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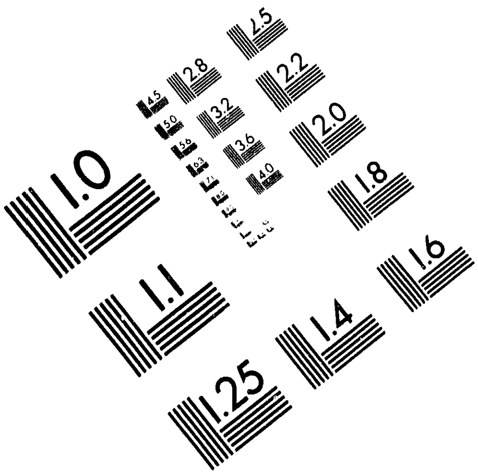
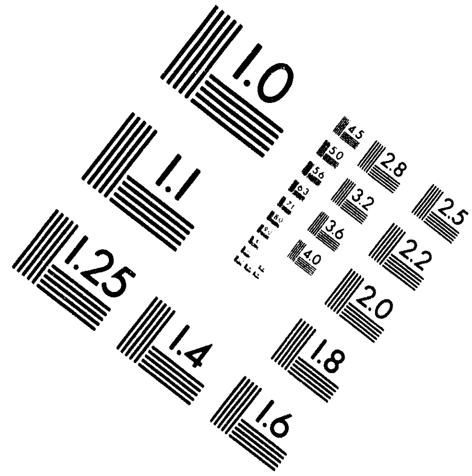

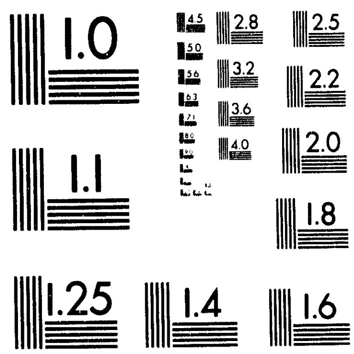

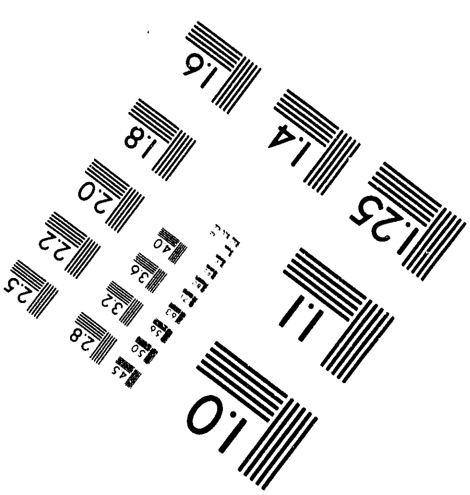
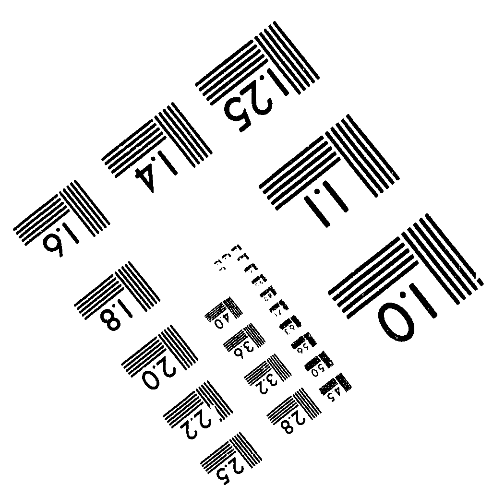

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DOE/PC/92521--T171

TECHNICAL REPORT
March 1, 1994 through May 31, 1994

Project Title: **LWA DEMONSTRATION APPLICATIONS USING ILLINOIS COAL GASIFICATION SLAG: PHASE II**

DOE Grant Number: DE-FC22-92PC92521 (Yr. 2)
ICCI Project Number: 93-1/4.4A-11M
Principal Investigator: Vas Choudhry, Praxis Engineers, Inc.
Other Investigators: Philip Steck, Harvey Cement Products, Inc.
Project Manager: Daniel Banerjee, Illinois Clean Coal Institute

ABSTRACT

The major objective of this project is to demonstrate the suitability of using ultra-lightweight aggregates (ULWA) produced by thermal expansion of solid residues (slag) generated during the gasification of Illinois coals as substitutes for conventional aggregates, which are typically produced by pyroprocessing of perlite ores. To meet this objective, expanded slag aggregates produced from an Illinois coal slag feed in Phase I will be subjected to characterization and applications-oriented testing. Target applications include the following:

- Aggregates in precast products (blocks and rooftiles)
- Construction aggregates (loose fill insulation and insulating concrete)
- Other applications as identified from evaluation of expanded slag properties.

The production of value-added products from slag is aimed at eliminating a solid waste and possibly enhancing the overall economics of the gasification process, especially when the avoided costs of disposal are taken into consideration.

During this reporting period, work continued on developing mix designs and preparing test specimens using expanded slag aggregates for precast concrete applications (Task 3) and construction aggregate applications (Task 4). The mix designs involve partial or total substitution of conventional lightweight aggregates by slag. While the cement content in the mixes was maintained at that typically used in conventional mixes, the cement-to-water ratio was modified to accommodate the slag aggregates. The mixes were made in small batches and used to prepare 2-inch test specimens. The unit weight and compressive strength values were measured and determined to be satisfactory. During the following quarter, these mix designs will be used to make batches of precast products for evaluation using production machines and molds.

tests indicated that the concentrations of RCRA metals in the TCLP extraction fluid were well below EPA limits.

