joints for piping between rubber tube and operation room as a provision for ground sinking.

Section 3 Tube manufacturing and installation

3.1 Tube manufacturing

Tube should be manufactured under careful quality control.

Explanation

Material and specification of rubberized fabric should be as described in 2.1, Chapter 2, Part of design. When tube is manufactured in a factory as in general cases, well arranged quality control is executed in processes of rubberizing, putting together and gluing. Unevenness or injury, if any however, leads to tube breakage. Hence sufficient care should be taken in manufacturing.

With regard to a large weir, adhesion is sometimes made on site because of restriction on tube transportation. Special care should be taken on quality control in such a case because site conditions such as dust and humidity are often adverse.

3.2 Tube transportation and installation

In tube transportation and installation, tube should be carefully handled so as to produce no deformation nor damage.

Explanation

Tube is wound into a roll for transportation from factory to site. Truck transportation, generally practiced, poses restrictions on packing dimensions and gross weight. Further, handling restrictions are posed in crain transportation for installation on the site regarding tube extension and centering. Except for case where adhesion is made on site, the maximum span is restricted with above-mentioned tube transportation and installation and temporary coffering.

3.3 Installation in general

Tube should be installed in such a manner that ensures water and air-tightness for inflating medium.

Explanation

Tube is held with holding fittings, and fixed with affixing bolts or anchor bolts.

Concrete structure curing period before tube installation should preferably be one week or more. It is recommended to execute torque control in tightening affixing bolts or anchor bolts on holding fittings.

In case when synthetic resin is used for securing water and air-tightness in installation of tube, face for resin application should be water-free.

Section 4 Various tests

4.1 Scope of tests

Scope of tests should be the materials listed below and their installation:

1. Tube's rubberized fabric
2. Anchor bolts or affixing bolts
3. Holding fittings
4. Piping
5. Operation equipment

Explanation

Tests of substructures and civil engineering structures should be naturally made separately. Descriptions in this book cover tests directly related with rubber weir functions.

4.2 Types of test

Types of test should be as follows:

1. Material test
2. Accessories test
3. Tube test
4. Operation equipment function test

4.3 Material test

Material test should be carried out in accordance with 2.1, Chapter 2, Part of design. Verification should be made based on maker's test report.

4.4 Accessories test

Accessories test should be made on specified materials.

Explanation

The specified materials include anchor bolts or affixing bolts, attachment fittings and pipes for piping.

The test can be substituted with material certificates proving that the appropriate material was used or maker's test certificates.

4.5 Tube test

Tube test should be made before and after installation.

Explanation

Test before installation should be made on extended tube to check dimensions against design drawings.

Test after installation should made on inflated tube with internal pressure equivalent to design tension about the following:

1) Air and water-tightness of tube itself and attachment

2) Conditions of attachment fittings, anchor bolts or affixing bolts

3) Appearance of entire tube

Test on water and air-tightness should be conducted with soapy water or the like.

4.6 Operation equipment function test

Verification that functions are sufficiently displayed should be made by raising and flattening rubber weir using operation equipment.

Chapter 2 Operation and Maintenance

Section 1 Generals

1.1 Fault

When a fault has occurred, its substance should sufficiently be gripped, notified to relating sections and treated properly.

Explanation

Relating section or division should contact maker according to necessity for a suitable treatment.

1.2 Records of operation

Person in charge of control should make a record, with controlled hydraulic quantities, when he has operated rubber weir.

Explanation

Person in charge of control should prepare a operation diary, in which necessary quantity of water and record of operation should be put down.

The record should include the following:

1) Meteorological and hydrological conditions

2) Name of weir operated, date and time of operation start and finish, water quantity discharged by weir operation and water level change

3) Other remarks

1.3 Record of inspection and maintenance

Person in charge should record results of inspection and maintenance of rubber weir, when made.

<u>Explanation</u>

Person in charge should prepare a list for inspection and maintenance of rubber weir in order to make it the standard of such works. The list should include parts names, inspection items, judgments and substances of maintenance.

Section 2 Weir operation

2.1 Preparation of operation rules

> Person in charge of rubber weir control should prepare operation rules in accordance with purpose of the weir installation.

