Determination of Material Properties and Deflection Behaviors for Contemporary Prestressed Beam Design

by

Michael Berry
Assistant Research Professor, Montana State University

Brian Kukay
Assistant Professor, Montana Tech

Jerry Stephens, Montana State University
Professor/Research Director

Charles Todd
Professor, Montana Tech

Western Transportation Institute
Montana State University and Montana Tech

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Montana Department of Transportation
2701 Prospect Avenue
P.O. Box 201001
Helena, MT 59620-1001

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PROBLEM STATEMENT

Full realization of the economies offered by prestress concrete girder bridges is being adversely affected by our limited knowledge of the specific properties of the concrete used in their construction, and our associated inability to accurately predict their deflections. These two related issues impede the use of more cost-effective designs, resulting in more conservative and costly structures, and/or issues with their serviceability. Both of these issues are particularly significant when a bridge is being replaced using phased construction, a process used to accommodate traffic during the construction period. The proposed research will provide the Montana Department of Transportation (MDT) design engineers with the data necessary to directly address these issues.

BACKGROUND SUMMARY

Prestress concrete beams have been commonly used in bridges since the late 1950s. They have proven to be cost effective, offering good structural performance and generally requiring low maintenance. With improved design procedures and materials, the range of spans for which they can be used and the economy they offer have increased. That being said, prestress concrete beams have always presented some added challenges in bridge design and construction, as their behavior is both time and stress level dependent. Often, several assumptions need to be made in predicting this behavior, and thus obtaining the desired roadway profile in the finished product can be uncertain. Nonetheless, a proper profile is important for the ride of a bridge and also can impact its long-term performance.

The proper deck profile is obtained by adjusting the deck forms and finishing equipment prior to concrete placement based on the desired profile and the predicted immediate and long-term deflection behavior of the bridge. The deflection behavior of the bridge up through deck placement is controlled by the properties of the beams. The long-term behavior is controlled by the combined properties of the beams and the deck. Understanding the properties of the materials in the beams and the deck is necessary for predicting the deflection behavior of the bridge and producing a quality bridge product.

Prestressed concrete analysis and design involves elastic and non-elastic properties. The elastic properties are fairly easily determined and applied in analysis. The non-elastic properties are time and stress-level dependent. These non-elastic properties are more difficult to determine and apply in analyses.

Historically, the elastic properties of the concrete predominated the overall behavior of prestress beams for construction purposes. Modern design uses higher levels of prestress force and allows higher levels of stress in the concrete. The result is that the non-elastic properties are becoming more important in predicting bridge behavior. Additionally, the demands of current projects often result in constructing bridges in phases to maintain traffic. During Phase 1 of construction, traffic is maintained on a portion of the original structure, while a portion on the new bridge is built. During Phase 2 of construction, traffic is shifted to the new portion of the bridge constructed in Phase 1, and reconstruction of the remainder of the bridge is completed. Phased construction increases the need to better understand the non-elastic properties of the beams, as these properties significantly affect the differential deflections the beams can experience between the two phases of construction.

Prestress beams deflect both upward and downward. The prestressing force is intended to counteract the gravity loads, and this force causes the beams to bend upward. Other loads, like the weight of the deck, cause the beams to bend downward. Over time, the bending of the beams change, both upward and downward, based on when the loads are applied, the magnitude of the loads, and the non-elastic properties of the concrete. With older design constraints, the upward and downward bending deflections tended to approximately cancel out. Errors in predicting the deflection behavior would rarely affect the quality of the end product.

Modern design procedures allow for safe designs where these upward and downward deflections are no longer as close to being balanced. The predicted imbalance in deflections may range up to as much as 6 inches over the first few years of the bridge's life. In addition, there is a large uncertainty in this predicted imbalance. For example, a predicted 6-inch difference may actually represent a range of 2 to 6 inches in final deflection imbalance.

A large imbalance in final deflections can be accounted for in design and construction when that imbalance can be reasonably predicted. The current level of uncertainty of the predicted deflection, however, is an issue that hampers implementation of more cost-effective designs. This uncertainty may result in more conservative and costly prestress concrete designs, selection of more expensive materials, or a poor quality end product. As previously mentioned, this issue is particularly significant when a bridge is constructed in phases to allow traffic to be maintained during construction, which has become a common requirement on many projects.