Expanded slag samples were also evaluated for their suitability as loose fill insulation, which is commonly used to fill voids in hollow concrete masonry units to improve the insulating properties of the outer walls and reduce heat loss. Although expanded slag has a higher unit weight than expanded perlite, it is free-flowing, nonfriable, and less dusty than perlite, which makes it suitable for this application.

Work in this reporting period focused on testing of expanded slag in insulating concrete and precast concrete applications, i.e., lightweight blocks and rooftiles. Insulating concrete is made from expanded perlite (Group I) and expanded clay (Group II) aggregates to produce concretes with a wide range of unit weights. As a result, the concrete compressive strength varies widely depending on the aggregate strength and the cement content of the mix. Expanded slag was tested for this application by preparing cement concrete mixes using expanded slag as the aggregate, using a 1:5 cement-to-aggregate ratio. Since only +20-mesh slag was expanded in Phase I, the available expanded slag samples lack the requisite fines content for this application. This can be made up by adding crushed expanded slag or natural sand. Therefore, two separate concrete mixes were made by adding sand and crushed expanded slag, respectively. Concrete test specimens prepared from these mixes were found to be satisfactory.

These tests also indicated that expanded perlite may be a better source of fines than crushed expanded slag in insulating concrete mixes. This will be determined in future tests.

A sample of currently used rooftile lightweight aggregate was obtained from a manufacturer and analyzed for particle size distribution, total and fractional unit weight, and total and fractional moisture, and the results were compared with corresponding values for expanded slag. It was determined that expanded slag could meet the specifications of conventional aggregates for this application by blending or preparing the slag prior to expansion in order to meet the size gradation requirements. This approach is typically followed when using conventional aggregates.

Testing of expanded slag to make precast concrete blocks was begun at the facilities of Harvey Cement Products, Inc. The first batch of tests has been completed. During the following quarter, the mix design will be finalized in order to produce a batch of blocks using machine molds. Evaluation of expanded slag in other applications is in progress.

OBJECTIVES

The Phase II work is aimed at testing and evaluating the large batch of expanded slag aggregates, encompassing a wide range of unit weights, that was produced in Phase I. The major objectives of the Phase II work are to:

- Conduct extensive physical, chemical, and environmental characterization testing of expanded Illinois slag aggregates
- Identify potential applications for expanded slag as a substitute for conventional ULWAs by comparing its properties with those of expanded perlite applications, with input from potential users
- Utilize the expanded slags in selected applications to generate performance data
- Conduct a detailed assessment of the technical and economic feasibility of using expanded slag in the applications tested.

It is anticipated that the data generated will be applicable for implementation in DOE-funded coal gasification projects currently under way in the Illinois basin. The two leading projects are: (i) Wabash River Coal Gasification Repowering Project in Indiana, operated by Destec and PSI Energy, and (ii) IGCC Repowering Project at Lakeside Generating Station in Springfield, Illinois.

INTRODUCTION AND BACKGROUND

Based on previous work performed by Praxis, it was established that slags have inherent properties of expansion or bloating upon thermal treatment. Their bulk density can be controlled to achieve values between 12 and 55 lb/ft^3 by changing the process conditions, i.e., temperature and kiln retention time. All three commonly used expansion methods, i.e., direct-fired kiln, vertical shaft furnace, and indirect-fired kiln, were used to produce expanded slag aggregates.

The Phase I effort, directed at developing techniques for producing ULWA, confirmed that a product with a unit weight of 12-20 lb/ft^3 can be produced from Illinois slag in either a direct-fired vertical shaft furnace or an indirect-fired horizontal shaft furnace. However, the indirect-fired furnace allowed better process control with minimal fusion problems during slag expansion. Using operating conditions determined during the pilot tests, a large batch of expanded Illinois slag aggregates was produced using an 18-in. diameter x 12-ft long indirect-fired horizontal furnace which is used by the manufacturer to generate scale-up data for the design of commercial furnaces.

In Phase II, expanded slag samples were characterized for their environmental acceptability and evaluated for their suitability as substitutes for conventional ULWAs in a number of applications including loose fill insulation, insulating concrete, precast concrete products, and other industrial applications. This work is being done with the involvement of potential users of expanded aggregates.

EXPERIMENTAL PROCEDURES

Experimental procedures for evaluation of the expanded slag aggregates were selected based on ASTM and Perlite Institute standards and specifications, as indicated below.

Precast Product Applications

Expanded clay aggregates are used to produce precast concrete products such as lightweight masonry blocks and rooftiles. Masonry blocks, a major application for LWAs, were selected for comprehensive applications testing and development in this project. Mix designs are typically developed by the manufacturer and are specific to the industry. However, cement concrete test specimens made fr... expanded slag using appropriate mix designs are being tested in accordance with the following standards:

- Cement concrete unit weight and compressive strength (ASTM C 495)
- Flexural strength for rooftile application (ASTM C 293)
- Resistance to freeze/thaw (ASTM C 666)
- Dry shrinkage (ASTM C 157)
- Test for staining materials in lightweight aggregates (ASTM C 641)

Construction Aggregates

The first application in which expanded slag was tested is as a substitute for expanded perlite for loose fill insulation, in accordance with the general requirements for perlite given in ASTM C 549, by conducting the following tests:

- Density of loose fill insulation (ASTM C 520)
- Thermal transmission properties (ASTM C 177)
- Surface burning characteristics (ASTM E 84)
- Water repellency (PI 303-85)
- Resistance to compaction (PI 306-80)

Expanded slag was also evaluated as an aggregate for insulating concrete aggregate. This evaluation involves the following tests:

- Unit weight of concrete (ASTM C 29)
- Compressive strength and density of insulation concrete (ASTM C 495)
- Thermal transmission properties of concrete (ASTM C 177)
- Fire rating (UL Design No. P920)

Rooftile Application

The specifications for rooftile aggregates and for mix designs using them are typically formulated by the manufacturer and considered proprietary information. However, minus 4-mesh aggregates are commonly used for this application, and the gradation specifications for this application are given in ASTM C 332. The procedures used for testing were developed based on generic mix design information obtained from manufacturers.

