FLORIDA DEPARTMENT OF TRANSPORTATION

Research Progress Report

Title: Time Dependent Load Response of Flexible Pipe Subjected to Sustained Loading

FDOT Contract Number: BDK75 977-21

University of Florida, Department of Civil and Coastal Engineering

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I. Activities Performed During Period: September 2009 - November, 2009

Soil Box

While the soil box was termed "complete" prior to the initiation of the project, there were numerous tasks that had to be performed during the period. Below (Figure 1.) is a photo of the box in August, 2009. The first issue dealt with involved the six access ports on the sides of the box. These provide the team with viewing/data collection portals to monitor the pipes during loading via a ring laser system (to be discussed later). Since the tests will involve dual tests, the middle portal will be used to bring the earth pressure cell cabling out to the data logging equipment. Hence, its cover had to be altered to allow the cabling to pass through the box and still retain the sand inside. In addition, the covers weight 400 lbs. each and are very difficult to maneuver on and off.

To address this, the Coastal technicians designed and fabricated a cover extractor. A photo of the device is shown in Figure 2. This has been tested and works extremely well. It will greatly add to both the safety and efficacy of the research.

Figure 1. The “completed” soil box, prior to start of project.

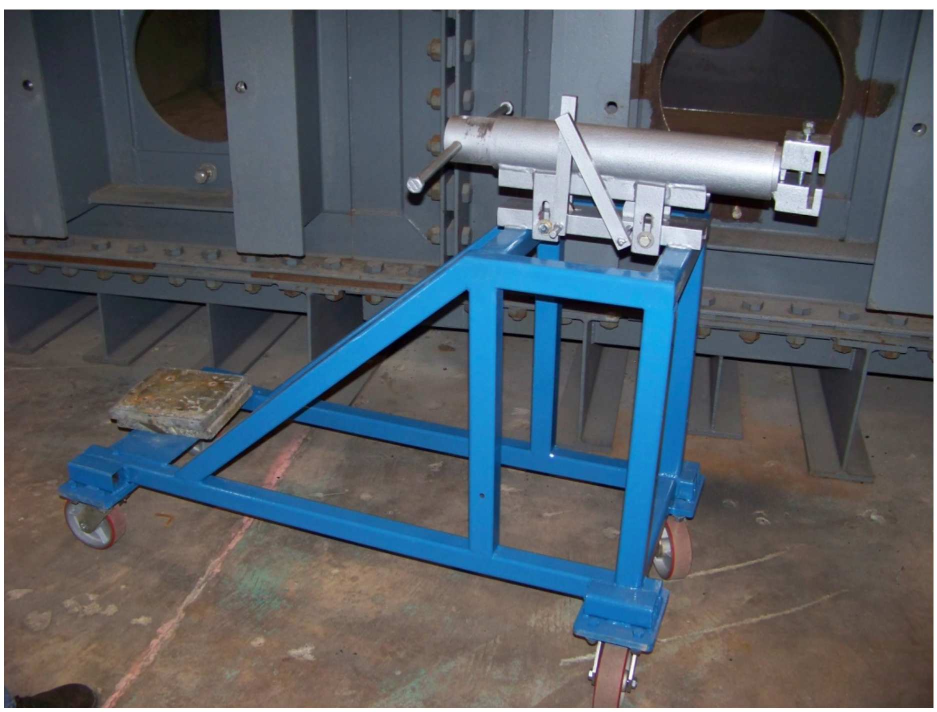


Figure 2. Cover extractor/positioning device.

As mentioned, the center cover is currently being altered to accept the internal instrumentation cabling. A photo (Figure 3.) of it being milled and altered is shown below.

Figure 3. Center portal cover being machined for cabling access

The interior of the box has been sanded and cleaned. All joints are sealed as seen in the photos in Figure 4 on the following page.

Figure 4. Sealed joints in interior of soil box.

While the filling of the box will be performed using a front end loader, access to the top of the box is required to place the steel loading plates and lift bags. Hence, a metal scaffold was designed and constructed shown in figure 5 below.

