# ARTIFICIAL REEF PROJECT

## INTERIM REPORT

Houston Lighting & Power Company

Texas A & M University at Galveston

JTM Industries, Incorporated

APRIL 1990

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## INTRODUCTION

Houston Lighting & Power Co. (HL&P), in conjunction with the JTM Industries Inc. - Ash Management Division (AMD) and Texas A&M University at Galveston (TAMUG), is currently investigating the use of coal combustion by-products (CCBP) as artificial reef substrate for the enhancement and construction of inshore oyster reefs and offshore fish reefs. Intensive laboratory and field research initiated in the spring of 1988 has yielded very promising results. State and federal regulatory agencies have been kept apprised of project results, and remain fully supportive of this effort to develop an environmentally sound, economic material suitable for the creation and enhancement of reef habitat. If economically feasible, large-scale production of artificial reef substrate materials for oyster reef construction and enhancement along the Gulf Coast of Texas is planned.

## BACKGROUND

Demand for reef substrate material continues to increase as a result of approved coastal development projects and their associated mitigation requirements, enforcement actions, and reef enhancement projects. The U.S. Army Corps of Engineers (COE) is currently involved with diverting the Colorado River near its mouth at Matagorda, Texas, back to its original course, which will allow it to empty into Matagorda Bay. This project alone will require the placement of enough substrate to create 54 acres of oyster reef in Matagorda Bay, which will employ about 100,000 cubic yards of material. The proposed deepening and widening of the Houston Ship Channel in Galveston Bay, Texas, if approved, would probably require the establishment of several hundred acres of oyster reef.

These major projects are accompanied by numerous minor projects in Galveston Bay which require oyster reef construction to mitigate habitat losses in associated areas. Enforcement action against dredge and fill permit violators may also call for the rehabilitation or construction of oyster reefs. In addition, increased fishing pressure offshore has caused a decline in populations of important sport and commercial fish species. The Texas Parks & Wildlife Commission has formed an Artificial Reef Advisory Committee in an attempt to create new offshore habitats for these declining fish populations.

Oyster and clam shell are the most commonly used substrate for the creation and enhancement of oyster reefs. These materials have historically been obtained by dredging buried shell deposits, but this source is rapidly declining, and thereby becoming more costly. Currently the dredging of shell deposits is strictly forbidden in

Texas waters. The nearest dredge operation occurs in Lake Pontchartrain, Louisiana, where sources are scarce and dredgers are facing pressure to cease operations. Coastal states are now seeking alternative substrate materials.

## UTILITY INDUSTRY EFFORTS

The idea of employing CCBP materials as artificial reef substrate is not new. In the early 1980's the New York Power Authority investigated their use as offshore reef substrate off Long Island, New York. Results of the project have been very positive. Subsequently, other U.S. utilities, including Baltimore Gas & Electric, Florida Power & Light, Mississippi Power Co., and Delmarva Power & Light, have initiated similar programs. Research has now ventured overseas, where the United Kingdom is investigating the use of CCBP materials in offshore artificial reef construction. With the increasing need for inshore oyster cultch materials, some of these programs are being directed to coastal bays.

## THE PROGRAM

The objective of this program is to provide an environmentally sound and economically feasible mix of CCBP materials from HL&P's W.A. Parish and/or Limestone Electric Generating Stations that can be used to construct or enhance inshore and offshore reefs. The primary materials used in this project are fly ash and bottom ash, which are by-products collected from the combustion of coal or lignite. Initial project investigations have dealt with ash materials derived from the combustion of low-sulfur western coal at the W.A. Parish Electric Generating Station. However, with the potential requirements of large volumes of materials, subsequent investigations have included a mixture of fly ash from W.A. Parish and bottom ash from the Limestone Electric Generating Station, a lignite-fired facility located near Buffalo, Texas.

In order to determine the environmental acceptability and cost effectiveness of CCBP materials in the marine environment, an intensive design and testing program was initiated in May 1988. Both State (Texas Parks & Wildlife Department) and Federal agencies (COE, U.S. Fish & Wildlife Service, and National Marine Fisheries Service) were advised of this project and kept informed of project developments. Guidance was sought from these agencies regarding testing protocols and requirements to obtain permit approval for the use of the CCBP material should scientific findings appear acceptable.

Material Design:

CCBP artificial reef material is comprised of two basic constituents, fly ash and bottom ash. Fly ash is a finely divided noncombustible residue which results from the burning of coal or lignite, and consists largely of silicon oxide, alumina, ferric oxide, and calcium oxide. It is naturally cementitious and sets up rapidly when combined with water. The fly ash from W.A. Parish is Type C (per ASTM C618-85), with a grain size of less than 0.02 mm for 95%-100% of the ash. Bottom ash is a noncombustible granular material which falls to the bottom of a furnace during coal or lignite combustion. Grain size for W.A. Parish bottom ash ranges from fine sand to coarse gravel. Hydrated fly ash/bottom ash mixtures have concrete-like properties including high compressive strength and excellent weathering characteristics.

