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Corrosion on welded joints of buried head race pipe

A case study of Daraudi Khola A Hydropower Project

by

Shankar Thapa

A THESIS
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The undersigned certify that they have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled "**Corrosion on welded joints of buried head race pipe: A case study of Daraudi Khola A Hydropower Project**" submitted by Mr. Shankar Thapa in partial fulfillment of the requirements for the degree of Master of Science in Technology and Innovation Management.

Supervisor, Dr. Sanjeev Maharjan,
Department of Mechanical and Aerospace Engineering,
IOE, Pulchowk Campus

External Examiner, Dr. Rameswor Maharjan,
Quality Control Engineer,
MADINA, Qatar

Tribhuvan University
Institute of Engineering
Department of Mechanical and Aerospace Engineering
Pulchowk Campus

Committee Chairperson, Dr. Sudip Bhattarai,
Head, Department of Mechanical and Aerospace Engineering,
IOE, Pulchowk Campus

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ABSTRACT

Engineering joints are done by welding processes and shielded metal arc welding is the found most common. Many hydro powers in Nepal have buried-type pipelines as a water conveyance system. These water conveyance systems pipelines suffer corrosion externally or internally also if protective coatings are done properly if scouring either on pipelines or tunnels which require timely maintenance for its increased service life. However, no any catastrophic failures have happened on pipelines due to corrosion of hydropower except massive earthquake knock in Nepal.

A study was carried out study on external welded regions of pipelines of Daraudi Khola “A” hydropower regarding corrosion. Most projects developed by NEA have buried pipelines. To carry out corrosion development on this project may be insignificant due to less years of operation. Two test specimen pipes of I.D. 300mm length, 1.25m, 6mm thickness, were developed using metal plates E250 and laid on two separate pits being laid with two different backfill materials without being painted.

The study suggests that soil sample containing sample A as loose soil with clay is more corrosive in comparison to sample B as sand mix gravels. Secondly, metal degradation buried by sample A is 0.2mm thickness whereas insignificant metal loss is found on sample B. On calculation, it is found that metal loss is 0.2mm on average when buried for almost 3 months. It considers that the remaining life of the test specimen pipe shell when buried by sample A lasts for 7.50 years without considering corrosion allowance. Location A on weld reinforcement are the most prone area for corrosion development. Considering 5% direct cost and neglecting indirect cost for utility/hydropower sectors then 26.71% i.e. NRs. 1,787.08 million of the total imported cost of materials must be allocated for the safety hazards and interruptions in plant operations.

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LIST OF ACRONYMS AND ABBREVIATIONS

HRP	Head Race Pipe
MW	Megawatt
M	Meter
SMAW	Shielded Metal Arc Welding
IS	Indian Standard
EN	British Standards
WPS	Welding Procedure Specifications
AWS	American Welding Society
UT	Ultrasound Test
K.M.	Kilometer
HPP	Hydropower Project
I.D.	Internal diameter
DPT	Dye penetrant test
MPT	Magnetic Particle test
NDT	Nondestructive test
cm	centimeter
min	minutes
mm	millimeter
min.	Minimum
MP	Mega Pascal
CE	Carbon equivalent
V	Voltage
A	Ampere
BS	British Standards
EN	European Standards
AWWA	American Water Works Association
WCS	Water Conveyance System

CHAPTER ONE: INTRODUCTION

1.1 Background

Most of the engineering joints on steel structures are done by welding processes. There are many ways of the metal joining process. Among the joining process made Shielded metal arc welding (SMAW) is found most common nowadays. This joining process is most feasible and more appropriate due to its portability. SMAW is an arc welding process with an external inert gas as a protective medium. SMAW is the most frequently used method to weld ferrous metals. At present, the SMAW process is widely used in the fabrication of hydraulic structures such as gates, penstocks, and other appurtenances of hydropower projects. However, engineers select materials based on properties that may be mechanical, strength, ductility, and toughness. In addition, dimensional stability, wear, the machinability, becomes important in some cases. So, materials choice for applications mostly depends on the tasks that these materials do. Corrosion is not the main reason why the material is selected. So, that means these materials did not necessarily possess corrosion-resistant properties and therefore, you need to impart corrosion to this material.

In order to define corrosion, it is the deterioration of materials in the presence of a chemical environment leading to a loss in their functions. Actually, the failure is due to the chemical environment that is exposed to the materials actually. The failure can happen even otherwise due to mechanical failures but corrosion failures are due to the chemical environment that leads to the corrosion failures. When we say failure, it is not necessarily the structural integrity loss it can be loss of the function of the desired component.

Corrosion is therefore a significant issue. It mostly affects metal pipelines, including those that are buried, underground, submerged, composed of cast iron, carbon steel, stainless steel, or alloy steel. For the hydropower as well as the oil and gas industries, this makes planning and choosing the optimum technologies and materials for pipelines and their corrosion protection systems a very essential problem.

However, most used material is E250. These materials contain less % carbon by weight. Due to its easier availability, workability and welding are most widely used materials based on low or high-head projects. In Nepal, these group materials are usually imported from neighbouring countries, India and China in the form of sheets. To join these materials E7018 electrode is used as a filler metal or rod in the form of wire. E7018 is used due to its excellent performance as well as high tensile strength and other mechanical properties. Pipeline corrosion is the degradation of the pipe material and the associated system as a result of their interaction with the working environment. Both metal and non-metal pipelines and accessories are affected. Corrosion in pipes and the consequent catastrophic breakdowns that can result in economic losses.

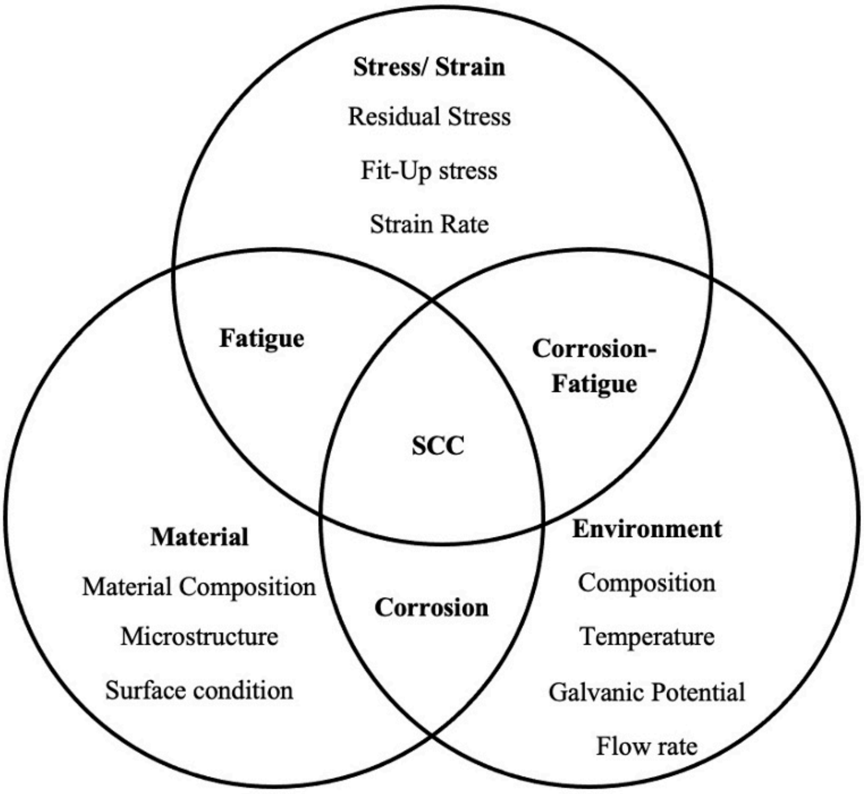

Figure 1.1: Venn diagram showing the relation best corrosions causing parameters

1.2 Context of Nepal

Pipelines are the major components with welded structures in hydropower projects as it conveys a quantity of water under a pressure head. Both for low as well as high-head projects, pipelines or tunnel structures are selected based on the optimization of the water conveying system. The long-length pipelines and the required diameter of pipes are manufactured and joined by the welding process. In recent years in Nepal, the hydro powers with pipelines have grown significantly over the years and these pipelines most of them are buried in the soil. So, these pipeline structures are suffering corrosion extensively and they are very important for any country. However, corrosion on both exposed and buried type pipelines has not been studied here but corrosion can be a big problem majorly on hydropower projects near future. No catastrophic failures have happened due to corroded pipelines. However, the collapse of the pipelines has been found due to a massive earthquake knock on the hydropower sector wherein many projects are yet to revive.

1.3 Problem statement

Welded joints are more prone to corrosion so there is more and more interest in the corrosion properties of welded joints. So, an assessment was carried out to know the corrosion degradation on weld joints especially on head race pipe/pipelines of Daraudi Khola A HPP.
For all buried pipelines paints are coated at the workshop whereas for exposed pipelines painting can be performed after complete installation at the job site. Due to the large inner diameter of the pipeline sandblasting activities before paintings were not performed but scoring with a wire brush is done. Since large-diameter sandblastings may not be an appropriate one since it takes a long period to carry out these operations. However at the pipeline surface where paints are peeled out rusting on the external pipe body surface was featured. It is still unknown whether the objective has been fulfilled or not. Although special care was taken during the painting of pipelines confirming with standards corrosion was seen on weld joints. But this thesis is solely focused on the study of corrosion on welded joints of buried pipelines. This research could be a resource material to other hydropower projects and upcoming hydropower with buried type pipelines about corrosion degradation on the welded joints along with welding discontinuities and the cost of the damage due to catastrophic failure on the corroded welded joints.

1.4 Objectives

1.4.1 Main Objective

To analyze corrosive nature of backfill materials, the corrosion degradation on welded joints and the surface of buried pipeline is backfilled by two different backfilling materials, one loose soil with clay and the other is a mixture of sand, gravel, and crushed rocks.

1.4.2 Specific Objectives

The specific objectives are:

i. To compare the corrosive nature of two backfill materials on the surface and weld joints of pipe shells
ii. To analyze corrosion degradation on the welded joint and surface prototype pipe shells.
iii. To analyze the probability of corrosion on weld zone.
iv. To identify welding discontinuities on the welded zone of prototype pipe shells using the non-destructive method
v. To calculate the loss or damage caused by corrosion in the hydropower industry.

1.5 Assumptions

The following assumptions were made:

i. Two identical prototype pipe shells each 1.25m length, I.D. 300 mm and 6mm thickness were fabricated and developed as a replica of I.D. 2500mm, 8mm thick pipe shells installed at Daraudi Khola A Hydropower Project.

ii. Corrosion development on pipelines of Daraudi Khola A HPP may be insignificant due to only a few years of operation. To overcome both prototype pipe shells were laid on separate pits without being coated.

iii. One backfill material is a mixture of sand, gravel, and pebbles and the other is local soil with clay materials that were used to bury two prototype pipe shells in separate pits.

iv. There is no change on both the pipe shells during welding although weather conditions may vary. Since the fabrication and welding processes done on real pipelines at the job site were done using the same methodology as adopted on prototype pipe shells.

v. On the calculation of loss of damage due to corrosion, 5% of the direct cost on the imported equipment price rate shall be considered.