Ultimately, the lower portion will be enclosed to create a small data acquisition control room.

Figure 5. Scaffold/Instrumentation cubical under construction

Earth Pressure Cells

To obtain the vertical and horizontal soil stresses in the soil box Geokon Model 4800 Earth Pressure Cells will be used. The earth pressure cells were available from a prior research project. The earth pressure cells were then cleaned up and tested with a vibrating wire readout box from Geokon to determine which pressure cells were still working. Once all of the working earth pressure cells were located, Geokon was e-mailed with all of the serial numbers to get the vibrating wire pressure transducer calibration reports. The zero readings were obtained and with the vibrating wire readout box, were put into an excel sheet to compare with the zero readings from the original calibration reports. This excel sheet was then sent to Geokon for evaluation to see which pressure cells needed to be sent back for re-calibration and which cells were good to be used right away.

After getting a response from Geokon 32 of the earth pressure cells were ready for use and only four earth pressure cells needed to be sent back for re-calibration. For the soil box only 18 pressure cells are necessary.

With all the working earth pressure cells it was then necessary to splice more wire onto most of them to be able to connect them to the datalogger outside of the soil box. The wire was then ordered from Geokon to provide the best quality wire since they will be buried for a prolonged period of time. The extra wire was spliced onto the existing wire and then concealed with a waterproofing compound to make sure none of the pressure cells failed from water damage during testing.

The next step in preparing for gathering the horizontal and vertical stresses in the soil box was acquiring the datalogger from Reid Lab. The datalogger being used on this projected is designed around the Campbell Scientific Inc. Measurement and Control System and paired with two 16 channel multiplexers. The software being used to record the data is MultiLogger. To check that the datalogger was in working condition it was connected to the computer that MultiLogger was being run on to see if it would be recognized. Once the datalogger and multiplexers were recognized by the computer the channels had to be checked. These were checked by connecting five earth pressure cells at a time to see if the zero reading matched the zero reading from the vibrating wire readout box. Then a small amount of pressure was applied to make sure the reading changed.

Now the system to gather the horizontal and vertical stresses is ready to be put in place in the soil box.

Lift bags.

The manufacturer of the lift bags completed the eight bags in late December. Originally the idea was to purchase off the shelf bags. However, the manufacturer agreed to produce larger ones for the project at a reduced cost. A photo of one of the 4 ft. by 4 ft., 59 ton bags is shown in Figure 6 below.

Figure 6. One of Eight Lift bags

Pipes.

The SMO was extremely helpful in acquiring the pipes. One set of them have been delivered during the quarter. A photo of them are shown in Figure 7. Below.

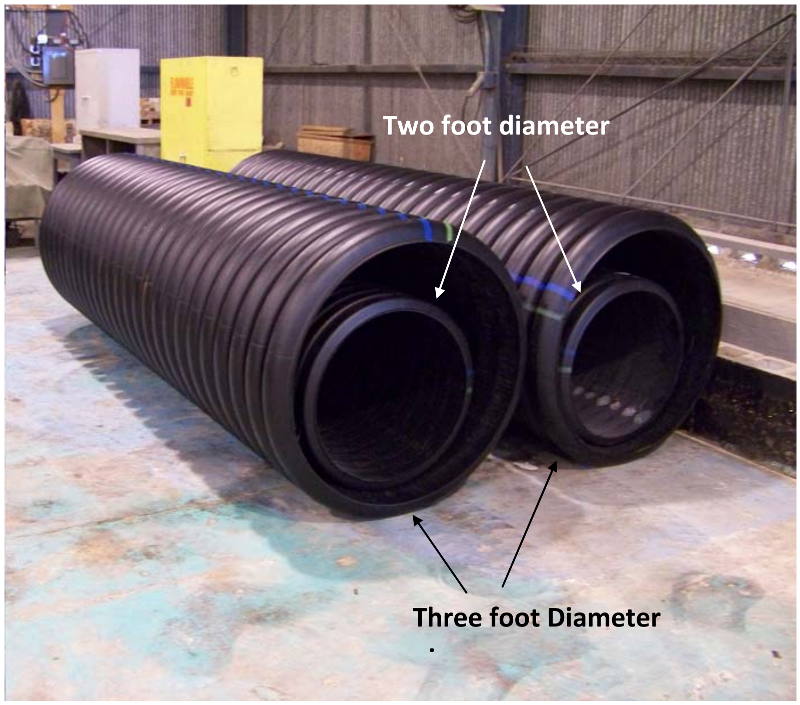


Figure 7. Delivered Flexible Pipes

Pipe Deflection Measurement.

