DYKES MATERIALS
2775 Mechanicsville Road • Norcross, Georgia 30071
Phone (770) 448-3392 • Fax (770) 242-7441
Jim Dykes, President

09/29/06

To Whom It May Concern:

Thank you for your interest in crushed concrete base. Dykes Materials, a division of Dykes Paving & Construction Co., Inc. has been producing and installing crushed concrete base in the Atlanta market for over 10 years. We have used this product on several high profile projects including the Hartsfield Jackson Airport and Turner Field with great success.

Dykes Paving request that crushed concrete base be considered for use on your project for the following reasons:

- **Hardness Factor - We have found that crushed concrete has a distinctive advantage over crusher run in the ability for it to "set-up" and remain hard during wet/winter conditions.**
- **Convenience - On projects with accelerated schedules, crushed concrete can be stockpiled onsite in advance. This minimizes the effect of traffic conditions on dump truck deliveries and allows for increased production by our base installation crew.**
- **100% Recycled Product- Customers can be proud of the fact that this material limits the demand for natural resources, drastically reduces the need for landfill space in our community and promotes a cleaner environment for us all.**

Provided below are several companies familiar with crushed concrete:

1. **Sailors Engineering – contact Jim Sailors PE at (770) 962-5922**
   Jim Sailors has extensive experience in the testing and specification of crushed concrete base.
2. **Worthing Southeast Builders – contact Steve Ingram at (770) 522-5781**
   Worthing Southeast is a leading builder of luxury apartment and condos in the Atlanta market. They specify crushed concrete on all of their new construction projects.
3. **Osbourne & Associates – contact Darrin Roby at (678) 822-7200**
   On the recent Viasat Project, we utilized approx. 5,800 tons of crushed concrete base for all of the interior paving. In addition, crushed concrete was used for all building pads and temporary site roads.
4. **Freese Construction – contact Jason Rehmert at (770) 850-9393**
   We are currently supplying approx. 10,000 tons of crushed concrete base for the Best Software project in Duluth, GA.

Dykes Paving has enclosed the GDOT specification for your review. Please feel free to contact me at (770) 527-5336 for additional information on this matter.

Sincerely,

Lee D. Young
Vice President – Materials Division

ENCLOSURE

ENGINEERING CONSULTING SERVICES, LTD.
Geotechnical ◆ Construction Materials ◆ Environmental

March 31, 2000

RECEIVED
APR 10 2000
HCG

Mr. Kevin Kiernan
Piedmont Capital
1380 W. Paces Ferry
Suite 180
Atlanta, GA 30327

RE: Crushed Concrete Graded Aggregate Base Material
Old Alabama Square
Alpharetta, GA
ECS Project No. 10:1320

Dear Mr. Kiernan:

As requested by Mr. Joe Reaves with PBS&J, ECS, Ltd. has review the submittal for a proposed crushed concrete base course material in the parking lot. In addition, we have received from Hardin Construction a sample of the proposed material in a 5 gallon bucket for confirming tests. ECS, Ltd. has assumed the sample provided is representative of the material that will be delivered to the Site.

Based on our review of the submittal and our confirming tests, it appears that the material meets GDOT requirements for Section 815, Group II aggregates. Therefore, it is our opinion that the submitted material is suitable for use as Graded Aggregate Base Course on this site. Our test results are attached.

We trust that this information will be sufficient. Please call if you have any questions.

Respectfully,

ENGINEERING CONSULTING SERVICES, LTD.

Richard E. Hoaglin, P.E.
Senior Project Engineer

Robert L. Goehring, P.E.
Principal Engineer

XC: PBS&J, Joe Reaves
Hardin, Richard Foreman

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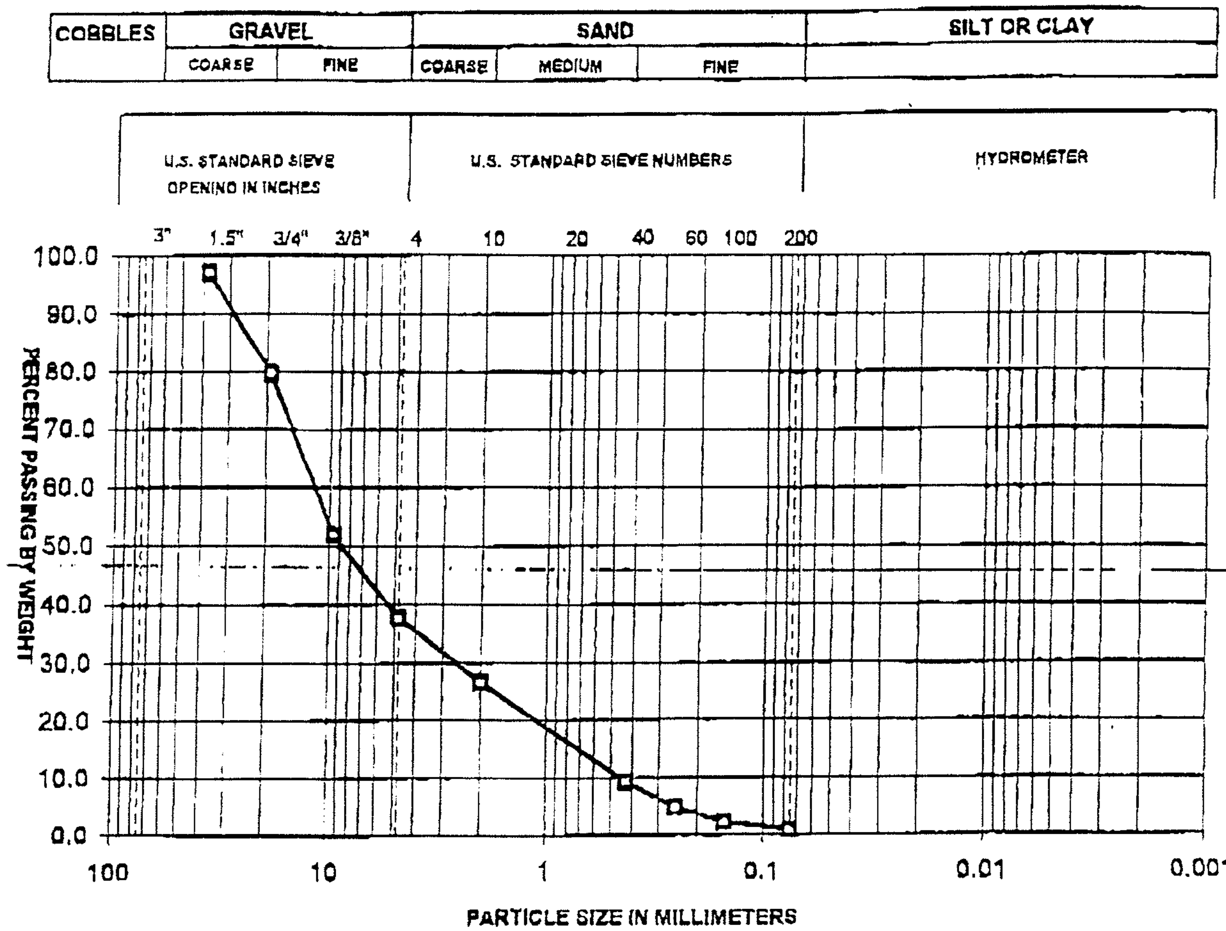
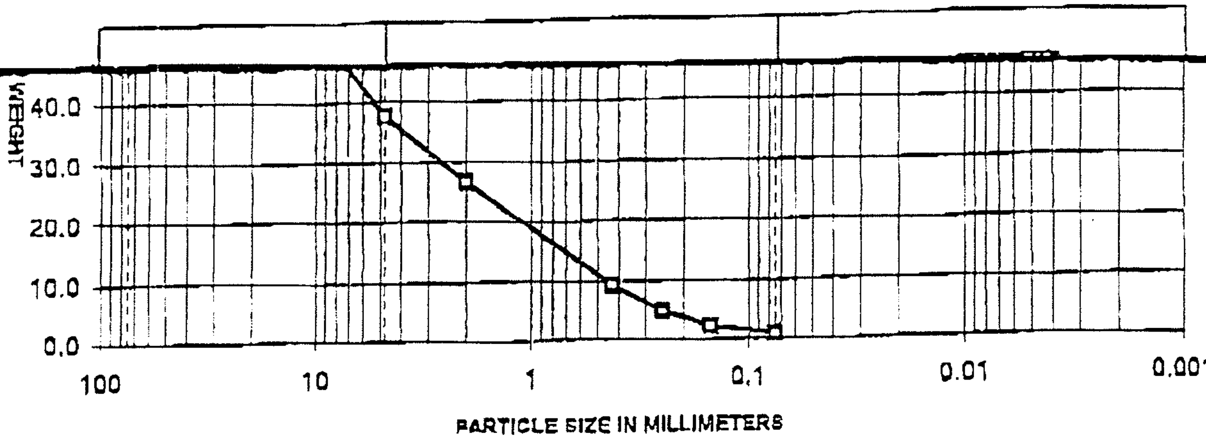