1.6 Limitations

i. Due to difficulty in the excavation of backfill material at the real job site, two identical prototype pipe shells were fabricated and developed following the standard welding methodology.

ii. Due to long probe cables on ultrasound instruments with low losses in data acquistion.

iii. For the experimental study, an artificial environment for the rapid corrosion development on both buried prototype pipe shells was created by the use of plastic material.

CHAPTER TWO: LITERATURE REVIEW

2.1 Overview

Welded joints in buried head race pipes pose a significant risk to infrastructure and pipeline management, particularly in hydroelectric power systems, where corrosion can have severe consequences. An important difficulty in managing infrastructure is corrosion on welded joints of underground head race pipes, especially in hydroelectric power plants. Even while these welded seams are crucial for the pipes' structural integrity, the harsh subterranean environment might make them prone to corrosion. In hydroelectric projects, buried head race pipelines are essential for moving water from the source to the turbines. However, burying these pipelines has drawbacks since the soil's surroundings and other environmental elements might start and speed up corrosion processes

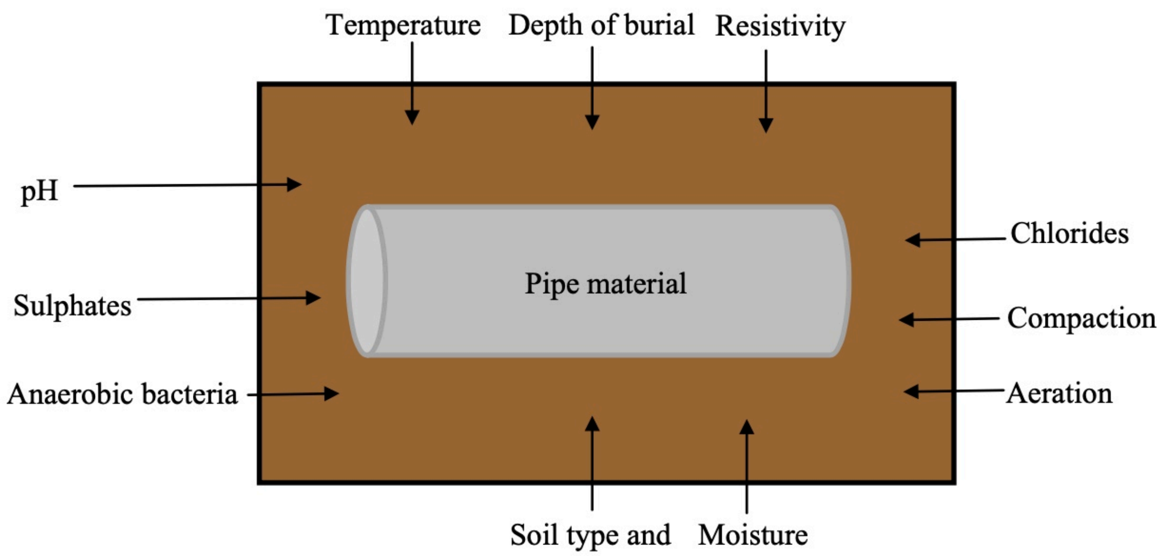

Figure 2.1: Essential elements influencing buried pipes' exterior corrosion

Several factors contribute to corrosion in buried welded joints. The interaction of the metallic surface of the pipe with the chemical makeup, moisture content, and corrosive substances of the soil can result in soil corrosion, which is a major problem. The development of biofilms by microorganisms on the surface of pipes can also lead to microbiologically influenced corrosion (MIC), which produces localized cells that hasten corrosion. Electrochemical reactions can make the problem worse when stray currents from neighbouring electrical sources are present. The rate of corrosion in these subterranean systems is influenced by several factors. The corrosion environment is significantly influenced by the soil's composition, which can range from acidic to alkaline, and its moisture content. By regulating the electrochemical processes taking place at the pipe's surface, proper cathodic protection, such as sacrificial anodes or impressed current systems, can help reduce corrosion. Another important factor in creating a barrier against corrosion caused by soil is the caliber of coatings and insulation used during installation.

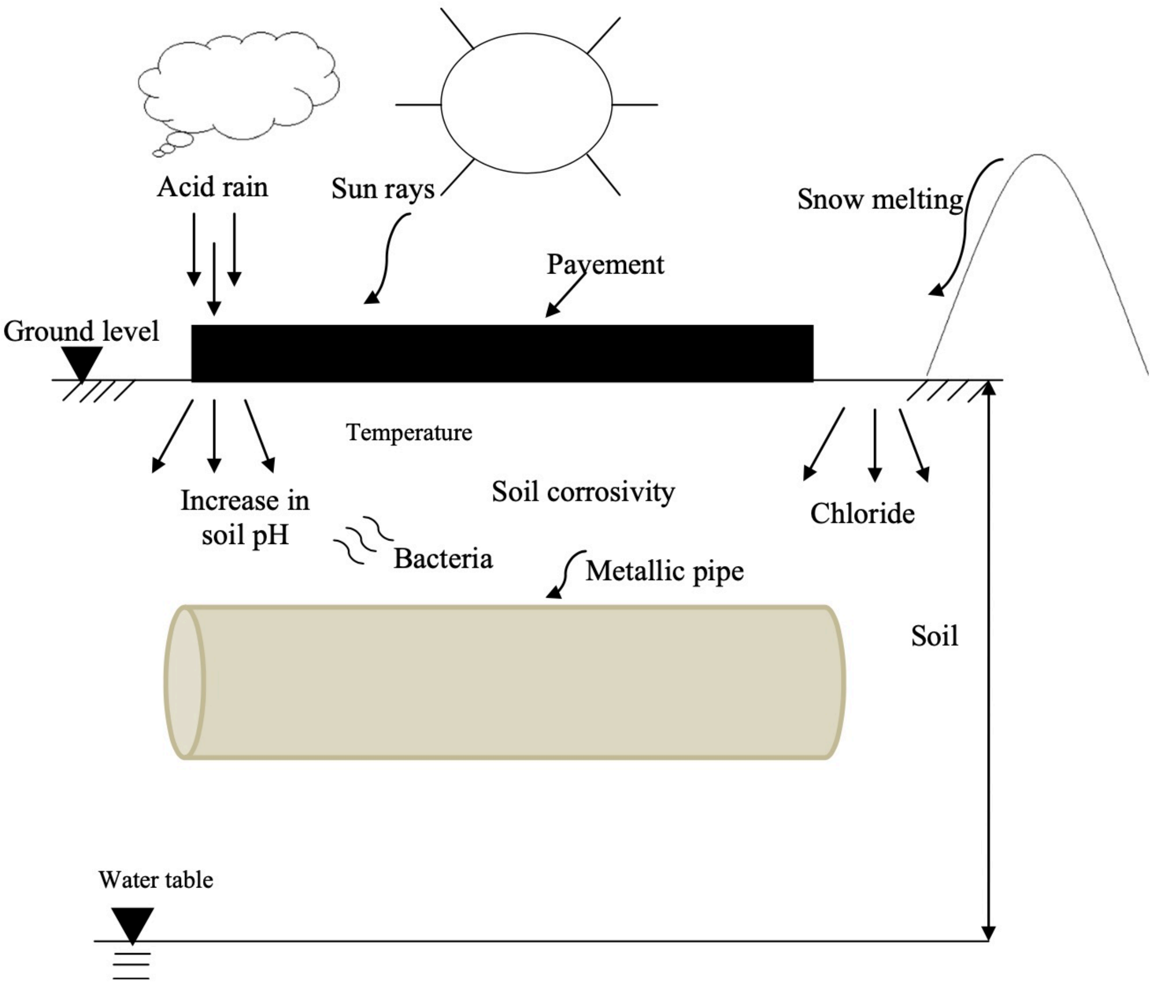

Figure 2.2: Mechanism of soil-based corrosion of metallic pipes (Wasim et al., 2018)

Regular inspection and monitoring are crucial for identifying corrosion early. Techniques like cathodic potential measurements, ultrasonic testing, and corrosion rate monitoring help detect potential issues. To prevent and maintain corrosion, select corrosion-resistant materials for pipes and welding materials, and implement effective coatings and wraps. Regular maintenance practices, such as inspections, cleaning, and repair, extend the lifespan of buried head race pipes and minimize their impact.

2.2 Site layout

Daraudi Khola HPP (6.40MW), an IPPs' commercially came into operation seven years before in 2016 and connected to NEA substation grid located at Gorkha Bazar, 14.0 k.m. East from the project location. This project has a special feature with a 4100.0m length buried type pipeline with 2.50 m I.D. and an overall 2.0-3.0 m gradient. Somewhere in between small length tunnel sections pipelines were found appropriate and installed. However, most pipeline alignments are buried confirming standard bedding materials following standards. Over a period of time let's say at the time of installation that may be due to proper or improper backfilling, ineffective painting or welding defects left rusting of welding joints seen on pipeline alignment. Corrosion can be on external or internal surfaces both. So corrosion on both exposed and buried type pipelines can be a big problem. Rusting in chemical reactions with the environment leads to corrosion.

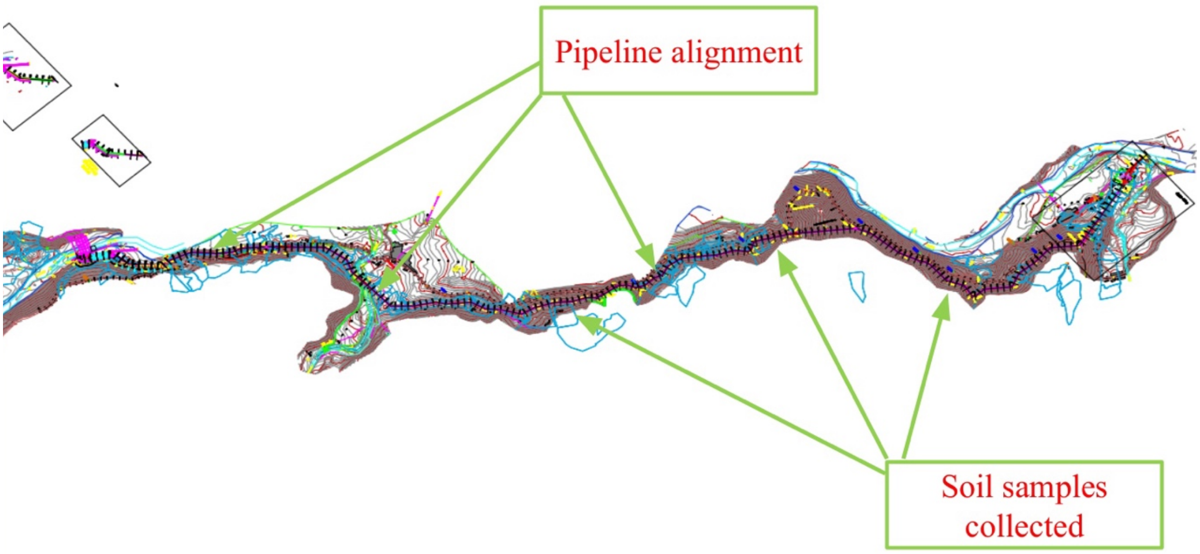

Figure 2.3. Site plant layout

2.3 Literatures

(Radhe Shyam Prasad, 1993) has studied the corrosion of buried pipes due to soil is a complex phenomenon that affects water pipes, causing loss of pipes, contamination, supply shutdowns, loss of efficiency, and damages. This issue is crucial for the waterworks industry in India, where data is scarce. The economic loss due to corrosion in the United States is estimated to be around one billion dollars per annum. A study was conducted to evaluate the corrosive nature of soil along a horizontal water pipe at the subsurface soil level, conducted around EP.

