Evaluation of the Efficiency and Effectiveness of Hot Rolled Sheet Piles on the Seawalls of Aurora Province, Philippines: A DPWH Aurora District Engineering Office Study

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Abstract: This study aimed to determine the Evaluation of the Efficiency and Effectiveness of Hot Rolled Sheet Piles on the Seawalls of Aurora Province, Philippines: A DPWH Aurora District Engineering Office Study. This study used the descriptive-analytical survey in which the current projects of the DPWH-Aurora pertained to the seawall throughout the province were assessed quantitatively based on the grounds of the Hot Rolled Sheet Piles being used in these projects. The findings revealed that hot-rolled sheet piles used in the seawall projects were moderately efficient and adequately effective. Among the three, hot-rolled and vinyl seemed very beneficial, but it was still the hot-rolled sheet piles recommended for use in seawall infrastructure projects.

Key Words: — *Efficiency, Effectiveness, Hot Rolled Sheet Piles, Seawalls.*

I. INTRODUCTION

Seawalls are common along the world's coastlines, and numerous improvised seawalls may be found in developing countries. Seawalls define the boundary between the sea and the land. They're commonly utilized in areas where further beach erosion would cause significant harm, such as when roads and buildings are set to fall into the sea. However, they do not address the causes of erosion while preventing additional shoreline erosion. Steel sheet pile walls, monolithic concrete barriers, rubble mound structures, brick or block walls, gabions, or wire baskets loaded with rocks are all examples of seawalls. Seawalls are typically rigid, extensively engineered constructions that are costly to build and necessitate adequate design and construction monitoring [1].

In the deflection of incoming wave energy, the geometry of the seaward face is crucial; smooth surfaces reflect wave energy, while uneven surfaces scatter the direction of wave reflection. Waves are anticipated to slam into the building with great force and move sand off- and along-shore away from it. Because seawalls are frequently erected as a last resort, they are constantly subjected to significant wave force. For stability, seawalls usually have a deep foundation. 'Deadman,' or earth anchors, can also be dug upland and attached to the wall by rods to overcome the ground pressure on the landward side of the building [2].

A seawall's principal benefit is excellent protection against coastal floods and erosion. A well-maintained and suitably planned barrier will help maintain the sea-to-land boundary, preventing additional erosion — this is especially crucial if the shoreline is home to significant infrastructure or other essential structures. Seawalls provide coastal flood protection against excessive water levels and define the land-sea border. Seawalls will defend against water levels up to the seawall design height if they are adequately engineered to resist the additional forces. Many seawalls were formerly designed based on the most significant known flood level [3].

Seawalls also take up far less territory than conventional coastal defences like dikes, mainly if vertical seawall designs are used. Land in the coastal zone is in great demand in many regions; overall, building costs could be reduced by minimizing the space needed for coastal defence. The

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improved protection afforded by seawall construction also helps preserve the hinterland's value and may encourage investment and growth. Furthermore, seawalls have a high amenity value if they are well constructed; in many nations, seawalls include promenades that encourage recreation and tourism.

Another advantage of seawalls in climate change adaptation is that they may be progressively upgraded by increasing the structural height. However, the seawall renovation must not jeopardize the structure's integrity. The new segment of the seawall will be joined to the pre-existing seawall via a 'construction junction.' Upgrades must take this weakened part into account and reinforce it properly.

Community-scale seawall construction is possible. There are numerous examples of improvised structures that have been built to safeguard individual houses and communities. However, ad-hoc seawalls are likely to pay significantly less attention to water levels, wave heights, and wave loadings during a severe storm. It is mainly because without a well-developed science and technological background, and these catastrophes are challenging to predict. In designing and building functional seawalls, some technical direction would be beneficial. It would help them be more effective during extreme events while reducing adverse effects on nearby coastlines.

Although ad-hoc or conventional low-tech seawalls can be built at a community level, these structures have provided poorer protection against extreme events than designs based on strong science and technology. They've also been shown to aggravate pre-existing issues. If any advice on modern seawall construction is given in developing nations, it appears to be informal. Local communities must be given at least primary design direction if effective design and construction occur. It could come from the government or non-profit organizations.