Explanation

Operation rules should sufficiently satisfy purpose of weir installation, and ensure development of weir performance as well as safety of operation.

2.2 Fundamentals of operation

> Rubber weir should be operated in accordance with operation rules.

Explanation

Special care should be taken for operation of weir important or including multiple spans so as not to mis-operate.
In case when weirs for multiple spans are to be flattened, difference of flattening rates span by span may occur, despite simultaneous operation, according to river conditions such as weir near to medium source is flattened earlier than others.
When operation is made with some time delays by spans, later weirs may become reluctant to flatten because of elevated downstream water level. From the fact that some flow velocity is required for complete flattening of rubber weirs, sufficient consideration should be taken on weir operation with a small water level difference.

2.3 Notification and warning

Before discharging water from rubber weirs, notification and warning should be issued to relating institutes separately specified.

Explanation

Person in charge should, when he wants to lower weir's water level by discharging, operate weir in accordance with prelimi-narily reached agreement with relating institutes and issue notification to people supposed to be influenced by water level change. Besides, he should inhibit for people to enter into dangerous areas near the weir and give warnings to people coming to the areas via placards and/or speakers.

2.4 Precautions to floods

Person in charge should, at times of flood, observe scheme of precautions to floods separately stipulated.

Explanation

Actual cases when scheme of precautions is to be taken are as follows:

1). case when Meteorological Agency or River controlling agency has issued flood warning or alarm relating to weir control based on Meteorological Business Law or Flood Prevention Law,

2) case when local meteorological agency has issued heavy rain warning and precipitation more than a specific value is foreseen, and

3) case when flow rate at weir point exceeds and discharge quantity is estimated to exceed predetermined value

Section 3 Inspection

3.1 Purpose of inspection

Inspection should be made on rubber weirs as required for maintaining their functions.

3.2 Inspection items

Inspection should be made on the following items:

1. Tube
2. Attachment fittings
3. Operation equipment
4. Pipings and valves
5. Concrete structures (foundation concrete and operation room)
6. Others

Explanation

Others in the table above include windows and doors of operation room, safety facilities, appended equipment, and soil and sands accumulation, rolling stones and flowing-down woods in river.

3.3 Method of inspection

Inspection should be made by method suitable for each item.

3.4 Period between inspections

Inspection period should be determined according to use conditions, functions and importance of objective unit.

Explanation

An example is given in the table below:

Table 2.1 Inspection List

Item	Period	Method	Substance
1. Tube	Six months	Visual	Damage
	As needed		
2. Attachment fittings	Six months	Visual	Deformation
	As needed		
3. Operation equipment	Six months	Visual, Noise	Performance,oiling, water supply
	As needed		
4. Pipings, valves	One year	- ditto -	Loose bolts, water leak, rust
	As needed		
5. Concrete structure	One year	Visual	Water leak to operation room, crack and other damage
	As needed		
6. Others	One year	Visual	Accumulated soil and sands in river, harmful matters near tube
	As needed		

"As needed" in this table represents cases such as heavy rain or weir operation.

Section 4 Maintenance and relatings

4.1 Maintenance in general

Rubber weir should be maintained so that it can be surely raised or flattened at any time.

4.2 Prevention of freezing

Rubber weir which must be operated in winter season should be maintained so as to avoid an event that it cannot be raised nor flattened due to freezing.

Explanation

There is possibility that rubber weir must be operated even in cold season for reasons of increased flow rate due to abnormal hot weather or rain, trouble occurrence and inspection. Hence, freezing of tube operation equipment should be avoided so as not to interfere operation in cases as mentioned above. But, no consideration is needed if there is no need for winter operation or no problem occurs even if weir is left frozen.

4.3 Soil and sands accumulation

When a large quantity of soil and sands have accumulated on tube, the accumulation should be removed with sufficient care so as to give no harm to tube.

Explanation

Accumulated soil and sands are removed using a heavy machine. But, one near tube should be carefully removed manually. Whereas soil and sands can be removed by tube internal pressure or repeated raisings and flattenings to some extent, complete raising is impossible.

