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Cement-Bentonite Cut Off Walls: A Comparison of the Hebron and Hibernia Bund Wall

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ABSTRACT

The Hebron Project is currently underway in Newfoundland and is expected to provide significant benefits to the province. The Hebron oil field is located in the Grand Banks offshore the island of Newfoundland. The field will be developed by a Gravity Based Structure (GBS) designed to hold 1.2 million barrels of crude oil and a Topsides deck that will contain living amenities and drilling and production capabilities.

Similar to the Hibernia platform constructed in the 1990s, construction of the Hebron GBS will begin in a dry dock in Great Mosquito Cove then will be towed to a Deep Water Site (DWS) nearby for completion. The platform will be completed by mating the GBS and the Topsides module and then towed to the field for installation.

In the past, Hibernia had a Bund Wall across Great Mosquito Cove constructed of an inner and outer rock berm with impervious till in between to create the dry dock. Initially, Hebron considered using rows of sheet piles or a type of rock berm across Great Mosquito Cove to restrict water from flooding the dry dock. However, the dry dock is currently fabricated by a large embankment dam (the Bund Wall) consisting of several sizes of crushed stone and a cement-bentonite cut off wall in the center.

The cement-bentonite cut off wall is made of a slurry that hardens to form a low permeability wall in the center of the Bund Wall. The implementation of this cut off wall provided savings in material volumes and decreased the water seepage flow rate into the dry dock. The amount of material required for the Hebron Bund Wall was approximately a third of the volume used for Hibernia and the water seepage into the drydock was decreased by a minimum of 50% compared to Hibernia.

This paper investigates the benefits of a cement-bentonite cut off wall through a comparison of the Hibernia and Hebron Bund Wall.

1 INTRODUCTION

The Hebron oil field was discovered offshore Newfoundland and Labrador (NL) in 1981 in the same area as the Hibernia field. It is located approximately 340km east-southeast of St. John's, NL (figure 1). The oil field is estimated to have 400-700 million barrels of recoverable resources, which will provide substantial benefits to the province.

Figure 1 - Location of the Hebron Oil Field [1]

The development of the Hebron oil field will be completed using a Gravity Based Structure (GBS) that will support the Topsides which includes drilling and production capabilities, as well as living amenities. Similar to Hibernia, the Hebron GBS will be constructed at the Bull Arm site in Great Mosquito Cove. GBS construction begins in the dry dock area (Great Mosquito Cove) then the partially completed GBS is towed out to the Deep Water Site (DWS) for completion and mating with the Topsides. After mating, the completed platform is towed to its permanent location in the Jeanne d'Arc Basin.

For construction to begin, a dry working area large enough for the GBS must be created by designing and implementing a Bund Wall to enclose the inner cove. After the Bund Wall is constructed, the enclosed area is dewatered and kept dry with the use of pumps. During Hibernia, the Bund Wall consisted of an inner and outer rock berm with an impervious till as the center. For Hebron, two types of walls were considered: rows of sheet piles or a type of rock berm [1].

2 THE HEBRON GBS

The overall diameter of the GBS will be approximately 130m with a height of 120m. The exterior wall of the GBS is the ice wall; this is designed to serve as protection from the conditions of the permanent site (i.e. icebergs, sea ice). The GBS consists of seven cells (caissons) with a single shaft in the center (figure 3). The seven cells will contain the crude oil and the shaft will include 52 well slots and support the Topsides. The storage capacity of the GBS will be 1.2 million barrels (190,000m^3).

