# Reducing Urban Heat Island Effect by Using Light Coloured Asphalt Pavement

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## ABSTRACT

"Non Roof". Credit 7.1 requires that at a minimum 50% of the hardscape (roads, sidewalks, courtyards, and parking lots) be constructed using materials having a Solar Reflective Index (SRI) value of 29 or higher. LCAP is a process of designing and constructing asphalt pavements that meet this SRI requirement. The purpose of the development of LCAP is to provide developers looking to achieve LEED certification with a paving alternative that provides performance that is equivalent to conventional asphalt pavement, but that will also meet the requirement of LEED Credit 7.1.

LCAP process includes aggregate selection, asphalt mix modification, placement of asphalt mix, stripping of surface asphalt film from new pavement, and evaluation of reflectivity of aggregates, mixes, and in-place pavements. The very light colour aggregate from Coco's Badgley Island Quarry is a suitable material for LCAP. Conventional new asphalt pavements have an SRI of about 5, and weathered asphalt pavements have an SRI of about 10. There are coatings and epoxy binder mixes available in the market that can be used to increase the SRI of asphalt pavements; however, these technologies are quite expensive, approximately five times more expensive than conventional asphalt. In the LCAP process, the required SRI should be achieved at somewhat increased cost for the final lift of asphalt only, significantly lower than current technologies available on the market.

In order to have a successful LCAP, the following three requirements have to be achieved:

- LCAP should meet the LEED requirement of SRI to be at least 29, at an additional cost of the surface asphalt lift that is acceptable to the user;
- Meet conventional asphalt mix acceptance criteria for either Marshall or Superpave mixes; and
- There shall be no adverse impact on long term pavement performance.

The primary advantages of this technology, in addition to meeting the LEED SRI requirement, are the following:

- Decreased heat high island effect in urban areas;
- Meeting the green standards being implemented by cities (e.g. City of Toronto), with a product that is cost comparable to the conventional product, and which provides equivalent performance;
- Improved long term durability and resistance to cracking due to decreased rate of oxidation;
- Enhanced frictional characteristics and macrotexture, at least early in the pavement life;
- Energy savings due to decreased requirements for lighting; and

Protection of the permafrost in the northern climates.

# 1.0 INTRODUCTION

Light Colour Asphalt Pavement (LCAP) is a process of designing and constructing asphalt pavements that meet the Leadership in Energy and Environmental Design (LEED) Solar Reflective Index (SRI) requirement, as outlined in Credit 7.1 entitled “Heat Island Effect: Non Roof”. Credit 7.1 requires that at a minimum 50 percent of the hardscape (roads, sidewalks, courtyards, and parking lots) be constructed using materials having a Solar Reflectivity Index (SRI) value of 29 or higher. The purpose of the development of LCAP is to provide developers looking to achieve LEED certification with a paving alternative that provides performance that is equivalent to conventional asphalt pavement, but that will also meet the requirement of LEED Credit 7.1.

LCAP process includes aggregate selection, asphalt mix modification, placement of asphalt mix, stripping of surface asphalt film from new pavement, and evaluation of reflectivity of aggregates, mixes, and in-place pavements. The very light colour aggregate from Coco’s Badgley Island Quarry was identified as a suitable material for LCAP. Conventional new asphalt pavements have an SRI of about 0, and weathered asphalt pavements have an SRI of about 6. Figures 1 and 2 show typical examples of new and weathered asphalt pavements. There are coatings and epoxy binder mixes available in the market that can be used to increase the SRI of asphalt pavements. However, these technologies are quite expensive, approximately five times more expensive than conventional asphalt. In the LCAP process, the required SRI should be achieved at somewhat increased cost for the final lift of asphalt only, significantly lower than current technologies available on the market. Figure 3 shows an example of appearance of a LCAP pavement.

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- Meeting the green standards being implemented by some cities, with a product that is cost comparable to the conventional product, and which provides equivalent performance;
- Improved long term durability and resistance to cracking due to decreased rate of oxidation;
- Enhanced frictional characteristics and macrotexture, at least early in the pavement life;
- Energy savings due to decreased requirements for lighting; and
- Protection of the permafrost in the northern climates.