When given the proper training, community seawall maintenance is likely to be doable. It could include instructing maintenance engineers on the most likely failure mechanisms, how often to inspect the structure, what to look for, and how to spot design flaws. If severe flaws are discovered, a professional company may be required to repair the building most efficiently.

Sheet piles are interlocking lengths of sheet materials driven into the ground to provide earth retention and excavation support. Steel sheet piles are the most prevalent, but they can also be made of wood or reinforced concrete. They're installed in a particular order to achieve the desired depth along the excavation perimeter or seawall alignment. The interlocked sheet piles form a wall for permanent or temporary lateral earth support with reduced groundwater inflow. If needed, anchors can be used to give additional lateral support.

II. Background

Sheet piles are often used for retaining walls, land reclamation, underground constructions such as car parks and basements, riverbank protection, seawalls, cofferdams, and other maritime applications. Permanent steel sheet piles are built to last for a long time. Sheet piles are often installed with vibratory hammers. An impact hammer might be used to finish the installation if the soils are too complex or dense. There are two basic processes for developing sheet piles: hot-rolled and cold-formed. Hot rolled heaps are created at high temperatures, and the interlocks appear to be more robust [4].

Hot-rolled steel sheet piles are primarily used in construction engineering projects because of their high rigidity, excellent driving properties, and high section modulus. The temperature of the hot-rolled piling portions is around 1,200° Celsius. As a result, the steel has high plasticity, allowing for various profile shapes [5].

Aurora province's location faces the Pacific Ocean, with most of its municipalities having shorelines. The Province of Aurora is located 232 kilometers east of Manila on Luzon's mid-eastern coast, between 15o 31' 02" and 16o 31' 00" N latitude and 121o 31' 02" to 122o 01' 30" E longitude. It is Central Luzon's most north-eastern province (Region III). Isabela and Quirino border it on the north, Nueva Ecija and Nueva Viscaya on the west, Bulacan and Quezon on the south, and the Pacific Ocean on the southeast. Aurora is known as the Pacific's "Gateway to the Pacific," boasting a 410-kilometer coastline.

Baler's survival is dependent on flood control infrastructure, which has recently experienced heavy flooding. According to DPWH records, three (3) flood control projects and one drainage structure are operational in Baler. A 344-meter road dike in Brgy is one of the flood control constructions. In Brgy., there is a 400-meter earth dike called Pingit. Buhangin and a 201-meter concrete sea wall were built along Brgy's shoreline. Sabang was built to shield the area from the scouring impacts of the sea. The lone drainage structure was built at Brgy. Castillo's Sitio Castillo. Sabang, where the Castillo River's discharge was rerouted from its original location on the east side of Sitio Castillo to its current location on the west side. It is just for the Baler municipality. Hence, this study is made to evaluate the efficiency and effectiveness of hot-rolled sheet piles on the seawalls of Aurora Province, Philippines: A DPWH Aurora District Engineering Office Study.

III. Steel Piling In Seawall

A seawall is a defensive structure or embankment built along the coast to reduce damage and disruption caused by waves, tides, tsunamis, hurricanes, and other natural disasters. Sea walls protect against storm surges and overtopping waves. They aid in retaining soil that would otherwise be lost or disturbed over time, preventing land from sliding. They also protect the residential estate, commercial properties, and other coastal resources from flooding [6].

As previously stated, seawalls can be constructed of concrete, but they are also frequently constructed of steel. Many are composed of concrete reinforced with steel. They can also be made of wood, stones, plastic, or composite materials. When a seawall needs to be built quickly and efficiently, vinyl seawalls are a common choice, but they must be updated every 20 years. Wooden seawalls are appealing, but they are the most vulnerable of all the forms. When it comes to seawalls, they might have concave, vertical, or stepped seaward faces. Revetments, which are defensive materials set on their slopes, are usually used to construct them. Quays and landing platforms for unloading and loading vessels may also be included. They could also include jetties, groins, and an offshore breakwater.