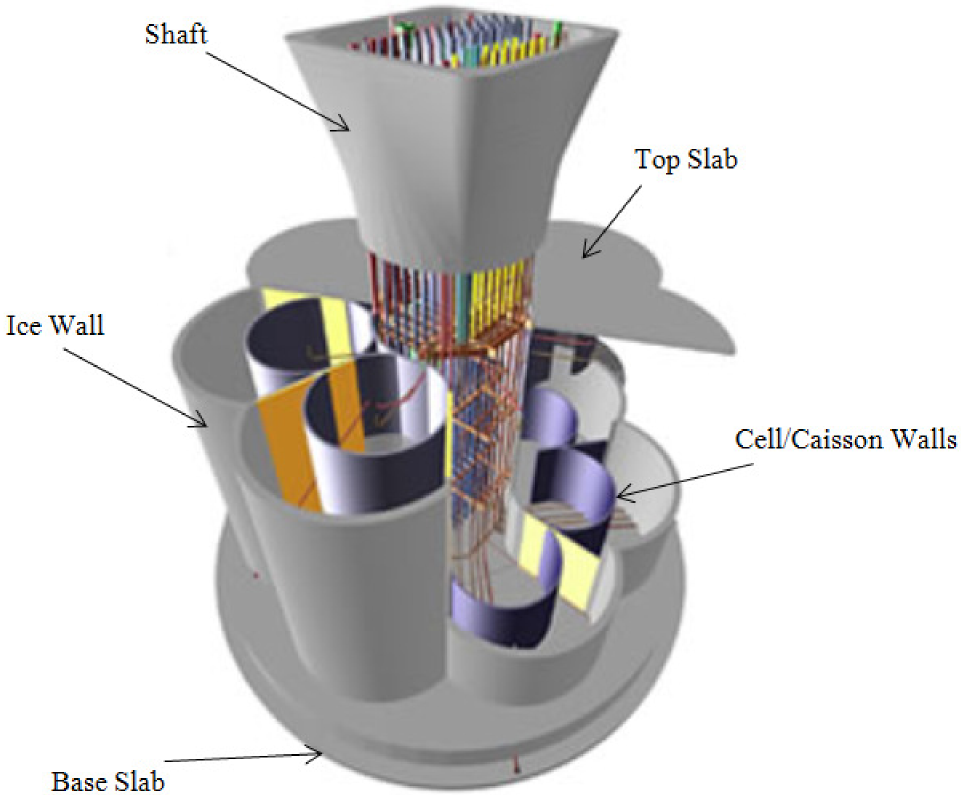

Figure 3 - Hebron Gravity Based Structure [3]

The construction of the GBS begins at the Bull Arm site in the dry dock until it has reached a specified height. Therefore, the Bund Wall must create a dry space large enough to accommodate the diameter of the GBS (130m). Following dry dock construction, the Bund Wall is removed and the dry dock is flooded. After this, the GBS is towed to the DWS for completion and the Topsides is bolted to the shaft and the completed Hebron platform will be towed to its permanent location and installed at an approximate water depth of 93m [3].

3 BULL ARM SITE

The Bull Arm site is located approximately 150km northwest of St. John's, NL, in the south end of Trinity Bay. The location was selected because it provides shelter for the construction area and has sufficiently deep water for construction at the DWS [2]. The site consists of two GBS construction areas - the dry dock and the DWS.

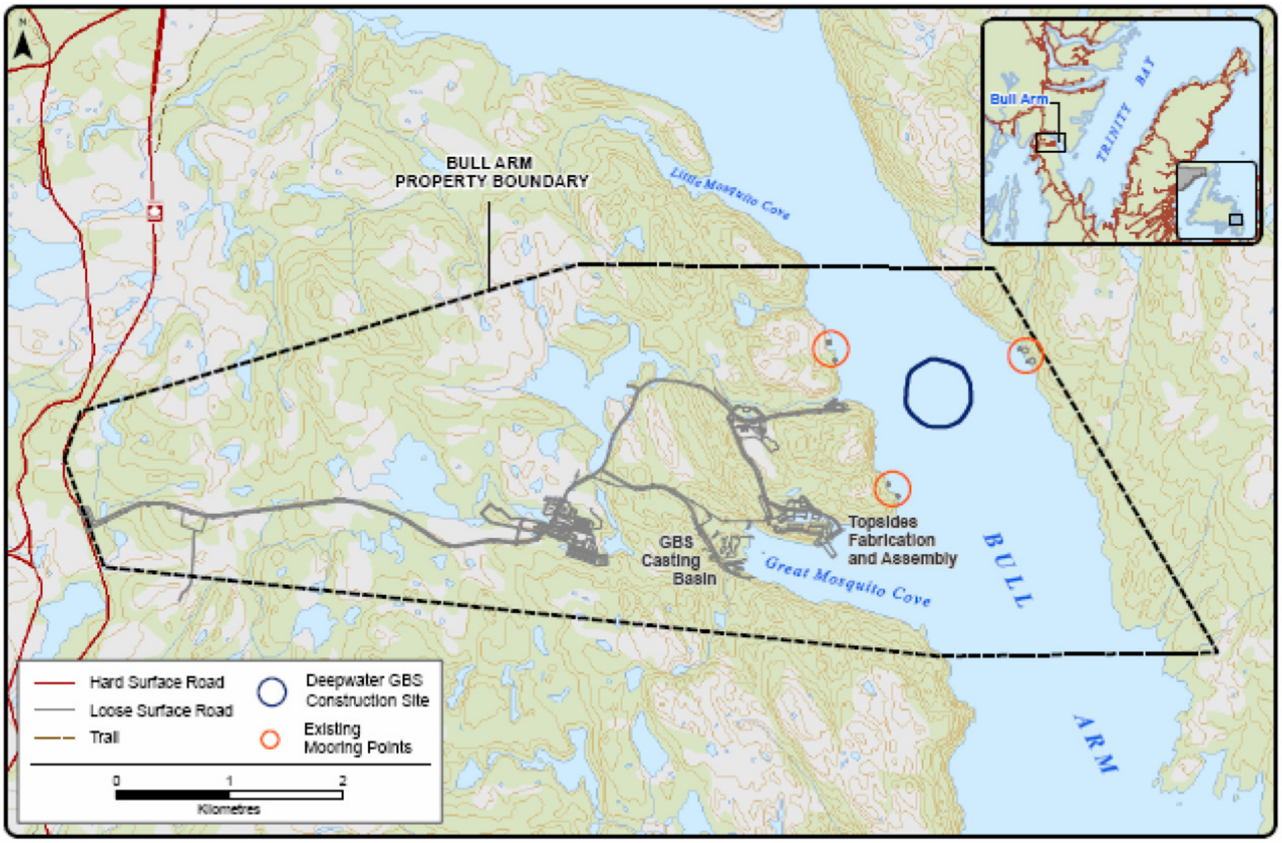

Figure 2 - The Bull Arm Site Construction Areas [1]

The dry dock site is located in Great Mosquito Cove (figure 2) which has an average width of 500m and a length of 1.5km [1]. The Bund Wall encloses an area with an approximate diameter of 180m and water depth of 16.5m [1] which will be dewatered to create the dry working area. The DWS is located in Bull Arm, as shown above on figure 2, and has an approximate water depth of 180m [1].