Measurement of the deflection of the individual pipe throughout the duration of the project is crucial. An initial meeting with the PI and a student took into account various ideas, ranging from a 3d laser to string pots. The laser was quickly eliminated as it was cost prohibitive, string post would become to cumbersome and lastly a simply trolley with rotating LVDT mounted on a track would be the design that was decided upon.

Design:

The design for trolley mounted servos would be the most economical and simplest design as stated previously. The trolley would be constructed of aluminum bar stock welded together and utilizing roller bearings would mount on to an aluminum W-section. There would be a total of 3 revisions to the design of the trolley system before it would ultimately come to a halt due to negotiations to obtain a laser measurement device.

The initial concept was to utilize a rod spanning roughly 10 ft to serve as the guide for one servo motor that would rotate about the center of the rod as it traversed the length of the pipe. The servo would utilize a slip ring design to have the ability of 360 degree travel. A simple Lab view program would be utilized in conjunction with a USB 6218 to act as the controller and data acquisition system for the devise. There would be many problems with this design as the rod would exceed feasible dimension to remain rigid and the measurement system would rely heavily on simply one LVDT.

Design two would incorporate the concept of LVDT however the major change would be that rather than a rod running through the center of the pipe there would be a W-section. The use of a W-section would allow for maximum use of the inertial properties of the shape yet maintain the weight to a minimal. This design would utilize a cage design to encapsulate the W-section and maintain a fixed frame of reference when making the measurements. The case would consist of welded aluminum bar and adjustable wheels to traverse the length of the pipe. However there were also problems with this design and that was that the two servos would not have full rotation and sections of the pipe would go unmeasured.

The final design would utilize the same idea as the second however would have two modifications to it. The first modification would be that there would be a total of four servo and four LVDTs to ensure measurement of the 360 degrees around the pipe. The other would be that there would be fixed ball bearings instead of adjustable wheels to ensure the fixed frame of reference. **Error! Reference source not found.**illustrates the conceptual idea behind the design.

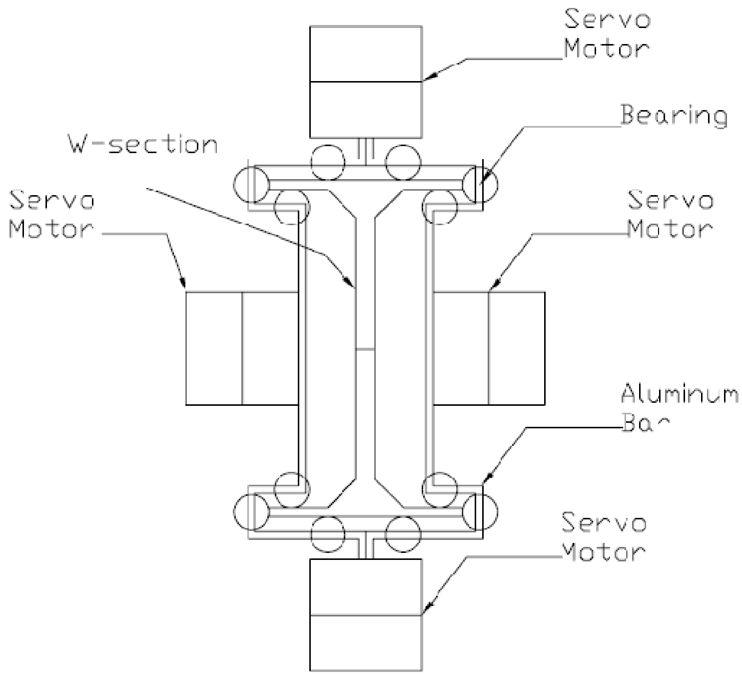


Figure 8. Design Schematic of Pipe Deflection Device

Note: While the above design was being considered, the PI contacted a supplier of Laser Ring Sensors. The company has agreed to “loan” a complete system (laser and software) for the duration of the project. Hence, this calibrated device will assuage any questions about the accuracy of the measurements.

