STATE INTERAGENCY AGREEMENT ESTIMATED COST $350,000 AGREEMENT NUMBER: GCA6766	ORGANIZATION AND ADDRESS The STATE OF OREGON acting by and through the STATE BOARD OF HIGHER EDUCATION on behalf of OREGON STATE UNIVERSITY (OSU), hereinafter called the "RESEARCH AGENCY." 308 Kerr Administration Building Corvallis OR 97331-2140 Description of Work To perform research relating to Extended discharge time and revolution count for Cast-in-Place concrete.

THIS AGREEMENT is between the STATE OF WASHINGTON, Department of Transportation, hereinafter called the "WSDOT" and the STATE OF OREGON acting by and through the STATE BOARD OF HIGHER EDUCATION on behalf of OREGON STATE UNIVERSITY (OSU), hereinafter called "RESEARCH AGENCY."

WHEREAS, it is the purpose of this AGREEMENT to perform research relating to extended discharge time and revolution count for Cast-in-Place concrete, and

WHEREAS, WSDOT does not have the necessary expertise to perform such research and is interested in having the RESEARCH AGENCY perform the research, and

WHEREAS, the RESEARCH AGENCY has the necessary personnel and equipment to perform such research and has indicated its interest in performing the research,

NOW THEREFORE, pursuant to the statutes contained in chapter 39.34 RCW, and in consideration of the terms, conditions, covenants and performances contained herein, and the attached Exhibits "A" and "B" which are incorporated and made a part hereof, IT IS MUTUALLY AGREED AS FOLLOWS:

I
GENERAL

The RESEARCH AGENCY shall furnish the necessary personnel, equipment, material and/or service(s) and otherwise do all things necessary for or incidental to the performance of the work set forth in Exhibit "B" Problem Statement, Scope of Work, and Budget Estimate.

II- SCOPE OF WORK

WSDOT has requested and RESEARCH AGENCY has agreed to perform research relating to extended discharge time and revolution count for Cast-in-Place concrete. This work is further detailed in Exhibit "B," Problem Statement, Scope of Work, and Budget Estimate, attached hereto and by this reference made a part of this AGREEMENT.

III
PERIOD OF PERFORMANCE

This AGREEMENT shall become effective upon the date of execution below, and shall terminate on June 30, 2013, unless terminated sooner per Section IV, "TERMINATION," or modified as provided for in Section XVII, "AMENDMENT."

IV
TERMINATION

Either PARTY to this AGREEMENT may terminate this AGREEMENT upon thirty (30) calendar days prior written notification to the other PARTY. If this AGREEMENT is so terminated by WSDOT, WSDOT shall reimburse the RESEARCH AGENCY for actual direct and related indirect costs incurred and non-cancelable obligations as of the effective date of termination.

If the RESEARCH AGENCY terminates the AGREEMENT, then WSDOT shall reimburse the RESEARCH AGENCY for actual direct costs incurred as of the effective date of termination. Upon the effective date of termination, the RESEARCH AGENCY shall immediately turn over copies of all records, files and documentation, in whatever form or format, to WSDOT. The copies of these records, files and documentation shall become the property of WSDOT to use as needed or required to complete the scope of work and there shall be no restrictions or limitations on their use.

V
PAYMENT

It is estimated that the maximum cost to complete the scope of work is Three Hundred Fifty Thousand Dollars ($350,000). The payments to the RESEARCH AGENCY for accomplishing the work herein will be based on the RESEARCH AGENCY's actual direct and related indirect expenditures. WSDOT Payments for performance of the work shall not exceed $350,000 unless the PARTIES mutually agree, in writing, to a higher amount according to the conditions set forth in Section XVII of this AGREEMENT prior to performing any of the work to be covered by the proposed cost increase.

VI
BILLING PROCEDURE

The RESEARCH AGENCY shall submit invoices for expenses incurred on a quarterly basis, to

WSDOT Research Office
PO Box 47372
Olympia WA 98504-7372

Payments to the RESEARCH AGENCY will be made by warrant within thirty (30) calendar days of receipt of an adequately detailed and documented invoice and a progress report describing the details of the research to date and the details the research plan for the next quarter. Payments will be made to the Research Agency, for work performed under this contract, in accordance with Exhibit "B", Problem Statement, Scope of Work, and Budget. WSDOT will not be responsible for payment of any expenses which are not detailed in Exhibit "B" unless such expenses have been approved in advance, and in writing, by WSDOT. Final payment will be made upon successful completion of the project and receipt by WSDOT of copies of the final deliverables. Upon expiration of this AGREEMENT, any claim for payment, up to the maximum amount of this AGREEMENT, not already made shall be submitted within ninety (90) calendar days after this AGREEMENT's expiration date.

VII
RECORDS MAINTENANCE

During the progress of the work and for a period of not less than six (6) years from the date of final payment to the RESEARCH AGENCY, the records and accounts pertaining to the work and accounting therefore are to be kept available for inspection and audit by the WSDOT and/or the U.S. Government and copies of all records, accounts, documents or other data pertaining to the project will be available for review at the RESEARCH AGENCY's place of business during normal working hours. If any litigation, claim or audit is commenced, the records and accounts along with supporting documentation shall be retained until all litigation, claim or audit finding has been resolved even though such litigation, claim or audit continues past the six year retention period.

