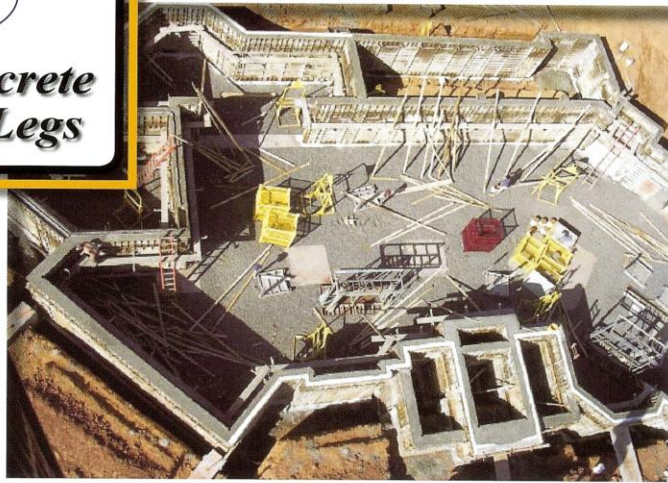


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## Five Part Series on the New TDOT 204.06 CLSM Specification

### Part 4: Sustainable CLSM Mixtures for 2006 TDOT 204.06

L. K. Crouch and Alan Sparkman

#### Introduction

This paper is the fourth in a five part series of technology transfer articles on the new 2006 TDOT 204.06 CLSM Specification (1). We hope you find the information presented helpful in producing CLSM mixtures meeting the new specification. In the fourth article, several examples of sustainable CLSM mixtures are presented. Further, the use of post-industrial byproducts in CLSM is encouraged in designing CLSM mixtures meeting the 2006 TDOT 204.06 Specifications. The final article in the series will address the future of CLSM in Tennessee.

#### Sustainable Development

“Sustainable Development” is a relatively new term to promote low environmental impact development. Sustainable development is more environmentally friendly or “green” compared to traditional development which is driven strictly by economic motives. Many references on the push for sustainable development are available. Sparkman (2) briefly described the LEED process in a Tennessee Concrete Winter 2005 article. Perhaps one of the best LEED references for concrete industry professionals is the Ready Mixed Concrete Industry LEED Reference Guide from the RMC Research Foundation, National Ready Mixed Concrete Association and the Portland Cement Association (3). The document, available as a free PDF download on the NRMCA website, is a comprehensive how to guide for qualifying for LEED points with concrete. To encourage sustainable development, LEED certified projects may receive tax incentives in many areas.

How does the 2006 TDOT 204.06 CLSM Specification affect sustainable development and the LEED process concerns? Three of the principal concerns for mixture proportioning for sustainable development are:

1. Reduction of greenhouse gas emissions by reducing the use of Portland cement;
2. Use of recycled or post-industrial byproducts;
3. Use of locally-available materials.

Table 1 shows performance-related property requirements of the 2006 TDOT 204.06 CLSM Specification. In addition, the 2006 TDOT 204.06 CLSM Specification allows the use of post-industrial byproducts such as Class C or F fly ash and ground granulated blast-furnace slag (GGBFS) as cementing materials. Further, the 2006 TDOT 204.06 CLSM Specification allows the use of aggregates with up to 20 percent passing the No. 200 sieve. As stated in Part 1, the applications for aggregates containing a high level (12-

Table 1. 2006 TDOT 204.06 Property Requirements

Performance-Related Property	General Use	Excavatable	Early Strength
Consistency	8" min.	8" min.	8" min.
Load application (ASTM D 6024) (4)	24 hours max.	24 hours max.	6 hours max.
Air content, if air entrained (ASTM D 6023) (5)		30% max.	30% max.
Compressive Strength @ 24 hours (ASTM D 4832)* (6)			30-psi min.
Compressive Strength @ 28 days (ASTM D 4832)*		30-psi min.	
Compressive Strength @ 98 days (ASTM D 4832)*		140-psi max.	

\* - may use 4x8 inch cylinder molds; preferred capping method is wet-suit neoprene in rigid retainers;

20%) of by-product fines are very limited. In the authors' opinion, such aggregates would qualify as post-industrial byproducts. The 2006 TDOT 204.06 CLSM Specification encourages innovation by allowing producers to select mixture proportions to achieve performance requirements. In a strictly economic sense, producers who can develop and deliver a CLSM mixture with lower material costs are rewarded with higher profits and/or additional market share. If a producer can develop and deliver a more sustainable CLSM mixture, the producer is rewarded with a “greener” image and a larger market share among customers with environmental concerns. It is important to note that if current government environmental initiatives continue, environmental concerns will become economic concerns.

