January

Crushed Concrete

This packet provides information about how and why to use crushed concrete in various road construction applications.

Research Summary	Using Recycled Concrete Aggregates in Portland Cement Pavement
Case Study #1	Crushing Railroad Ballast for Use as Recycled Flexbase Aggregate in TxDOT's Houston District
Case Study #2	Recycling Crushed Concrete and Spent Sand Blasting Material in Cement Stabilized Base
TxDOT Experience	Summary of TxDOT experience using crushed concrete in various applications
Material Availability	Map and table listing companies that generate, or anticipate generating in the next five years, surplus concrete and masonry stockpiles that could be used in construction projects
Material Processors	Map and table listing companies that have the ability and/or willingness to crush concrete to meet TxDOT specifications
Specifications	TxDOT Special Provisions which allow for the use of crushed concrete, including: • flexbase Special Provision 247-017 at http://www.dot.state.tx.us/insdtdot/orgchart/cmd/cserve/specs/ep247017.txt • asphalt stabilized base Special Provision 421-024 at http://www.dot.state.tx.us/insdtdot/orgchart/cmd/cserve/specs/ep421024.txt

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Material Brief

Concrete from roads, pavements, airfield runways, buildings, and other sources can be crushed for reuse. After crushing, magnets remove the steel rebar and the resulting aggregates are screened according to planned use. The crushed concrete produces hard, granular aggregates composed of inert mineral materials including sand, gravel, and crushed stone.

The American Concrete Pavement Association estimates that approximately 322 kilometers of concrete pavement is being recycled each year and approximately 5,440 metric tons of crushed concrete can be

reclaimed from 1.6 km of concrete pavement with an average thickness. This shows that 2.6 million metric tons of reclaimed concrete is being recycled annually in the United States.

TxDOT has specifications that allow crushed concrete to be used in flexbase, cement-stabilized base, and riprap. Additionally, crushed concrete can be used as coarse aggregates in Portland Cement Concrete and as fine aggregates in asphalt stabilized base.

Overview

Recycling of Portland cement started in Europe after World War II. With time and through necessity, recycled aggregates have become increasingly acceptable as road construction. It is estimated that approximately 100 million tons of concrete rubble is generated annually in the United States. This amount is projected to exceed 150 million by the year 2000. Landfill life will be unnecessarily shortened if this volume of rubble is dumped there; furthermore, a valuable material will be wasted if not recycled into usable aggregate products.

In comparison with the national annual aggregate production of more that 2 billion tons, concrete rubble represents only 5 percent of the aggregate market if it is all recycled. Since some rubble is lost during demolition and some will be disposed of in landfills, recycled concrete aggregate is probably less than 3 percent of the total aggregate market. Crushed concrete, nonethe-less, represents significant opportunities for economic and environmental benefits.

The Center for Transportation Research (CTR) of the University of Texas at Austin conducted a study on recycled materials for TxDOT. According to its findings, Pharr district had the biggest stockpile (3,624 metric tons) of old concrete. Nine of the twenty-one TxDOT districts responded to the survey already had stockpiles of crushed concrete and nineteen districts believed that old concrete could be used as road-base material. TxDOT engineers from Abilene, Atlanta, Beaumont and Dallas districts rated the performance of concrete as excellent.

Research Summary

Recycled Concrete Aggregates in Portland Cement Concrete Pavement

Problem Statement

Recycling of old concrete pavement has become an important issue as more concrete pavement reaches the end of its functional and structural life. Currently, economic considerations are the primary thrust for the use of recycled concrete aggregate (RCA) in portland cement concrete (PCC) pavement. However, as landfill spaces become more scarce and expensive, environmental considerations will play an important role as well.

The section of IH 10 in Houston District between Loop 610 and IH 45 is under reconstruction. The contractor decided to use 100 % of RCA in the new pavement concrete. This project is the first one in the nation where all the aggregates used for pavement concrete, both coarse and fine, are recycled with no virgin aggregates used. As such, there is not much information available regarding the performance of PCC pavement with 100 % RCA.