VIII
OWNERSHIP OF DATA / SOFTWARE

8.1 WSDOT reserves an irrevocable, royalty-free, non-transferable, non-exclusive right and license to use and reproduce all non- copyrighted or copyrighted material (including any computer software and its documentation or databases) first developed and delivered under this Agreement.

8.2 All reports published shall contain the following statement on the Credit Sheet: "The contents of this report reflect the views of the author(s) who is (are) responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the Washington State Department of Transportation. This report does not constitute a standard, specification, or regulation."

IX
SUBCONTRACTING

The RESEARCH AGENCY shall not subcontract for the performance of any work under this AGREEMENT without prior written permission of WSDOT. The inclusion of any subcontractor name, costs and duties in Exhibit "B" constitute written permission. No permission for subcontracting shall create between the WSDOT and the subcontractor, any contract or any other relationship. Signature execution of this AGREEMENT certifies the acceptance by WSDOT of the subcontractor already selected by RESEARCH AGENCY, if included in Exhibit "B." Additional subcontractors, if any are needed, will need prior written approval from WSDOT prior to beginning work under this AGREEMENT.

X
RESERVED

XI
PATENT AND INVENTION RIGHTS

Should patentable discoveries or inventions result from work described herein, the RESEARCH AGENCY shall maintain effective procedures to adhere to the provisions of Public Law 96-517 and to the implementing regulations of 37 CFR Part 401, including but not limited to the following:

1. The RESEARCH AGENCY shall disclose each subject invention to the WSDOT and make a written election within two years after disclosure whether it will retain title to the invention(s); agree to file a patent application; and include a statement that the invention was made with WSDOT and U.S. Government support.
2. In the event the RESEARCH AGENCY elects to retain title as described above, the RESEARCH AGENCY shall grant to the WSDOT and the U.S. Government a nonexclusive, irrevocable, nontransferable, paid-up license to practice or have practiced for or on their behalf, in perpetuity, any subject invention in the United States, its territories, and throughout the world and such additional rights as conferred by sections 202-204 of Title 35 United States Code.
3. The RESEARCH AGENCY shall include the following statement in the second paragraph of the specification of the application for any patents issued on a subject invention: "The United States Government and the State of Washington have a nonexclusive, irrevocable, nontransferable, paid-up license to practice or have practiced on their behalf, in perpetuity, any subject invention in the United States, its territories, and throughout the world and such additional rights as conferred by sections 202-204 of Title 35 United States Code."
4. The RESEARCH AGENCY shall provide the WSDOT with a list of all subject inventions or certification that there were no such inventions at the time of filing the final report as required by this AGREEMENT.
5. These patent and invention rights shall survive early termination of this AGREEMENT.

XII
DISPUTES

In the event that a dispute arises under this AGREEMENT, the PARTIES agree that before any legal action is initiated, the dispute shall be the subject of informal negotiation between the WSDOT and the RESEARCH AGENCY, or their designees, and/or the dispute shall be submitted to a neutral third party or parties for a recommended resolution. Each PARTY shall be responsible for its own costs, but the PARTIES agree that the cost of the third party or parties will be equally shared between WSDOT and the RESEARCH AGENCY.

XIII
REPORTS

1. The RESEARCH AGENCY shall submit to WSDOT a progress report on a calendar year quarterly basis. The progress reports are to be concise but in a sufficient detail to enable an evaluation of the progress of the Research project.
2. A final report of the findings and the results of the research, as well as draft report(s) shall be prepared by the Research Agency. The Research Agency shall furnish reports in the format prescribed by WSDOT. The "WSDOT Research Report Requirements" shall be used by the Research Agency as a guide for writing final and draft reports, and can be found at the web site: www.wsdot.wa.gov/research.
3. Research Notes are a two to four page summary of a research project, with the intent to make research results easily understood by a broad audience. The format can be found at the website stated in Section XIII.2. The Research Agency shall prepare a Research Note following the WSDOT approval of the Final Report.

XIV
LEGAL RELATIONS

To the extent permitted by law each PARTY shall defend, indemnify and hold harmless any and all other PARTIES this AGREEMENT, its officers, officials, employees, and/or agents from an against all claims, suits or actions arising from negligent acts or omissions of that PARTY, its officers, officials, employees, and/or agents while performing under the terms of this AGREEMENT. In the event of a claim for damages of any nature whatsoever arising out of the performance of this AGREEMENT caused by the concurrent actions of the PARTIES, their officers, officials, employees, and/or agents, each PARTY shall provide its own defense and be liable for damages, costs, fees or other amounts only to the extent of its individual actions that are the basis for the imposition of liability or damages. Further, RESEARCH AGENCY specifically shall defend and indemnify WSDOT against potential liability for actions brought by RESEARCH AGENCY'S employees or agents against WSDOT, and for purposes of this indemnity provision, expressly agrees to waive any immunity it may have under Title 51 RCW. Notwithstanding any other term of this Agreement RESEARCH AGENCY'S tort liability is subject to the conditions and limitations of the Oregon Constitution and the Oregon Tort Claims Act, ORS 30.260 through 30.300, and the Oregon Constitution, Article XI, Section 7.

