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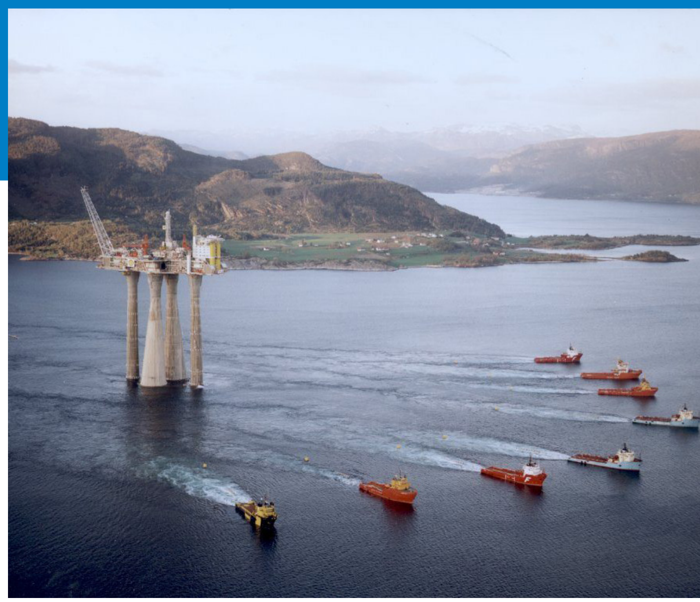

Offshore and Marine Concrete Structures: Past, Present, and Future

SP-337

Editor:
Mohammad S. Khan

American Concrete Institute
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Offshore and Marine Concrete Structures: Past, Present, and Future

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PREFACE

Offshore and marine concrete structures have not received enough attention in the recent past, at least in the United States. The complexity and safety concerns associated with these structures are such that they probably need more attention compared to many other types of concrete structures. Also, offshore and marine concrete structures are so global in nature that there is a higher need for better coordination and synchronization of design, construction, inspection, and maintenance practices in different parts of the world.

A two-part session, titled "Offshore and Marine Concrete Structures: Past, Present, and Future," was held at the Spring 2019 ACI Concrete Convention and Exposition on March 24-28 in Quebec City, Quebec, Canada. The session, sponsored by ACI Committee 357, Offshore and Marine Concrete Structures, highlighted accomplishments of the past, current state-of-the-practice, and a path for the future. This ACI Special Publication (SP) is a compilation of select papers presented at the session. The efforts of all the reviewers in assuring the quality of this publication is greatly acknowledged.

Mohammad S. Khan, Ph.D. P.E.
Editor

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Design and Construction Overview of Offshore Concrete Gravity-Based-Structures: Past, Present, and Future

Widianto, Jameel Khalifa, Erik Åldstedt, Kåre O. Hæreid, Kjell Tore Fosså

Synopsis: An offshore concrete Gravity-Based-Structure (GBS) is a massive concrete structure placed on the seafloor and held in place strictly by its own weight, without need for anchors. This paper focuses on concrete GBSs used as the base of integrated oil drilling and production platforms. The summary of key distinct structural features of several major GBSs, since the first Ekofisk GBS (installed in the North Sea, offshore Norway, in 1973) until the latest Hebron GBS (installed in the Grand Banks, Canada, in 2017), is presented. This paper also discusses several unique loads that GBSs have to resist. An overview of structural analysis and design methodology is described in detail. Key considerations for preliminary sizing of GBS structural components are presented. Typical construction phases, methods, and the importance of constructability are explained. Finally, potential future research topics that would result in a more cost-effective offshore concrete GBS are discussed.

Keywords: Floating Construction, Reinforced Concrete Design, D-regions, Structural Analysis, Offshore Structures, Strut-and-tie, Wave loads

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INTRODUCTION

An offshore concrete Gravity Based Structure (GBS) is a massive concrete structure placed on the seafloor and held in place strictly by its own weight, without need for piles or anchors. This paper focuses on concrete GBSs used as the base of integrated oil drilling and production platforms (topsides). The topsides typically includes drilling, production, processing, and accommodation facilities. Table 1 provides a summary of key distinct structural features of several major GBSs, starting with the first, Ekofisk GBS (installed in the North Sea, offshore Norway, in 1973), until the latest Hebron GBS (installed in the Grand Banks, Canada, in 2017). Several major GBSs are also shown in Figure 1.

General Characteristics

In contrast to typical buildings and bridges, there are several distinct features of offshore GBSs that pose unique challenges in the structural analysis, design and construction:

- They are typically massive in size, have a complex geometry and contain a significant number of "Disturbed" or D-regions. Typical examples of D-regions are locations with abrupt changes in dimensions (change in thickness or an opening in a wall), locations where concentrated loads are applied (such as post-tensioning anchorages), or deep beams where simple beam theory does not apply.
- The structural elements are heavily loaded and highly reinforced, with average reinforcement density of over 300 kg/m^3 (19 lb/ft^3) compared to 75-150 kg/m^3 (5-9 lb/ft^3) for typical buildings and bridges. This is partly because the member thicknesses have to be limited to minimize GBS weight to allow it to float during the various construction and installation phases.
- They contain many access openings and pipe penetrations that require additional reinforcement around them to replace the reinforcement interrupted by these openings. This further increases the local reinforcement density that can be as high as 600 kg/m^3 (37 lb/ft^3).
- They are typically located in harsh climates leading to enormous wave loads (>1,000 MN (225,000 kip)) and sometimes ice/iceberg impact loads (>500 MN (112,000 kip)).
- Some GBSs also have a requirement to store oil, hence be leak-tight. This subjects many structural members to large differential pressures and temperatures that requires post-tensioning and other