# In-Situ Measurements of Interlocking Concrete Pavement Response to Vehicular Loading and Environment


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ABSTRACT


This paper presents an innovative research project involving the design, construction and instrumentation of seven interlocking concrete pavement (ICP) crosswalks. In total there are four different structural designs presented. These were constructed at the Centre for Pavement and Transportation Technology (CPATT) test track and at the University of Waterloo Ring Road in 2007 and will involve the development of mechanistic-empirical design models for ICPs. Each of the test sections is instrumented with four sets of sensors to monitor the pavement performance under heavy truck traffic, typical municipal loadings and to quantify environmental effects. Data is collected at four hour intervals and includes stresses, strains and temperature. Moisture data is collected on weekly basis using time domain reflectometry probes. A database is being generated for all seven sections and the measured stress, strain, temperature and moisture measurements are analysed to evaluate the expected long-term performance of the structural components of ICP crosswalk designs. Truck loading data based on loading configuration is being collected using Weight-In-Motion at the CPATT test track. In addition, routine PFWD testing is performed to determine the in-situ conditions of the pavement

structures. This paper outlines the design, instrumentation, and initial pavement performance for the seven crosswalk sections. The paper also provides some data and in-situ performance of the seven crosswalks.

## Introduction

The Interlocking Concrete Pavement Institute (ICPI) and Centre for Pavement and Transportation Technology (CPATT) located at the University of Waterloo, crosswalk research project involved the construction of seven crosswalks with different base and bedding materials at the CPATT test track located in the Regional Municipality of Waterloo Waste Management Facility and at UW Ring Road. The objective of the research project is to quantify the structural performance of four Interlocking Concrete Paver (ICP) Crosswalk Designs under two loading scenarios. The CPATT test track encounters heavy truck loading primarily loaded garbage trucks while the UW ring road traffic is similar to a typical urban road. The research study is directed at defining the performance mechanics for designs with various bases and setting beds. The research will involve validation of current industry crosswalk design recommendations, establishing threshold values for type and/or number of axle loads (ESAL's) for various crosswalk assemblies, recommending new designs (or modifications to existing designs) as needed based upon the load/traffic/environment/ failure modes from the study. In short the research will offer design professionals with guidance on design protocols and performance of ICP crosswalks for various loading conditions.

Although the interlocking concrete pavers have provided many benefits, there is mounting evidence of early failures with respect to use in crosswalks. There have been varying failure modes noticed and there needs to be a better understanding of the various design aspects of using ICP in crosswalks. It is also important that the various constructability aspects and design aspects are balanced.

This paper outlines the design, instrumentation, and initial pavement model for the seven crosswalk sections. The paper also provides some data and in-situ performance of the seven crosswalks.

## Description of the Test Sites

There are two locations selected for the construction of the test sections considering the traffic composition. The first site is located at the Centre for Pavement and Transportation Technology (CPATT) test track in the south east corner of the Regional Municipalities of Waterloo Waste Management Facility, located in the City of Waterloo shown in Figure 1. This site is comprised of three crosswalks with different bases and bedding materials are constructed in June 2007. The pavement is subjected to heavy truck traffic primarily loaded garbage trucks.

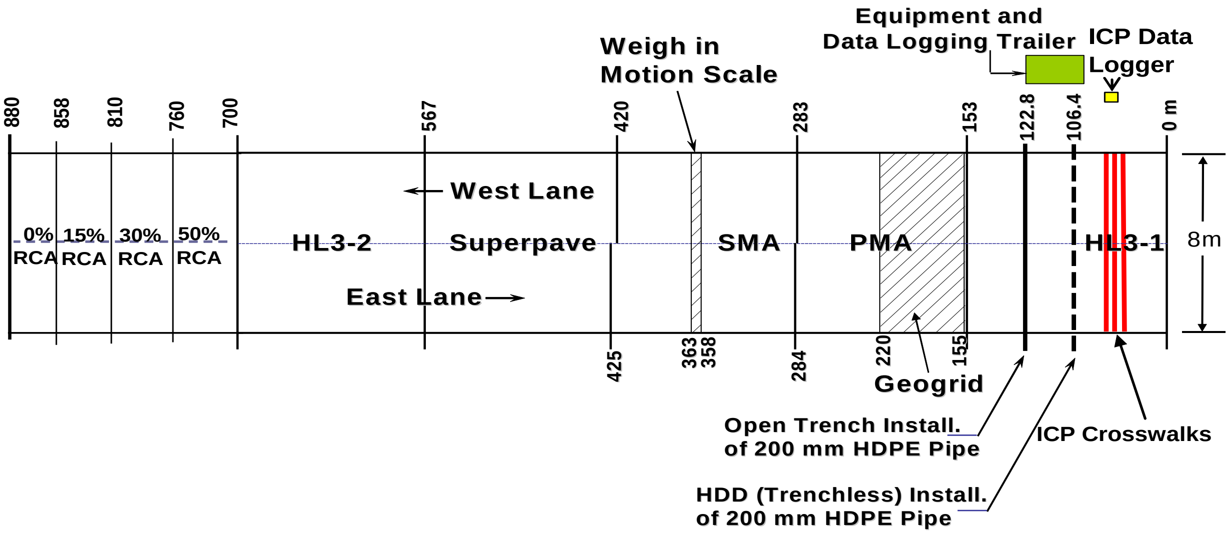


**Figure 1: CPATT Test Track**

The second test site is located at North Campus Gate intersection on the University of Waterloo Ring Road as illustrated in Figure 2. Four crosswalk sections with different designs are built during the reconstruction of the ring road in July and August, 2008. The road is similar to a typical city/municipal road.

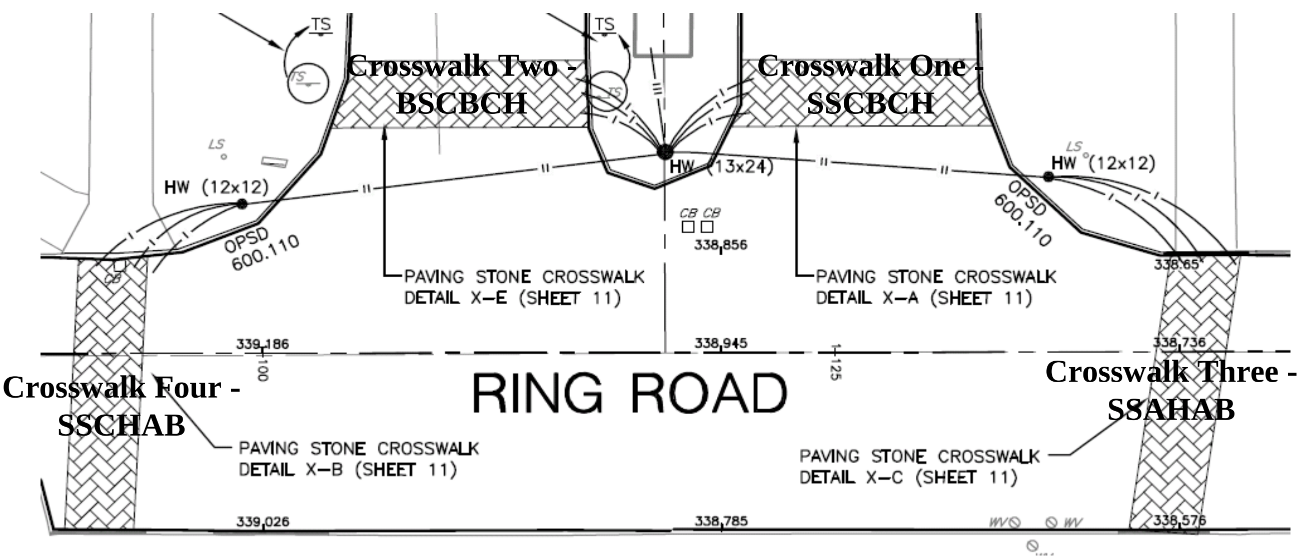


**Figure 2: Layout of Crosswalk Test Sections at UW Ring Road**

**Pavement Structure**

A typical interlocking concrete pavement crosswalk consists of concrete pavers placed on top of a layer of bedding sand over a base and sub-base layers. Four different ICP crosswalk designs are selected for this study. As surface course, 300mm long and 100mm wide interlocking concrete pavers are placed in herringbone pattern in all test sections.