Objectives

Objectives of this study were to (1) evaluate the engineering properties of recycled concrete aggregate (RCA) and portland cement concrete (PCC) made with that aggregate, (2) investigate the effect of RCA and PCC properties on continuous reinforced concrete pavement (CRCP) performance, and (3) develop guidelines for the effective use of RCA for CRCP.

There are a number of factors affecting CRCP performance. They include adequacy of the pavement structure, material properties, environmental conditions during concrete placement, and construction practices. The scope of this study was limited to laboratory evaluation of RCA and PCC material properties, performance evaluation of CRCP sections in the Houston District, and analysis of information to develop guidelines for the use of RCA in CRCP.

Findings - Performance

The following conclusions are made base on the investigation of the effect of RCA and PCC properties on CRCP performance.

Specific findings include:

- The CRCP sections utilizing 100 % recycled coarse and fine aggregates have performed well. No distresses, including spalling, wide cracks, punchouts, or meandering cracks, have taken place. The transverse crack spacing distributions are comparable to those in concrete with natural siliceous river gravel.
- The large amount of old mortar in recycled coarse aggregate does not appear to have an adverse effect on CRCP performance.
- Moisture control of recycled aggregate is critical in producing consistent and workable concrete.
- No significant adjustment in paving operations is necessary due to the use of 100 % recycled coarse and fine aggregate in concrete.

Finding regarding the engineering properties of recycled concrete aggregates and PCC made with them include:

- The properties of recycled aggregates measured in this study are consistent with those reported elsewhere – lower specific gravity, higher water absorption, and higher sulfate soundness loss and LA abrasion loss – compared with those of virgin aggregates.
- Recycled aggregates do not have a pronounced effect on compressive strength.
- Recycled fine aggregates have an adverse effect on flexural strength.
- The use of both recycled coarse and fine aggregates reduces modulus elasticity significantly.
- For the same water/cement ration, replacing virgin sand with recycled sand does not result in changes in tensile strength.
- Thermal coefficient of concrete containing 100 % recycled aggregate is much higher than that of virgin aggregate concrete.
- Recycled coarse aggregate has a much higher thermal coefficient than virgin aggregate due to the attached old mortar.
- Sodium sulfate causes more damage to recycled coarse aggregate than magnesium sulfate, which is opposite virgin aggregate.
- The effect of recycled aggregate on the abrasion resistance of concrete is inconclusive.
- The validity of sulfate soundness and LA abrasion tests as tools for evaluating the quality of recycled aggregate needs to be investigates.

The use of RCA in concrete has positive (larger creep, low modulus) and negative (Low strength, higher thermal coefficient) effects on CRCP performance. The combined effects can only be evaluated by actual long-term performance of CRCP in the field.

Findings - Constructability

In the beginning of the project, there was a problem producing concrete with consistent workability that met the minimum strength requirement. The primary reason for inconsistent workability was due to the lack of moisture control of recycled aggregate. A better sprinkler system was installed later for aggregate stockpiles, and moisture of the recycled aggregate was better controlled. This system mitigated the inconsistent workability problem. Paving operations were closely monitored to identify any variations that might result from using the recycled aggregate. Not much difference was observed.

Construction crews were interviewed for their opinion and experience with the handling PCC containing RCA. One of the most often heard comments was that the concrete was not consistent. The next most frequent comment was that concrete sometimes set too quickly. This quick-setting problem is believed to be caused by recycled fine the mixing. Construction crews stated that when the concrete was of good workability, the finishing operation was not much different from normal concrete paving.

Implementation

Even though it is too early to make any firm conclusions concerning the long-term effects of 100 % RCA on pavement performance, the good performance so far indicates RCA might be used for pavement concrete without compromising pavement performance.

Guidelines for the effective use of RCA for CRCP are under development. Once complete, the document will provide information on how to recycle crushed concrete for pavement concrete and what needs to be done to maximize its potential benefits.

The contents of this summary are reported in detail in TxDOT Research Report, 1753-1F, *Use of Crushed Concrete as Aggregate for Pavement Concrete*, by Moon C. Won.

This aggregate not being saturated during summary does not reflect the official views of TxDOT nor FHWA. To obtain a copy of this report, contact the TxDOT Research Librarian at (512) 465-7644.