Boring/ Sample No.	Depth (feet)	Symbol	LL	PI	Description
/		□			Crushed Concrete GAB
/		■			
/		△			
/		▲			

Project: Old Alabama Crossing Project No.: 1320 Date: 3/31/00	**Engineering Consulting Services, Ltd** **Atlanta, Georgia** **Grain Size Analysis**

COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	



Boring/ Sample No.	Depth (feet)	Symbol	LL	PI	Description
/		□			Crushed Concrete GAB
/		■			
/		△			
/		▲			

Project: Old Alabama Crossing

Project No.: 1320

Date: 3/31/00

Engineering Consulting Services, Ltd
Atlanta, Georgia

Grain Size Analysis

Worthing Southeast Builders, Inc.

Memo

File – Reference for use of crushed concrete.

To: Bob Atwood

From: Steve Ingram

Date: June 21, 2000

Re: 5375 Sugarloaf Parkway

Confirming our conversation of yesterday, we were going to go ahead and try the crusher run base on the current move-in. This area is generally described from the creek crossing north through the south end of Building 6. The balance of the project will go back to the standard graded aggregate base. I am attaching for your information, a copy of the letter from Hayne Palmer at United Consulting requesting that we take a proctor and other criteria in order to conform to our standard specifications. We will evaluate the performance at project end.

If any additional information is needed, please let me know.

cc: Steve Snodgrass
Rich Foran
File – Corresp. w/United Consulting, 995
File – Dyke's Paving, 995
Read File

800 Mt. Vernon Hwy., Suite 350, Atlanta, GA 30328 770/522-5781; Fax 770/522-5784

UNITED CONSULTING

June 19, 2000

Mr. Steve Ingram
Worthing Southeast Builders, Inc.
800 Mt. Vernon Highway
Suite 350
Atlanta, GA 30328
Via facsimile: (770) 522-5784

PROJECT: Crushed Concrete for Use as Graded Aggregate Base
Sugarloaf Parkway Apartments

Dear Steve:

We are in receipt of the information forwarded to our office from Dykes Paving & Construction Company concerning use of crushed concrete as graded aggregate base for the Sugarloaf Parkway Apartments project. After review of the information, including laboratory tests from Atlanta Testing & Engineering (11/11/95) and Environmental Consulting Services, Ltd. (03/21/00), it appears that crushed concrete can meet GDOT requirements for Section 815; Group II aggregates.

It is our opinion the crushed concrete may be utilized as Graded Aggregate Base on this site. The crushed concrete should meet all applicable site specifications including proper thickness and compaction levels. United Consulting will require a sample of the crushed concrete for performance of a modified Proctor (ASTM D-1557) to perform compaction testing. If the crushed concrete is placed in proper thickness and compaction levels (as specified for Graded Aggregate Base), it should adequately support the pavement design. United Consulting should provid daily onsite testing and monitoring services during placement of the crushed concrete base.

If you should have any questions, please feel free to contact us.

Sincerely,

UNITED CONSULTING

R. Hayne Palmer, Jr., P.G.
Vice President

H:\geophys\letters\2000\sugarloaf

July 27, 1994

DEPARTMENT OF TRANSPORTATION
STATE OF GEORGIA

SUPPLEMENTAL SPECIFICATION

MODIFICATION OF THE STANDARD SPECIFICATIONS; 1993 EDITION

SECTION 815 - GRADED AGGREGATE

Retain Section 815 as written and add the following:

815.03 CRUSHED CONCRETE BASE:

Sources of crushed concrete materials must be approved by the Office of Materials and Research. The criteria for approval shall be as outlined in Standard Operating Procedure No. 1 "Monitoring the Quality of Coarse and Fine Aggregates" except that the raw material will be recyclable concrete as specified herein rather than a geological deposit of aggregate.

The crushed concrete for use as base, subbase of shoulder course, shall be derived exclusively from Portland Cement concrete pavement or structural concrete and shall not contain any delivery unit washout material. With the exception that the aggregate will be recycled concrete, the finished product shall conform to the quality and gradation requirements of Sub-Section 815.01 for Group II Aggregates. The finished product shall also be free of foreign materials such as asphaltic concrete, steel reinforcement, clay balls, soils, epoxy expansion material and miscellaneous paving materials.