The provisions of this section shall survive the termination of this AGREEMENT.

The RESEARCH AGENCY shall also comply with Title VI, Civil Rights Act of 1964 (Exhibit "A").

XV
INDEPENDENT CAPACITY

The employees or agents of each PARTY who are engaged in the performance of this AGREEMENT shall continue to be employees or agents of that PARTY and shall not be considered for any purpose to be employees or agents of the other PARTY.

XVI
THIRD PARTY REVIEW

Funding agencies outside of the WSDOT participating in the funding of this project, which may include the Federal Highway Administration or other federal, and Washington state agencies, shall have the right to participate in the review or examination of the work in progress.

XVII
AMENDMENTS

This AGREEMENT may be amended by mutual AGREEMENT of the PARTIES. Such amendments shall not be binding unless they are in writing and signed by personnel authorized to bind each of the PARTIES prior to beginning any of the scope of work to be covered by the amendment.

XVIII
TRAVEL

The WSDOT hereby approves proposed in-state travel expenses, and out-of-state travel expenses identified for the RESEARCH AGENCY in Exhibit "B". Any out-of-state travel which is not identified specifically, by purpose or event, date and location, in the proposal must have prior written approval of the WSDOT to be eligible for reimbursement.

XIX
NOTICE

Any notice provided for under this AGREEMENT shall be in writing and delivered to the following addressee:

If to WSDOT:

Director of Transportation Research
Research Office
PO Box 47372
Olympia WA 98504-7372

If to Research Agency:

Oregon State University
308 Kerr Administration Building
Corvallis OR 97331-2140

XX
SEVERABILITY

If any provision of this AGREEMENT or any provision of any document incorporated by reference shall be held invalid, such invalidity shall not affect the other provisions of this AGREEMENT which can be given effect without the invalid provision, if the remainder conforms to the requirements of applicable law and the fundamental purpose of this AGREEMENT, and to this end the provisions of this AGREEMENT are declared to be severable.

XXI
ALL WRITINGS CONTAINED HEREIN

This AGREEMENT contains all the terms and conditions agreed upon by the PARTIES. No other understandings, oral or otherwise, regarding the subject matter of this AGREEMENT shall be deemed to exist or bind any of the PARTIES hereto.

XXII
Exhibits

The following exhibits are included as part of this AGREEMENT:

Exhibit A, Title VI, Civil Rights Act of 1964
Exhibit B, Problem Statement, Scope of Work and Budget Estimate

IN WITNESS WHEREOF, the PARTIES hereto have executed this AGREEMENT as of the dater last signed by the PARTIES below.

The STATE OF OREGON acting by and through the STATE BOARD OF HIGHER EDUCATION on behalf of OREGON STATE UNIVERSITY (OSU)

By: Eric Z. Anundson
Printed Name Eric Z. Anundson
Title Grant and Contract Officer
Date: 8/24/11

STATE OF WASHINGTON DEPARTMENT OF TRANSPORTATION

By: J.C. Lenzi
J.C. Lenzi, P.E.
Chief Engineer
Date: 8/31/11

Approved as to form (date) 8-16-2011

By: Guy M. Bowman
Guy M. Bowman
Assistant Attorney General

Exhibit "A"

Title VI, Civil Rights Acts of 1964

During the performance of this AGREEMENT, the Consultant,* for itself, its assignees and successors in interest, hereinafter referred to as the "Consultant," agree as follows:

1. Compliance With Regulations: The Consultant will comply with the Regulations of the Department of Transportation relative to nondiscrimination in Federally-assisted programs of the Department of Transportation Title 49, Code of Federal Regulations, Part 21, hereinafter referred to as the Regulations, which are herein incorporated by reference and made a part of this AGREEMENT.

2. Nondiscrimination: The Consultant, with regard to the work performed by it after award and prior to completion of the contract work, will not discriminate on the ground of race, color, or national origin in the selection and retention of subcontractors, including procurements of materials and leases of equipment. The Consultant will not participate either directly or indirectly in the discrimination prohibited by Section 8.4 of the Regulations, including employment practices when the contract covers a program set forth in Appendix A-11 of the Regulations.

3. Solicitations for Subcontracts, Including Procurements of Materials and Equipment: In all solicitations either by competitive bidding or negotiation made by the Consultant for work to be performed under a subcontract, including procurements of materials or equipment, each potential subcontractor or supplier shall be notified by the Consultant of the Consultant's obligations under this contract and the Regulations relative to nondiscrimination on the grounds of race, color or national origin.

4. Information and Reports: The Consultant will provide all information and reports required by the Regulations, or orders and instructions issued pursuant thereto, and will permit access to its books, records, accounts, other sources of information, and its facilities as may be determined by the State Transportation Department or the Federal Highway Administration to be pertinent to ascertain compliance with such regulations, orders and instructions. Where any information required of the Consultant is in the exclusive possession of another who fails or refuses to furnish this information, the Consultant shall so certify to the State Transportation Department, or the Federal Highway Administration as appropriate, and shall set forth what efforts it has made to obtain the information.

