Intern rapport nr. 2010

STALITE

Lett tilslag av ekspandert leirskifer
Dokumentasjon av egenskaper

Januar 1998

Veglaboratoriet

Intern rapport nr. 2010

STALITE
Lett tilslag av ekspandert leirskifer
Dokumentasjon av tilslagsegenskaper

Sammendrag

Raftsundet bru i Nordland fylke har en total lengde på 711 meter og et hovedspenn på 298 meter som ved ferdigstillelsen vil være verdens lengste for denne brutypen. De midterste 224 meter av hovedspennet utføres i lettbetong LC 60 med tyngdetetthet 19.5 kN/m^3.

Entreprenøren, AS Anlegg, har valgt å benytte et lett tilslag, **Stalite**, produsert av Carolina Stalite Company, USA. Stalite er lett tilslag av ekspandert leirskifer og tilfredstiller kravet i NS 3473 for lette tilslag til bærende konstruksjoner.

Foreliggende rapport er en gjennomgang av tilslagsegenskaper, dokumentert av produsenten, og inngår i det tekniske grunnlagsmaterialet som Statens vegvesen har basert sine vurderinger på. Statens vegvesen har akseptert at Stalite har tilfredstillende egenskaper og stillte entreprenøren fritt i valget mellom Stalite, Leca og Liapor.

Vurderinger av betongegenskaper og resultater fra forsøk utført på byggeplassen vil bli behandlet i en egen rapport.

Emneord: *Stalite, lett tilslag, ekspandert leirskifer, tilslagsegenskaper, lettbetong*

Kontor: *3530 Betong*
Saksbehandler: *Finn Fluge* *FFL*
Dato: *Januar 1998*

Statens vegvesen, Vegdirektoratet
Veglaboratoriet
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- 5 Korngraderingskurver fra leverandørens produksjonskontroll
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1. BAKGRUNN

Raftsundet bru i Nordland fylke har en total lengde på 711 meter over 4 spenn på henholdsvis 86,202, 298 og 125 meter. Hovedspennet på 298 meter vil ved ferdigstillelsen være verdenslengste spenn for fritt frembygg bruer. De midterste 224 meter av hovedspennet skal utføres i lettbetong LC 60 med densitet 19.5 kN/m^3. Av en total betongmengde på ca. 15.000 m^3 vil 2500 m^3 være lettbetong.

Høsten 1996 tok entreprenøren AS Anlegg kontakt med byggeledelsen for Raftsundet bru og ba om tillatelse til å benytte **Stalite** som lett tilslag. Begrunnelsen for å velge **Stalite** som lett tilslag var et ønske om å kunne fremstille en pumpbar høyfast lettbetong.

Henvendelsen fra AS Anlegg innebar at det måtte tas stilling til to spørsmål.

1. Aksept for bruk av **Stalite** som lett tilslag
2. Tillatelse til pumping av LC-betong.

I anbudsgrunnlaget var det stillt følgende krav mht pumping

"Høyfast LC-betong tillates ikke pumpet".

I brev til AS Anlegg sier Statens vegvesen Nordland at de har forståelse for entreprenørens ønske om å benytte pumping for all betong i overbygningen, og stiller seg positiv til utprøving av høyfast lettbetong med sikte på å kunne dokumentere pumparhet.
Statens vegvesen så ingen prinsippielle problemer knyttet til valg av lett tilslag, men påpekte at fordi **Stalite** var mindre kjent i Norge ville dokumentasjonsbehovet være større for dette tilslaget enn for Leca og Liapor.

Det ble videre krevet at utprøvingen av LC-betong med **Stalite** skulle suppleres med utprøving av en lettbetong med enten Leca eller Liapor som lett tilslag slik at man hele tiden hadde et alternativ.

Første halvår 1997 ble det samtidig med dokumentasjon av **Stalite** og utprøving av lettbetong med Stalite også utført to fullskala pumpeforsøk, hvor det første var mislykket. Mot slutten av oktober og i november er det utført nye pumpeforsøk som begge var vellykket.
Entreprenøren har ikke fått generell aksept for pumping, men kan benytte sitt system for utstøpning som forutsetter at betongen fylles i formen ved pumping.

Foreliggende rapport er en gjennomgang av dokumenterte tilslagsegenskaper for **Stalite** og danner det tekniske grunnlaget for at Statens vegvesen har akseptert at **Stalite** kan benyttes som lett tilslag til Raftsundet bru.
Entreprenøren er stillt fritt i valget mellom Stalite, Leca og Liapor.

Vurdering av betongegenskaper og resultater fra pumpeforsøk vil bli behandlet i en egen rapport.

2 DOKUMENTASJON AV LETT TILSLAG

2.1 Generelt

Som grunnlag for den vurdering Statens vegvesen skulle gjøre ble det utarbeidet en oversikt med krav til de egenskapene som skulle vektlegges, se vedlegg nr. A. I denne rapporten henvises det spesielt til Vedlegg A.2 "Lett-tilslag egenskaper som skal dokumenteres", som er en gjennomgang av kravene til det lette tilslaget.

Dokumentasjonsunderlaget er motatt i flere omganger. Et utsnitt er samlet i Vedlegg B. Det vises til Vedlegg B1 **Gjennomgang av dokumentasjon fra Carolina Stalite Company "Summary of Technical Information"** som var en første vurdering av dokumentasjon vedrørende **Stalite**, mottatt i desember 1996.

Stalite er et lett tilslag av ekspandert leirskifer og tilfredstiller kravet i NS3473, pkt. 7.3.3 for lette tilslag til bærende konstruksjoner.

Akseptvurdering av tilslaget baseres på dokumentasjon av følgende egenskaper:

1. Bulk density
2. Particle density
3. Water absoption
4. Moisture content
5. Particle size distribution
6. Additional properties.
   - Content of fines
   - Chloride content
   - Total sulphur content
   - Loss of ignition
   - Alkali-aggregate reaction
7. Freezing and Thawing

2.2 Bulk density

Produsenten **Carolina Stalite Company** deklarerer følgende verdier for løst ifyllt romvekt, kfr. Vedlegg nr. 1.

Fraksjon:	Romvekts intervall:
#4 - 3/4" (4 - 19 mm)	750 - 800 kg/m^3
#4 - 1/2" (4 - 12,5 mm)	770 - 830 kg/m^3

Krav: Romekt 800 kg/m^3 $\pm$ 50 kg/m^3

Stalite #4 - 3/4" er testet etter ASTM C - 330, kfr. Vedlegg nr. 2

Prøveresultat: Romvekt 797,7 kg/m^3

Tilslaget ligger innenfor samme romveksintervall som

Liapor 8 og
Leca 800

Tilslagsleverandørens dokumentasjon er tilstrekkelig, men verdiene skal verifiseres gjennom entreprenørens/betongleverandørens mottakskontroll.

2.3 Particle density

Carolina Stalite Company deklarerer følgende verdier for partikkeldensitet/korndensitet, kfr. Vedlegg nr. 1.

Fraksjon:	Korndensitet
#4 - 3/4" (4 - 19 mm)	1.470 - 1.540 kg/m^3
#4 - 1/2" (4 - 12,5 mm)	1.490 - 1.550 kg/m^3

Krav: Korndensitet 1500 kg/m^3 $\pm$ 75 kg/m^3

Verdiene ligger innenfor samme intervall som verdiene for

Liapor 8 og
Leca 800

Tilslagsleverandørens dokumentasjon er tilstrekkelig, men verdiene skal verifiseres av entreprenørens/betongleverandørens kontroll av leverandørsertifikater.

2.4 Water absorption

Typiske egenskaper for lettklinker er vist i tabell 1, brev av 21/10.1996 til AS Anlegg fra Axion, Tromsø, Vedlegg nr 3.

Her angis vannabsorpsjonen for **Stalite 1/2"**, etter 24 timer, å være 5%, mot 10 og 11% for henholdsvis Liapor 8 og Leca 800. Forannevnte verdi bekreftes i rapport fra LAW ENGINEERING av 6/7.1992, Vedlegg 4, hvor vanninnholdet etter nedsenking i vann ved atmosfæriisk trykk angis til 5,7% og hvor det rapporteres en SSD-verdi på 6,7% (SSD betyr vannmettet, overflatetørr)

Dette er meget lave verdier for lettklinker.

Det er i forannevnte rapport, Vedlegg nr. 4, også referert den økningen i vanninnholdet som det lette tilslaget fikk ved prøving under økende trykk. Ved et trykk på 21 ato (210 m vannsøyle) hadde tilslaget etter 30 minutter absorbert 10,7 % vann.

Tilslagets vannabsopsjons egenskaper er så langt tilstrekkelig dokumentert, men det forutsettes at verdiene verifiseres før produksjon av lettbetong igangsettes.

2.5 Moisture content

Det er et krav at entreprenøren eller hans underentreprenør kontrollerer fuktinnholdet ved mottak og under betongproduksjon.

Det er ved stikkprøver registrert et høyere fuktinnhold i tilslaget enn hva absopsjonsforsøkene viser. Dette innebærer at det totale fuktinnholdet i **Stalite** utgjøres av absorbert fuktighet og overflatefuktighet. Et enkelt forsøk hvor totalt fuktinnhold i tilslaget var bestemt til 10,1%, viste at man fjernet 3.9% av fuktigheten ved å tørke tilslagskornene med papirhåndkle.

Dette viser at det er viktig at betongprodusenten har kontroll med både totalt fuktinnhold og absorbert vann i tilslaget. Tilslaget skal være beskyttet mot nedbør.

2.6 Particle size distribution

Leverandøren har fremsendt siktekurver fra produksjonskontrollen av **Stalite** #4 - 1/2" (4 - 12.5 mm). Det er tatt ut 10 prøver over 1 måned. Resultatene, Vedlegg nr 5, viser at variasjonene er små og at **Stalite** kan leveres med jevn gradering.

Leverandøren bør også legge frem siktekurver for **Stalite** #4 - 3/4" hvis det er denne graderingen som skal benyttes i betongproduksjonen.

Under produksjon vil kravet til entreprenørens produksjonskontroll være som for vanlig tilslag. I tillegg forutsettes mottakskontroll.

2.7 Additional properties

2.7.1 Content of fines

Kravet til finstoffinnholdet er at mengden fine korn mindre enn 0.125 mm ikke skal variere mer enn $\pm$ 1.0% for fraksjoner > 4 mm.

På dette punktet er ikke leverandørens dokumentasjon fullstendig.

I Vedlegg nr. 1 deklarerer leverandøren at det for

fraksjoner	#4 - 3/4" passerer	0 - 15%	på sikt #4 (4.75 mm)
fraksjoner	#8 - 1/2" passerer	0 - 10%	på sikr #8 (2.36 mm)
fraksjoner	#16- 3/8" passerer	0 - 10%	på sikt #16 (1.18 mm)

Siktekurvene fra produksjon, Vedlegg nr. 5, viser for gradering #4 - 1/2" at 2.8% passerer sikt #8 og at det er mer enn 90 % sannsynlighet for at variasjonene på dette siktet er mindre enn ± 1,6%.

Det er derfor grunn til å anta at kravet til variasjon i finstoffinnholdet tilfredstilles for variasjoner på sikt #16 (1.18 mm).

Vurderingene styrkes forøvrig av de sikteanalysene som er utført og rapportert i forbindelse med utprøving av betongresepter.

Ytterligere dokumentasjon vil ikke bli krevet før leveranse til produksjon.

2.7.2 Chloride content

Rapport fra CHEM-BAC Laboratories, Vedlegg nr. 6, viser et kloridinnhold i **Stalite** på:

Klorid som NaCl = 0,60 ppm

Kloridinnholdet kan her være angitt feil, men selv om verdien skulle være 0.6o/oo er kloridinnholdet meget lavt. Det er ikke behov for ytterligere dokumentasjon.

2.7.3 Total sulphur content

Rapporter fra CHEM-BAC Laboratories, Vedlegg nr. 6 og 7, viser et meget lavt innhold av svovel i **Stalite**:

SO_3 - innhold < 0.05 ppm, vedlegg nr.6
Totalt svovelinnhold < 0.01%, vedlegg nr. 7

I de innledende vurderingen ble det konstatert at SO_3 - innholdet i tilslaget var ekstremt lavt. Man ønsket derfor å få verifisert denne verdien, men da som totalt innhold av svovelforbindelser i tilslaget. Ny laboratorierapport av 11.mars 1997, Vedlegg nr. 6, bekrefter at svovelinnholdet er lavt, mindre enn 0.01%.

Dokumentasjonen ansees som tilstrekkelig

2.7.4 Loss of ignition

Loss of ignition, bestemt etter ASTM C 114, er bestemt til < 0.1%, Vedlegg nr. 2.

Dette innebærer at mengden organisk materiale i tilslaget er neglisjerbart.

2.7.5 Alkali-aggregate reaction

Det er gjennomført AR-prøving etter "Mortar bar test", ASTM C 227.

Resultatene som først ble mottatt var av liten interesse fordi prøvingen ble utført med en lavalkali sement Na_2O_{ekv} = 0.57%.

Det er oversendt ny dokumentasjon fra LAW ENGINEERING; Vedlegg nr. 8, hvor prøvingen etter ASTM C 227 er gjennomført med en sement med Na_2O_{ekv} = 0.75%..

Ekspansjonen er målt til:

	Målt ekspansjon	Krav
3 måneder	0.014 %	< 0.05 %
6 måneder	0,017 %	< 0,1 %
9 måneder	0,015 %	
12 måneder	0,017 %	

Analyse av bruddflatene, basert på SHRP-C/PR-91-101, viser ingen synlige indikasjoner på at det etter 1 år har funnet sted alkalireaksjoner i tilslaget.

Dokumentasjonen ansees som tilstrekkelig.

2.8 Freezing and Thawing

Rapport fra LAW ENGINEERING, se vedlegg nr. 8, viser at **Stalite** tilfredstiller kravene i AASHTO T 103 mht frostbestandighet.

Dokumentasjonen ansees som tilstrekkelig.

3. KONKLUSJON

Stalite er et lett-tilslag av ekspandert leirskifer. Tilslagsegenskapene tilfredstiller de kravene som stilles til lette tilslag til bærende konstruksjoner. Under forutsetning av at det også oppnås tilfredstillende egenskaper for en lettbetong i fasthetsklasse LC60 sidestilles **Stalite** med Leca og Liapor for bruk som lett tilslag til Raftsundet bru.

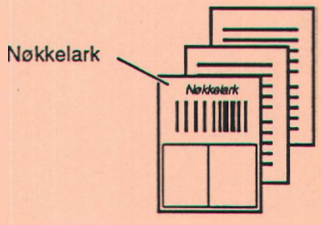
Nøkkelark til kopimaskinen Kodak 2110 *Artikkelnr. 950520N*

Ingen utmating

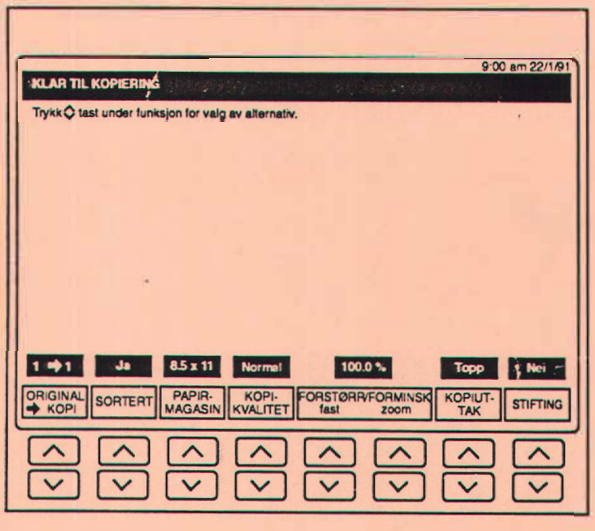
(Nøkkelarkene blir liggende i Feeder)

B R U K S A N V I S N I N G

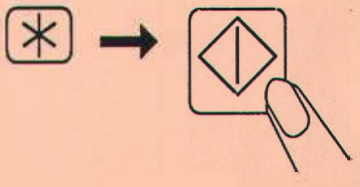
1. Legg nøkkelarket hvor som helst i originalsettet.



2. Legg originalene og nøkkelarkene i Feeder med forsiden opp, og velg standardfunksjoner.



3. Trykk på stjerne (*) og deretter på startknappen for å aktivere nøkkelarket.



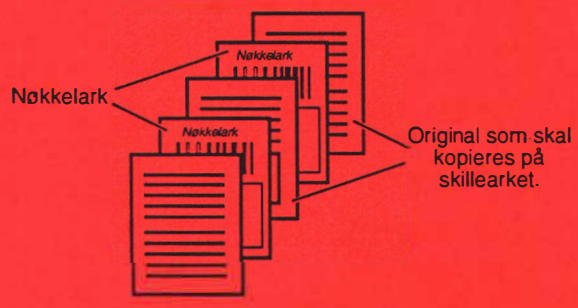
Nøkkelark til kopimaskinen Kodak 2110

Artikkelnr. 950520N

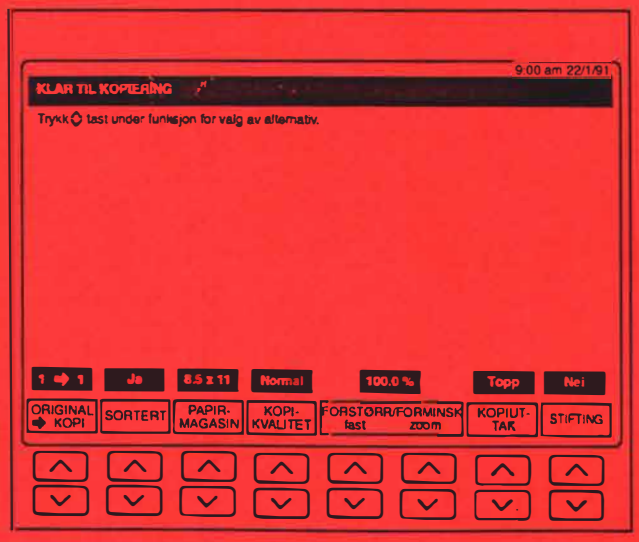
Skilleark – Kopiering på

B R U K S A N V I S N I N G

1. Legg nøkkelarket foran originalen som skal kopieres på skillearket.

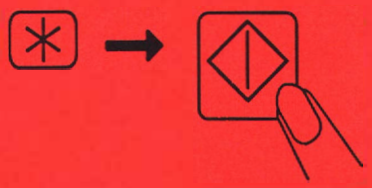


2. Legg originalene og nøkkelarkene i Feeder med forsiden opp, og velg standardfunksjoner.



3. Legg de blanke skillearkene i øvre papirmagasin.

4. Trykk på stjerne (*) og deretter på startknappen for å aktivere nøkkelarket.



Merk: Nøkkelarkene vil bli lagt i utmatingslommen. Du kan også bruke kopier av nøkkelark.

VEDLEGG - STALITE

1 Deklarerte verdier mht gradering, korndensitet og romdensitet
2 Prøving etter ASTM C 330 "Compliance testing"
3 Typiske egenskaper for noen typer lettklinker benyttet i høyfast betong.
Brev til AS Anlegg fra AXION AS 24/10.1996
4 Vannabsopsjon ved nedsenking i vann og under trykk.
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6 Kjemisk analyse av svovel og kloridinnhold
7 Kjemisk analyse av svovelinnhold
8 Prøving av alkalireaktivitet etter ASTM C 227.
9 Prøving av frostbestandighet etter AASTHO T 103.

VEDLEGG nr. 1.

Stalite: Structural Aggregate Gradations

Size	Specific Gravity	Unit Weight (Dump Loose) Lbs/Cubic Foot (Kgs/Cubic Meter
3/4" to # 4	1.47 to 1.54	47 to 50 (750 to 800)

Sieve Size	% Passing
1" (25mm)	100
3/4" (19mm)	90-100
3/8" (9.5mm)	10-50
#4 (4.75mm)	0-15

1/2" to # 4	1.49 to 1.55	48 to 52 (770 to 830)

Sieve Size	*% Passing*
3/4" (19mm)	100
1/2" (12.5mm)	90-100
3/8" (9.5mm)	40-80
# 4 (4.75mm)	0-20
# 8 (2.36 mm)	0-10

3/8" to # 8	1.57 to 1.64	50 to 54 (800 to 865)

Sieve Size	*% Passing*
1/2" (12.5mm)	100
3/8" (9.5mm)	80-100
# 4 (4.75mm)	5-40
# 8 (2.36mm)	0-20
# 16 (1.18mm)	0-10

Fines For Structural Concrete	1.75 to 1.85	53 to 57 (850 to 910)

Sieve Size	*% Passing*
# 4 (4.75mm)	97-100
# 8 (2.36mm)	70-85
# 16 (1.18mm)	40-55
# 30 (600µm)	30-40
# 50 (300µm)	17-25
# 100 (150µm)	14-17

STALITE

STM1194

VEDLEGG nr 2 side 1

LAW ENGINEERING

GEOTECHNICAL, ENVIRONMENTAL
& CONSTRUCTION MATERIALS
CONSULTANTS

June 18, 1993

Mr. Roberto Nunez
Carolina Stalite Company
P.O. Box 1037
Salisbury, NC 28144

Subject: Report of ASTM C 330-89 Compliance Testing
Revises May 17, 1993 Report
Stalite 3/4-inch Lightweight Aggregate
Law Engineering Job Number 5820466301

Dear Mr. Nunez:

Law Engineering has completed testing of a sample of Stalite 3/4-inch coarse aggregate submitted to this office on March 11, 1993. The purpose of our services was to test the subject material for compliance with ASTM C 330-89, "Standard Specification for Lightweight Aggregates for Structural Concrete". Freeze-thaw durability testing was not performed as part of this project. This work was authorized by your acceptance of our proposal No. 582.93005 dated March 11, 1993. We were provided with your Purchase Order number 8889 for reference and accounting purposes.

The test procedures and test results are presented on the attached tables.

The results of our testing indicate that Stalite 3/4-inch coarse aggregate complies with the requirements of ASTM C 330-89.

At your request an additional sample of the subject material was tested for Loss on Ignition on June 4, 1993. It is our opinion that the results presented in this report are representative of the material submitted. We reviewed our previous test data and procedures and cannot explain the previous test result.

Law Engineering appreciates the opportunity to continue serving Carolina Stalite. If there are any questions about this report, or if we may be of further service, please call.

Sincerely,

LAW ENGINEERING, INC.

Terry L. Viness, E.I.T.
Materials Engineer

for John R. Love, P.E.
Principal Materials Engineer

Attachments: Tables I through IV

facil\tlv\466301

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TELEFAX 404-881-0508

VEDLEGG nr. 2 side 2

ASTM C 330-89 COMPLIANCE TESTING
STALITE 3/4-INCH COARSE AGGREGATE
Carolina Stalite Company
June 18, 1993
Law Engineering Job No. 5820466301
Law Engineering Lab Number A93019

Table I - Chemical Composition

Property and Test Method	Test Result	ASTM C 330-89 Requirement
Organic Impurities (ASTM C 40)	Lighter than standard (Color Plate 1)	Lighter than standard
Staining (ASTM C 641)	No Stain	Note 1
Loss On Ignition (ASTM C 114)	<0.1 percent	≤ 5 percent

Table II - Physical Properties

Property and Test Method	Test Result	ASTM C 330-89 Requirement
Clay Lumps (ASTM C 142)	0.1 percent	2 percent, Maximum
Grading (ASTM C 136)	See Table III	See Table III
Unit Weight (ASTM C 29)	797.7 kg/m³ 49.8 lbs/ft³	55 lbs/ft³, 880 kg/m³ Maximum
Compressive Strength (ASTM C 39) Average of 3 at 28 days	3940 psi	3920 psi, Minimum(2)
Splitting Tensile Strength (ASTM C 496) Average of eight at 28 days	410 psi	318 psi, Minimum(2)
Drying Shrinkage (ASTM C 157)(3)	0.017 percent	0.07 percent, Maximum
Popouts (ASTM C 151)(3)	No Popouts	No Popouts

Notes:

(1) Aggregates producing a heavy or very heavy stain are subject to rejection depending on the results of further testing. Stalite produced no stain which indicates acceptable material.

(2) Required values interpolated from table in ASTM C 330-89 based on air-dry unit weight of concrete measured in accordance with ASTM C 567. Strength specimens were moist cured for 7 days then air-cured for 21 days in accordance with ASTM C 567. Concrete proportions and properties are attached.

(3) Drying shrinkage and popout specimens were proportioned in accordance with the requirements of ASTM C 330-89. Drying shrinkage specimens were cured in accordance with specific requirements of ASTM C 330-89.

VEDLEGG nr. 3

Vedlegg 1

Materialdokumentasjon

I forbindelse med overgang fra normal betong til MND betong for Hibernia prosjektet, ble det behov for å dokumentere at grunnleggende kriterier for dimensjonering ble opprettholdt ved lavere betongdensitet, og introduksjon av lettklinker.

Basert på forslag fra byggherrens byggetekniske konsulent S. B Leivestad (Berdal Strømme as) ble et omfattende prøveprogram ble iverksatt (tab. 5), og resultatene fra prøvingsanstalter i Canada og Norge, viste at betongen tilfredsstilte de oppsatte krav med god margin, ved bruk av Stalite Lettklinker.

Fullskala pumpeforsøk (Tab 3) viste også at det ikke var nødvendig å ta spesielle forholdsregler for å kunne transportere betong med 250-350 kg/m3 Stalite Lettklinker mer enn 250 m horisontalt og 30 m vertikalt, ved hjelp av vanlig pumpeutstyr.

Betongegenskaper

Resultatene fra utprøving av høgfast lettbetong for Hibernia plattformen er byggherrens (HMDC) eiendom, og så nær som for deler som tidligere er presentert ved international symposier, er ikke dataene offentlig tilgjengelig.

Basert på deler som er tilgjengelig, og egne laboratorie- og produksjondata, har jeg sammenstillet generelle opplysninger om høgfast lettbetong hvor deler av det grove tilslaget er erstattet med Stalite lettklinker i de følgende tabeller.

Tab.1 Typiske egenskaper for noen typer lettklinker benyttet i høgfastbetong

Material typer	Volumvekt løst lagret overflate tørr kg/m3	Densitet overflate tørr kN	Abs. 1 t vekt %	abs 24 t vekt %
Leca 800	800	14.50	8	11
Liapor 8	800	15.00	7	10
Lytag	800	15.00	12	20
Solite	700	14.00	9	10
Stalite 1/2"	770	15.00	-	5

*

Brev fra Axion As, Tromsø til AS Anlegg 21/10.1996

LAW ENGINEERING

GEOTECHNICAL, ENVIRONMENTAL & CONSTRUCTION MATERIALS CONSULTANTS

July 6, 1992

Mr. Roberto Nunez
Carolina Stalite Company
P.O. Box 1037
Salisbury, N.C. 28145-1037

Subject: Report of Pressurized Absorption Test Results
Carolina Stalite 1/2 inch Aggregate
Law Engineering Job No. 5720323801

Dear Roberto:

As authorized by you, Law Engineering has completed the pressurized absorption testing of 1/2 inch sized Stalite aggregate. The purpose of this testing was to provide data on the effect different applied pressures have on the absorption properties of the subject aggregate. As directed by Mr. Nunez, the subject aggregate was tested in the as-received and oven-dried conditions. This report presents the test procedures used and the results of our testing.

TEST PROCEDURE

A moisture content specimen was obtained from the specimen to measure the as-received moisture condition. A second specimen was soaked and tested to determine the SSD absorption of the submitted aggregate.

The remaining sample was then split into two subsamples. One subsample was kept in the as received condition until testing; the other subsample was oven dried at 230°F for approximately 48 hours prior to testing.

The following test procedure was performed on both the as-received and oven-dried specimens:

1) Initial weight in air was measured,

2) Weight of the sample suspended in water at atmospheric pressure was measured,

3) The sample was transferred to a pressure chamber filled with water and subjected to 50 psi for 5 minutes,

4) The sample was removed from the chamber and its suspended weight was remeasured,

5) Steps 3 and 4, above, were repeated for pressures of 100, 150, 200, 250, and 300 psi.

396 PLASTERS AVENUE, N.E.
ATLANTA, GEORGIA 30324
404-873-4761
TELEFAX 404-881-0508

VEDLEGG nr 4 side 2

The absorption for each pressure increment was calculated from the change in the suspended weights.

TEST RESULTS

The results of our testing are presented in the table and the attached graph.

Condition	Percent Absorbed Moisture	
	As-Received	Oven-Dried
Atmospheric	5.7	2.3
50 psi	7.4	4.9
100 psi	8.6	6.9
150 psi	9.4	7.5
200 psi	9.8	8.5
250 psi	10.7	9.3
300 psi	10.7	10.1

The SSD absorption of the aggregate was measured to be 6.7 percent. The absorbed moisture of the "oven-dried" specimen at atmospheric pressure is the result of difficulty in measuring the suspended weight of a dry absorbent material.

Law Engineering appreciates the opportunity to continue serving Stalite. If there are any questions about this report, or if we may be of further service, please call.

Sincerely,

LAW ENGINEERING, INC.