HL&P and AMD were involved in determining the optimum mix design for the project based on various costs and strength criteria. Nine different mix designs consisting of W.A. Parish fly ash and bottom ash were subjected to short term compressive strength testing. A small amount of cement (about 5%) was added to some mix designs to enhance bonding. A minimum compressive strength of 300 psi after 14-17 days was required to ensure that the materials could be mechanically handled without significant breakage. Four mixes exceeded this strength criterion and were chosen for long term testing. Long term testing involved the submersion of materials in an estuarine environment for extended periods of time. The average strengths of the four materials following submersion for 365 days ranged from 2,942 to 3,418 psi (see Attachment 1). These data indicate that the materials are ideally suited to withstand the harsh marine environment.

Material Testing:

Biological testing has been carried out under the direction of Drs. Sammy Ray and Andre Landry of Texas A&M University at Galveston. Each of the four materials that met or exceeded strength criteria were tested in the TAMUG hatchery against an oyster shell control for significant differences of oyster spat setability and general biofouling potential. There was no significant difference of hatchery reared spat setting among mix designs, nor with the shell control. All mix designs exhibited excellent biofouling potential. Long term growth of oysters attached to the CCBP substrate material appears excellent.

Since all four mix designs exhibited excellent biofouling characteristics, a potential reef material mix design was chosen based on strength characteristics and material cost analyses. With the selection of an economically viable mix design, AMD initiated efforts to develop a mass production technique. The technique producing the most desirable product for oyster cultch is a proprietary pelletization process. With this process AMD can mass produce pellets that are oblong, irregularly shaped, and rough textured (see photos). Pellet diameters range in size from 1 to 3 inches. These pellets are ideal for oyster cultch in that they exceed strength requirements and have a rough texture that will optimize surface area for oyster spat set. The rounded shape would increase the amount of interstitial space in the deployed reef, thereby increasing current flows through the substrate with the benefit of additional habitat for small marine organisms. Additionally, the pellet configuration will be compatible with existing harvest practices of the sport and commercial oyster fisherman.

Toxicity tests were conducted to conservatively determine the leaching potential of the prototype reef material in the marine environment. The EP Toxicity test was selected for determination of leaching potential. Results of these tests indicate that even under acidic leaching conditions (pH 5.0), the W.A. Parish (WP) and the W.A. Parish/Limestone (LS) mixtures leach very low levels of trace metals (see Attachment 2). Under ambient estuarine conditions where natural trace element concentrations occur in the water and the pH is higher (about 7.5-8.0), the rate at which elements would leach out of the CCBP material would be extremely low, if measurable at all.

Bioaccumulation tests were conducted by TAMUG on oysters that had been attached to the W. A. Parish CCBP materials for at least one year. These tests were conducted to determine if oysters grown on CCBP materials bioaccumulate trace elements from the material. Oysters were tested under three scenarios; 1) pre-spawn condition, 2) post-spawn condition, and 3) fresh water depuration condition. After an examination of test results, it was concluded by TAMUG that the HL&P W.A. Parish CCBP materials do not significantly contribute to the trace element load in oysters (see Attachment 3). Long-term bioaccumulation testing of the Limestone/W. A. Parish mixtures was begun subsequent to testing of the W. A. Parish only mixture and results are not yet available. However, due to the lack of any significant leaching of trace metals, the Limestone/W. A. Parish mixture is expected to be demonstrated as non-toxic, as is the W. A. Parish mixture.

With the wide variation that exists in the quality and chemical composition of coal and its by-products, it is necessary to rigorously test each source of material. Characteristics of

CCBP materials are facility specific, and CCBP materials from other sources cannot be assumed uniformly acceptable for this application.

## BENEFITS ASSOCIATED WITH THE DEPLOYMENT OF CCBP REEF MATERIALS

Deployment of CCBP substrate materials can have a significant positive impact on the environment. New inshore and offshore marine habitats can be safely created, while existing habitats can be enhanced. These benefits to the marine ecosystem can be accomplished while expanding the use of CCBP materials that are currently used in road base construction, soil stabilization, and as cement substitutes. This expanded re-use of CCBP materials could potentially reduce the extent of upland habitats dedicated to ash disposal, and at the same time reduce the impacts to submerged aquatic habitats associated with shell dredging in Louisiana.

Accompanying the many environmental advantages of using CCBP materials as reef substrate are numerous economic advantages. With the enhancement of the marine ecosystem comes an expansion of the commercial and recreational fishing industries. These industries would in turn stimulate local economies with increased sales of fuel, groceries, fishing equipment, diving equipment, motel/hotel rentals, etc. The enhancement and creation of oyster reefs would also assist the commercial oyster industry in Texas. This fishery has suffered numerous environmental setbacks such as habitat destruction, floods, disease, and predation. The creation of new reefs and the enhancement of existing reefs could expand the production base of oysters and consequently contribute to an increase in domestic production.

Recreational opportunities would also increase from the deployment of CCBP materials. One widely accepted fishery management strategy is the construction of artificial reefs as a means of maintaining fish stocks at levels that will provide acceptable return to anglers while ensuring renewal of the resource. Whether inshore or offshore, increased opportunities will be provided for the sport fisherman to catch fish. Offshore deployment would have the added benefit of providing recreational benefit to the diving community. Divers enthusiastically endorse the strategic placement of artificial reefs and are increasingly attracted to them as a source of nearshore diving opportunities.

