KATHMANDU UNIVERSITY

SCHOOL OF ENGINEERING

DEPARTMENT OF MECHANICAL ENGINEERING

INDUSTRIAL INTERNSHIP REPORT ON

INTERNSHIP AT HYDRO-CONSULT ENGINEERING LIMITED

In Partial Fulfillment of the Requirements for the

Bachelor's Degree in Mechanical Engineering

Lekhnath Gyawali [42100]

April, 2023

INTERNSHIP EVALUATION

INTERNSHIP AT HYDRO-CONSULT ENGINEERING LIMITED,

BUTWAL POWER COMPANY

This is to certify that I have examined the internship report and have found that it is complete and satisfactory in all respects and that any and all revisions required have been made.

Er. Saurav Gautam

Senior Mechanical Engineer, HCEL

Industrial Supervisor

Pratisthit Lal Shrestha

Assistant professor

Internship Coordinator (Design),

Kathmandu University

Daniel Tuladhar, PhD

Head of Department, Mechanical Engineering

Kathmandu University

HYDRO-CONSULT
ENGINEERING

Date: 9/04/2023

TO WHOM IT MAY CONCERN

This is to certify that Mr. Lekhnath Gyawali, a student of Bachelor of Mechanical Engineering of Kathmandu University, Dhulikhel, Nepal has successfully completed internship at Hydro-Consult Engineering for his Mechanical course in the Engineering Department. Mr. Gyawali has worked at Hydro-Consult Engineering Ltd as an Intern Mechanical Engineer from 16th of Jan 2023 to 9th of April 2023 and has gained a very good experience on the following subjects:

- SOLIDWORKS 3D Modelling of Gates and its appurtenances,
- SOLIDWORKS 2D drafting and design analysis,
- ANSYS static analysis of Bifurcations, TEE-joints, Bends and Pressure pipes,
- ANSYS CFX hydraulic analysis of Bifurcations, TEE-joints, Bends and Pressure pipes,
- Design of Manholes and Gates and their Excel sheets,
- Design of Expansion Joints with its Excel sheet,
- Excel design sheet for Buried/Embedded Penstocks.

In a short period of time, Mr. Gyawali has gained valuable experience in the subjects mentioned through his work in the office. He is a diligent and dedicated individual who excels at work collaboratively with others. Throughout his tenure in the office, he displayed obedience and exhibited honesty and loyalty.

We wish him every success in his future endeavor.

HYDRO-CONSULT
ENGINEERING LTD.

....
Ashok Joshi
Manager-Admin/HR
Hydro-Consult Engineering Ltd.

ACKONWLEDGEMENT

I would like to express my heartfelt gratitude to **Hydro-Consult Engineering** for providing me with the opportunity to gain invaluable experience and knowledge during my internship. Working with some of the greatest minds in hydropower development in Nepal has been a truly enriching experience for me. I would like to extend my thanks to **Er. Shyam Bhusal** sir, Divisional Head Engineering Design division, and **Mr. Ashok Joshi,** HR for giving me the chance to work in such a prestigious company. I would also like to express my sincere gratitude to **Er. Saurav Gautam**, Senior Mechanical Engineer and my supervisor, for his constant guidance and mentorship throughout my internship. His valuable feedback and support helped me to improve my skills and knowledge. I am also deeply grateful to **Er. Prajwol Luitel**, **Er. Bikalpa Khadka**, and **Er. Pawan Khanal** for their unwavering support and guidance in technical understanding. Their expertise and guidance have been invaluable to me in enhancing my understanding of the industry.

I would like to express my appreciation to my Industrial Training Coordinator, **Mr. Binaya K.C**., PhD, Associate Professor, DoME, KU, and **Mr. Daniel Thuladhar**, PhD, HoD DoME, KU for providing me with this opportunity. This training has given me the chance to experience the real working environment and gain practical skills that will help me in my future endeavors. Finally, I would like to thank my family and friends for their untiring support and encouragement throughout my internship. Without their support, I would not have been able to achieve my goals.

ABSTRACT

This internship report provides an overview of the work and learning experience during a twelve-week internship at Hydro-Consult Engineering Limited. The objective of the internship was to gain practical knowledge and skills in the field of mechanical engineering. During the internship, the main tasks included 3D modelling, 2D drawings validation, static and hydraulic simulation of various hydropower parts and design of hydropower related components. These tasks were completed under the supervision of the engineering team, and regular feedback and guidance were provided to ensure optimal performance. The internship provided an opportunity to learn about various engineering techniques and allowed for exposure to the corporate work environment, improved communication skills, and provided insights into the workings of an engineering department.

Overall, the internship was a valuable experience that provided hands-on learning and practical exposure to the hydropower industry. It also gave me the opportunity to apply my academic knowledge to real-world situations and enhanced my understanding of the industry.

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LIST OF ABBREVIATIONS

ANSYS	Analysis of Systems
ASME	American Society of Mechanical Engineers
AWWA	American Water Works Association
CFD	Computational Fluid Dynamics
BOQ	Bill of Quantity
BPC	Butwal Power Company
FoS	Factor of Safety
HCEL	Hydro-Consult Engineering Limited
IS	Indian Standard
PDV	Pressure Diameter Value

CHAPTER 1 INTRODUCTION

1.1 Company Background

Hydro Consult Engineering Limited (HCE) is a leading consulting company of Nepal especially in hydropower sector. It is the sister company of Butwal Power Company (BPC). BPC runs the Engineering consultancy business as a separate entity. HCE has inherited 26 years of professional experience from the BPC Hydro consult. HCE provides engineering services in the sector as driven by the need of society based on innovative approaches and technologies. It has extended its services in hydropower, water supply, irrigation, transport and other development sectors[1]. At this time, HCEL provides its services in 5 different countries involving 150 employees.

HCE aims to produce appropriate design and engineering solutions for development projects within Nepal and abroad. HCEL provides full range of services for the entire lifecycle of the Hydropower projects which consists of Prefeasibility Study, Detailed Feasibility Study Investigations, Feasibility Study Review, Detailed Engineering Design, Tender Document Preparation and Tender Evaluation, Construction Supervision, Project Management, Bill Verification, Operation and Maintenance services, Plant Rehabilitations and up-gradations.

Figure 1 Logo of Hydro-Consult Engineering

HCEL also offers the services for Institutional Strengthening & Capacity Development, Governance & Management, Monitoring and Evaluation, Policy and Research in all its sectors[2].

HCE has working relation, collaboration and knowledge sharing with international consulting firms such as FICHTNER GmbH & Co. KG. (Germany), Mott Macdonald (UK), SWECO (Norway), NORCONSULT (Norway), MULTICONSULT (Norway), Tractebel GmBH (Germany), DOLSAR Engineering Inc. Co. (Turkey), SMEC International Pty. Ltd. (Australia), Hydro Tasmania (Australia), BRP (Canada), NEWJEC Inc. Co in various projects. Similarly, HCE has also worked with various international donor agencies and banks, like World Bank, IFC, NORAD, USAID, etc.

Corporate History

• 1986 - (As BPC Hydro-consult)

• 1998 - (As HCPL under ownership of PEEDA)

• 2009 - (BPC bought major share of HCPL and transferred BPC Hydro-consult to HCPL)

• 2012 - (As Hydro-Consult Engineering Limited)

• 2021 – BPC holds full ownership of HCE.

Corporate Office: Buddhanagar, Kathmandu, Nepal

Figure 2 Corporate building of Butwal power company

Mission

Provide quality and cost-effective engineering services in water resources focusing on hydropower, environment and infrastructure sectors being a globally recognized consultant.

Vision

Centre of excellence in engineering services in water resources and infrastructure development with due respect to environment and stakeholders.

Objectives

- Develop and provide quality and cost-effective engineering services to maximize customer satisfaction.
- Expand the services and penetrate into new market.
- Develop and enhance professional skills and knowledge.
- Deliver socially acceptable and environment friendly engineering solutions with due priority to local resources and technology.
- Optimum utilization of available resources.
- Enrich the value of stakeholders.

1.2 Organizational Structure

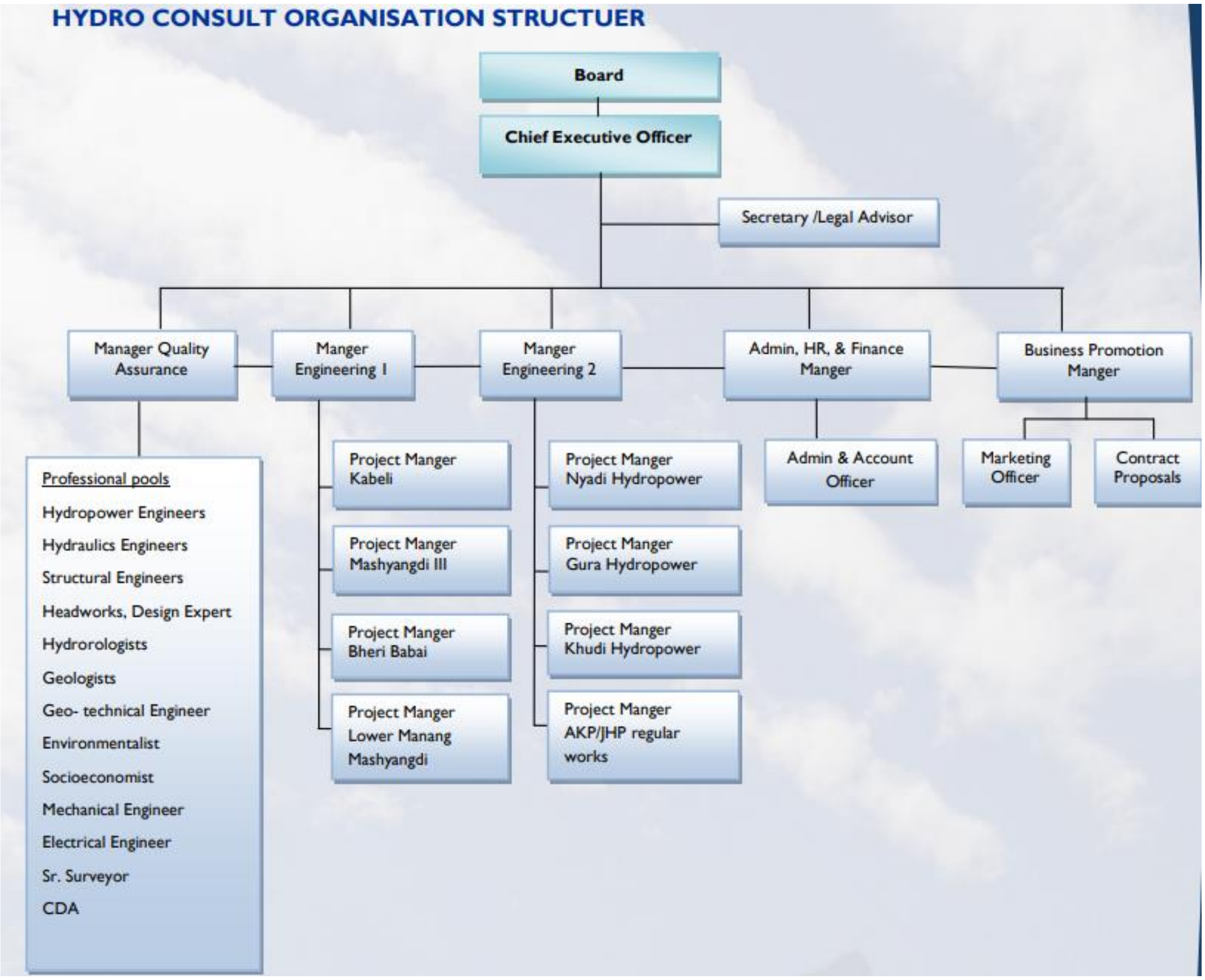


Figure 3 Organization structure of Hydro-Consult

1.3 National Projects

HCEL has been involved in various national projects providing various services like Construction Supervision, Detailed Engineering Design and Tender Document Preparation, Feasibility Study, Due Diligence Appraisal and Bill Verification. The figure below shows the projects in which HCEL has been working inside Nepal which involves about 40 projects including Lower Badigad Storage Hydropower Project (350 MW) which is still in Feasibility study phase.

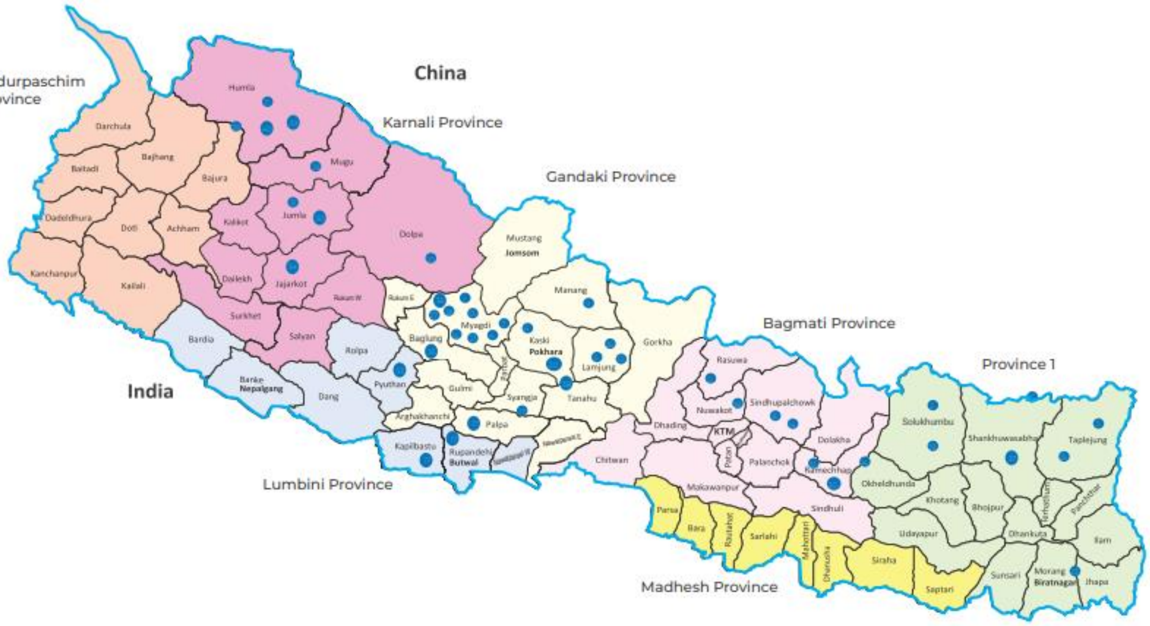


Figure 4 Projects in Nepal by HCEL

Summary of Projects of 2022

Table 1 Summary of projects of 2022

S.No.	Projects	Nos.
1	Feasibility Study	6
2	Detail Design and Tender Document Preparation	13
3	Construction Supervision and Management	4
4	Environmental Studies	5
5	Due Diligence Study and Bill Verification	5

1.4 International Projects

Along with national projects HCEL has worked in international projects which involves:

1. Orio Mini Hydropower & Rural Electrification Project (6.7MW), Uganda

HCE has been providing support for the Bid Evaluation of Civil, Hydro-mechanical, and Electromechanical bids (Technical and Financial part) to the client. At the same time, support documents for the negotiation with LOT-1 Civil & HM Contractor and LOT-2 EM Contractor are being prepared[3].

2. Gura Hydropower Project (5.6MW), Kenya

HCEL was entrusted with the job of overall management as well as review, comments and approval of detail design and construction drawings of civil, hydromechanical, electrical, electromechanical components and construction supervision for quality control. HCEL has supported the Employer to prepare the tender documents and procurement process for civil and electromechanical works. HCEL provided its service for design review and approval, construction quality supervision, contractors' claim review & recommendation to client etc. The construction of project works and service of HCEL has been successfully completed. The transmission line has already connected. The electricity has already generated and supplied to two tea factories of KTDA. HCEL is overseeing defect liability at present[3].

1.5 Objectives of Internship

The objectives of this internships are as follows:

- To gain practical experience in the field of study,
- To learn about the company and its operations,
- To network with professionals in the field,
- To develop and enhance professional skills,
- To build a portfolio of work samples.

CHAPTER 2 HYDROPOWER

Hydropower is a renewable energy source that uses the force of moving water to generate electricity. It is one of the oldest and most widely used sources of renewable energy in the world, with a long history of providing power to communities and industries. Hydropower is generated through the use of hydroelectric power plants, which typically consist of a dam, a reservoir, and a turbine. The dam is used to control the flow of water, creating a reservoir that can store water for later use. When the water is released from the reservoir, it flows through a turbine, which is connected to a generator that produces electricity[4].

Hydropower is a clean and renewable source of energy that produces no greenhouse gas emissions or air pollution. It is also highly efficient, with a conversion rate of up to 90%, meaning that almost all of the energy in the water can be converted into electricity. Hydropower has a number of advantages over other forms of renewable energy, such as solar or wind power. It is more reliable and predictable, as it is not dependent on weather conditions like wind and solar power. It also has a much longer lifespan, with hydroelectric power plants typically lasting for 50-100 years or more[5].

2.1 HYDROPOWER IN NEPAL

Hydropower in Nepal began in the 1950s, when the country's first hydropower plant was built at Pharping, near Kathmandu. The plant had a capacity of just 500 kilowatts, but it marked the beginning of a new era of electricity generation in Nepal. In the 1960s and 1970s, the government of Nepal began to invest heavily in hydropower development, recognizing the potential of the country's abundant water resources. During this period, several large-scale hydropower projects were built, including the Marsyangdi, Kali Gandaki, and Bhote Koshi projects. In the 1980s and 1990s, Nepal continued to expand its hydropower capacity, with the construction of several additional large-scale projects. The Upper Tamakoshi project, which began construction in 1997, was the largest hydropower project in Nepal at the time, with a planned capacity of 456 megawatts[6].

Today, hydropower accounts for over 90% of Nepal's total electricity generation capacity, with a total installed capacity of around 1,200 megawatts. The government of Nepal has set a goal of increasing its hydropower capacity to 15,000 megawatts by 2030, which would require significant investment in the development of new projects[7].