Terry L. Viness, E.I.T.
Materials Engineer

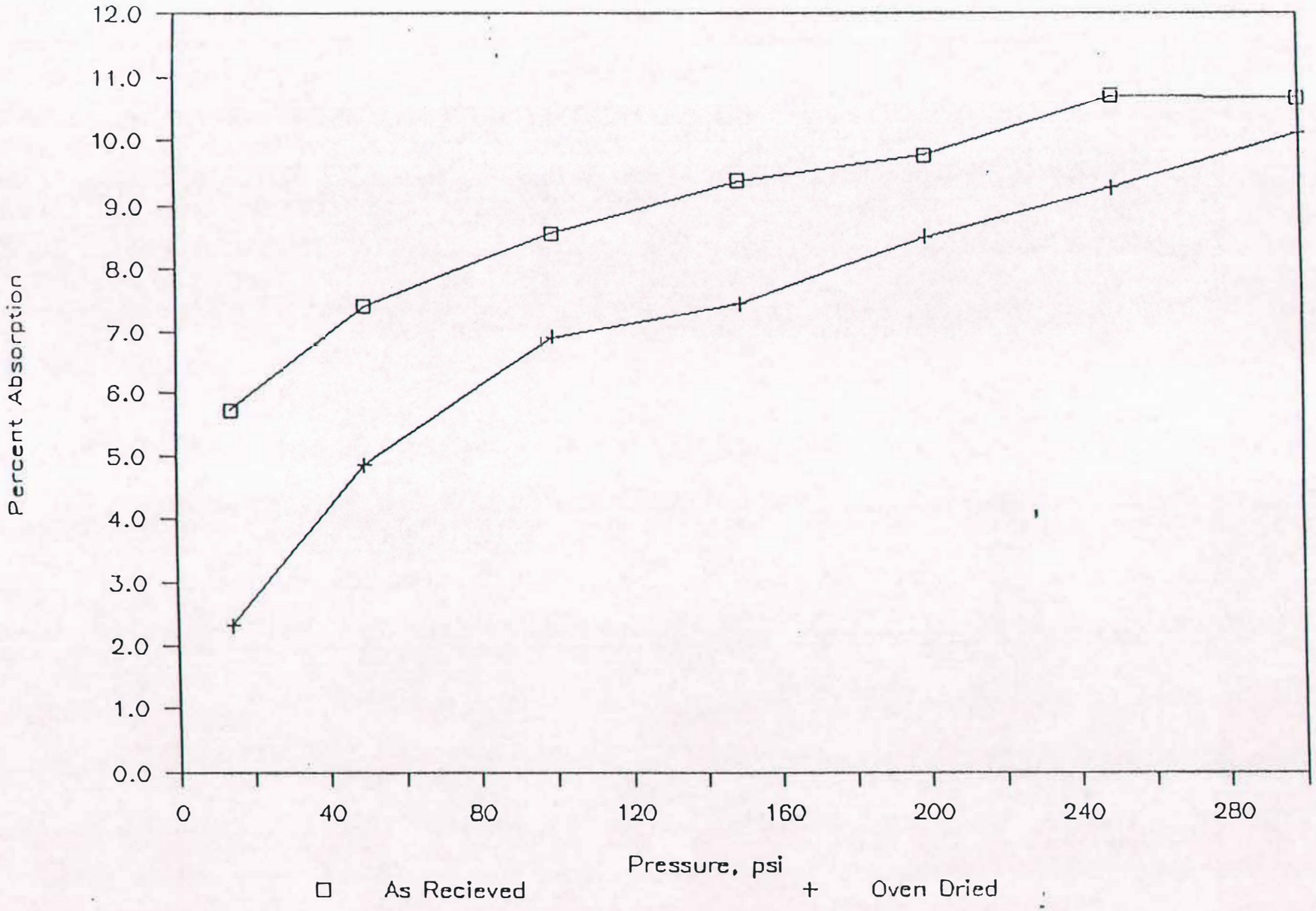
John Love, P.E.
Principal Materials Engineer

Attachment: Graph

tlv\323801

Pressure Absorption

1/2 inch Stalite



VED LEGG nr. 4 side 3

[redacted]

4/2 VEDLEGG nr. 5

side 1

THESE ARE TYPICAL GRADATIONS OF OUR 1/2 INCH "STALITE". THEY WERE TAKEN OVER A TIME OF APPROXIMATELY ONE MONTH.

SAMPLE #	GRADATION (PERCENT PASSING)				
SIEVE SIZE	3/4 (19mm)	1/2 (12.5mm)	3/8 (9.5mm)	#4 (4.75mm)	#8 (2.36mm)
1	100	91.3	52.9	6.7	2.9
2	100	92.6	54.1	6.6	3.3
3	100	92.9	56.7	7.1	3.1
4	100	93.0	53.3	5.5	3.5
5	100	92.0	46.0	3.7	1.2
6	100	93.2	51.0	3.9	2.4
7	100	92.1	48.5	3.5	1.5
8	100	91.6	59.8	8.8	5.9
9	100	92.6	52.8	2.8	1.9
10	100	93.6	52.2	4.1	2.5
AVERAGE	100	92.5	52.7	5.3	2.8

THIS MATERIAL IS PRODUCED TO COMPLY WITH ASTM C330

Mottatt fra Carlsen Stalite Comp. 24.4.97

AXION A/S

Oppdrag: RAFTSUNDET BRU

08.01.97 | Rilling | 1068 | K08

SIKTEKURVE STALITE 12mm (½")

Anm. KURVEN ER SAMMENSATT AV 10 SIKTEPRØVER FRA PRODUKSJON OVER CA 1 MNDR.
SIKTERESULTATENE ER MOTTATT FRA CAROLINA STALITE COMP. MERK X-X-X

Korn-diam. mm	Sikte-rest, gram	Sikte-rest. %

VEDLEGG nr. 6

CHEM-BAC Laboratories, Inc.

• P. O. BOX 19198, CHARLOTTE, N. C. 28219

TEL 394-6381
FAX #: 704 394-6382

November 4, 1992

REF: 1198

Analysis of Aggregate for Requested Tests

MADE FOR: Carolina Stalite
P.O. Drawer 1037
Salisbury, N.C. 28144

ATTENTION: Charles Freeman

MARKED: Sample received at Chem-Bac Labs, Inc. on 10/29/92
P.O. # 8837

ANALYSIS: Sulfur Trioxide --------- < .05 parts per million
Chloride as NaCl -------- .60 parts per million

Respectfully submitted,
CHEM-BAC LABORATORIES, INC.

J.C. Hudbell
Supervising Chemist

JCH/th

(4) VEDLEGG nr. 7

CHEM-BAC Laboratories, Inc.

• P. O. BOX 19198, CHARLOTTE, N. C. 28219
TEL. 394-6381
FAX #: 704 394-6382

March 11, 1997

REF: 1198
W.O. 1306

Sulfur Content of Sample

MADE FOR: Stalite Environmental
P.O. BOX 1098
Salisbury, N.C. 28144

ATTENTION: Bill Griggs

MARKED: Sample received at Chem-Bac Labs, Inc. on 02/17/97

ANALYSIS: Sulfur ---------- less than .010%

Respectfully submitted,
CHEM-BAC LABORATORIES, INC.

J.C. Hubbell
Supervising Chemist

JCH/th

Mottatt fra Carolina Stalite Comp. 04.04.97

VEDLEGG nr. 8 side 1 004

3/4

LAW
ENGINEERING AND ENVIRONMENTAL SERVICES

May 23, 1995

Mr. Roberto Nunez
Carolina Stalite Company
P.O. Box 1037
Salisbury, North Carolina 28145

Subject: Final Report
ASTM C 227-90 Test Results
Carolina Stalite Aggregate
Law Engineering Job No. 58206444801

Dear Roberto:

Law Engineering has completed testing of concrete mixtures containing Stalite aggregates in accordance with our Proposal No. 582-93093 (Revised). The purpose of our testing is to compare the alkali-silica reactivity of Stalite rotary kiln, expanded slate aggregate and a locally available normal-weight aggregate when using ASTM C 227-90, "Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)". This report presents the test procedures and test results.

Materials and Mixtures

Mortar Bars: Carolina Stalite Company provided an approximately 100 pound sample of Stalite 3/4-inch, rotary kiln, expanded slate aggregate. The Stalite aggregate sample was crushed in the laboratory, separated into size fractions, and combined to meet the requirements of ASTM C 227. The mixtures used were as specified by ASTM C 227. The aggregate batch weights presented in ASTM C 227 were adjusted to compensate for the difference in specific gravity between the Stalite aggregate and the natural aggregate being tested. This procedure was followed so that both the Stalite and the Reference mixtures had the same aggregate and paste volumes. The water-cement ratio of the Stalite mixture was 0.51 (152 grams of water/300 grams of cement) to produce a flow of 118.

Law Engineering obtained a natural quartzitic sand from Waugh, Alabama for use in the reference mixture. The natural sand is widely used in concrete in the Atlanta area and has an acceptable performance history with respect to alkali-silica reactivity in local projects. The natural sand was separated into size fractions and recombined in accordance with ASTM C 227. The mortar bar mixture was proportioned in accordance with ASTM C 227. The water-cement ratio of the reference mixture was 0.50 (150 grams of water/300 grams of cement) to produce a flow of 111.

Law Engineering obtained a sample of Type I portland cement from Birmingham, Alabama for use on this project. The cement was tested to verify its alkali content. The total alkalis, reported as Na_2O, was measured to be 0.75 percent when tested in accordance with ASTM C 114-88, "Standard Test Methods for Chemical Analysis of Hydraulic Cement".

15

Mr. Roberto Nunez:
LAW Job No. 50206448-01

May 23, 1995

VEDLEGG nr. 8 side 2

Cylinders: Several 3-inch diameter by 6-inch lightweight concrete cylinders were made using the same volumetric proportions as the ASTM C 227 mortar bars. Approximately 50 percent of the aggregate in the cylinders was uncrushed, 3/4 inch maximum sized, lightweight aggregate particles. The uncrushed lightweight aggregate particles were included in the cylinders to represent the aggregate in a typical lightweight structural concrete mixture. The cylinders were cured and stored in the same conditions as the ASTM C 227 specimens.

Test Procedures

Mortar Bars: Mortar bars were tested in accordance with ASTM C 227-90, "Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)".

Cylinders: Fractured faces of the cylinders were observed using the ultra-violet light technique presented in SHRP-C/FR-91-101, "Handbook for the Identification of Alkali-Silica Reactivity in Highway Structures". Fresh fractured faces were prepared and observed at the same ages as the ASTM C 227 measurements.

Test Results

Mortar Bars: ASTM C 227 test results are presented in the attached tables and figure. In summary, the mortar bars containing Stalite aggregate expanded and average of +0.017 percent compared to an average expansion of +0.012 percent for the reference mixture over the one year duration of the test. The range of the two results is less than the ASTM C 227 allowable within test variation for a single material.

Cylinders: The Stalite aggregate particles in the cylinder specimens did not exhibit visible indications of alkali-silica reactivity when viewed using the ultraviolet light technique and a 10x magnification over the one year duration of the test.

Law Engineering appreciates the opportunity of providing this service. If there are any questions about this report, or if we may be of further service, please call.

Sincerely,

LAW ENGINEERING, INC.

Terry L. Viness, P.E.
Senior Engineer

John R. Love, P.E.
Principal Engineer

Attachments: Summary of ASTM C 227 Test Results
Figure A

TLV/JRL:dh viness\50644801.rpt

3/6

Mr. Roberic Aunes
LAR Job No. [redacted]

May 23, 1995

VEDLEGG nr 8 side 3

ASTM C 227-90 TEST DATA
Carolina Stalite Company

STALITE AGGREGATE MIXTURE					Batch Date: 2/21/94
Reading Age	Length Change, percent				Average Length Change, %
	A	B	C	D	
1 day	0.000	0.000	0.000	0.000	0.000
14 days	0.007	0.007	0.007	0.007	0.007
28 days	0.007	0.007	0.007	0.007	0.007
2 months	0.012	0.011	0.011	0.011	0.011
3 months	0.015	0.014	0.014	0.013	0.014
4 months	0.018	0.018	0.018	0.016	0.018
6 months	0.018	0.017	0.018	0.016	0.017
9 months	0.016	0.015	0.016	0.014	0.015
12 months	0.017	0.016	0.017	0.016	0.017

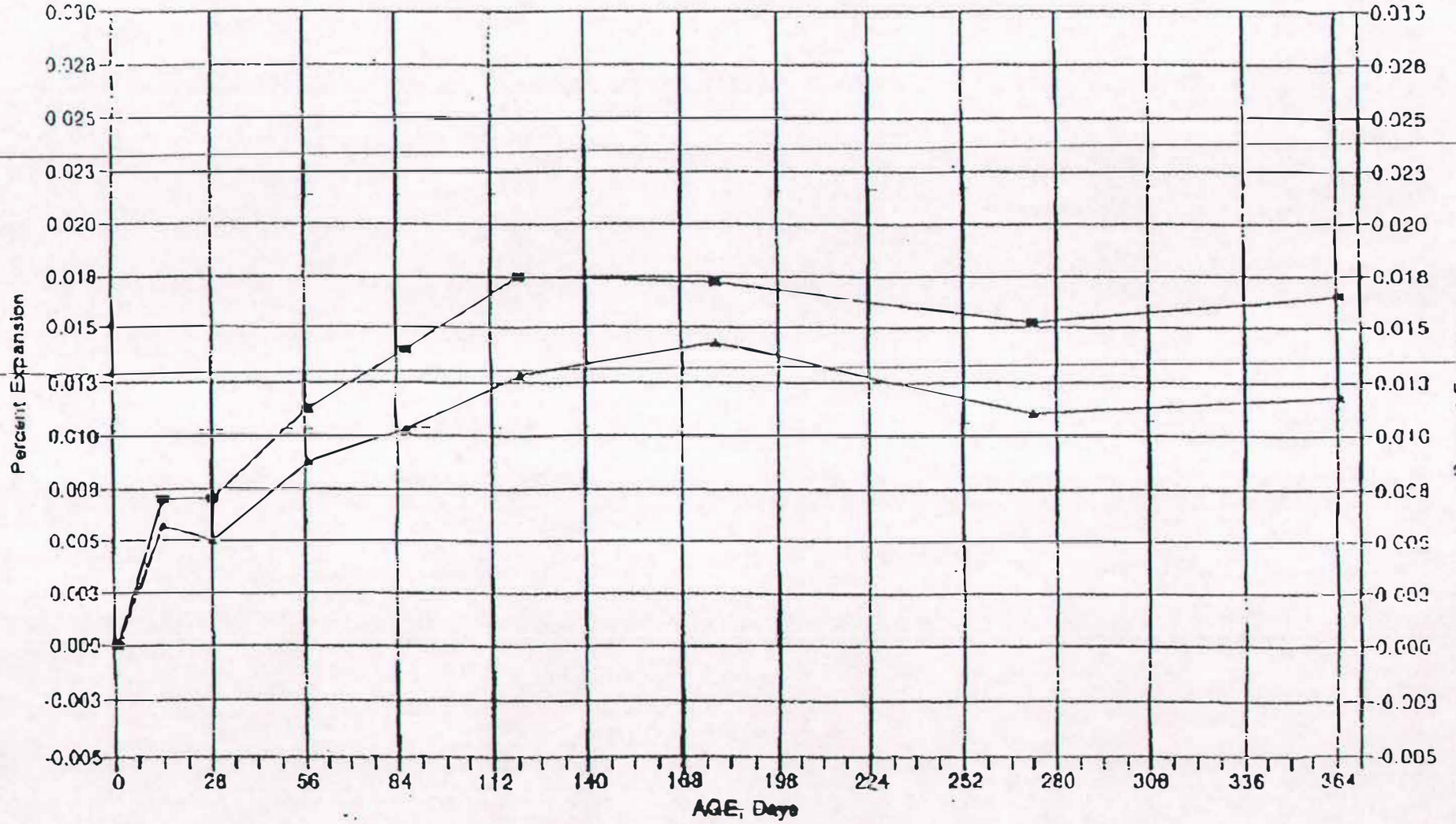
Note: The subject samples did not exhibit warping, surface cracking, or surface deposits during the testing.

REFERENCE MIXTURE					Batch Date: 2/21/94
Reading Age	Length Change, percent				Average Length Change, %
	A	B	C	D	
1 day	0.000	0.000	0.000	0.000	0.000
14 days	0.008	0.005	0.005	0.005	0.006
28 days	0.008	0.004	0.004	0.004	0.005
2 months	0.012	0.008	0.007	0.008	0.009
3 months	0.013	0.010	0.009	0.009	0.010
4 months	0.015	0.012	0.012	0.012	0.013
6 months	0.017	0.014	0.013	0.013	0.014
9 months	0.013	0.010	0.010	0.011	0.011
12 months	0.013	0.012	0.010	0.012	0.012

Note: The subject samples did not exhibit warping, surface cracking, or surface deposits during the testing.

ASTM C 227 TEST RESULTS
Carolina Stalite

FIGURE A



Note: Average of four bars per mixture

PREPARED BY LAW ENGINEERING
JOB NUMBER S820644601

5/24/95 TLV

NEDLEG6 nr. 8 side 4

VEDLEGG nr. 9

SUMMARY OF LABORATORY TESTING

Carolina Stalite
LAW Job No. 226-09230-01

SAMPLE INDENTIFICATION: Expanded Slate - Stalite

ASTM D698 Standard Test Methods for Moisture-Density Relations in Soils and Soil-Aggregate Mixtures Using a 5.5 lb Rammer and 12 in. Drop (one point at as received moisture)

Moisture: 0.08% Dry Unit Weight: 59.9 pcf

AASHTO T 103 Standard Method of Test for Soundness of Aggregates by Freezing and Thawing (Procedure C, 25 cycles)

Sample Fraction	Percent of Total Sample Retained	Sample Weight (gms)	Percent Passing Designated Sieve After Test	Weighted Percentage Loss
1 1/2"-3/4"	4.0	-	0.2*	0.01
3/4"-3/8"	76.5	1001.2	0.2	0.15
3/8"-#4	15.2	300.1	0.4	0.06
Minus #4	4.3	-	-	-
Total	100.0			0.22

*Assumed value per AASHTO T-103

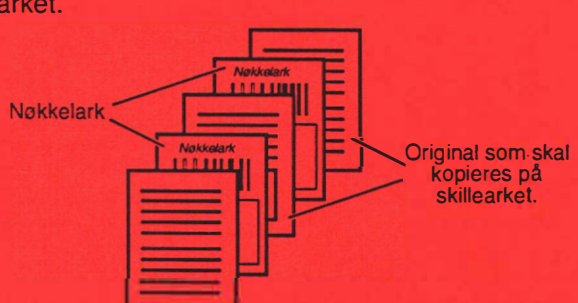
Nøkkelark til kopimaskinen Kodak 2110

Artikkelnr. 950520N

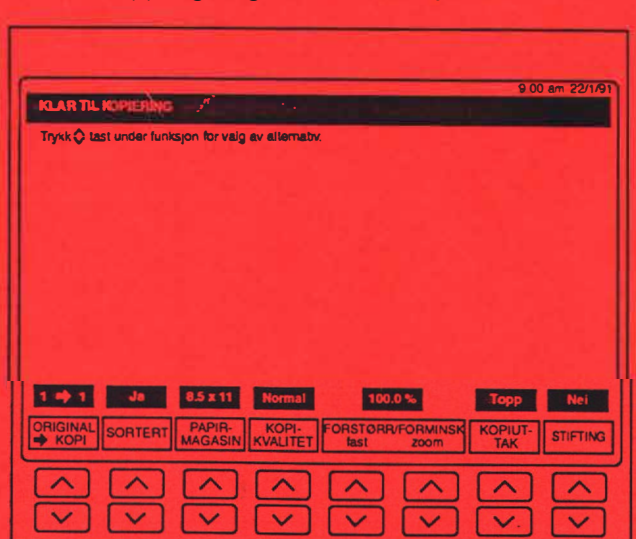
Skilleark – Kopiering på

B R U K S A N V I S N I N G

1. Legg nøkkelarket foran originalen som skal kopieres på skillearket.

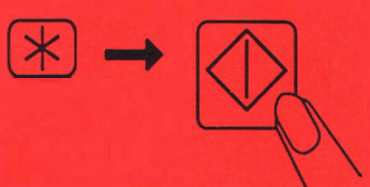


2. Legg originalene og nøkkelarkene i Feeder med forsiden opp, og velg standardfunksjoner.



3. Legg de blanke skillearkene i øvre papirmagasin.

4. Trykk på stjerne (*) og deretter på startknappen for å aktivere nøkkelarket.



Merk: Nøkkelarkene vil bli lagt i utmatingslommen. Du kan også bruke kopier av nøkkelark.

VEDLEGG A - KRAV TIL DOKUMENTASJON

A.1 LC-BETONG TIL RAFTSUNDET BRU
A.2 LETT-TILSLAGSEGENSKAPER SOM SKAL DOKUMENTERES

LC-BETONG TIL RAFTSUNDET BRU

Reseptutvikling av høyfast lettbetong LC 60 skal utføres og dokumenteres av entreprenør. Kravene til betongen er angitt i anbudsbeskrivelsen.

* Miljøklasse MA
* Fasthetsklasse LC 60
* Tyngdetetthet LC 60 19,50 kN/m^3
  tillatt variasjonsområde 18,9 - 19,7 kN/m^3
  med tilleggskrav min 4,5 kN/m^3
  forskjell mellom NC og LC betongene

* Delmaterialer:
  - Sement: Norcem Anleggsement eller tilsvarende
  - Tilsetningsstoff: Godkjent
  - Silikastøv: NS 3045
  - Sand: DGB-godkjent evt. tilsvarende dokumentasjon
  - Lett-tilslag: Se krav til dokumentasjon, vedlegg A.2

Entreprenøren skal proporsjonere en betong som møter kravene gitt foran. Reseptutviklingen kan utføres i laboratorium, men skal verifiseres gjennom fullskala utprøving, inkl. transport og utstøpningsprøver. Prosesskode-2 1997, prosess 84.4 kan være til hjelp.

Entreprenøren skal dokumentere:

* Betongsammensetning:
  - sementinnhold
  - delmaterialer
  - effektivt masseforhold v/(c+kp)
  - fuktinnhold i lett-tilslaget

Delmaterialene dokumenteres, gjennom leverandørsertifikater, entrepreørens mottakskontroll etc., hvor dette er krevet. Lett-tilslag skal dokumenteres spesielt. Kravet til dokumentasjon vil være mer omfattende dersom det velges et lett-tilslag som man ikke har erfaring med i Norge.

* Fersk betong egenskaper:
  - slumpmål / utbredelsesmål
  - romvekt (tyngdetetthet)
  - temperatur
  - luftinnhold

Hvis betongen "remixes" skal dette angis.

* Betongegenskaper - herdnet betong:
  - Fasthet: 3, 7, 28 og evt. 90 døgn
  - Tyngdetetthet: ved avforming, prøving
  - E-modul
  - Vanninntrengning
  - Hydratasjonsvarme

Entreprenøren skal i tillegg dokumentere at betongen etter blanding og transport kan støpes ut på en tilfredsstillende måte. Enklest vil det være å støpe ut noen større prøvestykker hvor det aktuelle vibratorutstyr anvendes.

- Temperaturutvikling registreres.
- Etter avforming inspiseres og større støpesår, større blæredannelser etc. registreres.
- Fasthet og tyngdetetthet bestemmes på utborede kjerner.
  (Denne prøvingen vil også avklare behovet for remixing.)

Hvor betongen skal transporteres ved **pumping** skal det gjennomføres praktiske pumpeforsøk som dokumenterer at betongen er pumpbar. I tillegg til de tester som er nevnt foran skal det også utføres en tynnslipanalyse.

Vedlegg A.2

LETT-TILSLAGSEGENSKAPER SOM SKAL DOKUMNETERES

Lett-tilslag som skal anvendes til konstruksjonsbetong skal dokumenteres som følger:

Det er entreprenørens ansvar å frembringe den dokumentasjon som kreves. Imidlertid vil det normalt være en fordeling mellom leverandør og entreprenørs oppgaver - uten at dette endrer ansvarsforholdene. Det skilles mellom:

A. Leverandørs dokumentasjon og deklarering av egenskaper
B. Egenskaper som leverandør holder kontroll med i sin produksjonskontroll.
C. Entreprenørs mottakskontroll, d.v.s. kontroll av leverandør-sertifikater, stikkprøvekontroll etc.
D. Entreprenørs kontroll av betongproduksjonen.

	Leverandør		Entreprenør	
	A	B	C	D
Bulk Density (romvekt)	X	X	X	X
Particle density (korndensitet) omfatter også kornstyrke	X		X	
Water absorpsjon (vannabsorpsjon)	X		X	
Moisture content (fuktinnhold)			X	X
Particle Size Distribution Grading - Korngradering)	X	X	X	X
Andre egenskaper				
- Content of fines	X			
- Chloride content	X			
- Total sulphur content	X			
- Loss of ignition	X			
- Alkali-aggregate reaction	X			

Engelske betegnelser i overensstemmelse med CEN-definisjoner.

1. **Bulk density (romvekt løst ifylt)**
Skal dokumenteres og deklareres av leverandør.
I Norge benyttes nå testmetoder i.h.t. forslag til CEN-standard pr. EN 1097-3

Det stilles ikke noe spesifikt krav til bulkdensiteten, men den skal være tilstrekkelig til å møte kravet til fasthet LC 60 og tyngdetetthet 19,50 kN/m^3.

Det stilles imidlertid krav til toleranser. Det lette tilslaget skal ikke leveres med større avvik fra deklarert verdi enn ± 7,5%, maksimalt 50 kN/m^3 (0,5 kN/m^3).

Bulk densitet inngår som del av:
- leverandørs dokumentasjon
- leverandørs produksjonskontroll
- entreprenørs mottakskontroll
- entreprenørs kontroll av betongproduksjon

2. **Particle density (partikkel densitet - korndensitet)**
Skal dokumenteres og deklareres av leverandør.
Forslag til CEN-standard pr. EN 1097-6 kan benyttes.

Kornstyrken er for ett og samme lette tilslag en funksjon av korndensiteten. Korndensiteten er derved en viktig materialparameter.

Korndesiteten skal deklareres så det stilles derfor, i utgangspunktet, ingen spesifikke krav. Basert på den erfaring vi har med lette tilslag vil korndensiteten ligge rundt 1.500 kg/m3.

Toleranseavvik på deklarert verdi skal ikke være større enn ± 7,5%, maksimalt 75 kg/m^3, men dersom bulkdensiteten holdes innen gitte toleranser vil kravet til korndensiteten være tilfredsstilt.

Korndensitet skal:
- deklareres av leverandør
- kontrolleres av entreprenør ved mottak (verifiseres).

3. **Water absorption (vannabsorpsjon)**
Skal dokumenteres og deklareres av leverandør. I Norge benyttes Sintef's Test procedure KS 70 119. Vannabsorpsjon er en viktig kvalitetsparameter.

Vannopptak ved nedsenking av ovnstørket lett tilslag skal bestemmes ved gitte tidspunkt, f.eks. etter 2 min, 10 min, 30 min, 1 time, 1 døgn, 14 døgn. Tilslagets vannabsorpsjon skal
- deklareres av leverandør
- verifiseres av entreprenør ved mottak

4. Moisture content (fuktinnhold)

Skal kontrolleres ved mottak på anlegget under betongproduksjon.
Forslag til pr. EN 1097-5 kan benyttes.

Ved leveranse av lett tilslag som skal benyttes til høystyrke betong er det krav om at tilslaget skal ha et jevnt fuktinnhold, f.eks. 5% ± 1%. Variasjon i fuktinnhold kan gi variasjoner i betongens fasthet og tyngdetetthet.

Fuktinnhold kontrolleres av entreprenøren
- ved mottak og
- under betongproduksjon.

5. Particle Size Distribution (Grading - Korngradering)

Skal dokumenteres og deklareres av leverandør.
Forslag til CEN-standard pr. EN 933-1 kan benyttes.

Korngraderingen skal være jevn og det er begrensninger m.h.t. over- og underkorn.

Korngradering inngår som del av:
- leverandørs dokumentasjon
- leverandørs produksjonskontroll
- entreprenørs mottakskontroll
- entreprenørs kontroll av betongproduksjon

6. Andre egenskaper

som leverandør skal dokumentere.

a) Content of fines
(innhold av korn < 0,125 mm)
Innholdet av fine korn skal ikke variere mer enn:
± 1,0%, fraksjoner > 4 mm
± 5,0%, fraksjonen 1 - 4 mm

b) Chloride content
c) Total sulphur content
d) Loss of ignition
e) Alkali-aggregate reaction

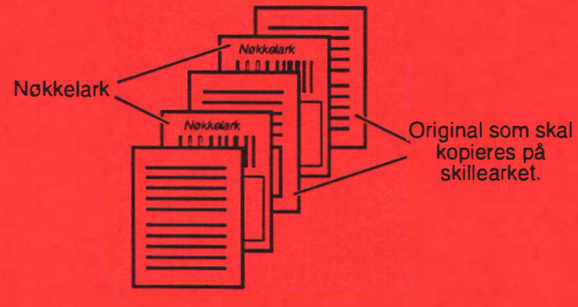
- leverandørs dokumentasjon.

Nøkkelark til kopimaskinen Kodak 2110 *Artikkelnr. 950520N*

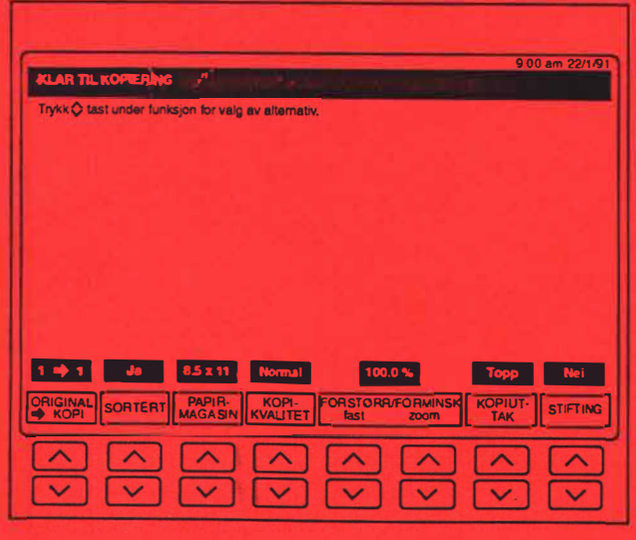
Skilleark – Kopiering på

B R U K S A N V I S N I N G

1. Legg nøkkelarket foran originalen som skal kopieres på skillearket.

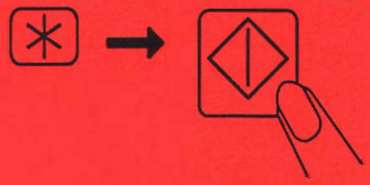


2. Legg originalene og nøkkelarkene i Feeder med forsiden opp, og velg standardfunksjoner.



3. Legg de blanke skillearkene i øvre papirmagasin.

4. Trykk på stjerne (*) og deretter på startknappen for å aktivere nøkkelarket.



Merk: Nøkkelarkene vil bli lagt i utmatingslommen. Du kan også bruke kopier av nøkkelark.

VEDLEGG B - STALITE EGENSKAPER

B.1 Gjennomgang av dokumentasjon fra Carolina Stalite Company "Summary of technical information".
B.2 SUMMARY OF TECHNICAL INFORMATION
B.3 Brev til AS Anlegg fra AXION AS 24/10.1996
B.4 Tilleggsdokumentasjon 10/4.1997

Gjennomgang av dokumentasjon fra Carolina Stalite Company "Summary of technical information".