Lastly, deployment of CCBP materials would expand educational opportunities for students interested in studying the marine environment. Scientific findings from this project will serve to expand the existing information base on artificial reef design, construction, and placement. These findings will assist scientists in making more educated decisions on future artificial reef projects.

CURRENT STATUS

A meeting with representatives from the Texas Parks & Wildlife Department, U.S. Fish & Wildlife Service, National Marine Fisheries Service, TAMUG, and HL&P was held on February 21, 1990, to discuss the results of toxicity testing. After a thorough examination of all available data, agency personnel unanimously agreed that the material was environmentally safe for use as artificial reef substrate (see Attachment 4).

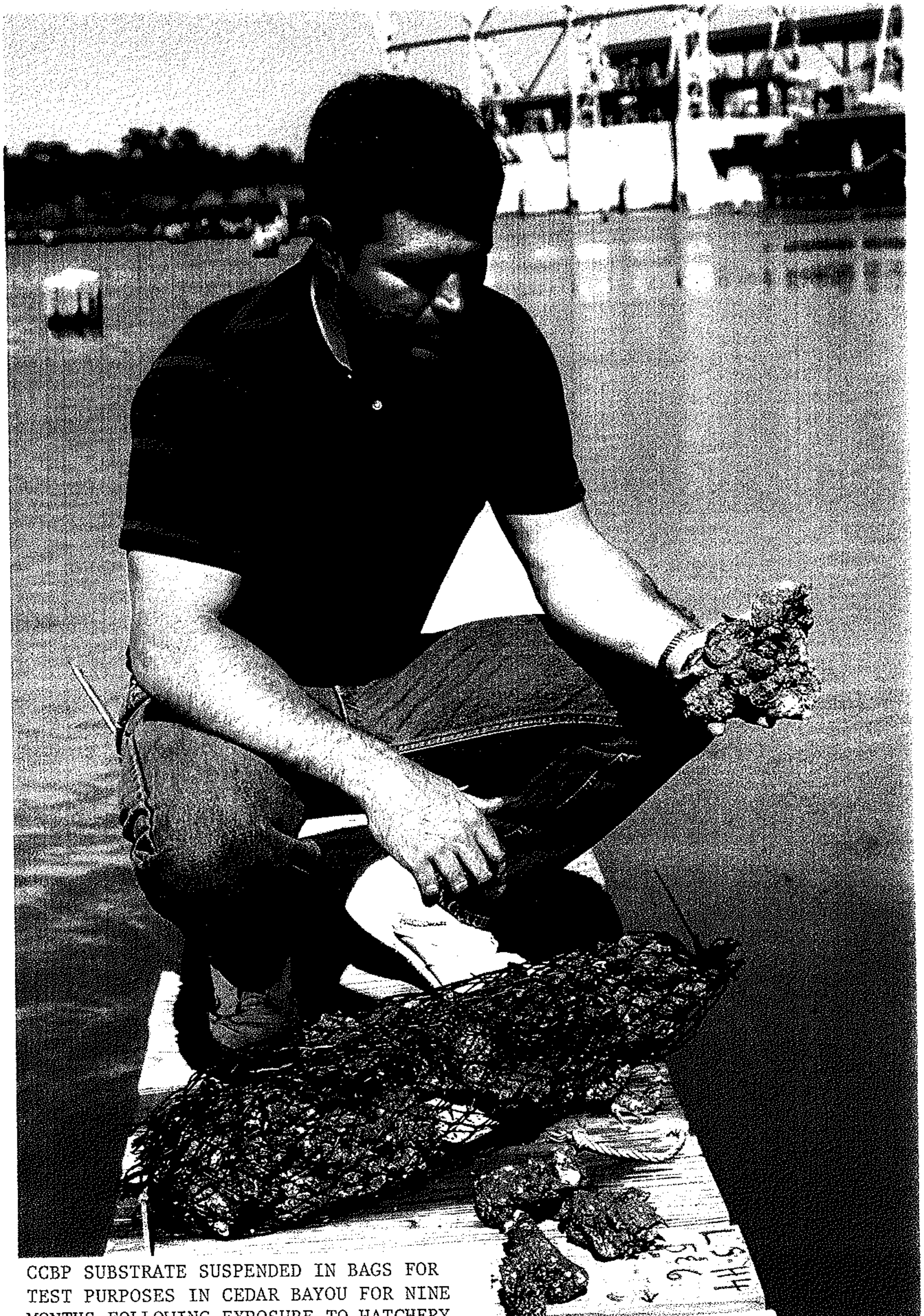
HL&P has received authorization from the COE to incorporate a small volume of CCBP material into a mitigation reef associated with the Clear Creek Diversion Project (see Attachment 5). Specifically, 10 cubic yards of the material will be placed on the west end of a newly established oyster shell bed area in the Seabrook Slough. HL&P is also preparing to seek authorization to establish four other small prototype reef sites in a wide range of salinity regimes in Galveston Bay. If approved, these prototype reefs will offer an opportunity to study in more detail the development of estuarine communities on the CCBP substrate, siting criteria, and construction techniques for inshore oyster reefs. Ultimately, HL&P anticipates CCBP substrate will be utilized in large scale mitigation and enhancement projects such as the Colorado River Diversion Project and the proposed Houston Ship Channel dredging project.

