Concrete with Recycled Materials

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Dr. Jiong Hu has a background in Civil Engineering and Construction Materials, and has been conducting concrete and construction-related research for 16 years. Dr. Jiong Hu is a member of American Concrete Institute (ACI), Transportation Research Board (TRB), and American Society for Engineering Education (ASEE). Dr. Jiong Hu is the current secretary of ACI committee 555, Concrete with Recycled Materials; and member of ACI Committees 130, Sustainability of Concrete, 237, Self-Consolidating Concrete; 238, Workability of Fresh Concrete; and TRB Committee AFN20, Properties of Concrete. Dr. Hu also served as principle investigator (PI) and co-PI in multiple projects related to innovative concrete technology and sustainable concrete development, associated with Federal Highway Administration, Texas Department of Transportation, Iowa Department of Transportation, and Department of Defense as he worked in Texas State University, and National Concrete Pavement Technology (CP Tech) Center at Iowa State University. His research interests include advance cementitious materials, sustainable concrete, recycled concrete materials, self-compacting concrete, fresh concrete properties and rheology of concrete, Portland cement concrete pavement, non-destructive testing of concrete structure.

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Recycling Lead-Based Paint Contaminated Deconstructed Masonry Materials as Aggregate for Portland Cement Concrete – A Cost Effective and Environmental Friendly Approach

Jiong Hu, Kejin Wang, James Gaunt
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Background

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- Many U.S. structures built before 1970-1980 contained lead-based paint (LBP), which is known as a human health hazard.
- Deconstruction of these LBP-contaminated buildings has progressed at a slow rate because of high disposal costs and environmental impacts.
- More cost-effective, environmentally friendly techniques for remedying and reusing these deconstructed masonry materials are needed.

Objectives

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- To provide an effective method for deconstruction of masonry buildings with minimum environmental impact, cost, and time;
- To use the deconstructed LBP masonry materials as concrete aggregate and sequester the LBP in new concrete;
- To establish a rational mix design method for proportioning non-toxic and well-performing concrete make with the recycled, lead-contaminated aggregate.

Approach

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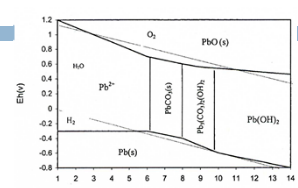
- Recycling the LBP-contaminated masonry materials as concrete aggregate with minimal processing
- Using portland and phosphate cement to sequester lead of the deconstructed masonry materials in concrete



Eh-pH diagram of an aqueous lead-carbonate system

- Degree of the hazard resulting from LBP primarily depends on the solubility of lead in the contaminated materials.
- The solubility of lead decreases with the increasing of pH value of the material.
- Portland cement concrete has a high alkalinity

Scope

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- Simulating lead-contaminated masonry materials and processing recycled aggregates
- Charactering the recycled aggregates
- Testing fresh and hardened concrete properties
- Statistical analysis of the test results
- Developing mix design nomographs
- Cost analysis

Simulating Lead-contaminated Masonry Materials from Deconstruction

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1. Collected different types of masonry materials (two types of concrete blocks and two types of clay bricks)
2. Made LBP (mixing basic lead carbonate, refined linseed oil, bodied linseed oil, and mineral spirits in a ball mill for 24 hours)
3. Painted the masonry materials with LBP
4. Crushed the lead-contaminated masonry with a jaw crusher

Monitoring Lead Concentration during Crushing – Wipe Test

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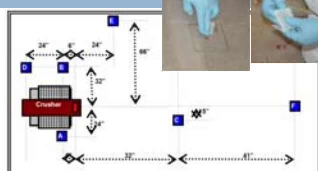

Location	Distance from crusher, in.	KimWipe ®, mg Pb/100cm²	Large Pieces, mg Pb/100cm²	Mass of Larger Pieces, g/100cm²
A	24.7	4.44	367	37.23
B	32.6	5.65	30.5	1.89
C	35.3	0.87	--	--
D	43.9	0.25	36.5	0.31
E	70.2	0.43	--	--
F	73.0	0.50	58.5	0.73