5. Sanctions for Noncompliance: In the event of the Consultant's noncompliance with the nondiscrimination provisions of this contract, the State Transportation Department shall impose such contract sanctions as it or the Federal Highway Administration may determine to be appropriate, including, but not limited to:

a. Withholding of payment to the Consultant under the contract until the Consultant complies, and/or
b. Cancellation, termination or suspension of the contract, in whole or in part.

6. Incorporation of Provisions: The Consultant will include the provisions of paragraph (1) through (6) in every subcontract, including procurements of materials and leases of equipment, unless exempt by the Regulations, order, or instructions issued pursuant thereto. The Consultant will take such action with respect to any subcontract or procurement as the State Transportation Department or the Federal Highway Administration may direct as a means of enforcing such provisions including sanctions for noncompliance. Provided, however, that in the event the Consultant becomes involved in, or is threatened with litigation with a subcontractor or supplier as a result of such direction, the Consultant may request the State to enter into such litigation to protect the interest of the United States.

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* Note: Any references to "Consultant" should read to mean "Research Agency."

EXHIBIT "B"

1 INTRODUCTION AND PROBLEM STATEMENT

The performance and economy of our infrastructure is dependent on specifications used to construct the infrastructure. Specifications that place restrictions on material suppliers and/or contractors can increase construction costs, but these additional construction costs often increase the likelihood of improved performance or safety, thereby reducing the overall life-cycle costs. It has been well established that lower life cycle costs are advantageous to the traveling public and taxpayers (Amelio and Van Geem 2000, Val and Steward 2003, Trejo and Reinschmidt 2007). However, not all specifications can be correlated with performance. These specifications are typically older specifications and often remnants of past prescriptive specifications. Specifications that do not provide improved performance or safety can result in higher costs with limited or no benefits, limiting the value of these specifications.

Ready mix (also referred to as ready mixed) concrete is used for many infrastructure systems. Specifications for the manufacture, transport, and placement of concrete have been established for some time. The manufacture of concrete consists of establishing a mixture proportion for the concrete and mixing the constituent materials to form a uniform concrete mixture. This concrete mixture can be mixed in central mixers, in trucks, or with a combination of both (referred to as shrink mixed concrete). Because the mixing process can influence the workability and longer-term performance characteristics of concrete, historical and existing specifications place limits on the mixing process. However, these limits were based on general assumptions using materials seldom used in today's concrete. This research proposes to identify and quantify concrete manufacturing variables, specifically time and the number of concrete truck drum rotations that influence the workability and performance of concrete mixtures used in the State of Washington.

Existing specifications from the Washington State Department of Transportation (WSDOT), the American Society for Testing and Materials (ASTM), and the American Association of State Highway and Transportation Officials (AASHTO) provide similar specification requirements for mixing and agitating truck mixed concrete. Table 1 shows a general overview of mixing requirements from the WSDOT Standard Specifications for Road, Bridge, and Municipal Construction (January 2010), the WSDOT Construction Manual (January 2011) and the ASTM C94 – 09a, Standard Specification for Ready-Mixed Concrete. AASHTO M157, Standard Specification for Ready-Mixed Concrete, also addresses mixing and delivery for concrete and these requirements are similar to the ASTM requirements. Figure 1 shows placement limits as a function of time and temperature for the WSDOT specifications (ASTM C94 specifications have minimum placement temperatures dependent on section size – larger section sizes allow lower temperatures). Although there are some differences in the WSDOT and ASTM/AASHTO standards, what is notable is that limits are placed on minimum and maximum truck drum rotations and placement times.

Placing limits on concrete mixing and placement can present challenges to contractors, especially when longer transport distances are required. Lobo and Gaynor (2006) noted that except for very soft aggregates, the revolution limits for mixing concrete is of "no practical consequences." The authors also noted that these limits were developed long ago when mixers were powered with separate

engines that had only one slow mixing speed (6 rotations per minute [rpm]). Central plants and truck mixers have the capabilities to mix concrete constituents at significantly different speeds than the older mixers. The National Ready Mixed Concrete Association (NRMCA) approves the use of concrete truck mixers and WSDOT requires that trucks be certified by NRMCA. The NRMCA Truck Mixer Manufacturers Bureau [TMMB] 100-05 Standard (2009), Truck Mixer, Agitator and Front Discharge Concrete Carrier, requires that mixing speeds be in the range from 6 to 18 rpm and the agitating speed be not more than 6 rpm. The plant certification requires that truck mixers contain a plate showing mixing speeds and that these mixing speeds are in the range of 4 to 22 rpm. Existing equipment is significantly different than the equipment used when the limits on drum rotations and mixing times were initially developed and research is needed to determine influence of mixing variables on workability, constructability, and longer-term performance of concrete.

Table 1 Concrete mixing specifications.