Other states that have or are studying the concretes used in their prestress girders and the subsequent deflections of these girders over time include Texas, Utah, and Washington. The Texas study is focusing on accurate estimates of initial cambers of several prestressed concrete beams fabricated at various plants in Texas (Texas DOT, 2011). On a related note, the modulus of elasticity expression and local material correction factors were the focus of a Utah DOT study (Barr et al., 2009). A Washington study focused on calculating camber as a function of time (Rosa, Stanton, and Eberhard, 2007). Here, instantaneous and time-dependent behavior of the concrete and steel were accounted for. While these studies offer useful methodologies and results that are of interest for comparative purposes, they do not preclude the need for this research, which will specifically be conducted for materials and construction and design practices used in Montana.

BENEFITS AND BUSINESS CASE

This project will provide MDT with important data on concrete material properties and beam deflection behaviors that will be used to move forward with new and more cost-effective prestress concrete bridge designs. Changes in materials, refinements in design, and modifications in standard practices have made it possible to use precast concrete bridge beams for longer spans and with less material than was previously possible. These beams, however, optimized with respect to strength and safety performance, exhibit different deflection behaviors than their traditional counterparts, and it has been found that accurately predicting their deflections over time is more critical to ensuring their total performance than previously was the case.

Notably, knowledge of deflection behavior over time is critical in producing and maintaining geometry in the finished bridge structure. One important function of this geometry is to ensure adequate drainage, which in turn helps to a) ensure driver safety in inclement conditions and b) increase facility longevity. Implementation of these more cost-effective bridge designs, however, has been hampered by uncertainties in predicting deflections and attendant bridge geometry, and the associated possibility that remedial action could be necessary after the structure is built if the resulting surface geometry is unacceptable. This project is intended to reduce these uncertainties by obtaining performance information pertinent to Montana materials and practices. This information will allow for a more complete realization of the economies offered by modern prestress concrete bridges in the form of long service lives and minimal maintenance requirements. Note that while the manufacturer could provide this type of information, it is believed that the cost to obtain it would ultimately be borne by the DOT customer. That is, in Montana and as is thought to be true in many states, the primary customer for prestress bridge beams is the state department of transportation. Further, the information being obtained herein on deflection behavior for staged construction practice is specific to MDT’s practices.

OBJECTIVES

The primary goal of this project is to provide guidance specific to Montana design and construction practices that will result in more efficient prestress concrete bridge structures. In this regard, the project is focused on providing improved concrete material properties in conjunction with a better understanding of girder deflection behaviors.

Specific objectives consist of:

1) determining through tests and analyses appropriate values for the elastic and non-elastic properties of the typical concrete used in MDT prestress concrete bridge girders; and
2) measuring the deflections through time experienced by girders in an actual bridge structure, comparing these deflections to those estimated analytically, and suggesting appropriate modifications in the analysis process to produce better deflection predictions.

RESEARCH PLAN

The research program described in this proposal provides an in-depth look at elastic and non-elastic material properties and associated long-term deflections of MDT prestress concrete bridge girders. Work will consist of a) determining by tests and analyses the engineering properties of a specific concrete typically used in Montana in prestress bridge girders, b) tracking actual deflections of girders made with this concrete from initial casting through the various stages of bridge construction and for a period of in-service use, and c) analyzing this information to provide guidance specific to Montana design and construction practices that will result in more efficient prestress concrete bridge structures. Specific work tasks include:

0) Project management
1) Literature review
2) Material properties measurement
3) Immediate and long term girder deflection measurements
4) Analysis of results and formulation of recommendations
5) Preparation of final report and dissemination of findings during ½ day seminar at MDT

Tasks 2 and 3 require the cooperation of the precast girder manufacturer, Cretex Concrete Products West (Cretex), of Helena Montana, in accessing information in their material properties database, and in sampling concrete and measuring girder deflections at their plant. Cretex has been approached by the research team and approves of this access to their facilities for the duration of this research project. A local ready-mix concrete company currently supplies the concrete at Cretex. However, Cretex plans on developing capabilities to produce their own concrete on site in the fall of 2011. This situation will be monitored and taken into consideration with respect to a) when sampling should be done for the basic material properties measurements, and b) selecting an appropriate bridge project and attendant girders for the field deflection measurements. The research team maintains close contact with Mr. Mike Pardy in these regards, who provides local representation on behalf of Cretex.