Office of Materials and Research

atlanta testing
& engineering

11420 johns creek parkway / duluth, georgia 30136 / (404) 476-3555

October 11, 1995

Dykes Paving and Construction Company, Inc.
2775 Jones Mill Road
Norcross, Georgia 30071

Attention: Mr. Bob Atwood

Re: Laboratory Testing and Engineering
Evaluation of Recycled Concrete
Job No. 14884, Report No. 41820

Gentlemen:

As requested, Atlanta Testing & Engineering has completed a testing program to evaluate the possible use of recycled concrete as a substitute for graded aggregate base. Our laboratory testing and evaluation were conducted in general accordance with our Proposal No. 95-635, dated June 30, 1995. Initially we proposed to obtain three samples of recycled concrete materials. However, a representative from Dykes Paving delivered one sample to our laboratory for the proposed testing program. This report outlines our laboratory testing procedures and results as well as our engineering evaluation based on the test results. The recycled concrete sample submitted by Dykes Paving was subjected to laboratory compaction and gradation testing, Los Angeles abrasion testing, and California bearing ratio (CBR) testing. The laboratory compaction test yielded a maximum dry density of 119.8 pounds per cubic foot (pcf) at an optimum moisture content of 12.5 percent. The grain size analysis test results indicate that the materials were in compliance with Georgia DOT Section 815 specified gradation limits for Group 2 graded aggregate. However, the sample gradation was slightly below the specified percent passing for the No. 200 sieve for the Group 1 classification. The Los Angeles abrasion test indicated the sample to have a measured percent wear of 42.9 percent, which is within Georgia DOT Section 800.1 requirements for both Class A and B and Group 1 and 2 aggregates. The sample was subjected to three CBR tests, indicating CBR test values of 108, 58, and 20, respectively, at varying degrees of compaction and moisture content levels. The test results are attached to this report.

Based on the laboratory test results obtained, it appears that recycled concrete samples similar to those tested generally meet with the Georgia DOT specified criteria for graded aggregate base materials. As noted, the grain size distribution analysis indicated that the percent passing of No. 200 sieve did not meet the specified criteria for Group 1 materials. Based on the L.A. abrasion test results, we believe that, during the compaction effort of these materials, additional fines (passing No. 200 sieve) may be generated which will bring this deficiency closer to compliance.

Although these materials may be capable of complying with Georgia DOT standards, based on our experience, additional stipulations regarding their use as graded aggregate base should be considered.

Due to the hydrates within the recycled concrete materials, we recommend that percent moisture determined in the field using hot plate field techniques be used only as an initial indication of the moisture content of these materials. The hot plate drying method drives off moisture within the materials that may provide an inaccurate moisture content of the materials and subsequent miscalculation of the actual field compaction. We recommend that samples of the materials be returned to the laboratory and allowed to oven dry over a 24-hour period as a confirmation to the field moisture content calculations. In addition, we recommend a nuclear test device not be used to determine the moisture content and field density of these materials. Again, due to the hydrates and other chemical constituents of the concrete materials, the nuclear density test equipment does not provide an accurate estimate of these compaction properties.

Based on the test results from the three CBR tests performed, we recommend that the recycled concrete materials be compacted to 100 percent of the maximum dry density as determined by the modified Proctor (ASTM D-1557) and the moisture content criteria of 0 to 2 percent dry of the optimum moisture content be stipulated to provide the highest CBR test value possible for these materials. As noted by the test results on Sample No. 1B, an increase in moisture has a dramatic lowering effect on the CBR test value.

We appreciate the opportunity to provide our engineering evaluation for Dykes Paving and Construction Company, Inc. If you have any questions concerning this report or if we may be of further assistance, please contact us.

Respectfully submitted,

ATLANTA TESTING & ENGINEERING

Kevin L. Privette, P.E.
Project Geotechnical Engineer

J. Howard Allred /ro

J. Howard Allred, P.E.
Construction Materials Consultant
Reg. Ga. 8144

KLP/JHA/jk

Attachments

MOISTURE/DENSITY RELATIONSHIP OF SOIL

atlanta testing & engineering
geotechnical & materials engineering and hydrogeology

11420 johns creek parkway / duluth, georgia 30136 / engineering (404) 476-3555 lab 476-8555

PROJECT: Dykes Paving-Recycled Concrete Evaluation

CLIENT: Dykes Paving & Construction Co., Inc.

JOB NO.: 14884

REPORT NO.: 41475

Sample No.: 1 Date Sampled: September 6, 1995

Location Sampled: Plant.

Visual Classification: Recycled concrete.