Generelt

Den fremlagte dokumentasjon er fra tidsperioden 1991 - 1993. De fremlagte tekniske opplysninger bør derfor verifiseres gjennom stikkprøver. Leverandøren skal deklarere de verdier som skal benyttes som grunnlag for mottakskontroll og styring av betong-produksjonen.

Forøvrig skal alle resultater som presenteres være gitt i SI-enheter. Likeledes skal størrelsen på prøvestykker angis., f.eks. om fasthetsprøving er utført på terning eller sylinder.

Del 1 Standardtesting i.h.t. ASTM C 330-89

Testing av lett-tilslag etter ASTM C 330-89 er mer omfattende enn hva som vanligvis kreves i Europa.

Resultatene fra undersøkelse av kjemiske egenskaper er relevante. Når det gjelder fysiske egenskaper er disse ikke relevante for vår bruk av tilslaget i høyfast lettbetong.

Testingen viser imidlertid at Stalite tilfredsstiller krav til lett-tilslag som skal benyttes i de fasthetsklasser som normalt velges.

Del 2 Dokumentasjon av bestandighet

a) De utførte fryse - tine forsøk er lite relevante for vårt tilfelle, men indikerer at tilslaget har en tilstrekkelig motstandsevne mot frostpåkjenninger.

b) Soundness test etter C88 indikerer at det lette tilslaget ligger langt innenfor de grensene ASTM C33 setter for normalt tilslag. Hvis det ikke er foretatt endringer i produksjons-opplegget vil dette være en tilstrekkelig dokumentasjon.

c) SO_3 - innhold.
Innholdet av SO_3 er meget lavt (neglisjerbart). Det fremgår imidlertid ikke av analysen om også andre svovelforbindelser inngår.

I forslag til CEN-standard pr. EN 1744-1 bestemmes totalt svovelinnhold. Kravet er at innholdet av S^{2-} ikke skal overskride 2%. I den tyske standarden DIN 4226 settes en grense for SO_3 til 1,0%, mens andelen S^{2-} -ioner utelates.

I forbindelse med en skadesak hvor lettbetong blokker disintegrerte fant NBI at en grense for samtlige svovelforbindelser, beregnet som ekvivalent SO_3, tilsvarende SO_3 ekv. $\leq$ 0,8% var sikker.

Leca har et svovelinnhold som SO_3 på $\approx$ 0,25%. Det ønskes en tilleggsanalyse hvor totalt svovelinnhold fremgår.

d) Kloridinnhold **meget** lavt og vurderes som tilstrekkelig dokumentert.

Del 3 Absorpsjonsegenskaper

a) Fryse - tine egenskaper
Ingen kommentarer ut over det som er anført under Del 2, pkt. a).

b) Alkali - silika reaktivitet
AR-prøvingen er her utført som "Mortar bar test" ASM C-227.
Det aktuelle forsøket er av **liten** interesse. Prøvingen er utført med en lav-alkali sement Na_2O ekv. = 0,57%. Forsøket sier derfor **intet** om tilslagets potensielle alkali-reativitet,men at den undersøkte resept er alkali-bestandig.

Hvis forsøket skulle sagt noe om det lette tilslagets egenskaper m.h.p. alakli-reativitet, burde det vært benyttet en sement med høyt alkali-nivå.

Vi har i Norge ingen gode testmetoder for å fastlegge lett-tilslags potensielle alkali-reaktivitet. Det har vært vanlig å benytte ASTM C-289 som er en kjemisk metode for å bestemme potensiell AR.

c) Kloridinntrengning
grei informasjon som bekrefter hva vi vet, f.eks. betydningen av silika-støv.

Del 5 pluss Del 6

Mekaniske egenskaper
Av interesse for oss er kun høyfast-betong med effektivt v/c-tall = 0,40 og lavere.

a) Trykkfasthet, spaltestrekk/tyngdetetthet

Stalite 3/4" - Mix D
Test series 1:
v/c = 0,42

fasthet:	28 døgn	51,4 MPa
spaltestrekk:	28 døgn	3,3 MPa
tyngdetetthet:	28 døgn	18,53 kN/m^3

Stalite 3/4" - Mix C
Test series 3:

v/c = 0,41

fasthet:	28 døgn	45,4 MPa
spaltestrekk:	28 døgn	2,6 MPa
tyngdetetthet:	28 døgn	17,96 kN/m^3

Stalite 3/4" - Mix D
Test series 3:

v/c = 0,37

fasthet:	28 døgn	48,3 MPa
spaltestrekk:	28 døgn	2,6 MPa
tyngdetetthet:	28 døgn	17,86 kN/m^3

Fasthetene er her sannsynligvis sylinderfasthet.

Med referanse til NS 3473 er da kravet til karaktriestisk fasthet f_{cck} = 49 MPa.
Med normal spredning betyr dette en tilsiktet middelfasthet f_{cck} = 55 MPa.

De fremlagte verdiene indikerer at det vil være mulig å fremstille en LC 60 betong.
En LC 60 SV-40 evt. LC 60 SV-30 (kfr. Prosesskode-2 1997) med tyngdetetthet 19,50 kN/m^3 vil sannsynligvis møte kravet til fasthet. Det bør imidlertid gjennomføres en relativt omfattende utprøving da de fremlagte resultatene ikke representerer noe reelt bidrag.

Tyngdetettheten må økes.

Ellers er det uklart om v/c-tallet refererer til effektivt vanninnhold?

Er for øvrig forundret over at spaltestrekkfastheten er så lav som ≈ 1/20 av trykkfastheten.

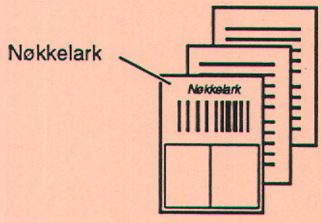
Nøkkelark til kopimaskinen Kodak 2110 *Artikkelnr. 950520N*

Ingen utmating

(Nøkkelarkene blir liggende i Feeder)

B R U K S A N V I S N I N G

1. Legg nøkkelarket hvor som helst i originalsettet.



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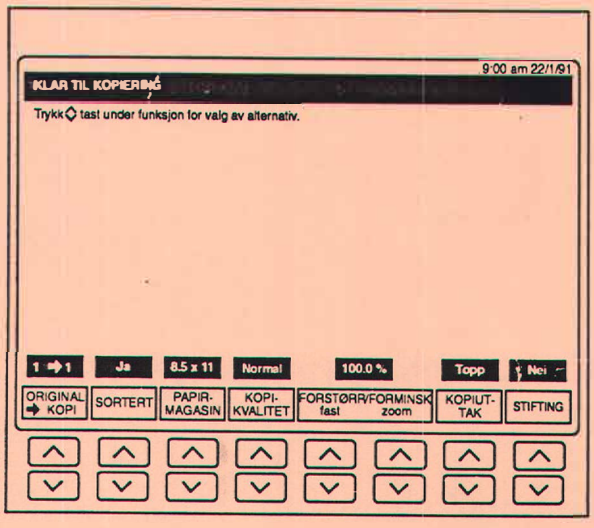
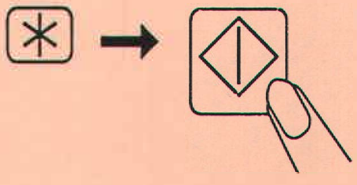


3. Trykk på stjerne (*) og deretter på startknappen for å aktivere nøkkelarket.

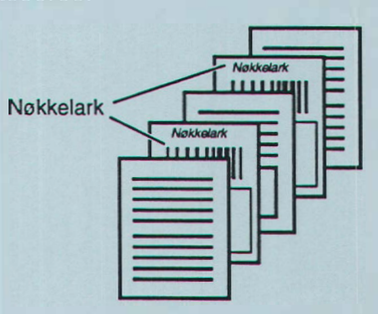


Nøkkelark til kopimaskinen Kodak 2110 *Artikkelnr. 950520N*

Skilleark – Fortrykte/Blanke

B R U K S A N V I S N I N G

1. Legg nøkkelarket eller -arkene akkurat der skillearkene skal plasseres.



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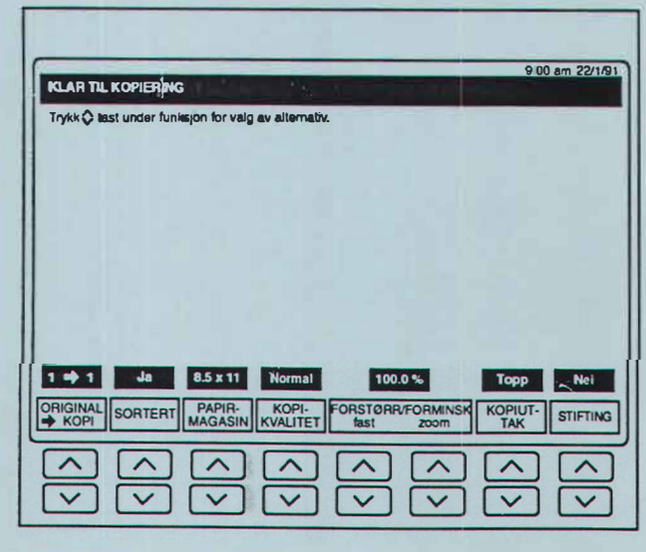
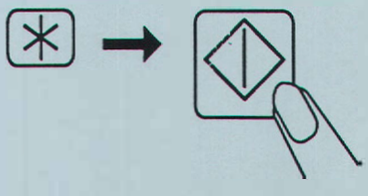


3. Legg de fortrykte/blanke skillearkene i øvre papirmagasin.

4. Trykk på stjerne (*) og deretter på startknappen for å aktivere nøkkelarket.



Merk: Nøkkelarkene vil bli lagt i utmatingslommen. Du kan også bruke kopier av nøkkelark.

VEDLEGG B.2

CAROLINA STALITE COMPANY

STALITE

ROTARY KILN EXPANDED SLATE

SUMMARY OF TECHNICAL INFORMATION

TABLE OF CONTENTS

1. CERTIFICATION FOR LIGHTWEIGHT AGGREGATE FOR STRUCTURAL CONCRETE

    a) Standard tests (ASTM C-330)

2. VERIFICATION OF AGGREGATE DURABILITY AND SOUNDNESS:

    a) Freeze and thaw resistance (AASHTO T- 103)
    b) Magnesium sulfate soundness (ASTM C-88)
    c) Sulfate trioxide content
    d) Soluble chlorine ion content (AASHTO T- 260)

3. VERIFICATION OF AGGREGATE ABSORPTION PERFORMANCE UNDER NORMAL AND HIGH PUMPING PRESSSURE

4. VERIFICATION OF CONCRETE DURABILITY AND SOUNDNESS:

    a) Freeze and thaw resistance (ASTM C-666)
    b) Alkaly silica reactivity (ASTM C-227)
    c) Chloride permeability (AASHTO T-277)

5. ENGINEERING PROPERTIES OF CONCRETE AT NORMAL AND HIGH STRENGTH LEVELS:

    a) Compressive strength
    b) Splitting tension strength
    c) Elastic modulus
    d) Creep
    e) Shrinkage

6. STRENGTH DEVELOPMENT CURVES FOR TYPICAL MIXES.

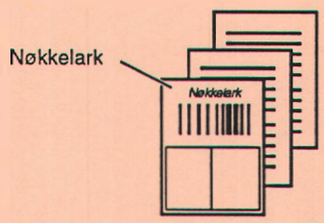
Nøkkelark til kopimaskinen Kodak 2110 *Artikkelnr. 950520N*

Ingen utmating

(Nøkkelarkene blir liggende i Feeder)

B R U K S A N V I S N I N G

1. Legg nøkkelarket hvor som helst i originalsettet.



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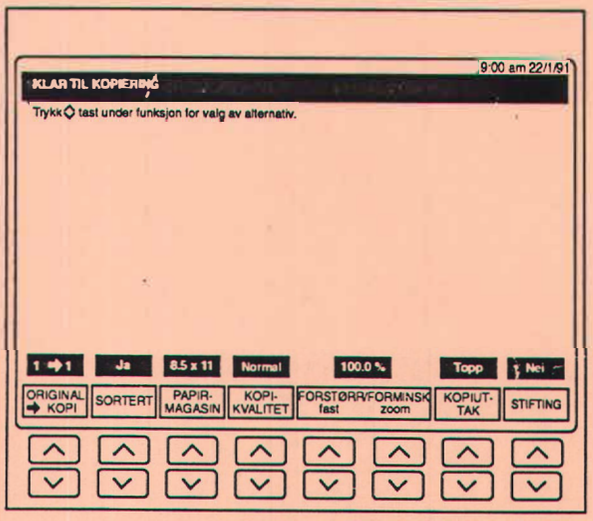

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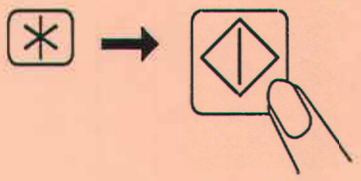
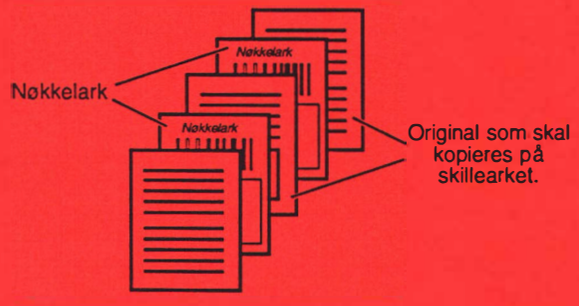


Nøkkelark til kopimaskinen Kodak 2110 *Artikkelnr. 950520N*

Skilleark – Kopiering på

B R U K S A N V I S N I N G

1. Legg nøkkelarket foran originalen som skal kopieres på skillearket.



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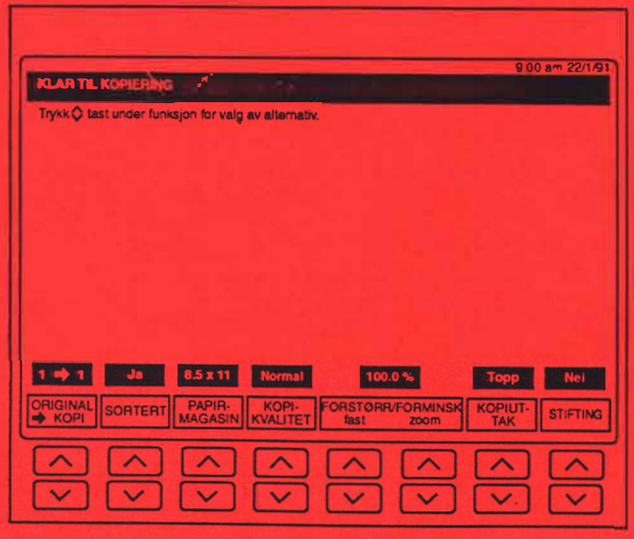

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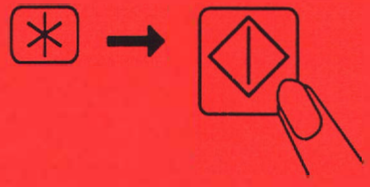


Merk: Nøkkelarkene vil bli lagt i utmatingslommen. Du kan også bruke kopier av nøkkelark.

Dokumentasjon av lettklinker for strukturell betong.
a) Standard tester (ASTM C-330)

DEL 1

STALITE

LIGHTWEIGHT STRUCTURAL CONCRETE

MATERIAL CERTIFICATION ACCORDING TO ASTM C-330

June 18, 1993

LAW ENGINEERING

GEOTECHNICAL, ENVIRONMENTAL
& CONSTRUCTION MATERIALS
CONSULTANTS

Mr. Roberto Nunez
Carolina Stalite Company
P.O. Box 1037
Salisbury, NC 28144

Subject: Report of ASTM C 330-89 Compliance Testing
Revises May 17, 1993 Report
Stalite 3/4-inch Lightweight Aggregate
Law Engineering Job Number 5820466301

Dear Mr. Nunez:

Law Engineering has completed testing of a sample of Stalite 3/4-inch coarse aggregate submitted to this office on March 11, 1993. The purpose of our services was to test the subject material for compliance with ASTM C 330-89, "Standard Specification for Lightweight Aggregates for Structural Concrete". Freeze-thaw durability testing was not performed as part of this project. This work was authorized by your acceptance of our proposal No. 582.93005 dated March 11, 1993. We were provided with your Purchase Order number 8889 for reference and accounting purposes.

The test procedures and test results are presented on the attached tables.

The results of our testing indicate that Stalite 3/4-inch coarse aggregate complies with the requirements of ASTM C 330-89.

At your request an additional sample of the subject material was tested for Loss on Ignition on June 4, 1993. It is our opinion that the results presented in this report are representative of the material submitted. We reviewed our previous test data and procedures and cannot explain the previous test result.

Law Engineering appreciates the opportunity to continue serving Carolina Stalite. If there are any questions about this report, or if we may be of further service, please call.

Sincerely,

LAW ENGINEERING, INC.

Terry L. Viness, E.I.T.
Materials Engineer

for John R. Love, P.E.
Principal Materials Engineer

Attachments: Tables I through IV

facility466301

396 PLASTERS AVENUE, N.E.
ATLANTA, GEORGIA 30324
404-873-4761
TELEFAX 404-881-0508

ASTM C 330-89 COMPLIANCE TESTING

STALITE 3/4-INCH COARSE AGGREGATE

Carolina Stalite Company

June 18, 1993

Law Engineering Job No. 5820466301

Law Engineering Lab Number A93019

Table I - Chemical Composition

Property and Test Method	Test Result	ASTM C 330-89 Requirement
Organic Impurities (ASTM C 40)	Lighter than standard (Color Plate 1)	Lighter than standard
Staining (ASTM C 641)	No Stain	Note 1
Loss On Ignition (ASTM C 114)	<0.1 percent	≤ 5 percent

Table II - Physical Properties

Property and Test Method	Test Result	ASTM C 330-89 Requirement
Clay Lumps (ASTM C 142)	0.1 percent	2 percent, Maximum
Grading (ASTM C 136)	See Table III	See Table III
Unit Weight (ASTM C 29)	797.7 Kg/m^3 49.8 lbs/ft^3	55 lbs/ft^3, 880 Kg/m^3 Maximum
Compressive Strength (ASTM C 39) Average of 3 at 28 days	3940 psi	3920 psi, Minimum(2)
Splitting Tensile Strength (ASTM C 496) Average of eight at 28 days	410 psi	318 psi, Minimum(2)
Drying Shrinkage (ASTM C 157)(3)	0.017 percent	0.07 percent, Maximum
Popouts (ASTM C 151)(3)	No Popouts	No Popouts

Notes:

(1) Aggregates producing a heavy or very heavy stain are subject to rejection depending on the results of further testing. Stalite produced no stain which indicates acceptable material.

(2) Required values interpolated from table in ASTM C 330-89 based on air-dry unit weight of concrete measured in accordance with ASTM C 567. Strength specimens were moist cured for 7 days then air-cured for 21 days in accordance with ASTM C 567. Concrete proportions and properties are attached.

(3) Drying shrinkage and popout specimens were proportioned in accordance with the requirements of ASTM C 330-89. Drying shrinkage specimens were cured in accordance with specific requirements of ASTM C 330-89.

ASTM C 330-89 COMPLIANCE TESTING

STALITE 3/4-INCH COARSE AGGREGATE

Carolina Stalite Company

June 18, 1993

Law Engineering Job No. 5820466301

Law Engineering Lab Number A93019

Table III - Gradation

Sieve Size or Number	Percent Passing	ASTM C 330-89 Required Percent Passing
1 inch	100	100
3/4 inch	98	90 - 100
1/2 inch	61	—
3/8 inch	32	10 - 50
No. 4	5	0 - 15
No. 8	2	—

ASTM C 330-89 COMPLIANCE TESTING
STALITE 3/4-INCH COARSE AGGREGATE
Carolina Stalite Company
June 18, 1993
Law Engineering Job No. 5820466301
Law Engineering Lab Number A93019

Concrete Proportions and Properties:

One-Cubic Yard Design Proportions:

Material	Source	Proportion
Cement	Blue Circle Type I, Atlanta Georgia	564 pounds
Coarse Aggregate	Carolina Stalite 3/4-inch	930 pounds, SSD
Fine Aggregate	R & S Aggregates, natural quartzitic sand Waugh, Alabama	1347 pounds, SSD
Water	Atlanta, Georgia	300 pounds
Admixtures	Daravair, W.R. Grace & Co.	2.8 ounces

Notes: (1) Design proportions were selected by Law Engineering based on the requirements of ASTM C 330-89 and previous experience with Stalite. The proportions were approved by Stalite prior to batching of the concrete.

(2) Gradations and specific gravities presented on the attached Aggregate Test Report.

Mixture Properties:

Property	Test Result	ASTM C 330-89 Requirement
Slump, inches	3	2 - 4
Air Content, percent	6.0	6 ± 1
Plastic Unit Weight, lbs/ft^3	116.0	---
Mix Temperature, °F	71	---
Yield, ft^3 per yd^3 batched	27.1	---
Water-Cement Ratio	0.53	---
ASTM C 567 Air-Dry Unit Weight, lbs/ft^3	114.6	115, Maximum

AGGREGATE TEST REPORT
CAROLINA STALITE
June 18, 1993
Law Engineering Job No. 5820466301

COARSE AGGREGATE	
Source:	Carolina Stalite Salisbury, NC
Material:	Stalite 3/4-inch
Sieve Size or Number	**Percent Passing**
1"	100
3/4"	98
1/2"	61
3/8"	32
No. 4	5
No. 8	2
Specific Gravity, SSD:	1.52
Percent Absorption:	5.5

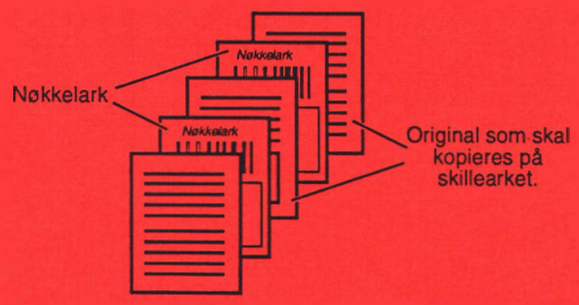
FINE AGGREGATE	
Source:	R & S Aggregates Waugh, Alabama
Material:	Natural Quartzitic Sand
Sieve Size or Number	**Percent Passing**
3/8"	100
No. 4	97
No. 8	85
No. 16	67
No. 30	35
No. 50	8
No. 100	2
No. 200	0.5
Fineness Modulus:	3.06
Specific Gravity, SSD:	2.63
Percent Absorption:	0.6

Nøkkelark til kopimaskinen Kodak 2110 *Artikkelnr. 950520N*

Skilleark – Kopiering på

B R U K S A N V I S N I N G

1. Legg nøkkelarket foran originalen som skal kopieres på skillearket.



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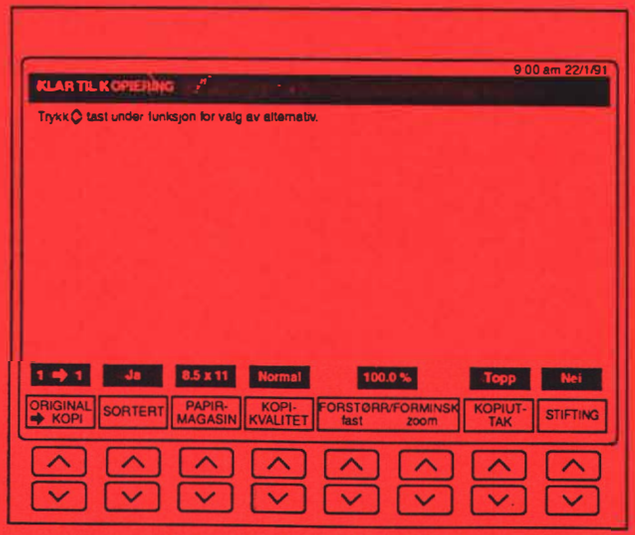

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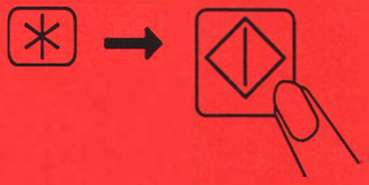


Merk: Nøkkelarkene vil bli lagt i utmatingslommen Du kan også bruke kopier av nøkkelark.

Dokumentasjon av fysiske egenskaper
a) Fryse-tine egenskaper (AASHTO T-130)
b) Magnesium sulfat bestandighet (ASTM C-88)
c) Sulfat trioksyd innhold
d) Innhold av løselige klorine joner (AASHTO T-260)

DEL 2

STALITE

AGGREGATE DURABILITY AND SOUNDNESS

TESTS FOR:

* FREEZE AND THAW
* MAGNESIUM SULFATE SOUNDNESS
* SULFATE TRIOXIDE CONTENT
* CLORIDES CONTENT

LAW ENGINEERING
A MEMBER OF LAW COMPANIES GROUP

July 22, 1992

Carolina Stalite Company
P.O. Box 1037
Salisbury, North Carolina 28144

Attention: Mr. Roberto Nunez

Subject: Report of Laboratory Testing
Expanded Slate - Stalite
Carolina Stalite
Salisbury, North Carolina
LAW Job No. 226-09230-01

Gentlemen:

As authorized by the acceptance of our Work Authorization Sheet dated May 26, 1992, Law Engineering has completed requested laboratory tests on the Expanded Slate (Stalite) sample which was submitted to our laboratory. Tests were performed in accordance with the appropriate sections of the following specifications:

- ASTM D698 Standard Test Methods for Moisture-Density Relations in Soils and Soil-Aggregate Mixtures Using a 5.5 lb Rammer and 12 in. Drop

- AASHTO T103 Standard Method of Test for Soundness of Aggregates by Freezing and Thawing

Results of these tests are tabulated on the attached "Summary of Laboratory Testing" sheets.

P.O. BOX 11297
CHARLOTTE, NC 28220
4333 WILMONT ROAD, SUITE 100
CHARLOTTE, NC 28208
704-357-8600

We appreciate the opportunity to be of service to you with this project. If you should have any questions concerning this report, or if we may be of further service to you, please do hesitate to contact this office at (704) 357-8600.

Respectfully submitted,

LAW ENGINEERING

Carrie Y. Wallace

Carrie Y. Wallace, C.E.T.
Laboratory Services Supervisor

Michael O. Hamlett

Michael O. Hamlett, C.E.T.
Laboratory Services Manager

CYW:MOH:kc

Attachment

SUMMARY OF LABORATORY TESTING

Carolina Stalite
LAW Job No. 226-09230-01

SAMPLE INDENTIFICATION: Expanded Slate - Stalite

ASTM D698 Standard Test Methods for Moisture-Density Relations in Soils and Soil-Aggregate Mixtures Using a 5.5 lb Rammer and 12 in. Drop (one point at as received moisture)

Moisture: 0.08% Dry Unit Weight: 59.9 pcf

AASHTO T 103 Standard Method of Test for Soundness of Aggregates by Freezing and Thawing (Procedure C, 25 cycles)

Sample Fraction	Percent of Total Sample Retained	Sample Weight (gms)	Percent Passing Designated Sieve After Test	Weighted Percentage Loss
1 1/2"-3/4"	4.0	-	0.2*	0.01
3/4"-3/8"	76.5	1001.2	0.2	0.15
3/8"-#4	15.2	300.1	0.4	0.06
Minus #4	4.3	-	-	-
Total	100.0			0.22

*Assumed value per AASHTO T-103

September 23, 1992

LAW ENGINEERING

A MEMBER OF LAW COMPANIES GROUP

Carolina Stalite Company
P.O. Box 1037
Salisbury, North Carolina 28144

Attention: Mr. Roberto Nunez

Subject: Report of Laboratory Testing
Lightweight Aggregate
Carolina Stalite
Salisbury, North Carolina
LAW Job No. 226-09230-01

Gentlemen:

As authorized by the acceptance of our Work Authorization Sheet dated May 26, 1992, Law Engineering has completed requested laboratory tests on the lightweight aggregate sample which was submitted to our laboratory. Testing was performed in accordance with the appropriate sections of the following specification:

- ASTM C88 — Standard Test Method for Soundness of Aggregates by Use of Sodium Sulfate of Magnesium Sulfate

Results of this test are tabulated on the attached "Summary of Laboratory Testing" sheet.

We appreciate the opportunity to be of service to you with this project. If you should have any questions concerning this report, or if we may be of further service to you, please do hesitate to contact this office at (704) 357-8600.

Respectfully submitted,

LAW ENGINEERING

Michael O. Hamlett, C.E.T.
Laboratory Services Manager

CYW:MOH:kc
Attachment

P.O. BOX 11297
CHARLOTTE, NC 28220
4333 WILMONT ROAD, SUITE 100
CHARLOTTE, NC 28208
704-357-8600
FACSIMILE 704 357-8630

SUMMARY OF LABORATORY TESTING

Carolina Stalite
LAW Job No. 226-09230-01

SAMPLE INDENTIFICATION: Stalite Lightweight Aggregate

ASTM C88 Soundness of Aggregate by Use of Sodium Sulfate or Magnesium Sulfate (Samples tested Using Magnesium Sulfate)

Sample Fraction	Percent of Total Sample Retained	Sample Weight (gms)	Percent Passing Designated Sieve After Test	Weighted Percentage Loss
1 1/2"-3/4"	5.0	504.5	0.0*	0.00
3/4"-3/8"	80.9	1000.9	0.0	0.00
3/8"-#4	12.1	301.0	1.1	0.01
Minus #4	2.0	---	---	---
Total	100.0			0.01

LAW ENGINEERING

GEOTECHNICAL, ENVIRONMENTAL
& CONSTRUCTION MATERIALS
CONSULTANTS

March 23, 1992

Mr. Bill Grigg
Carolina Stalite Company
Drawer 1037
Salisbury, North Carolina 28145-1037

Subject: Results of AASHTO T 260 Testing
Carolina Stalite Coarse Aggregate
Law Engineering Lab No. A92035

Dear Mr. Grigg:

Law Engineering has completed chloride ion content testing of the sample of Stalite coarse aggregate submitted to our laboratory on March 16, 1992. This work was authorized by your letter of March 16, 1992.

Three representative specimens of the submitted aggregate sample were tested in accordance with AASHTO T 260, "Sampling and Testing for Total Chloride Ion Content in Concrete and Concrete Raw Materials". The test specimens were prepared by crushing coarse aggregate particles to pass a No. 50 size mesh as required by AASHTO T 260.

Water soluble chloride ion contents of the three samples ranged from 0.005 to 0.006 percent with an average of 0.005 percent.