Task 0: Project Management

The Principal Investigator on this project will be Dr. Jerry Stephens. In addition to directing technical aspects of this project, Dr. Stephens will manage the project budget, schedule, and administrative tasks, and he will serve as the primary point of contact between the WTI research team and the MDT Project Manager. The project will begin with a kick-off meeting with the researchers and MDT to ensure everyone is informed of the contractual obligations and to clarify any technical issues and concerns. During the course of the project, the research team will submit quarterly progress reports to describe the status of the project with respect to timeline and budget. The project team will also submit task reports upon completion of specific tasks, and a project summary report and a final report upon completion of the project. The project team will also conduct a ½-day seminar at MDT at the conclusion of the project.

Task 1: Literature Review

While a preliminary literature review was conducted when developing this proposal, a more thorough review will be conducted at the beginning of the project. Notably, agencies that have been developing and adopting new prestress girder shapes and/or using girders on longer spans will be contacted regarding attendant serviceability, constructability, and other issues they may have encountered.

Task 2: Material Properties Measurement

This task will consist of laboratory work to establish elastic and non-elastic concrete property estimates that can be used in design. These estimates will be determined by measuring the properties of an appropriate sampling of the specific concrete mixture typically used in MDT prestressed beams. For budgeting purposes, it is assumed that sampling will take place at the Cretex facility in Helena, MT, which along with their facility in Billings, MT, comprise the two locations in the state at which prestressed bridge girders are manufactured. Further, it is assumed that the girders whose deflections will be field monitored in Task 3 of this effort will be manufactured at this same location.

Concrete samples will be collected for material property testing at five discrete times over the duration of this project. The first three collection events will occur during the first year of the project, with specific sampling times determined in consultation with MDT and Cretex. The fourth and fifth collection events will occur when the girders are cast for the field-deflection monitoring effort.

Cretex maintains a database of select short-term strength properties of the concretes used in their prestress girders. Cretex has indicated the availability of this database to the research team and this project. This information may prove to be valuable when establishing the variability of the mix through time and in determining optimum sampling times. The proposed sampling schedule will be provided to MDT for review, and actual sampling activities will be coordinated with Cretex. The research team will provide interim results from these three sampling periods to MDT, should unforeseen delays occur in girder casting and attendant execution of the fourth and fifth sampling events.

Relative to the sampling events associated with girder production for the field deflection monitoring effort, it is assumed that these girders will be cast in two separate pours (which may or may not be closely spaced). While the material properties of these girders are required to directly support the deflection monitoring effort, these data will also be used collectively with the data obtained from the three previous sampling efforts in characterizing the overall concrete behavior.

Table 1 presents the material properties and associated test dates that will be used for each concrete sample. Testing will be conducted over a one-year period. While the properties of concrete change throughout its life, the majority of these changes generally occur within the first year (Figure 1). As test results become available, analyses will be performed, providing relevant information on material properties for engineering design purposes. Further descriptions of these tests are provided below.

Table 1: Material Properties and Test Dates

Property	ASTM Test Method	Age to be Tested
Compressive Strength	C39	1, 28, 56, 180, 365 days
Elastic Modulus	C469	1, 28, 56, 180, 365 days
Rupture Strength	C78	1, 28, 56, 180, 365 days
Shrinkage	C490	Systematically over one year
Creep	C512	Systematically over one year