## 2.0 URBAN HEAT ISLAND EFFECT

Cities can be several degrees warmer than surrounding areas due to the built environment and the concentration of human activity, a phenomenon referred to as the urban heat island effect. This urban heat island effect has been studied for a number of years. Scientists at the Lawrence Berkeley National Laboratory have estimated that cities and urban areas are 3 to 8°F (2 to 4°C) warmer than surrounding areas due to the heat island effect. Smog levels have also been correlated with temperature increases. Thus, as the temperature of urban areas increases, so does the probability of smog and pollution.

Specific causes for these heightened temperatures and increased smog and pollution in urban areas include:

- Urban building materials absorb (as oppose to reflect) greater proportions of solar radiation;
- Impermeability of urban features limit the cooling effects of circulating water;
- Convective heat transfer is reduced in urban areas due to large density of buildings; and
- Anthropogenic heat (i.e., heat produced by humans) is greater in urban areas with increased population density.

Reducing the urban heat island effect can benefit air quality, lower electricity demand, and enhance human health and comfort. The potential benefits are significant on demographics alone. In the United States and Canada, about four out of every five persons reside in urban areas; 250 million people and 27 million respectively. Figure 4 [1] shows the phenomenon of increased air and surface temperatures in urban areas.

Among the important contributors to the urban heat island effect are pavements. Pavements are found to be a significant contributor because they constitute a substantial portion of the total urban coverage and pavements can store and radiate a significant amount of heat. Analyses in such cities as Chicago, Houston, Sacramento, Toronto, and Montreal have shown that pavements for both travel and parking can account for 29 to 39 percent of the urban land surface.

> ***"**… if you make all the roofs white, and if you **make the pavement a more concrete-type of colour than a black-type of colour** ... It's the equivalent of reducing the carbon emissions due to all the cars in the world by 11 years …**"***

*By Dr. Steven Chu, US Secretary of Energy and a Nobel prize-winning scientist (May 26, 2009)*

Like Dr. Chu said, light coloured or "cool" asphalt pavements are a means of reducing the urban heat island effect. Figure 5 [2] shows heat-related characteristics and processes in a pavement.

Figure 6 shows the thermal image of five adjacent surfaces at the Golder Mississauga office. The lowest temperature (28 °C) was for the grass surface even though the SRI value for the grass was as low as the weathered asphalt (41.7 °C). This phenomenon can be attributed to the cooling effect of circulating water through permeable surfaces and also highlights the importance of measuring temperature to complement the SRI index. The highest temperatures were for the darker, new asphalt (45.7 °C) and were about 4°C higher than the weathered asphalt. The temperature of concrete sidewalk was 32.2 °C of newly placed concrete and 37.3 °C of weathered concrete. It would be expected that if higher SRI values can be achieved for the LCAP, then larger differences will be observed when compared to conventional asphalt pavements.

## 3.0 LITERATURE REVIEW

A literature review was undertaken to define the urban heat island effect and methods to address it. The "Heat Islands – Understanding and Mitigating Heat in Urban Areas" by Lisa Gartland [2] provided abundance of useful information for the study team. The literature review included any work previously done in lightening the colour of asphalt pavements, and determining the methods and devices available for measuring solar reflectance and emittance. In 2009, a study was undertaken by NCAT to identify methods for achieving high-reflectance asphalt pavement [3]. As part of this study various techniques, including shot blasting, grit application and surface painting were applied to an asphalt test section. The SRI of each of the sections was determined. The study found that shot blasting the asphalt surface did not achieve the required minimum SRI of 29 and therefore was not able to create a high reflectance asphalt pavement. The minimum SRI of 29 chosen in this study was determined based on LEED criteria. In order to get LEED credits in the urban heat island category, this minimum SRI value must be met for at least 50% of the non-roof impermeable surfaces. Most of the other technologies investigated in this study had a cost that was greater than the shot blasting.

## 4.0 URBAN HEAT ISLAND EFFECT AND LCAP

The objective of this sustainability initiative is developing a LCAP technology that can alleviate the urban heat island effect and is economically and technically comparable to conventional darker asphalt pavement. The primary purpose of developing LCAP technology is to increase the proportion of solar radiation that is reflected by paved surfaces. LCAP will only be used for the surface course of the pavement structure, as reflectance is a pavement surface property, and the binder and other pavement layers will use conventional technologies. This new type of pavement is expected to address the first cause of urban heat islands as listed above and is expected to alleviate the problems associated with the increased urban temperatures.