Law Engineering appreciates the opportunity of providing this service. If there are any questions about this report, or if we may be of further service, please call.

Sincerely,

LAW ENGINEERING, INC.

Terry L. Viness, E.I.T.
Materials Engineer

John R. Love, P.E.
Principal Materials Engineer

396 PLASTERS AVENUE, N.E.
ATLANTA, GEORGIA 30324
404-873-4761
TELEFAX 404-881-0508

CHEM-BAC *Laboratories, Inc.*

• P. O. BOX 19198, CHARLOTTE, N. C. 28219

TEL 394-6381
FAX #: 704 394-6382

November 4, 1992

REF: 1198

Analysis of Aggregate for Requested Tests

MADE FOR: Carolina Stalite
P.O. Drawer 1037
Salisbury, N.C. 28144

ATTENTION: Charles Freeman

MARKED: Sample received at Chem-Bac Labs, Inc. on 10/29/92
P.O. # 8837

ANALYSIS: Sulfur Trioxide --------- < .05 parts per million
Chloride as NaCl -------- .60 parts per million

Respectfully submitted,
CHEM-BAC LABORATORIES, INC.

J.C. Hucbell
Supervising Chemist

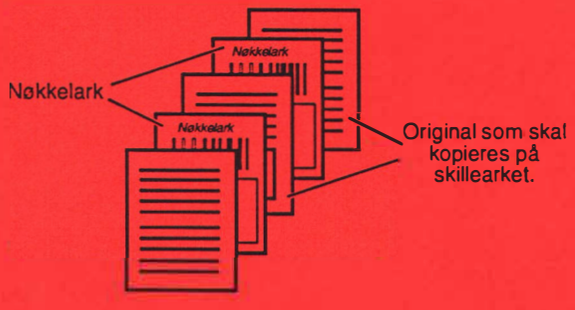
JCH/th

Nøkkelark til kopimaskinen Kodak 2110 *Artikkelnr. 950520N*

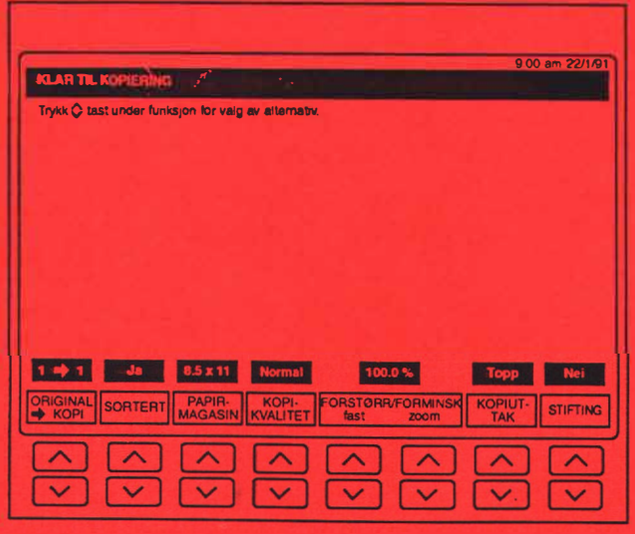
Skilleark – Kopiering på

B R U K S A N V I S N I N G

1. Legg nøkkelarket foran originalen som skal kopieres på skillearket.

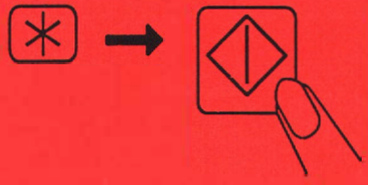


2. Legg originalene og nøkkelarkene i Feeder med forsiden opp, og velg standardfunksjoner.



3. Legg de blanke skillearkene i øvre papirmagasin.

4. Trykk på stjerne (*) og deretter på startknappen for å aktivere nøkkelarket.



Merk: Nøkkelarkene vil bli lagt i utmatingslommen Du kan også bruke kopier av nøkkelark.

Dokumentasjon av tillslagets absorpsjonsegenskaper
under normalt og høgt pumpetrykk.

DEL 3

STALITE

TESTS FOR:

AGGREGATE PERFORMANCE UNDER NORMAL AND HIGH PUMPING PRESSURE

July 6, 1992

LAW ENGINEERING

GEOTECHNICAL, ENVIRONMENTAL & CONSTRUCTION MATERIALS CONSULTANTS

Mr. Roberto Nunez
Carolina Stalite Company
P.O. Box 1037
Salisbury, N.C. 28145-1037

Subject: Report of Pressurized Absorption Test Results
Carolina Stalite 1/2 inch Aggregate
Law Engineering Job No. 5720323801

Dear Roberto:

As authorized by you, Law Engineering has completed the pressurized absorption testing of 1/2 inch sized Stalite aggregate. The purpose of this testing was to provide data on the effect different applied pressures have on the absorption properties of the subject aggregate. As directed by Mr. Nunez, the subject aggregate was tested in the as-received and oven-dried conditions. This report presents the test procedures used and the results of our testing.

TEST PROCEDURE

A moisture content specimen was obtained from the specimen to measure the as-received moisture condition. A second specimen was soaked and tested to determine the SSD absorption of the submitted aggregate.

The remaining sample was then split into two subsamples. One subsample was kept in the as received condition until testing; the other subsample was oven dried at 230°F for approximately 48 hours prior to testing.

The following test procedure was performed on both the as-received and oven-dried specimens:

1) Initial weight in air was measured,

2) Weight of the sample suspended in water at atmospheric pressure was measured,

3) The sample was transferred to a pressure chamber filled with water and subjected to 50 psi for 5 minutes,

4) The sample was removed from the chamber and its suspended weight was remeasured,

5) Steps 3 and 4, above, were repeated for pressures of 100, 150, 200, 250, and 300 psi.

396 PLASTERS AVENUE, N.E.
ATLANTA, GEORGIA 30324
404-873-4761
TELEFAX 404-881-0508

The absorption for each pressure increment was calculated from the change in the suspended weights.

TEST RESULTS

The results of our testing are presented in the table and the attached graph.

Condition	Percent Absorbed Moisture	
	As-Received	Oven-Dried
Atmospheric	5.7	2.3
50 psi	7.4	4.9
100 psi	8.6	6.9
150 psi	9.4	7.5
200 psi	9.8	8.5
250 psi	10.7	9.3
300 psi	10.7	10.1

The SSD absorption of the aggregate was measured to be 6.7 percent. The absorbed moisture of the "oven-dried" specimen at atmospheric pressure is the result of difficulty in measuring the suspended weight of a dry absorbent material.

Law Engineering appreciates the opportunity to continue serving Stalite. If there are any questions about this report, or if we may be of further service, please call.

Sincerely,

LAW ENGINEERING, INC.

Terry L. Viness, E.I.T.
Materials Engineer

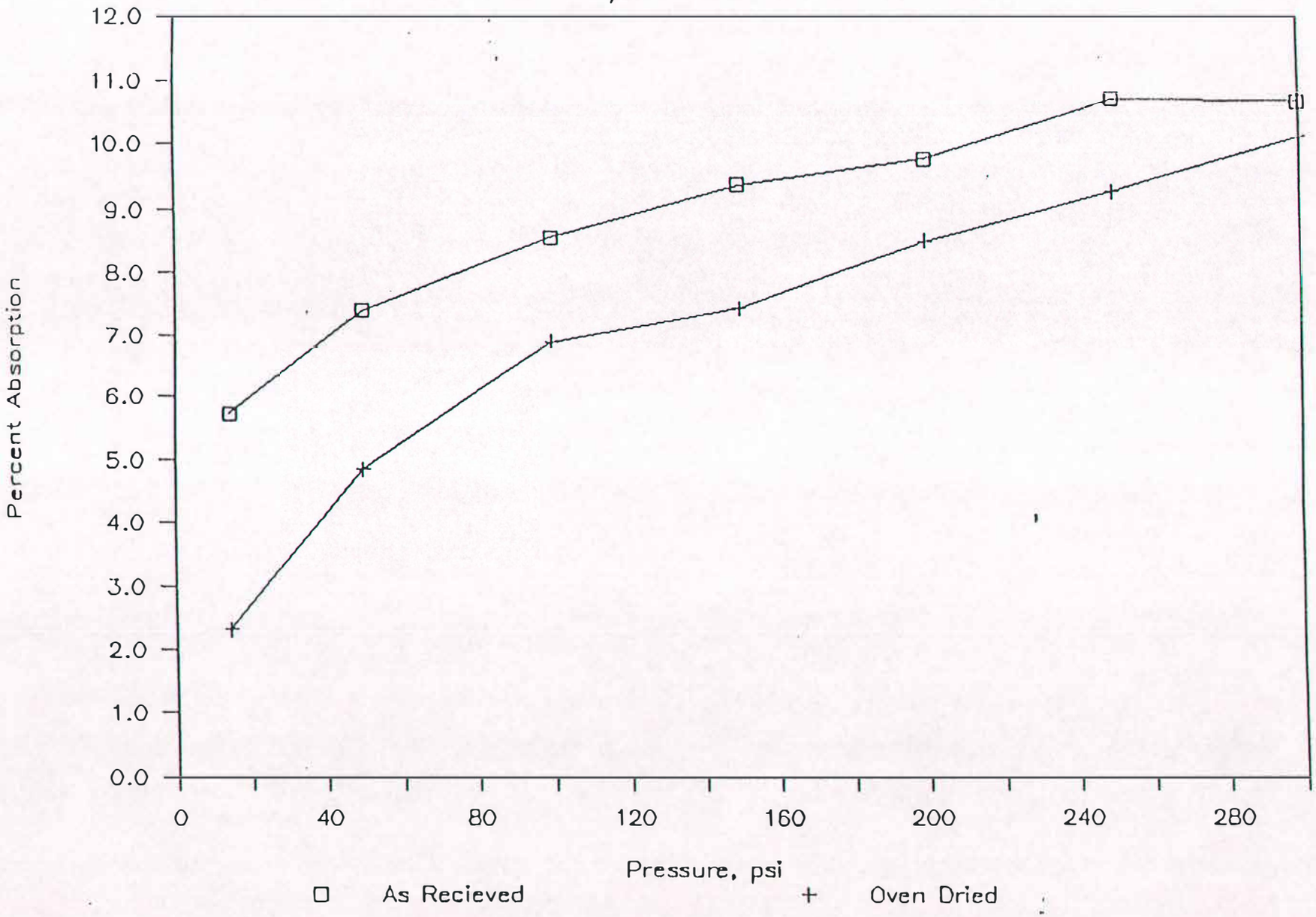
John Love, P.E.
Principal Materials Engineer

Attachment: Graph

tlv\323801

Pressure Absorption

1/2 inch Stolite

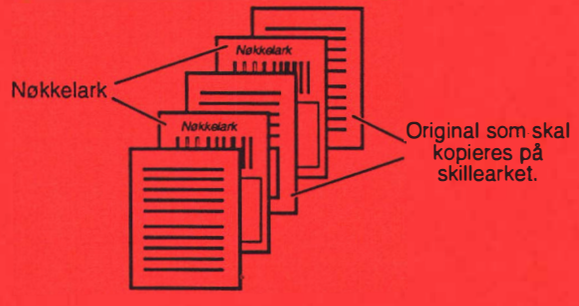


Nøkkelark til kopimaskinen Kodak 2110 *Artikkelnr. 950520N*

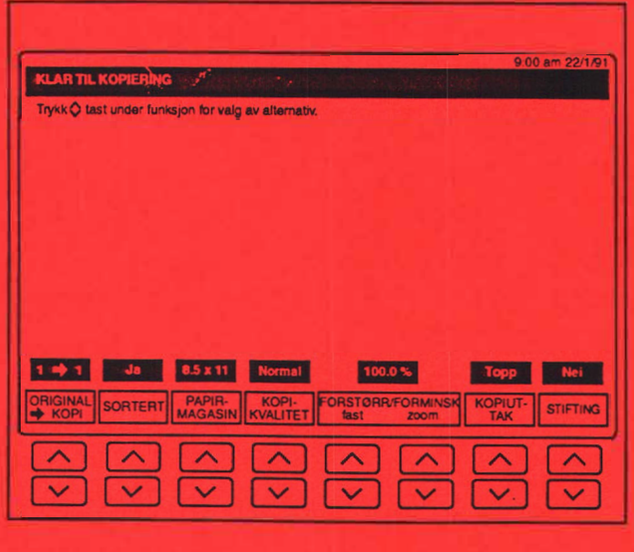
Skilleark – Kopiering på

B R U K S A N V I S N I N G

1. Legg nøkkelarket foran originalen som skal kopieres på skillearket.

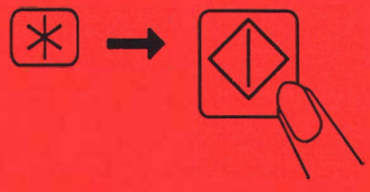


2. Legg originalene og nøkkelarkene i Feeder med forsiden opp, og velg standardfunksjoner.



3. Legg de blanke skillearkene i øvre papirmagasin.

4. Trykk på stjerne (*) og deretter på startknappen for å aktivere nøkkelarket.



Merk: Nøkkelarkene vil bli lagt i utmatingslommen Du kan også bruke kopier av nøkkelark.

Dokumentasjon av LWA betong fysiske egenskaper

a) Fryse -tine egenskaper (ASTM C-666)
b) Alkali-silika reaktivitet. (ASTM C-227)
c) Klorid inntrenging (AASHTO T-277)

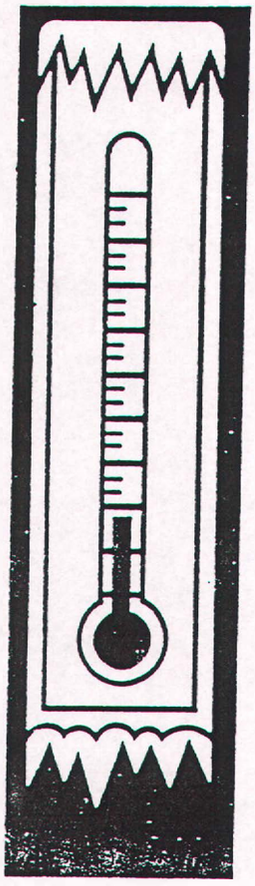
DEL 4

STALITE

CONCRETE DURABILITY AND SOUNDNESS

TESTS FOR:

* FREEZE AND THAW
* ALKALI REACTIVITY
* CHLORIDE PERMEABILITY



Freeze-Thaw Resistance Of Lightweight Aggregate Concrete

Written by David Stark

construction technology laboratories

A division of the PORTLAND CEMENT ASSOCIATION

Freeze-Thaw Resistance of Lightweight Aggregate Concrete

Written by David Stark
construction technology laboratories

Carolina Stalite Company has requested the Construction Technology Laboratories of the Portland Cement Association to evaluate a concrete mix containing **STALITE** lightweight coarse aggregate. The test procedure requested was rapid freeze-thaw according to ASTM C 666, Procedure A, except that 2% NaCl solution to be used instead of water. Both the weight loss and durability factor were to be monitored. Following are the details and test results of this work.

The cement, coarse and fine aggregate, and air entraining and water reducing admixtures, were supplied by Carolina Stalite. The lightweight coarse aggregate was used in the ambient dry condition, while the natural sand was used in the saturated surface-dry condition. Mix proportions, together with slump and air content, are given in Table 1.

Table 1
Concrete Mix Parameters

Cement content	635 lbs/cu. yd.
Mix water	267 lbs/cu. yd.
Coarse aggregate	950 lbs/cu. yd.
Fine aggregate	1274 lbs/cu. yd.
Slump	2.4 in.
Net air content	6.6%

Darex was used as the air entraining agent, while Hycol was added as a water reducer. The concrete was mixed in a 1½ cu. ft. pan type mixer on a 3-3-2 minute mix-rest-mix cycle, with slump and air content being measured immediately thereafter. Three companion 3x3x11¼ in. concrete prisms were made for freeze-thaw testing, while three 6x12 in. cylinders were made for compressive strength testing. After curing in the molds for one day, all specimens were demolded and transferred to 73°F moist room until testing. The prisms were cured for 14 days, at which time they were weighed and measured sonically for dynamic modulus, then transferred into test in a 2% sodium chloride solution. Freeze-thaw cycling was carried out in this solution according to ASTM C 666, Procedure A, at the rate of seven or eight cycles per day up to 300 cycles.

Table 2
Freeze-Thaw Test Results

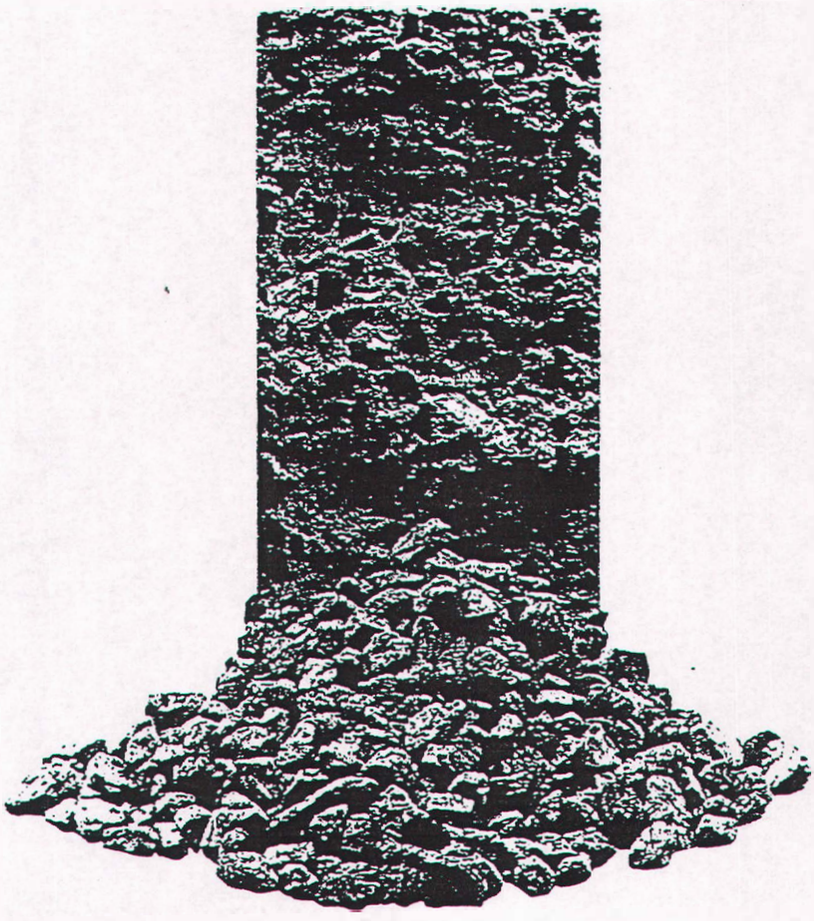
Percent Weight Loss at Cycle Indicated*			
Cycle	% Weight Loss	Cycle	% Weight Loss
31	0.18	175	1.09
60	0.29	200	1.29
89	0.47	234	1.51
115	0.63	260	1.79
145	0.70	300	2.09
Durability Factor 95.4%			

* All data are the average for three companion specimens.

Calculations of weight losses and the durability factor (DF) are given in Table 2. Here, data for 300 cycles show weight loss of only 2.09%, while the durability factor was 95.4%. Twenty-eight day compressive strength test results, given in Table 3, show satisfactory strengths for this mix design.

Table 3
28 Day Compressive Strength Data

Cylinder No.	Compressive Strength (psi)
1	5720
2	5120
3	5560
Average	5467



Rotary kiln expanded slate, **STALITE** is a most durable lightweight aggregate.

STALITE

CAROLINA STALITE COMPANY

MANUFACTURERS OF LIGHTWEIGHT AGGREGATE "STALITE"

PO Box 1037
Salisbury, NC 28145-1037
FAX 704-638-0742
704-637-1515

December 7, 1992

Mr. Roberto Nunez
Carolina Stalite Company
P.O. Box 1037
Salisbury, NC 28145

LAW ENGINEERING

GEOTECHNICAL, ENVIRONMENTAL
& CONSTRUCTION MATERIALS
CONSULTANTS

Subject: Report of Freeze-Thaw Testing
Stalite 3/4 Aggregate
Law Engineering Job No. 5720326901

Dear Mr. Nunez:

Law Engineering has completed the authorized testing of a laboratory concrete mixture containing Stalite 3/4 inch coarse aggregate. The purpose of our services was to measure the freeze-thaw durability of the concrete mixture. This report presents the materials, concrete mixture, curing procedures, test procedures, and test results.

Materials

The following materials were used:

Material	Type and Source
Cement:	Signal Mountain, Type I, Chattanooga, TN
Fly Ash:	Monex Resources, Class F, Plant Wansley Georgia
Coarse Aggregate:	Carolina Stalite, 3/4-inch, Salisbury, NC
Fine Aggregate:	R & S Aggregate, Waugh, AL, natural quartzitic sand
Admixtures:	MBVR and 440N, Master Builders

The Stalite 3/4-inch coarse aggregate was provided by Carolina Stalite. Other concrete materials were obtained by Law Engineering from a local ready mix concrete supplier.

Gradation, specific gravity, and absorption data for the aggregates used are attached.

396 PLASTERS AVENUE, N.E.
ATLANTA, GEORGIA 30324
404-873-2761
TELEFAX 404-881-0508

Mixture Proportions

Mr. Roberto Nunez of Carolina Stalite provided the following one-cubic-yard mixture proportions to be used:

Cement	600 lbs.
Fly Ash	115 lbs.
Stalite	880 lbs.
Fine Agg.	1235 lbs.
Water	286 lbs.

Admixtures:

MBVR	as-required to provide 5 to 6.5 percent entrained air
440N	29 ounces

Batching and Molding Procedures

Concrete was batched and specimens prepared in accordance with ASTM C 192, " Standard Practice for Making and Curing Concrete Specimens in the Laboratory". Compressive strength specimens were 6-inch-diameter by 12-inch cylinders. Freeze-thaw specimens were 3"x4"x16" prisms.

Measured Plastic Mixture Properties

The following plastic properties were measured in accordance with applicable ASTM procedures:

Slump	3 1/4 inches
Air Content	5.3 percent
Unit Weight	116.8 pcf
Actual Yield	26.7 cubic feet
Water-Cementitious Ratio	0.40 (includes pozzolan)

Hardened Properties

Compressive strength was measured in accordance with ASTM C 39, "Standard Test Method for Compressive Strength of Cylindrical Concrete Specimens". Compressive Strength specimens were cured in a moist room meeting the requirements of ASTM C 511, "Standard Specification for Moist Cabinets, Moist Rooms, and Water Storage Tanks Used in the Testing of Hydraulic Cement Concretes", from the time of demolding until time of testing.

The results of ASTM C 39 testing are presented below:

7 day Compressive Strength (single specimen)		4350 psi
28 day Compressive Strength		
		5870 psi
		5370 psi*
		5910 psi
	Average:	5910 psi

* Specimen was observed to have a cap failure; this test result was not used in calculating the average strength.

Two specimens were tested in accordance with ASTM C 666, "Standard Test Method for Resistance of Concrete to Rapid Freezing and Thawing", Procedure A, freezing and thawing in water. Freeze-thaw specimens were cured for 14 days in a water storage tank meeting the requirements of ASTM C 511 followed by seven days storage in laboratory air conditions at approximately 73°F. Fundamental transverse frequencies were measured using the Impact Resonance Method in accordance with ASTM C 215, " Standard Test Method for Fundamental Transverse, Longitudinal, and Torsional Frequencies of Concrete Specimens". The results of ASTM C 666 testing are presented below:

Number of cycles completed:	300
Relative Dynamic Moduli:	
Specimen A	103.9
Specimen B	102.0
Weight Change, grams:	
Specimen A	+55
Specimen B	+73

The attached graph presents the relative dynamic moduli as the test progressed.

The increase in weight of the test specimens over the duration of the test is probably the result of water absorbed by the specimens during testing. This is often observed when specimens begin testing in an air-dry condition. The test specimens did not exhibit observable effects of testing such as surface scaling or visible cracking. Relative dynamic moduli greater than or equal to 100 indicate that the concrete was essentially unaffected by the test procedure.

Law Engineering appreciates the opportunity of providing this service. If there are any questions about this report, or if we may be of further service, please call.

Sincerely,

LAW ENGINEERING, INC.

Terry L. Viness, E.I.T.
Materials Engineer

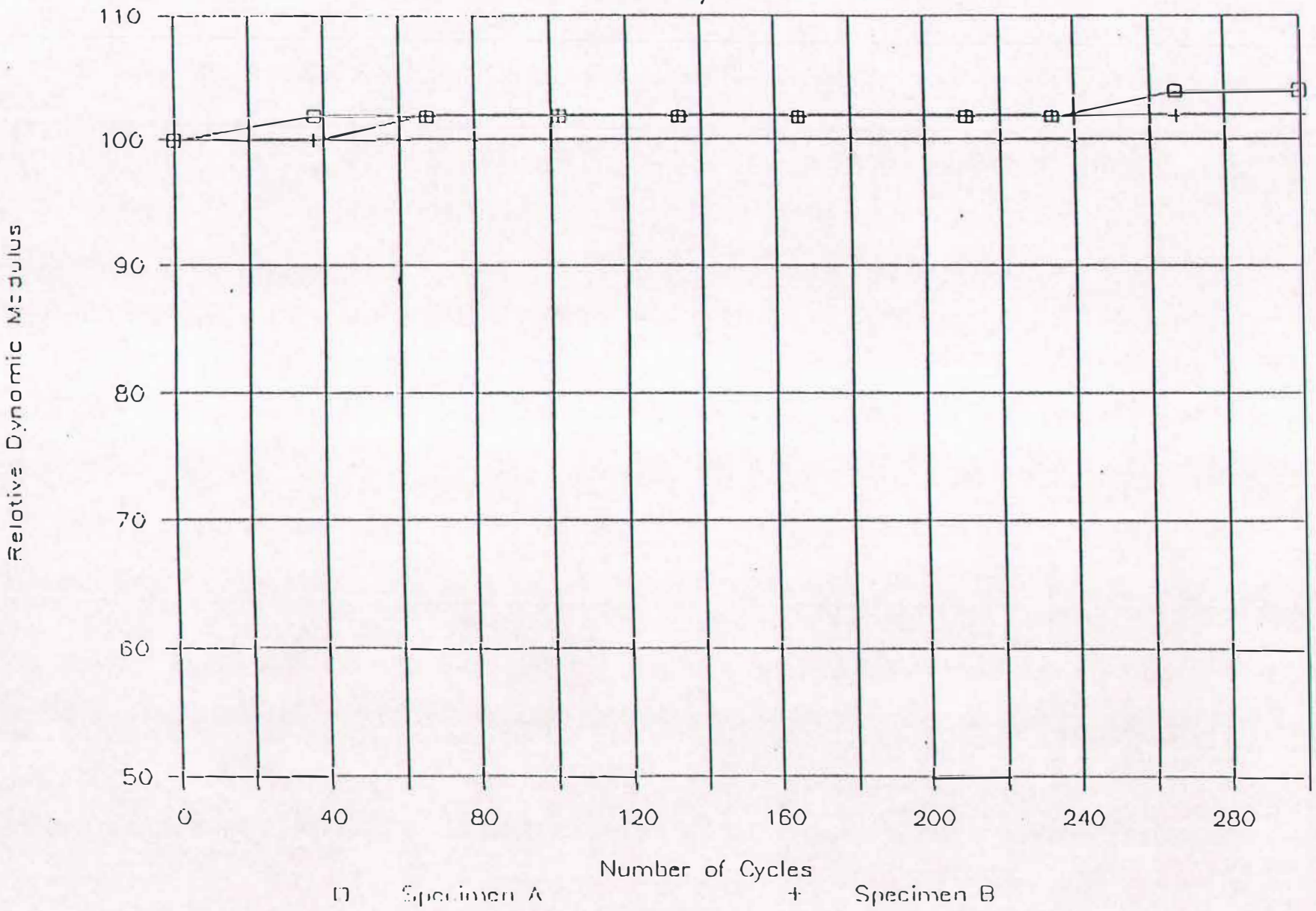
John R. Love, P.E.
Principal Materials Engineer

Attachment: Aggregate Test Report
Graph

\tlv\57203269

ASTM C666 Relative Dynamic Modulus

STALITE 3/4 INCH



April 16, 1992

LAW ENGINEERING

GEOTECHNICAL, ENVIRONMENTAL
& CONSTRUCTION MATERIALS
CONSULTANTS

Carolina Stalite Company
P.O. Box 1037
Salisbury, North Carolina 28145-1037

Attention: Mr. Roberto Nunez

Subject: Report of ASTM C 227, 9 Month Test Data
Alkali Reactivity Testing Results
Law Engineering Job No. 5620168601

Gentlemen:

Law Engineering has completed 9 month laboratory testing of concrete and mortar mixtures containing Carolina Stalite aggregates. The purpose of this work was to test the submitted aggregates for potential alkali reactivity. This work was authorized by Mr. Roberto Nunez of Carolina Stalite. Mr. Nunez provided us with the binder proportions for the mixtures tested. Aggregate and water proportions for the mixtures tested were determined in accordance with ASTM C 227. This report presents the materials, mixtures, test procedures, and test results to date.

MATERIALS

Cement

The cement was manufactured and supplied by Tarmac, Roanoke, Virginia. The cement was tested for compliance with the chemical requirements of ASTM C 150. The total alkali content of the cement, reported as Na_2O, was determined to be 0.57 percent. A copy of the chemical testing report for the cement is attached.

Fly Ash

A Type F fly ash produced by Georgia Power at Plant Wansley was used.

Aggregates

Aggregates were manufactured and supplied by Carolina Stalite.

1386 MAYSON STREET
ATLANTA, GEORGIA 30324
404-873-4761
TELEFAX 404-872-5927

MORTAR

Mixtures

Mortar bars were batched and molded in accordance with ASTM C 227, "Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)". The mortar mixtures were proportioned to provide a volume of Stalite lightweight aggregate comparable to mortar mixtures using normal weight aggregates.

As directed by Mr. Nunez, the aggregate used in the mortar mixtures was 3/4 inch Stalite material which was crushed and recombined in our laboratory to meet the grading requirements of ASTM C 227.

As directed by Mr. Nunez, three types of binder were used in the mortar portion of this evaluation:

Mix 1: 100% Portland Cement.

Mix 2: 90% Portland Cement and 10% Fly Ash.

Mix 3: 85% Portland Cement and 15% Fly Ash.