#### Can CLSM Mixtures Likely to Meet the 2006 TDOT 204.06 CLSM Specifications be Sustainable?

Portland cement contents of many CLSM mixtures meeting the 2006 TDOT 204.06 CLSM Specifications are very low compared to traditional Portland cement concrete. All non-air-entrained CLSM mixtures known to the authors that meet the 2006 TDOT 204.06 CLSM Specifications contain large quantities of byproduct supplementary cementing materials. Further,

all CLSM mixtures known to the authors use locally available aggregates which constitute the majority of the CLSM mixture's mass and volume. The following paragraphs detail CLSM mixtures likely to meet the 2006 TDOT 204.06 CLSM Specifications which meet the three sustainability criteria.

*General Use Mixtures Likely to Meet 2006 TDOT 204.06 Specifications*

Table 2 shows the sustainability criteria for CLSM mixtures likely to meet the 2006 TDOT 204.06 General Use Flowable Fill requirements only. CLSM mixtures likely to meet other 2006 TDOT CLSM Specifications are not included in Table 2. The mixtures all have a high percentage of recycled supplementary cementing materials and a low percentage of Portland cement. However, no mixture shown in Table 2 has a percentage of post industrial byproducts greater than 15 due largely to the use of river sand (not a recycled aggregate).

**Table 2. Sustainability Criteria for CLSM Mixtures Likely to Meet the 2006 TDOT 204.06 General Use Flowable Fill Requirements**

Mixture	PC (lbs/CY)	Fly Ash (lbs/CY), Class of Fly Ash	Aggregate (lbs/CY), Aggregate Type	Water (lbs/CY)	Percentage of Recycled SCM by Weight of Total Cementing Materials	Percentage Post Industrial Byproduct by Total Weight
C2	0	510 C	2483 RS	530	100	14
C4	15	370 C	2656 RS	510	96	10
C5	15	440 C	2537 RS	530	97	12
C6	15	510 C	2445 RS	540	97	15
C8	30	370 C	2601 RS	526	93	10
C9	30	440 C	2507 RS	537	94	13
C10	30	510 C	2485 RS	520	94	14
C16	60	440 C	2500 RS	530	88	12
F3	30	440 F	2508 RS	491	94	13
F4	45	300 F	2603 RS	510	87	9
F5	45	370 F	2552 RS	499	89	11
F6	45	440 F	2499 RS	490	91	13

100% replacement of Portland cement by recycled supplementary cementing materials  
 ≥ 80% replacement of Portland cement by recycled supplementary cementing materials

*The TTU Top Ten Candidate CLSM Mixtures to Meet the 2006 TDOT 204.06 EFF Specifications*

Table 3 shows the sustainability criteria for the TTU top ten candidate CLSM mixtures to meet the 2006 TDOT 204.06 EFF requirements. The CLSM mixtures shown in Table 3 are also good candidates to meet the 2006 TDOT 204.06 General Use Flowable Fill requirements. All the mixtures containing fly ash except TDOT 95F have a percentage of recycled supplementary cementing materials greater than 80 and a low Portland cement content. Two mixtures shown in Table 3, TCA FScr and TCA CScr, have a percentage of post industrial byproducts of 85 or greater due to the use of high-fines limestone screenings as aggregate and a high percentage of fly ash.

**Table 3. Sustainability Criteria for the TTU Research Top Ten Candidate CLSM Mixtures to Meet the 2006 TDOT 204.06 EFF Requirements**

Mixture	PC (lbs/CY)	Fly Ash (lbs/CY), Class of Fly Ash	Aggregate (lbs/CY), Aggregate Type	Water (lbs/CY)	Percentage of Recycled SCM by Weight of Total Cementing Materials	Percentage Post Industrial Byproduct by Total Weight
F9	60	440 F	2492 RS	498	88	13
TCA FScr	45	370 F	2611 LS Screenings	448	89	86
C3	0	580 C	2417 RS	530	100	16
TCA C	45	370 C	2605 RS	520	89	10
C13	45	440 C	2538 RS	520	91	12
C15	60	370 C	2542 RS	539	86	11
AE 100	100	0	2316 RS	270	0	0
AE 150	150	0	2450 RS	340	0	0
TCA CScr	45	370 C	2700 LS Screenings	506	89	85
TDOT 95F	100	250 F	2800 RS	500	71	7