Hydropower development in Nepal until the 1990s was government led and mostly international donor funded. The Electricity Act of 1992 and the subsequent feed-in tariff policy jumpstarted private sector investment in electricity generation. Currently, over a third of the electricity generation is from the private sector, with a huge pipeline of private projects under various stages of development[8].

As of mid-April 2022, Nepal's total installed electricity generation capacity was 2,191 megawatts. During the fiscal year 2020-21, total available electricity was about 8.9 terawatt-hours out of which about 36.5% was from independent power producers and 32% was imported from India. About 44% electricity was consumed by the residential sector, 37% by industries, 7% by commercial establishments and the remaining by the agricultural and other sectors. Electricity losses were about 16% and only 0.7% was exported to India. However, from June 2022, Nepal's electricity export to India has increased sharply, and is expected to now be a significant percentage of Nepal's hydroelectric generation. As of mid-March 2021, 93% of the population had electricity access and as of mid-April 2022, the per capita electricity consumption was 325 kilowatt-hours. Electricity to about 972,00 households in remote rural areas is from solar photovoltaic home systems or mini grids[8].

2.2 HYDROMECHANICAL COMPONENTS

Hydromechanical equipment drives and controls the water flow before and after it passes through the generating unit. They are one of the crucial parts of a Hydropower projects with which the flow of water is regulated. Hydromechanical equipment plays a crucial role in the operation of a hydropower project. The efficient operation of the equipment is essential for the plant to generate electricity reliably and consistently. Without proper maintenance and control, the equipment can fail, leading to downtime, reduced power output, and even safety hazards. Therefore, it is critical to ensure that the hydromechanical equipment is well-designed, maintained regularly, and operated safely by trained personnel. Some of the crucial components are listed below:

2.2.1 Gates

Gates are the mechanical devices which are used to control flow of water into the hydro plant and out of the hydropower plant when not needed. A gate consists of basically three components that are leaf, embedded parts and operating device. *The leaf* is a movable element that serves as bulkhead to the water passage and consists of skin plate and girders. The shield plate directly responsible for the water dam is called the skin plate. The seals, the components responsible for the water tightness, consist generally of rubber strips screwed on to the skin plate.

The embedded parts are the components embedded onto the concrete, which serve to guide and house the leaf, to redistribute to the concrete the forces acting on the gate, acting also as protection to the concrete edges and support element for the seal. The basic components of the embedded parts are: sill beam, wheel or slide tracks, side guides, counter guides, lintel, seal seats and, eventually, slot lining. *The operating device* is the means directly responsible for the opening and closure of the gate[9].

Figure 5 Installation of Radial Gate[10]

Commonly used Gates

1. Flap gate
2. Cylinder gate
3. Stoplogs
4. Slide gate
5. Radial gate
6. Caterpillar gate
7. Miter gate
8. Roller gate
9. Drum gate
10. Bear-trap gate
11. Stoney gate

2.2.2 Turbines

Hydropower turbines are the devices that convert the kinetic energy of flowing water into mechanical energy, which can be used to generate electricity. There are several types of hydropower turbines, the most common types are:

Pelton turbine: This type of turbine is used for high-head applications and operates by directing a high-velocity jet of water onto a series of buckets arranged around the edge of a wheel. The water pressure causes the wheel to rotate, which drives a generator to produce electricity.

Francis turbine: This type of turbine is used for medium to high-head applications and operates by directing water through a series of curved blades attached to a central rotor. The water flows around the blades, causing the rotor to rotate and generate electricity.

Kaplan turbine: This type of turbine is used for low to medium-head applications and operates by directing water through a series of adjustable blades attached to a central rotor. The angle of the blades can be adjusted to optimize the turbine's performance based on the flow rate and head of the water.

2.2.3 Penstocks

A penstock is a large pipe or conduit that carries water from a reservoir to a hydropower turbine. It is an essential component of a hydropower system, as it delivers the water to the turbine, which converts the kinetic energy of the water into mechanical energy that drives a generator to produce electricity.

Penstocks are typically made of steel or concrete and can be several meters in diameter and hundreds of meters in length, depending on the size and capacity of the hydropower plant. They are usually installed underground or partially buried to minimize the visual impact of the facility and to protect the pipe from environmental hazards such as landslides or rockfalls.

The water in the penstock is usually pressurized to increase its kinetic energy and maximize the efficiency of the turbine. The pressure is created by the height of the water column in the reservoir or by pumps that are used to elevate the water to a higher level.

Penstocks may also include various components such as valves, gates, and screens to control the flow of water and to prevent debris or other materials from entering the turbine.

Figure 6 Penstock pipe installation Mai Khola[11]

2.2.4 Bifurcations

A penstock bifurcation is a type of hydraulic structure used in hydroelectric power plants to divide the flow of water from a single into two or more separate pipes, each leading to a different turbine. The purpose of a penstock bifurcation is to increase the efficiency of the power plant by allowing multiple turbines to be powered by the same water source.

Penstock bifurcations can take many different forms, depending on the specific requirements of the power plant. Some bifurcations are designed to split the flow of water into two equal parts, while others may divide the flow into three or more smaller streams.

The design of a penstock bifurcation is an important aspect of the overall design of a hydroelectric power plant, and it requires careful consideration of factors such as the flow rate of the water, the size and shape of the penstock, and the number and type of turbines that will be used. The goal is to create a bifurcation that maximizes the efficiency of the power plant while minimizing the amount of energy lost through friction and turbulence in the water flow.

Figure 7 Bifurcation for Penstock[12]

2.2.5 Manhole

In hydropower systems, manholes are often used to provide access to various components of the system, including penstocks, turbines, and other equipment for maintenance and inspection purposes. Manholes can be constructed in various sizes and shapes, depending on the specific requirements of the system. In Penstock, they are designed with an opening that allows personnel to enter the penstock for maintenance work, and the opening is secured with a hatch or door that can be tightly sealed to prevent water from entering the manhole. Manholes are provided at a distance of 500m wherever necessary.

2.2.6 Expansion Joints

Expansion joints are installed in exposed penstocks between fixed point or anchors to permit longitudinal expansion, or contraction when changes in temperature occur and to permit slight rotation when conduits pass through two structures where differential settlement or deflection is anticipated. The expansion joints are located in between two anchor blocks generally downstream of uphill anchor block. This facilitates easy erection of pipes on steep slopes[13]. An expansion joint generally consists of parts like inner sleeve, clamp plates and glands.

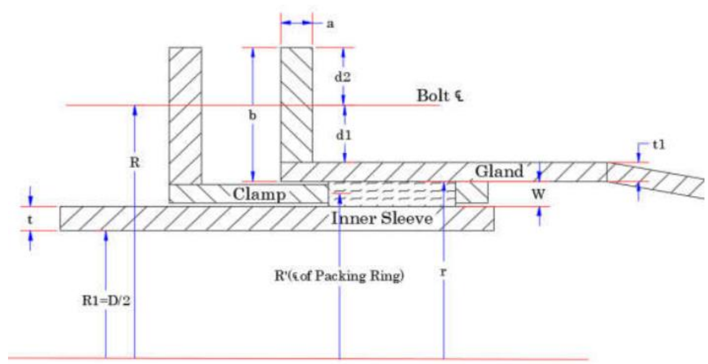


Figure 8 Schematic representation of Expansion Joint

2.2.7 Bends

Depending on topography, the alignment of the penstock is often required to be changed, in direction, to obtain he most economical profile so as to avoid excess excavation of foundation strata and also to give it an aesthetic look with the surroundings. These changes in direction are accomplished by curved sections, commonly called penstock bends. For ease of fabrication, the bends are made up of short segments of pipes with miter bends. Bends should be made with large-radius and small deflection between successive segments in order to minimize the hydraulic loss due to change in direction of flow. It is preferable to provide the radius of bend as 3 to times the diameter of the pipe and the deflection angle between each successive segments as 5 degrees to 19 degrees. For penstocks where conservation of head is very important, deflection angles from 4 degrees to 6 degrees may be used. From the consideration of alignment, penstock bends are generally classified as simple bends, compound bends and reducing bends[13].

Figure 9 Penstock Bend[14]

2.2.8 Bellmouth

A bellmouth is a type of hydraulic structure used in water intake systems, including those used in hydroelectric power plants. It is typically located at the entrance to a water intake structure and is designed to improve the efficiency of water intake by reducing the velocity and turbulence of the water as it enters the intake. A bellmouth is shaped like a cone, with a wide opening at the top and a narrow opening at the bottom. The wide opening allows water to flow smoothly into the cone, while the narrow opening at the bottom helps to reduce the velocity of the water and minimize turbulence.

2.2.9 Valves

Valves are essential components in hydropower plants, used to control and regulate the flow of water through various stages of the power generation process. The valves that are being commonly used are:

Butterfly Valve

It consists of a disc-shaped element with a rod through the center. The disc is positioned at a right angle to the pipeline, and it rotates around the rod to control the flow of the fluid. When the disc is aligned with the pipeline, the fluid flows through the valve, and when it is rotated 90 degrees, the flow is blocked. Butterfly valves are typically used in applications where a moderate degree of control over the flow is required, and where the pressure is relatively low[15].

Spherical Valve

Spherical valves, also known as ball valves, consist of a spherical ball-shaped disc with a hole in the center. The ball rotates around an axis to control the flow of the fluid through the valve. When the ball is aligned with the pipeline, the fluid flows through the valve, and when it is rotated 90 degrees, the flow is blocked. Spherical valves are typically used in high-pressure applications, where a tight seal is required to prevent leaks, and where precise control over the flow is not critical[16].

CHAPTER 3 WORK PERFORMED

3.1 2D Drawing familiarization and 3D Modelling

3.1.1 Part drawing

At initial phase of internship, the format of 2D drawing for the components that are to be validated are being familiarized. Here, the parts were checked if they are in accordance to the design criteria or not. The dimensions and numbers of parts in the design sheet should comply with the values in the Bill of Quantity (BOQ) table, any mistakes should be noted and should be reported to the supervisor or concerning agency. While going through part drawing the section column in BOQ should be carefully examined where parts section is provided which are mostly according to Indian Standards and the complete data for the part could be retrieve from IS code for that part.

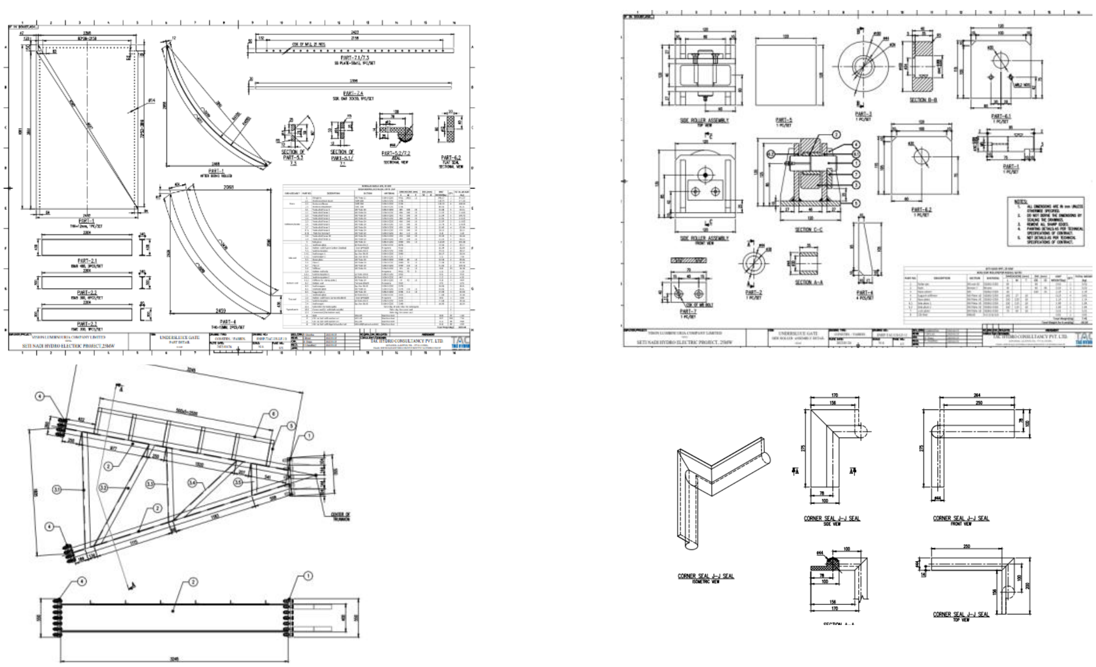


Figure 10 Part design sheets of Seti Nadi Undersluice Gate

SETI NADI KHOLA HPP, 25 MW												
BOQ-UNDERSLUICE RADIAL GATE LEAF												
SUB-ASSEMBLY	PART NO.	DESCRIPTION	SECTION	MATERIAL	DIMENSIONS (mm)			DIA. (mm)		UNIT	QTY.	TOTAL WEIGHT
					L	W	T	OD	ID	WEIGHT(kg)		(kg)
	1	Skin plate	MS Plate-12	IS2062-E250	4011	2492	12			941.57	1	941.57
Beam	2.1	Horizontal main beam	ISMB 400	IS2062-E250	2204					135.55	2	271.10
	2.2	Horizontal beam	ISMB 300	IS2062-E250	2204					101.39	6	608.34
	2.3	Horizontal top beam	ISMC 300	IS2062-E250	2204					80.01	1	80.01
Stiffeners/plates	3.1	Vertical stiffener 1	MS Plate-20	IS2062-E250	285	300	20			13.43	5	67.15
	3.2	Vertical stiffener 2	MS Plate-20	IS2062-E250	496	300	20			23.37	5	116.85
	3.3	Vertical stiffener 3	MS Plate-20	IS2062-E250	453	300	20			21.34	5	106.70
	3.4	Vertical stiffener 4	MS Plate-20	IS2062-E250	468	300	20			22.05	5	110.25
	3.5	Vertical stiffener 5	MS Plate-20	IS2062-E250	496	300	20			23.37	5	116.85
	3.6	Vertical stiffener 6	MS Plate-20	IS2062-E250	525	300	20			24.73	5	123.65
	3.7	Vertical stiffener 7	MS Plate-20	IS2062-E250	476	300	20			22.42	4	89.68
	3.7a	Vertical stiffener 8	MS Plate-20	IS2062-E250	476	390	20			29.15	1	29.15
	3.7b	Plate for hosting 9	MS Plate-20	IS2062-E250	162	125	20			3.18	1	3.18
	3.8	Vertical stiffener 10	MS Plate-20	IS2062-E250	410	300	20			19.32	5	96.60
	3.9	Vertical stiffener 11	MS Plate-20	IS2062-E250	293	288	20			13.25	5	66.25
	4	Side plate	MS Plate-12	IS2062-E250	3989	401	12			150.69	2	301.38
Side seal	5.1	Seal base plate	SS Plate-50x12	IS2062-E250	4074					19.56	2	39.12
	5.2	Rubber seal (Fluoro Carbon Cladded)	J Seal-ϕ44x100	Neoprene	4216					15.34	2	30.68
	5.3	Seal clamp plate	SS Plate-50x12	IS2062-E250	3991					19.16	2	38.32
	5.4.1	Seal stopper 1	Sqr. Bar 30x30	IS2062-E250	3986					28.17	2	56.34
	5.4.2	Seal stopper 2	Sqr. Bar 30x30	IS2062-E250	172					1.22	2	2.44
	5.5	Guide plate	MS Plate-10	IS2062-E250	3989	40	10			12.53	2	25.06
	5.6	Plate 1	MS Plate-10	IS2062-E250	3989	75	10			23.49	2	46.98
	5.7	Plate 2	MS Plate-10	IS2062-E250	3989	164	10			51.36	2	102.72
	5.8	Stiffener	MS Plate-10	IS2062-E250	155	65	10			0.80	20	16.00
	5.9	Rubber seal strip		Neoprene	4011	75	3			1.11	2	2.23
Bottom seal	6.1.1	Seal clamp plate 1	SS Plate-50x12	IS2062-E250	1962					9.42	1	9.42
	6.1.2	Seal clamp plate 2	SS Plate-50x12	IS2062-E250	447					2.15	2	4.30
	6.1.3	Stiffener for clamp plate 2	MS Plate-10	IS2062-E250	50	40	10			0.16	4	0.64
	6.2	Rubber seal	Flat seal-80x20	Neoprene	2852					6.91	1	6.91
	6.3	Seal stoppper	Sqr. Bar 30x30	IS2062-E250	2378					16.81	1	16.81
	6.4	Seal base plate	MS Plate-16	IS2062-E250	2378	150	16			44.81	1	44.81
	6.5	Support plate	MS Plate-10	IS2062-E250	2204	215	10			37.20	1	37.20
Top seal	7.1	Seal base plate	SS Plate-50x12	IS2062-E250	2423					11.64	1	11.64
	7.2	Rubber seal(Fluoro Carbon Cladded)	J Seal-ϕ44x100	Neoprene	2453					8.93	1	8.93
	7.3	Seal clamp plate	SS Plate-50x12	IS2062-E250	2423					11.64	1	11.64
	7.4	Seal stopper	Sqr. Bar 30x30	IS2062-E250	2398					16.95	1	16.95
Typical parts	10.1	Side roller (for radial gate)	Refer drg. of side roller for radial gate								3	
	10.2	Corner seal (J-J with bulb outside)	Refer drg. for cornel seal								2	
	10.3	Corner seal (Flat bottom seal)	Refer drg. for corner seal								2	
	11	Bolt	M12x65	Stainless steel						0.06	27	1.62
	12	CSK nut bolt with washer set	M12x50	Stainless steel						0.07	108	7.56
	12	CSK nut bolt with washer set	M12x85	Stainless steel						0.11	88	9.68

Figure 11 Bill of Quantity of Undersluice gate

3.1.2 Assembly drawing

Assembly drawing was used to validate the parts positioning and to validate the drawing if it complies with the number and types of parts shown in BOQ and in design sheet. Assembly drawing was later on used to create 3D model which further can be used to perform structural analysis to determine if it can bear the expected load that it is being designed for or not.