Hostel, University Campus, Roorkee. Resistivity profiling was carried out, and soil from seven different locations along the pipeline was characterized to assess the attacking nature of the soil. The study also predicted the possibility of soil corrosion on a vertical pipe using the sounding method of resistivity. The results showed that the soil at both sites in the ground is non-corrosive, suggesting that dissimilar corrosion cells may develop due to natural soil stratification or land-based activities. Regular soil evaluation along existing pipes is suggested due to increasing land-based activities.

(Wang et al., 2018) have has proposed a a method for analyzing how soil characteristics affect how cast-iron pipes corrode. The research examines a thorough historical record of underground cast iron pipe corrosion with an emphasis on the power law model's exponent and proportionality parameters. Since soil aeration and the exponent factor n are closely related, combining corrosion data based on soil aeration results in better connections between soil characteristics and corrosion rates. For asset managers and engineers, this research offers useful information that will help them anticipate with accuracy when cast iron pipes would fail due to corrosion.

(Li et al., 2001) has investigated by using Electrochemical polarization, EIS, SEM, energy-dispersive spectroscopy, and a thin-film electrical resistance probe to study the microbiologically influenced corrosion (MIC) of plain carbon steel in anaerobic soil. The findings demonstrated that sulfate-reducing bacteria (SRB) change the process of corrosion by forming hydrogen sulfide and iron sulfide coatings, decreasing polarization resistance, and speeding up corrosion. Localized corrosion caused by SRB is known as MIC, and the biogenic FeS coating breaks down in addition to it. Using the zero-resistance ammeter (ZRA) method, the localized corrosion rate may be determined.

(Regmi et al., 2015) has analysed 23 samples of soil from the Lalitpur district of the Kathmandu Valley were examined for 23 different soil characteristics, including moisture content, pH, resistivity, oxidation-reduction potential, chloride, and sulfate. The findings demonstrated that most soil samples were less corrosive than those used to furnish drinking water and were just slightly caustic. In the research locations, it was discovered that surrounding buried pipes with non-conducting materials like gravel or sand before burying them was successful in reducing corrosion and lengthening pipe longevity.

(Yan et al., 2023) has examined the influence of sulfate-reducing bacteria (SRB) on a welded joint's corrosion behaviour in a soil solution. Results indicated that SRB accelerated corrosion in the heat-affected zone (HAZ), which corroded more quickly and preferentially than weld metal and base metal. The MIC behaviour was greatly impacted by macro-galvanic corrosion in the welded junction, which led to preferential HAZ corrosion.

(Mahidashti et al., 2020) has investigated the failure of a transition pipeline in the soil environment, resulting in severe internal corrosion and a loss of $25 million. Field hydrostatic tests revealed leakages on the pipes, which were investigated using various techniques such as visual observation, optical microscope, SEM, and X-ray spectroscopy. The leakages were attributed to under-deposit corrosion caused by stagnant water inside the pipes, which contained high concentrations of corrosive ions like chloride. Additionally, corrosion products like magnetite were found to accelerate the corrosion. The findings suggest that proper corrosion mitigation strategies are proposed to prevent future failures.

(Huo et al., 2023) has investigated analytical techniques for investigating cross-sectional, transverse, and longitudinal pipe-soil interactions (PSI) issues in water pipelines. In order to assess current research trends, technical advancements, and potential future study areas, a comprehensive literature evaluation is carried out. Six research opportunities—friction in cross-sectional deformation, combined effects of bending and compression, soil reaction models, pipe flaws, soil spatial variability, and curved pipe behaviours—as well as relevant research works from online databases are analysed in the study. The study intends to aid newcomers in becoming acquainted with PSI analytical techniques and offer seasoned researchers' suggestions for future research topics.

(King et al., 1973a) has examined the corrosiveness of iron sulphides to mild steel, focusing on the amount of sulphide and exposure period. All sulphides were found to be corrosive, with a link between sulphur content and corrosiveness.

(Mohammadi et al., 2012) has used a crude thermomechanical processing device that uses two cooling rates and four peak temperatures to replicate the weld HAZ of API X-80 pipeline steel. At cooling speeds of 30 and 100 C/s, bainitic microstructures were seen, with larger passive current densities in alkaline solutions. The greatest martensite-retained austenite (M-A) phase was formed at the lowest peak temperature of 770°C, expanding the passive zone to higher potentials in alkaline solutions. In comparison to heat-treated samples, the corrosion current density was greater in acidic solutions and lower in alkaline solutions.

(Leis et al., 2006) has concluded that to modify the corrosion evaluation criteria for pipe bodies to weld seams, various failures and laboratory tests, as well as elements that significantly alter the relationship between welds and base metal. Metrics including mechanical and fracture qualities, pipeline loadings and service circumstances, and corrosion nature serve as guidelines for applying these criteria. In order to apply these measures, a flowchart was made. By comparing the projected results of the recommendations with those of full-scale testing, laboratory tests, and in-service failures involving corrosion on weld seams, the guidelines were found to be valid. The one-size-fits-all strategy, however, could provide conservative outcomes in some situations.

(King et al., 1973b) have conducted an X-ray inspection of a natural gas station revealed three instances of girth weld cracking. Numerous experiments were used to identify the failure mode, including as visual inspection, nondestructive testing, microstructure analysis, SEM, EDS, blasting tests, finite element simulations, physical and chemical tests. The major contributing factor to the failure occurrences was found to be welding flaws.

(Videla, 2002) has studied microbial colonization of industrial metals and alloys resulting in the formation of biofilms, primarily made of bacteria and water. These biofilms can significantly alter the corrosion behavior of structural metals and alloys, leading to localized changes in ions, pH, and oxygen levels. They also create diffusional barriers for chemical species exchange. The consequences of biocorrosion and biofouling can range from heavy contamination to structural failures. To mitigate these issues, appropriate monitoring strategies and field and laboratory microbiological techniques must be used. Assessments should be made for each industrial system, considering its history, operational conditions, water composition, and microbial contaminants.

(Abd-Elaziem et al., 2022) has studied A 16-year-old carbon steel alloy condensate pipeline had a pinhole at the girth weld. Various tests, including visual examination, energy-dispersive X-ray spectroscopy (EDS), scanning electron microscopy (SEM), chemical analysis, and hardness measurements, revealed welding defects and severe corrosion pits. The microscopic analysis revealed localized corrosion attacks as the root cause of the failure. XRD patterns showed the formation of iron oxyhydroxide corrosion products, while EDS results showed foreign elements of aluminum and chlorine promoting under-deposit corrosion, especially in stagnant water regions.

(Mobin & Zehra, 2023) has described the improvements in cathodic protection for concrete buildings in the air. A metal surface is created on the cathodic side of an electrochemical cell as part of the corrosion-control technique known as cathodic protection (CP). It is frequently used to safeguard steel buildings that are buried in the ground or immersed in water. Water and fuel pipelines, storage tanks, ships, offshore oil platforms, and oil well casings are just a few of the metallic structures that are protected by cathodic protection systems. The fundamental concepts of cathodic protection as well as recent developments in the area are covered in this chapter.

(Shaikh et al., 2011) has studied the SCC behavior of austenitic stainless steel and ferritic steel welds which is affected by defects and residual stresses, secondary phases formed during high-temperature service, and heat input. A continuous network of d-ferrite and s-phase deteriorates SCC resistance. Sensitization is harmful to SCC resistance, and hydrogen-assisted cracking during welding and environment-induced failure of ferritic steel joints can be improved with appropriate pre-heat and post-weld heat treatments.

(Bahadori, 2014) has concluded that Cathodic protection is a secondary corrosion control method used to safeguard metallic structures that are buried or submerged. It is regarded as a secondary approach and frequently used in conjunction with coatings. A coating system is often used as the major corrosion management strategy. Depending on age and installation technique, this system's efficiency can range from 50% to 99%.

2.3 Research Gap

Although previous research studies on corrosion degradation on welding joints on different pipe materials were carried out on buried pipelines i.e. gasoline pipelines mainly due to environmental conditions. But corrosion degradation on welded joints made by electrode material E7018 by use of different backfilling has yet to be defined for further studies. An illustrative case study on corrosion on welded joints of buried head race pipeline of Daraudi Khola A HPP was carried out by developing two prototype pipe shells and are being buried by soil samples collected from different locations of the existing project’s pipeline alignment shown in Figure 2.3.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1 Methodology

Research methodology was done based on Figure 3.1. It is divided into three sections and consists of specimen preparation, soil sample test and weld quality test on prototype pipe shell.