Other Applications

Other potential applications for expanded slag include filtration media and agricultural and horticultural applications. The suitability of expanded slag for these applications will be determined based on the results of characterization tests, especially the following:

- Trace element analysis
- Filtration testing
- Permeability
- Sink-float testing (PI 300-77)

RESULTS AND DISCUSSION

The technical work completed during this quarter is described by task in this section.

Task 1: Characterization of Expanded Slag Aggregates

The unit weight and compaction resistance (PI 306-80) of selected expanded slag aggregates were measured. Compaction resistance values were in the 60-250 psi range, which is 2-8 times higher than the 31.5 psi value measured for loose fill insulation-grade (minus 4-mesh) expanded perlite. However, the compaction resistance-to-unit weight ratio for various slag samples is slightly higher than that of perlite.

Physical characterization tests were conducted on various expanded slag samples, and the results were compared with those for expanded perlite at the same topsize. The true specific gravity of slag is slightly higher than that of perlite. The softening temperature of Illinois slag is at the higher end of the range reported for perlite.

The results of RCRA metals leachability testing, using the EPA/TCLP test, indicated that the leachability of expanded slag is below the EP toxicity limits. Therefore, its utilization should pose no leachability problems.

Task 2: Preliminary Evaluation of Expanded Slag Products

No additional work was done under this task in this reporting period.

Task 3: Testing of Slag in Precast Concrete Applications

Concrete Masonry Unit Production. In order to test the suitability of expanded slag aggregates for making lightweight concrete masonry units, mix designs were selected with the objective of replacing the conventional LWAs with slag but keeping the cement component constant. Water was added to achieve the desired slump for automatic filling of the mix in a block-making mold. This work was done at the facilities of Harvey Cement Products, Inc., a leading block manufacturer located in the greater Chicago area.

Table 1 gives the particle size distribution of the current LWA block aggregates and mixes as a whole.

Table 2 gives the mix designs that were prepared and tested using a combination of expanded coarse slag (SLA/C), expanded fine slag (SLA/F) and currently used aggregates. The mix designs consisted of the following on a volumetric basis:

SLA-C:	1/3 coarse slag, 2/3 conventional aggregates
Control:	Test containing only conventional aggregates
SLA-FC1:	1/3 SLA/C, 1/3 SLA/F, and 1/3 conventional aggregates
SLA-FC2:	20% SLA/C, 60% SLA/F and 20% conventional aggregates
SLA-F:	50% SLA/F and 50% conventional aggregates

Figure 1 presents the size distribution of the various aggregate mixes used in the above evaluation. As may be seen from this figure, the particle size distribution of the test mixes closely matches that of the control aggregates.

Table 1. Aggregate and Mix Particle Size Distribution

Material	1	2	3	SLA/F	SLA/C	Mix 1	Mix 2	Mix 3	SLA/C	Cont.	SLA/CF	SLA/CF	SLA/F
Test No.	BFS	LSS	SS	702/10	701/11				H408/1	H408/2	H408/3	H408/4	H408/5
Size	Wt% ret.	Wt% ret.	Wt% ret.	Wt% ret.	Wt% ret.	Wt% ret.	Wt% ret.	Wt% ret.	Wt% ret.	Wt% ret.	Wt% ret.	Wt% ret.	Wt% ret.
1/2 x 3/8"	0.2	0	0	0	1.1	0.1	0.1	0	0.1	0	0.1	0.1	0
3/8" x 4M	43.9	0.2	4.0	0.3	35.2	24.4	24.2	2.1	5.4	2.1	4.6	3.8	1.7
4 x 8M	34.3	20.3	22.8	9.2	54.0	28.2	28.0	21.6	24.8	21.6	22.2	21.1	18.8
8 x 16M	11.6	32.3	29.7	20.5	5.7	20.7	20.9	31	28.4	31.0	26.5	26.8	28.6
16 x 30M	2.9	15.5	20.1	32.6	0.7	9.4	8.6	17.8	16.1	17.8	17.2	18.1	21.1
30 x 50M	1.6	9.6	10.2	27.8	0.2	5.4	5.2	9.9	8.9	9.9	12.2	13	13.9
50 x 100M	1.1	7	5.4	8.1	0.6	3.6	3.8	6.2	5.6	6.2	6.4	6.6	6.6
100M x 0	2.0	15.1	7.9	1.5	2.5	6.9	7.9	11.5	10.5	11.5	10.7	10.6	9.2
Total	97.6	100	100.1	100	100	98.7	98.7	100.1	99.8	100.1	99.9	100.1	99.9