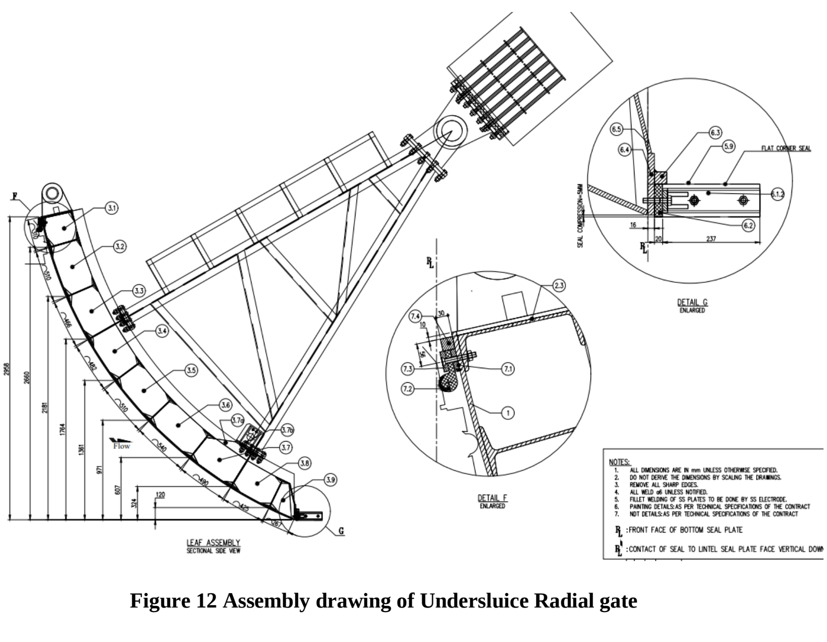


Figure 12 Assembly drawing of Undersluice Radial gate

3.2 3D Modelling

To get familiarize with hydro-mechanical components and their working 2D drawings and assembly were used to develop 3D model. The modelling was done with the help of Solidworks software.

3.2.1 Modelling of Sliding Gate

The slide gate is the simplest type of flat gate. It consists basically on a gate leaf that slides alongside guides embedded or fastened to the concrete. The leaf is provided with sliding surfaces, usually metallic, which under tight contact at the bearing surfaces act as seals[9]. The slide gate works by sliding up and down on tracks located on either side of the gate. When the gate is in the fully open position, water is allowed to flow freely through the penstock and into the turbine, generating electricity. When the gate is closed, water is prevented from entering the turbine, allowing maintenance and repairs to be performed.

3.2.1.1 Modelling of Approach Canal Gate's Leaf of Seti Nadi

The leaf of a slide gate refers to the moveable part of the gate that slides up and down to control the flow of water through a dam or penstock. The leaf is typically made of steel and is designed to withstand the extreme forces of water pressure and flow.

Leaf contains various parts which includes Steel plate, I and C beams, Stiffeners, Seal, Main roller and Side roller. Combination and proper design of all of these parts makes a leaf functional. Here, Steel plates and beams gives structural rigidity. Stiffeners are essentially steel reinforcements that are welded or bolted to the leaf, typically in a perpendicular orientation to the plate. The purpose of stiffeners is to provide additional rigidity and strength to the leaf, helping to resist the forces of water pressure and flow. Main roller is provided to guide the leaf as it slides up and down on tracks. Seals are used to prevent water from leaking through the gate when it is closed. Seals may be made of rubber, neoprene, or other materials. Fasteners are used to hold various components together in their respective places.

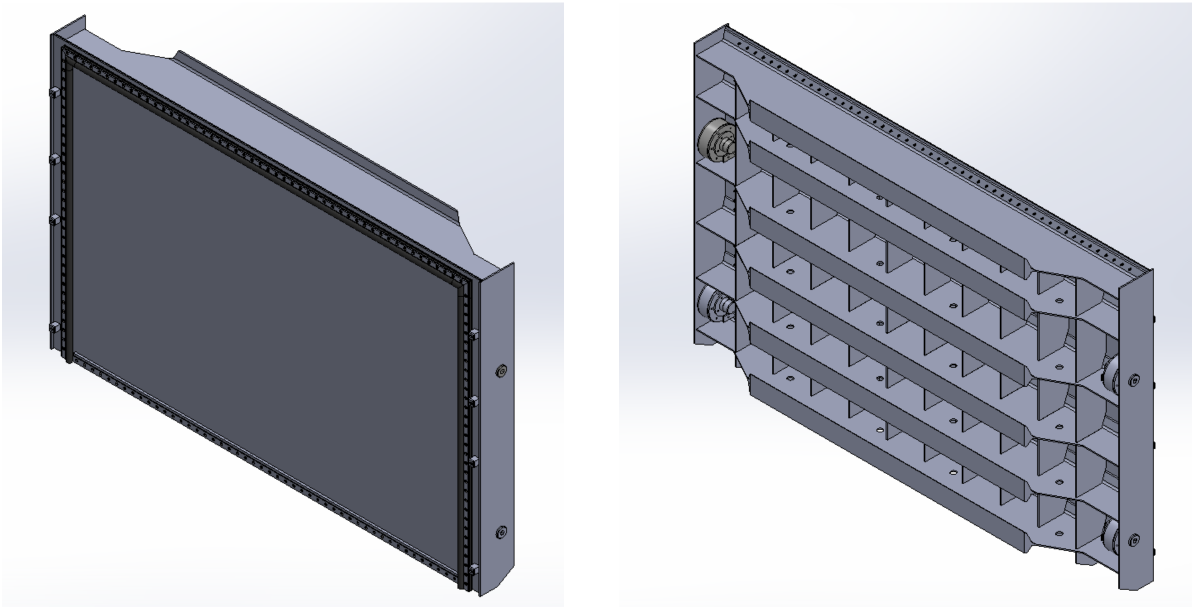


Figure 13 Front and back of approach canal leaf assembly

3.2.1.2 Approach canal Gate Frame Assembly

Frame is a structure that is used as a track for leaf to slide up and down. It is made of steel and contains beams like I-beam, C-beam, L-angle.

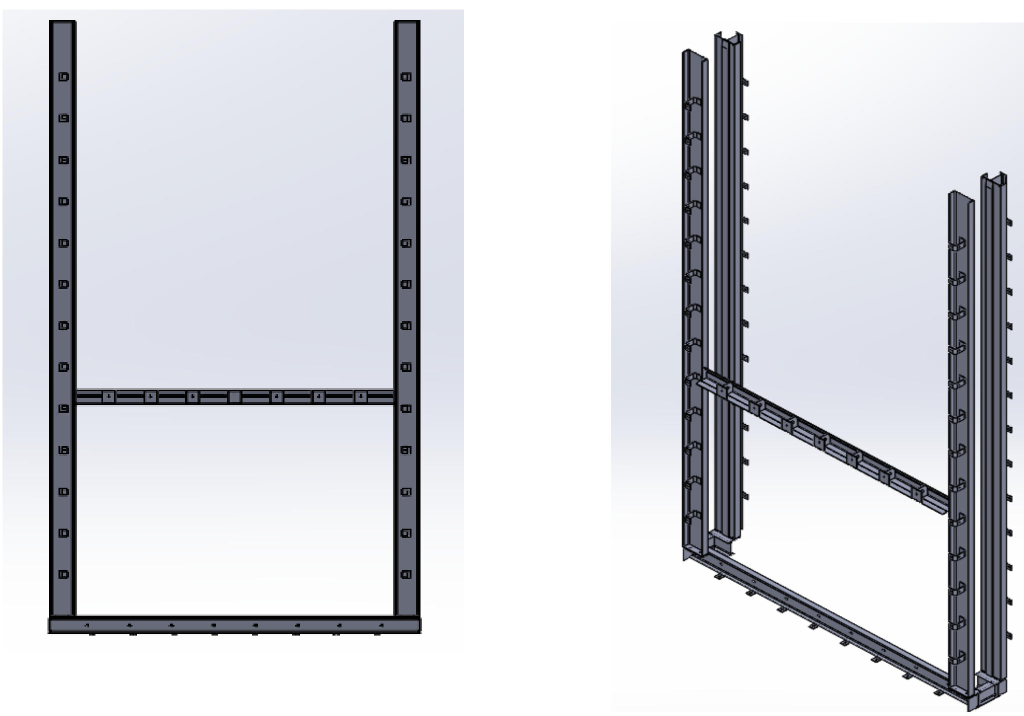


Figure 14 Approach canal Gate Frame Assembly

3.2.1.3 Final Assembly of Approach Canal Gate

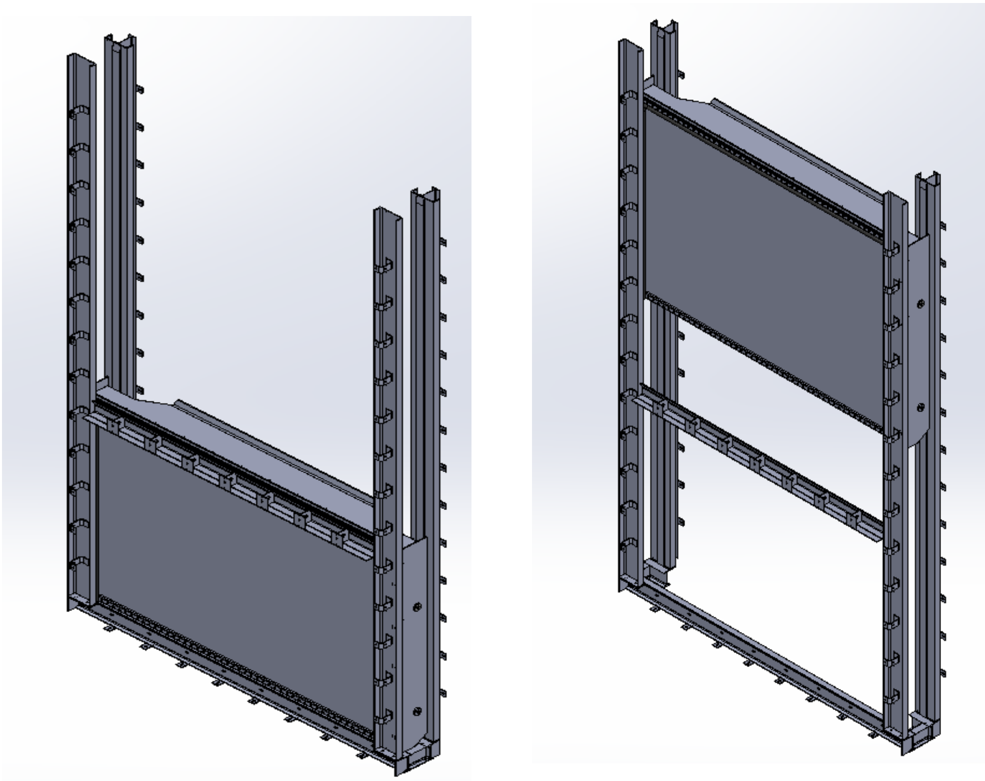


Figure 15 Final Assembly of Approach Canal Gate closed and opened position respectively

3.2.2 Modelling of Radial Gate of Seti Nadi

The Radial Gate (also called Tainter Gate) is a different type of floodgate used to control the water flow through dams' spillways and river barrage. The design of the Radial Gate consists of a reinforced curved skin plate that has horizontal beams to reinforce the structure and two main vertical beams to transfer the load to the main rotational arms located on either side. At the ends of the radial arms the rotation is being possible by a frame mounted 'trunnion' located on the adjacent concrete walls. This system enables circular rotation of the gate to be achieved during the 'opening/closing' operations[17].

3.2.2.1 Modelling of Leaf assembly for Undersluice Gate

Components used in radial gate are almost similar to that of Slide gates besides the skin plate, clamp plate, base plate used in this gate have a curve structures. Seals also have an 3d structure than that of slide gate in order to accommodate linkage from side and top seal.

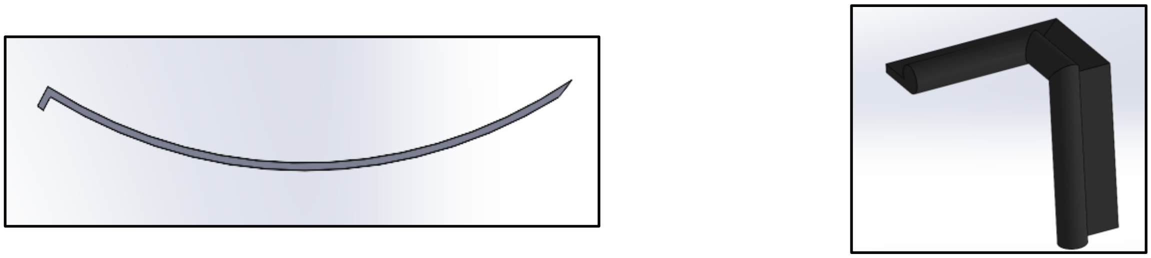


Figure 16 Clamp plate and J-J corner seal from left to right

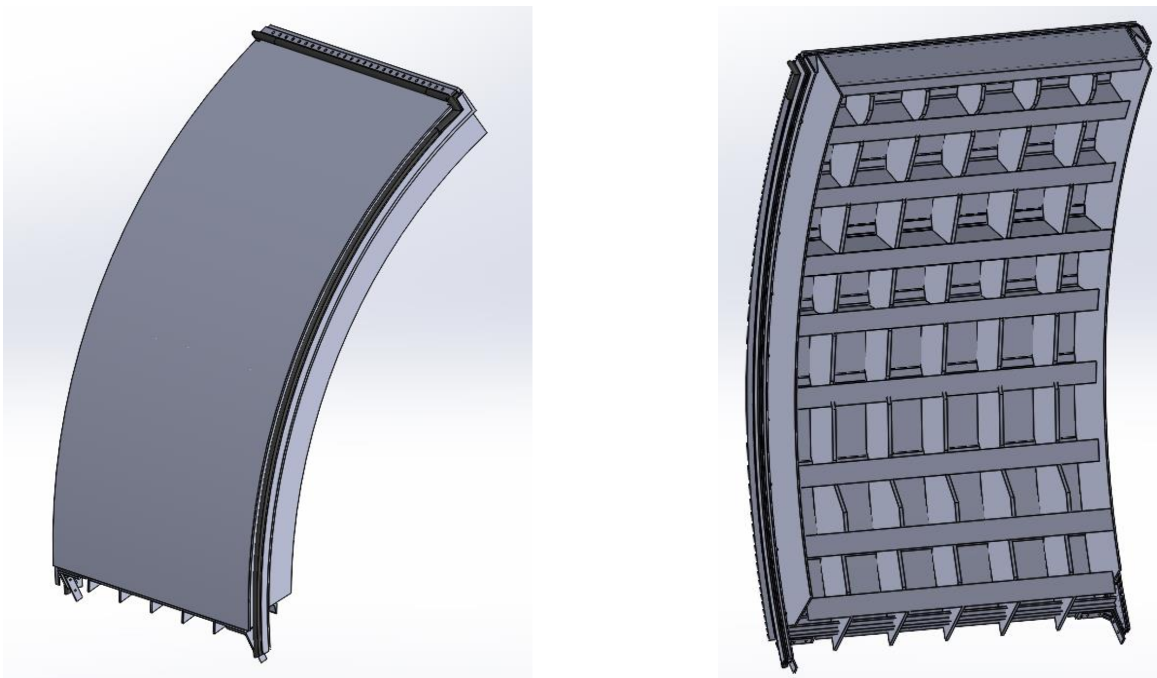


Figure 17 Skin Plate for Radial Gate

3.2.2.2 Modelling of Arm Assembly

The radial gate arm is connected from the gate leaf to the trunnion, it transfers the loads exerted in the leaf to the concrete support. It should be designed so as to withstand bending moment exerted on it.