Test Procedures

Mortar specimens were cured and tested in accordance with ASTM C 227-87.

Test Results

The results of the mortar testing to date are presented on the attached tables of data and graph. The graph presents the average for 4 specimans per mix.

CONCRETE

Mixtures

The concrete mixtures were proportioned to have binder, aggregate and water contents similar to the mortar mixtures. The aggregate used in the concrete were Stalite 3/4 inch coarse and Stalite fine aggregate. As directed by Mr. Nunez, two concrete mixtures were evaluated:

Mix 4: 100% Portland Cement Binder.

Mix 5: 85% Portland Cement and 15% Fly Ash.

Test Procedures

Concrete specimens were tested and cured in accordance with the procedures presented in ASTM C 227-87. Because of the large coarse aggregate particles, the concrete specimens are 4" x 4" x 11" prisms.

Test Results

The results of our testing of the concrete mixtures to date are presented on the attached table and graph. The graph presents averages for 3 specimens per mix.

Law Engineering appreciates the opportunity of providing this service. If there are any questions about this report please call.

Sincerely,

LAW ENGINEERING, INC.

Terry L. Viness, E.I.T.
Materials Engineer

William P. O'Hora
Engineering Technician

Attachments: Tables of Data (3 pages)
Length Change Graphs (2)

tlv/1686.rpt

TEST DATA SUMMARY
STALITE ALKALI REACTIVITY TESTING
LAB NO. A91083
JOB NO. 5620168601

April 16, 1992
READINGS BY WPO
CHECKED BY TLV

MORTAR – MIX 1: 100% PORTLAND CEMENT BINDER

AGE DAYS	LENGTH CHANGE, INCHES				
	SPECIMEN 1a	SPECIMEN 1b	SPECIMEN 1c	SPECIMEN 1d	SPECIMEN 1 AVG
0	0.0000	0.0000	0.0000	0.0000	0.0000
7	–0.0034	–0.0031	–0.0035	–0.0059	–0.0040
21	0.0003	0.0007	0.0009	0.0009	0.0007
28	0.0006	–0.0001	0.0012	0.0012	0.0007
56	0.0005	–0.0002	0.0008	0.0011	0.0006
91	0.0004	–0.0004	0.0006	0.0011	0.0004
119	–0.0003	–0.0004	0.0004	–0.0001	–0.0001
154	–0.0004	–0.0005	0.0002	–0.0002	–0.0002
182	–0.0005	–0.0006	0.0001	–0.0002	–0.0003
270	–0.0006	–0.0008	0.0001	–0.0004	–0.0004

MORTAR – MIX 2: 90% PORTLAND CEMENT + 10% FLYASH BINDER

AGE DAYS	LENGTH CHANGE, INCHES				
	SPECIMEN 2a	SPECIMEN 2b	SPECIMEN 2c	SPECIMEN 2d	SPECIMEN 2 AVG
0	0.0000	0.0000	0.0000	0.0000	0.0000
7	–0.0036	–0.0007	–0.0016	–0.0021	–0.0020
21	0.0001	0.0008	0.0006	0.0001	0.0004
28	0.0006	0.0009	0.0009	0.0008	0.0008
56	0.0002	0.0007	0.0007	0.0006	0.0006
91	–0.0002	0.0005	0.0002	0.0002	0.0002
119	–0.0013	–0.0003	–0.0002	–0.0008	–0.0007
154	–0.0012	–0.0005	–0.0001	–0.0004	–0.0006
182	–0.0013	–0.0006	–0.0002	–0.0005	–0.0006
270	–0.0013	–0.0007	–0.0001	–0.0006	–0.0007

TEST DATA SUMMARY
STALITE ALKALI REACTIVITY TESTING
LAB NO. A91083
JOB NO. 5620168601

April 16, 1992
READINGS BY WPO
CHECKED BY TLV

MORTAR – MIX 3: 85% PORTLAND CEMENT + 15% FLY ASH BINDER

AGE DAYS	LENGTH CHANGE, INCHES				
	SPECIMEN 3a	SPECIMEN 3b	SPECIMEN 3c	SPECIMEN 3d	SPECIMEN 3 AVG
0	0.0000	0.0000	0.0000	0.0000	0.0000
7	–0.0026	–0.0042	–0.0032	–0.0038	–0.0035
21	–0.0007	–0.0008	–0.0014	–0.0022	–0.0013
28	0.0002	–0.0005	–0.0005	–0.0009	–0.0004
56	0.0000	–0.0007	–0.0006	–0.0009	–0.0006
91	–0.0002	–0.0009	–0.0008	–0.0008	–0.0007
119	–0.0005	–0.0011	–0.0009	–0.0012	–0.0009
154	–0.0002	–0.0011	–0.0004	–0.0009	–0.0007
182	–0.0003	–0.0012	–0.0006	–0.0010	–0.0008
270	–0.0005	–0.0012	–0.0007	–0.0012	–0.0009

TEST DATA SUMMARY
STALITE ALKALI REACTIVITY TESTING
LAB NO. A91083
JOB NO. 5620168601

April 16, 1992
READINGS BY WPO
CHECKED BY.TLV

CONCRETE – MIX 4: 100% PORTLAND CEMENT BINDER

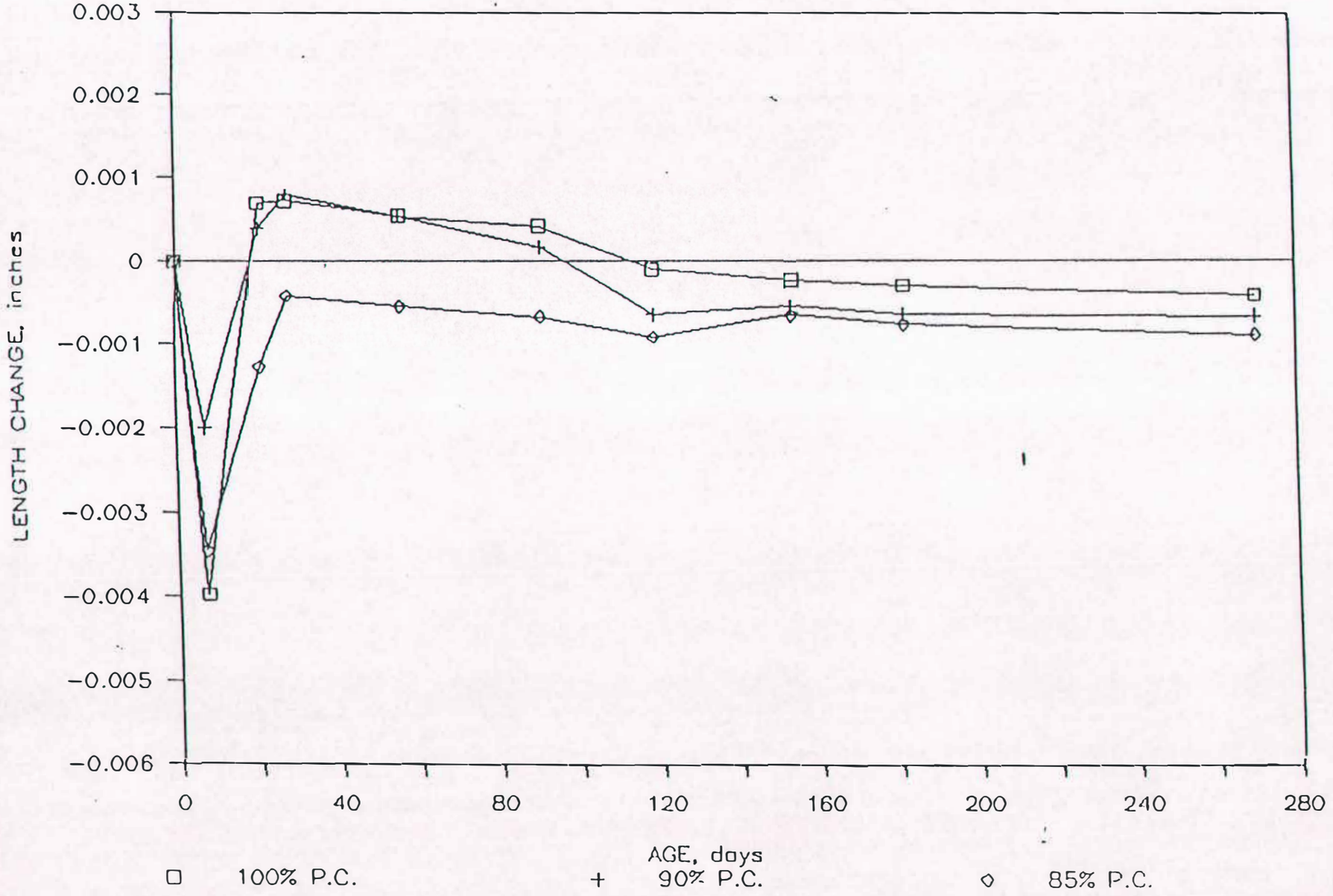
AGE DAYS	LENGTH CHANGE, INCHES				
	SPECIMEN 4a	SPECIMEN 4b	SPECIMEN 4c		SPECIMEN 4 AVG
0	0.0000	0.0000	0.0000		0.0000
7	0.0015	0.0014	0.0011		0.0013
14	0.0014	0.0015	0.0010		0.0013
21	0.0016	0.0016	0.0015		0.0016
28	0.0012	0.0011	0.0008		0.0010
42	0.0010	0.0009	0.0008		0.0009
56	–0.0005	–0.0003	–0.0007		–0.0005
91	–0.0008	–0.0004	–0.0008		–0.0007
119	–0.0013	–0.0007	–0.0009		–0.0010
154	–0.0011	–0.0008	–0.0010		–0.0010
182	–0.0013	–0.0009	–0.0010		–0.0011
270	–0.0014	–0.0011	–0.0012		–0.0012

CONCRETE – MIX 5: 85% PORTLAND CEMENT + 15% FLY ASH BINDER

AGE DAYS	LENGTH CHANGE, INCHES				
	SPECIMEN 5a	SPECIMEN 5b	SPECIMEN 5c		SPECIMEN 5 AVG
0	0.0000	0.0000	0.0000		0.0000
7	0.0004	0.0002	0.0002		0.0003
14	0.0004	0.0003	0.0003		0.0003
21	0.0001	–0.0001	–0.0001		–0.0000
28	0.0003	0.0000	0.0001		0.0001
42	0.0004	0.0002	0.0003		0.0003
56	–0.0011	–0.0012	–0.0012		–0.0012
91	–0.0009	–0.0011	–0.0012		–0.0011
119	–0.0005	–0.0007	–0.0005		–0.0006
154	–0.0006	–0.0008	–0.0006		–0.0007
182	–0.0007	–0.0007	–0.0007		–0.0007
270	–0.0006	–0.0006	–0.0009		–0.0007

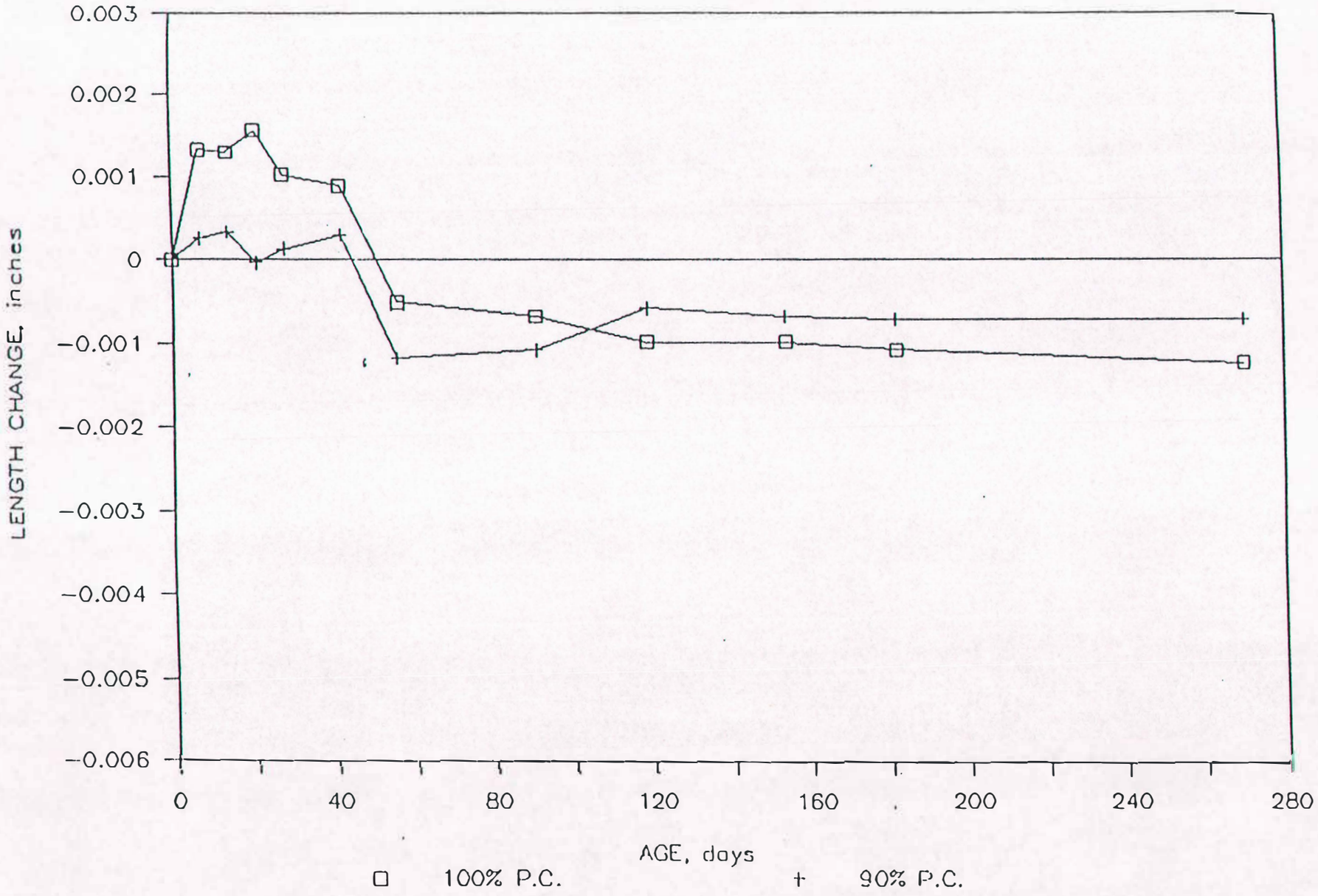
ASTM C227 RESULTS

Carolina Stalite Mortar Mixes



ASTM C227 RESULTS

Carolina Stalite Concrete Mixes



LAW & COMPANY
CONSULTING AND ANALYTICAL CHEMISTS
1761 MONTREAL CIRCLE
TUCKER GEORGIA 30084
(404) 934-8200

Chemical Report

4/11/91

Number 881131 Received: 4/8

33320
Mr. Terry Viness
Law Engineering
396 Plasters Avenue, NE
Atlanta, GA 30324

Description: Cement, Tarmac, Roanoke, VA. Stalite, PO #562.TLV

This cement sample complies with ASTM C-150.

Silica (SiO_2)	21.20 %
Aluminum Oxide (Al_2O_3)	4.90 %
Iron Oxide (Fe_2O_3)	3.13 %
Calcium Oxide (CaO)	62.50 %
Magnesium Oxide (MgO)	3.06 %
Sulphur Trioxide (SO_3)	2.37 %
Loss on ignition	1.63 %
Insoluble Residue	0.37 %
Sodium Oxide (Na_2O)	0.30 %
Potassium Oxide (K_2O)	0.41 %
Total Alkalis (as Na_2O)	0.57 %

*****

Respectfully submitted,
LAW & COMPANY

BY

5 14500eh

Chloride Permeability of Lightweight Concrete

Research Conducted for
Mr. Robert Nunez
Carolina Stalite Co.
Salisbury, NC

Chloride Permeability of Lightweight Concrete
Carolina Stalite Company
Final Report: April 20, 1992

This investigation was conducted to determine the chloride permeabilities of selected concretes made with lightweight aggregate conforming to ASTM C 330, produced by the Carolina Stalite Company, compared to an otherwise similar, conventional weight concrete. As part of this investigation, compressive strength and shrinkage values, plus standard plastic concrete characteristics (unit weight, volumetric air content, and slump) were also determined.

Four (4) separate concrete mixes were produced in late November, 1991. The mix composition was selected in concurrence with the advice of Stalite representatives. These mixes were intended to be representative of actual mixes considered for use in the practice. Four types of mixes were tested.

1. A commodity type concrete, conforming to the requirements of North Carolina Department of Transportation, State Class AA, produced with a Class F fly ash. In the data synopsis, this mix is referred to as "DOT AA". This mix served as the control, or comparison mix.

2. A lightweight concrete, similar to DOT AA in composition (including fly ash) except for the coarse aggregate. This mix was designated "LW Ash".

3. A lightweight concrete, similar to LW Ash in composition except that only portland cement was used (no ash). This mix was designated "LW Cmt".

4. A lightweight concrete, using silica fume as the mineral admixture, designated "LW Fume".

Water was added to achieve similar slumps in all mixes. The measured slump of lightweight concrete will generally be less than that of a conventional weight concrete for the same workability, due to the extra weight of the coarse aggregate itself. The water content for a given workability will therefore be slightly higher for lightweight mixes than conventional weight mixes, all else being equal. This investigation was based on equal slump mixes, since that is a more common comparison in practice.

Permeability was determined in accordance with AASHTO T 277, "Rapid Determination of the Chloride Permeability of Concrete" (RCPT). This test method was developed to determine chloride permeability of samples removed from existing concrete members. The test values are given as coulombs (C) passed in six hours. While the values have been correlated with 90 day ponding tests, they provide only a relative measure of permeability (eg, C > 4000

indicates a high chloride ion permeability).

Since the test method and the correlations were developed from testing two inch disks sawed from the top of drilled cores, it was felt necessary to use cores rather than molded cylinder specimens in this investigation. Therefore, 6" x 6" beam molds were cast, 3.75 inch diameter cores were drilled, and the top two inches sawed off to produce test specimens.

T 277 does not specify any particular curing conditions as it was primarily intended for testing members in structures. The choice of appropriate curing regimen was therefore chosen on the basis of standard design criteria for bridge decks or pavements. AASHTO rigid pavement designs are frequently based on 14 day strengths, and strength design methods for reinforced concrete are commonly based on concrete after 28 days of moist curing. Since structures undergo drying in service and drying is known to create drying shrinkage microcracking, it was felt that a more severe test for chloride permeability would include some drying time. It was originally believed that this might be particularly true with lightweight aggregate concrete which typically undergoes somewhat higher shrinkage than otherwise similar conventional weight mixes. Therefore, the beams were exposed to two weeks of air drying after moist curing, prior to drilling cores.

Rapid Chloride Permeability Tests (RCPT) were run on duplicate samples, each of which was the top two inches sawed from duplicate 3.75 inch diameter cores, drilled out after curing for

(1) 14 days moist and 14 days air dry, and
(2) 28 days moist and 14 days air dry.

Test cylinders were made for determining compressive strength under three different curing conditions. A standard compression test was conducted after 28 days of moist curing. In addition to this, compressive strength was determined at the same time and after the same curing conditions as the RCPT. Tests were conducted on duplicate 4" x 8" cylinders, using an unbonded capping system.

Three (3) 4" x 4" rectangular prisms were also cast for determination of air dry shrinkage. These tests were conducted in accordance with ASTM C 157 (Air Storage) except they were carried out for approximately four (4) months and results were extrapolated to one year. In all cases but one, the LW Fume mix, the rate of shrinkage had essentially dropped to zero by the end of the four months. However, the rate of shrinkage was very low at the end of four months for the LW Fume mix as well.

Mixing and fabrication of test specimens was conducted jointly by representatives of Stalite and the principal investigator. Sample preparation and testing was conducted by the principal investigator and a research assistant from North Carolina State University.

General Conclusions:

Data are tabulated in Appendix I. With one possible exception (the effect of drying on chloride ion permeability), no meaningful differences were found between two otherwise similar concretes using lightweight coarse aggregate or using conventional weight coarse aggregate.

The use of fly ash reduces chloride permeability somewhat, while the use of silica fume produces a dramatic reduction in chloride permeability. As expected, chloride permeability is reduced with continued moist curing. Chloride permeabilities, except for the mix containing silica fume, remained fairly high, even after curing for 28 days. These results are similar to that reported elsewhere in work not based on lightweight mixes.

The shrinkage of all mixes was low, with the minimum shrinkage obtained with the conventional weight aggregate mix.

The strengths of all mixes were good, based on cementitious material content and slump. The effect of drying on strength was very significant, however, and may have been contributed to the chloride permeability of mixes (see below).

The chloride permeability of the conventional weight aggregate mix (DOT AA, containing fly ash) is classified as "High". The chloride permeability of the LW Cmt mix is also classified as "High", although in both cases, the values are very close to minimum for that classification. The chloride permeability of the LW Ash mix is "Moderate"; the chloride permeability of the LW Fume mix is "Low".

The relative chloride permeabilities of the DOT AA and LW Ash mixes were much different than originally anticipated. These mixes had very similar ingredients and mix properties, with the DOT mix containing slightly less water. It was therefore expected that the RCPT values would be reasonably similar. However, coulombs passed through the conventional aggregate mix were found to be more than 15% higher than with the comparable lightweight aggregate mix.

The RCPT test has been reported to have a large variability (35%). It cannot therefore be conclusively stated that the differences in chloride permeability of the DOT AA, the LW Ash and the LW Cmt mixes are statistically significantly different. However, the variability in all mixes tested in this program was about 5%, except the conventional weight aggregate mix tested after 14 days moist curing and 14 days air drying, and it is the Principal Investigator's belief that the differences in chloride permeability found are real and are probably related to improved aggregate-matrix bond development with lightweight aggregate. More research in this area would be useful.

Appendix I, Data Summary
Chloride Permeability of Lightweight Concrete
Final Report: April 15, 1992

Quantities (nominal, pcy)		DOT AA	LW Ash	LW Cmt	LW Fume
Cement (Type I)		611	611	705	658
Fly Ash (Class F)		115	115	--	--
Silica Fume		--	--	--	43
Fine Aggregate		940	1200	1220	1230
ASTM (C 33, #57)		1900	--	--	--
Stalite (C 330, 3/4")		--	880	880	920
Water		260	280	270	240
WRA (oz/cwt)		4	4	4	6
w/(c+b)		.36	.39	.38	.34
Unit wt (plastic) (pcf)		141.2	113.4	112.8	116.2
Slump (in)		3 1/4	3 1/4	3	3 1/2
Air (%, volumetric)		6.4	7.5	9.3	6.8
days moist +	days air dry	Compressive Strength (psi)			
14	14	6250	5690	6740	7680
28	0	5510	5410	6150	7460
28	14	6590	6400	7360	8570
		Rapid Chloride Permeability (Coulombs)			
14	14	4750*	3860	4530	1700
28	14	4170	3560	4150	1530

* see text

Shrinkage data (extrapolated from 120+ days to 365 days):

microstrain	360	420	370	290

Raw material sources:

Portland Cement:	Blue Circle (Type I, low alkali)
Fly Ash:	AMC, Belews Creek (Class F)
Silica Fume:	Elkem
WRA:	Cormix, 400 N (lignin)
AEA:	W.R. Grace, (nvr)
stone:	Martin-Marietta, Garner, NC (crushed granite)
sand:	Lillington, NC

Appendix II, Discussion
Chloride Permeability of Lightweight Concrete
Final Report: April 20, 1992

Water to cementitious material ratio is given for all mixes, although, for lightweight mixes, its use is generally not recommended. For the low absorption lightweight produced by Stalite, the values are reasonably accurate. However, as with all lightweight mixes, they should be used with caution.

The air content of the LW Cmt mix was slightly higher than desired, but acceptable for this investigation. The higher air apparently offset the water demand for a 3 inch slump to a certain degree and therefore strengths were not as dramatically affected as expected.

Due to the low alkali content of the cement and the relatively coarse nature of the fly ash, the combination of cementitious materials used in these mixes is not optimum in terms of strength gain. These materials were selected for several reasons, however. First, they provide a reasonable lower bound on strength gain and pozzolanic activity. Second, they, or materials very similar, are commonly used in conjunction in commercially produced concrete in the Carolinas market.

The strength of all mixes, based on the cementitious material and slump of the mixes was about as expected at 28 days, but the effect of drying on strength was much more pronounced than originally anticipated. This is true for all mixes.

A problem arose in the Rapid Chloride Permeability Test conducted on the DOT AA mix at the earlier age. The value reported is based on a retest of the DOT AA mix. Since this was necessarily conducted at a later date, the true value is not known. The value reported is an estimate based on the ancillary testing required.

The test values obtained for the DOT AA mix at the early age (14 days moist and 14 days dry) were extremely variable. Although variation reported elsewhere (ASTM C 1202) is high, the variation found in all the other mixes tested in this series was minimal. Reproducibility has not been a problem in general for other RCPT in this facility and the reasons for the high variability found in the DOT AA mix is unknown. Although specimen preparation is suspect for one of the DOT AA samples, the overall high variability may be related to higher sensitivity to drying than originally anticipated. This is examined further below.

Shrinkage is primarily a paste phenomenon but restraint provided by the aggregate also plays an important role. The shrinkage of the DOT AA mix is lower than that of the LW Ash mix. Here, the stiffer stone is playing a role in the reduction of shrinkage, as expected. While the difference seen is typical for mixes with lightweight versus conventional coarse aggregate, it should also be noted that the data

for shrinkage and strength are consistent. The shrinkage value for the LW Ash mix is higher than for the LW Cmt mix. The volume of paste and the volume of water were both higher in the ash mix and the strengths were lower. The very low shrinkage of the LW Fume mix is somewhat surprising, even given the higher strengths of this mix. It is significant, however, that the values of estimated shrinkage strain of the lightweight aggregate concretes at one year are all relatively low compared to values given in ACI 209.

Looking at the DOT AA and LW Ash mixes, the values for shrinkage, strength and RCPT are inconsistent with expectations. The strength values are virtually identical. With the strong correlations between capillary porosity, permeability and strength, one would expect the chloride permeability of the DOT AA mix to be lower than the LW Ash mix. Since the shrinkage values are in line with both the water contents and the aggregate contributions, and strength values are consistent with expectations, the stiffer aggregate may be increasing permeability in the transition zone as stresses due to restraint increase. The aggregate-matrix bond development is typically better with lightweight aggregate.

The one problem encountered with this inference is the reported variation in test results. ASTM C 1202 reports (section 13.1.1) "Therefore the results of two properly conducted tests by the same operator on concrete samples from the same batch and of the same diameter should not differ by more than 35%...". The variation of the mixes in this study were all very low compared to this standard, except of course the one test of DOT AA mentioned above. The fact that this was not a problem with the lightweight mixes would seem to be further evidence that the conventional weight aggregate mixes tend to be more sensitive to drying shrinkage in terms of permeability. Clearly this area requires more research for a definitive answer.

Although we cannot conclusively state that the drying shrinkage is a more significant effect with conventional weight aggregate mixes than with lightweight aggregate mixes, it is the belief of the Principal Investigator, based in part on the test results and variation found in this work and in part on the nature of the transition zone in lightweight concrete that the differences found are real.

Nøkkelark til kopimaskinen Kodak 2110

Artikkelnr. 950520N

Skilleark – Kopiering på

B R U K S A N V I S N I N G

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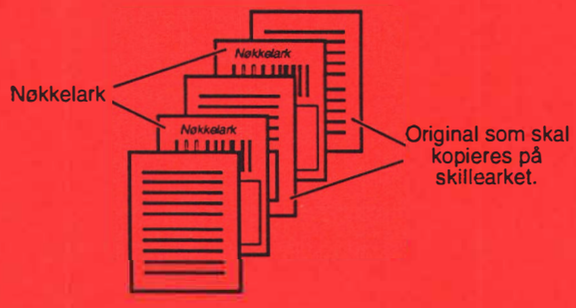
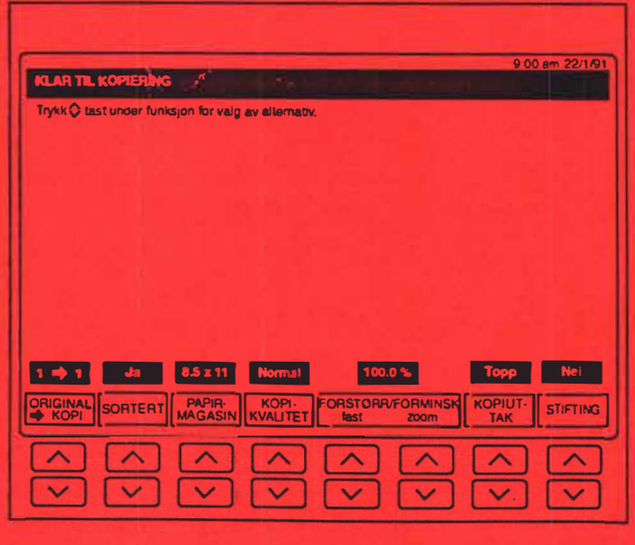


2. Legg originalene og nøkkelarkene i Feeder med forsiden opp, og velg standardfunksjoner.



3. Legg de blanke skillearkene i øvre papirmagasin.

4. Trykk på stjerne (*) og deretter på startknappen for å aktivere nøkkelarket.

Merk: Nøkkelarkene vil bli lagt i utmatingslommen. Du kan også bruke kopier av nøkkelark.

Mekaniske egenskaper hos normal- og høgfasthet lettbetong.

a) Trykkfasthet
b) Bøye-strekkfasthet
c) E-modul
d) kryp
e) svinn.

DEL 5

STALITE

LIGHTWEIGHT STRUCTURAL CONCRETE

ENGINEERING PROPERTIES FOR:

* NORMAL STRENGTH CONCRETE
* HIGH STRENGTH CONCRETE

Creep and Shrinkage of Lightweight Concrete

by Michael L. Leming

Department of Civil Engineering
North Carolina State University at Raleigh

Creep and Shrinkage of Lightweight Concrete

The following report is the result of a study sponsored by Carolina Stalite Company and conducted at North Carolina State University by Michael L. Leming.

Purpose: To investigate the creep and shrinkage potential of concrete made with STALITE lightweight aggregate (ASTM C 330). Conventional strength and elastic modulus, as well as standard plastic concrete characteristics were also determined.

Concrete Mixes: Four (4) different mixes of concrete were produced and examined.