Seawalls are frequently made with steel sheet piling when made of steel. Steel sheet piles are an excellent choice for seawall construction because of their relative ease of installation, strength, and endurance. Steel sheet pile is relatively long-lasting, even though it can be damaged and eroded by years of saltwater wear and tear. Vinyl sheet piles are also a suitable alternative to steel sheet piles when steel sheet piles aren't needed. While vinyl sheet piles are not as strong as steel sheet piles, they are less prone to corrosion.

Engineering specifications will vary depending on the location's needs where the seawall will be placed. Soil qualities, topography conditions such as grading and elevation, embedment, and water levels should be thoroughly analyzed during the design phase to achieve a high-quality build. In the construction process, zoning limitations and municipal ordinances must be considered [7].

After a seawall is built, the frequency and scope of maintenance and repair will vary depending on the materials used in construction and coastal conditions, such as how often storms occur in a particular location at any one time. Seawalls that are crumbling can put coastal properties and other resources at risk. Erosion holes, sinking soil, and long fractures can be problems if a seawall isn't correctly done. Damaged seawalls should be repaired or replaced as soon as possible to alleviate these concerns.

Excavators are used to prepare an area for installation and backfilling, pile driving equipment is used if piles are to be installed, barges are used to store equipment and materials, cranes, tiebacks, anchors, welding equipment, and other specialized equipment are used in seawall construction, depending on the project.

The benefits and drawbacks of building a new seawall must be carefully assessed in those regions where it is suggested. Seawalls are beneficial, but they can also harden the shorelines of coastal ecosystems and impede the natural coastal sediment exchange. Intertidal beaches and wetlands may be harmed as a result of this. Because of how they alter sediment flow, sea walls can also aid in the dissipation of beaches. On the other hand, a sea wall is an efficient option if the necessity to defend an area from natural disasters and erosion is vital.

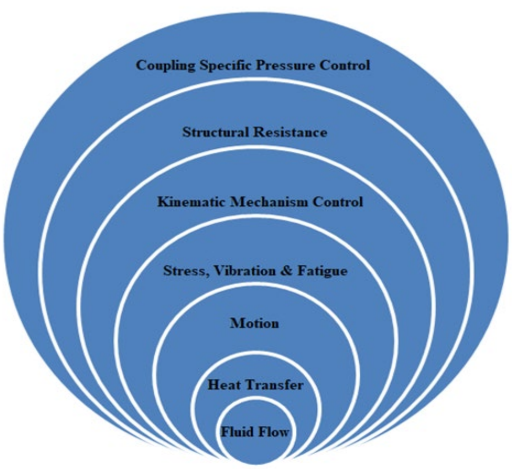
IV. Finite Element Model

Finite element analysis (FEA) is a critical method in civil engineering for numerically approximating physical structures that are too complex for typical analytical solutions. Consider a sheet pile with support at both ends loaded heavily in the central span. The deflection at the center span may be determined numerically fairly basic manner because the beginning and boundary conditions are finite and under control. Once the sheet piles are used in an actual application, such as a bridge or a seawall, the forces at play become much more complicated to analyze using fundamental mathematics [8].

FEA can be used to simplify a structure and understand its general behavior in a variety of structural and civil engineering challenges. Structural analysis determines how a structure will respond when subjected to loads such as gravity, wind, or, in extreme cases, natural disasters. Simple applied mathematics techniques can be used to study any architectural structure. The motion of water generated at the coast is more noticeable than that produced by inland canals. High current waves, tides, ocean currents, storm surges, tsunamis, wind currents, and other elements add to the complexity, and water particles, when combined with other causes, cause damage and destruction to maritime structures.

The civil engineers' examination of the problem in coastal flow challenges is complicated by the boundary conditions of wave-current reflection and diffraction. As a result, today's trend is for numerical-empirical coastal flow modeling (finite element modeling of fluid flows) and analysis. For decades, hydrological models have been used to assess water movement in porous soil and contribute to groundwater levels in coastal areas and watershed regions. While linear static analysis of hydrological projects such as dams takes into account the river's load on the dam, nonlinear analysis is required to account for the full effect of the conveyance system, which includes the inner cushion surface, an outer surface of steel liner tuber facing water contact, and concrete-steel liner contact, among other things.