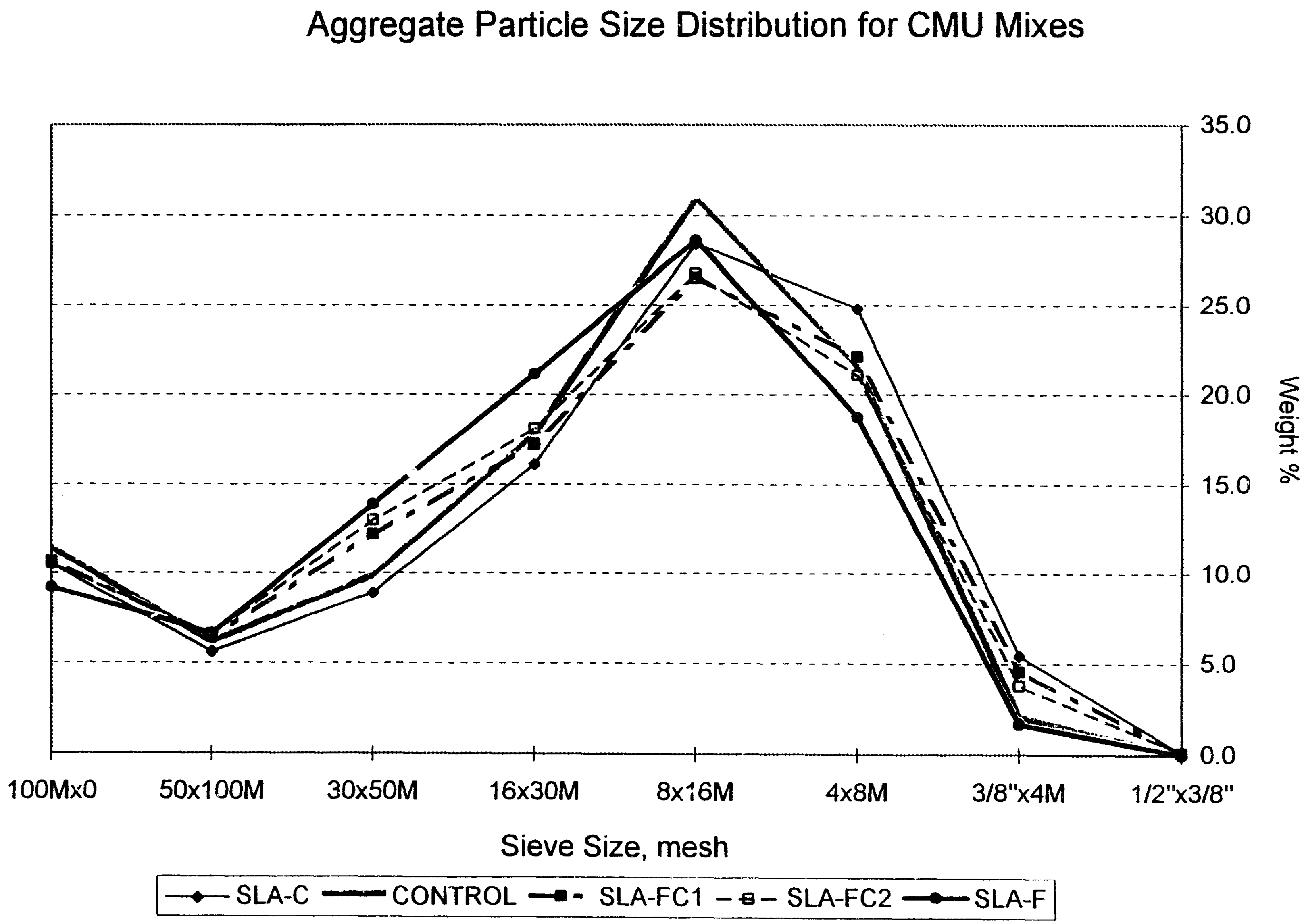
BFS: Blast furnace slag
LSS: Conventional fine aggregate
SS: Conventional coarse lightweight aggregate
Mix 1: Current mix
Mix 2: Alternate mix
Mix 3: Arch Design

Table 2. Concrete Block Mixes Using Expanded Slag

Test No	Contents	Vol, ml	Wt, g	Wt%	Concrete Unit Weight,	Comp. Strength, psi	
					lb/ft³	3-day	7-day
H40408-1	SLA/C	250	75	9.8			
Control	SLA/F	0	0	0			
	SS	250	347	45.6			
	LSS	250	338	44.4			
	Total	750	760	100			
	Cement	75	92				
H40408-2	SLA/C	0	0	0			
	SLA/F	0	0	0			
	SS	375	510	50.4			
	LSS	375	501	49.5			
	Total	750	1011	100			
	Cement	75	92				
H40408-3	SLA/C	250	63	12.4			
	SLA/F	250	106	20.9			
	SS	0	0	0			
	LSS	250	338	66.6			
	Total	750	507	100			
	Cement	75	92				
H40408-4	SLA/C	150	31	10.1			
	SLA/F	450	73	24			
	SS	0	0	0			
	LSS	150	200	65.7			
	Total	750	304	100			
	Cement	75	92				
H40408-5	SLA/C	0	0	0			
	SLA/F	375	151	22.4			
	SS	188	261	38.8			
	LSS	187	260	38.6			
	Total	750	672	100			
	Cement	75	92				

SS: Conventional coarse lightweight aggregate
LSS: Conventional fine aggregate
SLA/F: Fine (10 x 50M) slag after expansion
SLA/C: Coarse (1/4 x 10M) slag after expansion

Figure 1


Aggregate Particle Size Distribution for CMU Mixes
35.0
30.0
25.0
20.0
15.0
10.0
5.0
0.0
Weight %
100Mx0
50x100M
30x50M
16x30M
8x16M
4x8M
3/8"x4M
1/2"x3/8"
Sieve Size, mesh
SLA-C
CONTROL
SLA-FC1
SLA-FC2
SLA-F