Monitoring Lead Concentration during Crushing – Personal Air Quality Monitor

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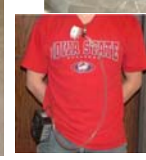
- The sample collected during an approximately three-hour, 1,000-lb run revealed an airborne lead concentration of 23.9µg/m³, which was less than the current OSHA permissible exposure limit (PEL) for lead (50µg/m³)



Characterizing Recycled Aggregate

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Properties	Concrete Block		Clay Brick	
	A	B	C	D
Specific Gravity	2.33	2.37	2.36	2.39
Bulk Unit Weight, pcf	88.55	87.85	81.45	85.43
Absorption, %	7.65	5.84	5.89	4.70
Compressive strength, psi	3056	4755	10679	14722
TCLP Pb, mg/L	4.17	1.29	142	77
Total Pb, g/Kg	15.4	10.1	12.5	5.82


Masonry A


Masonry B


Masonry C


Masonry D

TCLP Pb>5 mg/L → toxic material

Gradation and Voids of Recycled Aggregate

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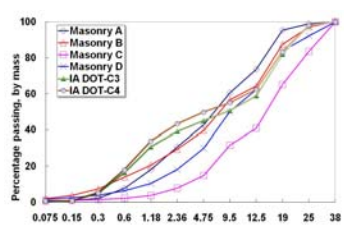

The crushed aggregates were used in concrete without any gradation modification.

	Concrete Block		Clay Brick	
	A	B	C	D
Voids in Aggregate	36.7	37.2	41.3	39.9

Cement Materials Used

Type I portland cement


Calcium sulfoaluminate (CSA) cement

Type I portland cement with 5% $CaHPO_4$

Concrete Mixing

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- 4 aggregates
- 3 cements
- 3 aggregate-to-cement ratios (3.0, 4.5, & 6.0)
- 4 workability levels (slump =1"-2", 3"-4", and 6"-7")
- Over 50 concrete mixes in total

Fresh Concrete Properties

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Slump 1"-2"


Slump 3"-4"


Slump 6"-7"

Hardened Concrete Properties

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Curing


Strength test

Depending on w/c, 28-day compressive strength of concrete made with some recycled aggregate can be over 6,000 psi.

Lead Content and Leachability of Concrete

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Total lead and pH tests

TCLP showed that most concrete samples had Pb concentration less than 5mg/L , and they should not be considered hazardous materials although the cycled aggregate is toxic.


TCLP (Toxicity Characteristic Leaching Procedure) Test

Effect of Cement Content and w/c on Concrete Strength

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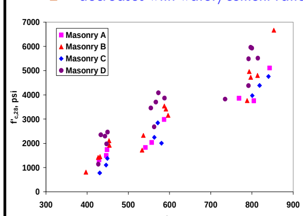
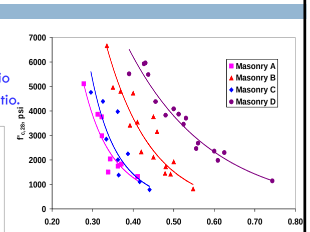
Concrete strength
- increases with cement content
- decreases with agg./cement ratio
- decreases with water/cement ratio.





Concrete made with masonry B and D had higher strengths than that made with masonry A and C.

Effect on Lead Content and Leachability

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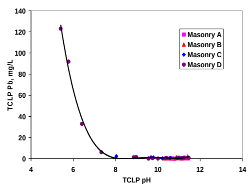

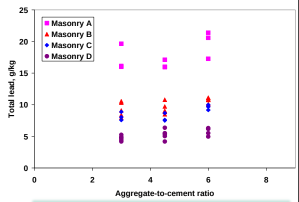

Except four concrete made with masonry material C, all other concrete samples had TCLP Pb value <5 mg/L and should not be considered as lead toxic.

Due to higher absorption of the concrete blocks, the total lead in concrete made with masonry materials A was higher than that of concrete made with clay brick (masonry materials C and D).