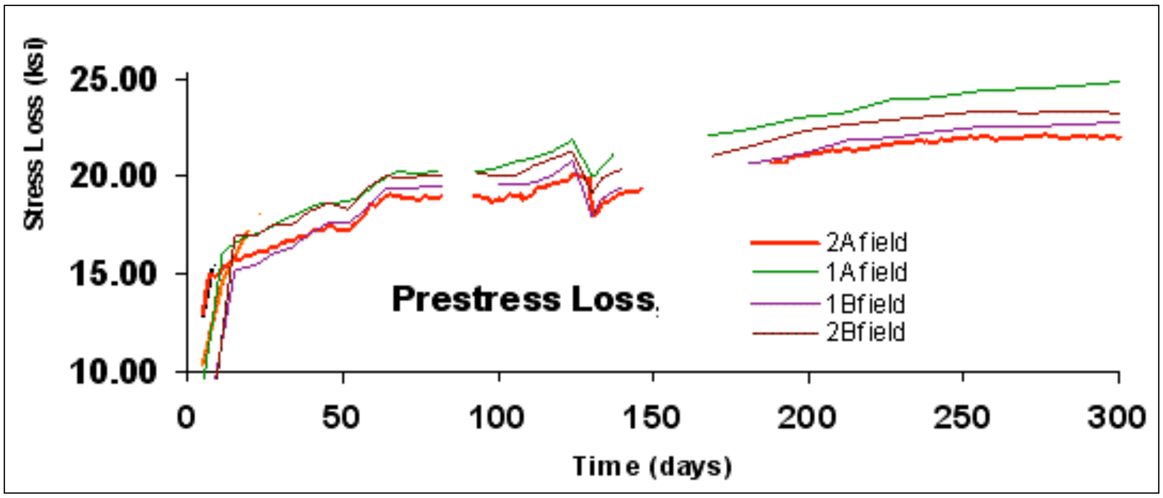

Figure 1: Prestress loss; high-strength, prestressed concrete stringers (Kukay et al., 2010)

Compressive Strength: Test method ASTM C39/AASHTO T22 will be used to determine the compressive strength of cylindrical concrete specimens obtained from molded cylinders. This property is used in the sizing of structural members and predicting beam behavior including residual prestress force and flexural capacity.

Elastic Modulus: Test method ASTM C469 will be used to determine the modulus of elasticity at designated times. This value is applicable within the customary working stress range of 0 to 40% of ultimate compressive strength. This property is used in sizing of structural members and predicting beam behavior including residual prestress force and flexural capacity.

Rupture Strength: Test method ASTM C78/AASHTO T97 will be used to quantify the rupture strength of plain concrete beams in four-point bending. This material property is used in the design of concrete members to evaluate the shear resistance provided by concrete, to determine the development length of reinforcement, and to predict the occurrence of concrete flexural cracking.

Shrinkage: Test method ASTM C490/AASHTO T160 will be used to determine length change due to shrinkage in hardened concrete in unloaded, unrestrained specimens. Shrinkage, another non-elastic property of concrete, is also used in predicting beam behavior such as the residual prestress force and deflection.

Creep: Test method ASTM C512-02 will be used to quantify the load-induced time-dependent compressive strain at selected ages for concrete. Modern design uses higher levels of prestress force and allows higher levels of stress in the concrete. The result is that non-elastic properties, such as creep, are becoming more important in predicting bridge-girder behavior. Creep estimates are used in predicting residual prestress forces, and are thought to play a particularly important role in estimating girder deflections.

Task 3: Measure Immediate and Long Term Girder Deflections

As previously mentioned, accurately predicting the deflection behavior of prestressed concrete girder bridges has become both more important and more uncertain as contemporary designs are implemented. A critical step towards taking full advantage of the materials and new cross-sectional shapes that are available (and towards obtaining better deflection predictions of over time) is to monitor the deflections of actual girders from initial transfer of prestressing force during construction into the service life of the completed bridge.

Deflection monitoring will be done on one of MDT's phased bridge construction projects. This effort will consist of the following subtasks.

1) Identify suitable bridge(s). Suitable bridge construction projects will be identified and ranked according to the nature of the project and number of prestressed beams available for monitoring. In addition, the bridge construction projects will be evaluated based on logistical considerations, such as the associated start and stop dates, ease of taking field measurements, and proximity from Helena, Butte, and Bozeman.

   For planning purposes, this proposal assumes the girders to be used in the deflection monitoring effort will be cast in Helena, MT. Further, based on preliminary information from MDT, a candidate bridge for this project is located in Kalispell, MT. These two assumptions should generally capture the extent of travel time and costs if a different selection is are made.

2) Collect immediate deflection field measurements. The first step associated with this task involves capturing girder deflections after release and during curing. Discrete measurements collected during this stage will terminate just prior to the bridge girders transport to the construction site.