Case Study #1

Crushing Railroad Ballast for use as Recycled Flexbase Aggregates in TxDOT's Houston District

Abstract

The Houston construction market boasts one of the highest recycling rates in Texas, especially when it comes to recycled aggregates. The distance to native aggregates resources (over 200 miles), high rate of construction, and rapid property redevelopment have stimulated the recycled aggregate markets to a level where they now supply an estimated 2.5 to 3 million tons of recycled products for construction annually, or as much as 1 / 4 of the total Houston area market. The sources for these products include highway, bridge and building demolition , and other sources including railroad right-of-way realignment.

This case study looks specifically at one such railroad right-of-way salvage effort, and the almost $3.6 Million savings to TxDOT by recycling valuable aggregates instead of disposal in landfills. The project was conducted along a former railroad right-of-way adjacent to the north side of IH-10 in Houston, Texas. Information regarding the location and type of materials, as well as economic aspects of the project, are located in this summary.

Note: In this case study TxDOT is both the generator of the material and the potential end user, enjoying savings in both aspects of the operation. The economics are still favorable when the crushed concrete is favorable when the crushed concrete is purchased from a third party.

Project Overview

In recent years, TxDOT has explored the use of recycled materials in its road construction and maintenance projects. A series of research efforts conducted by the state's engineering universities determined that many alternative materials promised a variety of engineering, economic and environmental benefits. Much of this research has been completed with positive findings and results. At the Federal level, large quantities of similar materials have historically been used as highway construction materials, with at least 34 states reporting some usage. This preponderance of evidence convinced the Houston District, when abandoning nearly 20 miles of railroad right-of-way, to seek a way to recycle the approximately 125,430 cubic yards of ballast and sub-ballast available.

Economic Analysis

Disposal in landfills near the right-of-way has historically been the most common method of managing this type of material. However, recycling was a very attractive option given the scarcity of local aggregates and the well-defined local gathering and distribution network for recycled materials. In addition to the high quality of the material (native rock ballast and sub-ballast), the economics of recycling over disposal were a clear vote for the reuse scenario. Approximately 125,430 cubic yards of the ballast material was made available by TxDOT in a competitive sealed bid.

Economic Analysis

Disposal Costs Avoided	
Disposal costs	$1.5 Million
Excavation and Transportation Landfill	$1.4 Million
Subtotal	**$2.9 Million**
Economic Benefit from Recycled Material Usage	
Approximate Recycled Material Production	200,000 tons
Cost of Competing Native Materials	$ 11.90/ton
Cost of Recycled Materials	8.90/ton
Subtotal (Economic Benefit)	**$0.4 Million**
Direct Revenue for Sale of Material	
Subtotal	**$0.29 Million**
Total Economic Benefit for TxDOT	**$3.59 Million**

Material Information

Railway company specifications for sub-ballast material match well with TxDOT specification for flexible base. Main railway ballast, however, requires intermediate processing to meet the flex base specification.

The chemical and physical characteristics of the recycled aggregate generated from this railroad right-of-way salvage effort were similar to those of typical native materials, foreign debris aside. Processing involved removal of foreign debris, and primary and secondary crushing and screening to achieve the correct gradation. To avoid inadvertent particle size segregation, fine aggregates and coarse aggregates are sometimes separately stockpiled. The finished product is expected to have very favorable mechanical properties for aggregate usage.

Results and Conclusion

The recycled aggregate met design and construction specifications as a substitute ingredient in the production of the recycled flexible base. Potential uses for the material include flexible and cement stabilized base, engineered fill, and other uses such as an aggregate in flowable fill or perhaps in hot mix asphalt concrete.

Economic advantages to the Department included a net economic benefit of approximately $3.59 million over traditional transportation and disposal alternatives.

Case Study #2

Recycled Crushed Concrete and Spent Sand Blasting Material in Cement Stabilized Base

A case study is being prepared by Texas Tech University summarizing a test project constructed in the Houston District using crushed concrete and spent sand blasting material in cement stabilized base. This project is located on SH6 just south of US 290 West. The TxDOT control number for this project is 1685-05-057. The case study should be completed in the fall and will be available on TxDOT's web site: www.dot.state.tx.us

Preliminary results for tests on selected crushed concrete bases used in the Houston District are provided in the table below.

