MARINE DRIVE PROTECTION BY FORMATION OF SEA FOREST CREATION UTILIZING BY-PRODUCT SLAG OF STEELMAKING PROCESS ON BAY OF BENGAL

T. Rahaman[1]* and S. Hossain [2]

[1]Postgraduate student, Department of Water Resource Engineering, Bangladesh University of Engineering and Technology, Dhaka-1000, Bangladesh, e-mail:tawhidbuet066@gmail.com
[2]Junior Engineer, Institute of Water Modeling (IWM), e-mail: shlitonbuet@gmail.com

ABSTRACT

The coastlines in Bangladesh are naturally dynamic, the result of continuous erosion and accretion processes. With more than 100km (62.5 miles) of sand, Cox's Bazar has the world's longest uninterrupted natural beach. Initially the Cox's Bazar Marine-Drive Road Project was approved to construct an 80 km long Cox's Bazar to Teknaf. The project is located in a very vulnerable area which is hazard prone. The mean sea level (MSL) has increased unexpectedly, and thus causing frequent surges to hit the shoulder of the road with the wave of about 20-25 feet height in different places. It has caused rapid erosion of seashore and exerted thereat with higher intensity to the nearby sea shore. Geo-textile bags filled with sand, which is temporary solution. It needs permanent structure to protect the marine drive. A heavy and permanent protective works like, sea wall is necessary for the sustainability of the road. In this paper, we try to investigate the alternate uses of steelmaking slag as a "Ferro block" for creating sea wall as well as improving the marine water environment by creating sea forest by "Slag reef block".

Keywords: *Cox's Bazar Marine Drive, Steelmaking Slag, Sea-wall, Marine drive protection.*

1. INTRODUCTION

The coastal zone of Bangladesh, an area covering 47,211 km² facing the Bay of Bengal or having proximity to the Bay, and the exclusive economic zone in the Bay, is generally perceived to be a zone of multiple vulnerabilities. Records of last 200 years show that at least 70 major cyclones hit the coastal belt of Bangladesh .The government of Bangladesh has already identified the zone as "vulnerable to adverse ecological process". With more than 100km (62.5 miles) of sand, Cox's Bazar has the world's longest uninterrupted natural beach. Initially the Cox's Bazar Marine-Drive Road Project was approved to construct an 80 km long Cox's Bazar-Teknaf Marine Road in 1993 but due to unavailability of fund the project was phased out. The 1st phase was designated for 24 km road from Kolatoli to Inani, another 24 km in the 2nd phase from Inani to Shilkhali and 3rd phase has earmarked 32 km from Shilkhali to Teknaf. The project is located in a very vulnerable area which is hazard prone. The mean sea level (MSL) has increased unexpectedly, and thus causing frequent surges to hit the shoulder of the road with the wave of about 20-25 feet height in different places. It has caused rapid erosion of seashore and exerted thereat with higher intensity to the nearby sea shore. Coastal erosion along main beach of Cox's bazaar over the decades caused by the waves and tidal surges results the shoreline shifting towards inland. It has endangered the largest sea beach and now the beauty of the beach is interrupted by these phenomena. In this paper, we try to investigate the alternate uses of steelmaking slag as a “Ferro block” for creating sea wall as well as improving the marine water environment by creating sea forest by “Slag reef block”. In Bangladesh we have a huge potentiality to use the recycled material of steel making slag which produced from 140 numbers of steel making plants in Bangladesh. [BRMA, 2014].This paper presents an assessment on the byproduct namely steelmaking slag resulting from scrap metal processing at induction furnace, Ladle Refining Furnace (LRF) & Electric Arc furnace. The aim of this study is to demonstrate that there are various ways via which scrap metal processing waste can be reused in marine drive protection work as well as improving environmental condition purpose instead of simply diverting them to the landfill or tube fill.