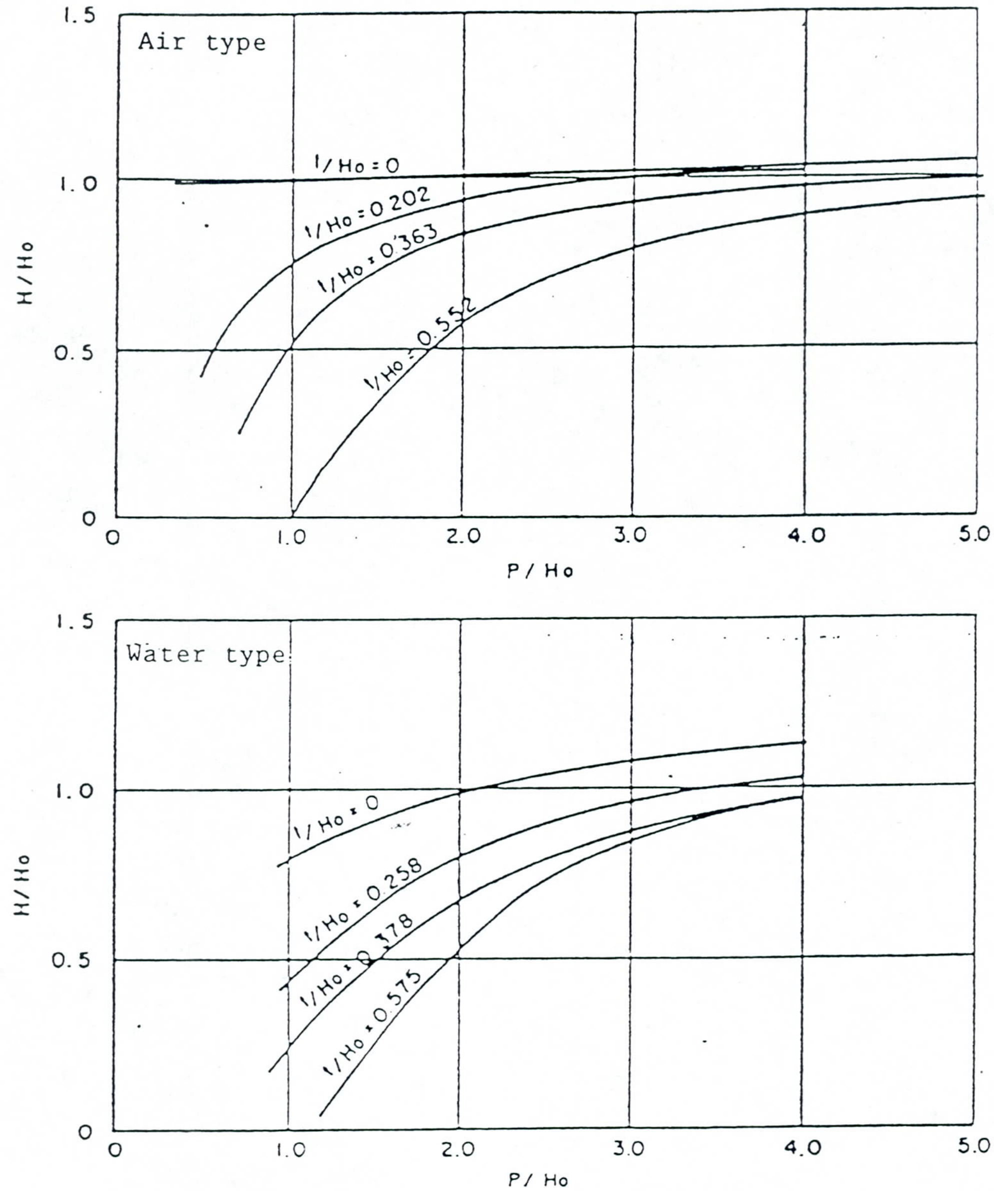
When to overpressure tube, preliminary consideration should be taken in relation with design load.

Reference: Sand removing capacity by tube inflation (with zero water depth in both upstream and downstream)

Fig. 2.1 shows results of model test with the fundamentals listed below:

Initial weir height	:	Air type Ho = 474 mm (P/Ho ≒ 1.0) Water type Ho = 410 mm (P/Ho ≒ 2.0)
Weir length	:	4.0 m
Side slope gradient	:	1:0
Grain size	:	D_{50} = 0.077 mm

With water put in water channel, sands were laid on flattened tube to a specific thickness and, then, water in the channel was drained to form accumulated sand layer. Inflating medium was gradually put into tube to raise weir, and tube internal pressure and minimum weir height were measured.