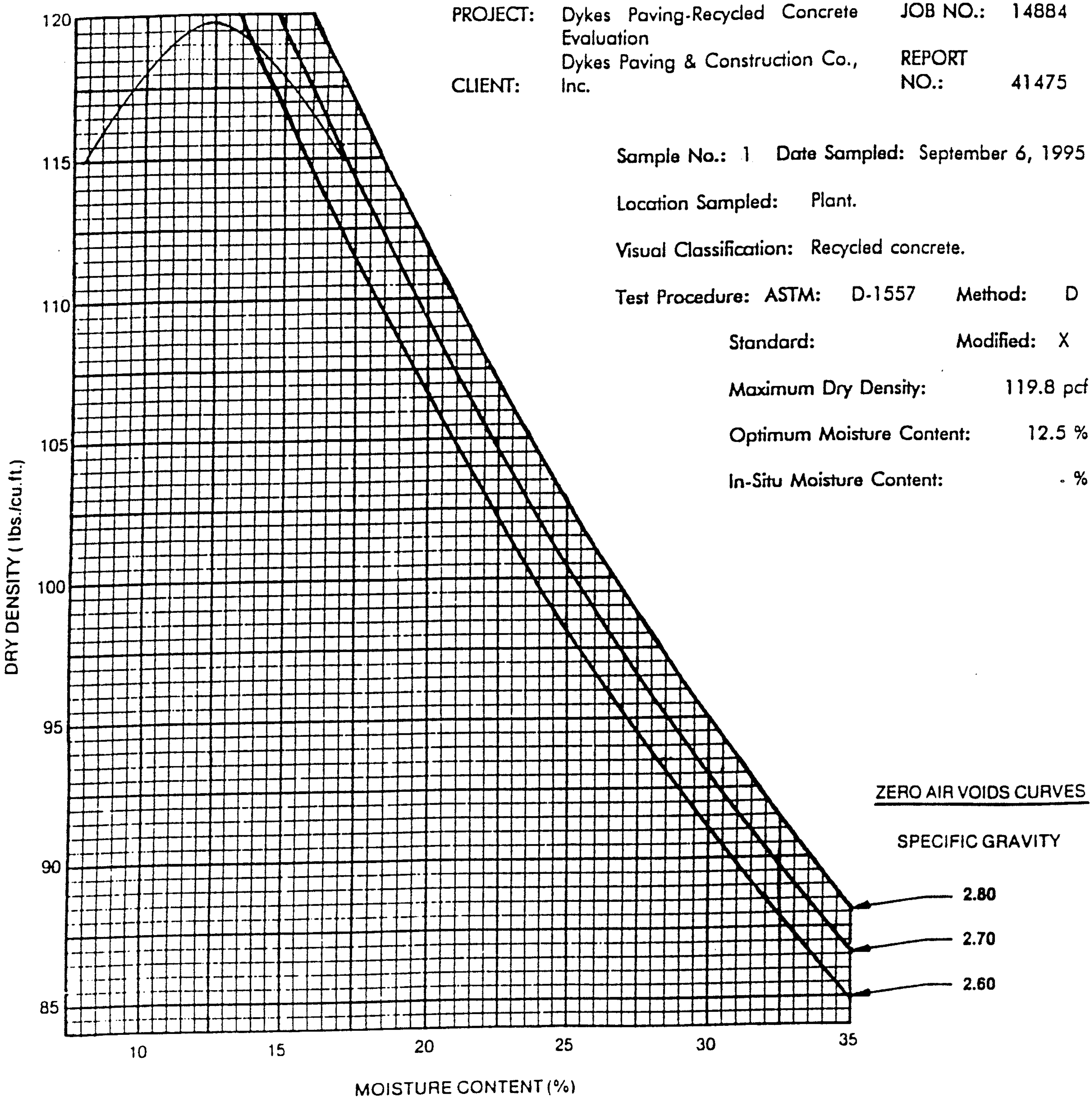
Test Procedure: ASTM: D-1557 Method: D

Standard: Modified: X

Maximum Dry Density: 119.8 pcf

Optimum Moisture Content: 12.5 %

In-Situ Moisture Content: - %



Report Distribution:

Dykes Paving & Construction Company, Inc./Mr. Bob Atwood (2)

BY: ____

DYKES PAVING - RECYCLED CONCRETE EVALUATION
JOB NO. 14884, REPORT NO. 41820

SIEVE ANALYSIS - AASHTO T-27			
Sieve Size	Percent Passing	Georgia DOT Section 815 Specified	
		Group II	Group I
2"	100.0	100	100
1 1/2"	100.0	97-100	97-100
1"	96.9	-	-
3/4"	83.6	60-90	60-95
1/2"	65.8	-	-
3/8"	55.7	-	-
#4	42.2	-	-
#10	33.1	25-45	25-50
#60	10.2	5-30	10-35
#200	3.7	0-15	7-15

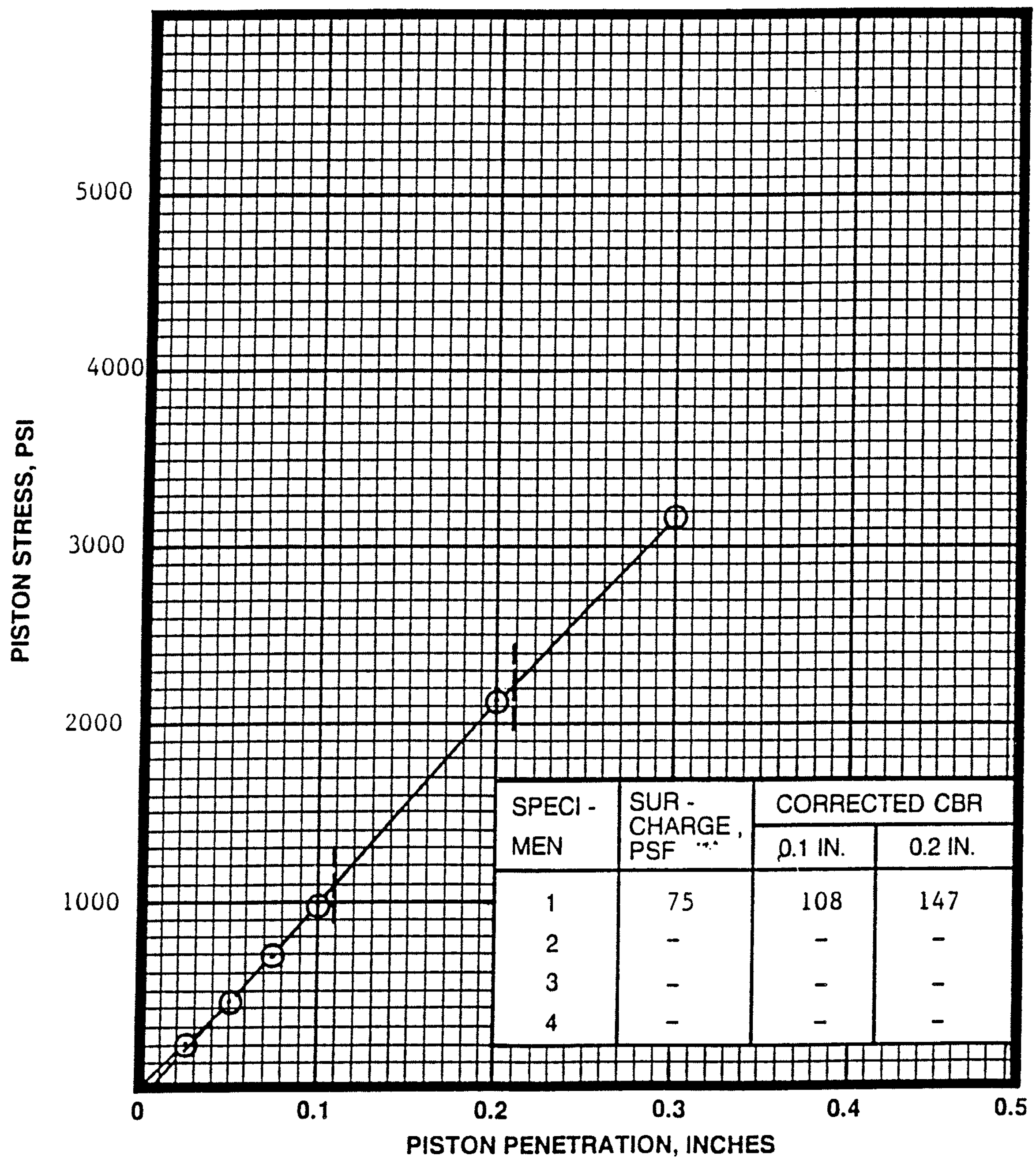
LOS ANGELES ABRASION - AASHTO T-96 "B" GRADING MEASURED PERCENT WEAR: 42.9		
Georgia DOT Section 800.1 Requirements		
	Class A	Class B
Group I Aggregates	0-40	41-55
Group II Aggregates	0-50	51-60

atlanta testing & engineering

CALIFORNIA BEARING RATIO TEST REPORT

PROJECT Dykes Paving		JOB NO. 14884	REPORT NO. 41820
DATE 9/21/95	BORING/PIT NO. –	DEPTH/ELEV. –	SAMPLE NO. 1
TEST PROCEDURE ASTM D1883		SAMPLE TYPE Bulk	REVIEWED KLP
SOIL DESCRIPTION Recycled Concrete			COMPACTION METHOD ASTM D698