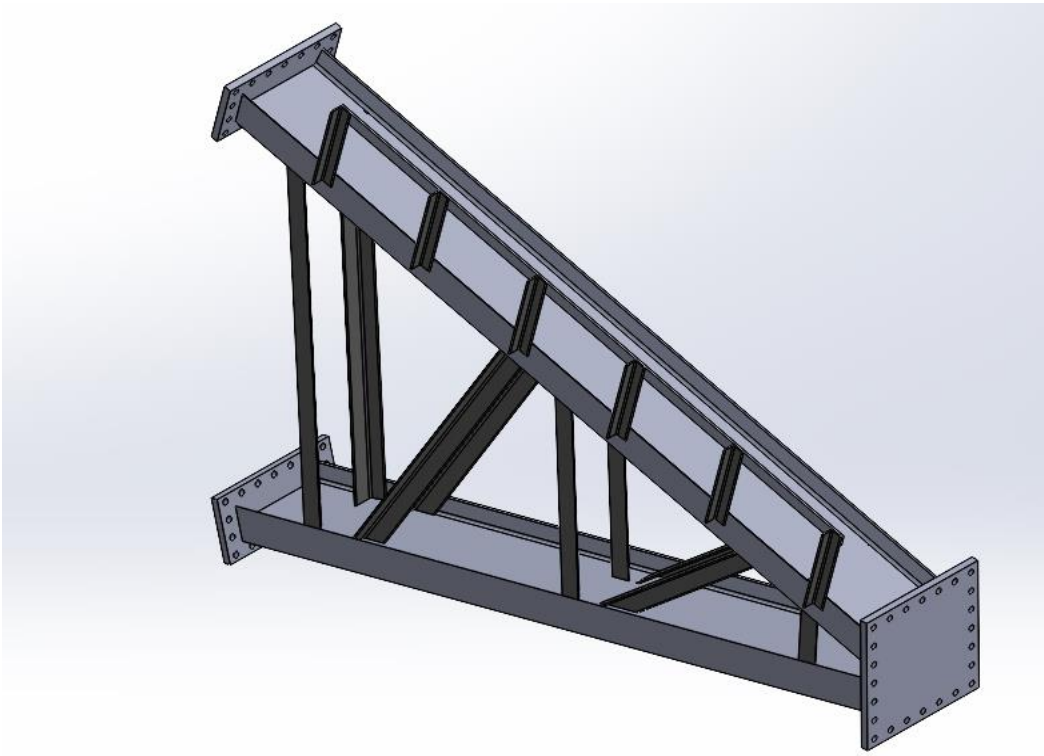


Figure 18 Arm assembly for Undersluice gate

3.2.2.3 Additional Components

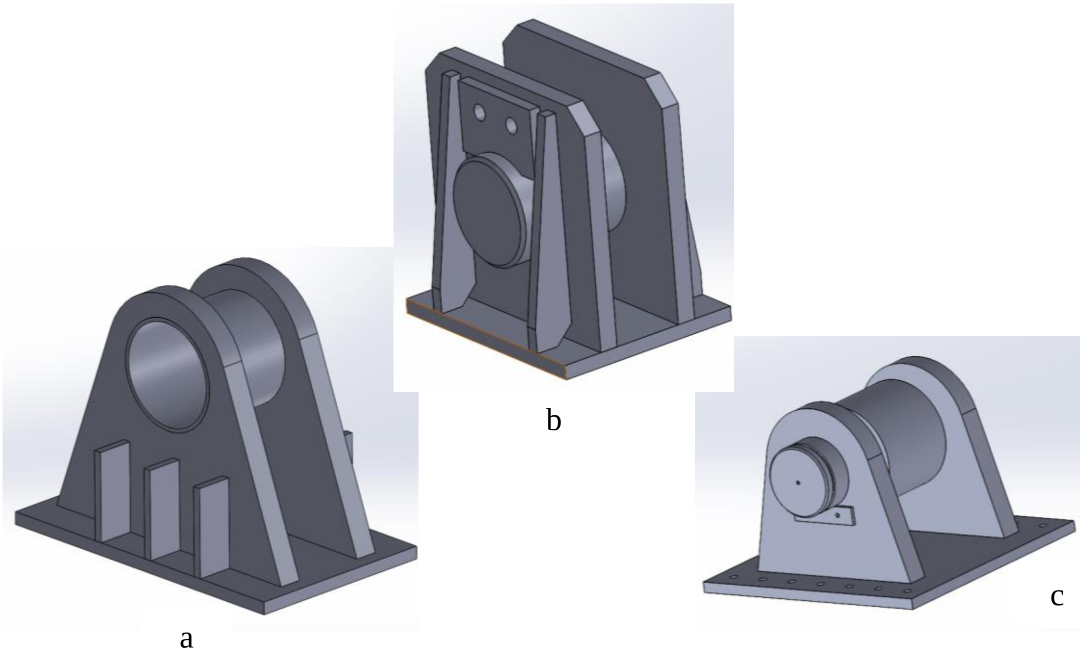


Figure 19 a. Dogging device b. Lifting Eye c. Trunnion Part

3.3 Structural and Hydraulic Analysis

3.3.1 TEE-joint - Seti Nadi

This is the joint of penstock pipe which divides the flow in two directions. In this study a T-section of Seti Nadi Hydropower is taken and its structural and hydraulic analysis was performed in ANSYS static structural and CFX respectively. For modelling purpose Solidworks software was used. General specifications of Tee are given below along with the schematic but some values are changed when the simulations are carried out:

Table 2 General specification of Seti Nadi Tee-joint

S.N.	Name	Value
1	Main Pipe Internal Diameter	2500 mm
2	Thickness of Penstock Shell	26 mm
3	Design Head	258 m
4	Thickness of Crotch Plate	96 mm
5	Internal Depth of Crotch Plate	25 mm
6	External Height of Crotch Plate	350 mm

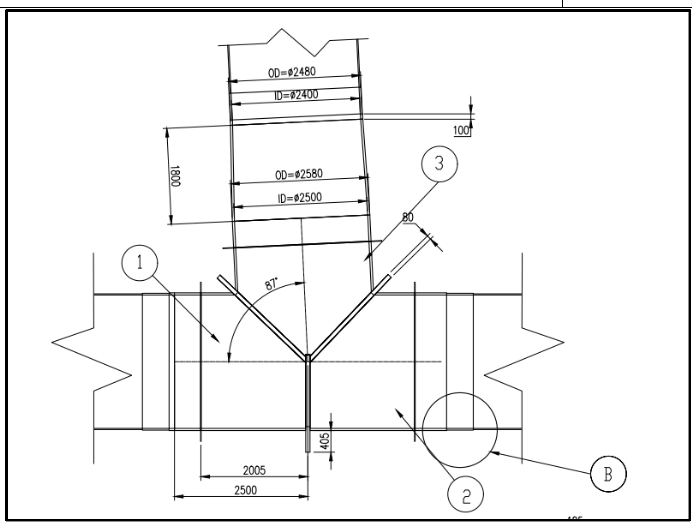


Figure 20 Schematic of T-section of Seti Nadi

3.3.1.1 Model generation

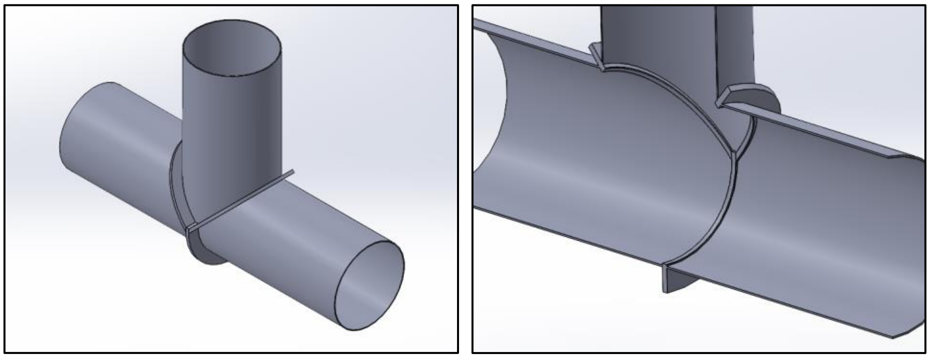


Figure 21 Solidworks model for T-joint

3.3.1.2 Static structural

Table 3 Details of T-joint

S.N.	Name	Value
1	Tensile Yield Strength of Crotch	420 MPa
2	Tensile Ultimate Strength of Crotch	570 MPa
3	Tensile Yield Strength of Penstock	350 MPa
4	Tensile Ultimate Strength of Penstock	490 MPa
5	No. of Nodes	639607
6	No. of Elements	331475
7	Internal Pressure	2.24 MPa

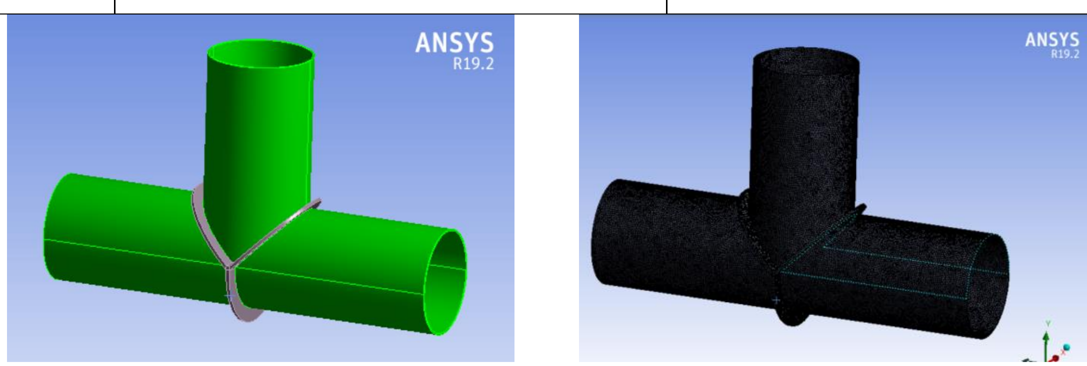


Figure 22 ANSYS Static structural analysis of T-joint

Result

On evaluating static results, it was observed that the maximum stress was exerting on inner section of crotch plate with the maximum value of 199.22 MPa, the maximum deflection was found to be 2.6372 mm on sides of crotch plate at on outer surface of main penstock pipe while overall factor of safety was recorded to be 1.86 which was considered as safe[19].

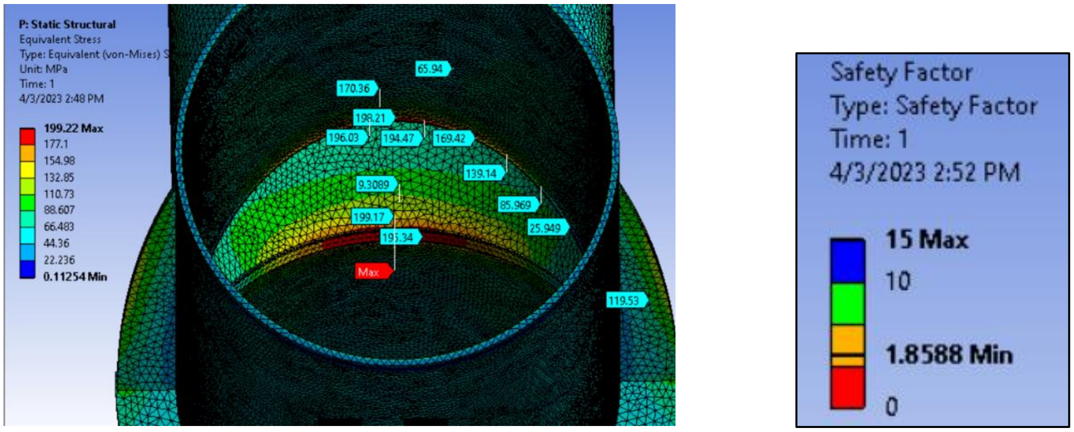


Figure 23 Equivalent von-mises stress in T-joint

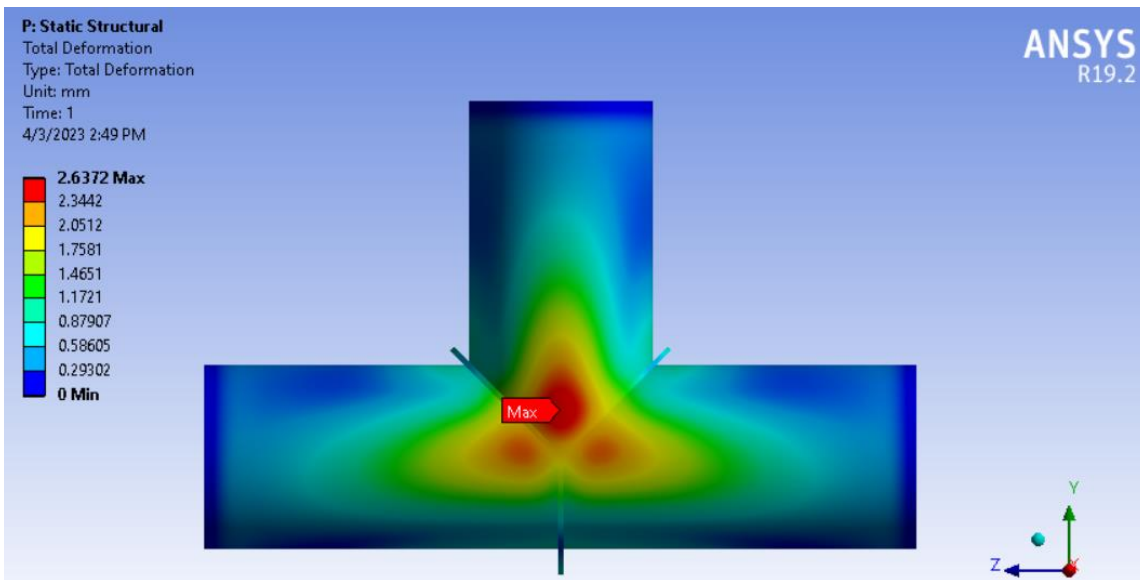


Figure 24 Maximum deflection in T-joint

3.3.1.3 Hydraulic Analysis

For the determination of head loss due to the sickle plate hydraulic analysis was performed. Head loss in a pipe refers to the pressure drop that occurs as a fluid flow through the pipe due to friction, turbulence, and other forms of resistance. It is typically expressed in units of length. The input parameters for the analysis are shown in table below:

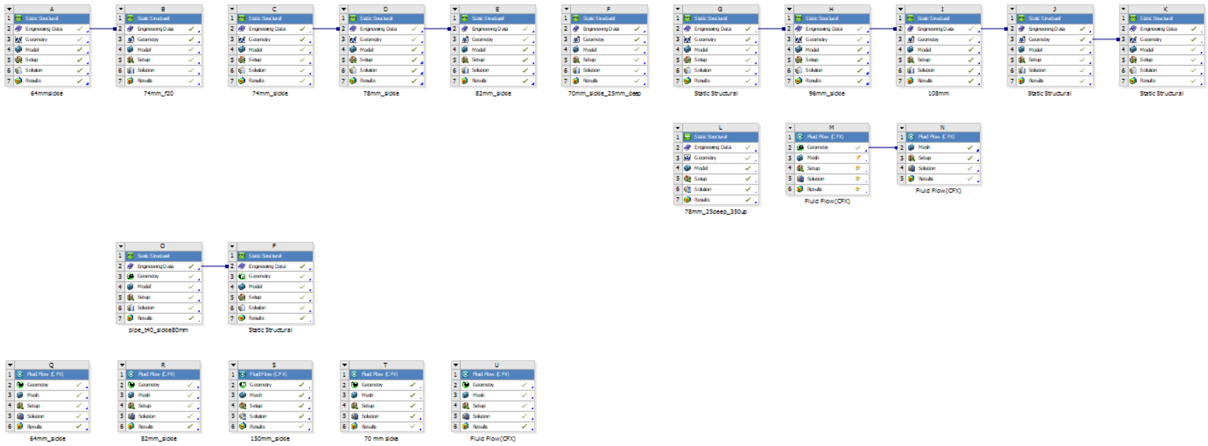


Figure 25 CFX analysis for head loss in Tee

Table 4 Input parameters for Seti Nadi hydraulic analysis

S.N.	Name	Value
1	Main Pipe Internal Diameter	2500 mm
2	Inlet pressure	2 MPa
3	Outlet mass flow rate	19500 kg/s
4	Iterations	100
5	Upper Outlet	Wall

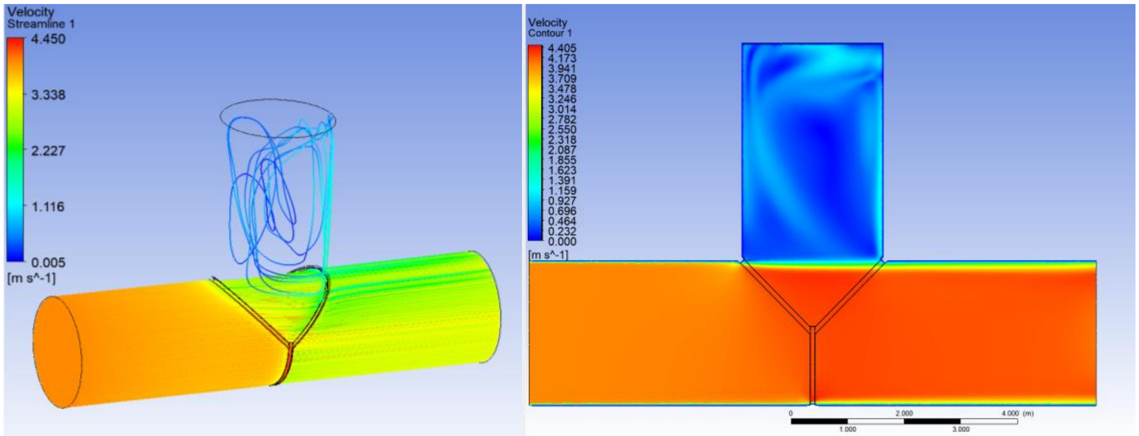


Figure 26 Velocity streamlines and contour plots

Result:

From the analysis it was found that the head loss to be 100mm for this section of pipe. After both structural and hydraulic analysis, the sickle plate of thickness 70mm of E440 selected. The sickle extends 25mm inside the pipe and extends 350mm outwards.