Soil Box Integrity

Preliminary results for a conservative estimate of soil box deflection were completed. This analysis took into account pinned end connections and reports that at the center of the span one can expect possibly 3/10 of an inch deflection assuming that the Wide Flange sections used are 50 ksi steel and a W16x32 section. This analysis takes into account self weight of the typical W section with an opposing pressure of 180 psi. The analysis was performed assuming composite section due to the longitudinal welds along the entire interface between the plate and W-section. The approximate load is 18,360 psf in the positive y direction as illustrated by Figure 1: Structural loading on soil box walls. The three charts are labeled appropriately beginning with the displacement followed by shear and ending with the moment diagram. The max expected moment is estimated to be roughly 230 kip-ft in the clock wise direction.

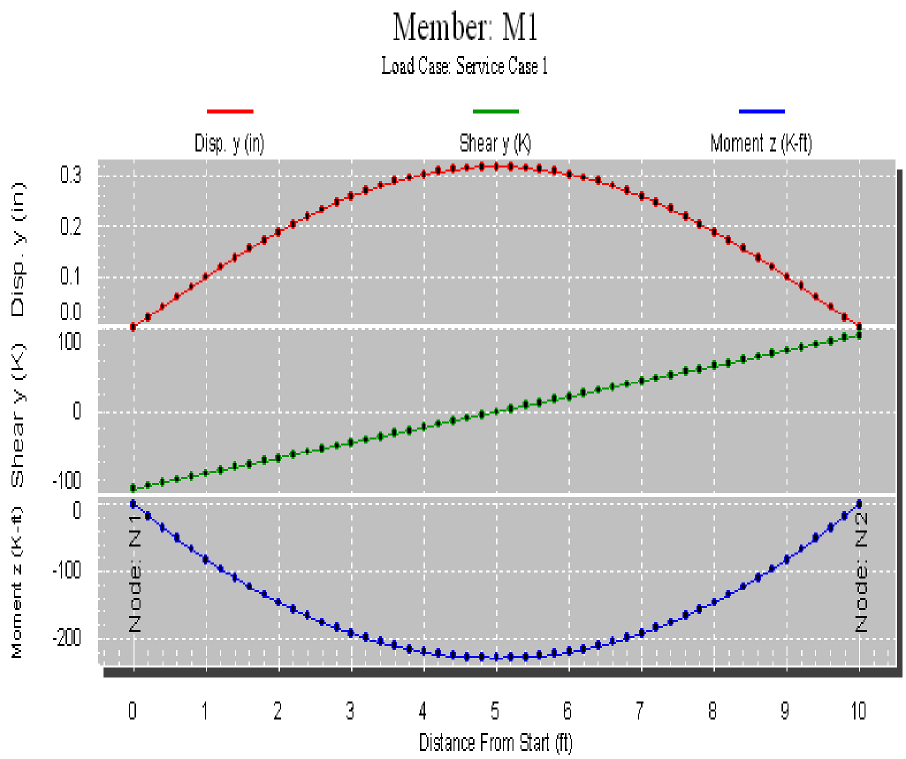


Figure 1: Structural loading on soil box walls

Loading Plate Deflection:

Assuming soil is free to deform and only provides reaction forces at the boundary of the plates and the inflated bags leave a circular foot print on the plate when inflated to 96 tons, a calculation to simulate zero support under the plate, followed by a calculation of a uniform load active on the same plate as a reaction was performed. The difference of the two would be an estimate as to how the plates will behave under simulated loading conditions. This analysis is to take the relative deformation of the plate and not the total deformation. Calculations for plates ranging from ¼ inch to 1.5 inches were analyzed. The equations to derive such conclusions were taken from (Young 1989).