Test Data on Crushed Concrete—Houston District

Highway/County	C-S-J	Date Sampled	LL	PI	D_a (lb./cu.ft.)	OMC (%)	Gradation (Cumulative Percent retained)
SH 249/Harris	720-3-73	1/10/96			122.1	10.5	
I-45/Harris		7/2/94	18.9	1.7	123.9	9.6	
IH 45/Harris	110-5-77	10/25/95	32	3	119.8	10.3	1-3/4" --- 0 No. 4 --- 53 No. 40 --- 67
SH 6/Harris	1685-05-057	6/10/97	22	2	123.8	9.3	
SH 249/Harris	0720-03-081	5/1/96	30	7	124.5	9.8	1-3/4" --- 0 No. 4 --- 62 No. 40 --- 77

LL = Liquid Limit **D_a** = Density
PI = Plasticity Index **OMC** = Optimal Moisture Content

Excerpts from Houston District specifications for crushed concrete in cement stabilized base indicate that "When salvaged existing base and asphaltic concrete pavement are used, the material shall be sized so that all the material, except the existing individual aggregate, shall pass the 2-inch sieve and be of a gradation to allow satisfactory compaction. The material is to be salvaged in a manner which will not introduce deleterious material (clay, organics, etc.). Material passing the No. 40 sieve (defined as soil binder) shall have a plasticity index not to exceed ten, and a liquid limit not to exceed 35 when tested in accordance with test method Tex-106-E." Additionally, the Houston District allows "With permission of the engineer, sand may be blended in the mix."

TxDOT Experience

Crushed Concrete

This table provides information about TxDOT's experience using crushed concrete in several different construction applications including: embankment and backfill, asphaltic concrete paving, base and subbase, and Portland Cement Concrete. The district, location, results, date installed, specifications used and additional comments are also provided.