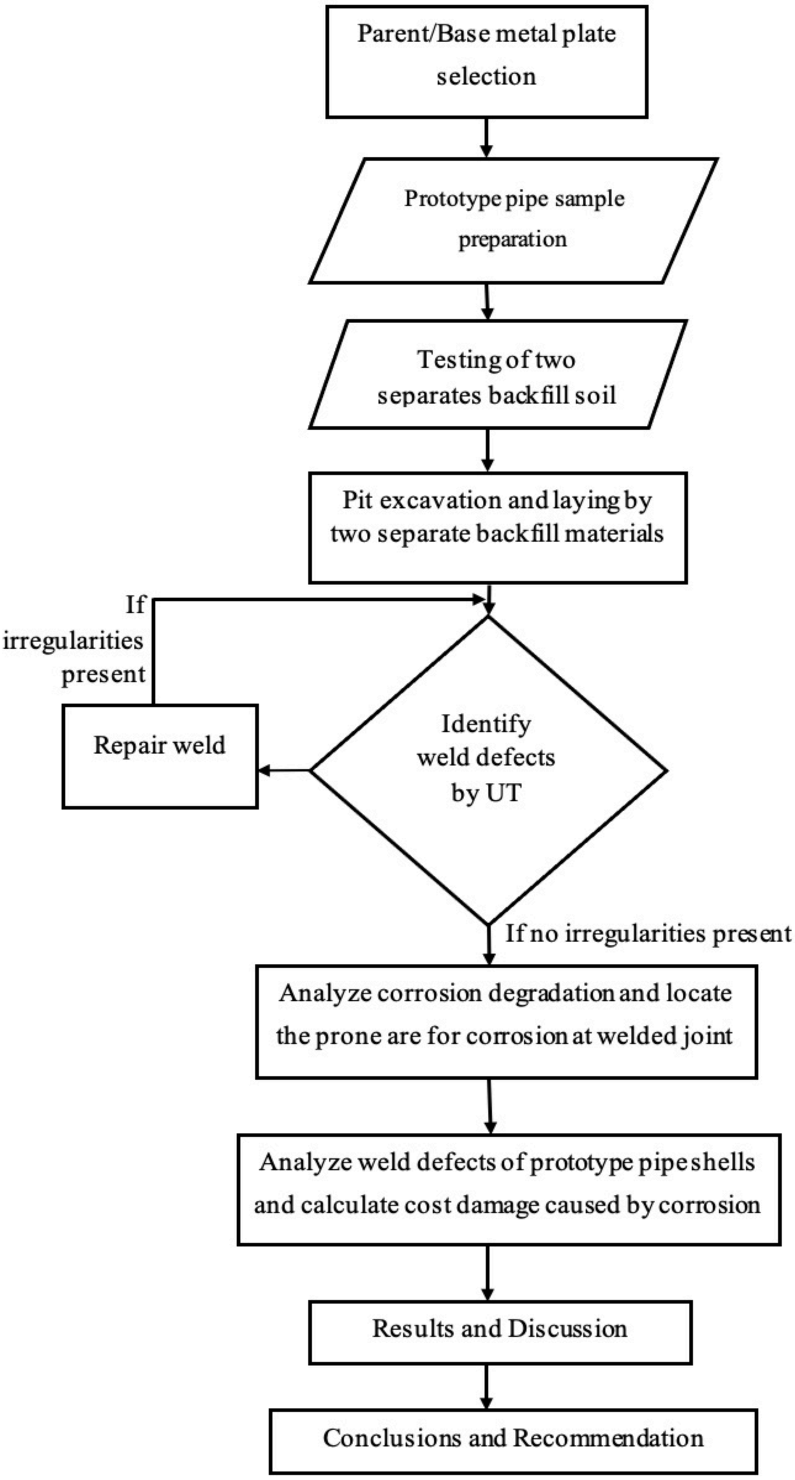

Figure 3.1: Research methodology

3.2 Parent/base metal selection

There are almost nine grades of steel. They have four sub-qualities (A, BR, B0, and C). These sub-qualities A, BR, B0, and C indicate the requirement of impact test-optional or mandatory at different temperature conditions and modes of de-oxidation. For the experimental study, the fabrication of two identical prototype pipe shells of E250 metal plate was selected since the pipelines of the project were installed with grade E250 and hence selected. The same material was selected to prepare prototype pipe shells in equivalent to the selected parent sheet metals for pipelines at Daraudi Khola A HPP. The chemical and mechanical properties of E250 metal plates are shown in Table 3.1 and Table 3.2 respectively.

Table 3.1 Chemical composition of E250

Grade Designation	Quality	Ladle Analysis Percent, Max					Carbon Equivalent(CE), Max	Mode of Deoxidation
		C	Mn	S	P	Si		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
E 250	A	0.23	1.5	0.045	0.045	0.4	0.42	Semi-Killed/killed
	BR	0.22	1.5	0.045	0.045	0.4	0.41	Semi-Killed/killed
	B0							
	C	0.2	1.5	0.04	0.04	0.04	0.39	Killed

Table 3.2: Mechanical properties of E250

Grade Designation	Quality	Tensile Strength, R_{in}, Min, Mpa (See Note 1)	Yield Stress $R_{eH,}$ Min MPa			Percentage Elongation A, Min at Gauge Length L_0=5.65	Internal Bend Diameter, Min (See Note 2)		Charpy Impact Test (See Note 3)	
			<20	20-40	>40		25	>25	Temp °C	Min J
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
E 250	A	410	250	240	230	23	2t	3t	–	–
	BR								RT	27
	B0								0	27
	C								(–)20	27

Table 3.1 shows that various grade steels with nearly the same composition and properties. They may vary in terms of yield stress MPa with thickness. But, from the corrosion perspective, the chemical composition of these different grades of steel are almost similar, with only a minor difference in chemical composition if noted. These strengths are achieved by different heat treatments.

3.3 Sample Preparation

Two identical prototype pipe shells were developed. Each prototype pipe specimens were 1.25m in length, internal diameter of 300mm, and was 6.0mm in thickness. Each of them was developed as a replica of I.D. 2500mm, 8mm pipe shells installed at Daraudi Khola A Hydropower Project with the same fabrication and welding methodology as adopted. The shop drawing for the prototype pipe shells is shown in Figure 3.1. The rolling/forming and welding processes were carried out according to the methodology. The welding process on these shells was done using E7018 as a filler rod or electrode. The chemical composition of E7018 confirming AWS is shown in Table 3.3. This electrode shows excellent performance in the properties of the weld.

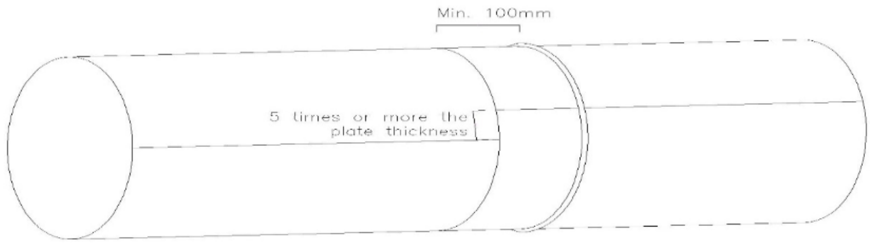

Figure 3.2: Prototype pipe shop drawing

Figure 3.3: Metal plate forming

Figure 3.4: Welded prototype pipe shell

Table 3.3: Chemical composition of E7018

S.N.	Chemical composition					
	Material	C	Mn	S	P	Si
1.	E7018	0.15 max	1.60 max	0.035 max	0.035 max	0.75 max

Since the prototype pipe shells were welded by SMAW shown in Table 3.4 with the standard welding specifications.

Table 3.4: Welding procedure specifications

S.N.	Welding Process	Shielded Metal Arc Welding (SMAW)
1	Joint design	Single-V joint with a 65 ± 5 degree included angle and a 1.6 ± 0.8 mm root face
2	Number of passes	Multi layered
3	Electrode	E 7018
4	Voltage	15-40V
5	Current	80-130 A
6	Polarity	Straight polarity
7	Travel speed	5-10 cm/min

3.4 Soil characteristics

Figure 3.5: Soil samples

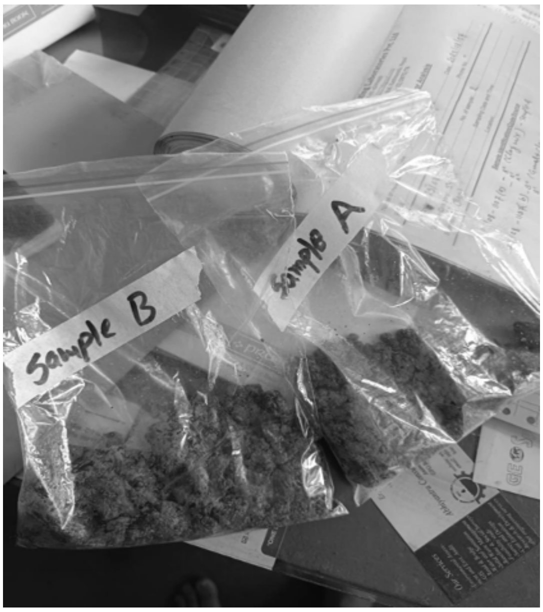

Figure 3.6: Soil samples

Soil samples at the level of the existing water pipe from seven locations at the test site were collected and analyzed. Porosity, moisture contents, sulphides, chlorides, pH, and acidity in soil were also evaluated. Samples of soils are shown in Figure 3.5 and Figure 3.6.

3.5 Mark Identification

Prototype pipe shells were completely rolled and laid on the two separate excavated pits. Before laying, the welded joints were marked with alphabet letters on the longitudinal and girth joints so that these points can be analyzed to support the study. In order to meet the specific objectives the prototype pipe shells were marked after fabrication as shown in Figure 3.7.

Figure 3.7: Mark identification

3.6 Backfill materials

Two identical prototype pipe shells were laid on two separate pits and are being buried by two different materials where no live loads are anticipated. However, due to different geographical and morphology, it may be desirable to align water pipeline in a half trench and cover the pipeline with a minimum of 2' of earth and rock. This option will be most effective for large diameters and where excavation is difficult. Pipelines at project site was established with backfill methodology as shown in Figure 3.8. At the project Daraudi Khola A HPP, the plan and profile of the pipelines were installed as per civil drawings issued by clients indicating elevations of the pipeline alignment. However, burying of prototype pipes were done by soil samples collected at the areas of the project pipeline alignment shown in Figure 2.2 above. Based on the issuance of civil drawings, the pipe manufacturer shall fabricate and lay a pipes as per construction schedule as shown in Appendix C.3. The trench were dug to special grade.

For experimental study, a normal trench suitable for two prototype pipe shells were dug. The excavation was carried out as per the figure shown to make the experimental study successful. A prototype pipe shell was buried using sand mixed pebbles, providing consistent support along the pipe full length. Trench backfill is not required, except for roadways, to prevent settlement or erosion.

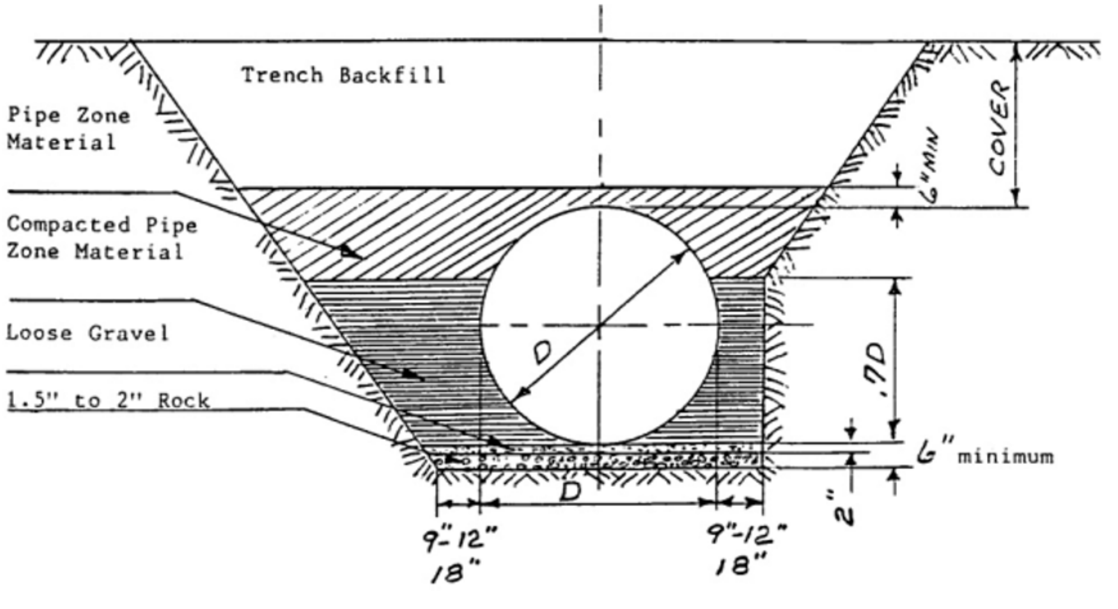

Figure 3.8: Special grade trench

3.7 Non destructive methods

The non-destructive test (NDT) is used to evaluate weld connections prior to the placement of the prototype pipe shells. These pipe shells were subjected to NDT utilizing an ultrasonic test kit. Dr. Floyd Firestone was the one who originally studied non-destructive ultrasonic testing. It was developed with the intention of detecting faults even when they were hidden under the material's surface. Later, additional researchers and publishers worked to improve the method and broaden the scope of its use. Visual examination, dye penetrant testing, magnetic particle testing, radiographic testing, and ultrasound testing are a few examples of the various NDT techniques. NDT of weldments, on the other hand, is a technique for finding weld defects without rupturing the component being tested. The ultrasound test is the machine selected to inspect the weld discontinuities in a weld and to measure the thickness of the pipe sheet metal. The ultrasound testing kit setup were used for collecting the primary data from the two prototypes, which shall be taken directly from the measuring instrument shown on Figure 3.9. The testing kit shall be fully calibrated to remove errors. The data extracted from the instrument shall be fully monitored to assess its performance too.