3.3.2 Bifurcation – Seti Nadi

Table 5 General specification of Seti Bifurcation

S.N.	Name	Value
1	Main Pipe Internal Diameter	2500 mm
2	Thickness of Penstock Shell	30 mm
3	Design Head	258 m
4	Thickness of Crotch Plate	100 mm
5	Internal Depth of Crotch Plate	447 mm(max)
6	External Height of Crotch Plate	859 mm(max)

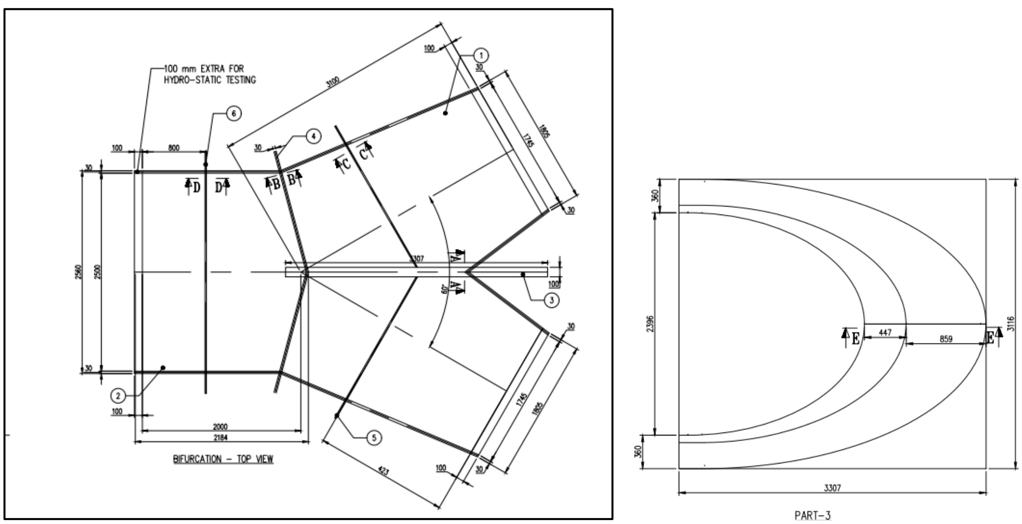


Figure 27 Schematic of Bifurcation and crotch plate of Seti Nadi

3.3.2.1 Model Generation

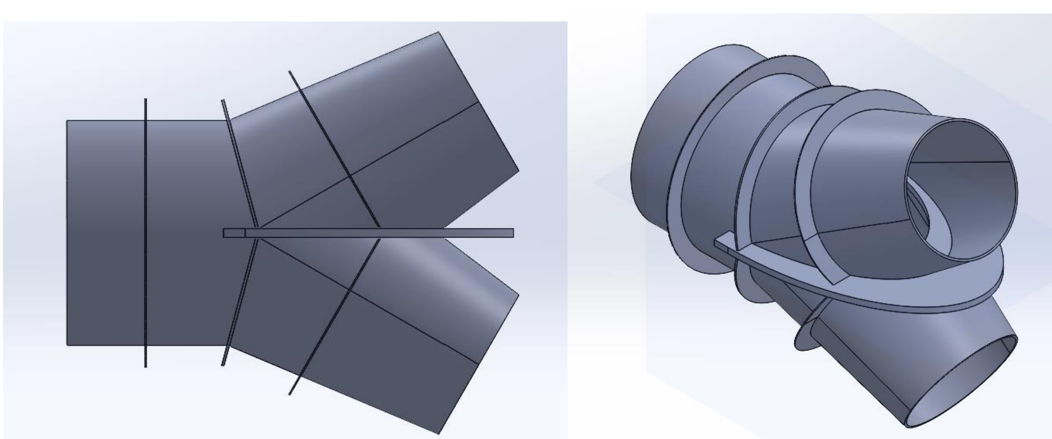


Figure 28 Solidworks model of Seti-Bifurcation

3.3.2.2 Static structural

Table 6 Seti-Bifurcation model specification

S.N.	Name	Value
1	Tensile Yield Strength of Sickle	330 MPa
2	Tensile Ultimate Strength of Sickle	410 MPa
3	Tensile Yield Strength of Penstock	380 MPa
4	Tensile Ultimate Strength of Penstock	540 MPa
5	No. of Nodes	332254
6	No. of Elements	173003
7	Internal Pressure	3.79 MPa
8	Bifurcation angle	60 deg
9	Diameter of both branches	1700 mm

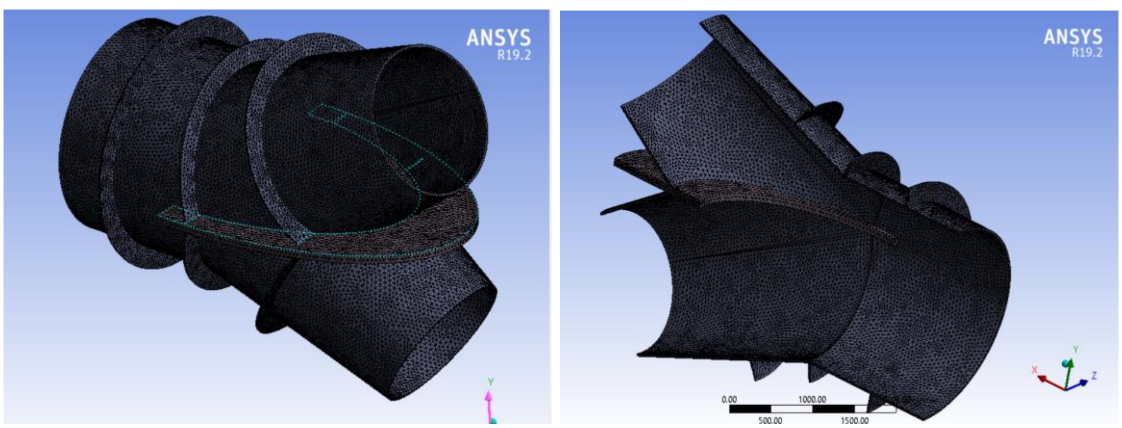


Figure 29 Seti-Bifurcation meshing in ANSYS

Result

On evaluating static results, it was observed that the maximum stress was exerting on inner section of sickle plate with the maximum value of 222.51 MPa, the maximum deflection was found to be 2.6372 mm on sides of sickle plate at on outer surface of main penstock pipe while overall factor of safety was recorded to be 1.7 which was considered as satisfactorily safe[19].

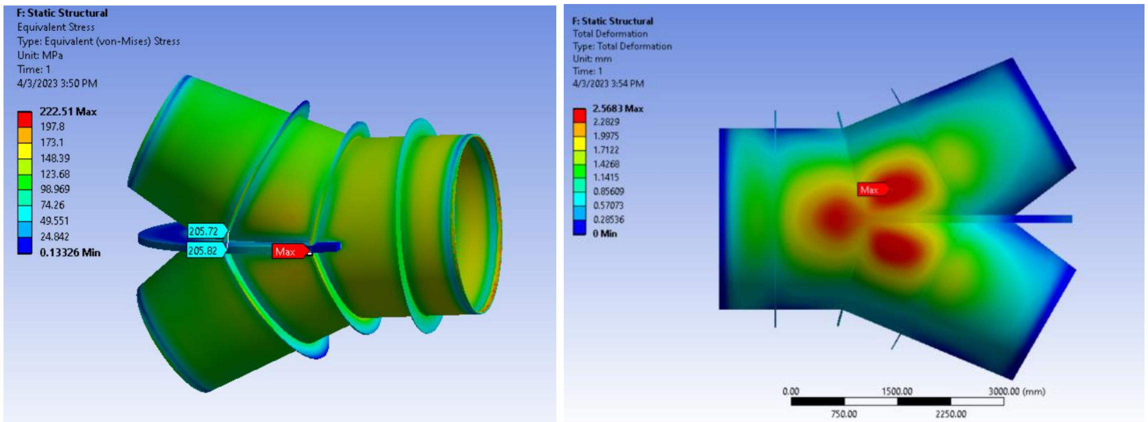


Figure 30 ANSYS results of Seti-bifurcation

When the bifurcation was subjected to internal pressure of 3.2 MPa with a gradual increase in pressure at first 15 minutes then 15 minutes of stagnant pressure and the final 15 minutes of decreasing pressure, following results are obtained:

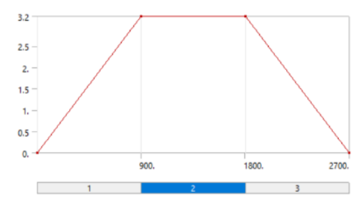


Figure 31 Input variable pressure

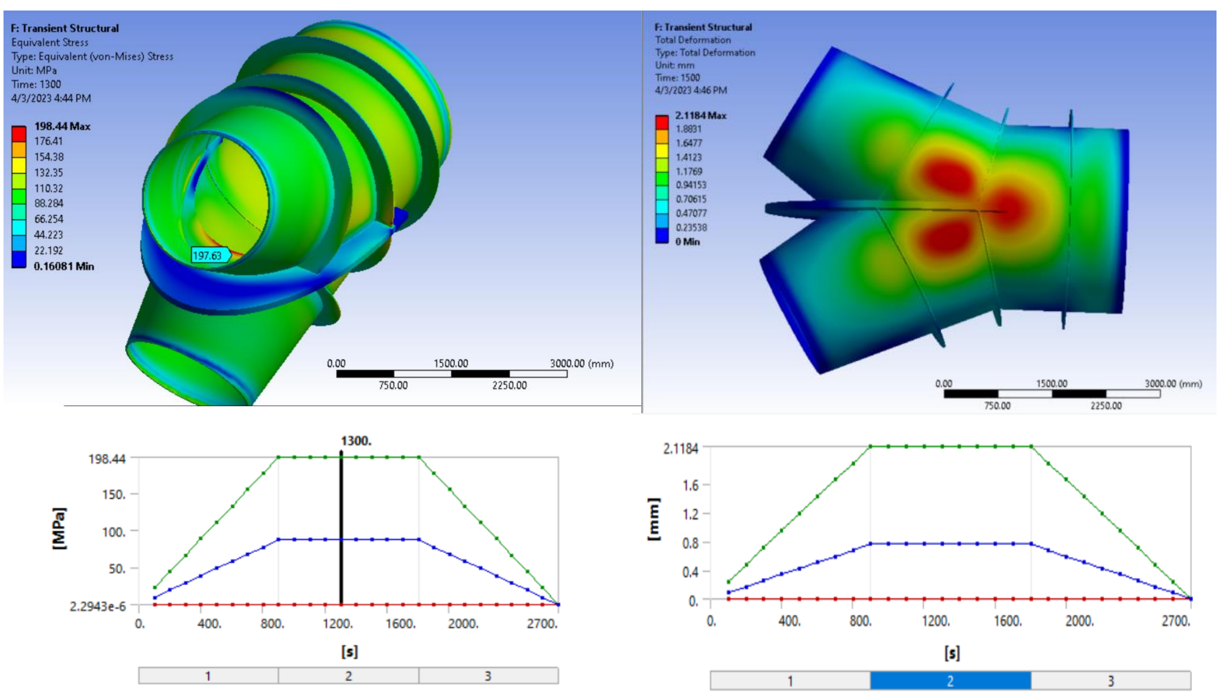


Figure 32 Stress and deformation according to variable pressure

3.3.2.3 Hydraulic Analysis

Table 7 Input parameters for Seti Nadi-Bifurcation

S.N.	Name	Value
1	Main Pipe Internal Diameter	2500 mm
2	Inlet pressure	2.529 MPa
3	Outlet mass flow rates	9000 kg/s for both outlet
4	Iterations	100
5	Bifurcation angle	60 deg

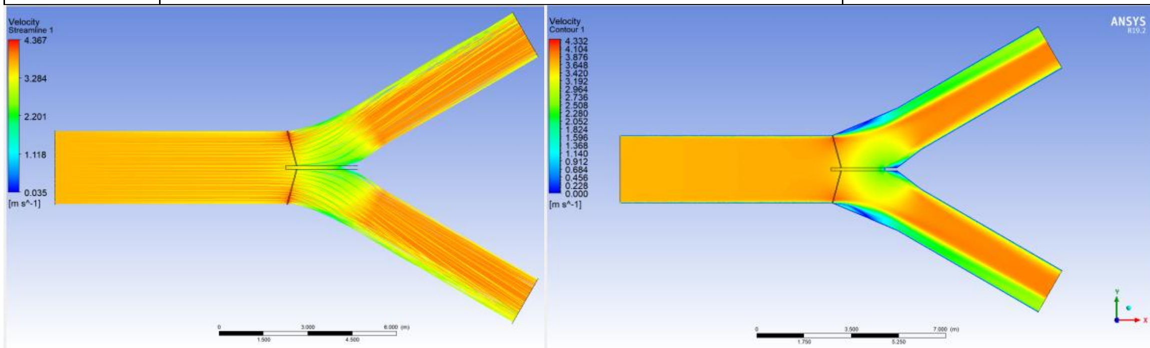


Figure 33 Velocity streamline and velocity contour plot of Seti-bifurcation

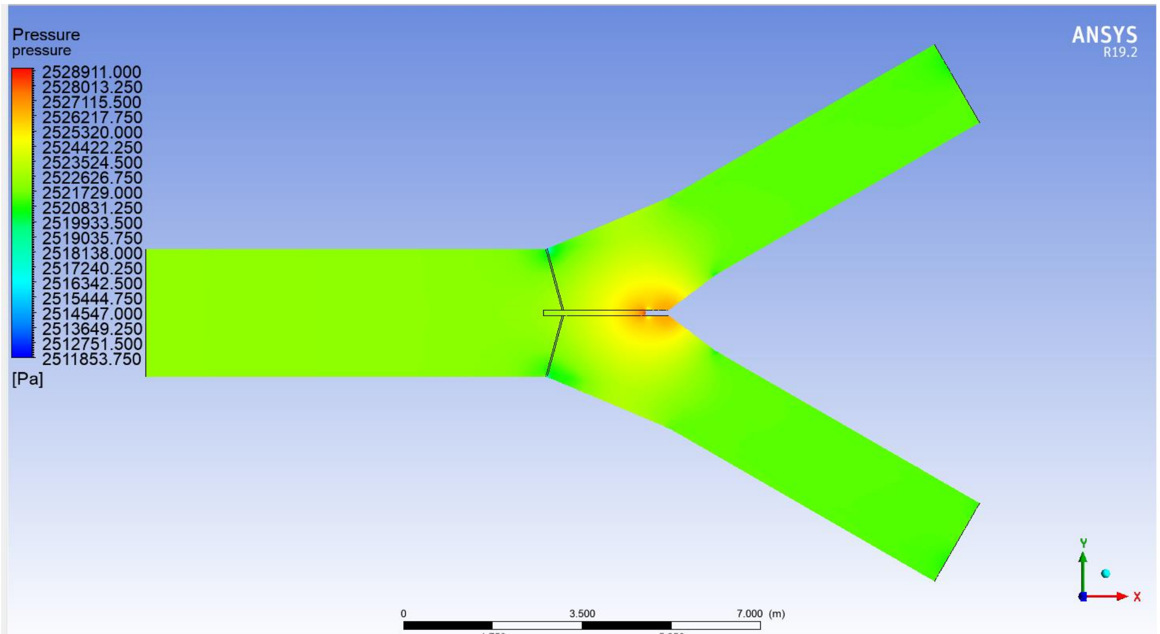


Figure 34 Pressure contour plot Seti-bifurcation

Result:

From the analysis it was found that this configuration produces a head loss of 100mm. From both structural and hydraulic analyis it was found to be suitable for installation.

3.3.3 Bifurcation-Dordi

Table 8 General information of Dordi bifurcation

S.N.	Name	Value
1	Main Pipe Internal Diameter	2000 mm
2	Thickness of Penstock Shell	44 mm
3	Design Head	258 m
4	Thickness of Sickle Plate	300 mm
5	Internal Depth of Sickle Plate	500 mm(max)
6	External Height of Sickle Plate	700 mm(max)
7	Angle of branching pipe	41.978 deg

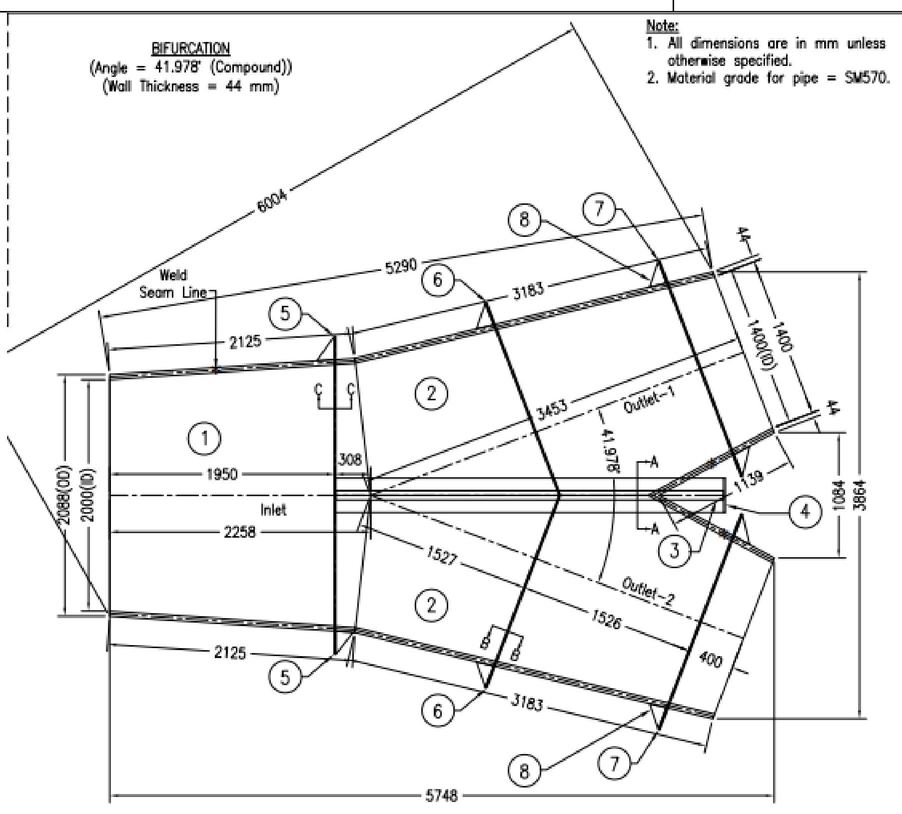


Figure 35 Schematic diagram of Dordi bifurcation

3.3.3.1 Model generation

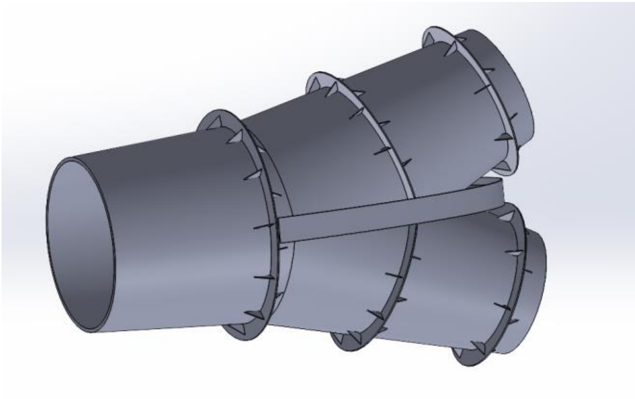


Figure 36 3D model of Dordi bifurcation

3.3.3.2 Static structural

General specifications on Dordi bifurcation.