SUMMARY

The HL&P Artificial Reef Project represents a unique and outstanding opportunity to simultaneously benefit environmental, economic, and social interests in the Texas Gulf Coast Region. As outlined in this report, the creation or enhancement of habitats for estuarine and marine organisms with CCBP substrate materials can significantly benefit the coastal environment. The deployment of artificial reef substrate materials can also offset the use of declining supplies of shell in the construction and mitigation of important development projects in the region. Other benefits include various commercial, recreational and educational opportunities. Coupled with these direct benefits is an opportunity to effectively recycle large volumes of material, which reduces required landfill volumes and serves as an important example of beneficial recycling efforts for others to build on.

PHOTOGRAPHS

CCBP SUBSTRATE PRIOR TO EXPOSURE TO
THE MARINE ENVIRONMENT



CCBP SUBSTRATE SUSPENDED IN BAGS FOR TEST PURPOSES IN CEDAR BAYOU FOR NINE MONTHS FOLLOWING EXPOSURE TO HATCHERY LARVAE

CLOSE-UP OF CCBP SUBSTRATE SHOWING NINE MONTHS OF OYSTER GROWTH FOLLOWING EXPOSURE TO HATCHERY LARVAE

ATTACHMENTS

ATTACHMENT 1

# ARTIFICIAL REEF PROJECT

## INTERIM REPORT

## ON

## COMPRESSIVE STRENGTH TESTING

## OF

## FABRICATED OYSTER REEF MATERIAL

PHASE I

# 1.0 Prototype Oyster Reef Material - W. A. Parish Fly Ash and Bottom Ash

## 1.1 Actual Mix Designs

A. Nine (9) separate mix designs utilizing varying ratios of fly ash: bottom ash were investigated. The actual mix design component percentages are as follows:

1:1 Ratios ("A" Series)

| Mix Components | Batch No. 1 (A1) | Batch No. 2 (A2) | Batch No. 3 (A3) |
|---|---|---|---|
| Fly Ash | 42.18% | 39.07% | 40.04% |
| Bottom Ash | 42.07% | 39.3% | 40.04% |
| Hydrated Lime | 5.04% | 2.3% | 0.0% |
| Portland Cement | 0.0% | 2.3% | 4.81% |
| Water | 10.71% | 17.0% | 15.11% |

2:1 Ratios ("B" Series)

| Mix Components | Batch No. 1 (B1) | Batch No. 2 (B2) | Batch No. 3 (B3) |
|---|---|---|---|
| Fly Ash | 49.30% | 50.00% | 49.01% |
| Bottom Ash | 24.46% | 25.00% | 25.76% |
| Hydrated Lime | 4.41% | 2.2% | 0.0% |
| Portland Cement | 0.0% | 2.2% | 4.49% |
| Water | 21.83% | 20.4% | 20.74% |

1:2 Ratios ("C" Series)

| Mix Components | Batch No. 1 (C1) | Batch No. 2 (C2) | Batch No. 3 (C3) |
|---|---|---|---|
| Fly Ash | 26.76% | 26.59% | 26.99% |
| Bottom Ash | 51.55% | 51.73% | 52.64% |
| Hydrated Lime | 4.70% | 2.35% | 0.0% |
| Portland Cement | 0.0% | 2.35% | 4.78% |
| Water | 16.99% | 16.98% | 15.59% |

## 1.2 Compressive Strength Testing

A. After an initial curing period of approximately 14 days, three 3) representative samples per mix design were selected for compressive strength testing. The results were as follows:

COMPRESSIVE STRENGTH (PSI)

DESIGN MIX BATCH

| A1 | A2 | A3 | B1 | B2 | B3 | C1 | C2 | C3 |
|---|---|---|---|---|---|---|---|---|
| 565 | 220 | 730 | 195 | 130 | 400 | 200 | 245 | 550 |
| 555 | 210 | 710 | 195 | 135 | 350 | 200 | 250 | 550 |
| 580 | 215 | 690 | 190 | 130 | 420 | 195 | 230 | 545 |

B. Based upon the results of the initial compression testing, mix designs A1, A3, B3, and C3 were selected from the original nine (9) for further study at Texas A&M University at Galveston (TAMUG) and the Cedar Bayou Marine Laboratory.