***Site 1-Test Track:***

The CPATT test track is in total a 880m long and eight metre wide road built at the Region of Waterloo Waste Management Facility. Three eight metre long and 3m wide crosswalks with different structural designs are constructed on top of the existing subgrade. Four ABS pipes with diameter of 75mm and length of 300mm are designed perpendicular to the road surface to be installed at the lowest level of the base course on each side the road.  A layer of non woven geotextile is designed in between base and bedding sand layer and the second layer of Geotextile is existed between granular subbase and sub grade.

The first crosswalk design is composed of 80mm interlocking concrete paver on the top of 25mm bedding sand layer, 200mm thick concrete base is built on the top of 400mm granular subbase as shown in Figure 3 and is called Sand Set Concrete Base Concrete Header (SSCBCH). 150mm wide concrete header is placed around the perimeter of the section.

The second crosswalk design is comprised of 80mm interlocking concrete paver on the top of 25mm bedding sand layer. 100mm thick asphalt base is built on the top of 50mm granular A and 400mm granular B subbase as shown in Figure 4 and is called Sand Set Steel Header Asphalt Base (SSSHAB). Two concrete curb along the edge of the road parallel to the road centerline are provided while L-shaped iron angle edge restraint are designed on top of the asphalt base on the both sides parallel to the center line of the crosswalk section.

The third crosswalk design is composed of 80mm interlocking concrete paver on the top of 25mm bituminous sand layer. Concrete base with 200mm thickness is built on the top of 400mm granular subbase as shown in Figure 5 and is called Bituminous Set Concrete Base Concrete Header (BSCBCH). 150mm wide concrete header is placed around the perimeter of the section.

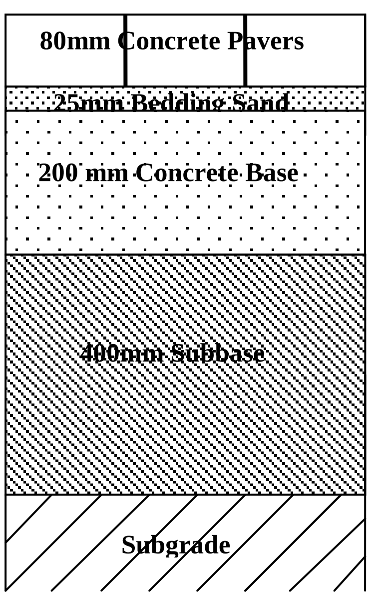


**Figure 3- Crosswalk One (SSCBCH)**

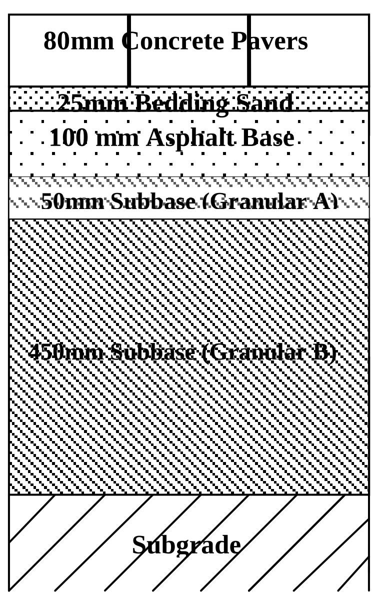


**Figure 4- Crosswalk Two (SSSHAB)**

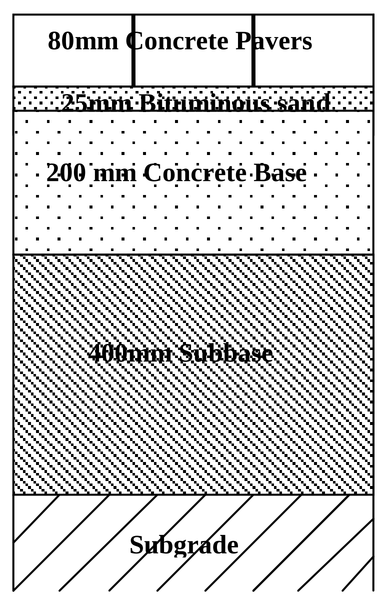


**Figure 5- Crosswalk Three (BSCBCH)**

*Site 2-University of Waterloo Ring Road:*

Four crosswalk sections with different structural designs are located on the University of Waterloo Ring Road. All crosswalk sections were built during the reconstruction of the ring road in July and August, 2008. Existing subgrade and subbase are utilized for the construction of the crosswalk sections.

Crosswalk One, Sand Set pavers over Concrete Base with Concrete Headers (SSCBCH), is 11.25m long and 2.635m wide and composed of 80mm interlocking concrete paver on the top of 25mm bedding sand layer. 200mm thick concrete base is built on the top of 300mm granular subbase as shown in Figure 6. 150mm wide concrete header is placed around the perimeter of the section.

The second crosswalk design, Bituminous Set pavers over Concrete Base with Concrete Headers (BSCBCH) is 11.25 long and 2.635 wide and is comprised of 80mm interlocking concrete paver on the top of 25mm bituminous sand layer. 200mm thick concrete base is built on the top of 300mm granular B subbase as shown in Figure 7. 150mm wide concrete header is placed around the perimeter of the section.

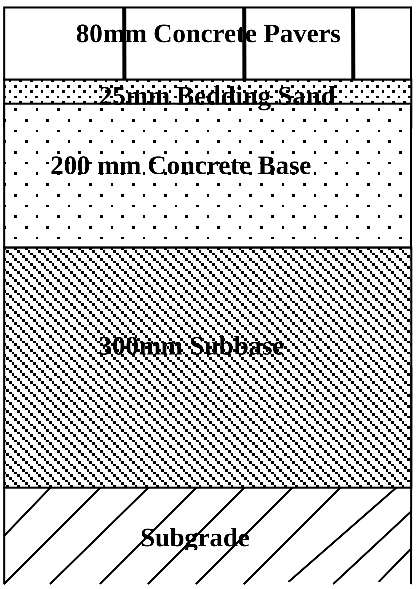


**Figure 6: Crosswalk One – SSCBCH**

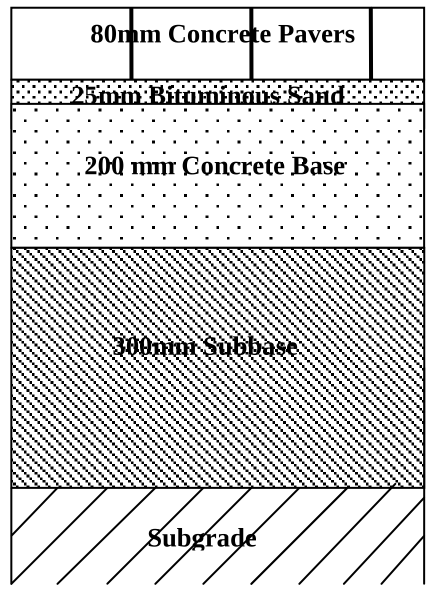


**Figure 7: Crosswalk Two - BSCBCH**

The third crosswalk design, Sand Set pavers with Aluminum Header over Asphalt Base (SSAHAB) is 12.50m long and 2.635m wide and is comprised of 80mm interlocking concrete paver on the top of 25mm bedding sand layer. 100mm thick asphalt base is built on the top of 50mm granular A base and 350mm granular B subbase as shown in Figure 8. Two concrete curb along the edge of the road parallel to the road centerline are provided while L-shaped aluminum angle edge restraint are designed on top of the asphalt base on the both sides parallel to the center line of the crosswalk section.