Lightweight Rooftile Production. The use of expanded slag for the rooftile application was tested in a commercial laboratory. This work involved testing a sample of the currently used lightweight aggregate (RT-1) and a sample of minus 4-mesh expanded slag (SLA-1). Figure 2 shows a plot of the particle size distributions of the rooftile aggregate and expanded slag against the minimum (F30-min) and maximum (F30-max) size ranges specified for conventional aggregates by the manufacturer; the raw data are presented in Table 3. As may be seen, the expanded slag generally meets the particle size range specified by the manufacturer, with the exception of the fines fractions. This is because the commercial aggregate had been screened to meet the requirements of the application whereas the slag sample was in its as-produced form. Screening the slag prior to expansion would ensure that it meets the desired size distribution.

Table 3 also presents other characterization data to allow comparison of the rooftile aggregate sample with the expanded slag sample. As may be seen, the expanded slag fractional unit weight varies considerably more than that of the conventional aggregate. The density of the plus 0.3 mm slag is less than that of the rooftile aggregate of the same size, while the density of the minus 0.3 mm slag is greater than that of similar sized rooftile aggregates.

The cement concrete designs were based on commonly used high cement-to-aggregate ratios, as indicated below:

Cement-to-aggregate ratio:	1:2.5
Water-to-cement ratio:	As needed to maintain zero or low slump
Plasticizer:	0.5%
Accelerator:	1.0%

The moisture content of the aggregate was measured to estimate the actual water added to the mix. The volume, weight, and unit weight of the aggregates were measured prior to preparing the mixes. Concrete test cylinders were made which will be tested for compressive strength following 7- and 28-day curing times. The results will be reported in the next report.

Task 4: Testing of Expanded Slag in Construction Applications

Loose Fill Insulation. Loose fill or masonry fill insulation is used to fill the cavities in exterior and interior hollow masonry units to improve insulation and reduce heat loss. The requirements for using expanded slag for this application were investigated during this quarter with reference to expanded perlite, using the criteria given in Table 4.

Figure 2

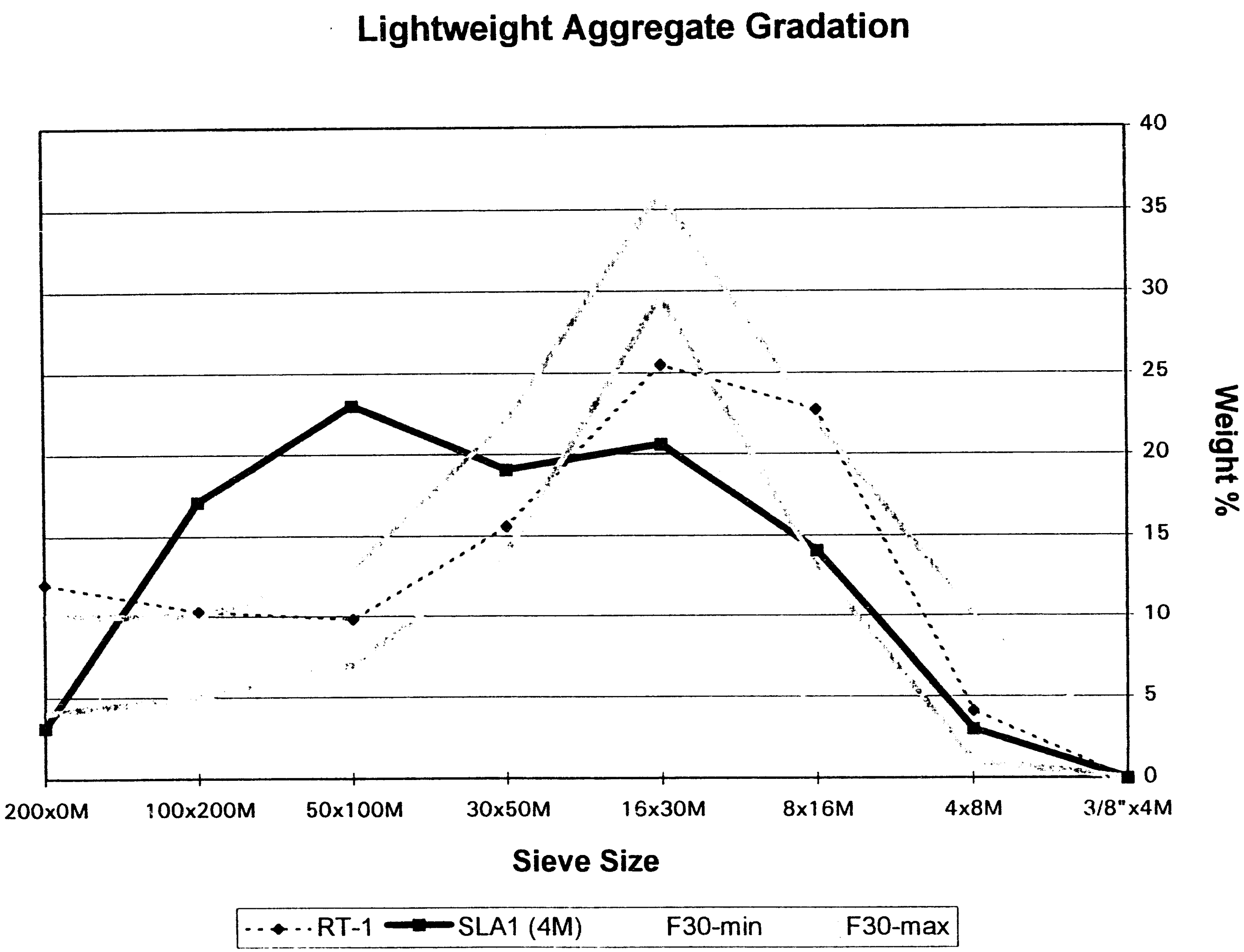

Lightweight Aggregate Gradation
40
35
30
25
20
15
10
5
0
Weight %
200x0M
100x200M
50x100M
30x50M
16x30M
8x16M
4x8M
3/8"x4M
Sieve Size
RT-1
SLA1 (4M)
F30-min
F30-max