C. A minimum compressive strength of 300 psi was adopted as the criterion for acceptance of newly cured blocks. In previous research sponsored by EPRI, it was established that minimum cured strengths of 300 psi was necessary in order for fabricated blocks to survive:

1. Production handling, transport, and reef placement.

2. Long-term saltwater immersion.

D. During Phase I testing, three (3) samples per selected mix design will be tested for compressive strengths at 7, 30, 90, 180 and 365 day intervals after initial water immersion. The final results are as follows:

A1 MIX DESIGN

| Time in Water | Compressive Strength (psi) | Avg. Comp. Strength (psi) | Avg. Strength Gain |
|---|---|---|---|
| 0 Days | 565<br>555<br>580 | 567 | - |
| 7 Days | 915<br>940<br>925 | 927 | 63.5% |
| 30 Days | 1585<br>1615<br>1700 | 1633 | 188% |
| 90 Days | 2320<br>2355<br>2595 | 2423 | 327.3% |

| | | | |
|---|---|---|---|
| 180 Days | 2420<br>2420<br>2595 | 2478 | 337% |
| 365 Days | 3185<br>2905<br>3080 | 3057 | 439.2% |

A3 MIX DESIGN

| Time in Water | Compressive Strength (psi) | Avg. Comp. Strength (psi) | Avg. Strength Gain |
|---|---|---|---|
| 0 Days | 730<br>710<br>690 | 710 | - |
| 7 Days | 1165<br>1190<br>1230 | 1195 | 68.3% |
| 30 Days | 1975<br>1940<br>1955 | 1957 | 175.6% |
| 90 Days | 3700<br>3475<br>3200 | 3458 | 387.1% |
| 180 Days | -<br>2630<br>2215 | 2423 | 241.3% |
| 365 Days | 3325<br>3335<br>3595 | 3418 | 381.4% |

B3 MIX DESIGN

| Time in Water | Compressive Strength (psi) | Avg. Comp. Strength (psi) | Avg. Strength Gain |
|---|---|---|---|
| 0 Days | 400<br>350<br>420 | 390 | - |
| 7 Days | 500<br>480 | 490 | 25.6% |

| | | | |
|---|---|---|---|
| 30 Days | 1200<br>1165 | 1182 | 203.1% |
| 90 Days | 1525<br>1695 | 1610 | 312.8% |
| 180 Days | 1525<br>1555 | 1540 | 294.9% |
| 365 Days | 2860<br>3460 | 3160 | 710.3% |

C3 MIX DESIGN

| Time in Water | Compressive Strength (psi) | Avg. Comp. Strength (psi) | Avg. Strength Gain |
|---|---|---|---|
| 0 Days | 550<br>550<br>545 | 548 | - |
| 7 Days | 985<br>1155<br>1020 | 1053 | 92.1% |
| 30 Days | 1780<br>1650<br>1565 | 1665 | 203.8% |
| 90 Days | 2425<br>2250<br>2075 | 2250 | 310.6% |
| 180 Days | 2285<br>1975<br>2355 | 2205 | 302.4% |
| 365 Days | 2840<br>2872<br>3115 | 2942 | 436.9% |

1.3 Strength vs. Time

A. A graphical plot of the average compressive strengths of the four (4) mix designs as a function of time in water submergence is shown in the attached plot, Figure 1.1. At 365 days, the observed average strength gains range approximately from 381% to 710% over the initial pre-submergence compression values.

2.0 Prototype Oyster Reef Material - W. A. Parish Fly Ash & Bottom Ash, W. A. Parish Fly Ash and Limestone Bottom Ash.

2.1 Actual Mix Designs

A. Ash Management Division (AMD) has indicated that a possible shortage of WAP bottom ash material for uose in the Artificial Reef Project could occur in the near future. To counteract this event, the use of LGS bottom ash in lieu of the WAP bottom ash in the mix designs was investigated.

The actual mix design component percentages are as follows:

WAP Fly Ash and WAP Bottom Ash - (A1)

Mix Components

| | |
|---|---|
| Fly Ash | 20.77% |
| Bottom Ash | 58.75% |
| Portland Cement | 4.68% |
| Water | 15.80% |

WAP Fly Ash and LGS Bottom Ash - (LMS)

Mix Components

| | |
|---|---|
| Fly Ash | 22.60% |
| Bottom Ash | 53.35% |
| Portland Cement | 4.60% |
| Water | 19.43% |

1.2 Compressive strength Testing

A. Three (3) samples per mix design will be tested for compressive strengths at 7, 30, 90, 180 and 365 day intervals after initial water immersion. The results at 90 days are as follows:

WAP Fly Ash and WAP Bottom Ash - (A1)

| Time in Water | Compressive Strength (psi) | Avg. Comp. Strength (psi) | Avg. Strength Gain |
|---|---|---|---|
| 0 Days | 470<br>460<br>475 | 468 | - |
| 30 Days | 1488<br>1523<br>1142 | 1384 | 195.7% |

| | | | |
|---|---|---|---|
| 90 Days | 1555<br>1705<br>1590 | 1617 | 245.5% |

WAP Fly Ash and LGS Bottom Ash - (LMS)

| Time in Water | Compressive Strength (psi) | Avg. Comp. Strength (psi) | Avg. Strength Gain |
|---|---|---|---|
| 0 Days | 350<br>400<br>315 | 355 | - |
| 30 Days | 2215<br>2250<br>1660 | 2042 | 475.2% |
| 90 Days | 3875<br>3770<br>3115 | 3587 | 910.4% |

2.3 Strength vs. Time

A. A graphical plot of the average compressive strengths of the mix designs as a function of time in water submergence is shown in the attached plot, Figure 2.1. At 90 days, the observed average strength gains range approximately from 245% to 910% over the pre-submergence compression values.