INDEX PROPERTIES	LL	PI	G_S	FINES, %
	–	–	–	–



SPECIMEN	SURCHARGE, PSF	CORRECTED CBR 0.1 IN.	CORRECTED CBR 0.2 IN.
1	75	108	147
2	–	–	–
3	–	–	–
4	–	–	–

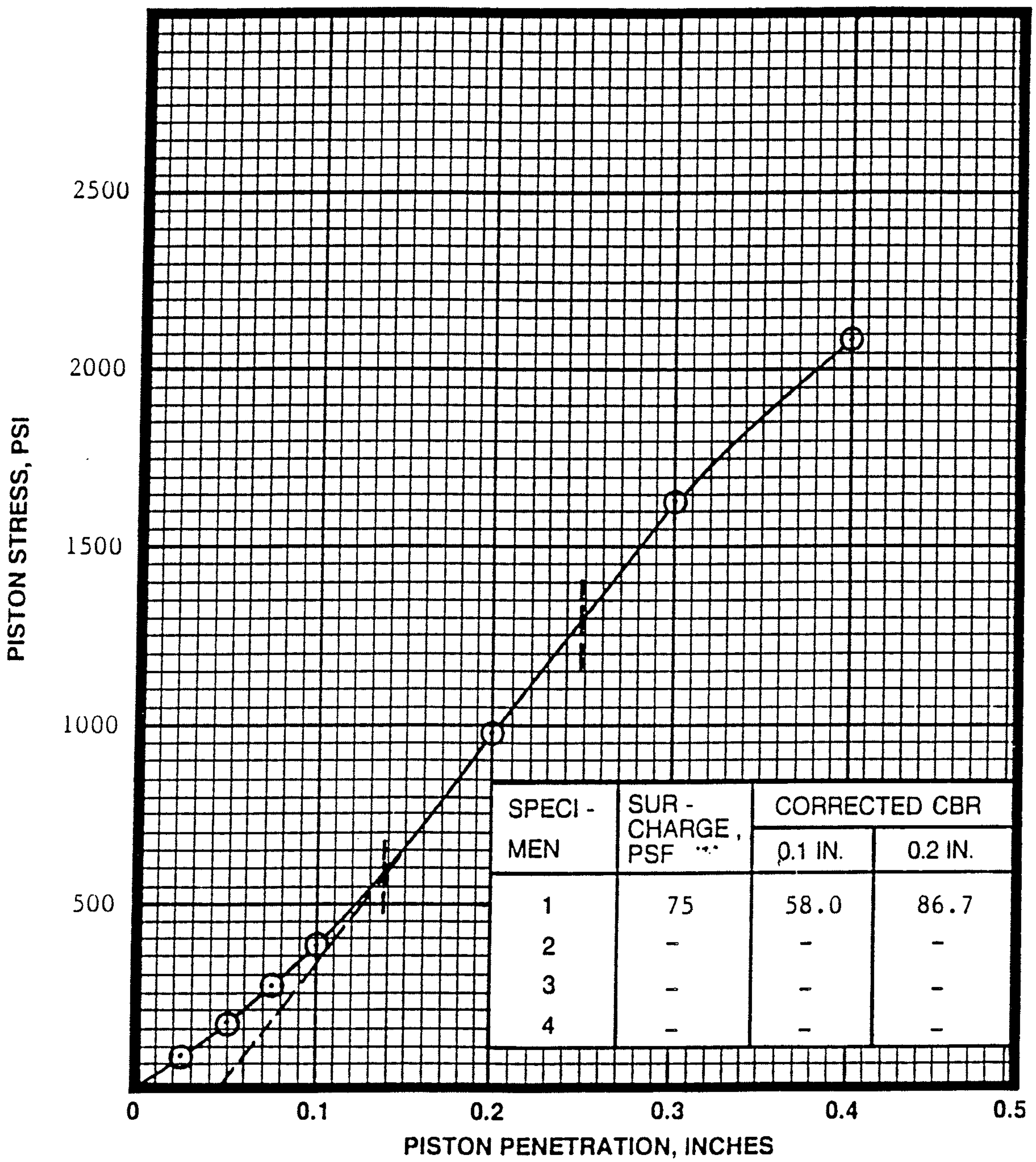
	INITIAL PROPERTIES				SOAKED PROPERTIES			
SPECIMEN	1	2	3	4	1	2	3	4
PERCENT COMPACTION	99.3	–	–	–	100.1	–	–	–
DRY DENSITY, PCF	119.0	–	–	–	119.9	–	–	–
MOISTURE CONTENT, %	12.2	–	–	–	12.2	–	–	–
SWELL, %		–			0	–	–	–

atlanta testing & engineering

CALIFORNIA BEARING RATIO TEST REPORT

PROJECT	Dykes Paving	JOB NO.	14884	REPORT NO.	41482
DATE 7/19/95	BORING/PIT NO. -	DEPTH/ELEV.	-	SAMPLE NO.	1A
TEST PROCEDURE	ASTM D1883	SAMPLE TYPE	Bulk	REVIEWED	KLP
SOIL DESCRIPTION	Recycled Concrete			COMPACTION METHOD	ASTM D1557