Statistical Analysis

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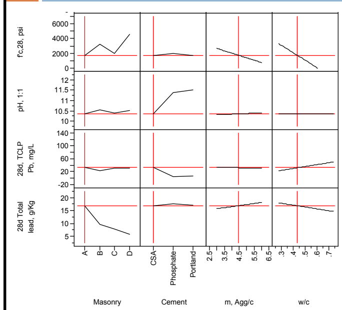

Additional Findings

- Calcium sulfoaluminate cement (CSA) cement provided concrete with higher early age compressive strength but did not affect 28-day strength.
- Addition of 5% phosphate in portland cement did not significantly change the TCLP lead concentrations and total lead in concrete. (Different amount of the addition shall be considered in future study.)

Mix Design Nomograph (MDN) Development

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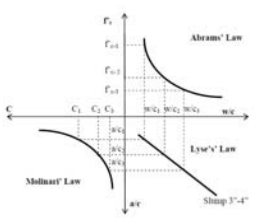
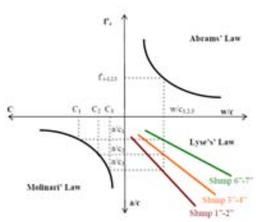
Nomographs were developed based on the test results and to be used for future mixture design of concrete with recycled LBP-contaminated aggregate.



For different strength



For different workability

MDN for Concrete with Masonry Materials A, B and Portland Cement

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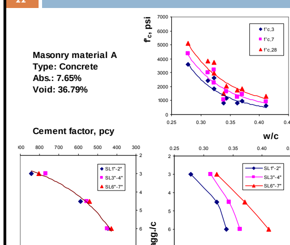

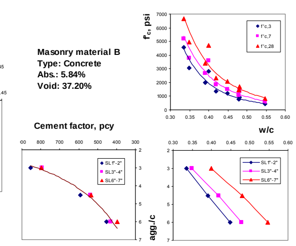

MDN for Concrete with Masonry Materials C, D and Portland Cement

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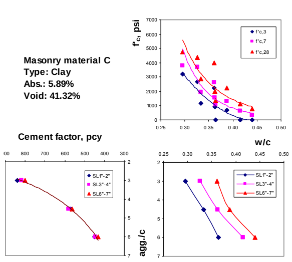

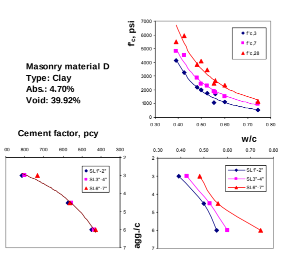

MDN for Concrete Made with Masonry B and Other Cements

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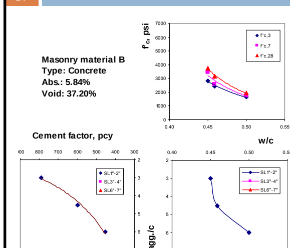
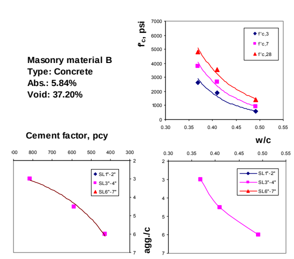


CSA Cement



Type I Cement with 5% Phosphate

Environmental Benefits

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- Use of lead-based paint contaminated masonry materials as recycled aggregate in concrete is protective of the environment and makes effective use of available resources while avoiding disposal costs.
- While most of the deconstructions of LBP contaminated masonry materials are simply disposed in a hazardous waste landfill because of the presence of unacceptable levels of lead, the success of this study showed that LBP contaminated materials could be used satisfactorily for a variety of constructions, including roadways, parking lots and foundations.
- Such reuse could potentially be within the local area so as to avoid transportation costs to a distant landfill.
- Results showed that concrete made with recycled LBP-contaminated deconstruction masonry materials will have satisfactory physical properties for general structural use, will not leach lead into the environment, and will not become hazardous wastes upon future deconstruction.

Cost Analysis - Cost for LBP Removal

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Technology for LBP removal	Range $/sq. ft.	Avg. $/sq. ft.
Thermal Spray Vitrification	3.50 - 9.50	5.00
Abrasive Blasting	5.00 - 18.00	8.00
Wet Abrasive Blasting	5.00 - 20.00	12.00
Vacuum Blasting	4.00 - 20.00	10.00
Water Blasting	4.00 - 20.00	13.00
Water Blasting with Abrasive Injection	4.00 - 19.00	9.00
Power Tool Cleaning To Bare Metal	5.00 - 15.00	7.00

A significant amount of money can also be saved by using LBP contaminated masonry materials in construction instead of costly removal and disposal of the LBP.