REEF2.CJB
10-13-89

ATTACHMENT 2

Western Atlas International
A Litton/Dresser Company

CORE LABORATORIES

# A N A L Y T I C A L   R E P O R T

892565

FOR

Houston Lighting & Power Co.
Bill Baker
EDC Central Lab
Houston, TX 77234

12/13/89

Western Atlas International
A Litton/Dresser Company

# CORE LABORATORIES

## LABORATORY TESTS RESULTS
12/13/89

JOB NUMBER: 892565 CUSTOMER: Houston Lighting & Power Co. ATTN: Bill Baker

SAMPLE NUMBER: 1 DATE RECEIVED: 11/21/89 TIME RECEIVED: 17:44 SAMPLE DATE: 11/21/89 SAMPLE TIME: :
PROJECT: SAMPLE: Artificial Reef LS-1 REM: 1x1 plastic bag

SAMPLE NUMBER: 2 DATE RECEIVED: 11/21/89 TIME RECEIVED: 17:44 SAMPLE DATE: 11/21/89 SAMPLE TIME: :
PROJECT: SAMPLE: Artificial Reef LS-1 Dup REM: 1x1 plastic bag

SAMPLE NUMBER: 3 DATE RECEIVED: 11/21/89 TIME RECEIVED: 17:44 SAMPLE DATE: 11/21/89 SAMPLE TIME: :
PROJECT: SAMPLE: Artificial Reef LS-1 Trip REM: 1x1 plastic bag

SAMPLE NUMBER: 4 DATE RECEIVED: 11/21/89 TIME RECEIVED: 17:44 SAMPLE DATE: 11/21/89 SAMPLE TIME: :
PROJECT: SAMPLE: Artificial Reef LS-2 REM: 1x1 plastic bag

SAMPLE NUMBER: 5 DATE RECEIVED: 11/21/89 TIME RECEIVED: 17:44 SAMPLE DATE: 11/21/89 SAMPLE TIME: :
PROJECT: SAMPLE: Artificial Reef LS-2 Dup REM: 1x1 plastic bag

SAMPLE NUMBER: 6 DATE RECEIVED: 11/21/89 TIME RECEIVED: 17:44 SAMPLE DATE: 11/21/89 SAMPLE TIME: :
PROJECT: SAMPLE: Artificial Reef LS-2 Trip REM: 1x1 plastic bag

| TEST DESCRIPTION | SAMPLE 1 | SAMPLE 2 | SAMPLE 3 | SAMPLE 4 | SAMPLE 5 | SAMPLE 6 | UNITS OF MEASURE |
|---|---|---|---|---|---|---|---|
| Extraction Procedure for Toxicity | done | done | done | done | done | done | |
| Digestion of Metals | done | done | done | done | done | done | |
| Arsenic (As), eptox extraction | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | mg/l |
| Barium (Ba), eptox extraction | 3.31 | 3.26 | 2.87 | 2.78 | 2.63 | 2.65 | mg/l |
| Cadmium (Cd), eptox extraction | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | mg/l |
| Chromium (Cr), eptox extraction | 0.11 | 0.14 | 0.17 | 0.15 | 0.14 | 0.14 | mg/l |
| Lead (Pb), eptox extraction | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | mg/l |
| Mercury (Hg), eptox extraction | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | mg/l |
| Selenium (Se), eptox extraction | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | mg/l |
| Silver (Ag), eptox extraction | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | mg/l |

APPROVED BY:______________________

10201 Westheimer
Houston, TX 77042
(713) 972-6700

Western Atlas International
A Litton/Dresser Company

# CORE LABORATORIES

## LABORATORY TESTS RESULTS
12/13/89

JOB NUMBER: 892565 CUSTOMER: Houston Lighting & Power Co. ATTN: Bill Baker

SAMPLE NUMBER: 7 DATE RECEIVED: 11/21/89 TIME RECEIVED: 17:44 SAMPLE DATE: 11/21/89 SAMPLE TIME: :
PROJECT: SAMPLE: Artificial Reef LS-3 REM: 1x1 plastic bag

SAMPLE NUMBER: 8 DATE RECEIVED: 11/21/89 TIME RECEIVED: 17:44 SAMPLE DATE: 11/21/89 SAMPLE TIME: :
PROJECT: SAMPLE: Artificial Reef LS-3 Dup REM: 1x1 plastic bag

SAMPLE NUMBER: 9 DATE RECEIVED: 11/21/89 TIME RECEIVED: 17:44 SAMPLE DATE: 11/21/89 SAMPLE TIME: :
PROJECT: SAMPLE: Artificial Reef LS-3 Trip REM: 1x1 plastic bag

SAMPLE NUMBER: 10 DATE RECEIVED: 11/21/89 TIME RECEIVED: 17:44 SAMPLE DATE: 11/21/89 SAMPLE TIME: :
PROJECT: SAMPLE: Artificial Reef WP-1 REM: 1x1 plastic bag