The benefits of the LCAP technology can be divided into three categories namely, social, environmental and pavement performance. Increased temperatures in urban areas can have adverse impacts on human health. Furthermore, the environmental benefits would include reduction in cooling requirements for buildings and urban storm water, and reduced air pollution. Also, if the LCAP heats up less than conventional asphalt pavements this would result in reduced aging of the asphalt binder resulting in better pavement durability and cracking resistance, and increased service life. LCAP will have better frictional characteristics and macrotexture, at least early in pavement life.

Multiple benefits have been identified for developers to use this technology. The enhanced reflectance capabilities of LCAP would result in reduction in the cooling requirements for adjacent building. The use of LCAP in parking lots, city streets, tunnels, etc., is expected to reduce the lighting requirements for these applications which will result in energy savings. Also, LCAP may have more aesthetic appearance and be more context sensitive than conventional asphalt pavements. Additionally, developers are provided with incentives by government agencies through various green building standards including the Canadian Green Building Council LEED accreditation [4], and the Toronto Green Building Standard [5]. The Toronto Green Building Standard is applicable to developments in the City of Toronto and employs a tiered system of compliance. Under this standard if Tier 2 compliance is achieved then developers could be entitled to a 20% refund of the development charge that they pay to the City [6]. In order to achieve Tier 2 compliance in the category of “Urban Heat Island Reduction: At Grade”, light colour asphalt pavement (high albedo) can be used for at least 75% of the non-roof hardscape. The non-roof hardscape in a development includes parking lots, driveways and all other hard landscaping [4].

In the MTO GreenPave rating system cool pavements would be entitled to two points towards their GreenPave certification. At its current state GreenPave does not include light colour asphalt pavements as a cool pavement alternative; however, concrete due to its light colour and high reflectance is able to achieve two points. Flexible pavement types that are included as cool pavement alternatives are porous asphalt and open friction courses and can achieve a maximum of one point. The LCAP technology, with its high reflectance, would have the potential to be included as a cool pavement with the potential of achieving two points as is the case with concrete. [7]

In the current pavement market there are technologies available to lighten the colour of asphalt surfaces; however, the majority of these technologies have a drastically higher cost than conventional asphalt which makes their regular use infeasible. Some of these technologies include synthetic binders that are colourless or highly reflective, and painting or applying coatings to the asphalt surface. The coatings and paint have to be reapplied on a regular basis in order to maintain the lightness of the asphalt pavement. The LCAP being developed by the study team is going to increase the solar reflectance of the asphalt pavement with a cost that is comparable to conventional asphalt.

Table 1 presents the SRI of some common types of pavements. The SRI’s of new concrete (grey and white) are both above the required value of 29, where as that of asphalt is close to zero. As concrete ages it darkens and the SRI value will decrease over time. The opposite is true for the case of asphalt, where the SRI will increase over time when the asphalt film wears off. The exact SRI of the aged asphalt will depend primarily on the type of aggregate used in the mix and how much of the asphalt coating has been removed from the surface aggregate. Table 1 shows that on average the weathered asphalt is still far from achieving the required minimum SRI of 29.

## 5.0 MEASUREMENT OF REFLECTANCE AND EMITTANCE

The SRI of the pavement is a function of the solar reflectance and the emittance of the pavement material. The solar reflectance can be measured in the field using a pyranometer. A pyranometer can measures the global solar radiation when facing the sun and measures the reflected radiation when facing the ground. The field reflectance is measured in accordance with the ASTM E1918, [8]. According to ASTM E1918, a 4 m diameter area is required for the measurement of reflectance in the field when using a pyranometer. This area ensures that 99% of the field of view of the pyranometer is contained in the desired measurement area.

Laboratory measurements of reflectance were determined in accordance with ASTM C1549 [9]. The portable solar reflectometer measures the reflectance of a minimum 1 inch diameter sample. A tungsten lamp is used to illuminate the sample in the sample port and the reflected beam is measured using six sensors. Each sensor is configured to measure a particular wavelength of the reflected beam. The readings from each of the sensors are combined using weighting factors to obtain the reflected beam in the solar spectrum.