Mixing Type	Agency Specification for Mixing Concrete							
	WSDOT (for concrete structures)				ASTM C94			
	Min Truck Revs.	Max Truck Revs.	Min Mix Time	Max Mix Time	Min Truck Revs.	Max Truck Revs.	Min Mix Time	Max Mix Time
Central Mixed	--	250[1]	1 min.	Typically 1.5 hrs.[2]	--	300 or max time	Capacity dependent[3]	1.5 hrs or max revs
Shrink Mixed	70 at mixing speed	320 total (mixing and agitation)	30 sec in stationary mixer + truck mixing	Typically 1.5 hrs.[2]	Must meet uniformity requirements	300 or max time	Must meet uniformity requirements	1.5 hrs or max revs
Truck Mixed	70 at mixing speed	320 total (mixing and agitation)	--	Typically 1.5 hrs.[2]	70 – 100 and must meet uniformity requirements	300 or max time	Must meet uniformity requirements	1.5 hrs or max revs

1. 2010 Standard Specifications; p. 6-9; if water or admixtures are added after initial mix an additional 30 revolutions are required.
2. Time is dependent on concrete temperature. See Figure 1.
3. Mixing time is 1 minute plus 0.25 minutes multiplied by the mix capacity (cubic yds) – 1) or per performance specifications

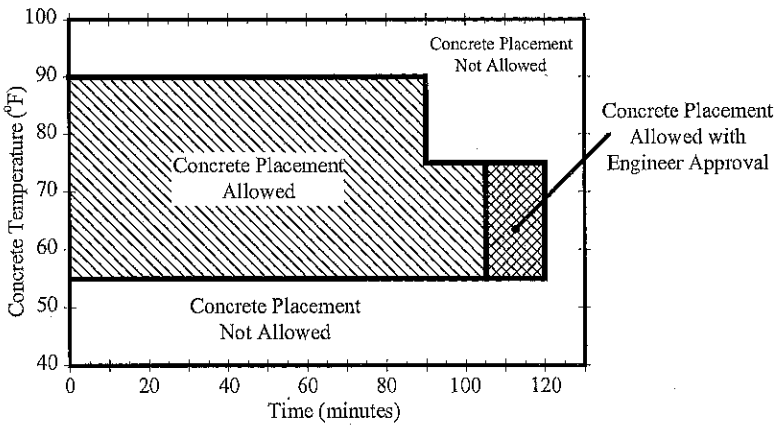


Figure 1 Limits for placement of concrete as specified by WSDOT.

In addition to changes in equipment, significant changes in concrete constituent materials have occurred over time. Although production of aggregates and cements are manufactured using similar methods from years past, smaller maximum size aggregate (MSA) is now required, aggregate sources have changed, alternative fuels are used for cement production, and cements are ground finer. However, the most significant change in constituent material is the newer admixtures that are used in concrete.

In 1916 the first self-discharging motorized concrete mixer was developed. However, good mixing of concrete was limited due to the poor quality and low power of the trucks available at the time. As a result of these limitations, ASTM published the first C94 specification in 1935, which required that the concrete be discharged within 1.5 hours after mixing (the limits on drum rotations was believed to be added later). After WWII, heavier trucks with more powerful engines were available, making concrete production easier and more consistent. However, work still continued on improving the setting time and workability of concrete. Water-reducing agents were being used in the 1960's and superplasticizers were developed in the 1970s (California State Water Project 1964; Mehta and Monteiro 1993). In the 1990's polycarboxylate based admixtures became more popular than the naphthalene and melamine based products. In addition, more powerful set controlling admixtures were developed. Although significant improvements in equipment and admixtures have occurred, the requirements in the specifications have not been modified to recognize these changes. In fact, a short search of the literature indicates limited research has been performed to assess how materials perform when mixed with modern equipment and if the original requirements of ASTM C94 are still applicable. Following is the team's current thinking on how to systematically identify material and mixing variables that influence the workability, constructability, and performance of concrete mixtures.

2 RESEARCH OBJECTIVES AND SCOPE OF WORK

Most specifications for the mixing, transportation, and placement of concrete place limits on the number of drum rotations and the time to discharge. These limits have been in place to help ensure the quality and performance of the finished concrete product. However, significant changes in both constituent materials and equipment have occurred since these limits were initially developed. If these limits do not correlate with workability, constructability, and performance, unnecessary constraints are placed on suppliers and contractors, which can lead to undue risks and high construction costs. Therefore, the objectives of this research are to determine if existing limits in the WSDOT specifications are applicable to typical concrete mixtures used in the State of Washington and if not, to identify key material, environmental, and/or mixing variables that can be used to ensure good concrete workability, constructability, and performance (mechanical and durability).

The scope of the proposed work will include collecting information from concrete suppliers and WSDOT personnel in the State of Washington, assessing the influence of time, temperature, and mixing revolutions (far beyond the existing limits) on the fresh material characteristics, assessing the hardened mechanical properties and durability characteristics of the concrete, and then developing recommendations to ensure the quality of concrete. This research cannot evaluate all constituent

materials, environments, and mixing procedures used in the State of Washington. Representative materials and mixing processes will be identified and evaluated under specific environmental conditions such that general mixing and transportation guidelines and limits for concrete can be developed.