SAMPLE NUMBER: 11 DATE RECEIVED: 11/21/89 TIME RECEIVED: 17:44 SAMPLE DATE: 11/21/89 SAMPLE TIME: :
PROJECT: SAMPLE: Artificial Reef WP-1 Dup REM: 1x1 plastic bag

SAMPLE NUMBER: 12 DATE RECEIVED: 11/21/89 TIME RECEIVED: 17:44 SAMPLE DATE: 11/21/89 SAMPLE TIME: :
PROJECT: SAMPLE: Artificial Reef WP-1 Trip REM: 1x1 plastic bag

| TEST DESCRIPTION | SAMPLE 7 | SAMPLE 8 | SAMPLE 9 | SAMPLE 10 | SAMPLE 11 | SAMPLE 12 | UNITS OF MEASURE |
|---|---|---|---|---|---|---|---|
| Extraction Procedure for Toxicity | done | done | done | done | done | done | |
| Digestion of Metals | done | done | done | done | done | done | |
| Arsenic (As), eptox extraction | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | mg/l |
| Barium (Ba), eptox extraction | 2.00 | 2.08 | 2.69 | 1.22 | 1.31 | 1.41 | mg/l |
| Cadmium (Cd), eptox extraction | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | mg/l |
| Chromium (Cr), eptox extraction | 0.12 | 0.12 | <0.02 | 0.06 | 0.08 | 0.14 | mg/l |
| Lead (Pb), eptox extraction | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | mg/l |
| Mercury (Hg), eptox extraction | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | mg/l |
| Selenium (Se), eptox extraction | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | mg/l |
| Silver (Ag), eptox extraction | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | mg/l |

APPROVED BY:____________________

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Western Atlas International
A Litton/Dresser Company

# CORE LABORATORIES

## LABORATORY TESTS RESULTS
12/13/89

JOB NUMBER: 892565 CUSTOMER: Houston Lighting & Power Co. ATTN: Bill Baker

SAMPLE NUMBER: 13 DATE RECEIVED: 11/21/89 TIME RECEIVED: 17:44 SAMPLE DATE: 11/21/89 SAMPLE TIME: :
PROJECT: SAMPLE: Artificial Reef WP-2 REM: 1x1 plastic bag

SAMPLE NUMBER: 14 DATE RECEIVED: 11/21/89 TIME RECEIVED: 17:44 SAMPLE DATE: 11/21/89 SAMPLE TIME: :
PROJECT: SAMPLE: Artificial Reef WP-2 Dup REM: 1x1 plastic bag

SAMPLE NUMBER: 15 DATE RECEIVED: 11/21/89 TIME RECEIVED: 17:44 SAMPLE DATE: 11/21/89 SAMPLE TIME: :
PROJECT: SAMPLE: Artificial Reef WP-2 Trip REM: 1x1 plastic bag

SAMPLE NUMBER: 16 DATE RECEIVED: 11/21/89 TIME RECEIVED: 17:44 SAMPLE DATE: 11/21/89 SAMPLE TIME: :
PROJECT: SAMPLE: Artificial Reef WP-3 REM: 1x1 plastic bag

SAMPLE NUMBER: 17 DATE RECEIVED: 11/21/89 TIME RECEIVED: 17:44 SAMPLE DATE: 11/21/89 SAMPLE TIME: :
PROJECT: SAMPLE: Artificial Reef WP-3 Dup REM: 1x1 plastic bag

SAMPLE NUMBER: 18 DATE RECEIVED: 11/21/89 TIME RECEIVED: 17:44 SAMPLE DATE: 11/21/89 SAMPLE TIME: :
PROJECT: SAMPLE: Artificial Reef WP-3 Trip REM: 1x1 plastic bag

| TEST DESCRIPTION | SAMPLE 13 | SAMPLE 14 | SAMPLE 15 | SAMPLE 16 | SAMPLE 17 | SAMPLE 18 | UNITS OF MEASURE |
|---|---|---|---|---|---|---|---|
| Extraction Procedure for Toxicity | done | done | done | done | done | done | |
| Digestion of Metals | done | done | done | done | done | done | |
| Arsenic (As), eptox extraction | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | mg/l |
| Barium (Ba), eptox extraction | 1.84 | 1.87 | 1.61 | 2.87 | 2.46 | 1.88 | mg/l |
| Cadmium (Cd), eptox extraction | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | mg/l |
| Chromium (Cr), eptox extraction | 0.04 | 0.12 | 0.12 | <0.02 | <0.02 | 0.06 | mg/l |
| Lead (Pb), eptox extraction | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | <0.05 | mg/l |
| Mercury (Hg), eptox extraction | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | <0.001 | mg/l |
| Selenium (Se), eptox extraction | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | <0.1 | mg/l |
| Silver (Ag), eptox extraction | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | mg/l |

