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จุฬาลงกรณ์มหาวิทยาลัย

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรดุษฎีบัณฑิต

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ลิขสิทธิ์ของจุฬาลงกรณ์มหาวิทยาลัย

DEVELOPMENT OF CEMENT-BASED ULTRA-HIGH STRENGTH CONCRETE

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The utilization of high strength concrete in the modern construction has lead to the remarkable benefits in duration and economics. Toward the workability to assure its strength and performance, the production of concrete with compressive strength greater than 150 MPa is still challenging. The primary objective of this research is to produce such an ultra-high strength concrete by using the commonly-used concrete making materials with the conventional practice.

The compressive behavior of concrete is firstly simulated by finite element analysis of triangular basic element. Aggregate particles are randomly generated in bulk matrix with interface. The constitutive relations of each phase are described by using smeared crack concept, on the basis of fictitious crack model. The principal properties of each material component significantly govern the concrete properties and performance. The internal structure of each concrete ingredient, i.e., cement, pozzolanic materials, as well as fine and coarse aggregate, would then be investigated physically, chemically and/or mechanically. The appropriate mix proportion for ultra-high strength concrete is determined by minimizing porosity to obtain the highest strength of proper flow for workable. To obtain this, the optimum water/cement ratio, the suitable addition of pozzolanic materials, and the selection of well-distributed high-strength aggregate are found as the keys. Strength-based gradation, which is also developed in this research, is considered as an influential indicator to qualify the potential coarse aggregate on packing intensity and load-carrying capacity.

The eight-step mix design procedure for ultra-high strength concrete is presented. The compressive strength of concrete is calculated by multiplying cement paste compressive strength, which is a function of water/cement ratio, by the coefficients associated with the existence of aggregate and pozzolans. Flowability of the mix is facilitated by using free water concept. With this procedure, a concrete with compressive strength up to 188.30 MPa at 28 days and 203.48 MPa at 91 days can be produced.

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การใช้คอนกรีตกำลังสูงก่อให้เกิดผลดีอย่างมากในการก่อสร้างสมัยใหม่ ทั้งในเรื่องของระยะเวลาการก่อสร้างและค่าใช้จ่าย การผลิตคอนกรีตที่มีกำลังรับแรงอัดสูงเกินกว่า 150 เมกะปาสคาลที่มีความสามารถในการทำงานได้ดี และสามารถประกันคุณภาพได้ยังคงเป็นเรื่องที่ท้าทาย ดังนั้น งานวิจัยนี้จึงมีจุดประสงค์หลักในการออกแบบส่วนผสมสำหรับคอนกรีตกำลังสูงมาก โดยใช้วัสดุผสมคอนกรีตที่หาได้ทั่วไปและวิธีการทำงานที่ใช้อยู่ตามปกติ

ความเป็นไปได้ของการผลิตคอนกรีตกำลังสูงมากนี้ได้ทำการศึกษาโดยการจำลองพฤติกรรมการรับแรงของโครงสร้างภายในคอนกรีตด้วยวิธีวิเคราะห์แบบไฟไนต์เอลิเมนต์ (Finite Element Analysis) โดยกำหนดชิ้นส่วนพื้นฐานเป็นรูปสามเหลี่ยม อนุภาคของมวลรวมถูกวางแบบสุ่มในวัสดุประสานโดยมีผิวสัมผัส ภายได้หลักการของรอยร้าวจำลอง (Fictitious Crack) และการกระจายรอยร้าวทั้งชิ้นส่วน (Smearred Crack) ในการอธิบายพฤติกรรมการรับแรงของชิ้นส่วนวัสดุ ซึ่งสามารถระบุคุณสมบัติพื้นฐานของส่วนประกอบของคอนกรีตเพื่อให้ได้สมรรถนะตามต้องการ จากนั้น ได้ทำการศึกษาคุณสมบัติของส่วนประกอบต่างๆ ของคอนกรีต อันได้แก่ ซีเมนต์ วัสดุปอชโซลาน มวลรวมละเอียดและมวลรวมหยาบ ทั้งทางกายภาพ ทางเคมี และ/หรือ ทางกล ส่วนผสมของคอนกรีตกำลังสูงมากจะพิจารณาจากหลักการปริมาณช่องว่างน้อยที่สุด เพื่อที่จะก่อให้เกิดกำลังรับแรงที่สูงที่สุด โดยมีการไหลอย่างเพียงพอ ซึ่งการใช้วัสดุปอชโซลานในปริมาณที่เหมาะสม และการคัดเลือกมวลรวมที่มีขนาดละเอียดและความสามารถในการรับแรงที่ดีจะเป็นกุญแจสำคัญ ดัชนีขนาดละเอียดกำลัง (Strength-Based Gradation Index) ซึ่งได้พัฒนาขึ้นในงานวิจัยชิ้นนี้ สามารถบ่งบอกศักยภาพของมวลรวมหยาบในการผลิตคอนกรีตกำลังสูงมากได้อย่างดีทั้งในเรื่องของความหนาแน่นในการจัดเรียงตัวและกำลังรับแรง

งานวิจัยนี้ยังได้เสนอ 8 ขั้นตอนการออกแบบคอนกรีตกำลังสูงมาก โดยกำลังรับแรงคอนกรีตสามารถคำนวณได้จากการคูณกำลังรับแรงของซีเมนต์เพสต์กับสัมประสิทธิ์เนื่องจากมวลรวมและวัสดุปอชโซลาน โดยที่ กำลังรับแรงของซีเมนต์เพสต์นี้เป็นสัดส่วนกับอัตราส่วนน้ำต่อซีเมนต์ หลักการนำอิสระได้นำมาใช้ในการปรับแก้การไหลของคอนกรีต จากวิธีการออกแบบที่นำเสนอนี้สามารถผลิตคอนกรีตที่มีกำลังรับแรงได้ถึง 188.30 เมกะปาสคาลที่อายุ 28 วัน และ 203.48 เมกะปาสคาลที่อายุ 91 วัน

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