The fourth crosswalk design, Sand Set pavers with Concrete Header over Aggregate Base (SSCHAB) is 12.50 long and 2.635 wide and is comprised of 80mm interlocking concrete paver on the top of 25mm bedding sand layer. 150mm thick aggregate base is built on the top of 350mm granular B subbase as shown in Figure 9. 150mm wide concrete header is placed around the perimeter of the section.

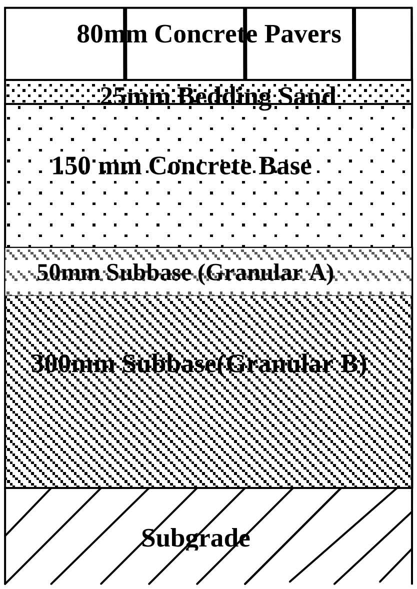


**Figure 8: Crosswalk Three – SSAHAB**

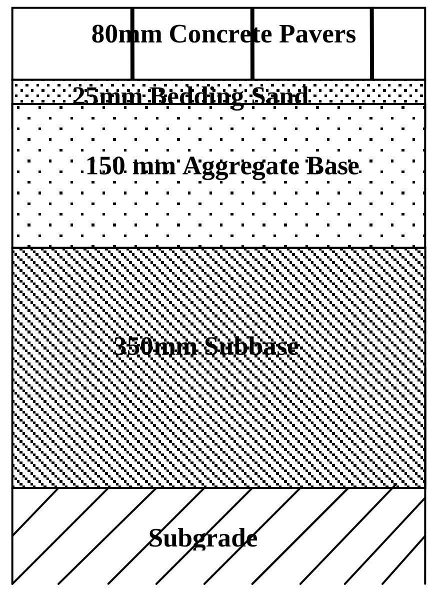


**Figure 9: Crosswalk Two - SSCHAB**

## Construction of Test Sections

### *Site 1- CPATT Test Track*

The construction of the CPATT interlocking concrete crosswalks at the test track was carried out in third week of June, 2008. Three crosswalks with 3m in width and 8.3m in length were retrofitted into the existing pavement. The following structural components were constructed for each section.

### Subbase

A shallow trench was excavated upto the depth of existing subbase to install mechanical and environmental sensors. Then the subbase material was backfilled and the entire surface is compacted with a vibrating plate compactor.

### Drainage

Eight ABS pipes with diameter of 75mm and length of 300 mm were installed perpendicular to the road surface at the lowest level of the base course before the construction of headers, curbs and bases. The pipes are filled with pea gravel and covered with geotextile to prevent the loss of bedding materials. Their purpose is to remove excess water from the base course. Since the road base is constructed with two percent slope towards the edge, four pipes were installed along the two outer edges of the bases.

**Concrete Header**
150mm wide concrete header with 32 MPa high early concrete was constructed around the perimeter of two concrete base section whereas two concrete curbs along the edge of the pavement was built for the asphalt base section. Wooden forms were installed around the perimeter of the crosswalk for curbs and headers before the concrete placement. Exposed concrete headers edges were trimmed to 3mm radius to reduce the likelihood of chipping.

**Concrete base**
Reinforcement rebars having mesh size of 150mm/150mm was placed on the top of the subbase course of two concrete base sections and high early concrete with 200mm thickness was placed. Three control joints for shrinkage were provided at three locations throughout the base.

**Asphalt Base**
HL-3 asphalt base was constructed with two 50mm lifts. The base was compacted with plate compactor after the construction of each lift.

**Edge Restraint**
For asphalt base crosswalk, L-shaped iron angle were installed on top of the asphalt base and along the cut pavement edge. The angle iron is 9.5cm wide and 9.5cm high and 6mm thick. Nails and screws were drilled through the angle iron and into the asphalt base in every 60cm to fasten the angle iron onto the base.

**Bedding Sands**
For crosswalk one and two, a layer of non woven geotextile was placed in the constructed base and a layer of bedding sand with thickness of 25mm was spread and screeded on top of the non woven geotextile. Screeding was carried out by dragging a screed board along preset rails to give uniform bedding layer thickness. For crosswalk three, the concrete base surface was prepared with an emulsified asphalt tack coat. A hot-sand asphalt mix was brought to the site and spread and compacted to 25mm thick layers. After the asphalt cooled, a thin coating of asphalt-neoprene adhesive was applied across the surface.

**Interlocking Concrete Pavers Laying**
Interlocking concrete pavers with dimension of 200mm × 100mm × 80mm was placed manually in 45 degrees herringbone pattern starting from the corner of the section. To ensure good lines are achieved, flick lines were used to deposit chalk onto the surface of the screeded bedding sand. Edge pavers are saw cut to fit against the sailor and soldier courses. The sailor and soldier are interlocking concrete pavers were placed in such a way that crosswalk two and three have three sides (one long side and two short sides) with sailor course and one long side with soldier course. In contrast, crosswalk one has sailor courses on the both sides. After the installation, the surface was compacted with a vibratory plate roller to compact the bedding sand, seat the pavers in it and force the bedding sand into the joints at the bottom of the pavers. The final elevation of the surface course was kept 6mm above the adjacent asphalt pavement to accommodate any future settlement.

**Jointing Sands and Final Compaction**

After initial compaction of the pavers, dry joint sand was spread on the surface and compacted with a vibratory compactor to ensure that the spaces between pavers are filled. Excess joint sand was then removed.

***Site 2- University of Waterloo Ring Road***

The construction of the CPATT interlocking concrete crosswalks at the University of Waterloo Ring Road was carried out during the reconstruction of ring road in July and August, 2008. All four sections have 2.635m in width and two sections have 12.50m long and other two are 11.25min length. The following structural components were constructed for each section.

**Subbase**

A shallow trench was excavated upto the depth of newly built subbase to install mechanical and environmental sensors. Then the subbase material was backfilled and the entire surface is compacted with a vibrating plate compactor.

**Drainage**

Eight ABS pipes with diameter of 75mm and length of 300 mm were installed perpendicular to the road surface at the lowest level of the base course before the construction of headers, curbs and bases. In crosswalk one 16 similar pipes were also placed along the southern face of the section. In crosswalk two eight similar pipes were installed perpendicular to the road surface along the two edge of the pavement section. In asphalt base two sets of four ABS pipes were placed along the outer edges of the base. The pipes are filled with pea gravel and covered with geotextile to prevent the loss of bedding materials. Their purpose is to remove excess water from the base course. Since the road base is constructed with two percent slope towards the edge, four pipes were installed along the two outer edges of the bases.

**Concrete Header**

150mm wide concrete header with 32 MPa high early concrete was constructed around the perimeter of two concrete base section and aggregate base section whereas two concrete curbs along the edge of the pavement was built for the asphalt base section. Wooden forms were installed around the perimeter of the crosswalk for curbs and headers before the concrete placement. Exposed concrete headers edges were trimmed to 3mm radius to reduce the likelihood of chipping.

**Concrete Base**

Reinforcement rebars having mesh size of 150mm/150mm was placed on the top of the subbase course of two concrete base sections and high early concrete with 200mm thickness was placed. Three control joints for shrinkage were provided at three locations throughout the base.