Table 9 Dordi-Bifurcation model specification

S.N.	Name	Value
1	Tensile Yield Strength of Material	440 MPa
2	Tensile Ultimate Strength of Material	570 MPa
3	No. of Nodes	412015
4	No. of Elements	234232
5	Internal Pressure	7.2 MPa
6	Diameter of both branches at outlet	1400 mm

Result

On evaluating static results, it was observed that the maximum stress was exerting on inner section of sickle plate with the maximum value of 249.05 MPa, the maximum deflection was found to be 2.35 mm on sides of sickle plate at on outer surface of main penstock pipe while overall factor of safety was recorded to be 1.76 which was considered as reasonably safe[19].

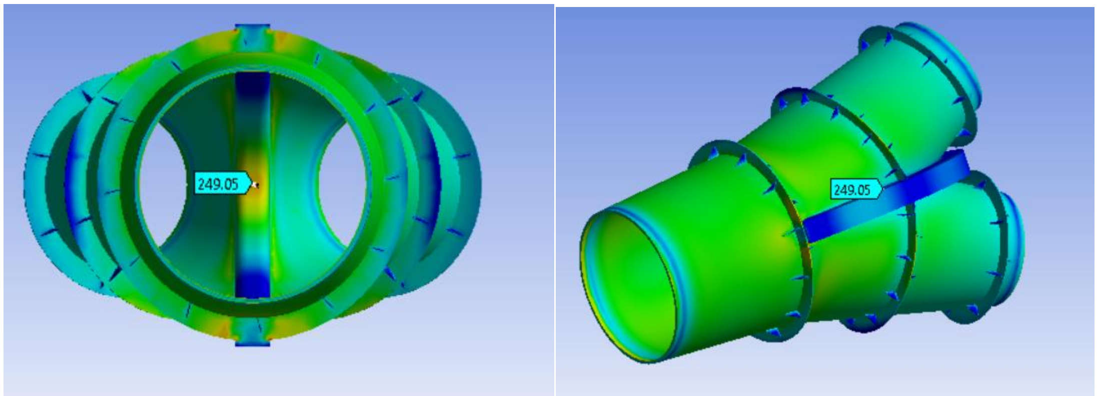


Figure 37 Stress distribution- Dordi bifurcation

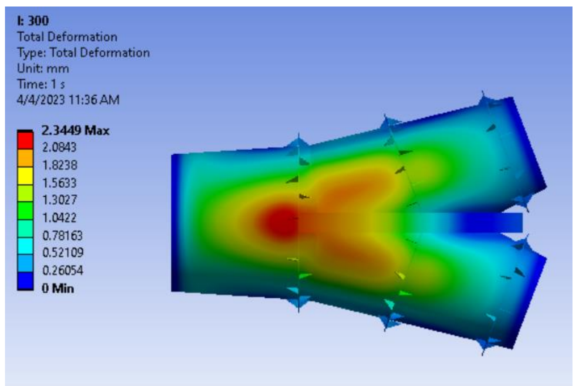


Figure 38 Maximum deformation- Dordi Bifurcation

3.3.4 Miter pipe Dordi- 90 deg

A Miter Elbow is a fabricated fitting used for direction change of the line. It is prepared by mitering (a cut at an angle) and then welding the pipe ends of the cut pieces to form a required bend, usually at 45° and 90°.Miter Elbow or Bend is made from miter cut pieces of pipe and the number of cuts and miter pieces is decided based upon the pressure and temperature the particular line carries. The miter pieces also known as gores or pipe-segments. There are two end segment and two middle segments in a 4-piece Miter bend.

Modelling- Dordi Miter Bend

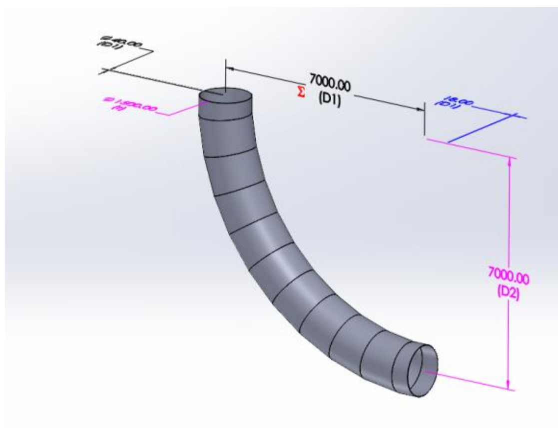


Figure 39 Solidworks modelling of miter bend

3.3.4.1 Static Analysis- Miter Bend

Table 10 General specification of meter bent

S.N.	Name	Value
1	Tensile Yield Strength of Material	450 MPa
2	Tensile Ultimate Strength of Material	570 MPa
3	No. of Nodes	361141
4	No. of Elements	181820
5	Internal Pressure	3.5 MPa
6	Diameter of both branches at outlet	1500 mm

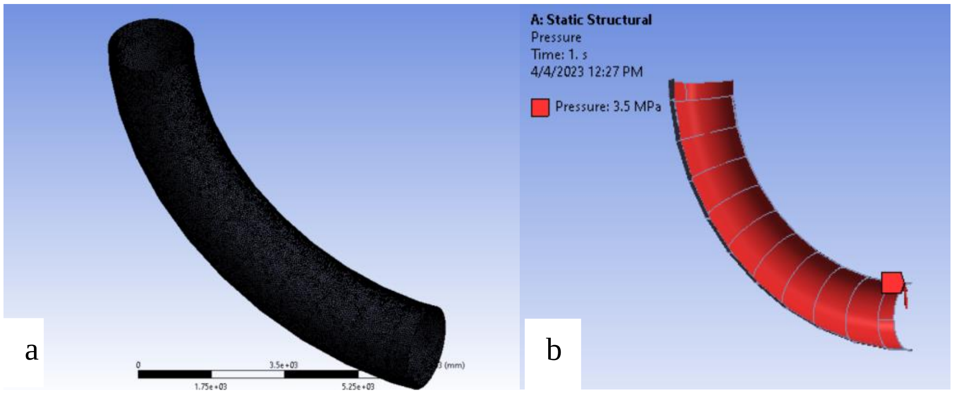
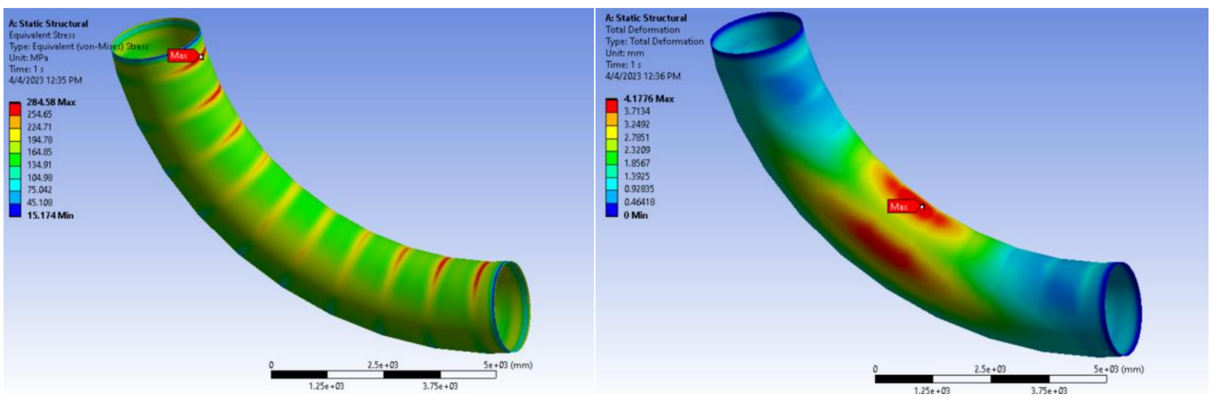


Figure 40 Miter bend- a. ANSYS Meshing b. Sectional view of applied pressure

Result

Here, the maximum stress of 284.58 MPa was found at the joining of meter sections with the maximum deformation of 4.2mm whereas the factor of safety was near to 1.6 which was regarded as satisfactory[19].



3.3.4.2 Hydraulic Analysis

Table 11 Input parameters of Dordi-Bend

S.N.	Name	Value
1	Internal Diameter	1500 mm
2	Inlet pressure	3.5 MPa
3	Outlet mass flow rates	10890 kg/s
4	Iterations	100
5	Bend angle	90 deg
6	Number of sections	11

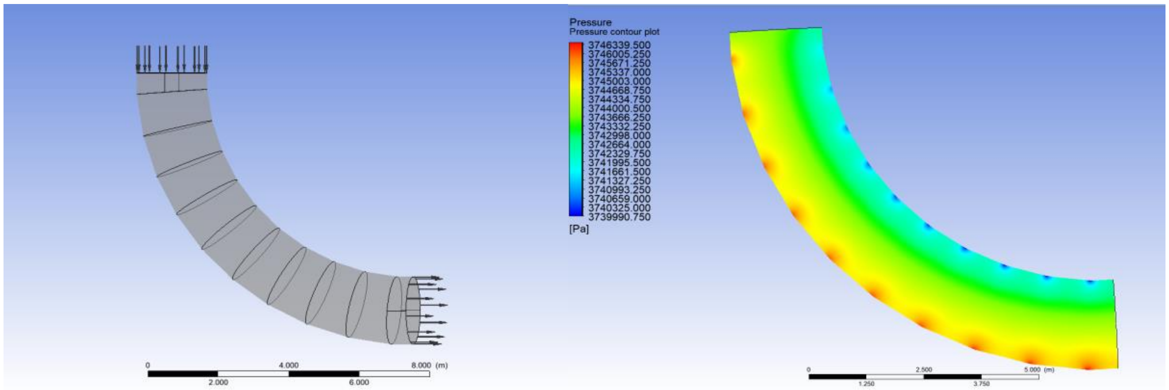


Figure 41 Miter bend analysis setup(left) and pressure plot(right)

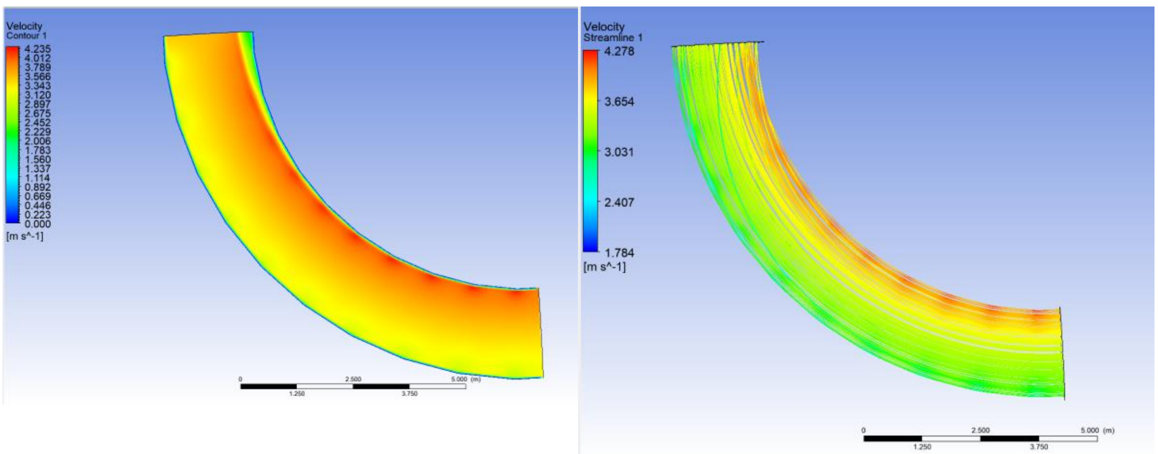


Figure 42 Velocity contour plot and velocity streamline

Result:

Being structurally stable and having a head loss of 35mm the structure was determined as suitable to use.

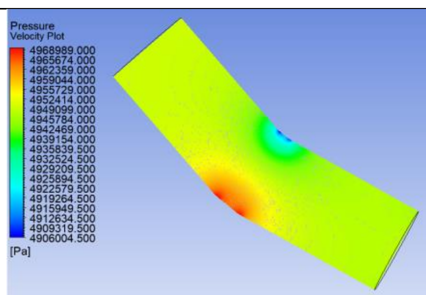
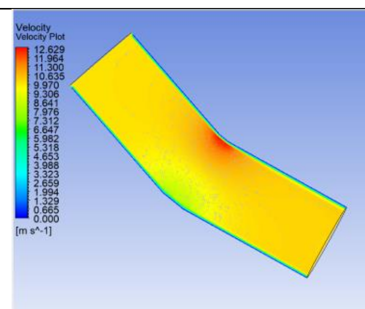
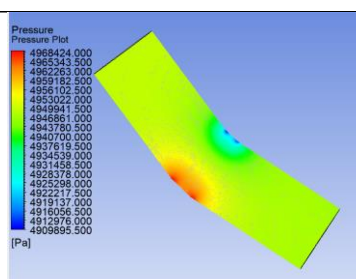
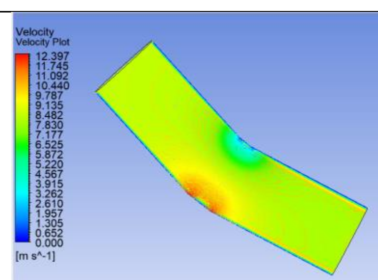
3.3.5 Miter pipe Dordi- 30 deg

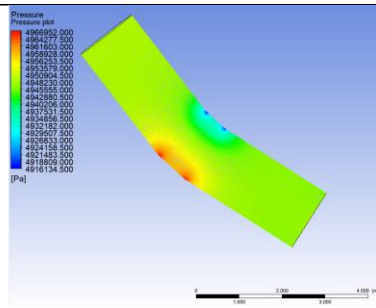
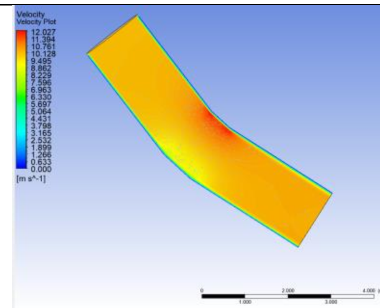
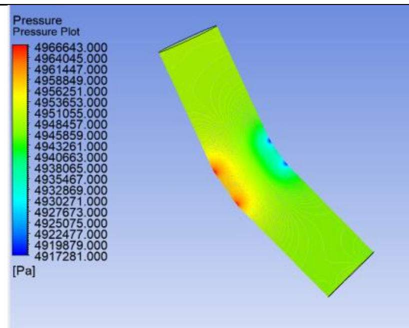
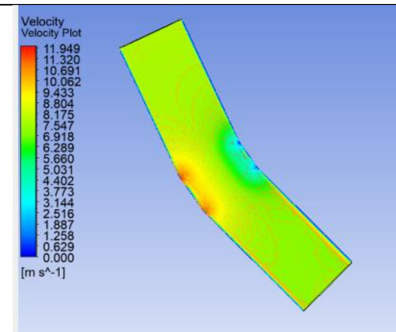
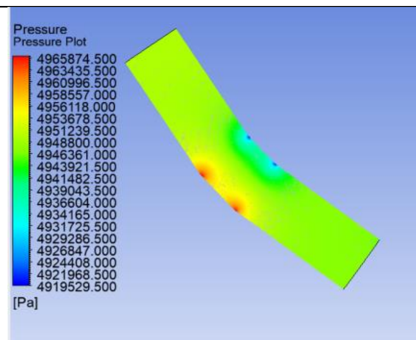
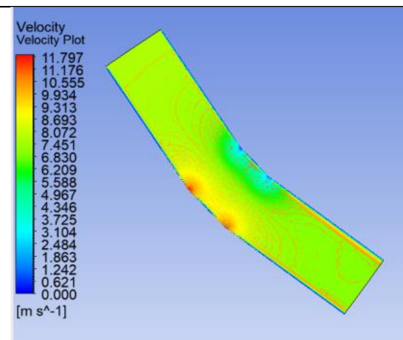
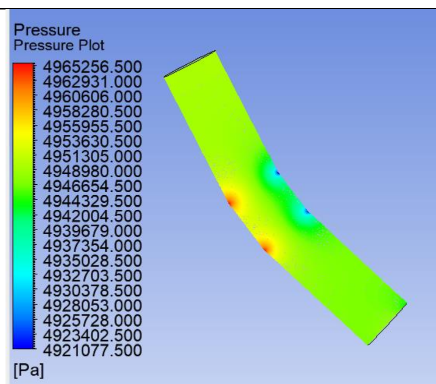
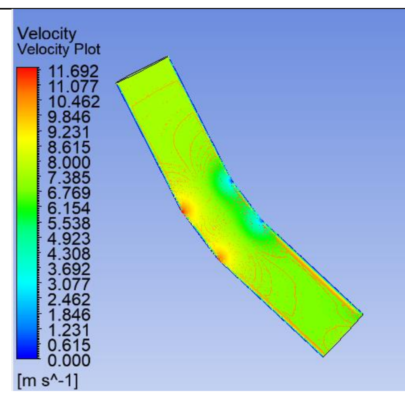
For a 30 deg change various diameter pipe were tested in order to determine the best suited bend which would produce minimum head loss and is statically stable. The radius of curvature of pipe tested have radius of 2000mm, 2500mm, 3987mm, 4500mm, 6000mm and 8000mm. The results of the simulations are listed below.:

Table 12 Inlet and initial condition for 30 deg bend

S.N.	Name	Value
1	Internal Diameter	1500 mm
2	Inlet pressure	5 MPa
3	Outlet mass flow rates	17700 kg/s
4	Iterations	100
5	Bend angle	30 deg
6	Number of sections	3

Table 13 Head loss according to curvature change

S.N.	Radius of curvature	Pressure Plot	Velocity Plot	Head Loss(cm)
1	2000 mm			0.26
2	2500 mm			0.27

<table>
<tr><td>3</td><td>3987 mm</td><td>
</td><td>
</td><td>0.25</td></tr>
<tr><td>4</td><td>4500 mm</td><td>
</td><td>
</td><td>0.26</td></tr>
<tr><td>5</td><td>6000 mm</td><td>
</td><td>
</td><td>0.29</td></tr>
<tr><td>6</td><td>8000 mm</td><td>
</td><td>
</td><td>0.33</td></tr>
</table>

Head loss vs Radius of curvature of pipe

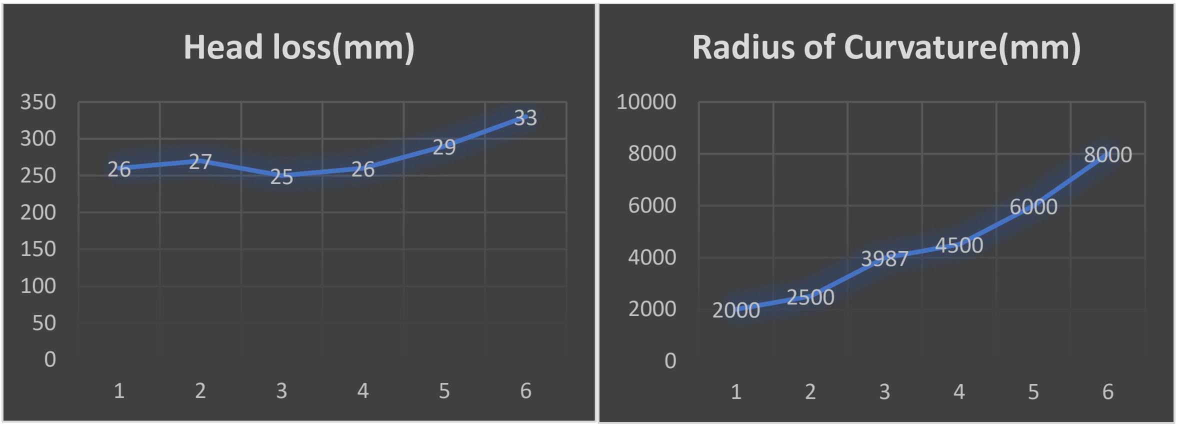


Figure 43 Head loss and Radius of curvature plot

From this analysis it was found that the head loss was lowest for the pipe with radius of curvature of 3987mm i.e., 25mm. Hence, the design of the bend pipe was found to be suitable for serving the purpose.

