RECYCLED AGGREGATE CONCRETE IN CHINA: FROM LABORATORY WORK TO ENGINEERING PRACTICE

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I am very sorry that I myself could not come to France and present my research work to all the distinguished professors and experts.

Jianzhuang, Xiao
Tongji University is one of the leading universities directly under the State Ministry of Education in China. The university now registers over 50,000 students at all levels from certificate and diploma courses to Bachelors Degrees, Masters, PhD programs and post doctoral attachments. There are over 4200 academic staff for teaching and/or research. Civil Engineering is top one in China.
1 Introduction

2 Laboratory research on RAC

3 Actual practice of RAC
1 Introduction

Shenyang Wulihe Stadium
[service life: 18 years, demolish: February 12, 2007]

Hubei Shouyi Sports Training Center
[service life: 10 years; demolish: June 16, 2009]
1 Introduction

Qingdao Railway Hotel
[ service life: 16 years; demolish: January 7, 2007 ]

Five Lakes Hotel, Nanchang
[ service life: 13 years; demolish: February 6, 2010 ]
1 Introduction

Lanzhou zhongli bridge
[ service life: 13 years; demolish: July 5, 2010]

Shanghai "The first bend in Asia"
[ service life: 11 years; demolish: February 13, 2008]
1 Introduction

Wenchuan earthquake
[ Time: May 12, 2008]

Demolished waste in Wenchuan earthquake
[ Time: May 12, 2008]
1 Introduction

Yushu earthquake
[Time: April 14, 2010]

Ya’an earthquake
[Time: April 20, 2013]
1.5 billion tons cement is produced and used in China, it occupies half in the world. As a result, about 8 billion tons fine and course aggregate need to be used in concrete. In addition, many aggregate is used in the basement of pavement. So, at least, 10 billion tons aggregate is needed in China in recent years.
Outlines

1 Introduction
2 Laboratory research on RAC
3 Actual practice of RAC
2 Laboratory research on RAC

2.1 Materials

2.2 Elements

2.3 Structures
2.1.1 Recycled aggregates

Process diagram for production of RCA

Grading curve of the natural and recycled coarse aggregate

Future: Improvement and upgrading
2.1.2 Recycled aggregate concrete (RAC)

Mix proportion is different from NAC.

Complicated micro-structures
2.1.3 Interfacial transition zone (ITZ) in RAC

Nanoindentation


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2.1.4 Compressive strength of RAC

Compressive strength development rule of RAC with cure age

Relationship between the compressive strength and the mass density
2.1.4 Compressive strength of RAC

Distribution model for compressive strength of RAC
2.1.5 Tensile strength of RAC

Uniaxial tension

Flexural tension

Failure pattern of RAC prisms under uniaxial tension and flexural tension loading
2.1.5 Tensile strength of RAC

Uniaxial tensile strength as a function of RCA

Uniaxial tensile stress-strain curves of RAC with different replacement percentage

From up to down, r is 0%, 30%, 50%, 70%, 100%
2.1.5 Tensile strength of RAC

Histograms for the distribution of splitting tensile strength of RAC
2.1.5 Tensile strength of RAC

Flexural tensile strength as a function of RCA

Fracture energy as a function of water/cement ratio of RAC
2.1.6 Constitutive relationship of RAC

Un-confined

Confined


2.1.7 Strength of RAC after fire

Relative of residual compressive strength of RAC with different RCA replacement percentage

Relative of residual flexure strength of RAC with different replacement percentage


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2.1.8 FEM simulation on RAC

Simplified and modified lattice model of Real RAC
2.1.8 FEM simulation on RAC

Stress-strain relationship curve of RAC

Failure model of RAC with simulation

2.1.9 Model recycled aggregate concrete

Dimension of $150 \times 150 \times 30\text{mm}$

Test specimen

Simulation model

Modeled recycled aggregate concrete

2.1.9 Model recycled aggregate concrete


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2 Laboratory research on RAC

2.1 Materials

2.2 Elements

2.3 Structures
2.2.1 Bond-slip between RAC and rebars


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2.2.2 Shear transfer across a crack in RAC

Push-off Specimens

Cracking


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2.2.3 Flexure of RAC Beams

Test setup

Curves of load versus the mid-span deflection

Bend test and results of RAC beams
2.2.4 Shear of RAC Beams

Test setup

Curves of load versus the diagonal crack width

Shear test and results of RAC beams
2.2.5 RAC columns

failure mode of RAC columns

Load-strain relationship

Performance of RAC columns

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2.2.6 RAC slabs

Test setup

Load - relative slip curve of some composite slabs

Test setup and main load-relative slip curve of composite slabs

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2.2.6 RAC slabs

Punching behaviour of RAC slabs
2.2.7 RAC block walls

Test setup

Skeleton curve of specimens

Seismic test and results of recycled concrete block walls
2.2.8 RAC frame joints

Failure mode  
Skeleton curve of specimens

Failure mode and results of column-beam joints
2.2.9 Semi-precast RAC beams

Bending

Shearing


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2.2.10 Semi-precast RAC columns

Externally precast

Internally precast

Loading

2 Laboratory research on RAC

2.1 Materials

2.2 Elements

2.3 Structures
2.3.1 Plane frame made of RAC

Test setup  Skeleton curve  Hysteretic curve

The seismic behaviour of plane frames

2.3.2 RAC blocks building

- Frame filled with recycled concrete blocks
- Shake table test on RAC small-sized hollow block structure


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2.3.3 Cast-in-place RAC space frame

Recycled concrete frame structure

The shaking table test for RAC frame structure

2.3.4 Precast RAC space frame

The shaking table test on precast RAC space frame structure

Jianzhuang Xiao, Thi Loan Pham, Tao Ding. Shaking table test on a precast frame structure made of recycled aggregate concrete. Submitted to Engineering Structures, 2013
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1 Introduction
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3.1 RAC pavement

RAC Pavement in Tongji University, Shanghai, China, 2004

RAC Pavement in Fudan University, Shanghai, China, 2007
3.2 RAC bricks and blocks

Two-story masonry structure with RACB in Shanghai, China, 2005
3.3 RAC frame building in EXPO 2010

Shanghai ecological home located in the 2010 Shanghai World Expo park
3.4 RAC Specifications and books
3.5 RAC Specifications and books

1. Waste concrete
2. Crush and sieving
3. Mix-proportion
4. Material and mechanical behavior
5. Structure
6. Construction and inspection
Concluding Remarks

1. Research on RAC should be from recycled aggregates to recycled concrete material and then recycled concrete structures.

2. Both material science and structural technology can improve the behaviour of recycled aggregate concrete. RAC can be a structural concrete.

3. From Laboratory research work to actual practice, specification or code is necessary.

4. Some successful applications of RAC in building structures in China will be helpful to promote and popularize this kind sustainable concrete.

5. Further material studies may be focused on the long-term properties, especially in the combined environment.
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Thank you for your kind attention!

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