There are as stated previously some constraints to this method of analysis. Due to the box design the soil is in fact confined and not allowed to experience field behavior in the sense that changes in horizontal and vertical stresses do not approach zero and any point. Winkler's method was considered for such analysis but found to be limiting in the sense that the soil is not exhibiting 100% field behavior hence total deformation of the plate cannot be calculated. However, the plates will be sufficiently thick to mitigate any warping.

Pipe restraint design

One of the most vexing issues to date concern the sealing of the ends of the pipes to the box, yet allowed movement to occur. The pipes have to be restrained to the wall to prevent soil from exiting the soil box yet provide no resistance to settling. Though the soil box was designed to be as square as possible due to manufacturing the walls have some imperfection due to the thickness of the plates and the amount of welding to secure them. When assembling the soil box for the first time and placing a sample directly into the soil box it was immediately apparent that it was going to be difficult to place the pipe section into the soil box and they not bind. A discussion began to take place and several ideas were proposed.

Idea one:

For the first idea the walls are lined with two layers of Visqueen and a thin layer of petroleum/silicon grease in between. This posed several problems when trial mach ups were assembled: the rough and thin walls from the corrugated pipes would bind and tear the visqueen. Figure 10. Visqueen below illustrates the concept on how the layering and setup would work

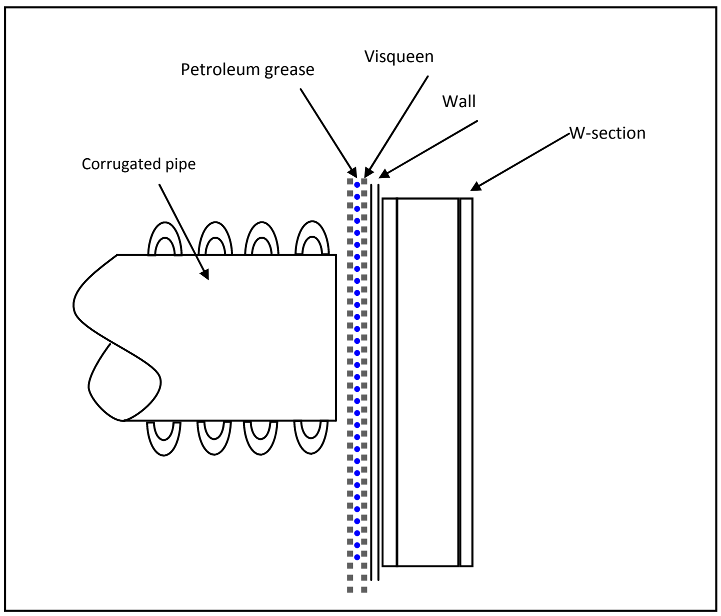
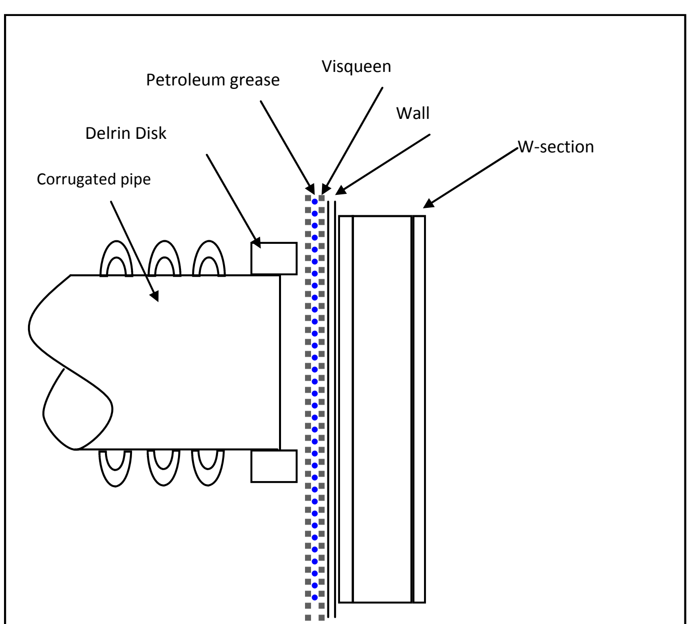


Figure 10. Visqueen

Idea two:

The second idea presented would incorporate a Delrin disk to slide along the Visqueen.