**Asphalt Base**

HL-4 asphalt base was constructed with two 50mm lifts. The base was compacted with plate compactor after the construction of each lift.

**Aggregate Base**
Aggregate base was constructed using existing Granular A materials. After installation of environmental sensors in subbase the trench was backfilled and aggregate base was built on the top of the subbase and compacted with a plate compactor.

**Edge Restraint**
For asphalt base crosswalk, L-shaped aluminum angle were installed on top of the asphalt base and along the cut pavement edge. The angle iron is 9.5cm wide and 9.5cm high and 6mm thick. Nails and screws were drilled through the angle iron and into the asphalt base in every 60cm to fasten the edge restraint onto the base.

**Bedding Sands**
For crosswalk one, three and four, a layer of non woven geotextile was placed in the constructed base and a layer of bedding sand with thickness of 25mm was spread and screeded on top of the non woven geotextile. Screeding was carried out by dragging a screed board along preset rails to give uniform bedding layer thickness. For crosswalk two, the concrete base surface was prepared with an emulsified asphalt tack coat. A hot-sand asphalt mix was brought to the site and spread and compacted to 25mm thick layers. After the asphalt cooled, a thin coating of asphalt-neoprene adhesive was applied across the surface.

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**Jointing Sands and Final Compaction**
After initial compaction of the pavers, dry joint sand was spread on the surface and compacted with a vibratory compactor to ensure that the spaces between pavers are filled. During compaction, the pavement is transformed from a loose collection of pavers to an interlocking system capable of spreading vertical loads horizontally.

**Quality Control**
Extensive sampling was performed throughout the construction of the research project. Samples were taken from the original Granular A and Granular B.  HL-3/4 sample was taken with the use of shovel. Twelve concrete cylinders were casted at each site to perform the laboratory compressive strength testing.

In addition to extracting samples, mix temperature of the HL3 and sand asphalt were also measured during the placement and before compaction. Slump and air-void testing were carried out for every batch of the concrete.

**Instrumentation**

Pavement instrumentation is crucial to understanding material performance in the field, as well as pavement system response to loading and environment. The goal of instrumentation is to assess the in-situ performance related to stress, strain, temperature and moisture. Sensors installed in pavement sections are divided into two categories. Temperature and TDR probes are installed to measure environmental responses whereas pressure cells and strain gauges are embedded to capture loading responses.

At test track, four different type of sensors namely vibrating wire strain gauges, earth pressure cells, temperature profiles and moisture probes are installed to determine the change of horizontal strain in asphalt and concrete bases, vertical earth pressure in base and subbase and temperature and moisture variation at different elevation in subbase as shown in Figure 10. The sensors cables were collected at a junction point and fed into a 100mm ABS conduit. The conduit is buried in a shallow trench and routed to the data logger box.

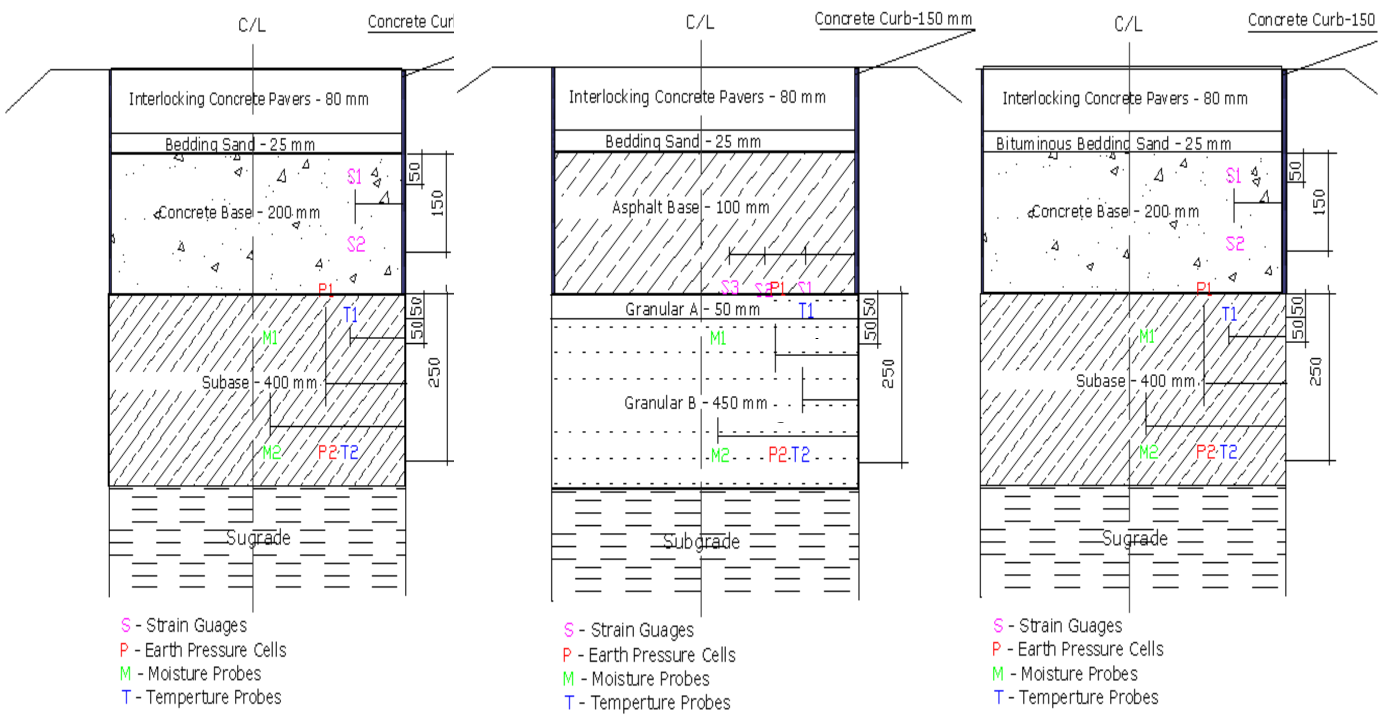


**Figure 10: Profile View of Instrumented Crosswalk Sections at Test Track**

At ring road, three different types of sensors namely vibrating wire strain gauges, temperature profiles and moisture probes were designed for concrete and asphalt base sections as shown in Figure 11 and 12. In contrast, only two types of sensors namely moisture and temperature probes are used in the aggregate base section. Four junction boxes are placed to collect the cables from all sections. All cables are fed into ABS conduits and collected in fourth junction box and finally routed to data logger placed in road island. After installation, all sensors were tested for functionality by connecting to the data logger A brief description of sensors installed in each crosswalk section is provided below.