Using the Finite Element Method (FEM), the physical system to be analyzed is broken down into simple discrete pieces. Frequently, the number of components required to describe a physical system effectively is quite large. By depicting the larger physical system as the sum of smaller and simpler elements, the solution is similarly simplified to the sum of smaller and simpler analyses. The figure below described the Finite Element Model used by the researchers.



V. METHODOLOGY

This study used the descriptive-analytical survey in which the current projects of the DPWH-Aurora pertained to the seawall throughout the province were assessed quantitatively based on the grounds of the Hot Rolled Sheet Piles being used in these projects. The analyses were based on the characteristics of the pile sheets being used in the projects and the depreciative enforcement of the projects' status as assessed by the civil engineers in the Municipal Engineering Offices, Provincial Engineering Office, and the Department of Public Works and Highway.

There was about 151 total population of engineers in the province, which were as follows:

Table.1. Distribution of Respondents

Office	Engineers	Sample Size
MEO-Baler	16	12
MEO-San Luis	12	8
MEO-Maria Aurora	15	11
MEO-Dingalan	9	7
MEO-Dipaculao	15	11
MEO-Dinalungan	7	5
MEO-Casiguran	11	8
MEO-Dilasag	9	6
PEO-Aurora	19	14
DPWH-Aurora	38	28
Total	151	110

This study aimed to evaluate the Efficiency and Effectiveness of Hot Rolled Sheet Piles on the Seawalls of Aurora Province, Philippines: A DPWH Aurora District Engineering Office Study. More specifically, it answered the following questions:

(a) How may the hot-rolled sheet piles used in seawall infrastructure projects of DPWH-Aurora be assessed through vital characteristics?

(b) How may the hot-rolled sheet piles used in seawall infrastructure projects of DPWH-Aurora be analyzed according to depreciative status?

(c) What may recommendations be driven to commend engineering practices in choosing materials for seawall infrastructure projects?

There were two sets of data analyses to analyze the data. The first one was to determine the characteristics of the hot-rolled pile sheets through stress, vibration, fatigue, motion, heat transfer, fluid flow, electrostatics, couplings, specific pressure control, structural resistance, and kinematic mechanism control. The second set was to determine the depreciative properties of the seawall projects through Undisturbed Natural Soil, Normal Water, Full Submersion and Rippling Sea Water Splashing, and low water level of Sea Water and Thickness reduction. The following scale will be observed:

Option	Scale	Adjectival rating
4-	3.26 – 4.00	Highly Efficient
3-	2.51 – 3.25	Adequately Efficient
2-	1.76 – 2.50	Moderately Efficient
1-	1.00 – 1.75	Lowly Efficient

VI. Results And Discussion

The findings showed a 2.18 average weighted mean with the verbal description of "Moderately Efficient."

Item	WM	Verbal Description
Stress	2.42	Moderately Efficient
Vibration	2.27	Moderately Efficient
Fatigue	2.47	Moderately Efficient
Motion	2.32	Moderately Efficient
Heat Transfer	2.35	Moderately Efficient
Fluid Flow	2.37	Moderately Efficient
Electrostatics	1.70	Lowly Efficient
Couplings Pressure	1.88	Moderately Efficient
Structural Resistance	2.15	Moderately Efficient
Kinematic Control	1.83	Moderately Efficient
Average Weighted Mean	2.18	Moderately Efficient

Although the friction fatigue of sheet piles has been well explored, only a few studies have concentrated on the friction fatigue of vibratory sheet piles. As a result, the current research concentrated on sheet pile fatigue. Model piles were installed using a vibratory hammer with varying frequencies and strengths in each test. A pair of strain gauges were carefully mounted to the surface with acrylic adhesive at various heights of the model piles. Both the accelerations at the pile head and the axial stresses of the pile were measured during the vibratory drill. During the pile drive, the pore water pressures in the soil were also monitored. The distributions of axial forces and shaft frictions along the pile were calculated by putting the measured variables into the equation of motion.

Whether a contiguous or secant concrete wall is contemplated, steel sheet piling is usually a considerably more cost-effective choice than concrete piling. The mixing and setting of concrete are a clear example of how project costs can rise owing to delays, whereas steel sheet piles are ready to go.' When employed as a permanent solution, steel sheet piles can provide the holy grail of durability for any project. Because of the corrosion-resistant qualities of steel, protective coatings, and design considerations such as for sacrificial thickness, their 'life' can last for decades. Steel sheet piles require very little maintenance, allowing them to remain out of sight and out of mind without the issues that alternative earthworks technologies can cause.