Idea Three:

The third idea and ultimately what is currently being designed and implemented borrows the idea from automotive pipe design. That is to say, attaching a pipe that is fixed to the engine to another pipe that perhaps may be fixed to a rigid part of a chassis joined together by a rubber hose to eliminate stress cracking, isolate vibrations and allowing for either pipe to have free motion to some degree. The investigation determined that as long as the rubber Durometer was kept roughly between soft and medium soft (40) it would not adversely hinder nor interfere with the dynamics of the test. This is the approach to be attempted.

Below helps to illustrate the components and the interaction of the pipe and flange that will be designed. Understanding that there is both a two foot and three foot diameter that must be tested the flanges will be designed with the same base as to minimize the holes needed to be drilled into the soil box wall. The rubber membrane will allow for the pipe to settle and deform freely yet maintaining a clear view port through the pipe for ease of monitoring with the different probes that will be utilized for monitoring the pipe deflections.

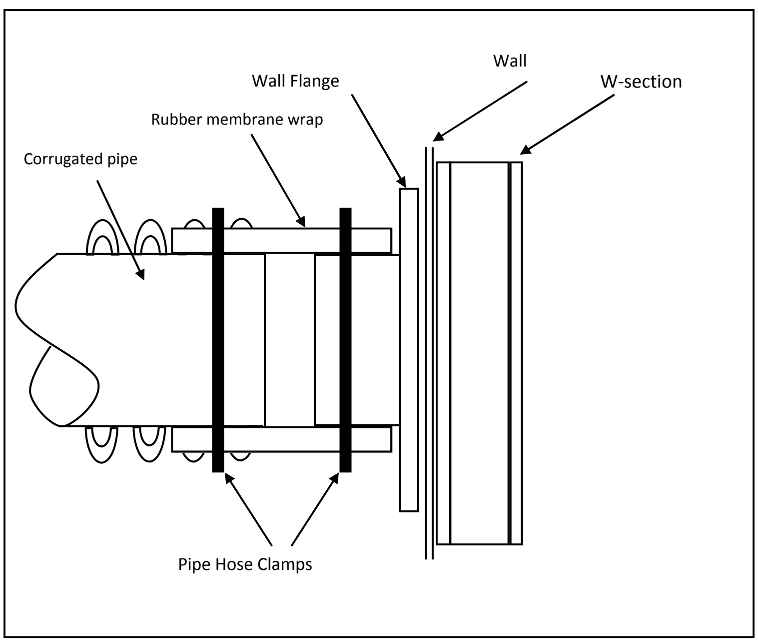


Figure 12. Flange pipe Design

II. Activities Planned for January - March 2010

During the next quarter the first series of tests will be performed. Tasks 2a and 3a will be completed. This will allow for as check out of the instrumentation, loading and deflection monitoring.

III. Summary of Modifications to be Requested

No changes or modifications are requested.

IV. Project Schedule

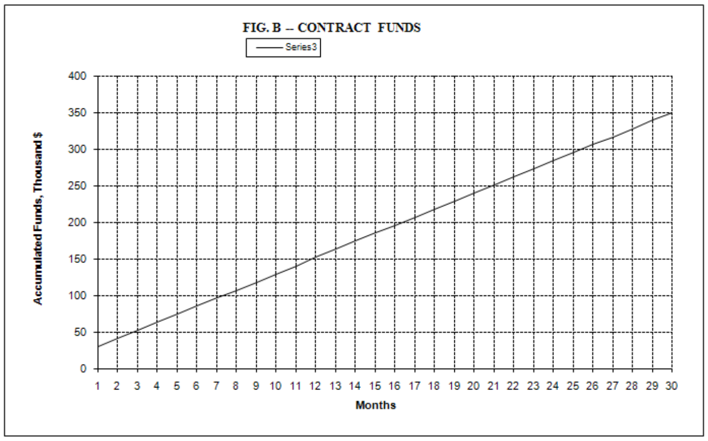
Please note that due to the expenditures to date, $3k, the plots cannot show this small increment. However, the next Progress Report will show an increase due to the purchase of the Lift Bags, installation, etc.