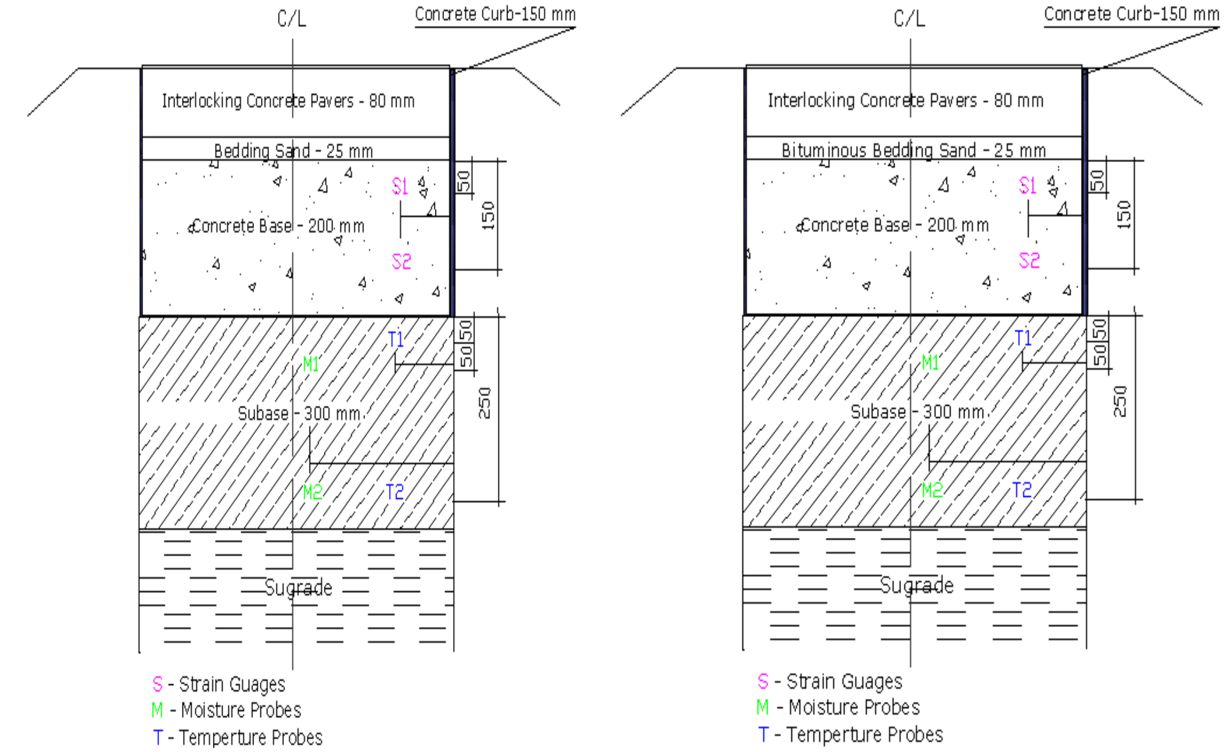


**Figure 11: Profile View of Instrumented Crosswalk One and Two at UW Ring Road**

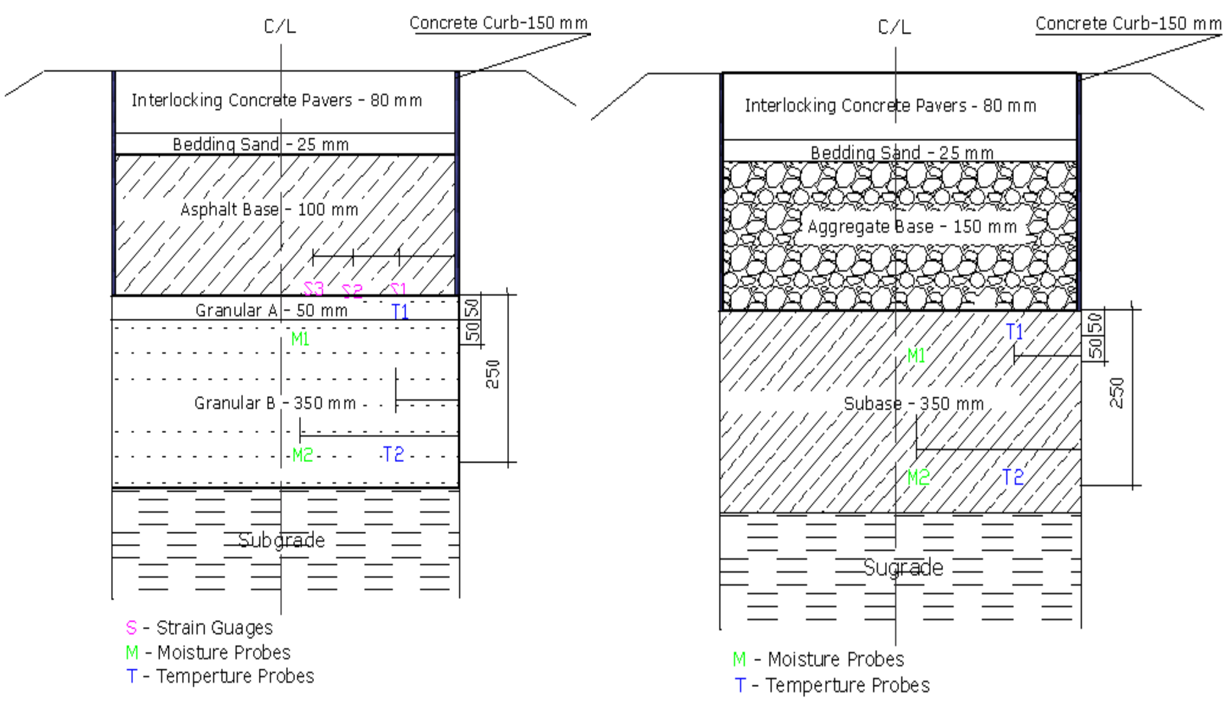


**Figure 12: Profile View of Instrumented Crosswalk Three and Four at UW Ring Road**

***Vibrating Wire Strain Gauges***

The strain gauges are designed to measure the change of strain and the change of temperature in the concrete. Concrete strain gauges (Model-VWSGE) are installed at 50mm and 150mm from the top of the concrete base at the right wheel pathway at test track site and at the left wheel pathway at ring road site. The gauges were set on special chairs to bring them in desired locations. Three asphalt strain gauges (Model-VWSGEA) are placed at the bottom of the asphalt base at 1.1m, 2.2m and 3.3m offsets from the road edge.

The strain gauge can measure actual strain changes due to changes in moisture content of the concrete and stresses from traffic loading. Thermal correction factor is used to adjust change in strain due to temperature changes. The following equation is used to convert measured resonance reading into change of strain.

$$\varepsilon_t = (S_n - S_0) * GF + (T_n - T_0) * (C_1 - C_2) \qquad (1)$$

Where, $\varepsilon_t$ = True strain (microstrain)

$S_n$ = Current resonance reading

$S_0$ = Initial resonance reading

GF = 1, Gauge factor for strain gauges model VWSGEA and VWSGE

$T_n$= Current temperature reading ($^oC$)

$T_0$= Initial temperature reading ($^oC$)

$C_1$= 12, Thermal Coefficient

$C_2$=11, Thermal Coefficient

A negative value indicates compressive strain and a positive value indicates tensile strain in above equation.

***Earth Pressure Cells***

Earth Pressure Cells, a device to measure the vertical stress are constructed from two circular stainless steel plates, welded together around their periphery. An annulus exists between the plates, which is filled with de-aired glycol. The cell is connected via a stainless tube to a transducer forming a closed hydraulic system. As stress is exerted on the surface of the cell, it pressurizes the fluid within the cell and the pressure transducer responds to changes in total stress applied to the cell.

Two pressure cells (Model-LPTPCO9-V) are installed horizontally in each section at test track site at the bottom of the concrete/asphalt base and at 250mm from the top of the subbase at 1.6m offset from the road edge. No pressure cells are installed in sections located at UW ring road.

The primary function of pressure cells is to monitor the change in the stress-state of the overlying layers and to measure the increase in vertical pressure due to traffic loading. The following equation is used to calculate the change of vertical stress-state.

$$\sigma = E * (P_n - P_0) * 10^{-6} \qquad (2)$$

Where, $\sigma$ = Vertical stress (MPa)

E = Elastic Modulus of material where the pressure cell is placed (MPa)

$P_n$= Current pressure reading
$P_0$ = Initial pressure reading

A negative value indicates compressive stress and a positive value indicates tensile stress in above equation.

***Temperature Probes***
Temperature probes are installed to measure temperature variation at different elevations within the pavement structure. The temperature probe consists of two thermistors at the distance of 200mm are installed vertically in the subbase in each section. The thermistors are located at 50mm and 250mm from the top of the subbase at 1.4m offset from the road edge.