100% replacement of Portland cement by recycled supplementary cementing materials  
 ≥ 80% replacement of Portland cement by recycled supplementary cementing materials  
 ≥ 40% post industrial byproduct by total weight of mixture

*ESFF Mixtures Likely to Meet 2006 TDOT 204.06 Specifications*

Table 4 shows the sustainability criteria for CLSM mixtures likely to meet the 2006 TDOT 204.06 ESFF requirements. The CLSM mixtures shown in Table 4 are also good candidates to meet the 2006 TDOT 204.06 General Use Flowable Fill requirements. However, the additional expense involved with ESFF mixtures typically precludes their use as General Use Flowable Fill. None of the mixtures contain fly ash or GGBFS and thus have a percentage of recycled supplementary cementing materials of 0. One mixture shown in Table 4, Limestone Screenings ESFF, has a percentage of post industrial byproducts of 76 due to the use of high-fines limestone screenings as aggregate. Recent research at TTU shows that it is possible to design ESFF mixture likely to meet the 2006 TDOT 204.06 Specifications that contain high percentages of recycled supplementary cementing materials. Additional information will be provided in Part 5 – The Future of CLSM in Tennessee.

**Table 4. Sustainability Criteria for CLSM Mixtures Likely to Meet the 2006 TDOT 204.06 ESFF Requirements**

Mixture	PC (lbs/CY)	Fly Ash (lbs/CY), Class of Fly Ash	Aggregate (lbs/CY), Aggregate Type	Water (lbs/CY)	Percentage of SCM by Weight of Total Cementing Materials	Percentage Post Industrial Byproduct by Total Weight
River Sand	300	0	2425 RS	317	0	0
Limestone Screenings	350	0	2335 LS Screenings	375	0	76
Limestone Manufactured Sand	300	0	2582 LS Man. Sand	317	0	0

≥ 40% post industrial byproduct by total weight of mixture

**Designing a More Sustainable CLSM Mixture to Meet 2006 TDOT 204.06**

There is no currently available formal procedure for designing 2006 TDOT 204.06 ESFF mixtures. However, the following paragraphs provide some advice that may be helpful in producing “greener” CLSM meeting 2006 TDOT 204.06 Specifications.

TDOT CLSM aggregate specifications allow the use of a wide variety of aggregate types and gradations (see Part 1). Aggregate typically makes up 75 percent or more of the total weight of the mixture. The complete virgin aggregate replacement with a post industrial byproduct aggregate almost guarantees a high percentage of post industrial byproduct by weight of the total mix. A forty percent or higher recycled content by weight of the total mixture can even be achieved with a partial replacement of virgin aggregate with a post industrial byproduct. High-fines limestone screenings worked well in TTU research. Other aggregate replacement possibilities include foundry sands and some industrial slag. Be sure to consider availability and variability of the source as well as possible environmental repercussions such as harmful leachates and long term chemical reactions such as corrosion of embedded objects when considering a post industrial byproduct as a CLSM aggregate.

Replacement of Portland cement with recycled supplementary cementing materials (fly ash and GGBFS) should always be considered for CLSM since these materials help in at least three ways:

1. Meeting 2006 TDOT 204.06 performance-related property requirements;
2. Lower cost compared to Portland cement;
3. More environmentally friendly than Portland cement.

**Summary**

1. Think green, promote sustainable development. Project a green image to customers.
2. Be innovative, try new things. The 2006 TDOT 204.06 CLSM Specification promotes innovation.
3. Reap the rewards, make Tennessee a better place to live and work.
4. Reap the rewards, increase your market share with environmentally concerned customers (soon to be everyone).

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#### Author Information

L. K. Crouch, Ph.D., P.E. is a professor of Civil Engineering at Tennessee Technological University.

Alan Sparkman is the executive director of the Tennessee Concrete Association.



## Index of Advertisers

### ADMIXTURES

BASF/Master Builders	25
Grace Construction Products	21
Sicalco Ltd.	38

### AGGREGATES

Carolina Stalite Company	13
Tennessee Aggregate Company	7

### CEMENT

Cemex	15
Lafarge North America	15

### FIBER

Durafiber, Inc.	15
-----------------	----

### FLY ASH

The SEFA Group	5
----------------	---

### INSURANCE

BB&T	inside front cover
------	--------------------

### MATERIAL SUPPLIER

Clemons Concrete Coatings	38
---------------------------	----

### READY MIX PRODUCERS

Builders Supply Co.	38
imi-Tennessee	11
Memphis Ready Mix	27
Mid South Concrete	27
Ready Mix USA	14
Southern Concrete	7