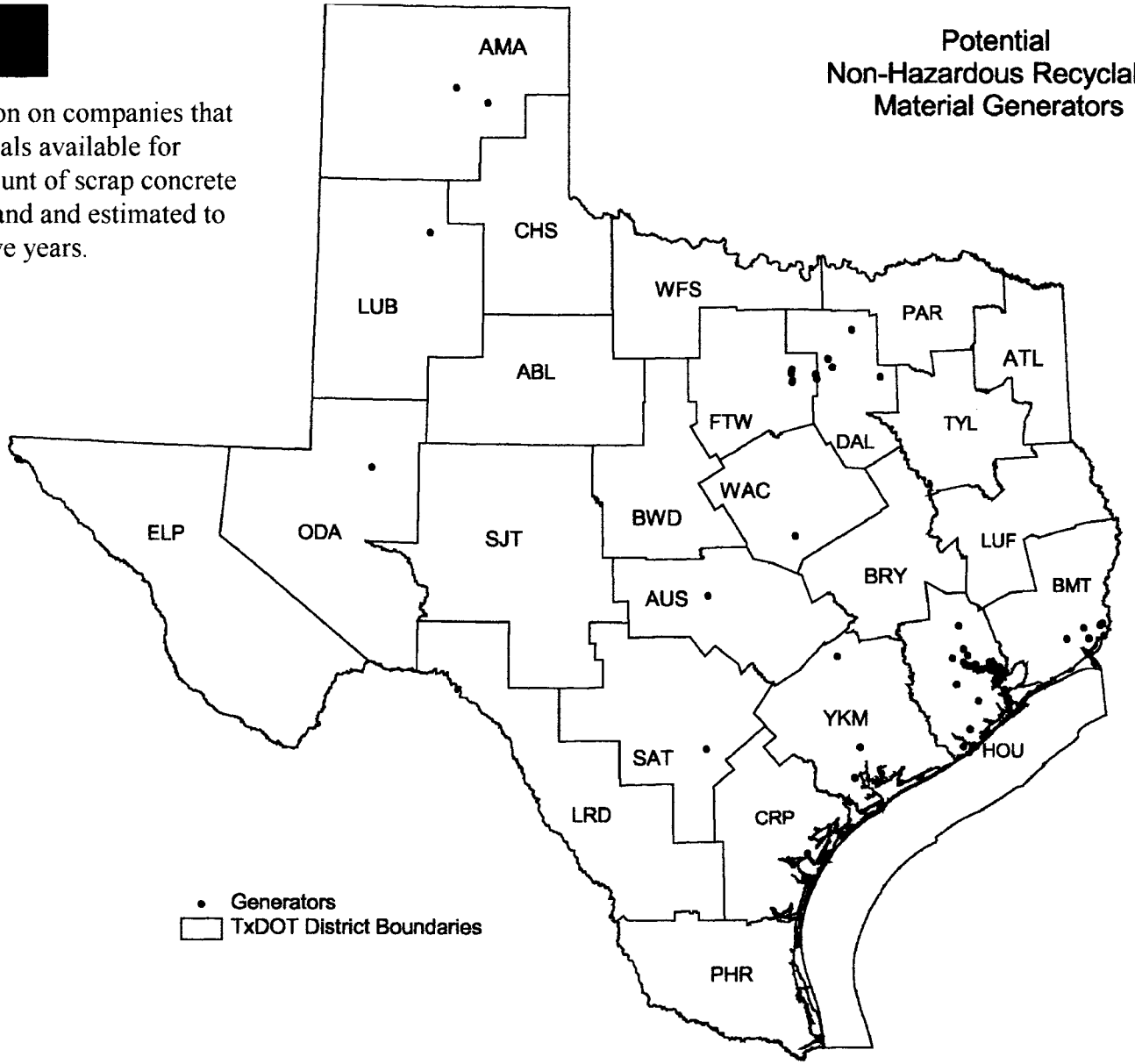
District Name	Construction Application	Results	Installed	Specification	Location	Additional Comments
Beaumont	Embankments & Backfill	Good	1994	None	SH 82, SH 87	Used for embankment to control erosion on Intercoastal Waterway.
Corpus Christi	Embankments & Backfill	Excellent	1977	132	Various	Embankments. Also, outfall erosion protection.
Lufkin	Embankments & Backfill	Excellent	1982		District wide	
Bryan	Paving Materials - Asphaltic Concrete	Good	1986	340-003-99	US 290 W	
Pharr	Paving Materials - Asphaltic Concrete	Good		1993 Specs. (3834)	US 281 S. of Pharr	Only used once in Type "A" hot mix.
Atlanta	Paving Materials - Base / Subbase	Good	1991	Standard	Panola, Bowie (US 79, FM 123, US 259)	
Austin	Paving Materials - Base / Subbase	Good	1987	No	Travis & Hays County	
Beaumont	Paving Materials - Base / Subbase	Good		274	SPUR 380	Cement stabilized base
Fort Worth	Paving Materials - Base / Subbase	Good	1991	81 88 (3-91)	Tarrant County	MSE Wall Backfill

Houston	Paving Materials - Base / Subbase	Good	1987	Item 276	District wide	Slightly lower compressive strength than crushed limestone but adequate for our requirements.
Paris	Paving Materials - Base / Subbase	Good	1989	Unknown	I-30 - Hopkins Co.	Material used to create a drainable subbase for new PCC.
Amarillo	Paving Materials - Portland Cement	Good	1996	360	IH 40	Used in place of a percent of cement.
Childress	Paving Materials - Portland Cement	Unknown	1996	247	Hall (US 287)	
Houston	Paving Materials - Portland Cement	Good	1996	Item 360 (S.P. 421)	IH-10	Pavement is being monitored.

If a TxDOT project using crushed concrete was omitted from this list, please use the form available on TxDOT's web site (www.dot.state.tx.us) or call (512) 416-2562.

Material Availability

This map and table provide information on companies that generate concrete and masonry materials available for recycling. The table indicates the amount of scrap concrete and masonry materials currently on-hand and estimated to be generated each year for the next five years.



Material Processors

This table, and the map following, provide information on companies that have expressed an ability and/or willingness to crush concrete to meet TxDOT specifications.