3) Collect long-term deflection field measurements, systematically over time. Discrete measurements will again be collected when the prestressed girders arrive on site and have been erected. In addition, discrete readings will be collected prior to deck placement and after deck placement for Phase 1 and 2 of construction.

In greater detail, deflection measurements will be collected for all, or a selection of the girders from a single bridge. Deflection measurements will be made immediately after release, and then prior to transport, after erection (prior to deck placement), and after deck placement for both Phase 1 and Phase 2 of construction. Note that the timing of these measurements allows for comparison of measured deflections with those predicted using standard multipliers suggested by the Precast/Prestressed Concrete Institute. While it would be desirable to monitor all of the girders in the bridge, if they are large in number and are cast at multiple times, consideration has to be given to the logistics involved in taking the early deflection measurements. The budget in this proposal includes one trip to the precast plant when the girders are cast for Phase 1 of the project, and a second trip when the girders are cast for Phase 2 of the project. Currently, the proposal assumes deflections will be determined from measurements made at the ends and quarter points of the girders using surveying equipment. Consideration is also being given to an option that uses fixed targets on the structure. If the bridge selected for monitoring is over water that could pose some additional challenges (and could result in a target based approach being required).

Task 4: Analysis of Results

The results of the research program will be thoroughly analyzed in this task. Statistical analyses will be done as possible and appropriate to provide concrete material properties and measures of their variability. These properties will be compared with default values typically assumed in prestress loss and deflection calculations. Measured and predicted girder deflections will be compared using relevant codes and potential computer model(s). Suggestions will be made on modifications to typical deflection calculations based on these comparisons.

Task 5: Final Report, ½-Day Workshop and Dissemination of Results

The research team will prepare a final report documenting the methodologies used, data collected, and complete findings of this investigation. The research team will also conduct a ½-day workshop at MDT in Helena on this study and the implications of the results on design and construction practices.

MDT INVOLVEMENT

MDT will be asked to facilitate (as necessary) activities conducted in conjunction with the prestress girder manufacturer (i.e., Cretex – Helena). The term "facilitate" as used herein simply means that if requested by Cretex, MDT will verify MDT's sponsorship of this project. Note that activities to be conducted by WTI research personnel as part of Tasks 2 and 3 that involve Cretex consist of:

1) accessing the girder manufacturer's database on concrete material properties,
2) collecting concrete samples from the prestress facility at three intervals during the first year of the project,
3) collecting concrete samples from the prestress facility when the girders are cast for the deflection monitoring effort, and
4) measuring girder deflections at the precast facility at release and thereafter.

As previously mentioned, Cretex is aware of these activities and supports this project.

Further, MDT will be asked to facilitate (as necessary) activities conducted by WTI research personnel at the field deflection-monitoring site (Task 3). These activities include:

1) measuring girder deflections after their installation and before the deck is cast, for both Phase 1 and 2 of construction, and
2) measuring girder deflections after the deck is cast, for both Phase 1 and 2 of construction.

To make these measurements, members of the research team will need access to the bridge during construction. While it is expected that taking these measurements will have negligible impact on overall bridge construction (relative to either cost or schedule), the bridge contractor should be made aware of them as MDT deems necessary.

MDT will be significantly involved in the selection of a suitable "phased bridge construction" project for the field deflection monitoring in Task 3.

Additionally, MDT will be asked to review and comment on the concrete sampling intervals proposed for the material properties testing to be conducted during the first year of the project (part of Task 2).

In keeping with standard requirements, MDT will also review and comment on task memorandums, quarterly reports, the final report, and the project summary report. Additionally, MDT will be asked for comments and input on the ½ day workshop to be conducted for MDT at the conclusion of the project.

PRODUCTS

The following products will be produced as a result of the proposed research:

1. Task memorandums and quarterly progress reports.
2. Final report (and cover page photograph) and ½ day workshop.
3. Project summary report.

IMPLEMENTATION

Depending on the outcome of this research, MDT could elect to change some of its prestress concrete bridge design and construction practices. This research will provide MDT bridge designers with data on concrete material properties relevant to these practices, as well as correlations between predicted and observed field deflections.