Table 3. Rooftile Aggregate and Expanded Slag Particle Size Distributions

Sample	Sample	RT-1(a)	RT-1	RT-1(b)	RT-1(c)	RT-1(d)	SLA1 (4M)	SLA1 (4M)	F30-min	F30-max	F30	SLA1 (4M)
Size	Size		Unit wt		Absorp.	Repell.	408/1	Unit wt			Range	408/1
mm	mesh	% ret.	lb/ft³ dry	SM%	%		% ret.	lb/ft³ dry	% ret.	% ret.	% ret.	Wt% Pass.
9.5x4.76	3/8"x4M	0		0			0	0	0	2	0-2	100
4.76x2.38	4x8M	4.1	45.1	15.8	18.1	243.7	3	17	1	10	1-10	100
2.38x1.19	8x16M	22.7	48.2	16	14.3	244	14.1	27	13	22	13-22	97
1.19x0.6	16x30M	25.5	48.6	16	11.1	243.5	20.6	39	29.7	36	30-36	82.9
0.60x0.30	30x50M	15.6	50.9	16	10.4	243.5	19.1	49	14	22	14-22	62.3
0.30x0.15	50x100M	9.8	55.8	16	4.4	243.8	23	64	7	13	7-13	43.2
0.15x0.07	100x200M	10.3	60.3	16.1	NA	243	17.1	80	5	10	5-10	20.2
0.07x0	200x0M	12	53.9	16.2	NA	NA	3.1	54	4	10	4-10	3.1
	Avg (calc)	100	51.27	16			100	51.8	73.7	125		
	Measured							44				

(a) Rooftile sample provided to Praxis
(b) Surface moisture estimated by saturating various size fractions
(c) Saturated surface dry (SSD) moisture determined by ASTM C127
(d) Water repellency determined using PI 303-85

Test work to evaluate the use of expanded slag for this application was started. Expanded perlite is typically surface-treated for water repellency and to reduce its dustiness prior to use. However, testing with slag was undertaken without any pretreatment.

Table 4. Expanded Slag vs. Expanded Perlite for Loose Fill Insulation (ASTM C 549)

Parameter	Test Method	ASTM C 549*	Expanded Slag
Particle size		95% minus 4 mesh	
Unit weight, lb/ft^3	ASTM C 520	2-11	>12.0
Water repellency	PI 303-85	175	240
H_2O absorption, wt% in 14 days		1.0	in progress
Thermal Conductivity**	C 177		
7.5 lb/ft^3		0.45	-
12.0 lb/ft^3		1.5	
20.0 lb/ft^3		-	
30.0 lb/ft^3		-	1.34
Surface burning characteristics	E 84		
Dustiness		85	NA

* For untreated expanded product (perlite).
** For 7.4-11.0 lb/ft^3 unit weight material of 1" thickness at 20°C, in $Btu/h\text{-}ft^2\text{-}°F$.
NA: Not analyzed or not available.

The following tests are in progress:

- Moisture absorption for a sample with a unit weight of 12 lb/ft^3
- Specific heat for two samples (12 and 20 lb/ft^3, respectively)
- Thermal conductivity on three samples (12, 20 and 30 lb/ft^3, respectively)
- Surface burning characteristics
- Free and combined moisture on 12 lb/ft^3 sample.

The performance of expanded slag was compared with that of expanded perlite for this application. Expanded slag exhibits considerably lower dustiness than expanded perlite, which will make it a more acceptable product for loose fill insulation applications. Also, its water repellency (Table 4) is considerably higher than that of perlite. However, since its unit weight is double that of perlite, double the amount of expanded slag by weight will be needed to fill the same volume. Our present assessment is that though the expanded slag will technically prove to be an acceptable material for this application, in order to achieve acceptance its delivered costs will have to be comparable to those of perlite on a volumetric basis.

Lightweight Insulating Concrete and Precast Products. Expanded slag is being evaluated for use in making insulating concrete in two steps: (i) laboratory evaluation and (ii) in a manufacturing environment. This approach requires fewer samples and is thus more economical. Laboratory tests were conducted with the expanded slag to evaluate its compressive strength and thermal conductivity. Table 5 presents the typical physical properties for perlite concrete which will be confirmed for slag. Three batches of cement concrete mixes using a 1:5 cement-to-aggregate ratio were made using the following mix design:

- Slag and sand with low water content
- Slag and sand with high water content
- Slag and crushed slag with high water content

Table 5. Typical Physical Properties of Insulating Concrete

Mix Ratio, Cement/Aggregate	Unit Weight lb/ft^3 (dry)	Compressive strength, psi (min)	Thermal Conductivity
1:4	36	300	0.83
1:5	30.5	200	0.71
1:6	27	125	0.58
1:8	22	80	0.46

Exploratory work including preparation of mix designs was done in a commercial laboratory where expanded slag and natural sand were used to simulate typical concrete mixes for insulating concrete. In these tests, expanded slag was blended to approximate the gradation of expanded perlite and an air entraining agent was used.