10201 Westheimer
Houston, TX 77042
(713) 972-6700

APPROVED BY:____________________

ATTACHMENT 3

# TEXAS A&M UNIVERSITY AT GALVESTON

**Mitchell Campus P.O. Box 1675 Galveston, Texas 77553**

Department of
Marine Biology

March 19, 1990

Mr. Ed Feith
Manager, Environmental Department
Houston Lighting & Power Company
P.O. Box 1700
Houston, Tx 77251

Dear Mr. Feith:

Assessments of the environmental suitability of several coal combustion byproduct mixtures (CCBP) developed by Houston Lighting and Power Company as substrate for oyster and fish reefs have been underway in our research facilities since 1988. Our initial assessment involved exposing various CCBP mixtures to hatchery-reared oyster larvae to determine the ability of these larvae to set and grow on the experimental substrate. This assessment indicated that oyster larvae setting on CCBP substrate developed into spat and exhibited rapid growth at a rate comparable to that for larvae setting on oyster shell controls. CCBP substrate deployed in natural larvae settings at three different Galveston Bay sites were rapidly colonized by fouling communities composed of oysters, barnacles, sea squirts, and algae and used for food and shelter by various species of crabs and fishes. These exposures to natural conditions proved conclusively that CCBP material is a viable alternative to oyster and clam shell in the development and enhancement of reef substrate.

Another criterior of environmental suitability of CCBP material is the degree of uptake or bioaccumulation of trace metals by oysters attached to the experimental substrate. Chemical analyses of oysters growing on CCBP substrate yielded no significant accumulation among the 10 trace metals tested. Oysters from the CCBP material and oyster shell control showed uptake of trace metals was generally not dependent upon the substrate to which they were attached but was a function of the surrounding water column and/or sediment. This finding concurred with the E.P. Toxicity test results (generated by a private lab under contract to HL&P) which found extremely low trace metal levels in leachate analyses of CCBP material.

Our findings, along with the independent results showing CCBP material to be a very stable substrate in aquatic environments, are indicative that the material has met stringent prerequisites to it being deployed in larger-scale experiments in the wild. More specifically, we recommend that CCBP material be deployed as bottom reef substrate in different areas of Galveston Bay and the Gulf of Mexico to further test its ability to enhance barren bottom areas, rehabilitate and/or create oyster reef substrate, and provide shoreline protection and stabilization. Mitigation projects with the U.S. Army Corps of Engineers and oyster reef enhancement efforts with Galveston Bay oyster fishermen are excellent vehicles for additional testing and subsequent acceptance of CCBP material as an environmentally suitable artificial substrate.

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MAR 1 9 1990
E. A. FEITH

We strongly support your efforts to develop and qualify CCBP material as environmentally suitable substrate for marine ecosystems and look forward to our continued participation in these efforts.

Sincerely,

Sammy M. Ray
Co-Principal Investigator
and

Andre M. Landry
Co-Principal Investigator

cc: Mr. Bill Baker, HL&P

ATTACHMENT 4

United States Department of the Interior
Fish and Wildlife Service
DIVISION OF ECOLOGICAL SERVICES
17629 EL CAMINO REAL, SUITE 211
HOUSTON, TEXAS 77058

February 22, 1990

Mr. Bill Baker
Houston Lighting & Power
P.O. Box 1700
Houston, Texas 77251

Dear Mr. Baker:

In response to the meeting held at our office on Wednesday, March 21, 1990, and after review of the toxicity data on the coal combustion by-product, the Fish and Wildlife Service has no reservation concerning the use of that material to build reefs for oyster production.

All of the tests on strength of the material, corrosion resistance, and lack of leachate toxicity indicate that the material will make a good substrate for reef formation. We appreciate the opportunity to review your proposal and are ready to provide further comments if needed.

Sincerely,

David L. Hankla
Field Supervisor

cc:
Area Supervisor, National Marine Fisheries Service, Galveston, TX
Texas Parks and Wildlife Department, Austin, TX

ATTACHMENT 5

**DEPARTMENT OF THE ARMY**
GALVESTON DISTRICT, CORPS OF ENGINEERS
P.O. BOX 1229
GALVESTON, TEXAS 77553-1229

MAR 30 1990

REPLY TO
ATTENTION OF:
Compliance & Special
Actions Section

SUBJECT: D-2891; Permit Requirements

Mr. Stephen S. Davies, Manager
Water and Ecological Resources Division
Environmental Department
Houston Lighting and Power Company
P. O. Box 1700
Houston, Texas 77251

Dear Mr. Davies:

This is in response to your March 3, 1990 letter requesting a determination of permit requirements to place ten cubic yards of man-made reef material. The fill will be utilized as part of the mitigation work for the Clear Creek Flood Control Project. The project is located in the Seabrook Slough, Seabrook, Harris County, Texas.

The project will involve the placement of ten cubic yards of coal combustion by-product material to enhance and create oyster and fish reefs. An individual permit will not be required to perform the work. However, if you propose to place the material outside of the mitigation site, a permit will be required.

If you have any questions concerning this matter, please contact Mr. James Gilmore at the above letterhead address or by calling (409) 766-3034.

Sincerely,

Fred L. Anthamatten
Chief, Compliance and Special
Actions Section