- **S-1.** A standard lightweight concrete of a type commonly used in commercial construction
- **S-2.** A commodity grade concrete similar to **S-1** except with conventional coarse aggregate (not lightweight)
- **S-3.** A mix with the same mortar fraction, paste proportions and coarse aggregate volume as **S-2**, but made with STALITE lightweight aggregate instead of conventional aggregate.
- **S-4.** A high strength lightweight concrete

Test Program: For each mix, a series of tests were conducted at the plastic and hardened stages of the concrete. First, unit weight, volumetric air content, and slump were determined. Then a series of 6" x 12" cylinders were cast to test the physical properties of the corresponding hardened concretes.

Duplicate cylinders were fabricated for determination of elastic modulus (E) and splitting tension strength ($f$ct) at 7 days and 28 days. Compressive strength (f'c) was determined by averaging the test results from two (2) specimens at 7 days. Results from three (3) specimens were used in determining compressive strength at 28 and 365 days.

Five (5) cylinders were cast with embedded brass gage points for determination of creep. Three (3) of these cylinders were loaded, and the remaining two (2) were kept as "control specimens." Additionally, three (3) rectangular prizms 4" x 4" were cast for determination of air dry shrinkage.

Conclusions: *Splitting tension strength* for all specimens at 7 and 28 days was determined to be within ACI 318 guidelines based on compressive strength. **S-1** and **S-3** showed higher splitting tension strength than is anticipated for most lightweight concretes. Splitting tension strength at one year was shown to increase very little.

The *tensile strength* of concrete is a small percentage of compressive strength in all high strength concretes. The values for **S-4**, the high strength mix using STALITE lightweight aggregate correspond very favorably to those reported by others who have investigated high strength lightweight concretes.

Values of *elastic modulus* for **S-1** and **S-3** were significantly higher than predicted by ACI equations based on compressive strength and unit weight. This is in all probability due to the fact that, compared to many other commercially available lightweight aggregates, the tested lightweight aggregate, STALITE (rotary kiln expanded slate), provides a superior stiffness. At the high strength level, again **S-4** data compare favorably to the results obtained from other tests of high strength lightweight concretes.

The *unit weights* (air dry) of **S-1** and **S-3** are well within the acceptable range for lightweight concrete for most commercial construction. The unit weight (air dry) of the high strength **S-4** is less than the maximum allowed even for conventional lightweight concrete.

The *values of creep* for the lightweight concretes are very low in comparison to national averages for all concretes.

There is no statistically significant difference in *shrinkage* between S-1 and S-3, nor between S-2 and S-4. The difference of approximately 20 percent in shrinkage values shown for S-2 and S-3 may be typical.

It is significant that the values of estimated shrinkage strain of the lightweight aggregate concretes at one year are all relatively low compared to national averages given in ACI 209. This is most likely related to the superior stiffness of the STALITE expanded slate aggregate.

Creep & Shrinkage
Laboratory Test Results

	S-1	S-2	S-3	S-4
Quantities (pcy)	Lightweight	Normal Wt.	Lightweight	Lightweight
Cement (type I)	546	560	550	536
GBFS (Grade 120)	---	---	---	342
Water	277	277	274	323
Normal Weight Aggregate				
ASTM C 33 (#67)	---	1710	---	---
STALITE Lightweight Aggregate				
ASTM C 330	900	---	950	940
Unit Weight (plastic)(pcf)	112.3	140.4	111.6	121.6
Unit Weight (dry)(pcf)	108.5	139.8	109.2	116.4
Slump (in)	4.5	4.25	4.25	6.75
Air (%)	7.8	7.0	7.1	1.5
Compressive Strength *f'c* (psi)				
7 Days	2960	3390	2900	5340
28 Days	3860	4420	3970	7180
365 Days	4540	5220	4670	8290
Splitting Tension Strength *fct* (psi)				
7 Days	345	375	365	370
28 Days	400	405	425	495
365 Days	410	405	425	520
Elastic Modulus E (million psi)				
7 Days	2.71	3.22	2.77	3.38
28 Days	2.93	3.61	2.94	3.58
365 Days	2.97	3.85	2.99	3.84
Creep Data (at 365 days)				
Load (kips)	35	40	35	50
% 28 day *f'c*	32	32	31	25
Specific Creep	0.84	0.43	0.89	0.29
Creep Coefficient	2.6	1.7	2.7	1.2
Shrinkage Data (at 365 days)				
Microstrain	380	360	390	310

Discussion of Results: When all factors other than aggregate weight are equal, the measured slump of lightweight concrete generally will be less than that of conventional concrete at the same workability. This factor was not incorporated into the S-3 mix. S-2 and S-3 had the same measured slump. This, in turn, has the effect of making the results somewhat easier to compare for the practicing engineer, although not quite as exact theoretically.

Compressive strength values were somewhat lower than anticipated. Air contents, however, were somewhat higher.

Unit weights (air day) of the standard lightweight concretes (S-1 and S-3) were below 110 pcf. The unit weight of S-4 was at the lower end of the 115 to 120 pcf range of unit weights typical of high strength lightweight concretes.

The creep coefficient shown is based on initial tangent modulus, NOT measured elastic modulus.

Specific creep of the moderate strength, lightweight concretes (S-1 and S-3) is significantly higher than that of the moderate strength, conventional normal weight concrete (S-2). These are very typical results. Note, however, that the values for the lightweight concretes are very low compared to national averages for all concretes. This result and the high relative values of elastic modulus are related to the stiffness of the STALITE lightweight aggregate.

For S-2 and S-3, which differed only in aggregate type, there appears to be only a small statistically significant difference in shrinkage. However, this analysis is based on data with large variability. Shrinkage is primarily a paste phenomenon, but restraint provided by the aggregate plays an important role. While the difference seen is typical for mixes with lightweight versus conventional coarse aggregate, it is interesting to note that the data for shrinkage, creep and elastic modulus are all consistent with an aggregate of superior stiffness.

STALITE

CAROLINA STALITE COMPANY

MANUFACTURERS OF LIGHTWEIGHT AGGREGATE "STALITE"

PO Box 1037

Salisbury, NC 28145-1037

FAX 704-638-0742

704-637-1515

June 18, 1991

LAW ENGINEERING

GEOTECHNICAL, ENVIRONMENTAL & CONSTRUCTION MATERIALS CONSULTANTS

Carolina Stalite Company
P.O. Box 1037
Salisbury, North Carolina 28145-1037

Attention: Mr. Roberto Nunez

Subject: Report of Laboratory Concrete Tests
Stalite High-Performance Concrete
Law Engineering Job No. 5620124901

Gentlemen:

Law Engineering has completed laboratory testing of Stalite High-Performance concrete mixtures, with the exception of compressive creep testing which continues until January 1992. The purpose of this work was to determine certain engineering properties of semi-lightweight concrete mixtures cured in laboratory and elevated-temperature conditions. The elevated-temperature conditions were intended to simulate prestressed concrete production conditions. This work was authorized by Mr. Roberto Nunez of Carolina Stalite Company by acceptance of Law Proposal No. 560.90025 (Revised).

This report presents the information about the materials, mixtures, and laboratory procedures used as well as the results of our testing. An executive summary is included for your convenience.

Law Engineering appreciates the opportunity of providing this service. If there are any questions about this report, or if we may be of further service, please call.

Sincerely,

LAW ENGINEERING, INC.

Terry L. Viness, E.I.T.
Materials Engineer

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Attachments

396 PLASTERS AVENUE, N.E.
ATLANTA, GEORGIA 30324

EXECUTIVE SUMMARY

The purpose of this work was to evaluate selected engineering properties of high strength semi-lightweight concrete mixtures cured in conditions to simulate post-tensioned and prestressed applications.

The testing program compared two concrete mixtures: one containing a Type I portland cement binder and one with a portland cement and silica fume binder. Both mixtures contained Carolina Stalite 3/4 inch coarse aggregate and a natural quartzitic sand from Waugh, Alabama. The gradations, specific gravities, and absorptions of the aggregates used are presented on the attached Aggregate Testing Report. Admixtures used were W.R. Grace products meeting ASTM C 494 requirements. The silica fume used was W.R. Grace "Force 10,000" slurry. Initial mixture proportions were suggested by Mr. Roberto Nunez of Carolina Stalite. Specific information about the mixtures used is presented in the following report.

Two batches of each mixture were tested in our laboratory. One batch was cured in standard laboratory conditions; the second batch was cured in a steam box for approximately 14 hours (beginning immediately after initial set) in general accordance with PCI MNL 117 procedures for accelerated curing of prestressed concrete members. Concrete temperatures were monitored and recorded during steam curing and are presented in the following report.

All compressive strength specimens were cured in our moist curing room after being stripped from the molds. The split tensile specimens were air dried until testing age after a period of six days in the moist cure environment. Flexural strength specimens were cured in a lime-water tank until tested. Linear drying shrinkage specimens were cured in a lime-water tank for six days, then air-dried in laboratory conditions.

Laboratory testing was performed in accordance with applicable ASTM procedures except where noted in the report. The testing procedures used are presented in the following report.

A summary of the laboratory testing results is presented on the following pages.

SUMMARY OF HARDENED CONCRETE TEST RESULTS
Carolina Stalite
June 18, 1991
Law Engineering Job No. 5620124901

Mix Identification Binder Type	1A PC	1B PC	2A PC+SF	2B PC+SF
Curing Method	STEAM	LAB	STEAM	LAB
Compressive Strength, psi				
1 day	4980	----	5500	----
3 day	5980	4780	5860	5770
7 day	6550	6500	6450	6460
28 day	6840	6710	6660	7040
91 day	7340	6680	6860	7720
Flexural Strength, psi				
3 day	615	595	610	615
7 day	635	650	630	625
28 day	685	760	675	730
91 day	760	730	700	700
Splitting Tensile Strength, psi				
3 day	520	450	530	525
7 day	520	475	510	500
28 day	550	575	500	495
91 day	565	570	555	---
Shrinkage, microstrain				
28 day	90	100	50	110
91 day	390	320	340	160
Modulus of Elasticity, million psi				
1 day	3.05	----	3.16	----
3 day	3.13	3.03	3.17	3.19
7 day	3.43	3.19	3.21	3.48
28 day	3.79	3.56	3.42	3.70

SUMMARY OF HARDENED CONCRETE TEST RESULTS
(continued)
Carolina Stalite
June 18, 1991
Law Engineering Job No. 5620124901

Mix Identification	**1A**	**1B**	**2A**	**2B**
Binder Type	PC	PC	PC+SF	PC+SF
Curing Method	**STEAM**	**LAB**	**STEAM**	**LAB**
Compressive Creep				
Applied Load, psi	2050	2050	2050	2050
Percentage of f'c	41	32	37	36
Initial Elastic Strain, microstrain	84	58	51	80
Specific Creep				
7 day	0.037	0.022	0.024	0.089
28 day	0.053	0.064	0.040	0.103
91 day	0.057	0.078	0.065	0.120
Creep Coefficient				
7 day	0.91	1.78	0.97	2.29
28 day	1.28	2.26	1.58	2.63
91 day	1.39	2.74	2.59	3.07

Notes:

1) PC denotes portland cement binder, PC+SF denotes portland cement and silica fume binder.

2) Equipment malfunction resulted in Mix 1B being loaded for creep at an age of 8 days.

3) Curing of specimens for specific tests is discussed in detail in the report.

4) Strength testing results are an average of at least two specimens per age, except no cylinders were available for split tensile testing at 91 days for Mix 2B.

MATERIALS

CEMENT

The cement used was an ASTM C 150 Type I portland cement manufactured by Medusa in Clinchfield, Georgia. The sample was obtained in bulk by Law Engineering at Medusa's Atlanta, Georgia distribution facility.

SILICA FUME

The silica fume used was "Force 10,000", a slurry manufactured by W.R. Grace & Company. The sample was obtained by Law Engineering from Williams Brothers, Inc., a local ready-mix concrete supplier.

AGGREGATES

The coarse aggregate, a 3/4 inch maximum sized expanded slate, was supplied by Carolina Stalite Company of Salisbury, North Carolina.

The fine aggregate was a natural quartzitic sand from Waugh, Alabama obtained by Law Engineering from Williams Brothers, Inc.

The gradations, specific gravities, and absorptions of the aggregates used are presented on the attached Aggregate Test Report.

ADMIXTURES

Admixtures used were manufactured by W.R. Grace & Company. The specific products used were WRDA-19, an ASTM C 494 Type F superplasticizer, and DAREX AEA, an ASTM C 260 air entrainer.

WATER

Batch water was from the City of Atlanta municipal supply.

CONCRETE MIXTURES

Two concrete mixtures were developed for this testing program. Mr. Roberto Nunez of Carolina Stalite suggested the initial mixture proportions which were modified by Mr. Nunez and Law Engineering based on laboratory trial batches. The one cubic yard design batch weights and plastic data for each laboratory test batch are presented below.

DESIGN PROPORTIONS

Material	Mixes 1A & 1B	Mixes 2A & 2B
Cement, lbs.	800	720
Silica Fume Slurry, lbs.	0	80
Coarse Aggregate, lbs. SSD	950	950
Fine Aggregate, lbs. SSD	1110	1126
Batch Water, lbs.	267	215
(Total Water)	(267)	(255)
Admixtures: oz./yd^3		
WRDA-19	96	104
Darex	4.8	1.0

TARGET PROPERTIES

	Mix Identification	
	1A & 1B	2A & 2B
Slump, inches	5±1	5±1
Air Content, percent	4.0	2.0
Unit Weight, pcf	116.1	114.8

PLASTIC TEST DATA

	Mix Identification			
	1A	1B	2A	2B
Slump, in.	4 3/4	6	4 3/4	3 1/4
Air Content, %	3.0	3.2	2.1	1.9
Unit Weight	116.6	116.0	116.0	114.9
Air Temperature, °F	71	71	72	72
Mix Temperature, °F	70	72	72	74
Actual Water, pcy	259.7	262.7	256.5	253.9
Actual Binder Content, pcy	805.5	800.6	809.0	801.0
Water-Binder Ratio	0.322	0.328	0.317	0.317
Yield, cubic feet	26.9	27.0	26.7	27.0

CURING PROCEDURES

Each of the two concrete mixtures were batched twice in accordance with ASTM C 192, "Standard Practice for Making and Curing Concrete Specimens in the Laboratory". One lab batch of each mixture was cured in accordance with ASTM C 192. The other lab batch was cured in a steam box. The steam curing was not begun until initial set of the concrete had occurred, as determined in accordance with ASTM C 403, "Test Method for Time of Setting of Concrete Mixtures by Penetration Resistance". Steam curing continued for approximately 14 hours, at which time preparation for 24 hour concrete testing was begun.

Concrete temperature was monitored continuously during the steam curing procedure by a thermocouple embedded in a 4"x 8" cylinder. The cylinder was for temperature monitoring purposes only and was located near the steam inlet to monitor the potential highest concrete temperature.

The steam curing box had been previously tested to verify that the rate of concrete temperature rise was within the requirements of PCI MNL 117, Quality Control Manual for prestressed concrete.

A graph of the thermocouple readings is attached. The curing box temperatures presented on the graph are an average of 5 thermocouple readings located at different heights and distances from the steam inlet.

All compressive strength specimens were cured in our moist curing room meeting ASTM C 511 after being stripped from the molds. The split tensile specimens were air dried until testing age after a period of six days in the moist cure environment. Flexural strength specimens were cured in a lime-water tank until tested. Linear drying shrinkage specimens were cured in a lime-water tank for six days, then air-dried in laboratory conditions.

TEST PROCEDURES

The natural sand was tested in accordance with applicable procedures presented in ASTM C 33, "Standard Specification for Concrete Aggregates", to document its gradation, absorption, and specific gravity.

The Carolina Stalite coarse aggregate had been previously tested in our laboratory for compliance with ASTM C 330, "Standard Specification for Lightweight Aggregates for Structural Concrete". The coarse aggregate specific gravity was determined using the pycnometer method presented in ACI 211, "Standard Practice for Selecting Proportions for Structural Lightweight Concrete".

Hardened concrete testing was performed in accordance with the following ASTM procedures:

ASTM C 39, "Test Method for Compressive Strength of Cylindrical Concrete Specimens",

ASTM C 78, "Test Method for Flexural Strength of Concrete (Using Simple Beam with Third Point Loading)",

ASTM C 157, "Test Method for Length Change of Hardened Hydraulic-Cement Mortar and Concrete",

ASTM C 469, "Test Method for Static Modulus of Elasticity and Poisson'S Ratio of Concrete in Compression",

ASTM C 496, " Test Method for Splitting Tensile Strength of Cylindrical Concrete Specimens",

ASTM C 512, "Test Method for Creep of Concrete in Compression",(with the exception that our measuring apparatus, a Wittemore Gage, was accurate to 0.0001 inches).

TEST RESULTS

The results of our aggregate testing are presented on the attached Aggregate Test Report.

The results of our concrete testing are presented in the Summary of Hardened Concrete Test Results.

Graphs of the creep strain with time are attached. Creep testing will continue until the concrete is one year old.

AGGREGATE TEST REPORT
Carolina Stalite
Stalite High Performance
June 18, 1991
Law Engineering Job No. 5620124901

Coarse Aggregate
Supplier: Carolina Stalite
Type: Expanded Slate
Nominal Size: 3/4 inch

Gradation:

Sieve Size	Percent Passing
1"	100
3/4"	95
1/2"	42
3/8"	19
No.4	5
No.8	1

Specific Gravity (SSD): 1.34
Absorption, percent: 6.1

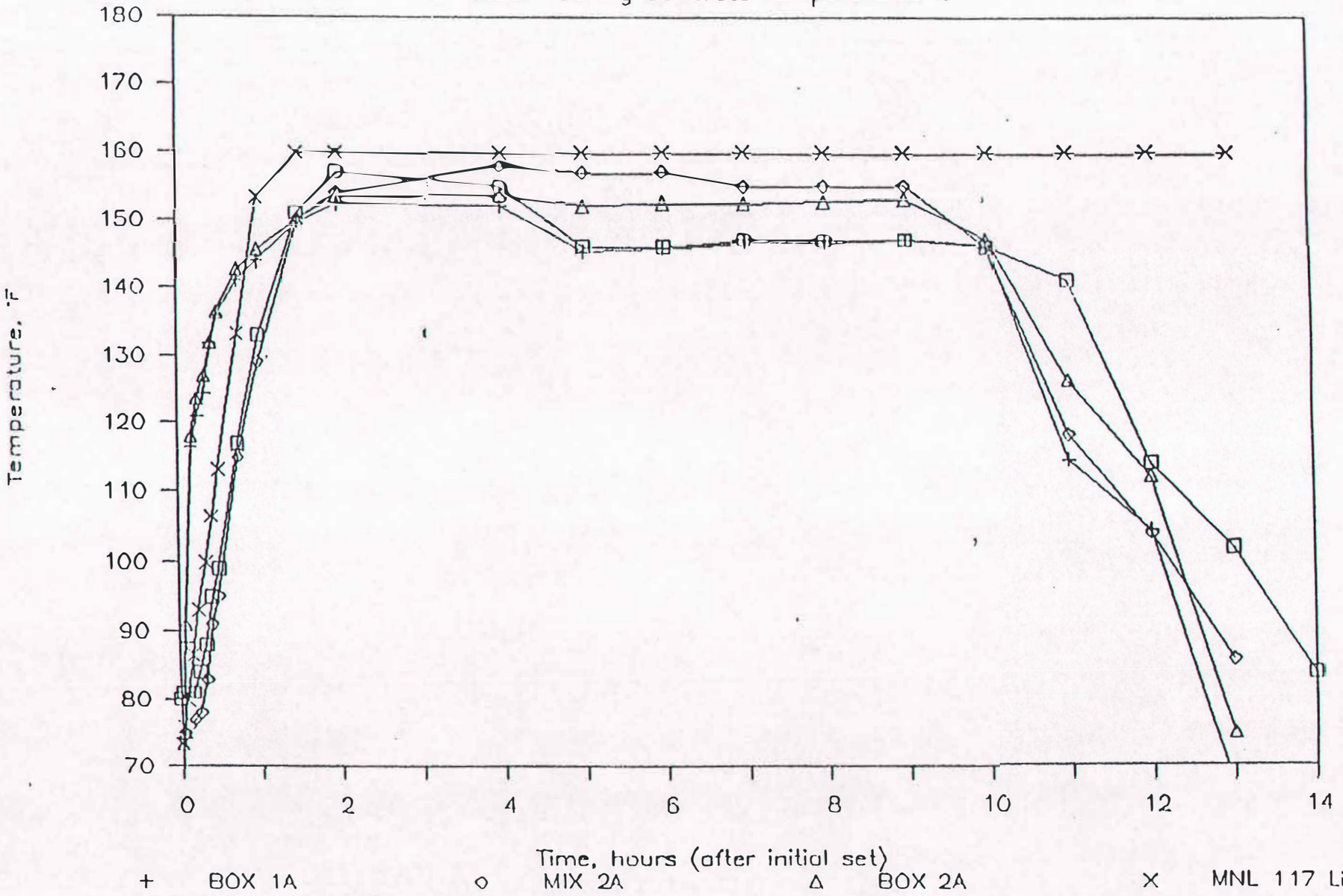
Fine Aggregate
Supplier: R & S, Waugh, Alabama
Type: Natural Quartzitic
Gradation:

Sieve Size	Percent Passing
3/8"	100
No. 4	99
No. 8	87
No. 16	72
No. 30	36
No. 50	6
No. 100	1
No. 200	0.5

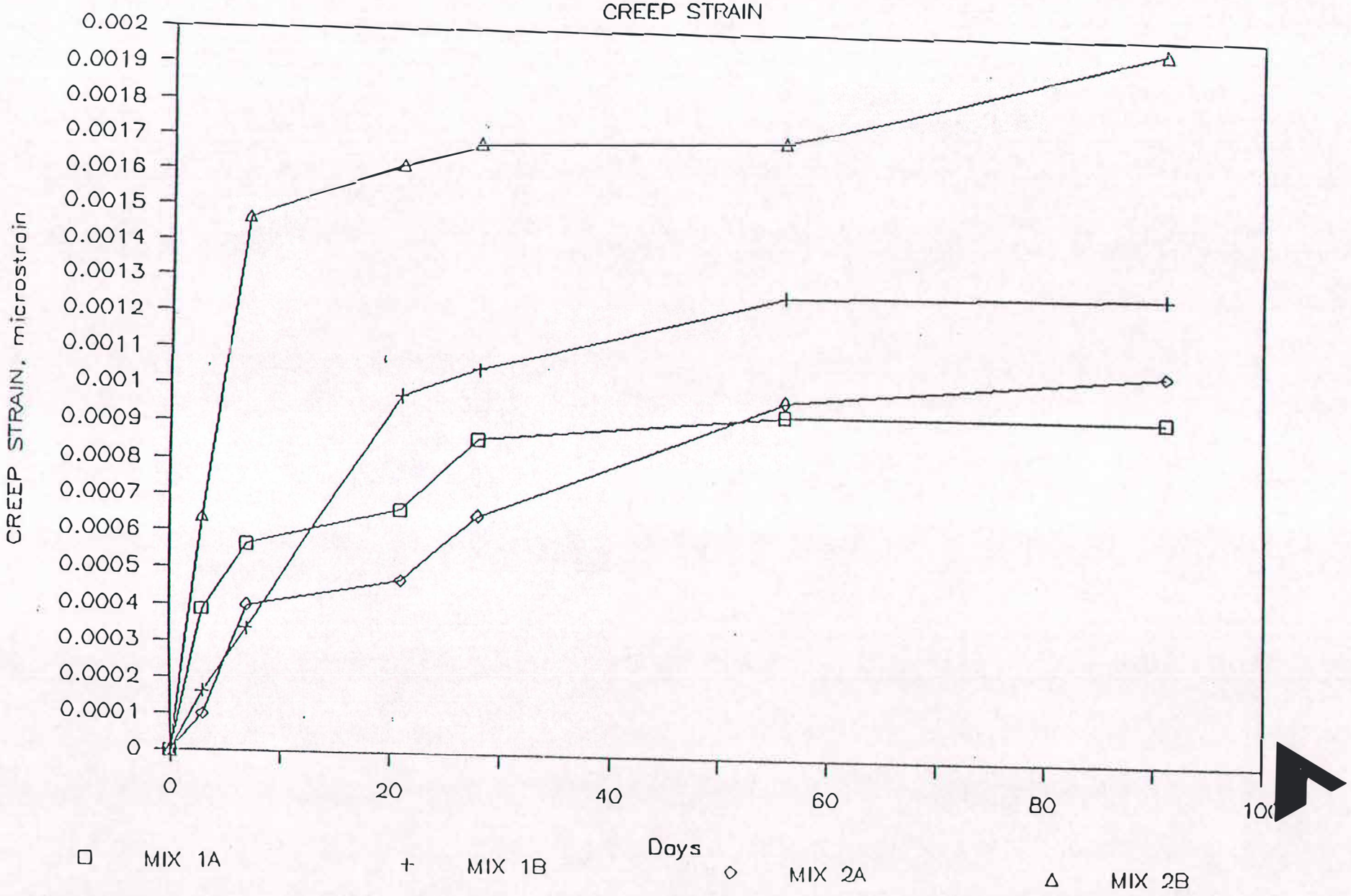
Fineness Modulus: 3.01
Specific Gravity (SSD): 2.63
Absorption, percent 0.6

STALITE HIGH PERFORMANCE

Steam Curing Concrete Temperatures



STALITE HIGH PREFORMANCE



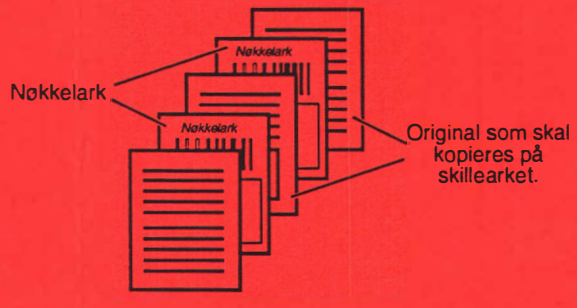
Nøkkelark til kopimaskinen Kodak 2110

Artikkelnr. 950520N

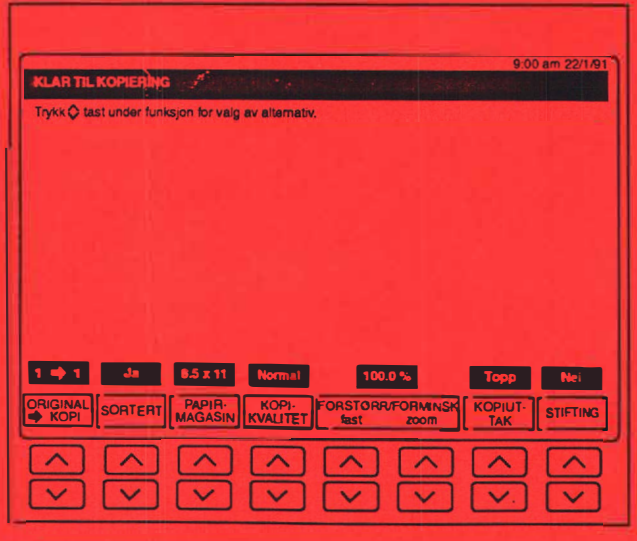
Skilleark – Kopiering på

B R U K S A N V I S N I N G

1. Legg nøkkelarket foran originalen som skal kopieres på skillearket.

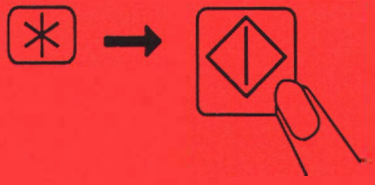


2. Legg originalene og nøkkelarkene i Feeder med forsiden opp, og velg standardfunksjoner.



3. Legg de blanke skillearkene i øvre papirmagasin.

4. Trykk på stjerne (*) og deretter på startknappen for å aktivere nøkkelarket.



Merk: Nøkkelarkene vil bli lagt i utmatingslommen Du kan også bruke kopier av nøkkelark.

Fasthetsutvikling for typiske betongblandinger.