H : Minimum weir height

Ho: Initial weir height

P : Tube internal pressure

t : Accumulation thickness (Over entire weir width)

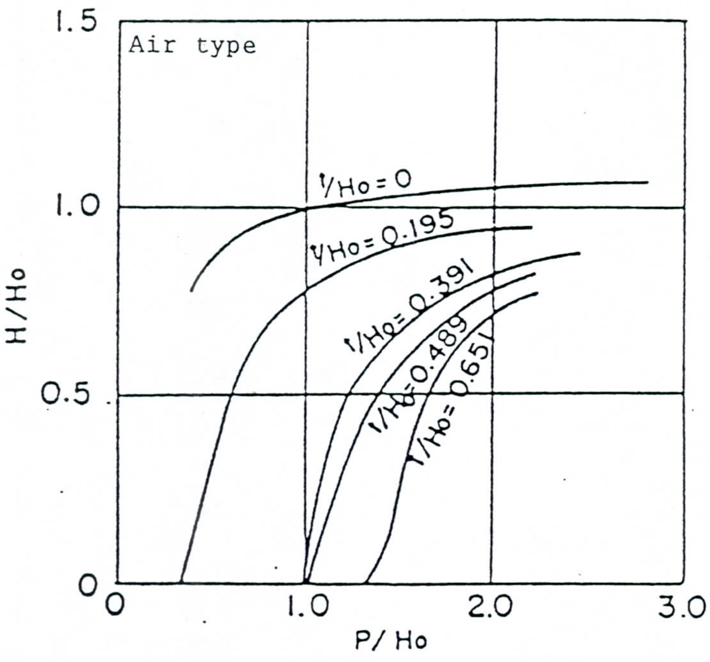
Fig. 2.1 Sand removing capacity by tube inflation (with zero water depth in both upstream and downstream)

Reference: Sand removing capacity by tube inflation (full water level in upstream and zero depth in downstream)

Fig. 2.1 shows results of model test with the fundamentals listed below:

Inflating medium	:	Air
Initial weir height	:	Ho = 307 mm (full water level in upstream and zero in downstream)
Weir length	:	2.5 m
Side slope gradient	:	1 : 0.5
Grain diameter	:	D_{50} = 0.26 mm

Test was conducted similarly to the previous example. Weir height was obtained by conversion against upstream full water based on experiment result.



H : Minimum weir height

Ho : Initial weir height

P : Tube internal pressure

t : Accumulation thickness (over entire weir width)

Fig. 2.2 Sand removing capacity by tube inflation (full water level in upstream and zero depth in downstream)

Reference

Fig. 2.3 gives results of model test which examined effect of soil and sands flushing with upstream storage water effectuated by raising and flattening tube in the experiment of "Sand removing capacity (zero depth in both upstream and downstream)" described in the previous example.