2. OVERVIEW OF MARINE DRIVE PROJECT AREA

The Cox's Bazar Marine-Drive Road Project 2nd Phase (Inani to Shilkhali Portion) is being implemented by Roads and Highways Department (RHD) and Bangladesh Army and sponsored by Ministry of Communications. The project is located in the Ukhiya & Teknaf Upazila of Cox's Bazar district in Chittagong Division. Initially the Cox's Bazar Marine-Drive Road Project was approved to construct an 80 km long Cox's Bazar-Teknaf Marine Road in 1993 but due to unavailability of fund the project was phased out. The 1st phase was designated for 24 km road from Kolatoli to Inani, another 24 km in the 2nd phase from Inani to Shilkhali and 3rd phase has earmarked 32 km from Shilkhali to Teknaf. Just after the completion of the 1st phase, 2nd phase project was originally approved by ECNEC on 15 April, 2008 with the implementation period of July, 2008 to June, 2013. Originally the project was formulated to construct a road of design type-5 (carriage way 12 feet) a typical district level road According to the IMED's evaluation report of the first phase, design type-5 was changed to design type-4, a typical regional highway.

3. CLIMATE CHANGE IMPACT ON MARINE DRIVE PROJECT

The idea of Climate Change Impact Analysis in project planning has evolved in recent days. The existing RDPP format does not include such type of analysis. So there is an absence of this analysis in the project. However, in the EIA report, the climate change impacts were identified. The project site is vulnerable to cyclones and tidal surges. Cyclonic storms develop in the Bay, generally in April-May and October-November, occasionally hitting the shorelines and causing severe damage on human settlements and vegetation. As a result of climate change, sea level rises of up to 43 cm are expected by 2050 and more frequent and extensive cyclones and tidal surges are expected. Historical tidal data for 2 decades up to 2005 show that a sea level rise (SLR) of 7.8 mm/year, which is many times more than the mean rate of global sea level rise over the past 100 years. It is interesting to note, that the report did not specify any mitigation measures for impacts directly due to climate change. The project is located in a very vulnerable area, the coastal, that is hazard prone. During the revision of this project, it was recognized that "global warming has caused a great threat to the existence of the Marine Drive Road along the sea beach". The increase in mean SLR leading to frequent wave surges of about 20-25 feet height hitting the sides of the road in different places was considered in the project design (RDPP pg 7, and 121). But it was not clear in which part of the designs, these issues have been incorporated.

4. ALTERNATIVE MEASURE USED BY STEEL SLAG

Steel slag is classified into two types according to production process: steelmaking slag and blast-furnace slag. In Bangladesh we get around 1, 20,000-1, 60,000 tons of steelmaking slag in every year .Efficient recycling of steelmaking slag has not in concern in our country. We have lots of opportunity to reuse this so called “waste material” as a byproduct. We can make environment-friendly steel slag hydrated matrix, called “Ferroform,” consisting mainly of steelmaking slag as aggregate and ground granulated blast-furnace slag as binder. “Ferroform” can be used as a substitute for concrete blocks and natural stones. This paper outlines the application technologies of “Ferroform” in sea wall as well as “slag reef-block” works, including the underlying characteristics of this new recycling-oriented material.

5. SLAG PRODUCTION SOURCES IN BANGLADESH

The main by-products resulting by steelmaking are slag’s (that represent 90% of the total by-products), dusts and sludge’s. On the average about 200 kg of byproducts per ton of steel result from the steel production through electric arc furnace, while about 400 kg of by-products per ton of steel production through BF/BOF (World Steel Association, n.d.).In which release rate is nearly about 20% to 40 %, but In Bangladesh release rate of slag is around 6% to 8 % of total melting process of furnaces.