DEL &

STALITE

STRENGTH DEVELOPMENT CURVES

FOR TYPICAL

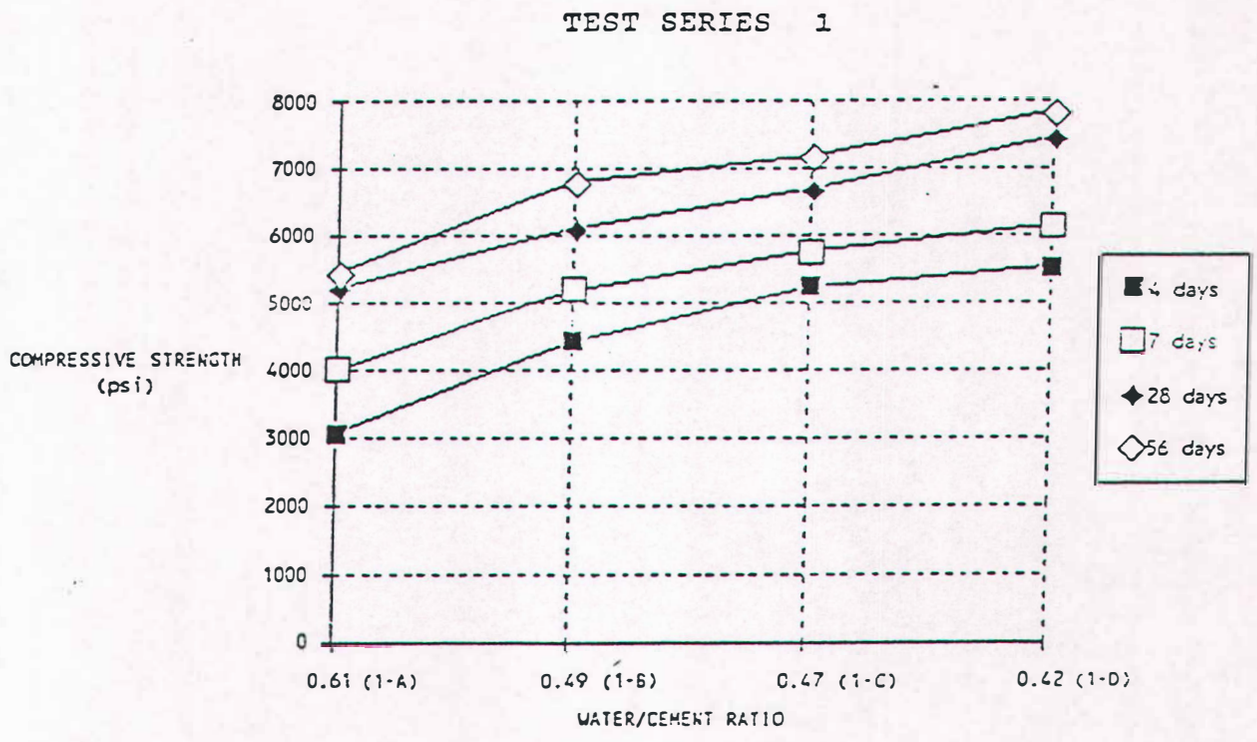
LIGHTWEIGHT CONCRETE MIXES

TABLE OF CONTENTS

TEST SERIES	MIX DESIGNS
1	A, B, C, D
2	A, B, C, D
3	A, B, C, D

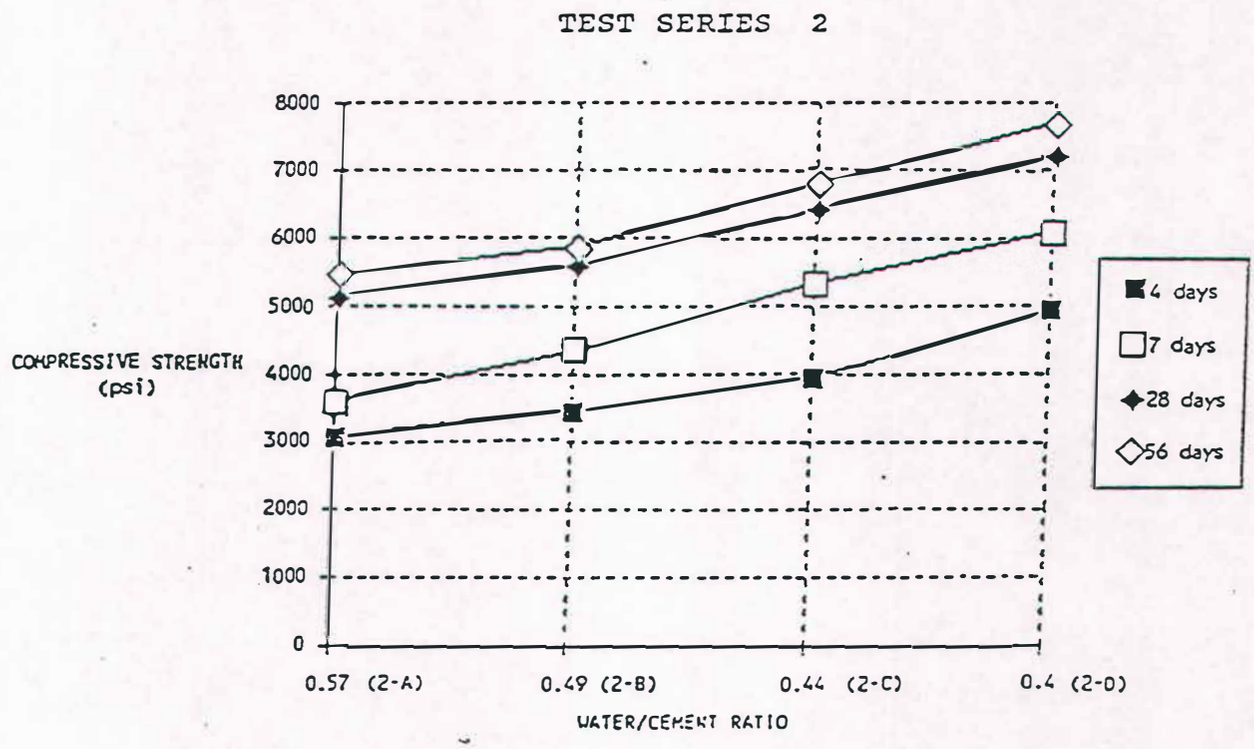
TEST SERIES '1'
STANDARD 3/4" MIS SERIES

Materials	Mix #1-A	Mix #1-B	Mix #1-C	Mix #1-D	
Cement, lbs:	517	611	705	799	362.4 kg
Air, ozs./cmt:	0.5	0.5	0.5	0.5	
Water Reducer,ozs./cmt:	4	4	4	4	
Lilesville Sand, lbs:	1483	1370	1257	1144	518.9 kg
3/4" Stalite, lbs:	830	850	870	890	403.7
Water, gals:	37.6	36.2	39.6	40.0	151.4 l
Unit Weight,pcf					
Theory:	115.9	115.9	116.0	115.1	1859.7
Wet:	115.15	115.7	115.77	117.42	1880.8
28 Days Air Dry:	113.53	114.47	114.54	115.7	1853.3
Air Range, %:	6±2	6±2	6±2	6±2	
Air, Actual, %:	4.0	5.5	6.0	6.0	
Slump Range, ins:	5±1	5±1	5±1	5±1	
Slump, Actual, ins:	3.5	4.75	5.0	5.0	12.7 cm
Water Cement Ratio:	0.61	0.49	0.47	0.42	
Compressive Test, Average:					
4 days, psi	3075	4430	5240	5535	38.2
7 days, psi	4005	5205	5755	6155	42.4
28 days, psi	5225	6100	6695	7455	51.4
56 days, psi	5465	6790	7170	7850	54.1
Splitting Tensile Strength:					
28 Days, psi	415.0	420.0	441.6	476.67	3.3


TEST SERIES 1
COMPRESSIVE STRENGTH (psi)
8000
7000
6000
5000
4000
3000
2000
1000
0
0.61 (1-A)
0.49 (1-B)
0.47 (1-C)
0.42 (1-D)
WATER/CEMENT RATIO
4 days
7 days
28 days
56 days

TEST SERIES '2'
STANDARD 3/8" MIX SERIES

Materials	Mix #2-A	Mix #2-B	Mix #2-C	Mix #2-D
Cement, lbs:	564	658	752	846.
Air, ozs./cmt:	0.7	0.7	0.7	0.7
Water Reducer, ozs./cmt:	4	4	4	4
Lilesville Sand, lbs:	1187	1069	955	843
3/8" Stalite, lbs:	925	950	970	990
Water, gals:	38.62	38.93	40.1	40.6
Unit Weight, pcf				
Theory:	111.0	111.0	111.04	111.12
Wet:	109.63	108.93	109.47	109.63
28 Days Air Dry:	109.3	108.6	109.0	110.7
Air Range, %:	8±2	8±2	8±2	8±2
Air, Actual, %:	8.5	9	9	7.5
Slump Range, ins:	5±1	5±1	5±1	5±1
Slump, Actual, ins:	5.75	5.25	5.75	6.0
Water Cement Ratio:	0.57	0.49	0.44	0.40
Compressive Test, Average:				
4 days, psi	3050	3450	3935	4935
7 days, psi	3610	4350	5345	6055
28 days, psi	5140	5615	6420	7215
56 days, psi	5470	5875	6810	7675
Splitting Tensile Strength:				
28 Days, psi	391.67	410.0	415.0	451.67

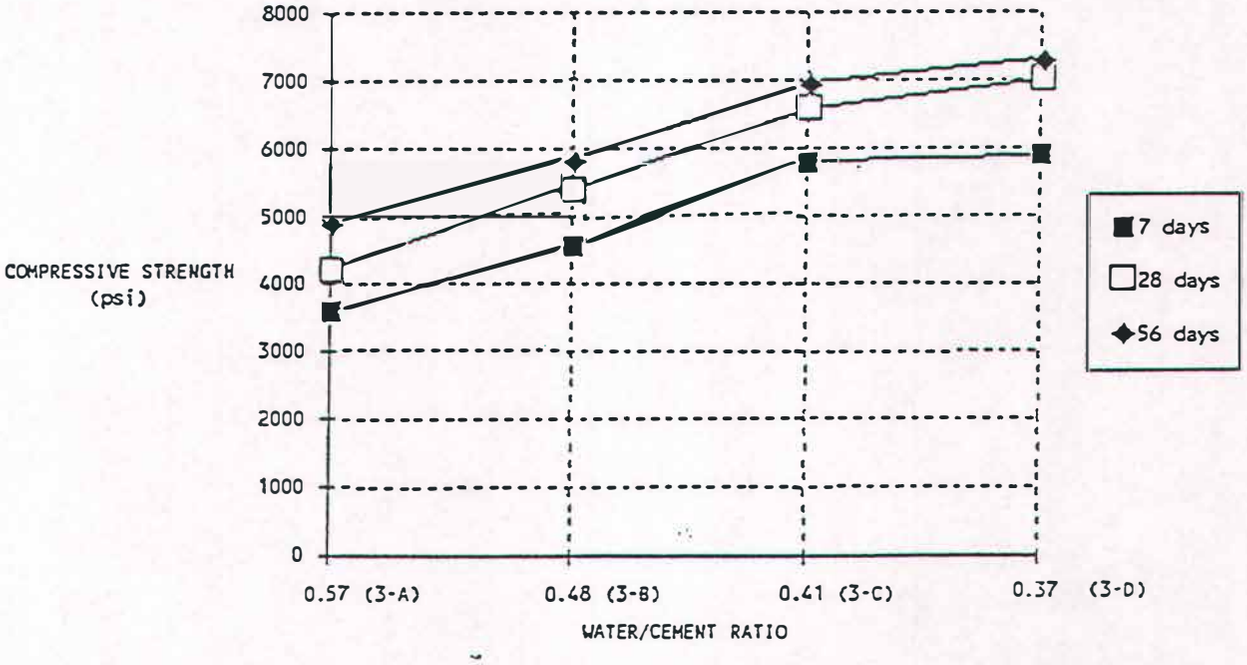

TEST SERIES 2
COMPRESSIVE STRENGTH (psi)
8000
7000
6000
5000
4000
3000
2000
1000
0
0.57 (2-A)
0.49 (2-B)
0.44 (2-C)
0.4 (2-D)
WATER/CEMENT RATIO
4 days
7 days
28 days
56 days

SINCE F&R 1881

TEST SERIES '3'
STANDARD 3/4" MIX SERIES

Materials	Mix #3-A	Mix #3-B	Mix #3-C	Mix #3-D
Cement, lbs:	517	611	705	799
Air, ozs./cmt:	0.5	0.5	0.5	0.5
Water Reducer,ozs./cmt:	4	4	4	4
Lilesville Sand, lbs:	1367	1254	1141	1028
3/4" Stalite, lbs:	890	930	950	970
Water, gals:	35.04	35	35	35
Unit Weight, pcf				
Theory:	114.02	114.3	114.36	114.4
Wet:	112.1	112.4	112.9	112.8
28 Days Air Dry:	110.2	110.77	112.13 1796	111.5 1786
Air Range, %:	6±2	6±2	6±2	6±2
Air, Actual, %:	6.5	6	6	6.25
Slump Range, ins:	5±1	5±1	5±1	5±1
Slump, Actual, ins:	4	4.75	5.25	5.5
Water Cement Ratio:	0.57	0.48	0.41	0.37
Compressive Test, Average:				
7 days, psi	3580	4555	5810	5895
28 days, psi	4215	5420	6585 45.4	7010 48.3
56 days, psi	4945	5835	6950	7295
Splitting Tensile Strength:				
68 Days, psi	366.67	366.67	376.67 2.6	381.67 2.6

TEST SERIES 3



TEST DATA

FINE AGGREGATES

Material:	LILESVILLE SAND
SIEVE SIZE	PERCENT PASSING
3/8"	100.0
#4	98.8
#8	88.1
#16	72.6
#30	43.1
#50	10.9
#100	2.8
Fineness Modulus:	2.85
Specific Gravity:	2.62
Absorption, %:	0.7

COARSE AGGREGATES

Material:	3/4" STALITE	3/8" STALITE
SIEVE SIZE	PERCENT PASSING	PERCENT PASSING
1"	100.0	100.0
3/4"	95.6	100.0
1/2"	38.2	100.0
3/8"	16.0	95.5
#4	3.6	15.0
#8	N/A	2.5
Specific Gravity:	1.5	1.56
Absorption, %:	5.8	5.0

SINCE
F&R
1861

TEST DATA

MATERIALS USED:

Santee Portland Cement, Type I

W.R. Grace & Company, Darex, Air Entraining Agent

W.R. Grace & Company, WRDA - Hycol, Water Reducing Agent

B.V. Hedrick Sand and Gravel Company, Lilesville Pit Sand

Carolina Stalite Company, 3/8" Structural Lightweight Aggregate

Carolina Stalite Company, 3/4" Structural Lightweight Aggregate

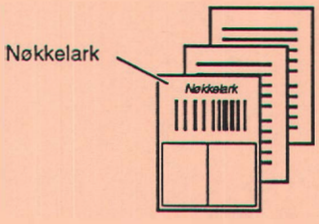
Nøkkelark til kopimaskinen Kodak 2110 *Artikkelnr. 950520N*

Ingen utmating

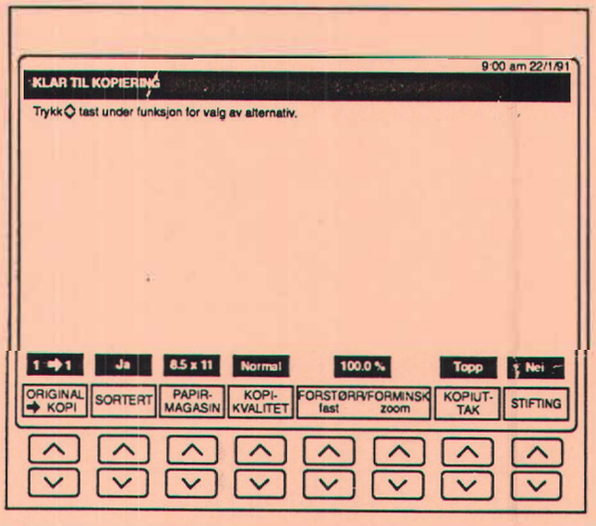
(Nøkkelarkene blir liggende i Feeder)

B R U K S A N V I S N I N G

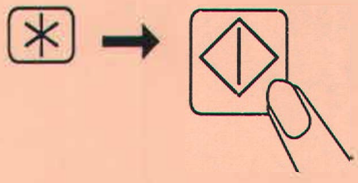
1. Legg nøkkelarket hvor som helst i originalsettet.



2. Legg originalene og nøkkelarkene i Feeder med forsiden opp, og velg standardfunksjoner.



3. Trykk på stjerne (*) og deretter på startknappen for å aktivere nøkkelarket.

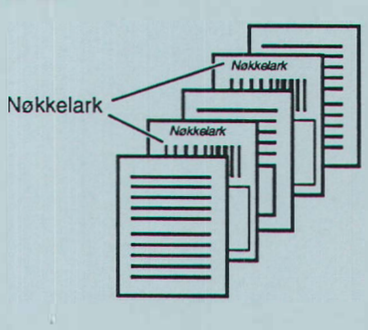


Nøkkelark til kopimaskinen Kodak 2110 *Artikkelnr. 950520N*

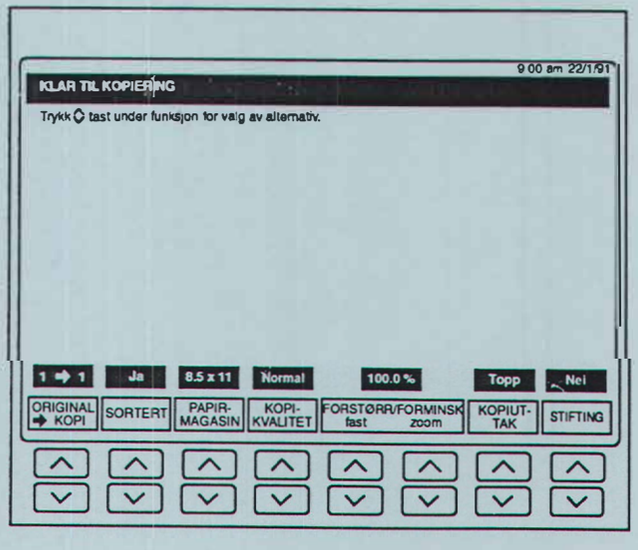
Skilleark – Fortrykte/Blanke

B R U K S A N V I S N I N G

1. Legg nøkkelarket eller -arkene akkurat der skillearkene skal plasseres.

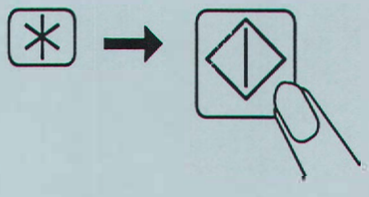


2. Legg originalene og nøkkelarkene i Feeder med forsiden opp, og velg standardfunksjoner.



3. Legg de fortrykte/blanke skillearkene i øvre papirmagasin.

4. Trykk på stjerne (*) og deretter på startknappen for å aktivere nøkkelarket.



Merk: Nøkkelarkene vil bli lagt i utmatingslommen. Du kan også bruke kopier av nøkkelark.

VEDLEGG B.3

AS Anlegg
Raftsundet Bru
8460 Hamarøy

AXION AS

Fiolveien 15
9016 TROMSØ

Telefon 776 84231/94 571441
Telefaks 776 89510

Fokus Bank 9065-1906856

Your ref B. Kristiansen Our ref 1063/RSV Tromsø 21.10.96

Raftsundet Bru. Dokumentasjon for betong med Stalite Lettklinker.

Jeg viser til vårt brev av 05.10.96, og telefonkontakt 15.10.96 vedrørende pumpbarhet, vann absorpsjon og densitet for Stalite Lettklinker.

Som avtalt oversender jeg en del resultater fra prøving av lettbetong basert på Stalite Lettklinker. I tillegg viser jeg til resultater fra prøving av produksjonsbetong hvor deler av det grove tilslaget er erstattet med Stalite Lettklinker.

Generelt.

Som nevnt har Stalite lettklinker ikke tidligere vært benyttet i høgfast (fck høgere enn 45 Mpa) produksjonsbetong med densitet 20 kN. Imidlertid er betong med trykkfasthater 7o Mpa (sylinder fasthet) og volumvekt 20 kN utprøvet på laboratorienivå ved flere anledninger.

Stalite Lettklinker har også vært benyttet til produksjonen av ca 120.000 m3 MND (Modifisert Normal Densitet) betong for en GBS type plattformen som er under bygging på østkysten av Canada. Plattformen, som har et isforsterket betongunderstell, er spesifisert i henhold til NS 3473 og deler av Ns 3474, med betong i fasthetsklasse C80 (69 Mpa sylinderfasthet), og har en beregnet brukstid på 30 år.

I løpet av byggeprosessen oppsto det behov for å redusere betongens densitet med ca 10 % for å øke plattformens marine stabilitet under utslep.

Det ble besluttet å benytte en Modifisert Normal Densitet betong, hvor deler at det grove tilslaget ble erstattet med Stalite Lettklinker i et forhold som gav en in- situ betongdensitet i størrelsesorden 2.20 kN, uten at betongens E-modul ble redusert med mer enn 10%, samtidig som kravene til andre materialegenskaper ble opprettholdt.

Det var likeledes et krav at eksisterende delematerialer og

produksjonsutstyr måtte kunne benyttes.

Av de 7 typer lettklinker fra produsenter i Japan, Tyskland, Norge, Usa og Canada, som ble vurdert som aktuelle materialer, var det imidlertid bare Stalite Lettklinker som kunne tilfredsstille alle de oppsatte krav, og ca 45. 000 tonn ble i løpet av perioden 1994-95 levert til prosjektet.

Sammenlignet med andre typer lettklinker har Stalite Lettklinker meget lav vann absorpsjon (tab 1), og kan derfor, helt eller delvis, vannmettes før blanding, uten at vektøkningen blir for stor.

Porestrukturen medvirker også til at vann fra mørtelfasen i mye mindre grad vil bli presset inn i tilslagskornene under pumping/utstøping, enn hva som er tilfellet for de fleste andre typer lettklinker.

Dette forholdet kommer klart fram ved å sammenligne forskjellige typer lettklinker som utsettes for vanntrykk på ca 1 Mpa (tilsvarende maksimal trykk i normale betongpumper). I disse tilfeller vil Stalite Lettklinker typisk vise maksimalt vannoppsug i størrelsesorden 10 %, mens andre sammenlignbare typer lettklinker, vil viser vannoppsug over 20 %.

På dette grunnlag mener jeg derfor at det skal være fult mulig å pumpe lettbetongen som er beskrevet for Raftsundet Bru, ved å bruke Stalite, eller tilsvarende typer lettklinker.

Imidlertid vil det være nødvendig a forsta utprøving av betongresepter i fullskala for å dokumtere pumpbarhet og støpelighet.

Dersom det er ønskelig stiller vi gjerne vår erfaring og materialprøver til rådighet i forbindelse med en slik proporsjonering og ettarprøving, og vi vil også gjerne delta i samtaler med de involverte parter i fall det vil være behov for vår erfaring på produksjon og dokumentasjon av høgfast lettbetong.

Med hilsen
AXION AS

Tore Høland

vedlegg

Vedlegg 1

Materialdokumentasjon

I forbindelse med overgang fra normal betong til MND betong for Hibernia prosjektet, ble det behov for å dokumentere at grunnleggende kriterier for dimensjonering ble opprettholdt ved lavere betongdensitet, og introduksjon av lettklinker.

Basert på forslag fra byggherrens byggetekniske konsulent S. B Leivestad (Berdal Strømme as) ble et omfattende prøveprogram ble iverksatt (tab. 5), og resultatene fra prøvingsanstalter i Canada og Norge, viste at betongen tilfredsstilte de oppsatte krav med god margin, ved bruk av Stalite Lettklinker.

Fullskala pumpeforsøk (Tab 3) viste også at det ikke var nødvendig å ta spesielle forholdsregler for å kunne transportere betong med 250-350 kg/m3 Stalite Lettklinker mer enn 250 m horisontalt og 30 m vertikalt, ved hjelp av vanlig pumpeutstyr.

Betongegenskaper

Resultatene fra utprøving av høgfast lettbetong for Hibernia plattformen er byggherrens (HMDC) eiendom, og så nær som for deler som tidligere er presentert ved international symposier, er ikke dataene offentlig tilgjengelig.

Basert på deler som er tilgjengelig, og egne laboratorie- og produksjondata, har jeg sammenstillet generelle opplysninger om høgfast lettbetong hvor deler av det grove tilslaget er erstattet med Stalite lettklinker i de følgende tabeller.

Tab.1 Typiske egenskaper for noen typer lettklinker benyttet i høgfastbetong

Material typer	Volumvekt løst lagret overflate tørr kg/m3	Densitet overflate tørr kN	Abs. 1 t vekt %	abs 24 t vekt %
Leca 800	800	14.50	8	11
Liapor 8	800	15.00	7	10
Lytag	800	15.00	12	20
Solite	700	14.00	9	10
Stalite 1/2"	770	15.00	-	5

Tab.2. Endringer i betongegenskaper ved bruk av Stalite Lettklinker til erstatning for normalt tilslag. Masseforhold 0.31-0.35.

Stalite 1/2 " kg	%	Egenskaper herdet betong Densitet kN	trykk-fasthet Mpa 1)	Bøye/strekk fasthet Mpa	E- Modul GPa	Luft-innhold %
665	55	1928	65.2	4.2	-	1.7
603	43	2018	70.9	4.6	27.7	2.3
431	28	2139	74.9	5.4	29.2	1.6
290	18	2232	79.2	5.5	33.2	1.8
156	9	2322	87.4	6.1	35.2	1.8
0	0	2400	89.8	5.4	37.2	1.6

Anm: 1) Sylinderfasthet.

Tab.3. Hibernia GBS. Oversikt over variasjoner i ferske betongegenskaper før og etter pumping. Basert på produksjonsdata fra glidestøping av Ice Wall el 9.2 - 18.8 i perioden 07-13.09.94.

EGENSKAP		FØR PUMPING 1)	ETTER PUMPING 2)
SLUMP	maksimum	250 mm	250 mm
	minimum	220 mm	160 mm
	ar. middel	241 mm	220 mm
DENSITET	maksimum	21.75 kN	22.55 kN
	minimum	21.20 kN	22.00 kN
	ar. middel	21.40 kN	22.20 kN
LUFT-INNHOLD	maksimum	6.8 %	4.4 %
	minimum	5.7 %	2.4 %
	ar. middel	6.3 %	3.4 %
BETONG TEMPERATUR	maksimum	15 oC	19 oC
	minimum	11 oC	13 oC
	ar. middel	13 oC	16 oC

Anm. 1) 15 prøver tatt fra trommelbil ved blandeverk.
2) 25 prøver tatt fra form etter pumping.

Tab.4. Stalite Lettklinker. Typisk blandetabell for høgfast produksjonsbetong.

Densitet (in- situ)	19.30 kN	22.00 kN
Materialer (kg/m3)		
Sement	420	420
Silika	30	30
Vann	160	160
Sand normal vekt	680	900
Stein -"-	-	470
Stein lettklinker	650	240
Plastiserende og luft innførende tilsetnings-stoffer		
masseforhold	0,35	0.35
Trykkfasthet 28 d (Sylinderfasthet)	65 Mpa	75 Mpa

Tab. 5. Prøveprogramm for dokumentasjon av materialegenskaper for MND betong basert på Stalite Lettklinker for Hibernia GBS.

Materialegenskap.	Prøvemetodikk
Trykkfast (sylinder)	CSA A23.2-9C
-"- (terning)	NS 427A
Bøye-strekk fasthet	CSA A23.2-13C
Strekkfasthet (direkte)	eget opplegg
E-modul under trykk	ASTM C469
-"- strekk	eget opplegg
Stress/strain diagram under trykk	ASTM C469
Volumvekt/absorpsjon	ASTM C642
Luftinnhold/slump	CSA A23.2-4C/7C
Fryse/tineegenskaper	ASTM C666
Kryp/svinn	ASTM C512/157/492
Bruddenergi	Rilem TC50
Vanninntrenging	DIN/ISO
Uttrekk av armering	Rilem
Lastoverføring fra t-hode armering	Rilem

vedlegg 2. Data fra fullskala pumpeforsøk (tidligere oversendt)

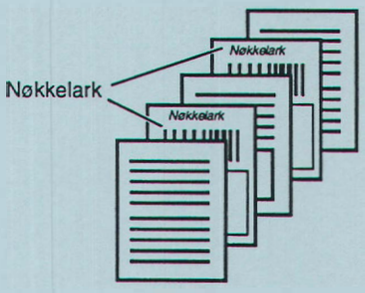
-"- 3. Teknisk brosjyre Stalite Lettklinker for Hibernia GBS.

Nøkkelark til kopimaskinen Kodak 2110 *Artikkelnr. 950520N*

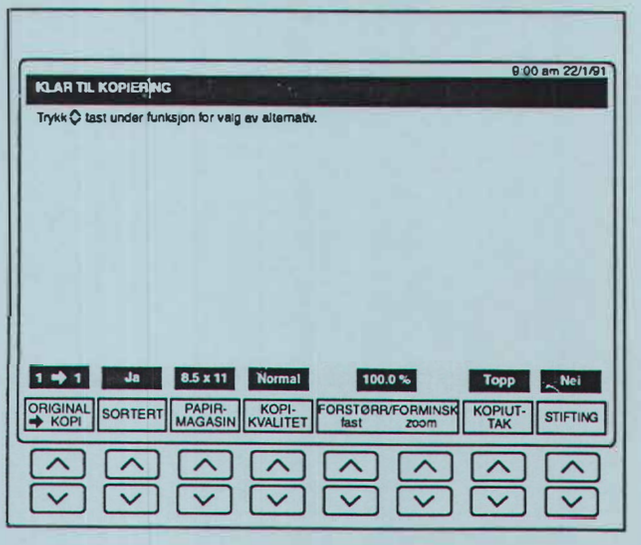
Skilleark – Fortrykte/Blanke

B R U K S A N V I S N I N G

1. Legg nøkkelarket eller -arkene akkurat der skillearkene skal plasseres.

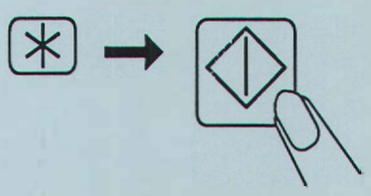


2. Legg originalene og nøkkelarkene i Feeder med forsiden opp, og velg standardfunksjoner.



3. Legg de fortrykte/blanke skillearkene i øvre papirmagasin.

4. Trykk på stjerne (*) og deretter på startknappen for å aktivere nøkkelarket.



Merk: Nøkkelarkene vil bli lagt i utmatingslommen. Du kan også bruke kopier av nøkkelark.

M Hatt 10.4.97

VEDLEGG B.4

POLEKONSULT A/S
Adresse : Fiolveien 15 9016 Tromsø
Telefon : 776 78660 / 94 571441
Telefaks: 776 71441

Til: AS ANLEGG	Telefaks nr 76159996	Dato 08.04.97
For Bård Kristiansen	Fra Rolf Valum	Tot. ant sider ~~14~~ 15

Vedr. Dokumentasjon Stalite Lettklinker.

Viser til dagens telefonsamtale og oversender som avtalt en del manglende dokumentasjon vedrørende Stalite Lettklinker som følger:
1. Bekreftelse på at tidligere rapportert svovelinnhold i Stalite Lettklinker er å forstå som total svovelinnhold.

Kommentar: Bekreftelsen som jeg fikk oversendt fra Stalite, er ikke videre nyttig siden den ikke gir tilstrekkelig sporbarhet. Jeg har varslet leverandøren, og håper på å få en akseptabel bekreftelse snarest.

2/1-2. Rapport fra Høgskolen i Stavanger men resultater fra prøving av betong fra prøvepumpingen 20.02.97
Kommentar: Sylindre er utstøpt etter pumping, mens terninger er utstøpt før pumping.

3/1-7. Rapport fra prøving av alkali-silika reaktivitet i hh til ASTM C 227 for Stalite Lettklinker.

Kommentar: Vedlagt er også en oversettelse til norsk av rapporten, samt kopi av et utdrag av ASTM 33 som gjengir maks. godkjent ekspansjon for at materialene kan ansees som ikke reaktive. Merk at tekst til tabeller og fig. ikke er oversatt til norsk, men kan oversendes innen kort tid dersom det er ønskelig.