Among NDT, an ultrasound test based on reliability and cost-effectiveness is the most used machine to identify the discontinuities/defects on the welded joint. At first, the inspection kit was calibrated using stop blocks so as to remove the errors if present. Before being utilized for inspection, the machine has to be calibrated based on the characteristics of the test piece. Among the NDT, machines ultrasonic test machine was used as a tool to measure the thickness of the weld joints. In the UT test ultrasound waves are introduced into the test piece to locate the surface and internal defects of discontinuities.

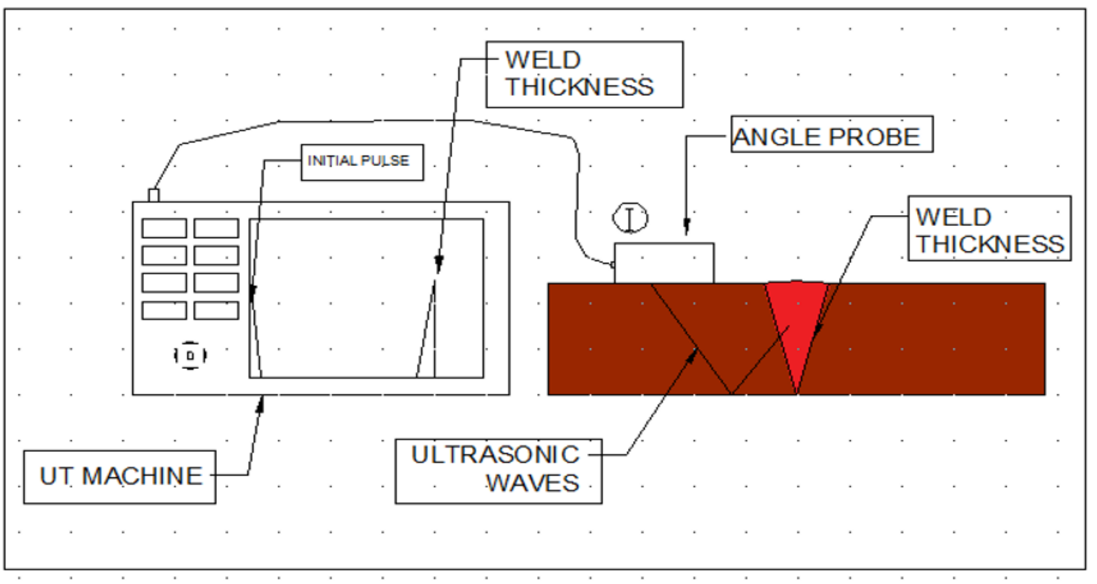

Figure 3.9: Block diagram of UT kit

When a beam of sound is directed into the specimen it reflects at the interfaces and defects. An instrument that captures the pulse's signal and its echoes.

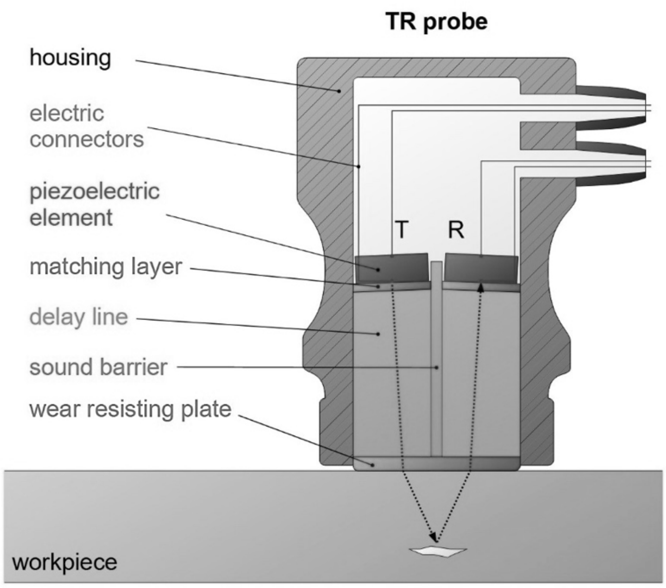

Figure 3.10: Components of a TR probe

These devices are also utilized to do various types of data analysis on the incoming information. An ultrasound test uses high-frequency sound waves (between 0.5 to 15MHz) to conduct examinations. It is the link that joins the transducer to the diagnostic tool. Energy is released by the pulsar in controlled bursts. The transducer's echoes are delivered to the diagnostic device through the reception portion. The ultrasonic devices are used in conjunction with duet probes and gauging angle probes to detect weld faults and quantify thickness. These devices might be manual or automatic, portable or stationary. In order to measure thickness and find faults, duet and angle probes are utilized. The pulse is generally delivered into this machine, whereas the angle probe emits the pulse at an angle different than 90°.

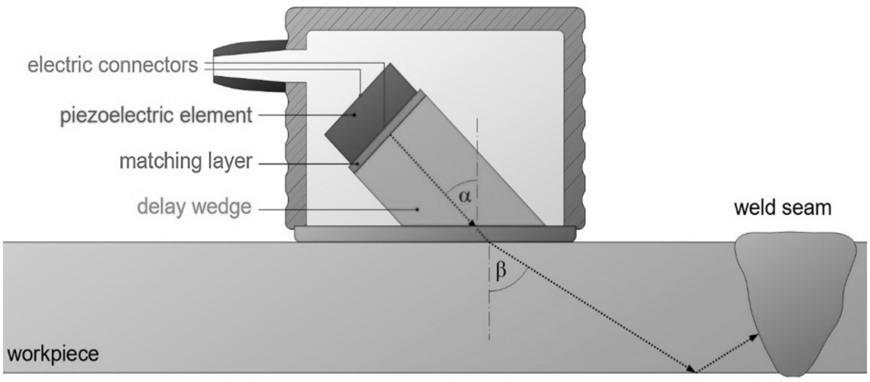

Figure 3.11: Components of an angle probe

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Corrosive nature of backfill materials

The observations were recorded as given in Table 4.1. The data are extracted from the soil sample test report as attached in Appendix C.3. The pH, sulphide, chloride, and sulphates were estimated in soil solutions. Dry pulverized samples were slurried with distilled water in a ratio of 1:10 (w/v). The slurry was homogenized by mechanically shaking it for 2 hours and allowed to stand overnight and filtered.

Table 4.1: Physical, chemical properties, and chemical characteristics of two sample soils

S.N.	Soil parameters	Soil sample at site					
		A^o	A^1	A^2	B^o	B^1	B^2
1.	Acidity mg/100g	46	47	45	22	23	21
2.	Redox (mv)	53	54	56	62	61	63
3.	Resistivity (-cm)	851	850	86.2	990	992	991
4.	Porosity %	31.22	31.24	32.01	38.21	39.10	38.52
5.	Dry unit wt kN/m3	18.32	18.47	18.44	22.31	24.01	23.45
6.	Sp. gravity	2.61	2.68	2.65	2.42	2.38	2.28
7.	pH	4.5	4.6	4.7	6.4	6.5	6.4
8.	Sulphide (mg/1kg soil)	80	78	82	72	70	68
9.	Moisture content (%)	38	39	38	28	26	24
10.	Chloride (mg/1kg soil)	47	42	51	24	21	22
11.	Sulphate (mg/1kg soil)	65	62	64	54	52	49

Table 4.1 shows the soils properties. Sample A refers to loose soil with clay whereas sample B refers to sand mix pebbles. It was found that the moisture content of soil sample A and soil sample B is 28% and 32%. Respectively. Metal corrosion rates are higher in moderately damp soils than they are in severely dry or totally saturated soils. Iron will be quickly oxidized by oxygen creating a protective coating at low water content, preventing the diffusion process that would otherwise cause polarization in the corrosion electrode. After the onset of corrosion, a

substantially increased water content might cause the transfer of ferrous ions, improving the anode's depolarization and consequently promoting the corrosion processes. Corrosion is known to be influenced by the pH of the soil, either directly or indirectly. Since hydrogen ions, which are commonly measured by pH value, operate as reducing agents in the electrode reaction in the corrosion process, pH can affect both the electrode kinetics and the corrosion cell potential. Numerous elements, including the presence of carbon dioxide, organic acid, minerals, and pollution from industrial wastes, can impact the soil's pH. pH of soil sample A and soil sample B is found to be 5 and 6.1. Although soils with a pH between 5.5 and 8.5 can also produce significant corrosion when microorganisms like sulfate-reducing bacteria (SRB) proliferate in an anaerobic environment, soils with a pH between 5.5 and 8.5 are frequently thought of as more corrosive than neutral or alkaline soil. The chloride content in all soil samples A and B was found to be 56 mm/kg and 32 mm/kg which were found to be mild corrosive and less corrosive in nature respectively. Sulfate content is soil samples A and B was found to be 73 mg/kg and 62 mg/kg which is found to be less corrosive. The resistivity of soil sample A and soil sample B is found to be 840 Ω-cm and 980 Ω-cm which is corrosive in nature.

Table 4.2: Soil parameters VS soil corrosivity

Soil Parameter	**Soil Corrosivity**
Soil Resistivity (Ohm.cm)	
> 20,000	Less Corrosive (LC)
10,000 - 20,000	Mildly Corrosive (MiC)
5,000 -10,000	Moderately Corrosive (MoD)
< 5,000	Corrosive (C)
Chloride Content (ppm)	
< 50	Less Corrosive (LC)
50 -100	Mildly Corrosive (MiC)
> 100	Corrosive (C)
Sulfate Content (ppm)	
< 100	Less Corrosive (LC)
100 - 200	Mildly Corrosive (MiC)
> 200	Corrosive (C)

Table 4.3: Parameters assigned to corrosiveness.

S.N.	Soil parameters	Parameters points					
		A^o	A^1	A^2	B^o	B^1	B^2
1.	Redox (mv)	0	0	0	0	0	0
2.	Resistivity (Ω-cm)	3	3	3	1	1	1
3.	pH	4	4	4	2	2	2
4.	Sulphide (mg/1kg soil)	1	1	2	3	2	4
5.	Moisture content (%)	2	2	2	1	1	1
	Sum	10	10	11	7	6	8

Points shows that both soil samples are corrosive in nature samples exceeding point 10. Hence, the results show that loose soil with clay is more corrosive with regards to sand-mixed pebbles gravel.

4.2 Corrosion degradation

Corrosion degradation is analyzed based on the metal loss. The thickness measurement was carried out using UT.

