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Original Article

Effects of No Stiffness Inside Unbonded Tendon Ducts on the Behavior of Prestressed Concrete Containment Vessels

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ABSTRACT

The numerical simulation methodologies to evaluate the structural behaviors of prestressed concrete containment vessels (PCCVs) have been substantially developed in recent decades. However, there remain several issues to be investigated more closely to narrow the gap between test results and numerical simulations. As one of those issues, the effects of no stiffness inside unbonded tendon ducts on the behavior of PCCVs are investigated in this study. Duct holes for prestressing cables' passing are provided inside the containment wall and dome in one to three directions for general PCCVs. The specific stress distribution along the periphery of the prestressing duct hole and the loss of stiffness inside the hole, especially in an unbonded tendon system, are usually neglected in the analysis of PCCVs with the assumption that the duct hole is filled with concrete. However, duct holes are not small enough to be neglected. In this study, the effects of no stiffness inside the unbonded tendon system on the behaviors of PCCVs are evaluated using both analytical and numerical approaches. From the results, the effects of no stiffness in unbonded tendons need to be considered in numerical simulations for PCCVs, especially under internal pressure loading.
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1. Introduction

Reactor containments might be subjected to high internal pressure under severe conditions such as a loss-of-coolant accident. As a final barrier, the containments have to prevent radioactive materials that can seriously damage public health and welfare from being released to the external environment. Therefore, a containment must be able to sustain its function for its life time.

Most of the containments built in recent decades are of the prestressed concrete containment vessel (PCCV) type. For as long as PCCVs have been designed, built, and monitored, there have been continuous discussions on technical issues including pros and cons between bonded and unbonded tendon solutions in post-tensioning. An important issue under discussion is the reliability of analysis methods and tools to verify design criteria and lifetime behaviors of PCCVs. The methodology to evaluate structural integrity of PCCVs using numerical simulation has been substantially developed with the help of the rapid growth in computational technology [1–5].

However, several issues remain to be investigated closely to narrow the gap between tests and numerical simulations. For example, a numerical analysis to simulate the test results obtained from the structural integrity test (SIT) for a PCCV expected smaller displacements than the measured ones by > 20% at some locations, even though the state-of-the art numerical simulation methodology was used [1]. The gaps of displacements between the SIT and the numerical simulation were relatively high, especially in geometrically noncontinuous regions such as near buttress and near penetrations. Similar gaps between tests and simulations have been reported in previous studies such as International Standard Problem on Containment Integrity (ISP) 48 [2,3].

Studies to improve the methodology to simulate structural behaviors of PCCVs, especially under internal pressure, to minimize the gap between tests and simulations have been performed.

In previous studies, the gaps between displacements from the SIT for a PCCV and displacements from the numerical analyses simulating the test were found to be reduced under consideration of no stiffness effects inside unbonded tendon ducts [4,5].

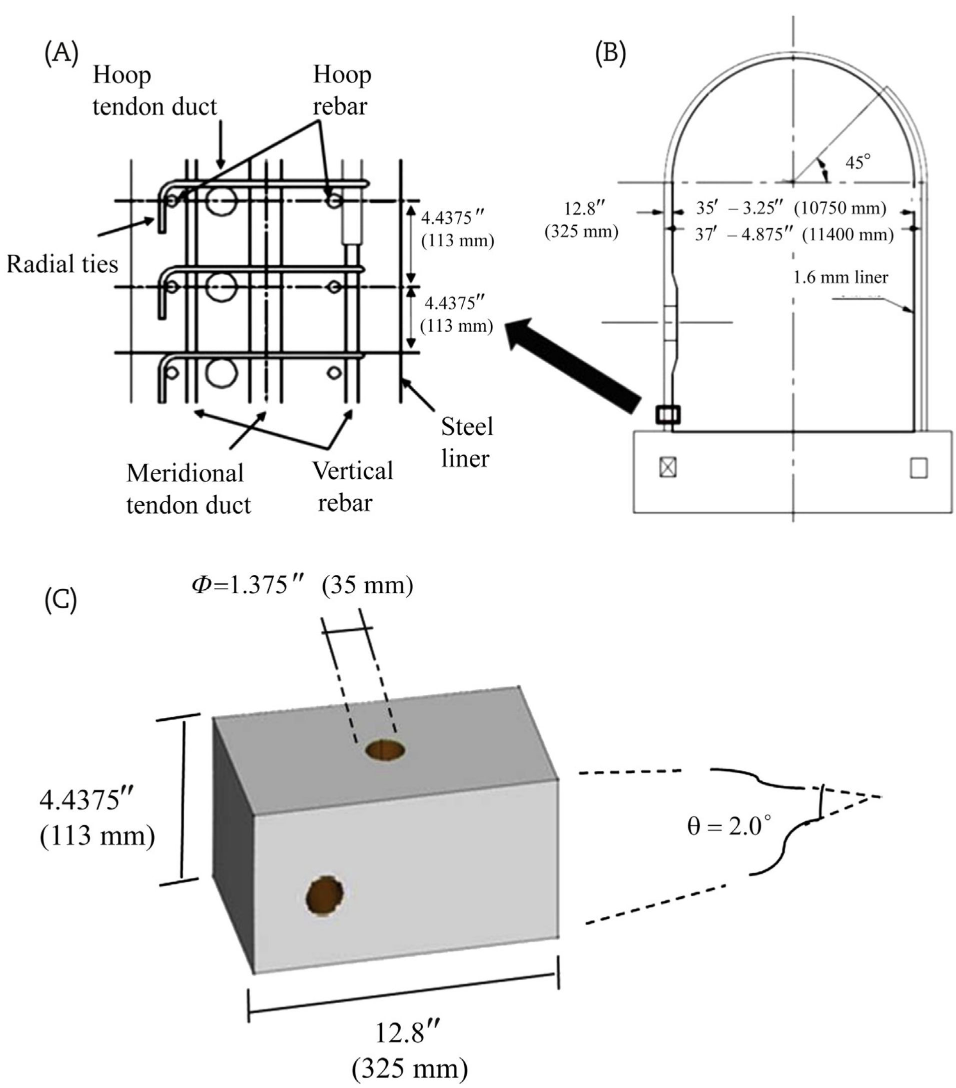

Fig. 1 – The 1:4 scale PCCV model. (A) Typical wall section. (B) 1:4 scale model section. (C) Unit pattern of tendon ducts arrangement in wall. PCCV, prestressed concrete containment vessel.

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