INDEX PROPERTIES	LL	PI	G_s	FINES, %
	-	-	-	-



SPECI-MEN	SUR-CHARGE, PSF	CORRECTED CBR 0.1 IN.	CORRECTED CBR 0.2 IN.
1	75	58.0	86.7
2	-	-	-
3	-	-	-
4	-	-	-

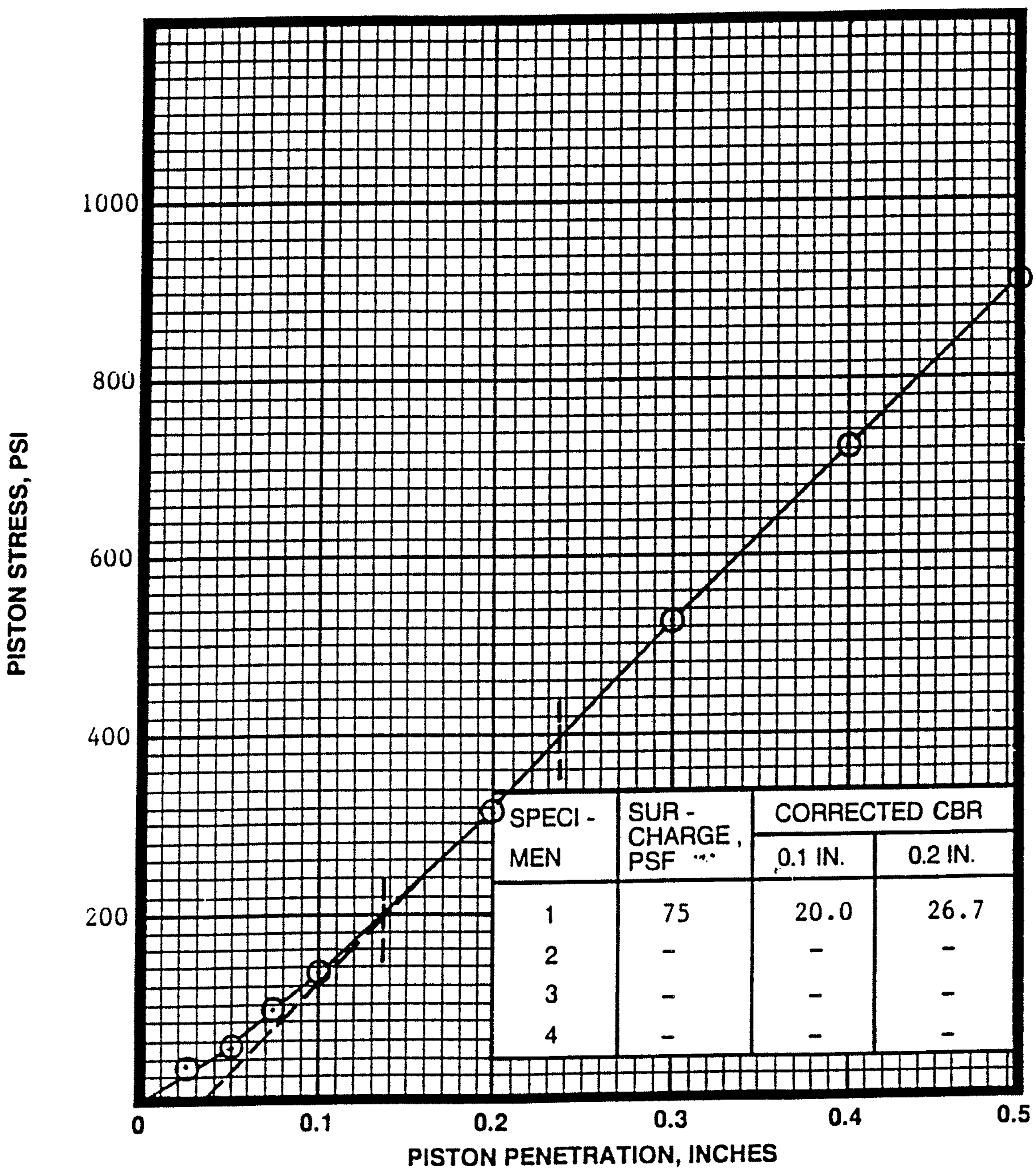
	INITIAL PROPERTIES				SOAKED PROPERTIES			
SPECIMEN	1	2	3	4	1	2	3	4
PERCENT COMPACTION	99.5	-	-	-	99.5	-	-	-
DRY DENSITY, PCF	119.2	-	-	-	119.2	-	-	-
MOISTURE CONTENT, %	13.0	-	-	-	12.7	-	-	-
SWELL, %	-				0	-	-	-

atlanta testing & engineering

CALIFORNIA BEARING RATIO TEST REPORT

PROJECT Dykes Paving		JOB NO. 14884	REPORT NO. 41482
DATE 9/19/95	BORING/PIT NO. –	DEPTH/ELEV. –	SAMPLE NO. 1B
TEST PROCEDURE ASTM D1883		SAMPLE TYPE Bulk	REVIEWED KLP
SOIL DESCRIPTION Recycled Concrete			COMPACTION METHOD ASTM D1557

INDEX PROPERTIES	LL –	PI –	G_s –	FINES, % –



SPECIMEN	SURCHARGE, PSF	CORRECTED CBR 0.1 IN.	CORRECTED CBR 0.2 IN.
1	75	20.0	26.7
2	–	–	–
3	–	–	–
4	–	–	–

	INITIAL PROPERTIES				SOAKED PROPERTIES			
SPECIMEN	1	2	3	4	1	2	3	4
PERCENT COMPACTION	95.7	–	–	–	96.3	–	–	–
DRY DENSITY, PCF	114.6	–	–	–	115.4	–	–	–
MOISTURE CONTENT, %	17.3	–	–	–	16.7	–	–	–
SWELL, %	–				0	–	–	–

2nd Int. PhD Symposium in Civil Engineering 1998 Budapest

REACTIVITY IN RECYCLED CONCRETE AGGREGATE

Mats Karlsson
Chalmers University of Technology, Division of Building Technology
SE-412 96 Göteborg, Sweden

SUMMARY

Full scale tests with crushed concrete used in sub-bases in roads show that the material has capacity to reharden, very slowly but also after prolonged periods of time. The rehardening process in crushed concrete aggregate has been analysed with a thermogravimetric method, comparing the change in chemical composition in the aggregate when set with water, compacted and hardened. It has been shown that grinding of crushed mortar, even if reground to cement fineness, will not activate the unhydrated cores of cement observably. If the mortar is ground together with surface active additive, the material set with water gives compressive strength of 2.8 MPa in 15 days. This is likely due to increased bonding between the ground cores of sand and cement, allowing further crystallisation of ground material to occur closer and chemically better bonded to silicate surfaces.

Keywords: Recycling, concrete, aggregate, thermogravimetry

1. INTRODUCTION

1.1 Background

Annually 1.5 million tons of mineral demolition waste, mainly consisting of concrete and bricks, is produced in Sweden every year (Karlsson, 1997). The use of recycled concrete in Sweden is currently being impeded by the lack of material acceptability criteria and control procedures associated with processes and implementations as well as by rules and regulations which are unsuited for this type of material. Recycled concrete aggregate (RCA) has in field tests in road constructions shown to be well as good as conventional materials, and the material has been used as normal aggregates as 1:1 (which means complete replacement). RCA also contains recoverable binding energy. In Finland, the material have, with the right treatment, shown to give the earth constructions a bearing capacity 2-3 times higher than that of crushed rock (Kivekäs, 1997).

The objective with this paper is to investigate if there is a resource value in recycled old crushed concrete related to the cement. Results from life cycle assessment of concrete (Vold, R nning, 1995) show that the emissions and resource depletion are mostly generated within the life cycle of cement. Concrete may contain cores of unhydrated cement and calcium hydroxide formed during the hydration. Since all concrete structures to be demolished has been degradated due to carbonation, the calcium hydroxide has been more or less reduced and formed calcium carbonate. The carbonation means that the recycled concrete aggregate in the cement phase will partly consist of limestone, one of the minerals from which cement once was produced.

1.2 About the project

The general aim of the ongoing project "recycling concrete" is to establish a sustainable waste management of concrete, in particular the utilization of concrete waste as a resource. Concrete waste may be used in road construction and in building construction.

The research is intended to have two main streams.

The **first main stream** comprises systematising, treatment and sorting at recycling of concrete with Swedish aggregates taking into account the cleanness of the aggregate, the properties of the fresh and the hardened concrete. A guide-line proposal for use of recycled concrete aggregates in new concrete has been forwarded from Building Technology, Chalmers University of Technology, to Swedish National House of Boarding and Planning (NBHP) in October 1997, and in December 1997 a proposed document is distributed for consideration by NBHP (NBHP Handbook, 1997) and will be published during summer 1998. The handbook is based very much on Danish and Dutch experiences. It is however necessary, that the handbook coefficients for calculation of deformations and for shrinkage and creep are determined for Swedish recycling materials. Further, the systems for quality assurance should be controlled and eventually be improved.