Emissivity measures a materials capability of emitting energy in the form of heat. The emissivity of the material was measured in accordance with ASTM C1371 [10]. The device measures the emissivity of a minimum 2.25 inch diameter sample. The emittance measurements are made at a temperature of 65°C. A voltmeter is adjusted such that is displays the emittance of a calibrated sample. Once the calibration is undertaken, the device can be placed on the sample to be measured. The device measures emissivity by comparing to another material of known emissivity.

The solar reflectivity index is calculated using the reflectance and emittance measurements and methods laid out in ASTM E1980 [11]. The index is a measure of increase in the temperature of a surface when it is exposed to the sun. The higher the SRI the lower will be the increase in surface temperature.

## 6.0 INITIAL INVESTIGATION – FIELD AND LABORATORY

The initial reflectance measurements were carried out on in-service pavements. The pavements selected were in the Mississauga and Waterloo areas and were typical ones and those that looked the lightest in colour due to being weathered and incorporating light colour aggregates. None of the sites that were tested exhibited the desired SRI of 29. Typical values are shown in Table 2. This further confirmed that additional study was required to achieve the desired reflectance for asphalt pavements.

At the LCAP laboratory phase, the primary objective was to identify the preferred aggregate type, optimum asphalt mix gradation and stripping mechanism that would result in the final pavement having an SRI greater than 29. The first step in the laboratory phase was to identify rock types that were sufficiently light colour such that when processed aggregate was incorporated into the surface asphalt mix, the pavement that could meet the SRI requirement. Figures 6 and 7 show typical examples of investigated aggregates and mixes, respectively.

Once the suitable aggregates had been selected, a mix design was developed to maximize the area of exposed aggregate on the pavement surface and not to compromise other required properties including volumetrics. Finally, several surface stripping methods were tested to identify the optimal method to be used in the field.

The laboratory testing results to date clearly showed that by blending the right aggregate types, modifying the mix gradation, using the optimum asphalt cement content and applying effective asphalt cement stripping method, it is possible to produce pavement that exhibits SRI values that meet the required LEED minimum of 29.

## 7.0 LARGER SCALE TEST STRIP

The very light colour aggregate from Coco’s Badgley Island Quarry was identified as a suitable material for LCAP. A sample of a surface course asphalt mix 2 m by 2 m in size was prepared by Coco Paving in their Windsor plant and moved to the Etobicoke facility for SRI testing. The asphalt cement film was stripped from the top of the surface.

The SRI measurements were obtained using a field pyranometer. This instrument requires a very large test area for accurate measurement. The main obstacle was the lack of suitable weather condition. The test requires a perfect sunshine conditions with no clouds. The testing had to be delayed number of time due to the presence of clouds. Figure 9 shows the first sample prepared by Coco Paving.

The calculated SRI of the sample was 13. It was then decide to use reflectivity enhancer in the second asphalt mix. Figure 10 shows the appearance of the second asphalt sample after stripping. Because of the weather issues the SRI of the second sample has not been tested yet. The results of the most recent SRI testing will be presented at the CTAA 2017 conference.

## 8.0 SUMMARY

The urban heat island effect is observed in large number of cities. Black colour pavements have significant contribution to the increase of surface temperatures in urban areas. An extensive research study is carried out on light colour asphalt pavement. The objective is to develop a pavement that will meet the LEED requirement of SRI not lower than 29. The research included laboratory investigation of aggregates and mix designs and field investigation of SRI survey of number of asphalt pavements, from newly paved to weathered that incorporated light colour aggregates.

The very light colour aggregate from Coco’s Badgley Island Quarry was identified as being a suitable material for LCAP. The first sample, using virgin materials, had SRI of 13. A second sample was prepared with enhanced reflectivity materials. Due to weather issues the SRI has not been determined yet. It will be reported at the CTAA conference.

## 9.0 REFERENCES


1. Lisa Gartland, “Heat Islands – Understanding and Mitigating Heat in Urban Areas”, Earthscan, UK and USA, 2008.

2. Cambridge Systematics, “EPA Cool Pavement – Task 5, Cool Pavement Report”, June 2005.

3. Tran, N., and B. Powell, “Strategies for Design and Construction of High-Reflectance Asphalt Pavements”, NCAT Report No. 09-02, National Centre for Asphalt Technology, April 2009.