Table 4.4: Comparison of corrosion degradation

Backfill Material		Local Soil with clay		Sand mix gravels	
S.N.	Weld Joint type	Identification number (IN)	Weld thickness (mm)	Identification number (IN)	Weld thickness (mm)
1	Girth joint	a	5.8	a"	6.0
2		b	5.8	b"	6.0
3		c	5.8	c"	6.0
4		d	5.8	d"	6.0
5	Longitudinal joint	e	5.8	e"	6.0
6		f	5.8	f"	6.0
7		g	5.8	g"	6.2
8		h	5.8	h"	6.1
9		i	5.8	i"	6.1

Three readings at one marked point were taken and based on average this primary data were measured. Table 4.4 shows the corrosion degradation on pipe shells.

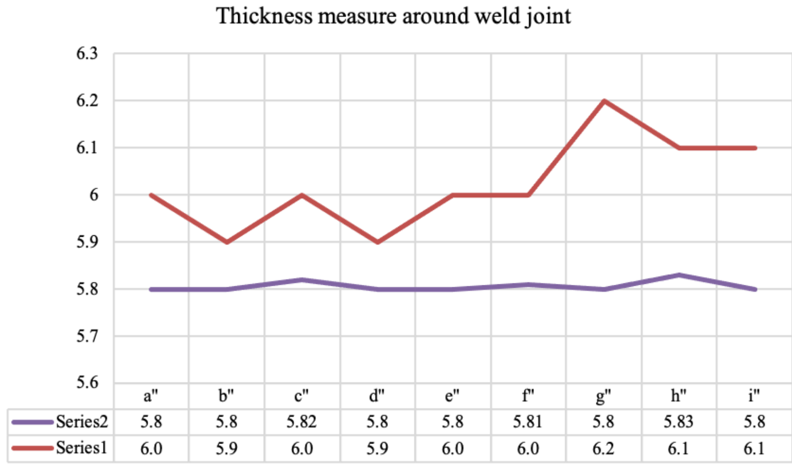

Figure 4.1: Corrosion degradation in the weld joint

In the graph, the upper band shows the thickness measured was 6.00mm using the ultrasonic machine at the marked points where pipe shells were buried by sand mixed pebbles. Similarly, lower bands show the thickness measured on average was 5.80mm on pipe shells buried by loose soil with clay. Metal loss is 0.2mm in thickness. The loss may be due to rust developed on the pipe shell surface. It is assumed that with loose soil clay the metal loss was 0.2mm on average. Since prototype pipe shells were supposed to be buried for almost 3 months. The results show that metal loss per year is 0.80mm. The remaining life of the pipe shell when being buried in loose soil with clay last only for 7.50 years without considering corrosion allowance. However, metal loss with sand mix pebbles were insignificant.

4.3 Position of corrosion growth on weld

Figure 4.2 shows the single V- butt joint with included angle “α”, plate thickness “t”, and root opening “R”. Three points on the face of the welding section are marked.

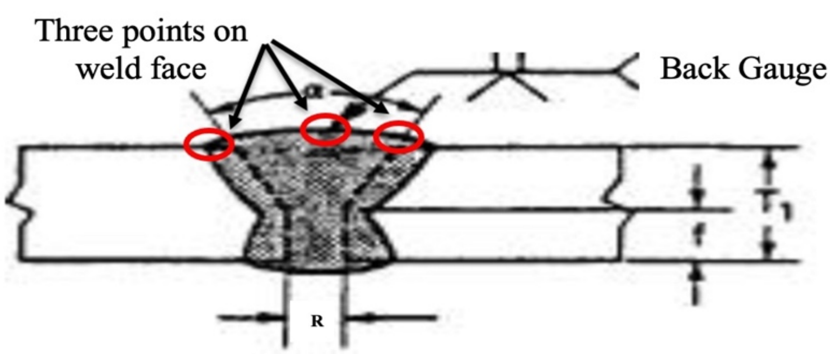

Figure 4.2: Pin holes on weld joints

The markings are made to find the most corrosive area where corrosion is most likely to occur. These analyses are made both identical pipe shells. When the welding section of a pipe shell is buried the most prone area for. The heat-affected zone is more prone to corrosion in respect to other marked points. Since, metallurgical, mechanical properties alter during welding.

Figure 4.3: Pipes buried by sand gravels mix

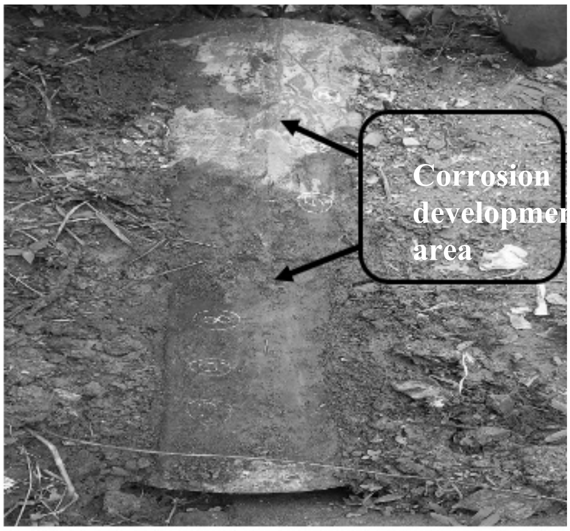

Figure 4.4: Pipes buried by loose soil clay

Stainless steel chromium, which forms a passive oxide layer on the surface that prevents rusting and corrosion. Different types of stainless steel offer varying levels of corrosion resistance, making it suitable for a wide range of environments. Fiberglass Reinforced Plastics (FRP) penstocks are corrosion-resistant and lightweight, making them an ideal choice for water treatment plants and wastewater facilities. They offer excellent resistance to both chemical and biological corrosion. Titanium and its alloys are well-suited for corrosive water environments, particularly those with high chloride content or elevated temperatures. They are used in both seawater applications and those involving chemical processing. Depending on the specific environment and type of water, certain plastics and coatings might be used to protect penstocks from corrosion. Examples include epoxy coatings and polyethylene linings. Corrosion growth is mostly likely to occur in heat affected zone of the base metal and weld deposition interface. The corrosion development is most likely to take place at the weld joint than on parent metals due to less corrosion resistance of the weld joint. If pipes are uncoated, corrosion is likely to occur at points where defects like undercuts, surface flaws porosity, etc. are majorly present. Upon neglecting defects Figure 4.3 and Figure 4.4 as well as results suggest that corrosion is most likely to start at the interface of the weld joints that may be either girth or longitudinal joints on viewing both buried pipe shells.

4.4 Weld discontinuities

The discontinuities present on the welding joints were studied on root welding joints during the welding of prototype pipe shells. This test is carried out on a visual inspection of the root welding. If defects like cracks, or porosity are seen these are removed by the grinding process. Weld defects are seen on the welded joints of the prototype pipe shells before being buried. The defects like pin holes and cluster porosity were seen as shown in Figure 4.5 and Figure 4.6. This defect was carried out using Dye penetrant test (DPT) and found on carrying out root welding. These types of defects also assist in the development of corrosion.

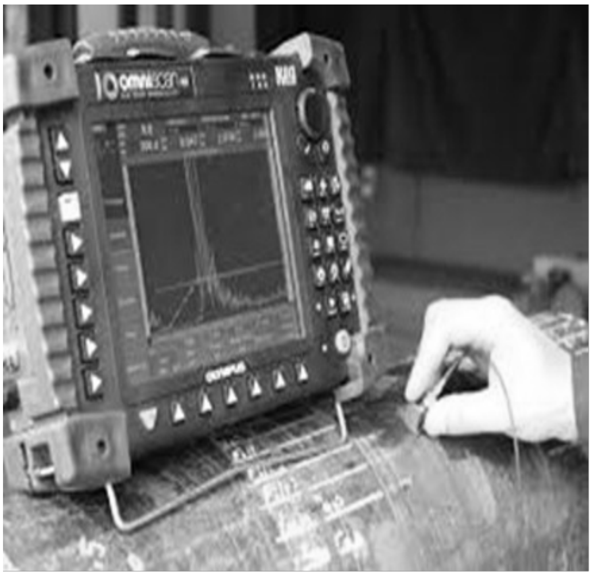

Figure 4.5: Defects seen on weld joint

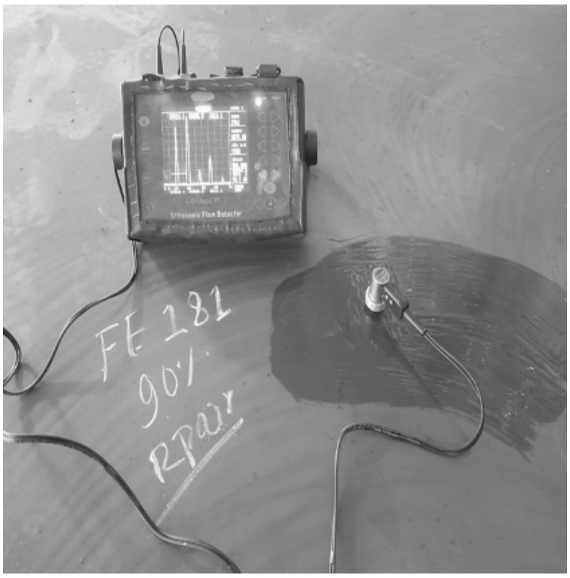

Figure 4.6: Weld joint to be repaired

In this experimental study UT machine was used to detecting the thickness of the test piece and depth of irregularities. UT is carried out since the metal plate thickness is 6mm and ASME recommends UT to measure the thickness of a minimum of 6mm. Flaws or irregularities like porosity, slag inclusions, lack of root penetration, and undercuts are the defects UT used to measure on welded joints of test specimens.

In order to generate flawless, smoothly fused weldments, skill practice is necessary. Making mistakes like rushing during the welding process might result in flaws inside the weldment. Pipe shell creates acidic environment, corroding weld joints, enabling faster data collection. SMAW is the welding procedure known as shielded metal arc welding (SMAW) has the potential to affect how well the welded junction resists corrosion. The corrosion resistance of the weld and the surrounding base metal can be affected by a number of welding settings in SMAW.