The mixes were cast into 2-inch cube specimens to test their compressive strength at 7- and 28-day intervals. The results will provide preliminary data needed to develop mix designs for both precast concrete products and insulating concrete. One of the specimens will also be used to test the insulating properties of slag concrete. These tests will assist in establishing the quantity of water needed to make insulating concretes using slag. The results for one of the 28-day compressive strength tests, given in Table 6, indicate that this value exceeds the required ultimate value of 200 psi.

Table 6. Results of Insulating Conctete Mix Design Tests

Test	**Aggregate**			**Comp. Strength psi**	**Unit Weight lb/ft^3**
	Slag 4 x 50M	Slag 50 x 200M	Sand (-50M)	28-day	
BSK-1	85%	15%	-	297	42.0
BSK-2	100%*	-	-	NA**	
BSK-3	85%	-	15%	NA**	

*Size consist conforming to perlite specifications.
** Testing in progress.

CONCLUSIONS AND RECOMMENDATIONS

The following conclusions may be drawn based on the work conducted in this quarter:

- The lowest unit weight obtained for expanded slag (12 lb/ft^3) is at the upper end of the range typically measured for expanded perlite (5-12 lb/ft^3). However, there are a number of applications (precast products or insulating concrete) for which expanded slag aggregates with unit weights between 12 and 40 lb/ft^3 could be used.

- Expanded slag may be used as a substitute for expanded perlite in loose fill insulation applications. Although its unit weight is twice that of perlite, it is considerably less dusty and has better water repellency.

- Based on the results of laboratory tests, the use of expanded slag to make insulating concrete appears to be a viable option.

Based on the technical evaluation and results of the tests conducted to date, the most promising initial applications for expanded slag appear to be in construction applications such as loose fill insulation, insulating concrete, and precast concrete products.

PROJECT MANAGEMENT REPORT
March 1,1994 through May 31, 1994

Project Title: **LWA DEMONSTRATION APPLICATIONS USING ILLINOIS COAL GASIFICATION SLAG: PHASE II**

DOE Grant Number: DE-FC22-92PC92521 (Yr.2)
ICCI Project Number: 93-1/4.4A-11M
Principal Investigator: Vas Choudhry, Praxis Engineers, Inc.
Other Investigators: Philip Steck, Harvey Cement Products, Inc.
Project Manager: Daniel Banerjee, Illinois Clean Coal Institute

COMMENTS

Work in this quarter proceeded at a slower pace than planned in tasks related to utilization of expanded slag to make a large batch of precast concrete products because the plant where some of test work is to be done is having production problems and is therefore moving slower than expected.

However, the laboratory testing in this quarter progressed well. We expect to make up the overall project progress in the upcoming quarter.

PROJECT EXPENDITURES

Projected expenditures and estimated actual expenditures for the first three quarters ending 31 May 1994 are given in Table 1 and plotted in Figure 1. As may be seen, the total cumulative expenditure for the first two quarters is slightly lower than the budgeted amount.

PROJECT SCHEDULE

The project schedule, presented in Figure 2, indicates a project start date of September 1, 1993, and a completion date of August 30, 1994. Though work on the project has been slightly behind schedule in the first three quarters, it is expected that project progress will be back on schedule by the final quarter.

Table 1
PROJECTED AND ESTIMATED EXPENDITURES BY QUARTER

Quarter*	Type of Costs	Direct Labor	Fringe Benefits	Materials & Supplies	Travel	Major Equipment	Other Direct Costs	Indirect Costs	Total
Sept. 1, 1993 to Nov. 30, 1993	Projected	3,549	710	0	780	0	3,726	6,224	14,989
	Estimated	6,396	1,279	0	0	0	0	9,940	17,615
Sept. 1, 1993 to Feb. 28 1993	Projected	8,280	1,656	0	1,820	0	8,694	14,522	34,972
	Estimated	11,092	2,218	0	511	400	0	17,305	31,526
Sept. 1, 1993 to May 31, 1994	Projected	17,744	3,549	0	3,900	0	18,630	31,118	74,941
	Estimated	22,562	4,512	0	1,697	0	4,527	35,617	68,915
Sept. 1, 1993 to Aug. 31, 1994	Projected	23,658	4,732	0	5,200	0	24,840	41,490	99,920
	Estimated								