The **other main stream** comprises an analysis of rehardening reactions obtained at crushing of concrete. These are mainly to be found in the corn fraction 0-4 mm. At fabrication of self-compacting concrete, concrete filler amount of more than 500 kg/m^3 are needed. Lime filler, which is used for the time being, could be replaced by cheaper ground recycling concrete together with very efficient new superplasticizers. The degradation of calcium hydrate in concrete due to carbonation will bee in different stages for different types of concrete structures, depending on original concrete, climate and age of structure. It will therefore be necessary to quantify not only the strength but also the condition of demolished concrete to be able to predict characteristics of crushed concrete in different applications.

The investigations presented in this paper belong to the "other main stream" and have a preliminary character.

1.3 Reactivity in mortar phase

The fact that crushed concrete aggregate rehardens in earth constructions has been shown during the last decades. Concrete is a material with an initial high energy level and the degradation in the material is often slow. The cement in concrete hydrates until the growth becomes limited through limited water supply to the cement core. There is consequently always a buffer of unhydrated cement in concrete depending mainly on the water-cement ratio.

The reactivity in the mortar phase in RCA is investigated for two reasons.

1. It is valuable to be able to quantify the rehardening properties in RCA to use the material as efficient as possible.

2. For the time being it is difficult to use the fine fraction at mixing new concrete because of lacking knowledge about its properties. Grinding and activation of the fines will show whether these could be separated and used more efficiently as binder.

2. LABORATORY TESTS

2.1 Methodology

Laboratory samples with well-defined properties of hardened mortar are produced. The concretes were cast in 40•40•160 mm standard prisms for testing of cement, according to EN 196-1.

After one day of curing the mortar samples were remoulded and stored at room temperature (20″C) in water until day of crushing. Then the mortar was crushed, in some cases reground to cement fineness, and set with water again. The material was set with water to an earth moisture consistency and compacted by hand in the moulds with a similar performance in all cases.

The set material was then tested for compressive strength after different periods of curing at room temperature (20″C) under dense plastic membrane.

The rehardening mechanisms were analysed with a thermogravimetric method, comparing the chemical composition in the material at crushing and after different periods of rehardening.

In thermogravimetry the weight loss is registered when a specimen is heated. The weight losses recorded is due to evaporation of water or decomposition of hydration products. A program suitable for hydrated cement and cement composites has been developed at Chalmers University of Technology (Helsing-Atlassi, 1993), for a thermogravimetric analyser which could be programmed for 5 temperature steps; a LECO-Mac500. The chosen temperature intervals and the corresponding decomposition compounds are:

20-105 °C	physically bound water
105-380°C	CSH and CAH (calcium silicate hydrates and calcium aluminate hydrates)
380-450°C	$Ca(OH)_2$ + some hydrates
450-600°C	Some hydrates + carbonation products other than calcite
600-975°C	calcite + some secondary hydration products

2.2 Materials

The specimen preparation was performed according to Methods of testing cement, EN 196-1. The cement used was standard Portland and the sand used complies with particle size distribution and mineral composition according to CEN Standard sand, with maximum particle size of 1.6 mm. The amount of cement was 500 kg/ m^3 and that of sand was 1500 kg/ m^3 . The water cement ratio was 0.50 and the prisms were tested for compressive strength before crushing.

2.3 Test program

Three series of investigation have been performed. Specimens in all three series were prepared from the same batch of mortar and casted at the same time.

1. After 8 days of curing the mortar was crushed with a jaw having opening corresponding to the initial aggregate maximum size, i.e. 1.5 mm. Compressive strength at crushing was 40 MPa. The crushed material set with water was tested for compressive strength after 36 days and 52 days, and was compared with the strength of the original mortar.
2. After 28 days of curing the mortar was crushed and also ground for 3 hours in a laboratory ball mill. Compressive strength at crushing was 46 MPa. The ground material, set with water, was tested for compressive strength after 31 days of curing.
3. After 44 days of curing the mortar was crushed and separated in two parts. Compressive strength at crushing was 50 MPa. One part of the material was ground as in series two, and the other part was ground together with an superplasticiser, Mighty 100, dry powder. The ground material was tested for compressive strength after 8 and 15 days.

3. RESULTS AND DISCUSSION

When the original mortar was 8 days old, prisms was taken for the **1st series of investigation**. In series 1 there is still a significant hydration increase in the original concrete, but it is obvious that the secondary mortar has not achieved any higher degree of hydration compared to original mortar. Fig.1, show the themogravimetric weight loss for secondary mortar after 36 days of membrane curing, the original mortar when crushed (8 days) and original reference stored in water (44 days). The weight loss is obtained by weighting the mortar when weight becomes constant weight at investigated temperature (retained weight) and then relating it to weight of cement in mortar at 975 °C. The compressive strength increased from 40 MPa in original mortar after 8 days to 50 MPa after 44 days. Meanwhile the secondary mortar achieved a maximum compressive strength of 1.7 MPa.

The investigation was repeated also when secondary mortar was cured for 52 days. The thermogravimetric weight loss curves are almost identical to those given in Fig.1, for original 44 days and secondary mortar. Compressive strength of secondary mortar increased slightly to 2.0 MPa.

The crushed material is shown to be reactive and increases strength parallel with hydration growth in reference mortar. Completely hydrated cement contains about 25 % chemically bound water. At 8 days the amount of chemically bound water was 10% of ignited cement, which means that 60 % of the cement cores still were unhydrated.

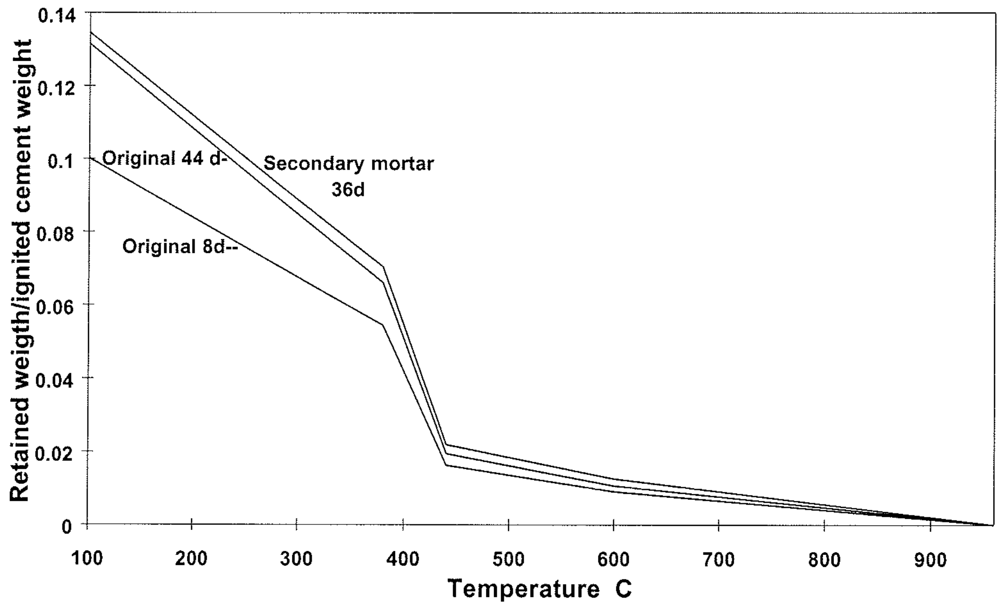


Figure 1. Thermogravimetric weigth loss curves for hydrated cement systems in original mortar after 8 and 44 days and secondary mortar after 36 days.