In Bangladesh around 140 number steel mill use steel melting process in the furnaces. During melting in furnaces, slag removal rate is around [6%-8%] which means, If Bangladesh has a consumption of 4 million Ton of Steel, then half of mill produce their product by melting process at induction furnace followed by ladle refining furnace & EAF which is around 2 million ton. During this melting process slag are removed in different roots of production of steel.
If furnaces melt around 2 million ton of scrap metal, then the Slag removal rate will be in a range of = 6% of 20,00000MT= 1, 20,000 MT/Y to
= 8% of 20,00000MT= 1, 60,000 MT/Y
But in the real situation, slag production rate is relatively more due to lack of refining process.
So, 1, 20,000-1, 60,000 MT of steelmaking slag is presently produced in Bangladesh per annum.

Total production capacities of all steel mills are around 8 million ton per annum, [IDLC, 2013]. If steel industry increase their production, slag removal also increased by 2, 40,000 MT to 3, 20,000 MT per annum, if we consider removal rate 6 % to 8 % of total melting.

6. COMBINATION OF EROSION PROTECTION OPTIONS

Combining hard and soft solutions is sometimes necessary to improve the efficiency of the options and provide an environmentally and economically acceptable coastal protection system. A planned retreat where the coast is left to erode can be expensive, unnecessary and sometimes impossible, especially in highly modified environments such as tourism areas and waterfront cities. To optimize the long-term positive impact of soft solutions, many combinations with hard solutions can be selected; combining beach nourishment and artificial headlands/groins and revegetation and temporary offshore breakwaters/artificial reefs that act as interim hard structures is the most common approach. But if we combine a new technology which is made from recycled material like steel slag can be an alternative way of sustainable use of industrial waste. Ferroform block as a sea wall & slag reef block as an underwater sea forest creation can be effective way to protect the marine drive.

7. FERROFORM –A NEW TECHNOLOGY FROM STEEL MAKING SLAG

7.1 Manufacturing Process

In Ferroform, steelmaking slag is used instead of the fine and coarse aggregates in concrete, and ground granulated blast-furnace slag (granules of molten blast-furnace slag obtained through a process of quenching, grain refining, drying and pulverizing), fly ash, and alkali activator (lime dust, slaked lime, cement, etc.) are employed instead of the cement in concrete. Of these materials, steelmaking slag, ground granulated blast-furnace slag, and water are essential. If recycled water is used, Ferroform can be manufactured entirely from recycled materials. Ferroform is manufactured by mixing, placing and curing these materials. Since this process is the as the same as with concrete, concrete manufacturing equipment can be use as is without modification.(Fig.1)shows an example of the composition of Ferroform in comparison with that of normal-weight concrete.

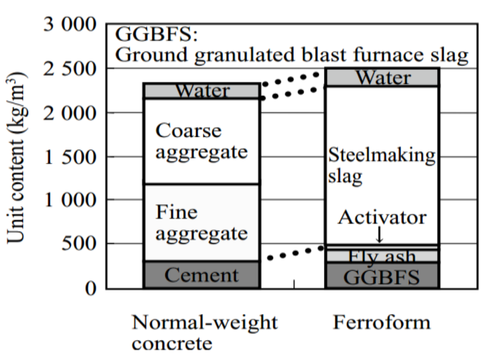

Figure1: Comparison between Normal-weight Concrete and Ferroform (Source: JFE Tec. report)

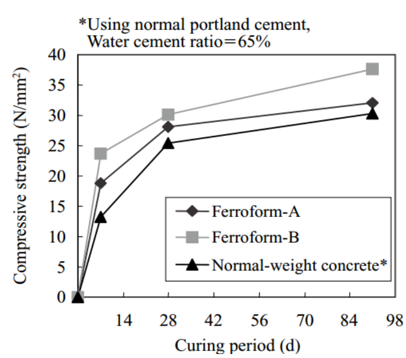

Figure 2: Relation between Compressive strength and the curing period (Source: JFE Tec. report)