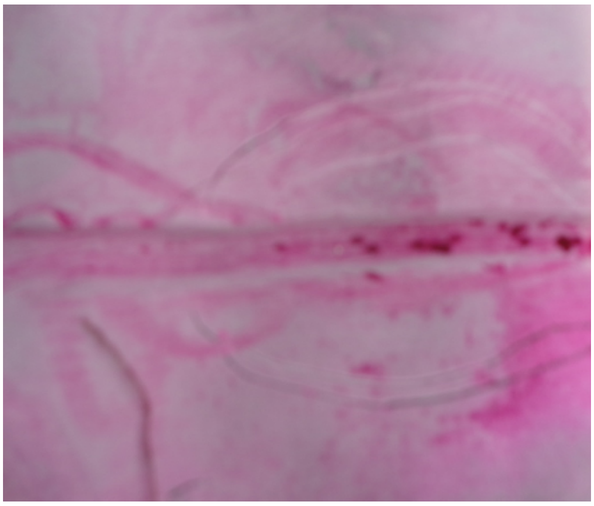

Figure 4.7: Cluster porosity on weld joints

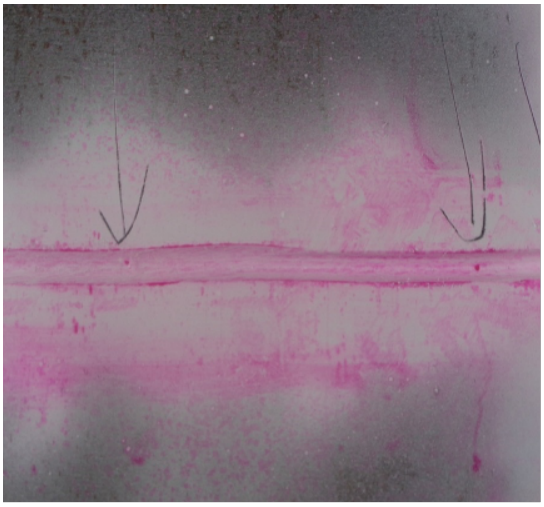

Figure 4.8: Pin holes on weld joints

The choice of electrode composition has a big impact on how resistant the weld is to corrosion. With varied quantities of alloying elements like chromium, nickel, and molybdenum, different kinds of electrodes can increase corrosion resistance. Similarly, different chemicals that affect the welding process and the final qualities of the weld may be found in the coating on SMAW electrodes. Some coatings are intended to increase arc stability, while others may increase the weld's corrosion resistance. Heat input, penetration depth, and overall weld quality are all impacted by welding current. Overly high or low current levels may result in unfavorable microstructural changes in the weld, which may compromise its ability to resist corrosion. In SMAW, the coating on the electrode produces a shielding gas that shields the weld pool from contaminating air particles. The cleanliness and corrosion susceptibility of the weld can be affected by the shielding gas's composition. Besides these other factors arc length, preheat and interpass temperature, post-weld heat treatment, surface cleaning and passivation, joint design and preparation.

4.5 Loss of damage due to corrosion

Corrosion is regarded as an issue that cannot be avoided and must be acknowledged as a natural process that will occur. The life of exposed metallic components to the environment may and should be extended by taking certain steps.

Although more attention is given to the control and prevention of corrosion, negligence is still a problem in the hydropower projects of Nepal. Table 4.5 shows according to Nepal Rastra bank, the total items of NRs. 1,45,658.60 million and NRs.1,33,813.50 million have been imported in 2022 and 2023 respectively.

Table 4.5: Corrosion cost breakdown sector-wise (Government of Nepal, 2022)

Category	Sectors	Assign	Direct cost of corrosion per sector		
			x Million NRs.	%	Overall %
Infrastructure	Highway bridges	A	5062	28	13.51
	Hydropower pipelines	B	6002	33.2	
	Waterways	C	5003	27.68	
	Hazardeous materials storages	D	1005	5.56	
	Airports	E	1005	5.56	
Utilities	Drinking water system	F	11235	31.43	26.71
	Electrical utilities	G	16503	46.17	
	Telecommunications	H	8005	22.4	
Transportation System	Motor vehicles	I	18056	64.11	21.05
	Aircraft	J	6050	21.48	
	Hazardeous material transport	K	4057.5	14.41	
Production and manufacturing	Cement industries	L	9060	17.48	38.73
	Petroleoum	M	8604	16.6	
	Pharmaceuticals	N	8605	16.6	
	Pulp and paper	O	3045	5.87	
	Agricultural	P	11000	21.22	
	Food processing	Q	3005	5.8	
	Electronics	R	2506	4.84	
	Home appliances	S	6005	11.59	

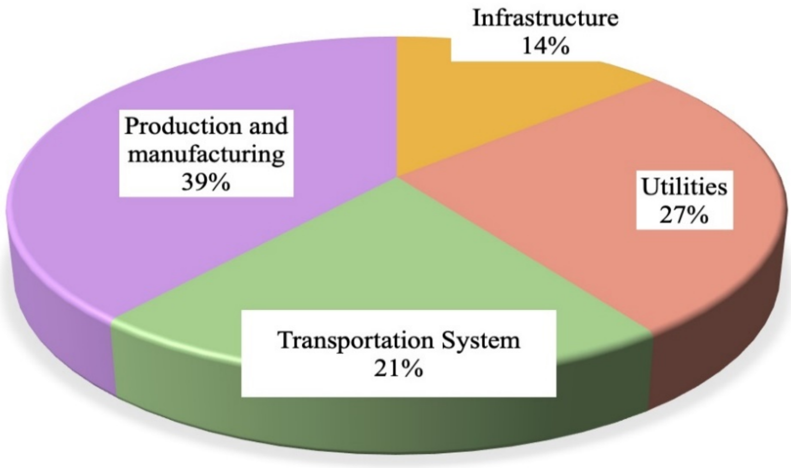

Figure 4.9: Cost of damage due to corrosion

All subsequent research demonstrates that, in highly developed nations, corrosion represents a consistent cost to a country's gross national product. The cost of corrosion-related damages is calculated by adding together both direct and indirect costs. However, this term has not been given any distinction in Nepal. By excluding indirect costs only direct cost is adopted, to study and try to calculate the overall costs related to corroding components in Nepal. Neglecting the expected indirect cost. The pie chart shown in Figure 4.9 illustrates the cost of damage brought on by corrosion in the hydropower and water sector utilities.

If 5% of the direct cost is assumed for utility sectors then 26.71% of the total imported cost were to be allocated in order to prevent costly safety risks and plant operations disruptions. Hence, the cost of damage for utility/hydropower is NRs. 1,787.08 million.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

The case study calculated that the soil sample containing loose soil with clay than with sand mix pebbles though both samples were corrosive in nature based on resistivity of the soil collected from the area of the project.

Since prototype pipes with material E250 were buried by two different backfill materials for a period of 3 months as done for experimental study. Based on thickness measurement it shows that the metal loss is about 0.2mm in thickness on prototype pipe buried by loose soil with clay. On the other pipe showed insignificant loss on the metal due to corrosion. On calculation the experiment shows that the metal is 0.8mm a year which is significantly high. And remaining life of the prototype pipe shell buried on loose soil only lasts for 7.50 years without considering corrosion allowance.

The pipelines must be buried with sand mixed with pebbles and gravel with respect to loose soil with clay.

The heat-affected zone is more prone to corrosion in respect to other marked points. Since, metallurgical, mechanical properties alter during welding. Weld discontinuities can be the source of corrosion development in buried pipelines.

On consideration of 5% of the direct cost neglecting indirect cost it is assumed for utility/hydropower sectors then 26.71% of the total imported cost were to be allocated in order to prevent costly safety risks and plant operations disruptions. Hence, loss is around NRs. 1,787.08 million.

It is further recommended to extend this research for a more accurate result if this study is to be taken forward by considering:

1. Buried-type pipelines under operations for more than 30 years.
2. Corrosion a long-time process so time limitation is a problem. Pipes buried with different backfill materials over the pipeline alignment can be studied. Only two soil samples were collected within pipeline alignment.
3. No protective considerations were done so study can be made by considering some protective coatings over the pipe shells.
4. Effect on protective coatings of buried pipelines by the nature of soil.
5. Long-term testing of pipes of different material grades can be studied.

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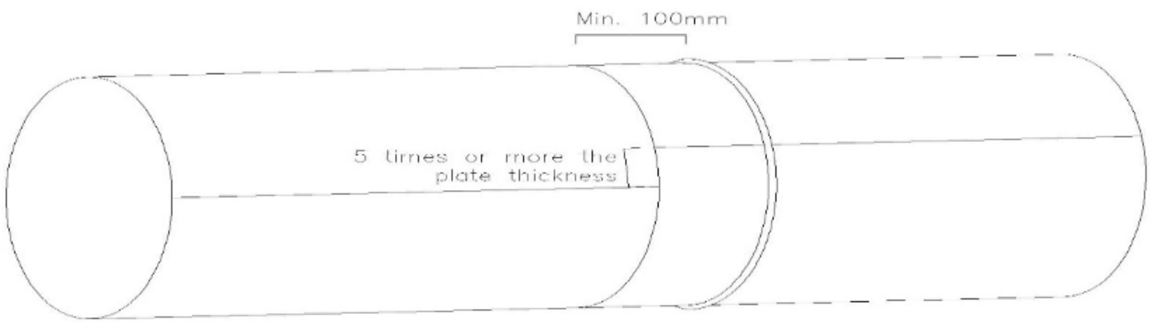
Appendix A: Test specimen



Appendix A.1: Prototype pipe shell block diagram

Appendix A.2: Mark Identification on Pipes

Appendix B: Testing and Data Collection

Appendix B.1: Testing of Sample

Appendix C: Test report and Work Schedule

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GLOBAL INSPECTION CONSULTANCY PVT. LTD.

KATHMANDU, NEPAL

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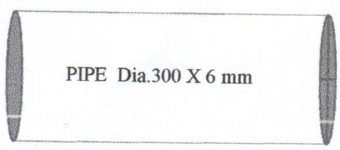
ULTRASONIC THICKNESS SURVEY REPORT

CLIENT	Er. SHANKAR THAPA	REPORT NO	GIC/NDT/UTT/01
SIZE	DIA: 300 MM, THK: 6 MM	DATE OF TEST	5/8/2023
MATERIAL SPEC.	E250	EQPT. MAKE/MODEL	MODSONIC
SURFACE CONDITION	AS CLEANED	EQPT. SR. NO.	E4491-1215
COUPLANT	MOBIL & GREASE	CODE REFERENCE	ASME SEC. V
TEST SURFACE	OUTER SURFACE OF THE PIPE	ACCEPTANCE CODE RI	ASME SEC. V, APPENDIX 23

S.N.	ITEM NAME	LOCATION NO.	THICKNESS MEASURE	RESULT	S.N.	ITEM NAME	LOCATION NO.	THICKNESS MEASURE	RESULT	REMARKS
1	SAMPLE 'A' PIPE	E'	5.8, 5.7, 5.8	ACCEPTABLE	1	SAMPLE 'B' PIPE	E	6.0, 6.2	ACCEPTABLE	
2	SAMPLE 'A' PIPE	F'	5.8, 5.8, 6.0	ACCEPTABLE	2	SAMPLE 'B' PIPE	F	6.0, 6.0	ACCEPTABLE	
3	SAMPLE 'A' PIPE	G'	5.8, 5.8	ACCEPTABLE	3	SAMPLE 'B' PIPE	G	6.0, 6.4	ACCEPTABLE	
4	SAMPLE 'A' PIPE	H'	5.8, 5.8, 5.8	ACCEPTABLE	4	SAMPLE 'B' PIPE	H	6.0, 6.2	ACCEPTABLE	
5	SAMPLE 'A' PIPE	I'	5.8, 5.8, 5.8	ACCEPTABLE	5	SAMPLE 'B' PIPE	I	6.0, 6.4	ACCEPTABLE	



All dimensions are in mm

NAME: PRAKASH DHITAL

SIGN:

DATE: 05/08/2023

INSPECTOR

GLOBAL INSPECTION CONSULTANCY PVT. LTD. NEPAL GIC Estd.2057 A team of Inspection Specialist and Associated Services