3 PROPOSED RESEARCH PROGRAM

When water and cement are introduced a complex set of chemical reactions occur that result in time dependent changes to the cement-water system. These chemical reactions between the water and cement, also termed hydration, initially result in stiffening of the concrete and later contribute to the strength development and durability of the concrete. The quality of the concrete is dependent on the constituent materials in the concrete mixture, the temperature of the concrete materials and surrounding environment, and the manner in which the concrete is processed and placed. The Portland Cement Association (2002) reports that excessive mixing of concrete can lead to excessive temperature rise, loss of entrained air, lower strengths, and higher slump loss. These characteristics, and others, will be investigated.

The research team will perform this research in four distinct phases. Phase 1 will include procurement and characterization of the materials that will be used in the research program. Phase 2 will be performed in two tasks. The objective of the first task (Phase 2 – Task 1) is to perform a general assessment to identify material, mixture, or environmental characteristics that, upon longer mixing times or mixing revolutions, may affect some general fresh or hardened characteristics of the concrete. This phase will be followed by a second task (Phase 2 – Task 2) that will investigate fewer materials, mixtures, and environmental conditions but will investigate a larger number of fresh and hardened concrete characteristics. Following Phase 2, a field assessment (Phase 3) will be performed to correlate the laboratory findings with the field findings. Phase 4 will include analysis of the results and documentation of the research findings. A detailed description of each phase and task follow.

3.1 Phase 1 - Material Procurement and Characterization

The objective of this research project is to determine if mixing time and number of truck drum revolutions influence the characteristics and properties of concrete. Concrete is made from a wide variety of constituent materials under various environmental conditions and these variables can affect the characteristics and properties of the concrete. In an ideal world researchers would mix all different material combinations (aggregate types, aggregate sizes, cements, supplementary cementing materials (SCM), admixtures, and even water) in actual concrete mixing trucks under different environmental conditions for varying times and drum revolutions and would then assess the effect of these variables (material types, truck types, environmental conditions, mixing times, drum revolutions, etc.) on the constructability, mechanical properties, and durability characteristics of the concretes. However, what if the researchers proposed to perform all the research in the field at three different temperatures and during the research project the state experienced lower than normal temperatures and the highest temperature could not be assessed? The fact is our world is not ideal and time, budget, and reality constraints require that a systematic and cost-effective approach be

taken to achieve the goals and objectives of the research.

Phase 1 of this research will include the procurement and assessment of materials that will be used in the research project. Initial meetings with WSDOT personnel concluded that the WSDOT personnel will work with the Washington Aggregates and Concrete Association (WACA) to identify potential aggregate sources that can be used in the research. The research team proposes to perform initial testing on 15 to 18 different sources of materials. Materials will be identified initially by WSDOT personnel (through WACA) and then the researchers will arrange for the procurement and transport to the laboratories at Oregon State University. After receiving the materials at the laboratories, materials will be characterized.

Table 2 shows possible material characterization tests. An oxide analysis of the cement will be obtained from an independent lab and the chemistry of the mixing water will be determined. The admixtures used in the research will be described based on manufacturer's data and available information. When available, material characteristics reported in the aggregate source approval (ASA) or provided by the producer will be used for characterizing the materials. It is anticipated that this phase will take 2 to 3 months.

Table 2 Possible test procedures

Material Characteristic	Test Standard
Aggregate Bulk Density	ASTM C29, *Standard Test Method for Bulk Density ("Unit Weight") and Voids in Aggregate*
Aggregate Absorption	ASTM C127, *Standard Test Method for Density, Relative Density (Specific Gravity), and Absorption of Coarse Aggregate*
Aggregate Size Distribution	ASTM C136, *Standard Test Method for Sieve Analysis of Fine and Coarse Aggregates*
Aggregate Abrasion Resistance[1]	ASTM C131, *Standard Test Method for Resistance to Degradation of Small Size Coarse Aggregate by Abrasion and Impact in the Los Angeles Machine*
Setting Time of Cement	ASTM C191, *Standard Test Method for Time of Setting of Hydraulic Cement by Vicat Needle*

1. This test may be performed and testing will be dependent on test costs.

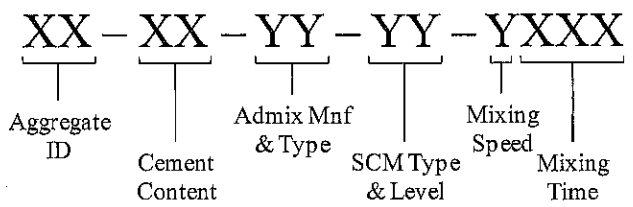
3.2 Phase 2 Experimental Laboratory Test Program

The experimental research will consist of two tasks – one task assessing the affect of several material types and proportions, environmental conditions, mixing time, and drum revolutions on a select number of early-age and hardened concrete characteristics. This approach allows for an assessment of a large number of materials and conditions such that variables in these materials and conditions can be identified and further assessed in the Task 2 test program. Task 2 will assess a fewer number of materials, mixtures, and conditions but will focus on variables that were identified in Task 1 as influencing the early-age and hardened characteristics of the concrete. The following sections provide the research team's current thinking on the laboratory testing tasks.

3.2.1 Phase 2 – Task 1 General Laboratory Investigation

After materials have been procured and assessed, the researchers will evaluate the fresh characteristics and hardened mechanical properties of a larger number of materials from Washington.