SCHEDULE

This project will be completed in a little over two years after its commencement, barring any delays associated with construction of the bridge to be used for the field deflection monitoring effort. The anticipated project schedule by task is presented in Table 2. At present, a kickoff meeting is scheduled for September 2011. The submission date for the final report is December 2013. The ½-day workshop at the conclusion of the project will be scheduled following submission of the final report, as comments on the report could affect the workshop content. A specific schedule of deliverables is presented in Table 3.

Work will begin on the material properties testing at the conclusion of the literature review and survey of relevant information. Work on field monitoring of girder deflections will begin at the time the bridge girders are cast and conclude following the completion of Phase 1 of the bridge construction. Based on input from MDT, it has been assumed for budgeting purposes that a bridge to be constructed in 2013 in Kalispell (Kalispell West) will be used for this project. Note that even with this assumption, some uncertainties still remain in the proposed schedule associated with: a) the sequencing of the construction of the girders (Phase 1 and 2 girders may or may not be constructed at the same time), and b) the time period between the two phases of construction (i.e., completion of first phase and subsequent tear down and construction of second phase). The proposed schedule assumes that all the girders for the bridge will be cast at approximately the same time, and that Phase 1 and 2 of construction will be done in the same construction season. Further, it is assumed that the girders will be cast approximately 3 months prior to girder placement in Phase 1 of construction, and that this will occur the summer of 2013. As may be obvious, all dates associated with the bridge construction are subject to change, and the project activities associated with the girder deflection monitoring effort would change accordingly.

Table 2: **Schedule of Tasks**

	Year 1				Year 2				Year 3	
Task/Milestone	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Project Start	X									
Project Management; 0	X	X	X	X	X	X	X	X	X	
Literature Review; 1	X									
Measure Material Properties; 2		X	X	X	X	X				
Measure Immediate and Long Term Girder Deflections 3					X	X	X	X		
Analysis of Results; 4				X	X	X	X	X	X	
Final Report, 1/2 Day Workshop : 5									X	

Table 3: Schedule of Deliverables

	Year 1				Year 2				Year 3	
Deliverable	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	
Kickoff Meeting	X									
Technical Memorandum[a]		Task 1			Task 2[b]		Task 3	Task 4		
Quarterly Report[a]		X	X	X	X	X	X	X	X	
Final Report									X	
Half Day Workshop									X	

[a] *Technical memorandums and quarterly progress reports will be completed at the end of the month following completion of the appropriate task and/or quarter.*

[b] *Should unforeseen delays in girder casting occur, the research team can provide interim results from the previous three sampling periods to MDT.*

STAFFING

The primary research team is composed of two faculty members from WTI-MSU and two faculty members from WTI-MT Tech along with student researchers from both institutions. Collectively, the research team has extensive research experience in prestressed concrete structures, long-term bridge monitoring programs, and concrete material properties testing. This work has ranged from bridge monitoring/testing and concrete materials testing for MDT to a multi-year bridge study for the Utah Department of Transportation. This work has all been characterized by:

- an interest in bridge performance,
- a better understanding of fundamental elastic and non-elastic material properties, and
- a better understanding of how each can be used to improve upon current prediction values.

The experience and role of the primary research team are described below:

Jerry Stephens will serve as a PI on this project. In addition to directing technical aspects of this project, Dr. Stephens will manage the project budget, schedule, and administrative tasks, and he will serve as the primary point of contact between the WTI research team and the MDT Project Manager. Dr. Stephens has been PI and Co-PI on several bridge related lab/field research projects for MDT and Caltrans. Additionally, Dr. Stephens has worked with alternative materials for nearly two decades and has pioneered (with Doug Cross) research on 100 percent fly ash concrete. His research interest in concrete began with the investigation and development of innovative high-strength and fiber-reinforced concretes for military structures. With this background, he has been researching the use of concrete structures and alternative concrete materials in civil engineering construction since joining MSU in 1989. He is a full professor at Montana State University and is the Research Director at WTI.