***Moisture probes***
A moisture probe (TDR) is a device consisting of three 600mm long stainless steel rods for measuring volumetric moisture content in pavement's unbound layers. Two probes are installed horizontally in each section at 100mm and at 250mm from the top of the subbase and at 3m offset from the road edge.

**Data Collection and Monitoring**
Data collection involves using a direct wire which sends data from the data logger using the Logger Net software to a laptop computer. Logger Net is a software that writes and compiles monitoring programs to transfer the program to the data logger and to retrieve the data by direct wires.

Stress, strain and temperature data are being collected from August 15, 2007 at the test track and from November 20, 2007 at the ring road at four hours interval and the moisture data is collected on a weekly basis using Model 6050X1 Trase System.

Environmental changes have a direct impact on the structural capacity of the pavement, and consequently its performance. Pavement materials are sensitive to moisture, temperature and rainfall. Quantifying the effect of these environmental factors is necessary for incorporation in the pavement evaluation process. Temperature data is collected at four hours interval and moisture data is collected on a weekly basis to determine the seasonal variability of these two parameters and their influence in strain and stress accumulation.

Climatic data (ambient temperature and rainfall) is also being obtained from UW weather station for the ring road projects and from Regional of Waterloo Waste Management Facility weather station for test track project. These data are analysed to determine their influence in the performance of the pavement structure.

Traffic data (AADT, vehicle type distribution, axle weight data for each vehicle type) at test track is obtained from region of waterloo waste management automation system. The CPATT test track encounters heavy truck loading primarily loaded garbage trucks. There is a Weigh-In-Motion scale as well to keep accurate load records. Traffic design loading for crosswalk projects is based on the AASHTO design procedure is represented using Equivalent Single Axle Load (ESAL) concept. It is calculated that there is approximately 150,000 ESAL/year. The University of Waterloo Ring Road has traffic similar to a typical urban road with approximately 10% truck and 5% bus traffic. The annual calculated ESAL is approximately 26,000 a year.

**Pavement Responses**

The load distribution and failure modes of flexible asphalt and interlocking concrete pavement are very similar. The pavement carries load as a flexible pavement and pavement failure primarily through rutting in the layers under the block surface. The major failure modes for the asphalt and concrete base courses are fatigue cracking, rutting and low temperature cracking.

Since the fatigue cracking is a function of horizontal strain at the bottom of asphalt, horizontal strain in concrete layers and vertical compressive stresses in granular layers, pavement responses analysis included the tensile strain on the underside of the asphalt concrete base layer, tensile strain in concrete base course and the vertical compressive stress in granular subbase courses. Trendlines of stress and strain accumulation are influenced by variations in environmental conditions i.e. temperature, rainfall and moisture. Those parameters are taken into account while making initial performance prediction.

The initial performance is carried out on the basis of measured values of strain and stress accumulation. The strain and stress accumulation in different crosswalk design assemblies over time and respective environmental data at both sites are presented in Figure 13, 14, 15,16,17,18.

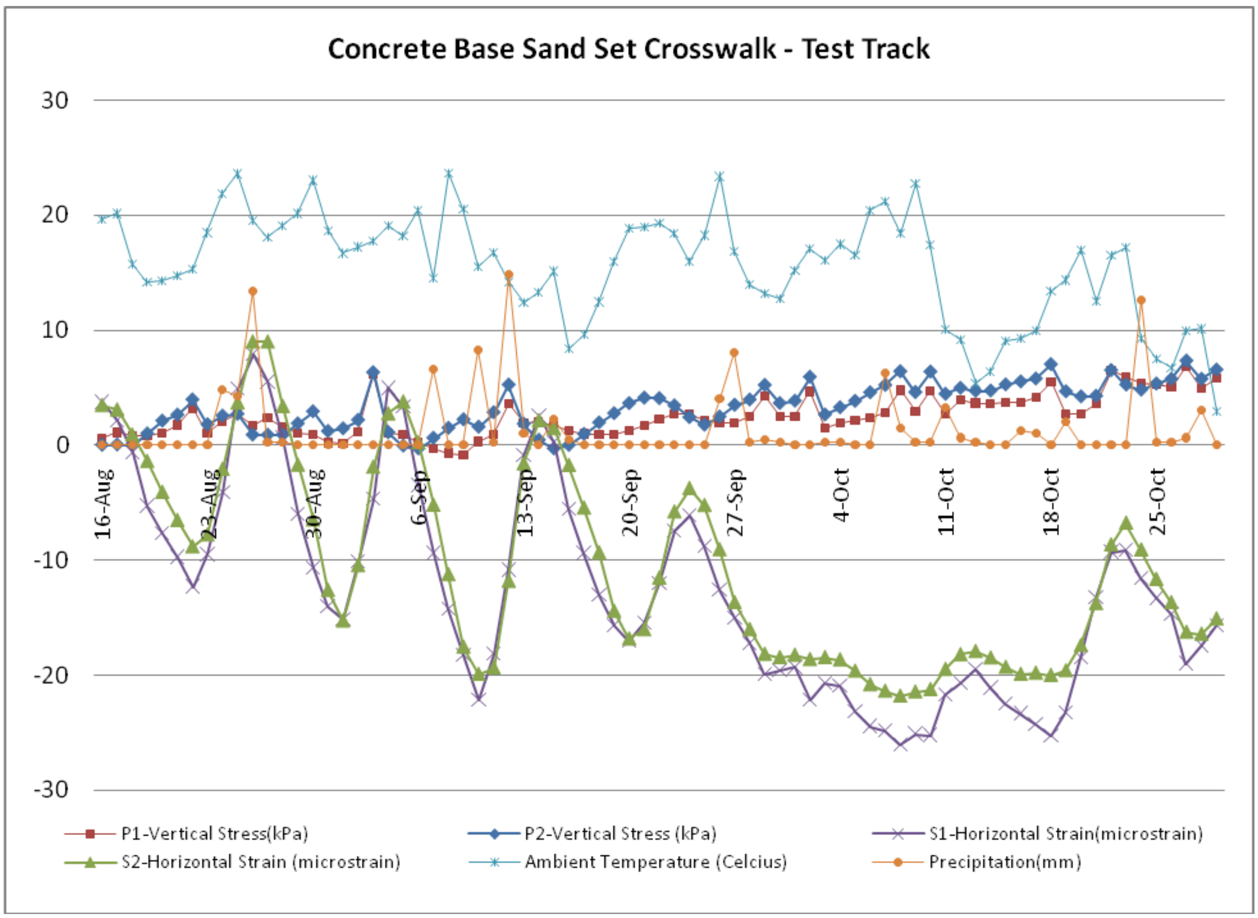


**Figure 13: Measured Data in Crosswalk One over Time at Test Track**

Figure 13 shows the accumulation of stress, strain and temperature and precipitation data over 2.5 months period. There is formation of compressive strain inside the concrete base in the first few months. Tensile vertical stress is formed in granular subbase layer in this period under the influence of traffic loading and environment factors.