PROJECT SCHEDULE

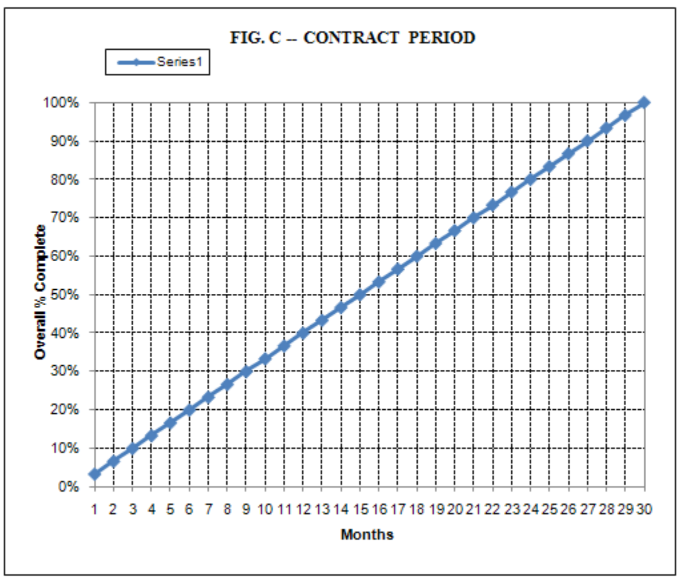
Project Title	Time Dependent Load Response of Flexible Pipe Subjected to Sustained Loading				
FDOT Project No.	To be Determined	FY	2009	Month	Jun
Research Agency	University of Florida				
Principal Investigator	Dr. David Bloomquist, Dr. Tim McGrath				

RESEARCH TASK	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	ESTIMATED % COMPLETION
Task 1																									5
Install Visqueen Sheeting/Purchase Lift Bags																									4%
Task 2a																									7
Install Bedding Material/Earth Pressure Cells																									
Task 3a																									4
Install Two 36" HDPE Pipes/Backfill/Flooding																									
Task 4a																									10
Fill Box/Install Pressure Cells/Lift Bags																									
Task 5																									4
Conduct Triaxial/1D Compression Tests																									
Task 6																									3
Finalize Design/Construction of LVDT Profiler																									
Task 7																									6
Conduct Staged Load Tests on Dual 36" HDPE Pipe																									
Task 8A																									10
Repeat Tests on Single Pipes w/ Trench Boxes																									
Task 8B																									8
Repeat Test Series on 36" Corrugated Steel Pipe																									
Task 8C																									8
Repeat Test Series on 36" Corrugated Aluminum Pipe																									
Task 8D																									8
Repeat Test Series on 36" PVC Pipe																									
Task 8E																									8
Repeat Test Series on 24" HDPE Pipe																									
Task 8F																									8
Repeat Test Series on 24" Corrugated Steel Pipe																									
Task 9																									10
Perform FEM modeling																									
Task 10																									1
Preparation of Final Report																									
																									100%
Overall % Complete Projected	4%	8%	12%	16%	20%	24%	28%	32%	36%	40%	44%	48%	52%	56%	60%	64%	68%	72%	76%	80%	85%	90%	95%	100%	
Overall % Complete Actual	4																								

FIG. A -- OVERALL PROJECT SCHEDULE



Funds Expended	%	$3,292.89.
Contract Amount	$	350,451
Expended This Month	$	0
Total Exp. to Date	$	$3,292.89.
Balance	$	347,158



Time expended	%	3
Starting Date		9/1/2009
Completion Date		3/31/2012