NAME: Shankar Thapa

DATE: 05/08/2023

SIGN:

CLIENT

GIC/NDT/UT/01

Appendix C.1: Ultrasonic thickness survey report

Soil Water and Air Testing Laboratories Pvt. Ltd.
VAT No: 605928743
Tel: +977-01 4249480
Email: swatlab2017@gmail.com
PO Box: 25752, Kathmandu, Nepal
Sisir Marga 11, Babarmahal, Kathmandu, Nepal

SOIL ANALYSIS REPORT

Name of Client:	Shankar Thapa	**Lab Code:**	23/08-1107
Collector:	Shrijana Neupane	**Location:**	-
Source:	Soil	**Sampled By:**	Client
Sampling Date:	-	**Test Performance Date:**	2023/08/04-2023/08/08
Receipt Date:	2023/08/04	**Issue Date:**	2023/08/08

Parameters	**Unit**	**Results (Loose Soil with Clay)**	**Results (Sand Pebbles Mix)**
		Sample A	**Sample B**
Acidity	mg/100g	42	24
Resistivity	Ω-cm	840	980
Porosity	%	28.01	38.21
Dry Unit Wt.	kN/m^3	18.32	26.31
Sp. Gravity	-	2.53	2.27
pH	-	5.0	6.1
Sulphide (mg/kg)	mg/kg	71	59
Moisture Content (%)	%	28	26
Chloride (mg/kg)	mg/kg	56	32
Sulphate (mg/kg)	mg/kg	73	62

Note: The integrity of the sample and results are dependent on the quality of sampling. The results refer only to the parameters tested of the samples provided/collected for analysis. Statements of conformity have been made without taking Measurement Uncertainty into account except when specifically requested by the customer.

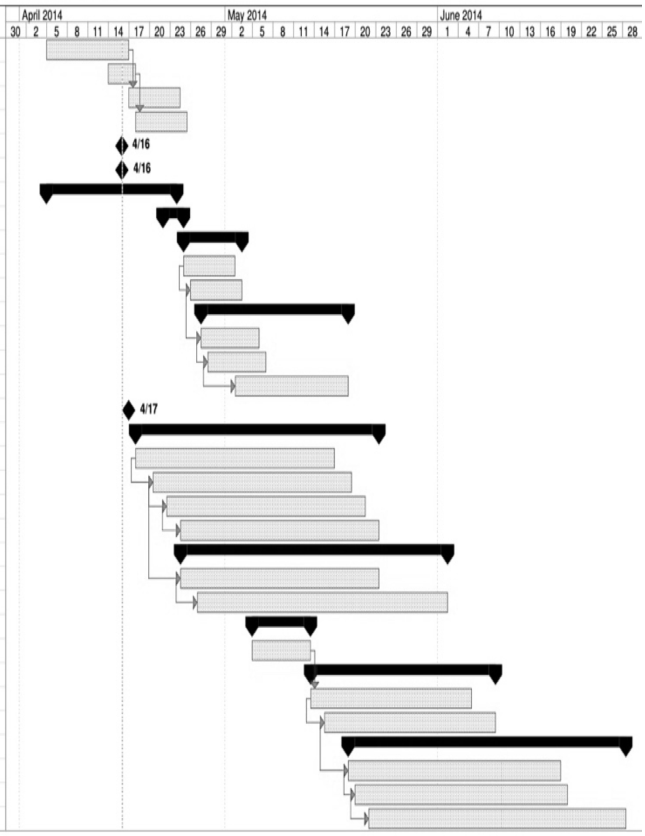
Analyzed By | Checked By | Authorized By

The report shall not be reproduced except in full, without approval of the laboratory.

Appendix C.2: Soil Test Report

WORKING SCHEDULE FOR CONSTRUCTION OF
DARAUDI HYDROPOWER 6.5 MW

ID	Task Name	Duration	Start	Finish	Predecessors
1	**PREPRATION OF WELDING METHODOLOGY**	**10 days**	**Sat 4/5/14**	**Wed 4/16/14**	
2	**PREPRATION OF SHOP DRAWING**	**4 days**	**Mon 4/14/14**	**Thu 4/17/14**	
3	**APPROVAL OF WELDING METHODOLOGY**	**7 days**	**Thu 4/17/14**	**Thu 4/24/14**	**1**
4	**APPROVAL OF SHOP DRAWING**	**7 days**	**Fri 4/18/14**	**Fri 4/25/14**	**2**
5	**SITE CAMP PREPARATOIN**	**0 days**	**Wed 4/16/14**	**Wed 4/16/14**	
6	**FABRICATION OF HR PIPE (1ST LOT, 100M)**	**0 days**	**Wed 4/16/14**	**Wed 4/16/14**	
11	**FULL WELDING OF HR PIPES (1ST LOT, 100M)**	**16.5 days**	**Sat 4/5/14**	**Wed 4/23/14**	
14	**INSPECTION & TESTING OF HR PIPES (1ST LOT, 100M)**	**3 days**	**Tue 4/22/14**	**Thu 4/24/14**	
16	**Paintings (1ST LOT, 100M)**	**8 days**	**Fri 4/25/14**	**Sat 5/3/14**	
17	Applicatin of Glo protek	7 days	Fri 4/25/14	Fri 5/2/14	15
18	Application of Epoxy Coaltar	7 days	Sat 4/26/14	Sat 5/3/14	17SS+1 day
19	**TRANSPORTATION & INSTALLATION OF HR PIPES (100M)**	**18 days**	**Sun 4/27/14**	**Sun 5/18/14**	
20	Transportation of HR pipes	7 days	Sun 4/27/14	Mon 5/5/14	18SS+1 day
21	Installation & Levelling	7 days	Mon 4/28/14	Tue 5/6/14	20SS+1 day
22	Site Welding	13 days	Fri 5/2/14	Sun 5/18/14	21SS+4 days
23	**ARRIVAL OF 2ND LOT MATERIALS (200 ton /400m length)**	0 days	Thu 4/17/14	Thu 4/17/14	
24	**FABRICATION OF 2ND LOT HR PIPE**	**31 days**	**Fri 4/18/14**	**Fri 5/23/14**	
25	Rolling & tack Welding @ 8 pcs per day	25 days	Fri 4/18/14	Fri 5/16/14	
26	Assembly of HR pipes @ 8 pcs per day	25 days	Sun 4/20/14	Mon 5/19/14	25SS+2 days
27	Assembly of HR pipe & Stiffner @ 8 pcs per day	25 days	Tue 4/22/14	Wed 5/21/14	26SS+2 days
28	Welding of stiffner	25 days	Thu 4/24/14	Fri 5/23/14	27SS+2 days
29	**FULL WELDING OF HR PIPES (2ND LOT)**	**32 days**	**Thu 4/24/14**	**Mon 6/2/14**	
30	Root welding	25 days	Thu 4/24/14	Fri 5/23/14	26SS+4 days
31	Full welding	30 days	Sun 4/27/14	Mon 6/2/14	30SS+2 days
32	**INSPECTION & TESTING OF HR PIPES (2ND LOT)**	**7 days**	**Mon 5/5/14**	**Tue 5/13/14**	
33	Visual & DPT Test	7 days	Mon 5/5/14	Tue 5/13/14	
34	**Paintings (100M)**	**22 days**	**Tue 5/13/14**	**Mon 6/9/14**	
35	Applicatin of Glo protek	20 days	Tue 5/13/14	Thu 6/5/14	33
36	Application of Epoxy Coaltar	20 days	Thu 5/15/14	Mon 6/9/14	35SS+2 days
37	**TRANSPORTATION & INSTALLATION OF HR PIPES (2ND LOT)**	**33 days**	**Mon 5/19/14**	**Sat 6/28/14**	
38	Transportation of HR pipes	25 days	Mon 5/19/14	Wed 6/18/14	36SS+3 days
39	Installation & Levelling	25 days	Tue 5/20/14	Thu 6/19/14	38SS+1 day
40	Site Welding	30 days	Thu 5/22/14	Sat 6/28/14	39SS+2 days



Project: Master Work Schedule of Dzc Date: 27 July 2013	Task		Progress		Summary		External Tasks
	Split		Milestone		Project Summary		External Milestone
	Deadline						

Appendix C.3: Working schedule for construction of pipeline fabrication

Appendix D: Welder Qualification

Format no: QF/ME/005

AMARA RAJA INFRA PVT LTD
HI RISE PLANT
WELDER QUALIFICATION TEST
(QW-301, Secion-IX, ASME code)

NAME OF WELDER :	Vijay Kumar Sahani	Welder No.	010
WPS No. :	4p1/003	Date	15.12.10
Welding Process :	SMAW	Type	3G
Base material (s) welded :	is2062 Steel	Thickness	20,25,30

Welding Parameter			Actual values	Range Qualified
Backing (Metal, weld metal,Welded from both side etc.)			Ps2062,Plates	
ASME "P" Number To "P" Number			1	
Base Metal : Plate/Pipe :	Diameter :	Groove	Double V	
		fillet	4lavers	
	Thickness :	Groove		
		fillet		
Filler metal specification / classification				
Filler metal "F" No.				
Weld Metal Thickness for GTAW Process				
Weld Metal Thickness for SMAW Process			20,25,30	
Weld Metal Thickness for GMAW Process				
Weld Metal Thickness for FCAW Process				
Weld Metal Thickness for SAW Process				
Welding position :			3G	
Progression :				
Backing Gas for GTAW, PAW or GMAW				
Welding Polarity :			ru	
Welding current (Amp):	Starting stage:		Running stage:	
Travel Speed(per minute) :	m/mn			
shielding gasType :			Flow rate(LPM):	

Visual Examination Results	Pass	Radiography Report No:&Date	Test Date : 2005.10	
Radiography Test Results	Pass		Guided Bend Test Results :	psis2062
Fillet Weld-Fracture Test		1115X21.05.15		
Macro Test Fusion			Length & percent of defects	
Fillet Leg size	300			

Welding Test Conduct By	sass-G
Mechnical Test conduct By	Pralccesh -M (Say Test Lab Chenna)
Laboratory Test No.:	1530

We certify that statement in this are correct and that the test coupons were prepared, welded, and tested in accordance with the requirement of section IX of ASME Code

Test witnessed by :	Sij Kumar
Welder certified by:	S. Jaya Prallesh

ARIPL
Petamitta (Vil)
Talupulapalli (Post)
Puthalapattu (Mandal)
Chittoor Dist. 517 124

CLIENT
Mangal Precasts Products.

Appendix D: Welder Qualification Test

Corrosion on welded joints of buried head race pipe A case study of Daraudi Khola A Hydropower Project

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4	Li Lv, Shaojun Yuan, Yu Zheng, Bin Liang, Simo O. Pehkonen. "Surface Modification of Mild Steel with Thermally Cured Antibacterial Poly(vinylbenzyl chloride)–Polyaniline Bilayers for Effective Protection against Sulfate Reducing Bacteria Induced Corrosion", Industrial & Engineering Chemistry Research, 2014 Crossref	38 words — 1%
5	Pierre R. Roberge. "Corrosion Inspection and Monitoring", Wiley, 2007 Crossref	35 words — < 1%
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