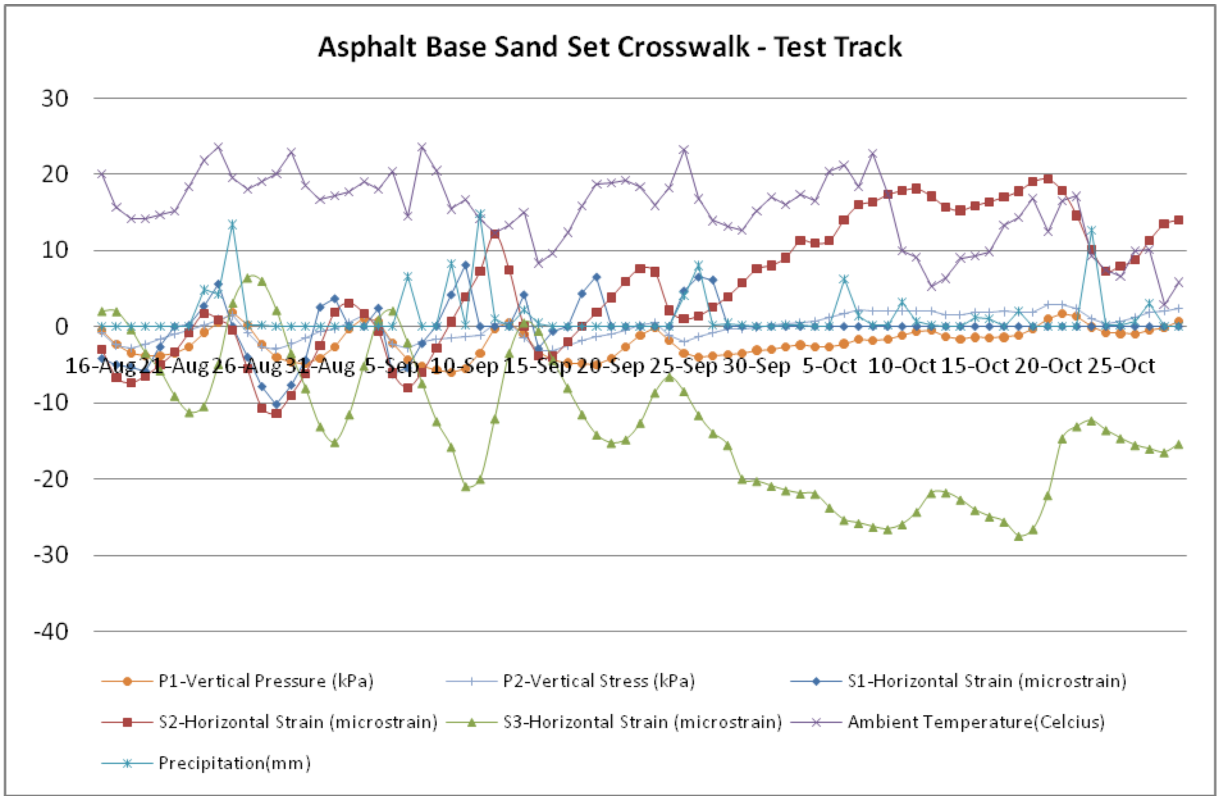


**Figure 14: Measured Data in Crosswalk Two over Time at Test Track**

Figure 14 shows the accumulation of stress, strain and temperature and precipitation data over 2.5 months period in asphalt base section. There is formation of compressive strain at the bottom of asphalt base under left wheel path whereas asphalt base in between two wheel path is experiencing tension in the first few months. Strain gauge under right wheel path was not working properly in this period. Compressive stress was formed in early stage and tensile stress in later stage in subbase layer.

Figure 15 shows the accumulation of stress, strain and temperature and precipitation data over 2.5 months period in bituminous set concrete base section. There is formation of tensile strain inside the concrete base and tensile vertical stress in the subbase layers in the first few months.

Figure 16 shows the accumulation of horizontal strain, and temperature and moisture data over fifteen days period in sand set concrete base section on ring road. There is formation of compressive strain inside the concrete base.

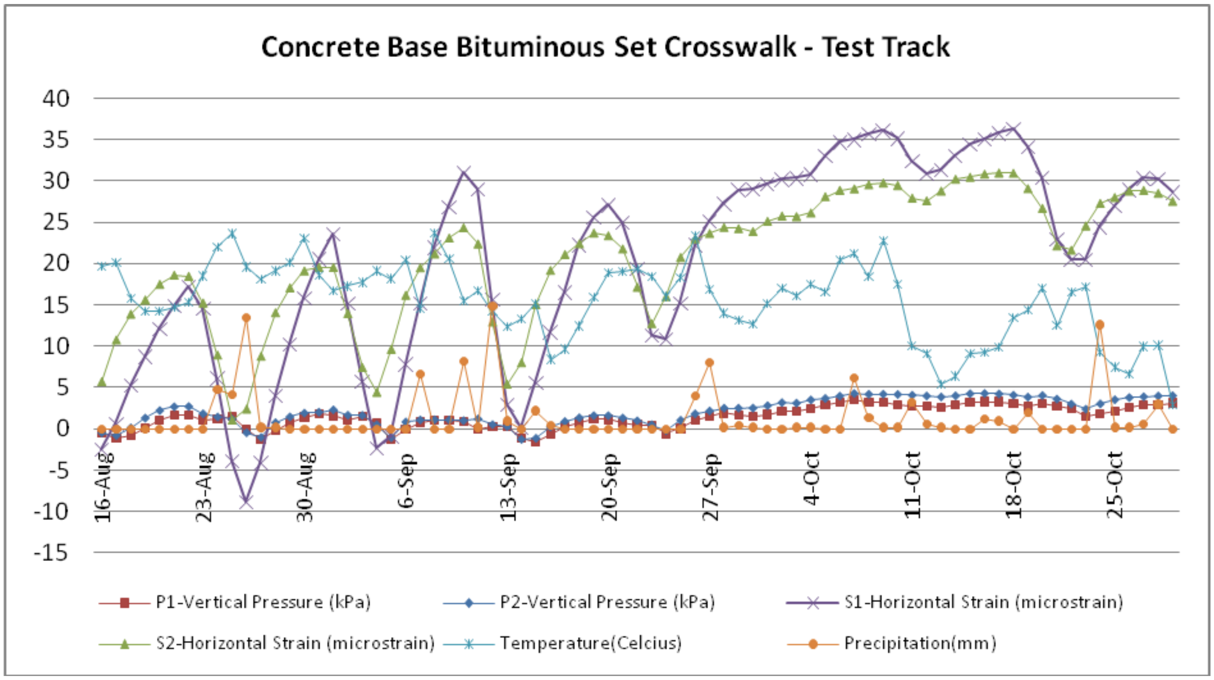


**Figure 15: Measured Data in Crosswalk Three over Time at Test Track**

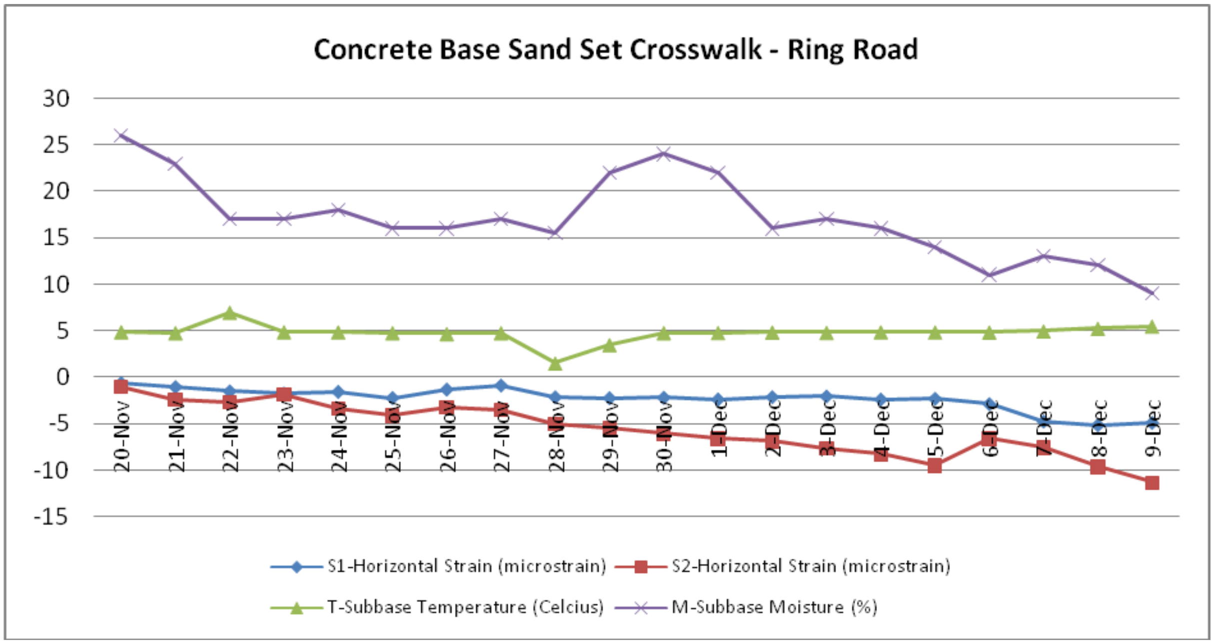


**Figure 16: Measured Data in Crosswalk One over Time at Ring Road**

Figure 17 shows the accumulation of horizontal strain, and temperature and moisture data over fifteen days period in bituminous set concrete base section on ring road. There is formation of compressive strain inside the concrete base.