Item	WM	Verbal Description
Undisturbed Natural Soil	3.38	Highly Effective
Normal Water	3.19	Adequately Effective
Full Submersion	3.50	Highly Effective
Rippling Sea Water	2.50	Adequately Effective
Splashing	3.31	Highly Effective
Low Water Level	2.50	Adequately Effective
Thickness Reduction	3.25	Highly Effective
Average Weighted Mean	3.09	Adequately Effective

The findings showed a 3.09 average weighted mean with an "Adequately Effective" verbal description.

Hot-rolled sheet piles have thicker and tighter interlocks, making them more suited for severe pile driving. Sheet piling can be driven in challenging ground conditions due to this. A sheet pile is usually made of steel in most building situations. It's a hot-rolled steel sheet section with interlocking clutches that connects to other sheets of the same type. These robust and durable components form a length of sheet pile wall when driven into the ground and bonded together.

Steel sheet piles hold the earth, water, or seawater on one side while protecting physical items such as property, land, infrastructure, or people. They can be used for either permanent or temporary lateral earth or water retention, with the erected sheet piles being removed once their purpose has been fulfilled. Steel sheet piles are used in building projects to provide efficient and effective excavation support.

Steel sheet piles provide stability and strength, and when purchased from a reputable supplier, they come with quality assurances built into their hot-rolled steel manufacturing methods. The assurance that steel sheet piles have been rigorously tested before leaving the manufacturer and have passed all of the demanding quality controls is invaluable. It provides a high level of justified confidence. Engineers can gain the advantage of managing a greater retained height than you might have imagined possible by anchoring and propping a steel sheet piling wall. Having this option to raise control over the groundworks can make a significant difference in approaches and potentially save money.

VII. Conclusion And Recommendation

Deep excavations are frequently protected with steel sheet piles. It is now possible to plan and monitor the quality of work using modern methods. The following are some of the benefits of steel sheet piles:

They can be easily transported and installed using modern, high-efficiency equipment for driving, vibration pressing, and pressing; (reduction of work scope in the foundation construction area – once material unloading is complete, the construction site is occupied solely by a pile driver or pressing machine with a crane that handles the sheet piles;

Sheet pilings provide a very flexible work schedule - no risk of unplanned downtime; sheet piles can be lifted out and driven back in;

When the steel sheet piles can be retrieved, the expenses are significantly lowered, and the project's environmental impact is restricted because the water relations can be wholly or partially restored.

They can be joined together; the profiles, length, height of wall crown, and shape of future excavation footprint can all be selected freely;

When vertical forces are transferred in a planned manner, they have a high bearing capacity at low settlement; immediate loads can be applied once pushed in.

Steel elements in the soil provide sufficient durability in adverse environmental conditions, often without proper maintenance, as evidenced by observations made for over hundred-year-old embankments or equally old communication structures; observations made for over hundred-year-old embankments or equally old communication structures allow to say that steel elements in the soil provide sufficient durability in adverse environmental conditions, often without proper maintenance;

Because steel sheet piles are transported in a single truck, they ensure a clean site area and, more importantly, restrict heavy vehicle traffic (concrete mixer vehicles).

Practical Implication:

There are some limitations to using sheet piles:

- Steel sheet piles have a restricted length due to shipping constraints and the limited height of pile-driver masts. In some circumstances, this may necessitate the deployment of a palisade of injection piles to "lengthen" the sheet pile wall. Such solutions have already been applied with great success.
- It is often impossible to immerse the sheet piles using traditional means. Drilling or water jetting is then required to assist in the immersion process. Such processes lower soil strength at the point of contact with the wall, resulting in higher pressures than those assumed in the design.
- Steel sheet piles can be destroyed or partially separated in interlocking joints if they come into contact with obstructions in the soil. When the wall performs the function of sheet piling, a "window" is created, allowing groundwater to flow into the excavation.

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