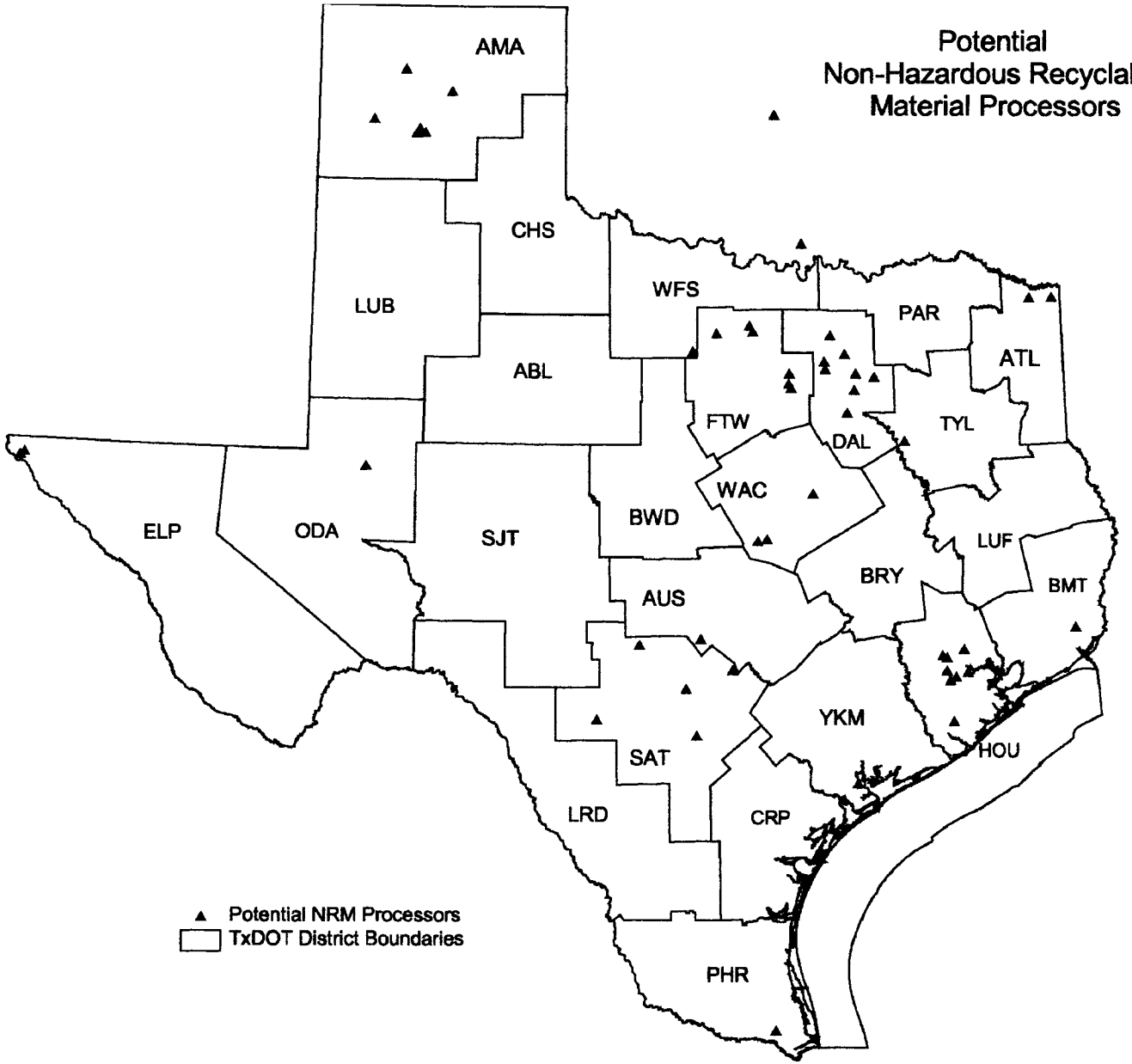
Name	City	State	ZIP	TxDOT district	Phone	Concrete	Mobile processing
Allied Paving Company	El Paso	TX	79904	El Paso	(915) 755-7625	A / W	TRUE
Amarillo Road Co. - Rock Crusher	Amarillo	TX		Amarillo	(806) 335-2922	A / W	TRUE
American Materials Inc	Missouri City	TX	77459	Houston	(281) 449-1506	A / W	TRUE
Arbuckle Materials	Edmond	OK	73083		(405) 340-6026	W	TRUE
Archer-Western Contractor	Arlington	TX	76006	Fort Worth	(817) 640-3898	A / W	TRUE
Ballanger Construction Co.	San Benito	TX	78586	Pharr	(956) 399-5381	A / W	FALSE
Bay LTD.	Corpus Christi	TX	78469	Corpus Christi	(512) 289-7995	A / W	TRUE
Beck Pit	Mission	TX	78573	Pharr	(956) 581-2751	W	TRUE
Big City Crushed Concrete	Dallas	TX	75229	Dallas	(972) 243-5820	A / W	TRUE
Bowie Bridge LLC	New Boston	TX	75570	Atlanta	(903) 628-6670	W	FALSE
Cherokee Bridge & Road Inc.	Junction	TX	76849	San Angelo	(915) 446-3710	A / W	TRUE
Clemons Trucking	Dallas	TX	75241	Dallas	(972) 224-1130	W	TRUE
Colorado Materials Co. Inc	New Braunfels	TX	78132	San Antonio	(512) 396-1555	A / W	FALSE
Dolese Bros. Co - Recycle Plant	Oklahoma City	OK	73101	NA	(405) 235-2311	A / W	TRUE
Durwood Greene Construction Co.	Angleton	TX	77515	Houston	(409) 848-3040	A / W	TRUE
E.D. Baker Corporation	Borger	TX	79007	Amarillo	(806) 273-7501	A / W	TRUE
Foremost Paving Inc	Weslaco	TX	78596	Pharr	(956) 968-5471	A / W	TRUE
Franklin Industrial Minerals	Nolanville	TX	76559	Waco	(254) 698-2511	A / W	FALSE
Fuller & Sons	Amarillo	TX	79108	Amarillo	(806) 373-6049	A / W	TRUE
Garrett Construction	Ingleside	TX	78362	Corpus Christi	(512) 776-7575	A	TRUE
Gifford-Hill & Co - Ferris Plant	Ferris	TX	75125	Dallas	(972) 225-7328	W	FALSE
Gifford-Hill & Co. - Bridgeport Plant	Bridgeport	TX	76426	Fort Worth	(940) 683-4294	W	FALSE