The researchers will assess a Class 4000 concrete mixture. The investigation will use one type of cement and the conditions shown in Table 3. This test plan will assess the influence of aggregate type, cement quantity (and aggregate quantity), chemical admixture manufacturer, admixture type, SCM replacement level, and temperature on the characteristics of concrete mixed at different times and drum revolutions. The mixtures will be identified as follows:



where X's are digits and Y's are letters. The two digit aggregate ID will be correlated with ASA numbers (01 through 13), cement content will identify the weight percent of cement in the concrete mixture, the admixture manufacturer will use the first letter of the manufacturer and the type will include either A for air-entraining admixture (AEA), H for high range water reducer (HRWR), or R for retarder, SCM type will be either F for fly ash or S for slag and the SCM levels will be 0, 1, or 2 (representing none, moderate replacement, and high replacement levels), mixing speed will be L for low or H for high, and mixing time will be the number of minutes mixed. Therefore, a mixture identification of 05-15-BA-F2-L300 would be for a mixture containing aggregate 5 with 15% weight percent cement containing and air-entraining admixture from manufacturer B, containing a high volume of fly ash that was mixed at low speed for 300 minutes.

Table 3 Proposed experimental plan for Phase 2, Task 1

Aggregate Source	Cement Content	Chemical Admixture Manufacturer			Fly Ash/Slag Replacement Level	Mixing Time (min.)		Temperature
		HRWR	AEA	Retarder		@ moderate rpm	@ high rpm	
1 - 12	Moderate	None	None	None	None	15, 30, 60, & 150	60 & 150	~70 °F
13	Low, Moderate, High	None	None	None	None	15, 30, 60, & 150	60 & 150	~70 °F
13	Moderate	Manf. A & Manf. B	None	None	None	15, 30, 60, & 150	60 & 150	~70 °F
13	Moderate	None	Manf. A & Manf. B	None	None	15, 30, 60, & 150	60 & 150	~70 °F
13	Moderate	None	None	Manf. A & Manf. B	None	15, 30, 60, & 150	60 & 150	~70 °F
13	Moderate	None	None	None	Moderate and High Fly Ash Levels	15, 30, 60, & 150	60 & 150	~70 °F
13	Moderate	None	None	None	Moderate and High Slag Levels	15, 30, 60, & 150	60 & 150	~70 °F
13	Moderate	None	None	None	None	15, 30, 60, & 150	60 & 150	~70 °F & ~90 °F

The fresh characteristics of all mixtures will be assessed for slump (ASTM C143), slump loss, air content (ASTM C231), and unit weight (ASTM C231) and visual observations will be recorded for each mixture. The 28- and 56-day compressive strength values (ASTM C39) will be assessed for each mixture and select mixtures will be assessed for freeze-thaw performance (ASTM C666) and chloride transport (ASTM C1556). The setting time and temperature of all concrete mixtures will be assessed following ASTM C403 and ASTM C1064, respectively. When applicable, mixing will follow ASTM C192, Standard Test Method for Making and Curing Concrete Test Specimens in the Laboratory. The researchers will assess the initial set time of the different mixtures and mix for as long as possible without allowing the concrete to set in the mixer (some mixing times may have to be changed based on results from the setting time studies).

3.2.2 Phase 2 – Task 2 Detailed Laboratory Investigation

Following the Phase 2, Task 1 investigation, the research team will assess the results and identify variables that influence the fresh and hardened characteristics of concrete mixed for different times and drum revolutions. Knowing these variables, the researchers will generate a comprehensive research plan to further assess the influence of these variables on a wide variety of properties and characteristics. It is anticipated that approximately 6 mixtures will be selected for the detailed laboratory study. The research team's current thinking is to evaluate compressive strength (ASTM C39) at 7, 28, and 56 days, modulus of elasticity (ASTM C469) at 28 days, modulus of rupture (ASTM C78) at 28 days, splitting tensile strength (ASTM C496) at 7, 28, and 56 days, and length change following ASTM C157. Tests for durability will likely include characterizing the air void system in accordance with ASTM C457, the diffusivity of the concrete following ASTM C1556, rapid chloride permeability following ASTM C1202, and freeze-thaw performance following ASTM C666. A more detailed plan will be developed after the Phase 1 results have been analyzed. Phase 2 is anticipated to take approximately 16 months.

3.3 Phase 3 Field Assessment

To validate the laboratory findings, the research team will work with a concrete plant in the State of Washington. A concrete mixture proportion similar to a mixture used in the laboratory program will be mixed in a central mixer and placed in a concrete mixer truck. Sampling from the truck will occur after predetermined revolutions (similar to those tested in the laboratory phase). Throughout the field testing, temperature of materials, mixers, and environmental conditions will be carefully monitored. Slump, slump loss, concrete temperature, and air content will be assessed for each sampling. Specimens will also be fabricated to assess the compressive strength, modulus of elasticity, air-void system, freeze-thaw performance, and the chloride diffusivity. It is anticipated that this task will take 2 months.

3.4 Phase 4 Data Analysis and Documentation of the Research Findings

The statistical analysis will be performed to identify the influence of the material characteristics, processing variables, and temperature on early-age characteristics, mechanical properties, and durability characteristics. Using the test results and standard statistical analysis techniques, the

research team will identify correlations between mixing processes and temperature such that value-adding recommendation for specifications can be provided. It is anticipated that this task will take 2 months.