Michael Berry will serve as a co- PI on this project. Dr. Berry is an assistant research professor at Montana State University, and has a research background in reinforced concrete structures and the behavior of these structures subjected to earthquake excitations. More recently his work has focused on alternative concrete materials and their use in structural elements. He currently serves on the Transportation Research Board Committee on Basic Research and Emerging Technologies Related to Concrete, and several American Concrete Institute committees including ACI 341-Earthquake Resistant Bridge Columns and ACI-306 Cold Weather Concreting. Dr. Berry will be responsible for the creep and shrinkage testing and associated analyses. Additionally, he will assist with the field deflection monitoring effort, analysis of results, and preparation of project deliverables.

Brian Kukay will serve as a Co-PI on this project. Dr. Kukay has successfully completed a long-term bridge-monitoring project and has developed non-destructive tests that relate to prestressed concrete bridge girders. He is an assistant professor at Montana Tech, and his research interests include the destructive and non-destructive testing of concrete and wood members; he has publications in both areas. Dr. Kukay is an active member of the American Society of Civil Engineers and the National Forest Products Society. He currently serves as the secretary for the Montana Section of ASCE and is a member ASCE/SEI’s Timber Bridge Committee. Dr. Kukay will be responsible for coordinating the concrete material properties test effort. The compression and rupture strength tests will be conducted at MT Tech under his supervision. Additionally, he will assist with the field deflection monitoring effort, analysis of results, and preparation of project deliverables.

Charles Todd will provide support for the statistical components of this project. Dr. Todd is a full, tenured professor in the department of Mathematical Sciences at Montana Tech. Dr. Todd received the Rose and Anna Busch Faculty Achievement award in 2008 and was nominated several times prior to this. Dr. Todd is a member of the American Statistical Association and the Institute of Mathematical Statistics. Dr. Todd has authored several publications and provided numerous formal consultations to industry.

Administrative Support – The administrative staff at WTI-MSU will provide post-award purchasing and accounting support for the project. The communications staff will assist with the preparation of deliverables. Gloria Carter, Research Project Administrator, will provide similar support for the MT Tech portion of the project.

The project team will be collaborating with Cretex on items related to material properties, mix designs, prestress applications, and the scheduling thereof.

The project will also employ graduate and undergraduate students to assist in sampling and testing the concrete, field monitoring of girder deflections, analyzing the test results, and preparation of the final report. The projected level of effort by project personnel is summarized in Table 4. These personnel can commit the time necessary to complete this work in a timely and deliberate manner. Professional members of the research team will not be changed without written consent of MDT.

Table 4: Schedule of Staffing

Name of Principal, Professional, Employee, or Support Classification		Role in Study	Task 0	Task 1	Task 2	Task 3	Task 4	Task 5	Total
MSU	Jerry Stephens	Principal Investigator	87	20	20	20	20	144	311
	Mike Berry	Co-Principal Investigator	20	50	48	68	40	98	324
	Graduate Student	Specimen collection, testing,measurements, and data analysis	0	160	320	152	400	160	1192
	Administrative Staff	Administrative Support	8	0	0	0	0	0	8
	Clerical Staff	Report Preparation	8	0	0	0	0	40	48
Montana Tech	Brian Kukay	Co-Principal Investigator	20	50	48	68	50	98	334
	Charles Todd	Statistical analysis	0	20	50	0	0	32	102
	Gloria Carter	Technical editing, DOT survey assistance	8	32	0	0	0	0	40
	Graduate Student	Specimen collection, testing,measurements, and data analysis	0	160	200	152	400	160	1072
Total			151	492	686	460	910	732	3431

FACILITIES

With respect to the materials property testing and field deflection monitoring to be done in this project, a majority of the required equipment is already available at WTI-MSU and at WTI-Montana Tech. The additional equipment that must be acquired to conduct this research will be purchased with funds from the WTI University Transportation Center program. The dollar amounts of these purchases are identified in the budget.

BUDGET

This project is being supported by $19,824 in funding from the WTI University Transportation Center program matched by $128,104 in MDT funding, as shown in the itemized budget presented in Table 5. The Contracted Services listed in Table 5 consist of the work to be done on this project by WTI-MT Tech. A further itemization of MT Tech's budget is presented in Table 6. The pay and benefit rates of the investigators are shown in Table 7. Projected expenditures by task are shown in Table 8. Total and MDT projected expenditures by state and federal fiscal years are shown in Tables 9 and 10, respectively. Within Task 5 (Final Reporting), the specific costs of the Project Summary Report and the Workshop are $561 and $1,683, respectively.