Gifford-Hill & Co. - Cobb Plant	Seagoville	TX	75159	Dallas	(972) 287-4500	W	FALSE
Gifford-Hill & Co. - Waco Plant	Waco	TX	76705	Waco	(254) 752-4385	W	FALSE
Gilvin-Terrill Inc - Crusher	Amarillo	TX	79105	Amarillo	(806) 944-5200	A / W	TRUE
H&B Contractors Inc	McGregor	TX	76657	Waco	(254) 848-4461	W	FALSE
H.V. Caver Inc	Atlanta	TX	75551	Atlanta	(903) 796-8253	W	FALSE
Holms Construction	Amarillo	TX	79121	Amarillo	(806) 356-8294	A / W	TRUE
Ingram ReadyMix Inc.	New Braunfels	TX	78132	San Antonio	(830) 625-9156	W	FALSE
J.H. Strain & Sons Inc. #1 Crusher	Tye	TX	79563	Abilene	(915) 668-1227	A / W	TRUE
James Cape & Sons Co.	Racine	WI	53401		(414) 639-2552	A / W	TRUE
Jobe Concrete Products Inc	El Paso	TX	79930	El Paso	(915) 565-4681	A / W	TRUE
Jones Brothers	Odessa	TX	79760	Odessa	(915) 332-0721	A / W	TRUE
L.A. Fuller & Sons Construction Inc	Amarillo	TX	79107	Amarillo	(806) 373-6049	A / W	TRUE
Lewis Construction Co. - Dumas	Dumas	TX	79029	Amarillo	(806) 935-5641	A / W	TRUE
Leyendecker Materials	Laredo	TX	78041	Laredo	(956) 722-5126	A / W	FALSE
M. Hanna Construction Company	Ennis	TX		Dallas	(903) 885-6772	W	TRUE
Marock Inc.	Dallas	TX	75229	Dallas	(972) 869-2971	A / W	FALSE
Mathews Construction Company	Jasper	TX	75951	Beaumont	(409) 384-4520	W	FALSE
Mendez Construction Company	Corpus Christi	TX	78469	Corpus Christi	(512) 265-9500	W	TRUE
Meridian Aggregates	Powderly	TX	75473	Paris	(903) 732-3124	W	TRUE
Pavers Supply Co. - Conroe Plant	Conroe	TX	77303	Houston	(409) 756-6960	A / W	TRUE
Rebcon Inc	Dallas	TX	75220	Dallas	(972) 444-8230	W	FALSE
Recycled Stone Co. - Huntsville Plant	Huntsville	TX	77340	Bryan	(409) 756-6960	A / W	TRUE
Russell & Sons Construction Co.	Longview	TX	75602	Tyler	(903) 758-5578	A	TRUE
Sanco Materials Co.	Robert Lee	TX	76945	San Angelo	(915) 944-9693	A	FALSE
South Texas Aggregates	Knippa	TX	78870	San Antonio	(830) 934-2614	A / W	TRUE
Southern Crushed Concrete - Chrisman	Houston	TX	77039	Houston	(281) 987-8789	A / W	TRUE
Southern Crushed Concrete - Gasmer	Houston	TX	77035	Houston	(281) 987-8789	A / W	TRUE
Southern Crushed Concrete - Griggs	Houston	TX	77021	Houston	(281) 987-8789	A / W	TRUE
Southern Crushed Concrete - Tanner Road	Houston	TX	77041	Houston	(281) 987-8789	A / W	TRUE
Southern Crushed Concrete - Wilcrest	Houston	TX	77072	Houston	(281) 987-8789	A / W	TRUE