This project will result in publications of the research findings in leading journals. The research findings will also be documented in a final report. It is anticipated that the report will include a description of the overall project and objectives, test procedures used, project data, findings on the influence of mixing variables and temperature on the early-age and hardened characteristics, and recommendations from the research. The research team will provide recommendations on the discharge time and maximum number of revolutions, if needed, and will provide a draft specification.

The research team also realizes that performance specifications come in a wide variety of forms and are dependent on many conditions. For example, it is often more difficult for smaller producers to participate in projects with performance specifications because these smaller producers are reluctant or unable to bear the risks. If draft performance specifications are deemed appropriate and assuming that all producers can participate, it is important that measurable performance indicators are assessed and correctly sampled. In addition, there is usually some type of payment multiplier associated with performance specifications, where the multiplier is dependent on an individual or set of performance indicators. Therefore, the performance indicator must be measureable in a reasonable amount of time after the product is placed.

The research team will work with WSDOT personnel to outline specifications based on the research outcomes. Because suppliers and contractors will use these specifications, it will likely be beneficial to include these groups in the development and revision of these specifications as poorly developed and/or written specifications often lead to ambiguity in expectations and higher construction costs. Understanding the concerns of these groups can also result in better specifications.

The research report will clearly and comprehensively document all aspects of the research program. It is anticipated that this task will take approximately 3 months.

4 REFERENCES

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5 Education and Experience Qualifications of the Researchers

If successful in procuring this research, David Trejo will be the principal investigator. David has a B.S., M.S., and Ph.D. in Civil Engineering from the University of California at Berkeley (1991, 1993, and 1997). Prior to returning to school David spent approximately 8 years in the construction industry operating heavy equipment. David spent almost 12 years on the faculty at Texas A&M University where he was promoted first to Associate Professor and then to full Professor. He was also Division Head for the Constructed Facilities Division at the Texas Transportation Institute from 2005 to 2009. In 2009 David accepted the Construction Education Foundation Endowed Chair (now the Hal D. Pritchett Endowed Chair) in the School of Civil and Construction Engineering at Oregon State University. David's research focuses on the constructability and performance of construction materials, with specific focus on concrete materials. He has procured over $7 million in research and participated or led over 15 research projects. These projects have been funded by FHWA, Texas Department of Transportation, NASA, the National Cooperative Highway Research Program, and other organizations. David is also the Associate Editor for the ASCE Journal of Civil Engineering Materials and has been a member of two NAE teams focusing on durability of materials.

Jason Ideker will consult with the research team as needed. Jason earned his B.S. from the Georgia Institute of Technology in 2002 and his M.S. and Ph.D. from the University of Texas at Austin (2004 and 2008). Jason has procured several research projects on cementitious systems since joining the faculty in the School of Civil and Construction Engineering at Oregon State University in 2008.

Young Hoon Kim is a post-doctoral scholar in the School of Civil and Construction Engineering at Oregon State University. He earned his B.S. and M.S. from Korea University and a Ph.D from the Zachry Department of Civil Engineering at Texas A&M University (2008). His research interests are performance of concrete materials and structures.

The team is well qualified to perform the research and has significant research experience in concrete materials research.

6 Proposed Budget and Justification

Funding is being requested to perform the proposed research described in this document. The PI has requested 1.5 months for each year. A post doctoral scholar will be funded on the project for ½ time. A graduate student researcher will also work on the project at 49% effort for the duration of the project. In addition, 2 undergraduate researchers will be hired for the first year and 1 undergraduate researcher will be hired for the second year. These time commitments are appropriate for a research project that includes significant testing, as is the case with the proposed research. The research team has requested funding for supplies and materials to carry out the research. Although supplies are available, due to the large number of specimens that will be fabricated, additional supplies will be required. It is anticipated that a concrete mixer, forms for the specimens, and other miscellaneous supplies will be needed to perform the research. Costs for materials and transportation of these materials have been included. Although the material and transportation costs are not yet known, an estimated costs has been included. If organizations provide these materials at no cost, the funds will be used to purchase additional supplies, as the availability of these will control the research schedule. Funding has also been requested to travel to the State of Washington – this travel may include visits to the sponsor, visits to material suppliers, visits to concrete producers, or visits to collect information required for the project. All proposed costs are reasonable and necessary to perform the proposed research.

Budget Period: July 1, 2011 to June 30, 2013

PROPOSED BUDGET			
	Year 1	**Year 2**	**Cumulative**
Salaries	$87,114	$77,593	$164,707
Fringe Benefits	$13,263	$14,130	$27,393
Tuition Remission	$14,528	$15,690	$30,218
Consultants	$0	$0	$0
Equipment	$0	$0	$0
Supplies & Materials	$15,250	$4700	$19,950
Travel	$4221	$2757	$6978
Other Expenses	$0	$0	$0
Total Direct Costs	$134,377	$114,870	$249,246

Total Indirect Costs	$55,130	$45,623	$100,753

Total Costs Requested	$89,507	$160,463	$350,000