* Cumulative todate

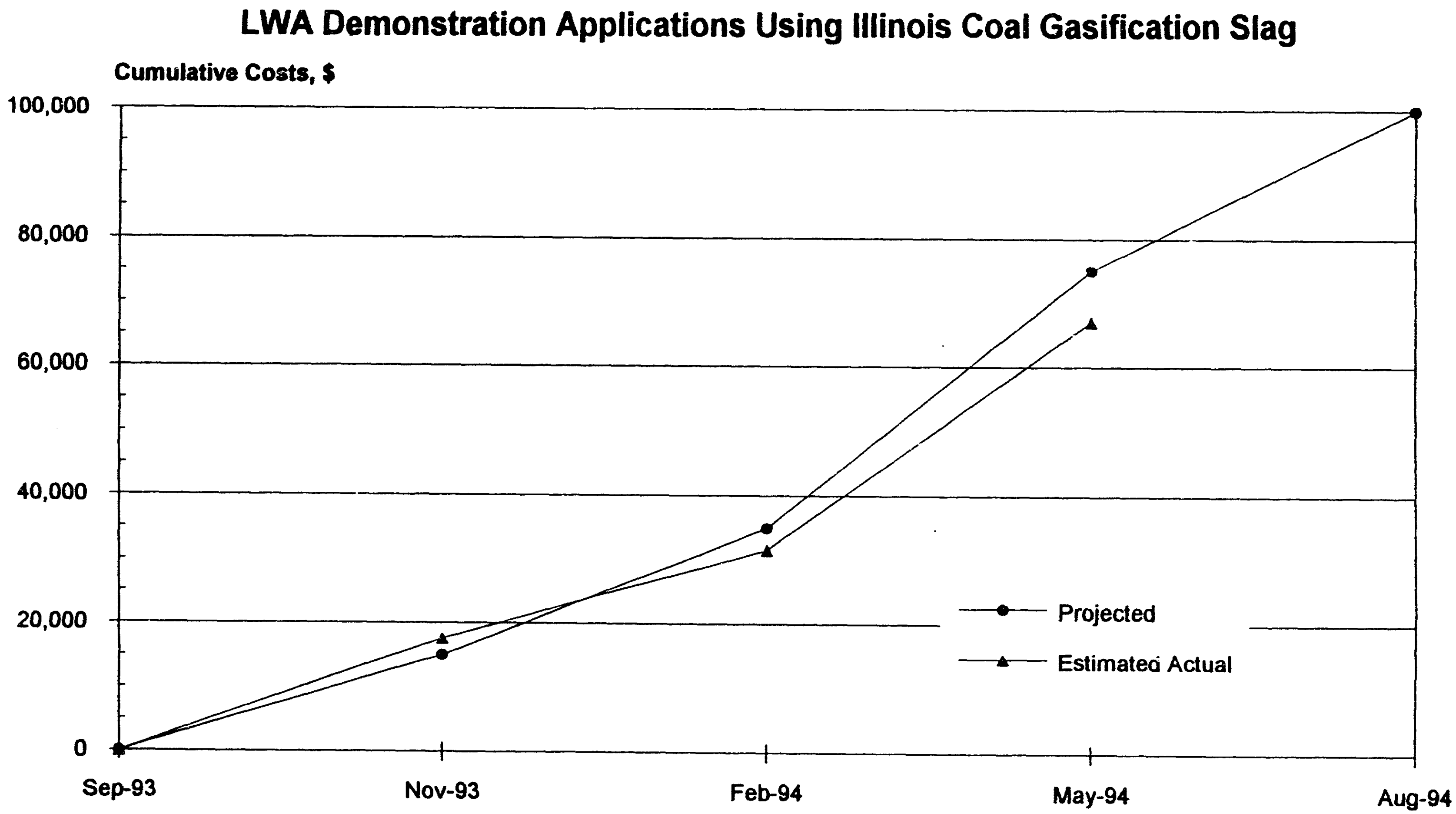


Figure 1
Costs by Quarter

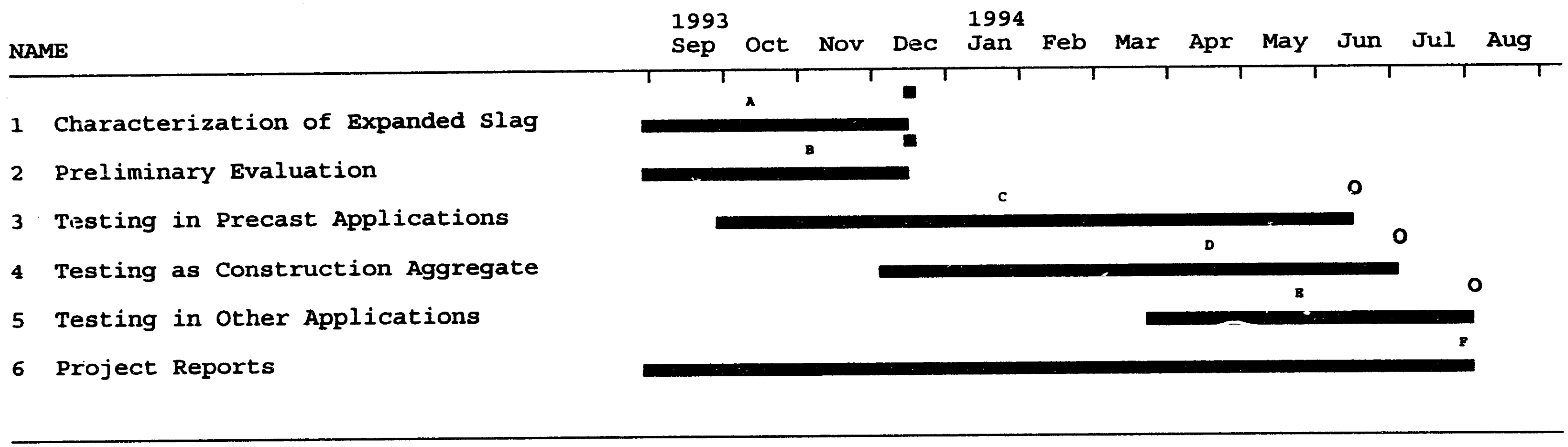


Figure 2. Schedule of Project Milestones

PROJECT MILESTONES

A. Characterization Completed
B. Applications for Expanded Slag Identified
C. Lightweight Blocks Made
D. Testing of Expanded Slag as Aggregate Completed
E. All Testing Completed
F. Final Report Submitted

■ Completed
O Revised completion date

DATE
FILMED
10/17/94

END