3.3.6 Pressure testing pipe – Lower Solu (82MW)

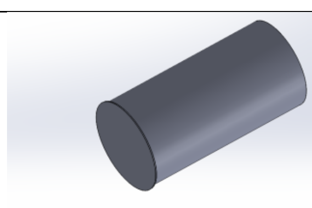
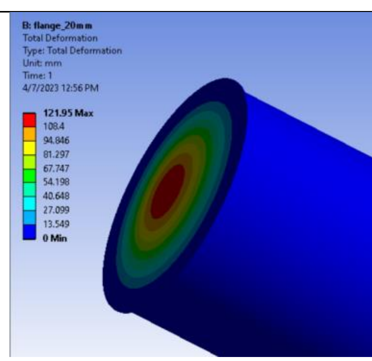
A restriction is to be designed to use in a pressure testing pipe for the safe and sound operation. Penstocks are designed to carry water at high pressures, which can be dangerous if there is a failure or leak. Pressure testing ensures that the penstock is strong enough to withstand the maximum operating pressure without any failures, ensuring the safety of people and equipment in the vicinity. The test pressure should be 1.5 times the maximum allowable working pressure. When the test pressure has been reached it should be held for a minimum of 15 to 20 minutes. During testing any sorts of leakage in joints, flanges, bolts and any critical part should be carefully noted. The various designs and their analysis are given below in reference of Lower Solu hydropower project.

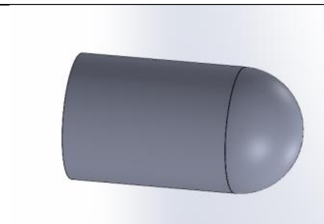
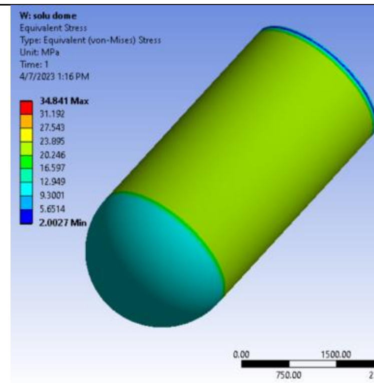
Table 14 Lower Solu penstock detail for pressure test

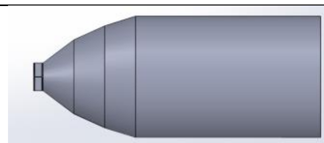
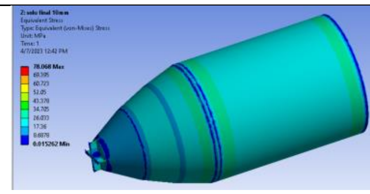
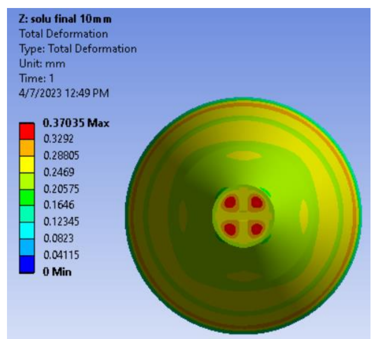
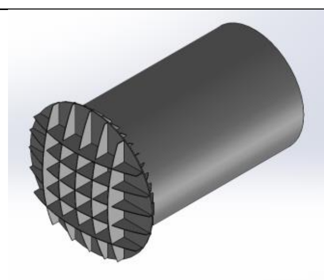
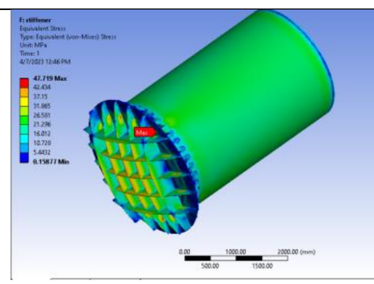
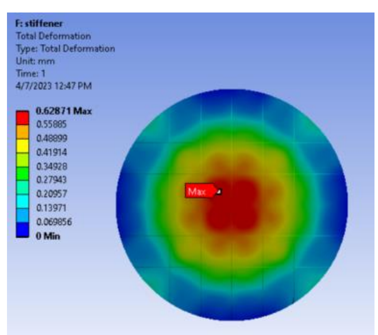
S.N.	Name	Value
1	Tensile Yield Strength of Material	350 MPa
2	Tensile Ultimate Strength of Material	490 MPa
3	Internal Pressure	0.2 MPa
4	Outer Diameter	2420 mm
5	Inner Diameter	2400 mm

3.3.7 Static Analysis

Table 15 CAD, Static Analysis and result of different penstock pressure test designs

S N	Design Type	CAD	Static analysis	Remarks
1.	With only blind flange			Deflection = 121mm Equivalent stress = 709.88 MPa FoS = 0.49 *Structurally not suitable

<table>
<tr>
<td>2.</td>
<td>Dome pipe</td>
<td></td>
<td>
</td>
<td>Deflection = 0.15 mm
Equivalent stress = 34.8 Mpa
FoS = 10

*Extremely time consuming for manufacturing</td>
</tr>
<tr>
<td>3.</td>
<td>Using reducers</td>
<td></td>
<td>

</td>
<td>Deflection = 121mm
Equivalent stress = 709.88 MPa
FoS = 4.48</td>
</tr>
<tr>
<td>4.</td>
<td>Bracing plates</td>
<td></td>
<td>

</td>
<td>Deflection = 121mm
Equivalent stress = 709.88 MPa
FoS = 7.3</td>
</tr>
</table>

3.3.8 Manhole

In hydropower systems, manholes are often used to provide access to various components of the system, including penstocks, turbines, and other equipment for maintenance and inspection purposes. For validation and inspection of manholes drawing a design sheet is created which helped to determine the loopholes in the design sheet provided by consulting company. For this purpose, the following books and references are used:

1. ASME Section VIII Rules for construction of pressure vessels. Division II. 2019 edition[18]
2. ASME Section VIII Rules for construction of pressure vessels. Division I. 2019 edition[19]
3. Steel Pipe: A Guide for Design and Installation. AWWA MANUAL M11[20]
4. Indian Standard STRUCTURAL DESIGN OF PENSTOCK - CRITERIA PART 3 SPECIALS FOR PENSTOCKS[21]

3.3.8.1 Design Sheet

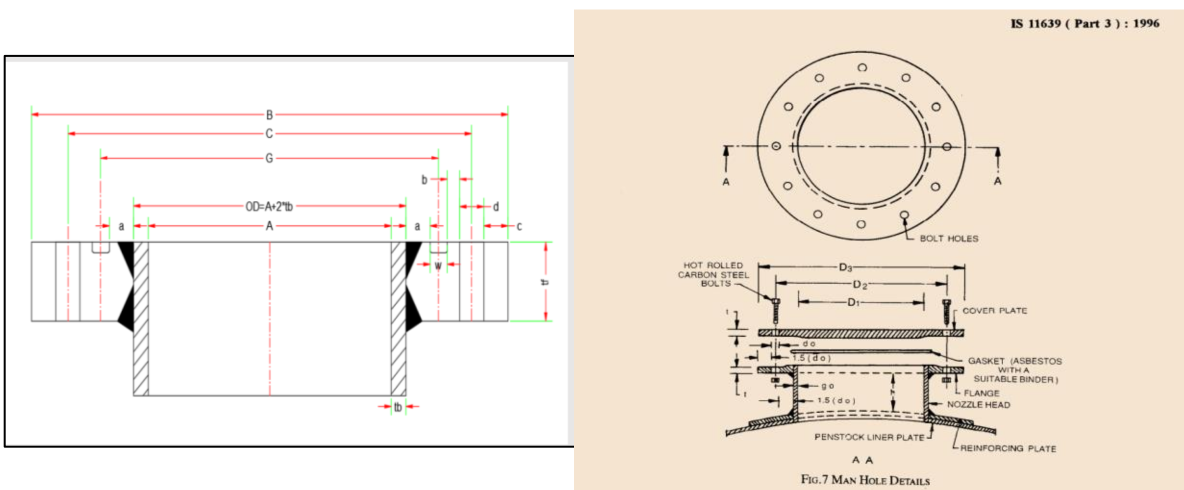


Figure 44 Manhole References from book and consultant company

MANHOLE	
Penstock Diameter, mm	2800
Penstock Thickness, mm	10

Head, m	30	
Surge, %	150	
Total head, m	75	
Internal (Static) Pressure, Mpa	0.736	
Allowable stress (**σ**), Mpa	143.33	
Branch Pipe angle, degree	90	
Material	**IS2062 E275**	
COVER PLATE		
Half of minor axis (radius), b, cm	30	
Half of major axis (radius), a, cm	30	
Corrosion Allowance, mm	2	
Stress Concentration Coefficient, (B/A)	1.24	**Table 1.25-1**
Thickness t, mm	25.93	
Corrosion Allowance, 2 mm	27.93445993	
Add Bossed Part 5mm	32.93445993	
Final thickness	**33 mm**	
FLANGE		
Neck inside Dia, D1, mm	600	
Flange Thickness, mm	12	
Neck outer diameter, mm	624	
BOLT		
Selected Bolt	M20	
Diameter, mm	20	

PCD of O ring, mm	678	
Bolt Pitch Circle Diameter, mm	752.000	
Flange outer diameter, mm	812.000	
Circumferential Spacing Between Bolts, mm	200	
No of bolts	11.812	
Adopted no of bolts	20.000	
Total Load during operation, kN	265.631	
Yield strength of selected bolt, kN	156.800	
FOS	11.806	SAFE
Flange Moment, kNmm	9828.365	
K	1.353	
Y	6.575	
Bolt Correction Factor, Cf	1.000	
Flange Thickness, mm	27.41	
Additional Groove Depth, mm	8.000	
Corrosion Allowance, mm	2.000	
Final Flange Thickness	**38 mm**	
Adopted Flange Thickness	**38 mm**	

O-RING GROOVE	
Initial diameter, mm	10
Perimeter, mm	31.41592654
Targeted Compression, %	25
Compression, mm	2.500

Minor axis Length, mm	7.500	
Major axis Length, mm	11.990	
Clearance, mm	1.500	
Width, mm	13.490	
Final width w, mm	14.000	
Depth of groove, mm	2.500	

Selection of Reinforcement

Reinforcement is provided around the section of penstock from where the hole is cut out in order to fit the manhole structure. Since this cut-out weakens the section an extra layer of reinforcement has to be provided in order to design a safe structure. The widely used reinforcement types are shown below namely collar plate, crotch plate and wrapper plate. These plates are chosen according to PDV and d/D ratio value.

PDV	d/D	M Factor	Reinforcement Type
>9000	all	-	Crotch Plate
6000-9000	>0.7	0.000167 PDV	Wrapper
<6000	>0.7	1.0	Wrapper
6000-9000	≤0.7	0.000167 PDV	Collar
<6000	≤0.7	1.0	Collar

*These reinforcements are for resistance to internal pressure. They should be checked for ability to resist external loads.

Figure 45 Selection criteria of reinforcement plate

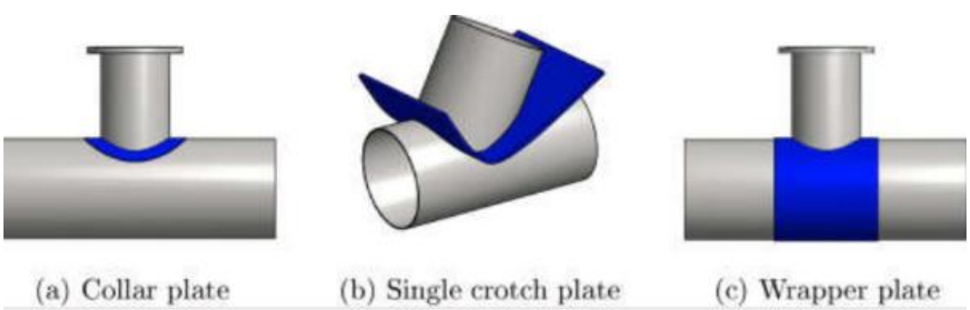


Figure 46 Types of reinforcement used

Selecting Type of Reinforcement

PDV	580.09
Plate Type	**Collar**

For PDV < 6000, M = 1

Collar Design

Main Pipe		
Tr	0.284949872	inch
Branch Pipe		
tr	0.063052738	inch

Theoretical Reinforcement Area, Ar		
Ar	6.731099334	in^2
Available Area, Aa		
Aa	3.535978023	in^2
Reinforcement Area, Aw		
Aw	3.195121311	in^2

w	12.28346457	
Minimum Thickness		
T	0.130057823	in

Reinforcement width		
w	12.28346457	in
Minimum allowable width		
w(min)	8.188976378	in
Width		
w	12.28346457	in
	312	**mm**
Overall reinforcement width		
W	**1248**	**mm**
Thickness (with corrosion allowance)		
T	**5.30**	**mm**

3.3.9 Expansion Joint

An expansion joint shall be attached at a place where an excessive stress is liable to be generated in axial direction by temperature and pressure change or by other external factors. An expansion joint shall be strong enough and watertight. For sleeve type expansion joint it is recommended to make sleeve 5 cm longer than the calculated value[22].

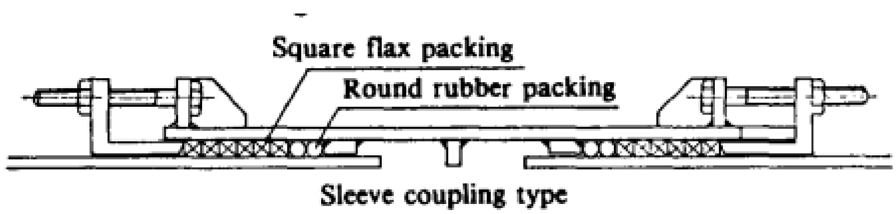


Figure 47 Schematic of sleeve coupling type expansion

References from following books and manuals were taken:

1. ASME Section VIII Rules for construction of pressure vessels. Division II. 2019 edition
2. Indian Standard STRUCTURAL DESIGN OF PENSTOCK - CRITERIA PART 3 SPECIALS FOR PENSTOCKS[21]
3. Technical Standards for Gates and Penstocks[22]

3.3.9.1 Design Sheet

EXPANSION JOINT		
Penstock Diameter, Dp	2400	mm
Penstock Thickness	18	mm
Expansion Joint Head	180	m
Surge	0	%
Design Head	180	m
Design Pressure	1.78	N/mm^2
Material	IS2062 E410	
Material UTS	540	
Material Yield	410	
FOS	0	
Allowable	180.00	MPa
Weld Joint Efficiency	90	%
Packing Material	Flax	
Poisson's Ratio of Packing material	0.3	

BOLT DESIGN		
Bolt	M20	
Bolt Diameter	20.00	mm
Bolt Grade	4.6	
UTS	400	N/mm^2
YTS, Yo	240	N/mm^2
Bolt Yielding Force, F(bolt)	58800	N

Thickness of Inner Sleeve, t	20	mm	
Thickness of Gland, t1	25	mm	
Width of Packing, w	26	mm	
Diameter of center of packing ring, D'	2466	mm	
No of Bolts(assume)	36		
Factor of Safety, *fs*	1		
Bolt Pressure, P1	**10.51**	**N/mm^2**	
Pressure, P2	**4.50**	**N/mm^2**	**SAFE**

INNER SLEEVE DESIGN			
Inner Radius of Sleeve, R_l	1200	mm	
Design Pressure Ration(P2/P)	1.25		
P2	2.22		
Plate Constant, λ	0.008295	/mm	
Minimum Length of Sleeve, L'	757.4995192	mm	
Adopted Sleeve Length	860		
λL'/2	3.566695		
Angel(λL'/2)	0.062251		
Stress, σ_1	129.49	N/mm^2	
Axial Movement due to P2, M	28.36	Nmm	
Stress, σ_2	0.43	N/mm^2	
Combined Stress, σ	129.70	N/mm^2	
Allowable Stress, σ_{all}	180.00	N/mm^2	**SAFE**

GLAND DESIGN			
Inner Radius of Gland, r	1246	mm	
Plate Constant, λ	0.007280716		
Bolt Force Per mm of Inside Circum. F	270.38	N/mm	
d1	40	mm	
d2	60	mm	
Flange Thickness, a	25	mm	
Flange Height, b	125.00	mm	
PCD of Bolt Circle, R	1311.00	mm	
Applied Moment per mm Inside Circum, Mt	14195.19032	N	
Mo	13080.93	Nmm/mm	
Bending Stress in Leg, σb	125.5769097	N/mm^2	
Compressive Stress in Leg, σc	-10.82	N/mm^2	
Total Stress, σ	136.392	N/mm^2	
Allowable Stress, σ_{all}	287.00	N/mm^2	SAFE

CLAMPING PIECE DESIGN		
Clamp Material	IS2062 E300	
Thickness of Clamping Pipe, tc	22	mm
Inside Radius of Clamping Pipe, ri	1222.00	mm
Outer Radius of Clamping Pipe, ro	1244.00	mm
Mean Radius of Clamping Pipe, rm	1233.00	mm
Gland Plate Constant	0.007281	
Bolt Force Per mm of Inside Circum. F	273.24	N/mm^2
Applied Moment per mm Inside Circum, Mt	21312.36	Nmm/mm
Flange Thickness, a	25	mm

b	149.00	mm	
Mo	13082.46	Nmm/mm	
Bending Stress in Leg, σb	125.5916025	N/mm^2	
Compressive Stress in Leg, σc	-10.93	N/mm^2	
Total Stress, σ	136.52	N/mm^2	
Allowable Stress, σ_{all}	210.00	N/mm^2	**SAFE**

3.3.10 Steel Liner

The steel liner is typically made from high-strength, corrosion-resistant steel and is designed to withstand the high pressures and flow rates associated with the transportation of water in a penstock. It is also designed to resist the corrosive effects of the water and to provide a smooth surface to minimize frictional losses. Steel liner is installed where:

a. It is required to control leakage out of the tunnel because of unfavorable geologic conditions;

b. There is insufficient rock cover to withstand the internal pressure within the tunnels such that a potential for undesirable leakage exists because of hydraulic jacking along horizontal or near horizontal joints;

c. Wherever the internal water pressure exceeds the minor principal stress in the surrounding rock mass such that potential for hydro fracturing or hydraulic jacking exists usually along vertical or near vertical joints if impermeable liner is not provided[23].