Stringtown Materials L.P.	Stringtown	OK	74569		(580) 346-7376	W	FALSE
Sundt Construction	Austin	TX	78719	Austin	(512) 891-5834	A / W	FALSE
Texas Industries (TXI)	Tomball	TX	77375	Houston	(281) 357-3565	A / W	TRUE
Vega Sand and Gravel Inc.	Vega	TX	79092	Amarillo	(806) 267-2147	A / W	TRUE
Vulcan Materials Co. - 1604 Quarry	San Antonio	TX	78247	San Antonio	(210) 695-8547	A	FALSE
Williams Brothers - Airtex Crusher	Houston	TX	77073	Houston	(713) 522-9821	A / W	TRUE
Williams Brothers - Bennington Crusher	Houston	TX	77022	Houston	(713) 522-9821	A / W	TRUE
Zack Burkett Co. - Perry Pit	Graham	TX	76450	Wichita Falls	(940) 549-6732	A / W	TRUE
Zack Burkett Co. - Richards Pit	Jacksboro	TX	76458	Fort Worth	(940) 549-6732	A / W	TRUE

The information provided in this table is based on submission by the companies list. TxDOT does not represent that any of such information is necessarily accurate or correct. Likewise, TxDOT does not intend, nor should anyone conclude, that companies listed are endorsed in any way, for any purpose, by TxDOT.

Any person or firm not listed, who believes that person or firm qualifies to be so listed, is invited to submit the required information. Please contact Andy Andrasi at (512) 416-2562, for more information.


Potential
Non-Hazardous Recyclable
Material Processors
AMA
CHS
LUB
WFS
PAR
ATL
ABL
FTW
DAL
TYL
WAC
ELP
ODA
SJT
BWD
LUF
BRY
BMT
AUS
YKM
HOU
SAT
LRD
CRP
PHR
Potential NRM Processors
TxDOT District Boundaries

Specifications

The following TxDOT Special Provisions allow for the use of crushed concrete in flexbase and asphalt stabilized base.

- Flexbase Special Provision 247-017
  http://www.dot.state.tx.us/insdtdot/orgchart/cmd/cserve/specs/ep247017.txt

- Asphalt Stabilized Base Special Provision 421-024
  http://www.dot.state.tx.us/insdtdot/orgchart/cmd/cserve/specs/ep421024.txt