7.2 Strength and Density

The mixture proportions of Ferroform shown in (Table-1) and the relationship between the compressive strength of Ferroform and its curing period is shown in (Fig.2) Like concrete, the strength of Ferroform increases with age, most probably because the curing reaction of ground granulated blast-furnace slag and fly ash, which are binder materials, continues over an extended period. It is commonly known that the compressive strength of concrete is correlated to water cement (w/c) ratio .The compressive strength of Ferroform can be controlled in the same way as with concrete, using the mixing proportions of its materials (ground granulated blast-furnace slag, fly ash, alkali activator, and water) as indicators .The compressive strength of Ferroform can be designed up to around 35 N/mm² at age of 28 days. This level of strength corresponds to that of normal-weight concrete and semi-hard stones. The mechanical properties of Ferroform, such as tensile strength, flexural strength, Young's modulus, and abrasive coefficient, also are correlated with its compressive strength in the same way as with concrete. These properties of Ferroform are shown in (Tabel-2) below. The tensile strength, flexural strength and other strength values indicated in the table are those measured at a compressive strength of 24 N/mm2, which is the common proportioning strength of blocks. Because the values of tensile strength, flexural strength and Young's modulus of Ferroform are on the same level as those of concrete, its design strength can be the same as with concrete. In addition, as steelmaking slag, which has a higher density than natural aggregates (density in saturated surface-dry condition: 2.8–3.6 g/cm³ for steelmaking slag; 2.7–2.8 g/cm³ for natural aggregates), is used as a material for Ferroform, it has a greater mass per unit volume than concrete, being 2.4 to 2.6 t/m³ for the standard mixture as compared with 2.3 t/m³for normal-weight concrete. This feature of Ferroform is very advantageous when used in dynamic structures for marine applications, as it can provide excellent stability against wave in coastal environments.

Table 1: Mixture proportions of Ferroform (Source: JFE Tec. report)

Number	Slump (cm)	Air (%)	Unit content (kg/m³)						Water reducing agent (g/m³)
			Water	GGBFS	Activator		Fly ash	Steel-making slag	
					CH	NP			
A	17.5	2.2	202	300	0	50	97	2 019	2 682
B	19.5	2.8	187	300	0	50	130	2 019	4 796
C	—	2.0	173	413	0	83	83	1 920	5 780
D	22.0	3.0	186	371	37	0	273	1 527	2 700
E	18.0	3.1	245	420	42	0	210	1 470	2 520

GGBFS : Ground granulated blast furnace slag
CH: Calcium hydroxide NP: Normal Portland cement

Table 2: Comparison of various properties between
Ferroform and normal-weight concrete (Source: JFE Tec. report)

Item	Ferroform	Normal-weight concrete
Young's modulus* (kN/mm²)	24	25
Tensile strength* (N/mm²)	2.2	1.9
Flexural strength* (N/mm²)	4.0	3.4
Abrasive coefficient** (cm³/cm²)	0.04	0.09
Density (t/m³)	2.4–2.6	2.3
Median pore size (µm)	0.02	0.09

8. SEAWALL & SEA FOREST CREATION -A PRACTICE FROM JAPAN

8.1 Ferroform as a seawall:

A large slope protection blocks of Ferroform, each having dimensions of 1000 mm×1000 mm×200 mm, were used in a seawall construction project in the area of JFE Steel's Kurashiki District, West Japan Works (construction period: 2005 to 2006). About 12, 000 blocks were manufactured in four months by vibration and pressure forming and steam curing in a plant. The formability of these blocks was identical to those of concrete. As can be seen below the finished blocks were installed on the face of the slope of the seawall extending for a total length of 1500 meter (m). As this example reveals, mass production of large Ferroform products is also possible using the vibration and pressure forming process.