PART - 2 BURIED / EMBEDDED PENSTOCKS IN ROCK		
STRUCTURAL DESIGN OF STEEL LINING		
INPUT		
Variable	**Value**	
Diameter of Penstock, Dp	2000	mm
Internal Radius of Penstock	1	m
Thickness of Penstock, tp	32	mm
Head	100	m
Surge	25	%
Design Head	125.00	m
Design Pressure, P	1233750.00	Pa
Liner Shell Thickness	10	mm
Liner Shell Thickness	0.01	m
Contact Zone Width of Stiffener, b	0.01	m

Modulus of elasticity of concrete, Ec	1.83E+07	N/m^2
Modulus of elasticity of Steel, Es	2E+11	N/m^2
Modulus of elasticity of Rockmass, Er	1000000	N/m^2
Poisson's Ratio for Steel,μ_s	0.28	
Poisson's Ratio for Concrete,μ_c	0.15	
Poisson's Ratio for Rockmass,μ_r	0.2	
Radius of External Surface of Concrete	1.3	m
Co-efficient of Expansion of Steel, α_s	0.000011	per °C
Co-efficient of Expansion of Concrete, α_c	0.00007	per °C
Average Temperature During Placing of Concrete, T	25	°C
Actual temperature, To	28	°C
Initial Gap (Liner-Concrete), Yo	0.02	m
Radius to the end of radial fissure in Rock, d	1.2	m
Proportion of internal pressure transferred to surrounding rock	0.2	
Modulus of plastic deformation of concrete	25000000000	N/m^2
Modulus of Plastic deformation of cracked rock same as concrete	25000000000	N/m^2
Modulus of plastic deformation of sound rock	3000000000	N/m^2
Poisson’s ratio	0.2	
Yield Point Stress in Steel, Fy	350000000	N/m^2
Steel allowable stress, f_n	200000000	N/m^2
Spacing of Stiffener Rings, L	1.2	m
Number of full waves, n	9	Range (1-18)
Permissible Yield Stress of Liner, σ_y	100000000	N/m^2

OUTPUT

DESIGN FOR INTERNAL PRESSURE

Variable	Value

Hoop stress in Penstock Without Rock Participatation		
Pressure Wave Velocity(a)	876.9230769	m/s
Hoop stress, fst	123375000.00	N/m^2
For Penstock embedded in well reinforced homogeneous mass concrete without fissures or cracks		
K1	3.90	
Pressure Shared by Steel Liner,Ps	1231189.09	N/m^2
Hoop Tensile Stress in Steel Liner, fst	123118908.6	N/m^2
Hoop Tensile Stress in Concrete inner surface, fct	9983.85	N/m^2
For Penstock embedded in fissured concrete and rock		
Pressure to close the Gap Yo (Liner-Concrete), Po	43402777.78	N/m^2
M-value	0.945327937	
Pressure Shared by Steel Liner, Ps	1233751.53	N/m^2
Hoop Tensile Stress in Steel Liner, fst	123375153.1	N/m^2
Tangential Tensile Stress, frt	-1.275633872	N/m^2

DESIGN FOR EXTERNAL PRESSURE		
Critical External Pressure for Unstiffened Shell		
A) Vaughan's Formula		
K-value	200	
E'	2.17014E+11	
Coeff of P^2cr,a	1	
Coeff of Pcr,b	42864316.24	
Coeff, c	1.07431E+13	
Critical External Pressure, Pcr	-252112.1775	N/m^2
	-42612204.06	N/m^2
B) Amstutz's Formula		

K-value	200	
E'	2.17014E+11	
fy	391703795.9	N/m^2
Critical External Pressure, Pcr	1938164.024	N/m^2

Critical External Pressure for Stiffened Shell

Timoshenko Equation

K-value	200	
K^2	40000	
E'	2.17014E+11	
λ	120	
λ^2	14400	
n^2	81	
Critical External Pressure, Pcr	1066666.667	kN/m^2

The center to center spacing of stiffener rings should **not be more than 240 times** and **not less than 60 times** the thickness of steel liner.

Size of Stiffener Rings

Sectional Area, Ar	0.063146012	m^2
Total Area of Composite Section, A	2.222739634	m^2
Minimum Handling Thickness, to	5.10	mm
Equivalent Thickness, t'	390.3976647	mm
Associated Width, l	166	mm
Initial Freedom, Yo	0.02	m
Distance b/w neutral axis of combine section to stiffener extreme edge, V	0.10	m

Overall diameter	2.84	m
Moment of Inertia of Combined Section about NA, I	2.43	m^4
K1	1.18033E-11	
K2	11.06083936	
K3	4.77674E+11	
K4	3.0475E+13	
Pcr	-11.41	N/m^2
f(x)	25024482690274.10	

3.3.11 Gate

Gates are the mechanical devices which are used to control flow of water into the hydro plant and out of the hydropower plant when not needed. Gates are typically made of steel and are located in the waterway, either upstream or downstream of the turbine. They can be opened or closed manually or automatically, depending on the design of the power plant. The gates can also be used to regulate the water level in the reservoir or to divert water to a different location. Hydropower gates come in different types and designs, such as vertical lift gates, radial gates, tainter gates, and sluice gates, each with its own unique features and functions.

GATE

DESIGN INPUT		
NAME	**VALUES**	
Design Head, H	9.1	m
Type of Gate	Low Head Gate	
Gate Height, h	1	m
Seal Height, Ha	1.06	m
Clear Width, b	1	m
Side Seal Span, B	1.09	m
Roller Span	1.2	m
Water Head to the Gate Center	8.6	m
Material Selected	IS2062 E250	
Yield Stress	250	MPa
Ultimate Tensile Stress	410	MPa
Allowable Bending Stress	112.50	MPa
Allowable Shear Stress	87.50	MPa
Young's Modulud of elasticity	2E+11	Pa

Skin Plate Thickness(assumed)	10 mm
Number of Vent	2 Nos.
Number of Gates	2 Nos.

HORIZONTAL BEAMS

Number of Horizontal Beam

Number of Horizontal Beams	2.07	Nos.
No. of Beams Adopted	3.00	Nos.
No. of Beams Adopted with Top Beam	4.00	Nos.

Position of Horizontal Beams

ß-parameter	10.67

Distance from the Bottom			Distance from the Top		
y_k1	874.53	mm	Top to 1st Beam	185.47	mm
y_k2	514.23	mm	1st and 2nd Beam	360.30	mm
y_k3	168.46	mm	2nd and 3rd Beam	345.77	mm
			3rd to 4th Beam	168.46	mm

Selection of Beam Section

Acceleration due to gravity, g	10	m/s^2
Specific Weight of water, γ	10	kN/m^3

Normal Load Conditions

Water Thrust at Max. Head	9.90	Tonnes
Assuming Extra Dynamic Load	25	%
Total Load	12.38	Tonnes
Load on Each Beam	4.13	Tonnes
UDL on Beam	3.79	T/m

Maximum Bending Moment	0.68	T-m
Allowable Stress	112.50	MPa
Required Section Modulus	59.41	cm^3
Maximum Load Condition		
Allowable Stress	150.00	MPa
Water Thrust at Max. Head	9.90	Tonnes
Seismic Intensity	0.24	
Inertial Force of Gate during Earthquake	0.12	Tonnes
Dynamic Pressure, P_d	5.99	tf/m^2
Dynamic Force due to earthquake	0.76	Tonnes
Load due to Vibration	0.99	Tonnes
Total Load	11.77	Tonnes
Load on Each Beam	3.92	Tonnes
UDL on Beam	3.60	T/m
Maximum Bending Moment	0.65	T-m
Required Section Modulus	42.38	cm^3
Selection of Beam		
Max Section Modulus	59.41	cm^3
Select Beam	**ISMB 125**	
Section Modulus, z	71.20	cm^2
	SAFE	
Moment of Inertia	445.00	cm^4
Maximum Deflection	1.02	mm
Seal Compression	3.00	mm
Allowable Deflection	2.40	mm
Unit mass of Beam	**13.30**	kg/m

SAFE

VERTICLE STIFFNERS			
S.N.	**Cases**	**Bending Moment**	**Shear Force**

1	A<B	(P*A^3)/12	(P*A^2)/12
2	A=B	(P*B*A^2)/12	(P*A*B)/4
3	A>B	P*B*(3*A^2-B^2)/24	(P*B*(2*A-B)/4

Panel No.	Distance of Horizontal Beam(A), m	No. of equally spaced vertical stiffeners	Distance of Vertical Stiffeners (B)	P at the Midspan of Panel (ton/m^2)	Bearing Moment M (ton-m)	Shear Force(ton)
1	0.19	9	0.111	8.65	0.0036	0.062
2	0.36	9	0.111	8.57	0.0150	0.145
3	0.35	9	0.111	8.76	0.0140	0.141
4	0.17	9	0.111	9.02	0.0030	0.057
5	0.00	9			0.0000	0.000
6	0.00	9			0.0000	0.000
7	0.00	9			0.0000	0.000
8	0.00	9			0.0000	0.000

Particulers	Values		
Maximum Bending Moment	0.01	ton-m	
	146844.71	N-mm	
Maximum Shear Force	0.1452	ton	
	1424.02	N	
Section Selection			
Thickness	10.00	mm	
Width	250.00	mm	
Area	2500.00	mm^2	
Section Modulus	104166.67	mm^3	
Bending Stress	1.41	Mpa	
Shearing Stress	0.85	Mpa	
Allowable Bending Stress	112.50	Mpa	SAFE
Allowable Shearing Stress	87.50	Mpa	SAFE

CHAPTER 4 CONCLUSION

In conclusion, my internship experience in a hydropower company has been an enlightening and rewarding journey for me. Not only did it expose me to the practical aspects of my field, but it also helped me to discover a new pathway to my career. The exposure I received to the industry and the professionals within it have allowed me to better understand my strengths, weaknesses, and future aspirations. Throughout the internship, I received professional suggestions and guidance from experienced mentors and colleagues. This support helped me to flourish my knowledge and learn how to apply it to real-world situations. The interactions with these professionals have allowed me to develop a better understanding of the industry, as well as the importance of teamwork, communication, and attention to detail.

One of the highlights of my internship was the use of software like ANSYS, SolidWorks, and Excel. These industry-standard tools were essential in helping me improve my technical skills and become more familiar with industry-related software. By utilizing these programs, I was able to gain a deeper understanding of how to create and manipulate designs and models that are essential for hydropower projects. Overall, my internship experience has given me a strong foundation for my future career in hydropower.

In conclusion, my internship experience in a hydropower company has been an invaluable opportunity for me. I am grateful for the knowledge, guidance, and experience that I have gained during this time. I am excited to apply what I have learned to my future career and to continue to grow and develop as a professional in the hydropower industry.

CHAPTER 5 REFERENCES

[1] "Hydro Consult Engineering Limited HCEL — Consulting Organization from Nepal, experience with ADB, WB — Civil Engineering, Design, Electrical Engineering, Environment & NRM, Mechanical Engineering, Roads & Bridges, Transport, Water & Sanitation sectors — DevelopmentAid." https://www.developmentaid.org/organizations/view/102684/hydro-consult-engineering-limited-hcel (accessed Mar. 30, 2023).

[2] "Who-we-are - Hydro-Consult." https://www.hcel.com.np/who-we-are/4 (accessed Mar. 30, 2023).

[3] "Projects - Hydro-Consult." https://www.hcel.com.np/projects/international (accessed Mar. 30, 2023).

[4] "How Hydropower Works | Department of Energy." https://www.energy.gov/eere/water/how-hydropower-works (accessed Apr. 12, 2023).

[5] P. Saravanan and N. Emami, "Sustainable tribology: Processing and characterization of multiscale thermoplastic composites within hydropower applications," Tribology of Polymer Composites: Characterization, Properties, and Applications, pp. 241–277, Jan. 2020, doi: 10.1016/B978-0-12-819767-7.00013-X.

[6] R. H. Sharma and R. Awal, "Hydropower development in Nepal," Renewable and Sustainable Energy Reviews, vol. 21, pp. 684–693, 2013, doi: 10.1016/J.RSER.2013.01.013.

[7] "Overreliant on hydropower." https://kathmandupost.com/columns/2023/02/04/the-danger-of-overreliance-on-hydropower (accessed Apr. 12, 2023).

[8] "The Role of and Challenges and Prospects for Hydropower Development in Nepal's Energy Sector – Nepal Economic Forum." https://nepaleconomicforum.org/the-role-of-and-challenges-and-prospects-for-hydropower-development-in-nepals-energy-sector/ (accessed Apr. 12, 2023).

[9] P. C.F. Erbisti, "Design of Hydraulic Gates," Design of Hydraulic Gates, May 2014, doi: 10.1201/B16954.

[10] "RAD_GATE_PIC.jpg (5312×2988)." https://d2zm9amfddap0m.cloudfront.net/media/prod/RAD_GATE_PIC.jpg (accessed Mar. 31, 2023).

[11] "Projects in Mai Khola basin to add 22 MW to national grid within a year - myRepublica - The New York Times Partner, Latest news of Nepal in English, Latest News Articles." https://myrepublica.nagariknetwork.com/news/projects-in-mai-khola-basin-to-add-22-mw-to-national-grid-within-a-year/ (accessed Mar. 31, 2023).

[12] "Projects." http://commsagdl.com/index.php/en/projects (accessed Mar. 31, 2023).

[13] "IS-Criteria For Structural Design of Penstock-11639 - 3." https://www.scribd.com/document/368443266/Is-Criteria-for-Structural-Design-of-Penstock-11639-3 (accessed Mar. 31, 2023).

[14] "Penstock Bends in M.W. Industrial Area , Industrial Links | ID: 3767685448." https://www.indiamart.com/proddetail/penstock-bends-3767685448.html (accessed Mar. 31, 2023).

[15] "Butterfly Valves: What Is It? How Is It Used? Types Of." https://www.iqsdirectory.com/articles/butterfly-valve.html (accessed Mar. 31, 2023).

[16] "Ball Valve - How They Work | Tameson.com." https://tameson.com/pages/ball-valve-introduction (accessed Mar. 31, 2023).

[17] “Radial Gates - Vortex Hydra Dams.” https://www.vortexhydradams.com/hydraulic-works/radial-gates/ (accessed Apr. 03, 2023).

[18] “BPV Complete Code - 2021,” ASME Boiler and Pressure Vessel Code - 2021 Edition, Accessed: Apr. 05, 2023. [Online]. Available: https://www.asme.org/codes-standards/find-codes-standards/bpvc-complete-code-boiler-pressure-vessel-code-complete-set

[19] “VIII. Pressure Vessels - Division 1,” Boiler and Pressure Vessel Code - 2010 Edition, Accessed: Apr. 05, 2023. [Online]. Available: http://www.asme.org/kb/standards/bpvc-resources/boiler-and-pressure-vessel-code---2010-edition/viii--pressure-vessels---division-1

[20] “M11 Steel Pipe: A Guide for Design and Installation, Fifth Edition.” https://engage.awwa.org/PersonifyEbusiness/Bookstore/Product-Details/productId/65277103 (accessed Apr. 05, 2023).

[21] “IS 11639-3: Structural design of penstocks - Criteria, Part 3: Specials for penstocks : Bureau of Indian Standards : Free Download, Borrow, and Streaming .” Accessed: Apr. 05, 2023. [Online]. Available: https://archive.org/details/gov.in.is.11639.3.1996

[22] “Technical Standars For Gates and Penstocks | PDF.” https://www.scribd.com/doc/26614319/Technical-Standars-for-Gates-and-Penstocks# (accessed Apr. 05, 2023).

[23] “Water Conveyance System Design Guidelines DoED”.