Table 5: Project Budget by Item

Item	MSU	MDT	Total
Salaries	$0	$49,180	$49,180
Benefits	$0	$11,464	$11,464
In-State Travel	$0	$2,666	$2,666
Out-of-State Travel	$0	$0	$0
Expendable Supplies, Minor Equipment, Repair and Maintenance	$14,010	$0	$14,010
Contracted Services	$0	$47,132	$47,132
Participant Costs	$0	$0	$0
Total Direct Costs	$14,010	$110,442	$124,452
Overhead - 41.5% MSU and 20% MDT (on contracted services overhead only applied to $25K)	$5,814	$17,662	$23,476
Total Project Cost	$19,824	$128,104	**$147,928**

Table 6: Breakdown of Contracted Services by Item

Item	Montana Tech
Salaries	$30,435
Benefits	$5,176
In-State Travel	$2,666
Out-of-State Travel	$0
Expendable Supplies, Minor Equipment, Repair and Maintenance	$1,000
Participant Costs	$0
Total Direct Costs	$39,276
Overhead (20% MDT)	$7,855
Total Project Cost	$47,132

Table 7: Pay Rate and Benefits

Name of Principal, Professional, Employee, or Support Classification		Hourly Rate	Benefit Rate
MSU	Jerry Stephens	$52.55	30%
	Mike Berry	$44.96	30%
	Graduate Student	$14.00	10%
	Administrative Staff	$41.77	33%
	Communication Staff	$26.00	33%
Montana Tech	Brian Kukay	$37.76	25%
	Charles Todd	$40.58	25%
	Administrative Staff	$20.49	46%
	Graduate Student	$12.00	5%

Table 8: Project Budget by Task

Task	Budget
0 - Project Management	$14,508
1 - Literature Review	$16,548
2 -Measure Matieral Properties	$25,644
3 - Measure Initial and Long Term Deflections	$35,412
4 - Analysis of Results	$21,536
5 - Final Reporting	$34,280
Total	**$147,928**

Table 9: Total Project Budget by Fiscal Year

	State Fiscal Year			Federal Fiscal Year		
Item	2012	2013	2014	2012	2013	2014
Salaries	$12,750	$25,501	$10,929	$18,215	$25,501	$5,464
Benefits	$2,972	$5,944	$2,548	$4,246	$5,944	$1,274
In-State Travel	$691	$1,382	$592	$987	$1,382	$296
Out-of-State Travel	$0	$0	$0	$0	$0	$0
Expendable Supplies and Minor Equipment	$3,632	$7,264	$3,113	$5,189	$7,264	$1,557
Contracted Services	$12,219	$24,439	$10,474	$17,456	$24,439	$5,237
Participant Costs	$0	$0	$0	$0	$0	$0
Total Direct Costs	$32,265	$64,531	$27,656	$46,093	$64,531	$13,828
Overhead	$6,086	$12,173	$5,217	$8,695	$12,173	$2,608
Total Project Cost	$38,352	$76,703	$32,873	$54,788	$76,703	$16,436

Table 10: MDT Project Budget by Fiscal Year

	State Fiscal Year			Federal Fiscal Year		
Item	2012	2013	2014	2012	2013	2014
Salaries	$12,750	$25,501	$10,929	$18,215	$25,501	$5,464
Benefits	$2,972	$5,944	$2,548	$4,246	$5,944	$1,274
In-State Travel	$691	$1,382	$592	$987	$1,382	$296
Out-of-State Travel	$0	$0	$0	$0	$0	$0
Expendable Supplies and Minor Equipment	$0	$0	$0	$0	$0	$0
Contracted Services	$12,219	$24,439	$10,474	$17,456	$24,439	$5,237
Participant Costs	$0	$0	$0	$0	$0	$0
Total Direct Costs	$28,633	$57,266	$24,543	$40,904	$57,266	$12,271
Overhead	$4,579	$9,158	$3,925	$6,541	$9,158	$1,962
Total Project Cost	$33,212	$66,424	$28,468	$47,446	$66,424	$14,234

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