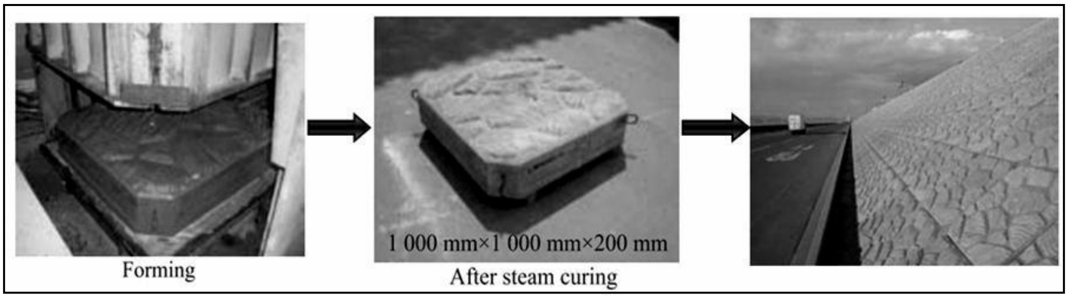

Figure 3: Production and execution of seawall construction using Ferroform blocks

8.2 Ferroform as a slag reef block to form a sea forest:

At the Wakayama Steel Works, NSSMC is carrying out a test using converter slag reef blocks in a reef habitat for fish. In October 2008, 12 converter slag reef blocks (each weighing 7 tons) were sunk in the coastal area of Shimizu-ura, Kainan City in Wakayama Prefecture. Since then, they have observing the changes in the distribution of marine life, attached sea creatures, fish, and shellfish. The results of observations made in April 2010 showed that the converter slag reef blocks tended to have more types and quantity of seaweed and attached sea creatures than the crushed stone blocks that were used for comparison. Benefits of the reef block are

- Attenuate the waves that accompany cyclones and tsunamis.
- Provide an amenity and a source of food, materials and for marine habitat.
- Allowing seaweed absorbed CO^2 to grow up in the "sea forests".

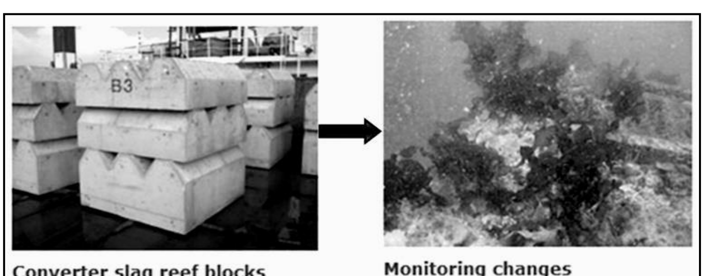

Figure 4: Converted slag reef block installation & its monitoring over period

9. PRESENT SITUATION & FUTURE RESEARCH OPPORTUNITY

There is no comprehensive industry statistics on slag produced versus slag utilized in Bangladesh. Most of the cases landfill is the main solution for all these steel industries. Reuse of this slag as "Ferroform" & "slag reef-block" can be a good solution for erosion control measure along Cox's bazaar marine drive. This sector can be profitable for both industrial & resource recycling through future research work in Bangladesh. Proper research facility, funding and R&D activity should take place for a better understanding of recycled material use for the protection of marine drive.

10. CONCLUSION

Coastal erosion and accretion are natural processes; however, they may become a problem when exacerbated by human activities or natural disasters. Three main conclusions can be drawn on combating coastal erosion along cox's bazar marine drive.

- Marine-Drive Road 2nd phase of the project was not designed considering the assumed Climate Change result up to 2030. Geo-textile bags filled with sand, which is temporary solution of this project. It needs permanent structure to protect the marine drive. The project could learn from international best practices of recycled material's uses for an effective technical & economic solution.

- A heavy and permanent protective works like, sea wall is necessary for the sustainability of the road. If we use recycled material steelmaking slag, which have a huge disposal at our steel industries can optimize the cost of the seawall block. If our researcher come forward & make a real-time effect on these techniques at their laboratory, this can be a huge opportunity for our country to practice of recycled materials.

- A rigorous scientific design study is required for the sustainability for the marine drive road. For the third phase, climate change and disaster risk reduction issue needs to be addressed. . It should be well protected from sea erosion, which although would larger amount of investment, but a combine solution like sea forest creation by "slag reef block" along the shoreline with a hard structure like "ferroform" seawall can optimize the total environmental & economic cost of this project.

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