4/1-3. Oversikt over typiske sikte kurver fra produksjonen av 1/2" (12mm) Stalite lettklinker over en periode på ca 1 mndr.
Kommentar: I henhold til ASTM er det ikke krav til fraksjonering på 16 mm som er den øvre grensen vi ønsker å benytte til Rafsundet Bru. Stalite vil derfor blande materialer fra 3/4 " og 1/2" for å produsere en gradering som vi ønsker. NS har ingen krav til gradering av tilslagsmaterialene men SV i pk 2 (97) gir en anbefaling til kombinert gradering. Stalite vil produsere et materiale med D100 = 16 mm og som sammen med den aktuelle sanden møter kravene i Pk2 dersom det er ønskelig.
Det er også vedlagt et utdrag av ASTM 330 som viser kravene til gradering for konstruktiv lettklinker.

Som nevnt har jeg ikke fått satt i sving apparatet for å utføre tynnslipanalyse på en terning som ble utstøpt for pumping 20.02.97, men vil nå få ut fingeren fra en unevnt

kroppsdel, og få prosessen i gang. Jeg er redd resultatene ikke kan foreligge før om vel 2 uker.

Dersom dette er et problem ber jeg om at du kontakter meg. Ellers håper jeg at det er noe nytte i materialet jeg oversender.

Hilsen

Rolf Valen

(1)

CHEM-BAC Laboratories, Inc.

• P. O. BOX 19198, CHARLOTTE, N. C. 28219
TEL. 394-6381
FAX #: 704 394-6382

March 11, 1997

REF: 1198
W.O. 1306

Sulfur Content of Sample

MADE FOR: Stalite Environmental
P.O. Box 1098
Salisbury, N.C. 28144

ATTENTION: Bill Griggs

MARKED: Sample received at Chem-Bac Labs, Inc. on 02/17/97

ANALYSIS: Sulfur ---------- less than .010%

Respectfully submitted,
CHEM-BAC LABORATORIES, INC.

J.C. Hubbell
Supervising Chemist

JCH/th

Mailed to Carolina Stalite Comp. 04.04.97

Avdeling for teknisk - naturvitenskapelige fag

2/1

Institutt for Bygg og Anleggsteknikk
Betongprøvestasjonen

Axlan A/S
Postboks 2255
9001 TROMSØ

Stavanger 07.04.97

Att: R.Walum

ANG. TESTING AV E-MODUL, VANNINNTREGNING OG DENSITET

Vedlagt resultat fra testing avtalt pr. telefon samt notat av 17.03.97.

Prøvestykkene ble merket syl.1, syl.2, tern. A, tern. B av oss etter mottakelse.

Testingen har tatt noe mer tid enn antatt. Dette beklager vi.
Bortsett fra resultat av trykkfasthet som har fått mer enn 28 døgn, så mener vi denne ekstra tid ikke har hatt noen innvirkning på de andre resultatene.

Vi håper at resultat er i samsvar med deres forventning.

Vennlig hilsen
for HiS

Svein O. Wick

Vedlegg: Testing av prøvelegemer i betong, vanninntreningsforsøk (2)

Høgskolen i Stavanger
Postboks 2557
Ullandhaug
4004 Stavanger
Telefon 51 83 10 00
Telefax 51 83 10 80
Institutt for bygg
og anleggsteknikk
Besøksadresse
Ullandhaug
4004 Stavanger
Telefon 51 83 17 00

[redacted]

Avdeling for teknisk - naturvitenskapelige fag

2/2

BETONGPRØVESTASJONEN

TESTING AV PRØVELEGEMER I BETONG	PRODUSENT REG.NR.	REG.NR. 12/97
		REKV.NR.

Testing i h.h.til: E-MODUL - *NS 3676*
DENSITET - *NS 3673*
VANNINNTREGNING - *NS3420/ ISO/DIS 7031*

Byggeplass: Raftsund bro
Støpested: Prøvepumping
Prøvetaker: Axian A/S

Støpt dato: 20.02.97
Mottatt dato: 19.03.97
Prøvet dato: 3 -4.04.97

PRØVELEGEME: 2X syl 100x200mm
2X tern. 100x100x100mm

TILSIKTET KVALITET: LC60

MERKET: syl. 1, syl. 2,tern. A,B
PRODUSENT: Hålogaland Grus& Betong Myrland

PRØVE NR	Syl.1	Syl.2	A	B		
PRØVEALDER	42	42	42	42		
DIAmm / Side mm	101	100,5	100,5	100		
HØYDE mm / Side mm	200,5	200,5	101	100,2		
BRUDDLAST kN	512	491				
TRYKKFASTHET SYL. N/mm2	63,9	61,9				
Midlere trykkfasthet N/mm2						
VEKT kg	3,126	3,049	1840,7	1830,4		
VOLUM mm3	1615	1578	1011,1	997,2		
DENSITET kg/m3	1936	1932	1820,7	1836*		
MIDLERE DENSITET kg/m3						
E-MODUL Eo GPa	26	24				
Ec GPa	24	21.5				
VANNINNTREGNING mm			8	10		

Anmerkninger: Sylinder ikke sirkulær. Større porer i både syl.1 og syl.2
*Visuelt synes det å være mer småporer i terning enn i sylindrer. Terninger lagret fuktig, ikke i vann, i.h.h til standard. Syl. lagret i vann før testing

testrolf.doc/gw

Sign: [redacted]

07.04.97

Høgskolen i Stavanger
Postboks 2557
Ullandhaug
4004 Stavanger
Telefon 51 83 10 00
Telefaks 51 83 10 80
Institutt for bygg og anleggsteknikk
Besøksadresse
Ullandhaug
4004 Stavanger
Telefon 51 83 17 00
Telefaks 51 83 17 80

3/1

Oversettelse av rapport av 23.02 95 fra Law Engineering, Inc. til Mr Roberto Nunez Carolina Stalite Company, PO Box 1037
Salisbury, North Carolina 28145, USA.

Oversettelsen er foretatt av Rolf Valum 06.04.97.

Ref. Sluttrapport: ASTM C277-90 Prøveresultater.

Dear Roberto.

Law Engineering har utført undersøkelser av betong med Stalite Lettklinker som tilslag i henhold til vårt tilbud Nr. 582-93092 (revidert).

Formålet med undersøkelsen har vært å sammenligne alkali-silika reaktiviteten i Stalite Lettklinker med et lokalt tilgjengelig tilslag med normal densitet. Undersøkelsen er utført i henhold til ASTM C227-90 "Standard Test Methode for Potential Aklali Reactivity of Cement-Aggregate Combination (Mortar Bar Methode)" (Standard metode for undersøkelse av potensiell alkali-silica reaktivitet i sement-tilslag kombinasjoner (mørtel- prisme metode)).
Denne rapporten presenterer prøveprosedyrer og resultater.

Materialer og blandinger.

Mørtel prismer: Vi har mottatt ca 50 kg prøver av Stalite 19mm (3/4") lettklinker som er en ekspandert skifer produsert i rotasjonsovn. Materialet ble knust, sortert i fraksjoner og sammensatt i vårt laboratorie til en graderingskurve som tilfredsstiller kravene i ASTM C-227. Betongblandingene var som spesifisert i ASTM C 277, men tilslagsandelen ble justert i forhold til spesifikasjonene, for å kompensere for forskjellen i densitet mellom Stalite Lettklinker og det naturlige tilslaget som ble undersøkt. Dette ble gjordt for at både Stalite og refeeranseblandingen skulle få samme tilslags- og pastvolum. For blandingen med Stalite ble det benyttet et v/c tall på 0,51 (152 gr vann/300 gr sement), noe som gav en flyt på 118.

Til referanseblandingen benyttet vi en kvartsittisk natursand fra Waugh, Alabama. Sanden er mye benyttet som betongtilslag i området rundt Atlanta, og har gjennom lokale prosjekt over lengere tid vist akseptabel bestandighet med hensyn til alkali-silika reaktivitet. Sanden ble fraksjonert og sammensatt på vårt laboratorum i henhold til kravene i ASTM C 277. Mørtelen ble sammensatt i henhold til kravene i ASTM C 277, med et v/c forhold på 0.50 (150 g vann/300 g sement), og med en flyt på 111.

Som bindemiddel ble det benyttet en Type 1 portland sement fra Birmingham, Alabama. Sementen ble undersøkt i henhold til ASTM 114-88 "Standard Test Methode for Chemical Analysis of Hydraulic Cement" (Standard Metode for Kjemisk Analyse av Hydraulisk Sement). for å verifisere innholdet av alkalier. Innholdet av totale alkalier, rapportert som Na20 ble målt til 0.75%.

Sylindre: Det ble utstøpt flere lettbetong sylindre med dxh= 76X154mm fra betongblandinger med samme volumetriske blandingsforhold som i mørtelprismene i henhold til ASTM V 277. I disse blandingene av lettbetong, var ca 50 % av tilslaget tilsatt som standard (uknust) 3/4" (19mm) Stalite Lettklinker, for å representere tilslagsfordelingen i en typist standard LC betong. Sylindrene fikk samme herdings- og lagrings betingelser som mørtelprismene i henhold til ASTM C 277.

Prøveprosedyrer.

Mørtelprismer: Prismene ble prøvet i henhold til ASTM C227-90 "Standard Test Methode for Potential Aklali Reactivity of Cement-Aggregate Combination (Mortar Bar Methode)" (Standard Metode for Undersøkelse av Potensiell Alkali-Silica Reaktivitet i Sement-Tilslag Kombinasjoner (mørtelprisme metode)).

Sylindre: Bruddflatene i sylindrene ble undersøkt ved hjelp av en teknikk som benytter seg av ultrafiolett lys, og er gjengitt i SHRP-C/FR-91-101, " Handbook for the Identification of Alkali-Silica Reaktivity in Highway Structures". (Håndbok for identifisering av Alkali-Silika Reaktivitet i Motorveikonstruksjoner). Bruddflatene ble preparert og undersøkt ved samme alder som prøvingen i henhold til ASTM C 227.

Resultater.

Mørtelprismer: Resultatene fra prøving wtter ASTM C 227 framgår av vedlagte kurver og figurer, og viser at prismene som inneholdt Stalite Lettklinker hadde en gjennomsnittlig ekspansjon på +0.017% etter ett år. Tilsvarende ekspansjon for referanseblandingen var +0.012%. Spredningen på de to resultatene er mindre enn hva ASTM C 227 aksepterer for spreding mellom flere prismer fra samme betongblanding.

Sylindre: Sylinderprøvene viste at tilslagspartiklene fra Stalite Lettklinker ikke hadde synlige indikasjoner på alkali-silika reaktivitet ved undersøkelse med ultrafiolett lys og 10x forstørrelse i løpet av det året undersøkelsen foregikk.

Law Engineering setter pris på mulighetn til å få yte denne tjenese. Dersom det skulle være spørsmål forbundet til denne rapporten, eller om vi kan være til ytterligere hjelp, ber vi om å bli kontaktet.

med hilsen

Law Engineering, Inc.

Vedlegg: Sammenstilling av ASTM C 227 Prøveresultater
Figur A.
Utdrag av ASTM C 33. Kommentarer til prøvemetode C 277.

3/3

X1.1.3 *Test Method C 227*—The results of this test method when made with a high-alkali cement, furnish information on the likelihood of harmful reactions occurring. The alkali content of the cement should be substantially above 0.6 %, and preferably above 0.8 %, expressed as sodium oxide. Combinations of aggregate and cement that have produced excessive expansions in this test usually should be considered potentially reactive. While the line of demarcation between nonreactive and reactive combinations is not clearly defined, expansion is generally considered to be excessive if it exceeds 0.05 % at 3 months or 0.10 % at 6 months. Expansions greater than 0.05 % at 3 months should not be considered excessive where the 6-month expansion remains below 0.10 %. Data for the 3-month tests should be considered only when 6-month results are not available.

X1.1.4 *Test Method C 342*—This test method is intended primarily for research concerning the potential expansionof cement-aggregate combinations subjected to variations of temperature and water saturation during storage under prescribed conditions of test. Its use is mainly by those interested in research on aggregates that are found in parts of Kansas, Nebraska, Iowa and possibly other adjoining areas.

X1.1.4.1 In addition to its usefulness in research, this test method has been found useful in the selection of aggregates of the so-called "sand-gravel" type found mainly in some parts of Kansas, Nebraska and Iowa, which contain very little coarse material; generally 5 to 15 % retained on the No. 4 (4.75-mm) sieve. Much work has been done on the problems of using these aggregates successfully in concrete and is reported in summary in the "Final Report of Cooperative Tests of Proposed Tentative Method of Test for Potential Volume Change of Cement-Aggregate Combinations," Appendix to Committee C-9 Report, Proceedings, ASTM, Volume 54, 1954, p. 356. It indicates that cement-aggregate combinations tested by this procedure in which expansion equals or exceeds 0.200 % at an age of 1 year may be considered unsatisfactory for use in concrete exposed to wide variations of temperature and degree of saturation with water. In that geographical region, the problem has been reduced through the use of partial replacement of the "sand-gravel" with limestone coarse aggregate.

X1.1.5 *Potential Reactivity of Carbonate Aggregates*—The reaction of the dolomite in certain carbonate rocks with alkalies in portland cement paste has been found to be associated with deleterious expansion of concrete containing such rocks as coarse aggregate. Carbonate rocks capable of such reaction possess a characteristic texture and composition. The characteristic texture is that in which relatively large crystals of dolomite are scattered in a finer-grained matrix of calcite and clay. The characteristic composition is that in which the carbonate portion consists of substantial amounts of both dolomite and calcite, and the acid-insoluble residue contains a significant amount of clay. Except in certain areas, such rocks are of relatively infrequent occurrence and seldom make up a significant proportion of the material present in a deposit of rock being considered for use in making aggregate for concrete. Test Method C 586 has been successfully used in (*1*) research and (*2*) preliminary screening of aggregate sources to indicate the presence of material with a potential for deleterious expansions when used in concrete.

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This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, PA 19103.

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LAW
ENGINEERING AND ENVIRONMENTAL SERVICES

May 25, 1993

Mr. Roberto Nunez
Carolina Stalite Company
P.O. Box 1037
Salisbury, North Carolina 28145

Subject: **Final Report**
ASTM C 227-90 Test Results
Carolina Stalite Aggregate
Law Engineering Job No. 5820644801

Dear Roberto:

Law Engineering has completed testing of concrete mixtures containing Stalite aggregates in accordance with our Proposal No. 582-93093 (Revised). The purpose of our testing is to compare the alkali-silica reactivity of Stalite rotary kiln, expanded slate aggregate and a locally available normal-weight aggregate when using ASTM C 227-90, "Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)". This report presents the test procedures and test results.

Materials and Mixtures

Mortar Bars: Carolina Stalite Company provided an approximately 100 pound sample of Stalite 3/4-inch, rotary kiln, expanded slate aggregate. The Stalite aggregate sample was crushed in the laboratory, separated into size fractions, and combined to meet the requirements of ASTM C 227. The mixtures used were as specified by ASTM C 227. The aggregate batch weights presented in ASTM C 227 were adjusted to compensate for the difference in specific gravity between the Stalite aggregate and the natural aggregate being tested. This procedure was followed so that both the Stalite and the Reference mixtures had the same aggregate and paste volumes. The water-cement ratio of the Stalite mixture was 0.51 (152 grams of water/300 grams of cement) to produce a flow of 118.

Law Engineering obtained a natural quartzitic sand from Waugh, Alabama for use in the reference mixture. The natural sand is widely used in concrete in the Atlanta area and has an acceptable performance history with respect to alkali-silica reactivity in local projects. The natural sand was separated into size fractions and recombined in accordance with ASTM C 227. The mortar bar mixture was proportioned in accordance with ASTM C 227. The water-cement ratio of the reference mixture was 0.50 (150 grams of water/300 grams of cement) to produce a flow of 111.

Law Engineering obtained a sample of Type I portland cement from Birmingham, Alabama for use on this project. The cement was tested to verify its alkali content. The total alkalis, reported as Na_2O, was measured to be 0.75 percent when tested in accordance with ASTM C 114-88, "Standard Test Methods for Chemical Analysis of Hydraulic Cement".

Mr. Roberts Name:
LAW Job No. 9620644801

May 23, 1995

Cylinders: Several 3-inch diameter by 6-inch lightweight concrete cylinders were made using the same volumetric proportions as the ASTM C 227 mortar bars. Approximately 50 percent of the aggregate in the cylinders was uncrushed, 3/4 inch maximum sized, lightweight aggregate particles. The uncrushed lightweight aggregate particles were included in the cylinders to represent the aggregate in a typical lightweight structural concrete mixture. The cylinders were cured and stored in the same conditions as the ASTM C 227 specimens.

Test Procedures

Mortar Bars: Mortar bars were tested in accordance with ASTM C 227-90, "Standard Test Method for Potential Alkali Reactivity of Cement-Aggregate Combinations (Mortar-Bar Method)".

Cylinders: Fractured faces of the cylinders were observed using the ultra-violet light technique presented in SHRP-C/FR-91-101, "Handbook for the Identification of Alkali-Silica Reactivity in Highway Structures". Fresh fractured faces were prepared and observed at the same ages as the ASTM C 227 measurements.

Test Results

Mortar Bars: ASTM C 227 test results are presented in the attached tables and figure. In summary, the mortar bars containing Stalite aggregate expanded and average of +0.017 percent compared to an average expansion of +0.012 percent for the reference mixture over the one year duration of the test. The range of the two results is less than the ASTM C 227 allowable within test variation for a single material.

Cylinders: The Stalite aggregate particles in the cylinder specimens did not exhibit visible indications of alkali-silica reactivity when viewed using the ultraviolet light technique and a 10x magnification over the one year duration of the test.

Law Engineering appreciates the opportunity of providing this service. If there are any questions about this report, or if we may be of further service, please call.

Sincerely,

LAW ENGINEERING, INC.

Terry L. Viness, P.E.
Senior Engineer

John R. Love, P.E.
Principal Engineer

Attachments: Summary of ASTM C 227 Test Results
Figure A

TLV/JRL:ds \wines\9644801.rpt

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Mr. Robert Nunez
LAN Job No. 9[illegible]

May 23, 1995

ASTM C 227-90 TEST DATA
Carolina Stalite Company

STALITE AGGREGATE MIXTURE					Batch Date: 2/21/94
Reading Age	Length Change, percent				Average Length Change, %
	A	B	C	D	
1 day	0.000	0.000	0.000	0.000	0.000
14 days	0.007	0.007	0.007	0.007	0.007
28 days	0.007	0.007	0.007	0.007	0.007
2 months	0.012	0.011	0.011	0.011	0.011
3 months	0.015	0.014	0.014	0.013	0.014
4 months	0.018	0.018	0.018	0.016	0.018
6 months	0.018	0.017	0.018	0.016	0.017
9 months	0.016	0.015	0.016	0.014	0.015
12 months	0.017	0.016	0.017	0.016	0.017

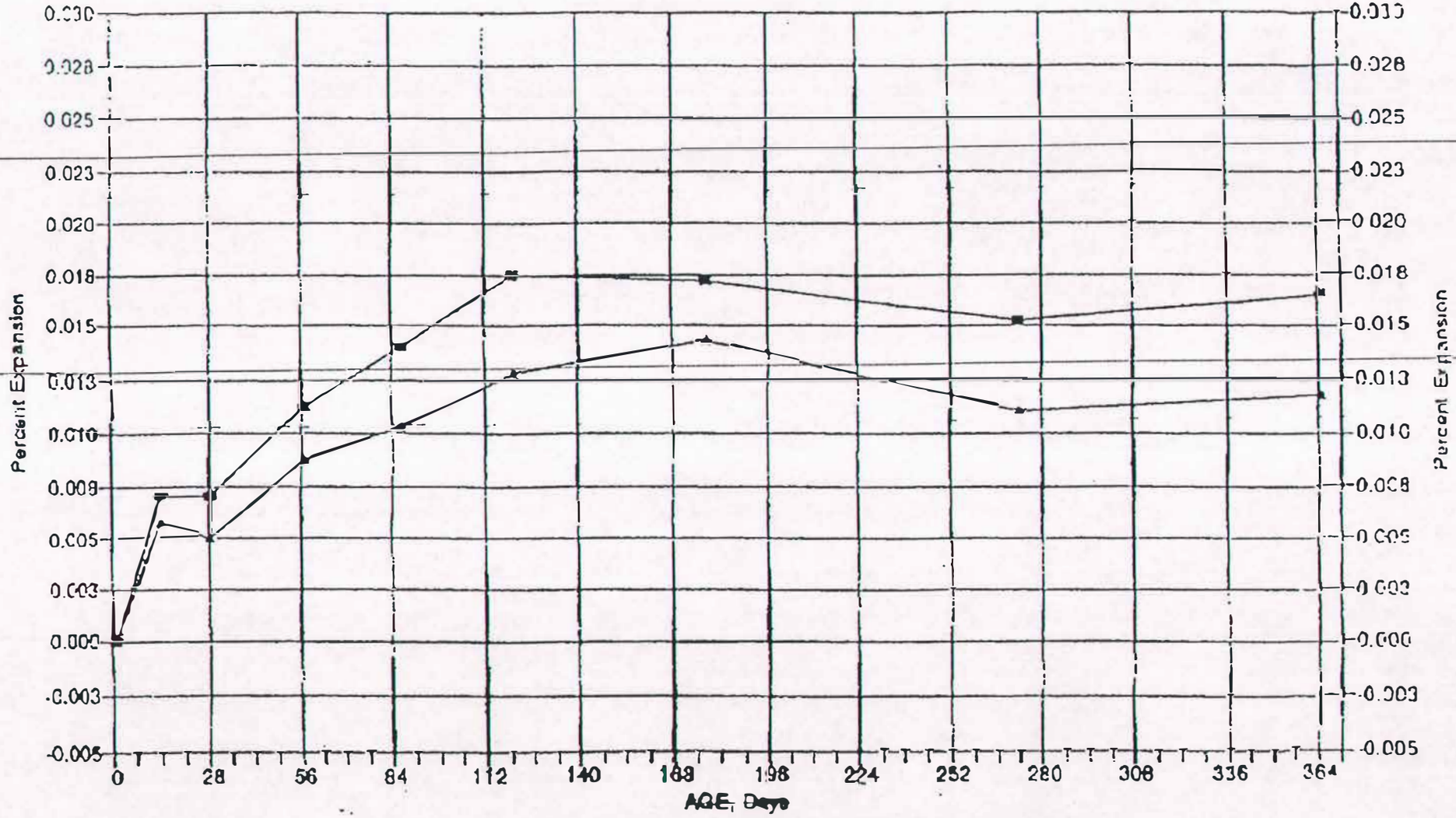
Note: The subject samples did not exhibit warping, surface cracking, or surface deposits during the testing.

REFERENCE MIXTURE					Batch Date: 2/21/94
Reading Age	Length Change, percent				Average Length Change, %
	A	B	C	D	
1 day	0.000	0.000	0.000	0.000	0.000
14 days	0.008	0.005	0.005	0.005	0.006
28 days	0.008	0.004	0.004	0.004	0.005
2 months	0.012	0.008	0.007	0.008	0.009
3 months	0.013	0.010	0.009	0.009	0.010
4 months	0.015	0.012	0.012	0.012	0.013
6 months	0.017	0.014	0.013	0.013	0.014
9 months	0.013	0.010	0.010	0.011	0.011
12 months	0.013	0.012	0.010	0.012	0.012

Note: The subject samples did not exhibit warping, surface cracking, or surface deposits during the testing.

ASTM C 227 TEST RESULTS
Carolina Stalite

FIGURE A



Note: Average of four bars per mixture

PREPARED BY LAW ENGINEERING
JOB NUMBER S820644001

STALITE REFERENCE

5/24/95 TLV

AXION A/S

08.01.97 | [illegible] | 1068 | K68

Oppdrag:
RAFISUNDET BRU

SIKTEKURVE STALITE 12mm (½")

Anm. KURVEN ER SAMMENSATT AV 10 SIKTEPRØVER FRA PRODUKSJON OVER CA 1 MNDR.
SIKTERESULTATENE ER MOTTATT FRA KAROLINA STALITE COMP. MERK X-X-X

Korn-diam. mm	Sikte-rest, gram	Sikte-rest. %

[redacted]

[redacted]

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THESE ARE TYPICAL GRADATIONS OF OUR 1/2 INCH "STALITE". THEY WERE TAKEN OVER A TIME OF APPROXIMATELY ONE MONTH.

SAMPLE #	GRADATION(PERCENT PASSING)				
SIEVE SIZE	3/4 (19mm)	1/2 (12.5mm)	3/8 (9.5mm)	#4 (4.75mm)	#8 (2.36mm)
1	100	91.3	52.9	6.7	2.9
2	100	92.6	54.1	6.6	3.3
3	100	92.9	56.7	7.1	3.1
4	100	93.0	53.3	5.5	3.5
5	100	92.0	46.0	3.7	1.2
6	100	93.2	51.0	3.9	2.4
7	100	92.1	48.5	3.5	1.5
8	100	91.6	59.8	8.2	5.9
9	100	92.6	52.8	2.8	1.9
10	100	93.6	52.2	4.1	2.5
AVERAGE	100	92.5	52.7	5.3	2.8

THIS MATERIAL IS PRODUCED TO COMPLY WITH ASTM C330

McHatty for Martin State Comp. 3.4.97

4/3

TABLE 1 Grading Requirements for Lightweight Aggregates for Structural Concrete

Size Designation	Percentages (by Weight) Passing Sieves Having Square Openings								
	1 in. (25.0 mm)	¾ in. (19.0 mm)	½ in. (12.5 mm)	⅜ in. (9.5 mm)	No. 4 (4.75-mm)	No. 8 (2.36-mm)	No. 16 (1.18-mm)	No. 50 (300-µm)	No. 100 (150-µm)
Fine aggregate				100	85–100	...	40–80	10–35	5–25
No. 4 to 0									
Coarse aggregate					0–10	...	...	...	
1 in. to No. 4	95–100		25–60						
¾ in. to No. 4	100	90–100		10–50	0–15	...	...	...	
½ in. to No. 4		100	90–100	40–80	0–20	0–10	...	...	
⅜ in. to No. 8			100	80–100	5–40	0–20	0–10	...	
Combined fine and coarse aggregate		100	95–100	...	50–80	...	...	5–20	2–15
½ in. to 0			100	90–100	65–90	35–65	...	10–25	5–15
⅜ in. to 0									

TABLE 2 Unit Weight Requirements of Lightweight Aggregates for Structural Concrete

Size Designation	Dry Loose Weight, max. lb/ft³ (kg/m³)
Fine aggregate	70 (1120)
Coarse aggregate	55 (880)
Combined fine and coarse aggregate	65 (1040)

TABLE 3 Weight of Sieve Test Sample for Fine Lightweight Aggregates

Range of Nominal Weight of Aggregate		Weight of Test Sample, g
lb/ft³	kg/m³	
5–15	80–240	50
15–25	240–400	100
25–35	400–560	150
35–45	560–720	200
45–55	720–880	250
55–65	880 –1040	300
65–70	1040–1120	350

plastic over the burlap will facilitate keeping it wet. Remove specimens from the molds not less than 20 nor more than 48 h after casting and store in a moist room maintained at 73.4 ± 3°F (23 ± 1.7°C) with a relative humidity of not less than 95 %. At the age of 7 days, remove the specimens from the moist room, measure for length, and store in a curing cabinet maintained at 100 ± 2°F (37.8 ± 1.1°C) with a relative humidity of 32 ± 2 %.

NOTE 4—The air immediately above a saturated solution of magnesium chloride ($MgCl_2$) at 100°F (37.8°C) is approximately 32 % relative humidity.

8.4.3 *Report*—After storage in the cabinet for 28 days, determine the change in length of each specimen to the nearest 0.01 % of the effective gage length. Report the change in length as the drying shrinkage of the specimen; report the average drying shrinkage of the specimens as the drying shrinkage of the concrete.

8.5 *Test for Popout Materials*—Prepare concrete specimens for the test for popout materials as described in method for preparation of samples for shrinkage of concrete. Cure and autoclave the specimens in accordance with Test Method C 151. Visually inspect the autoclaved specimens for the number of popouts that have developed on the surface. Report the average number of popouts per specimen.

8.6 *Test for Freezing and Thawing*—Make freezing and thawing tests of concrete, when required, in accordance with Test Method C 666.

8.7 *Grading (Method C 136)*—Follow the procedures of Method C 136, except that the weight of the test sample for fine aggregate shall be in accordance with Table 3. The test sample for coarse aggregate shall consist of 0.1 ft^3 (2830 cm^3) or more of the material used for the determination of unit weight. The aggregate, when mechanically sieved, shall be sieved for only 5 min.

8.8 *Unit Weight (Loose) (Test Method C 29)*—The aggregate shall be tested in an oven dry condition utilizing the shoveling procedure.

8.9 *Clay Lumps and Friable Particles in Aggregates*—Test Method C 142.

9. Rejection

9.1 Material that fails to conform to the requirements of this specification may be rejected. Rejection shall be reported to the producer or supplier promptly and in writing.

10. Certification

10.1 When specified in the purchase order or contract, a producer's or supplier's certification shall be furnished to the purchaser that the material was manufactured, sampled, and tested in accordance with this specification and has been found to meet the requirements. When specified in the purchase order or contract, a report of the test results shall be furnished.

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Stalite: Structural Aggregate Gradations

Size	Specific Gravity	Unit Weight (Dump Loose) Lbs/Cubic Foot (Kgs/Cubic Meter
3/4" to # 4	1.47 to 1.54	47 to 50 (750 to 800)

Sieve Size	% Passing
1" (25mm)	100
3/4" (19mm)	90-100
3/8" (9.5mm)	10-50
#4 (4.75mm)	0-15

1/2" to # 4	1.49 to 1.55	48 to 52 (770 to 830)

Sieve Size	*% Passing*
3/4" (19mm)	100
1/2" (12.5mm)	90-100
3/8" (9.5mm)	40-80
# 4 (4.75mm)	0-20
# 8 (2.36 mm)	0-10

3/8" to # 8	1.57 to 1.64	50 to 54 (800 to 865)

Sieve Size	*% Passing*
1/2" (12.5mm)	100
3/8" (9.5mm)	80-100
# 4 (4.75mm)	5-40
# 8 (2.36mm)	0-20
# 16 (1.18mm)	0-10

Fines For Structural Concrete	1.75 to 1.85	53 to 57 (850 to 910)

Sieve Size	*% Passing*
# 4 (4.75mm)	97-100
# 8 (2.36mm)	70-85
# 16 (1.18mm)	40-55
# 30 (600µm)	30-40
# 50 (300µm)	17-25
# 100 (150µm)	14-17

STALITE