Cost Analysis – Approach

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- Cost-saving analysis to compare such a masonry deconstruction method with tradition ones (including LBP removal, hazardous and non-hazardous material deposal) for three hypothetical building.
  - Building I: floor area 3,000 ft^2, LBP-contaminated wall surface 13,000 ft^2
  - Building II: floor area 18,000 ft^2, LBP-contaminated wall surface 33,000 ft^2
  - Building III: floor area 96,000 ft^2, LBP-contaminated wall surface 104,000 ft^2
- Three different disposal scenarios were considered in this comparison analysis.
  - Scenario I – disposal in a construction waste landfill
  - Scenario II – disposal in a secure (hazardous waste) landfill
  - Scenario III – LBP removal then disposal in a construction waste landfill

Cost Analysis – Disposal Avoidance Savings

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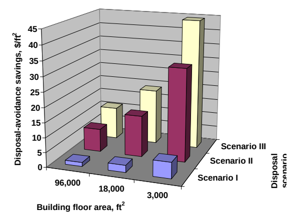
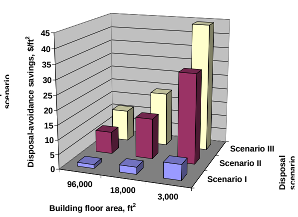


Concrete Block Masonry



Clay Brick Masonry

Conclusions

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- Lead in the LBP-contaminated aggregate can be sequestered in concrete due to the high alkalinity of portland cement. The concrete mixes made with the recycled masonry materials as aggregate did not have the toxicity characteristic because lead in the TCLP extracts was less than 5mg/L.
- Upon ultimate disposal, properly designed concretes made with LBP-contaminated aggregates would not be considered hazardous wastes under the Resource Conservation and Recovery Act (RCRA).
- Desirable workability and strength of concrete can be achieved with these recycled aggregates by changing concrete mix proportions. Such concrete mixes can be used satisfactorily for a variety of constructions, including roadways, parking lots and foundations.

Conclusions (cont'd)

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- The method for mix design nomograph development demonstrated in this study can be easily adapted by field engineers for designing concrete with aggregates recycled from different field deconstruction projects.
- The cost analysis for three hypothetical buildings and three different disposal scenarios indicated that the savings from using the LBP-contaminated masonry materials as recycled aggregate in concrete could range from approximately $8/$ft^2$ to $45/$ft^2$, depending on the size of the deconstruction project and the applicable environmental protection regulations.
- The cost savings may result from eliminating LBP removal and waste material disposal, which will minimize the use of secure landfills, eliminate the time and equipment required for sieving and re-grading recycled aggregate, and reduce natural aggregate consumption for concrete construction.

Acknowledgement

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- Related Publications:

  - J. Hu, K. Wang, J. A. Gaunt, "Behavior and Mix Design Development of Concrete Made with Recycled Aggregate from Deconstructed Lead-Contaminated Masonry Materials", Construction & Building Materials, Accepted for Publication, 2012
  - J. Hu, K. Wang, J. A. Gaunt, "Sequestering Lead by Utilizing Lead-Based Paint (LBP) – Contaminated Masonry Materials as Recycled Aggregate in Portland Cement Concrete", Journal of Solid Waste Technology and Management, vol. 37, No.4, p. 260-172, November 2011
  - J. Hu, K. Wang, J. A. Gaunt, "Design Concrete with Recycled Lead-Contaminated Deconstructed Masonry Materials as Aggregate", International Conference on Sustainable Urbanization (ICSU 2010), Hong Kong, China, 15-17 December 2010
  - J. Hu, K. Wang, J. A. Gaunt, Recycling Lead-Based Paint Contaminated Deconstructed Masonry Materials as Aggregate for Portland Cement Concrete - A Cost Effective and Environmental Friendly Approach, Resources, Conservation and Recycling, vol. 54, No. 12, October 2010

Question and Comments?

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- Contact Information:
  - Dr. Jiong Hu
  - 512-245-6328
  - Jiong.hu@txstate.edu
  - http://uweb.txstate.edu/~jh211/