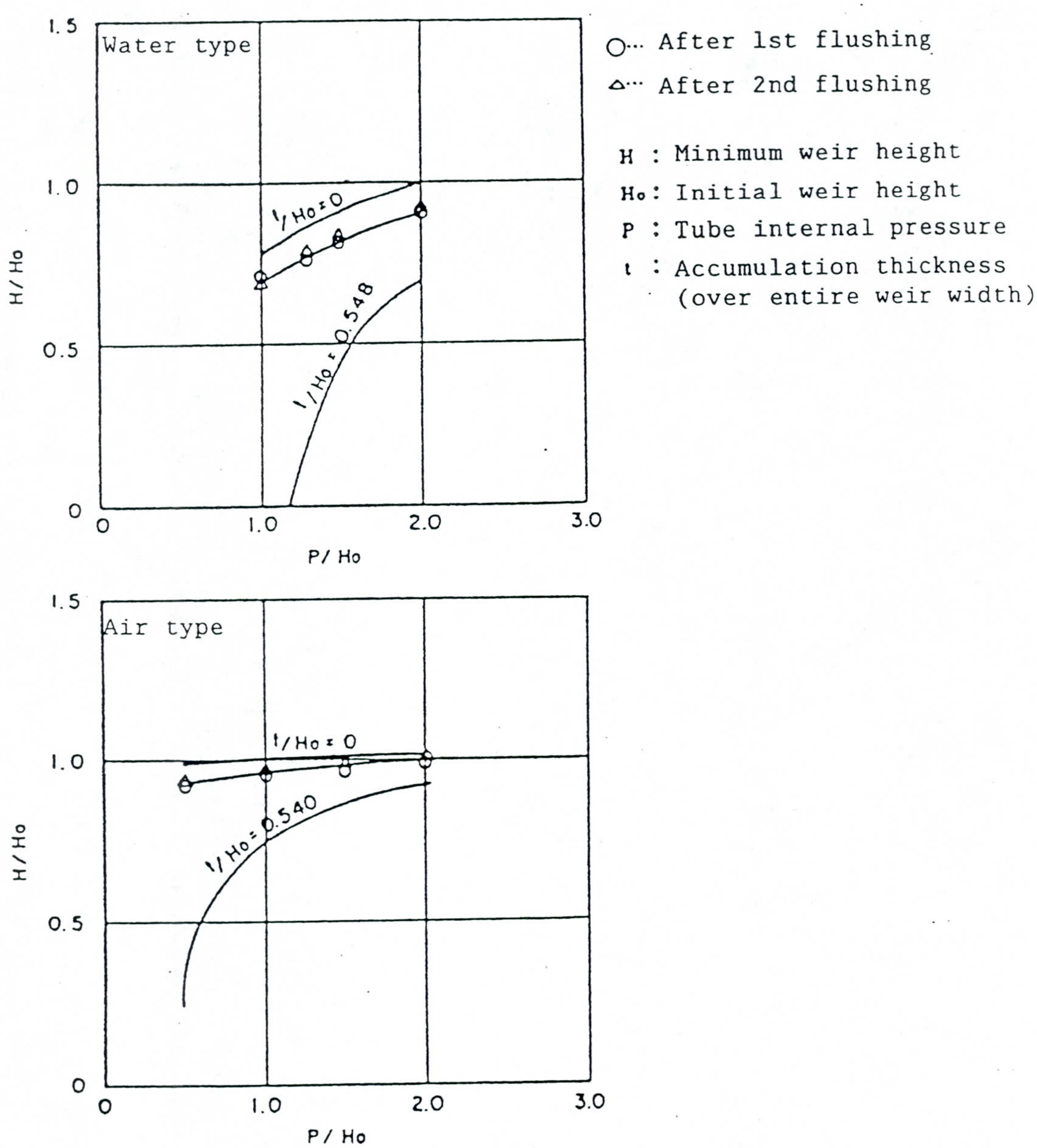


Fig. 2.3 Sand removal by tube inflating flushing

From model test results presented above, it is considered that, under the condition that sands of a thickness of approx. 20% of weir height are accumulated over the entire weir width, approx. 95% of initial weir height is restored with an internal pressure P/H = 2.0 for air type and P/H = 3.0 for water type. Although flushing also restores weir height of 90 to 95% of the initial, further restoration is impossible even with more repetitions of flushing if soil and sands are fed from upstream. However, it should be minded in practical application of experimental results that similarity cannot be established for soil grains between the actual and the model.

Section 5 Repair

5.1 Classification of repairs

Repairs are classified as below: 1. Tube 2. Equipment and units 3. Pipings

5.2 Method of repair

Repair should be done by suitable method.

<u>Explanation</u>

Methods currently adopted and necessary cautions are as described below:

1. Tube

   Small damages are repaired with "wooden plugs", "rubber plugs", and "patches". Large ones are repaired by vulcanizing adhesion, for which repair portion must be dried because adhesion in water is yet to be developed. Repaired portion should have a strength equivalent to undamaged portion.

2. Equipment and units

   Damaged or faulty parts should be either repaired or replaced.

3. Pipings

   Damaged or faulty valves, etc. should be either repaired or replaced with spare parts or totally with a new unit.
   Rusted valves, etc. should be repaired by removing rust and recoating.