4 THE BUND WALL

Initially, the Hebron project considered two options for the Bund Wall: a sheet pile wall or a form of rock berm [1]. A sheet pile wall could be an advantageous option for the Hebron GBS project due to easy installation/removal and the ability to reuse materials. However, similar to the Hibernia project, this option was not selected due to the rocky floor of the cove [2] which would have proven difficult for sealing the bottom of the sheet pile wall. The selected design was similar to the concept of the Hibernia Bund Wall which included an inner and outer rock berm with an impervious fill in the center.

The Hebron Bund Wall was mainly constructed of 3/4" and 4" aggregate with a cement-betonite slurry in the center for a low permeability cut off wall. Riprap extends over 1 meter above the top of the wall and approximately 2 meters below the low water level to act as wave protection. The riprap consists of durable rock fragments and runs along the length of the wall facing the water.

4.1 Cement-Bentonite Cut Off Wall

The cut off wall is embedded in the 3/4" aggregate which serves as a semi impervious area during the placement of the slurry wall. The cut off wall is made from a mixture of Wyoming-type bentonite, Portland cement (type GU) and ground slag. These materials each have properties that influence the overall mix:

- Wyoming bentonite is a highly absorbent clay that can absorb up to ten times its own weight in water and swell up to 16 times its original size [4].
- Type GU Portland cement is general purpose cement that is used when the properties of other specialized cements are not required. The combination of cement and bentonite allows for the mixture to set and form a rigid barrier against the flow of water [5].
- Ground slag is an additive that causes the slurry to harden and decreases the hydraulic conductivity of the mixture. The addition of ground slag is anticipated to decrease the permeability to $1x10^{-9}$ cm/s from $1x10^{-6}$ cm/s (without slag).

The combination of these materials result in a slurry that will harden to form a low permeability cut off wall, with a compressive strength of approximately 20MPa, to prevent water from entering the GBS construction area. The thickness of the cut off wall is based on design requirements to resist hydrofracturing, cracking and erosion as well as the width of the clamshell bucket to be used for the excavation of the cut off wall.

Considering the bedrock in the location of the Bund Wall is fairly pervious, the cut off wall must extend into the bedrock when possible. When the bedrock is inaccessible, the cut off wall will simply extend into the original till a minimum of 1 meter. It is also possible cracks in the rock foundation could allow water to enter the dry dock, therefore it is necessary to perform foundation grouting to decrease its permeability. This is done by pumping grout into holes drilled in the rock [6].

5 COMPARISON OF HIBERNIA AND HEBRON BUND WALL

Considering the similarities between the Hibernia and Hebron projects, the success of implementing a cement-bentonite cut off wall can be assessed by comparing each Bund Wall. The anticipated seepage and total material volume for each project's Bund Wall are summarized in Table 1 below.

Table 1 - Hibernia and Hebron Bund Wall Comparison

	HIBERNIA	HEBRON
Anticipated Seepage	1000 - 10,000 L/min	380 - 750 L/min
Total Material Volume	680,000 m^3	213,000 m^3

It is evident from Table 1 that the Hebron project designed and constructed a Bund Wall in the same location as the Hibernia Bund Wall with a lower seepage rate and significantly less material. The estimated seepage rates for the Hebron Bund Wall are lower than Hibernia and have a much smaller range. This is due to the cement-bentonite cut off wall in the center of the wall. The permeability of the Hibernia Bund Wall was on the lower end of the expected range with a seepage rate of 1600L/min [2]. This value is twice as large as the highest seepage rate expected for the Hebron Bund Wall. In addition, the Hebron Bund Wall used approximately one third the material volume of the Hibernia Bund Wall which could be partially attributed to the use of the cement-bentonite cut off wall. For the Hibernia Bund Wall 280,000m^3 of till was used as an impervious core [2] compared to approximately 700m^3 of cement-bentonite for the Hebron Bund Wall.

6 CONCLUSION

The implementation of a cement-bentonite cut off wall in the center of the Hebron Bund Wall was quite effective in maintaining a dry working area for the first phase of GBS construction. The cut off wall minimized the amount of material required for the Bund Wall and provided low seepage rates after it was completed. Therefore, the use of cement-bentonite slurry walls could potentially reduce overall construction costs. The reduction in material also reduces labour costs associated with placing the material and transportation costs. Also, the low seepage rate after construction reduces the number of pumps required throughout the life of the dry dock. In conclusion, cement-bentonite cut off walls can be an excellent and cost efficient alternative in the development of dry docks.

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