In 2nd **series of investigation** prisms with the original mortar were taken after 28 days of curing. Even though approximately 40 % of the cement had not hydrated in the mortar, no increased hydration in the ground material could be observed. The secondary mortar was tested for compressive strength after 31 days of curing and reached only 0.3 MPa.

The unhydrated cores of cement in the original mortar are by this shown to be very hard, if not impossible to activate. This supports earlier findings (Hansen, Narud, 1982), showing that crusher fines from recycled aggregate do not qualify as hydraulic cements even when ground to cement fineness.

In the 3rd **series of investigation** prisms with the original mortar were taken after 44 days of curing. Two separate secondary mortars were made, one activated when grinding with 1 % by mass surface active additive of the crushed mortar to be grind. The additive was Mighty 100 dry powder. Compressive strength was tested after 8 days and 15 days. No difference in the thermogravimetric analysis were observed between 8 and 15 days of curing. For the secondary activated mortar compressive strength after 8 days was 1.8 MPa and after 15 days 2.8 MPa. The Secondary mortar not activated had no measurable compressive strength after 8 days and reached only 0.3 MPa after 15 days of curing.

The thermogravimetric weight loss curves shows a significant reduction between 380-450 °C, showing a weight loss of Calcium hydroxide in the activated material, see Fig. 2. The grinding damages silicate crystals and the surfaces of these becomes in some extent amorphous. The addition of surface active additives while grinding prevent the surfaces from ageing (re-crystallisation). Consequently calcium hydroxide formed during cement hydration is likely to give crushed concrete aggregate rehardening properties if siliceous particles are dissoluted from concrete aggregate and cement grains, causing a pozzolanic type reaction. However, when comparing thermogravimetric weight loss curves for the secondary activated mortars at 8 and 15 days of curing there is no visible difference. A separate investigation was performed to investigate if a chemical reaction occurs with calcium hydroxide and superplasticiser. It became obvious that that this was the case. However, this reaction seems to occur relatively fast, and will therefore not explain the strength increase in the secondary activated mortar between 8 days and 15 days. More likely the bonding between the ground cores of sand and cement has been improved by the surface active additive, allowing further crystallisation of ground material to occur, not faster but closer and becoming chemically better bonded to silicate surfaces.

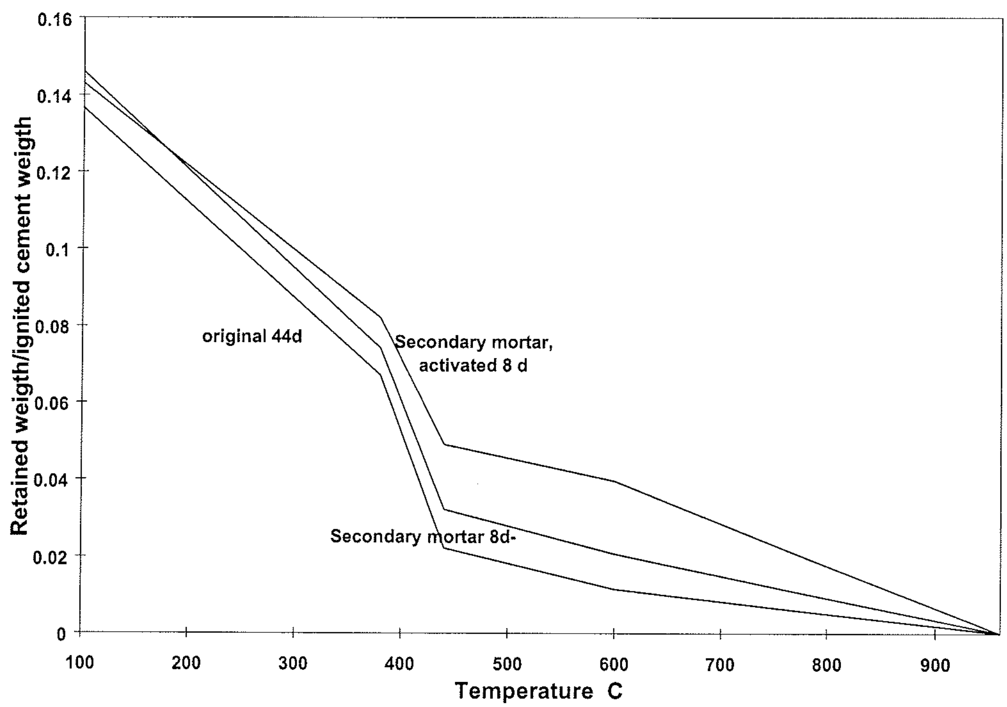


Figure 2. Thermogravimetric weight loss curves for hydrated cement systems in original mortar after 44 days and secondary mortar unactivated and activated after 8 days.

4. CONCLUSIONS

The rehardening process in crushed concrete aggregate has been analysed with a thermogravimetric method, comparing the change in chemical composition in the material. It has been shown that grinding of crushed mortar, even if reground to cement fineness and set with water, will not activate the unhydrated cores of cement observably. This indicates that the unhydrated cores of cement continues to hydrate slowly towards core centre hidden in an inert shell. The termograviometric analysis show, besides some carbonation in the ground material, no change in degree of hydration for the ground material set with water, compared to reference concrete.

Grinding increases the degree of amorphous structure of siliceous aggregates and the addition of surface active superplasticiser prevent the surfaces from ageing. The grinding destroys silica crystals and the surfaces of these becomes in some extent amorphous. Calcium hydroxide formed during cement hydration is likely to give crushed concrete aggregate rehardening properties if siliceous particles are dissoluted from concrete aggregate, causing a pozzolanic type reaction. It is doubtful that this mechanism is the explanation to the short time strength increase for the mortar ground with superplasticiser, since the sand used is a commonly used aggregate of granite with highly crystalline nature and thus low silicate solubility. This is supported with the termograviometric analysis, showing no difference in the set material between 8 and 15 days, inspite the strength increase. More likely bonding between the ground cores of sand and cement has been improved, allowing further crystallisation of ground material to occur and form closer and chemically better bonded surfaces.

5. REFERENCES

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