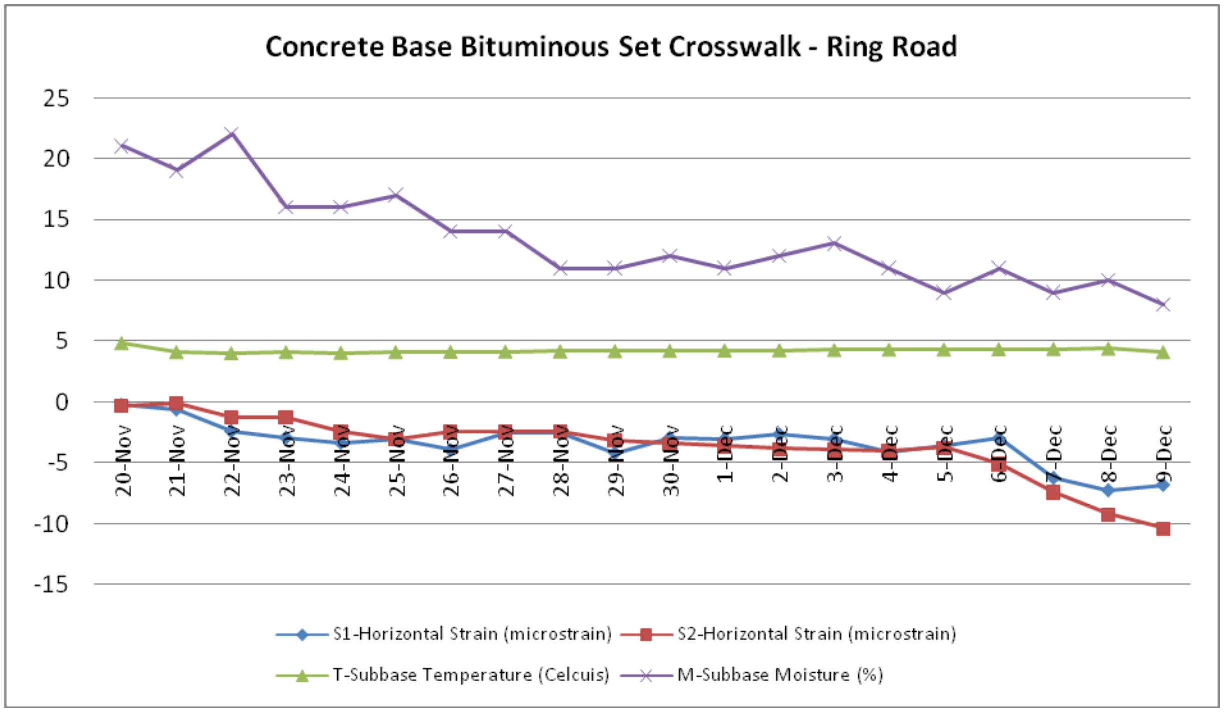


**Figure 17: Measured Data in Crosswalk Two over Time on Ring Road**

Figure 18 shows the accumulation horizontal strain and temperature and moisture data over fifteen days period in sand set asphalt base section on ring road. There is formation of tensile strain at the bottom of asphalt base.

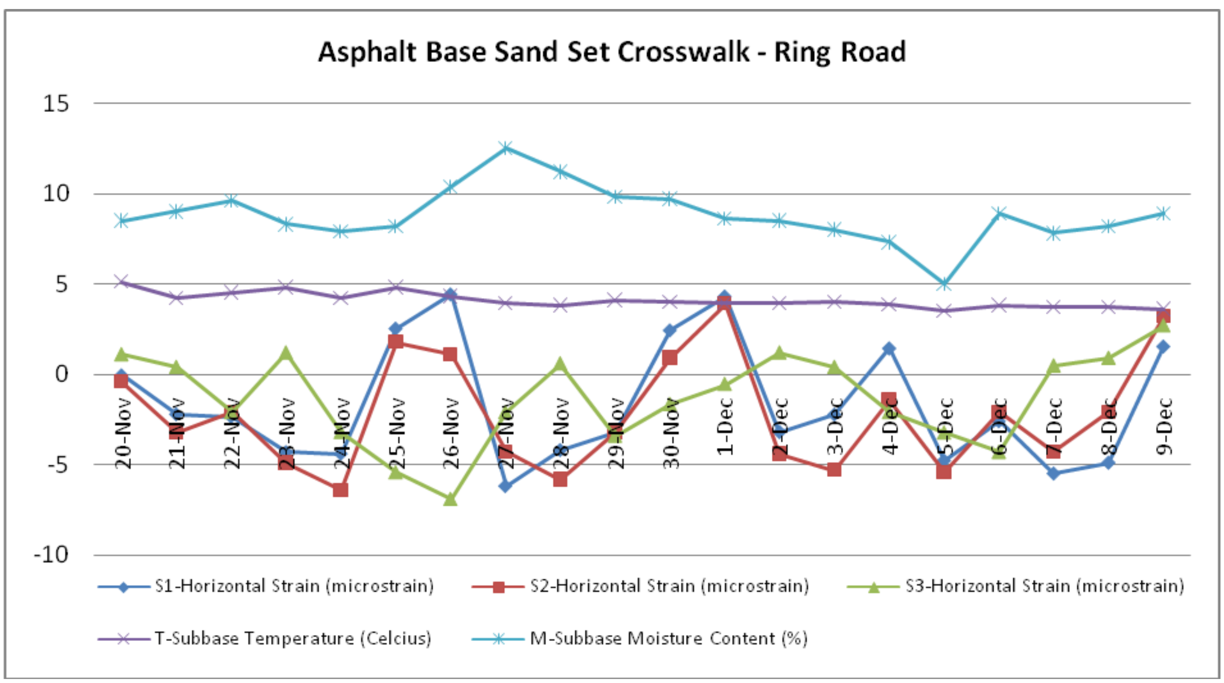


**Figure 18: Measured Data in Crosswalk Three over Time on Ring Road**

**Conclusion and Recommendations**

a) Seven test sections were built at two sites in Waterloo to assess the structural performance of four different interlocking concrete pavement crosswalk design assemblies under two different loading scenarios.
b) Six sections are instrumented with mechanical and environmental sensors whereas aggregate base section on ring road has only environmental sensors. Structural evaluation of this section will be carried out by using Portable Falling Weight Deflectometer.
c) Long-term monitoring of the pavement performance is needed. For this purpose, a database will be established within CPATT to regularly monitor the performance of the test sections.
d) Routine performance testing including distress (type, severity, density) surveys, roughness, and deflection will be carried out.
e) Pavement predictive models will be developed based on empirical and analytical relationships to describe pavement behavior to reflect traffic and environmental conditions.

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