4. Canadian Green Building Council, “LEED Canada for New Construction and Major Renovations 2009”, Canadian Green Building Council, Ottawa, ON, 2010.

5. City of Toronto, “Toronto Green Standard”, City of Toronto, Toronto, ON, December 31, 3010.

6. City of Toronto, “Tier 2 & The Development Charge Refund Incentive”, City of Toronto, retrieved on May 17, 2011 from http://www.toronto.ca/planning/environment/developerinfo .htm.

7. MTO, “GreenPave: Green Pavement Design Rating System Reference Guide for New Construction and Rehabilitation of Ontario Pavement Structure”, Ontario Ministry of Transportation.

8. ASTM E1918 - 06, “Standard Test Method for Measuring Solar Reflectance of Horizontal and Low-Sloped Surfaces in the Field”.

9. ASTM C1549 - 09, “Standard Test Method for Determination of Solar Reflectance Near Ambient Temperature Using a Portable Solar Reflectometer”.

10. ASTM C1371 – 04a, “Standard Test Method for Determination of Emittance of Materials Near Room Temperature Using Portable Emissometers”.

11. ASTM E1980, “Standard Practice for Calculating Solar Reflectance Index of Horizontal and Low-Sloped Opaque Surfaces”.

**TABLES**

**Table 1: Typical SRI Values from the LEED Green Building Rating System [5]**

| Material | Emissivity | Reflectance | SRI |
|---|---|---|---|
| Typical New Grey Concrete | 0.9 | 0.35 | 35 |
| Typical Weathered Grey Concrete | 0.9 | 0.20 | 19 |
| Typical New White Concrete | 0.9 | 0.70 | 86 |
| Typical Weathered White Concrete | 0.9 | 0.40 | 45 |
| New Asphalt | 0.9 | 0.05 | 0 |
| Weathered Asphalt | 0.9 | 0.10 | 6 |

**Table 2: SRI of Different Pavement Surface**

| Pavement Surface | SRI |
|---|---|
| Light Coloured Asphalt | 12 to 18 |
| Weathered Asphalt | 6 |
| Concrete | 26 |
| Curing Compound Concrete | 43 |
| Grass | 19 |

FIGURES

Figure 1. Example of appearance of a new asphalt pavement with SRI about 0.

Figure 2. Example of appearance of a weathered asphalt pavement with SRI about 6.

Figure 3. Example of LCAP pavement of ongoing research.

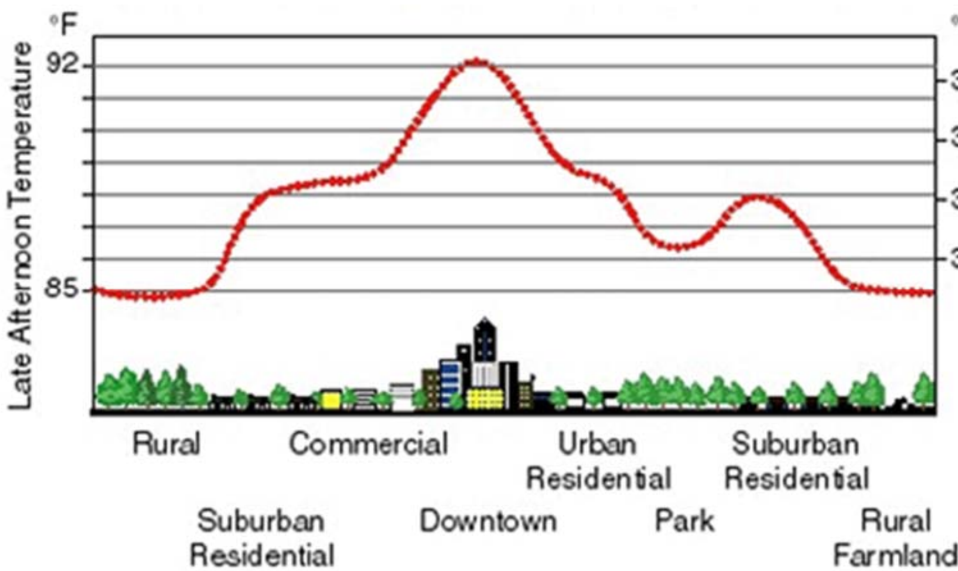


**Figure 4. Phenomenon of increased air and surface temperature in urban areas [1]**

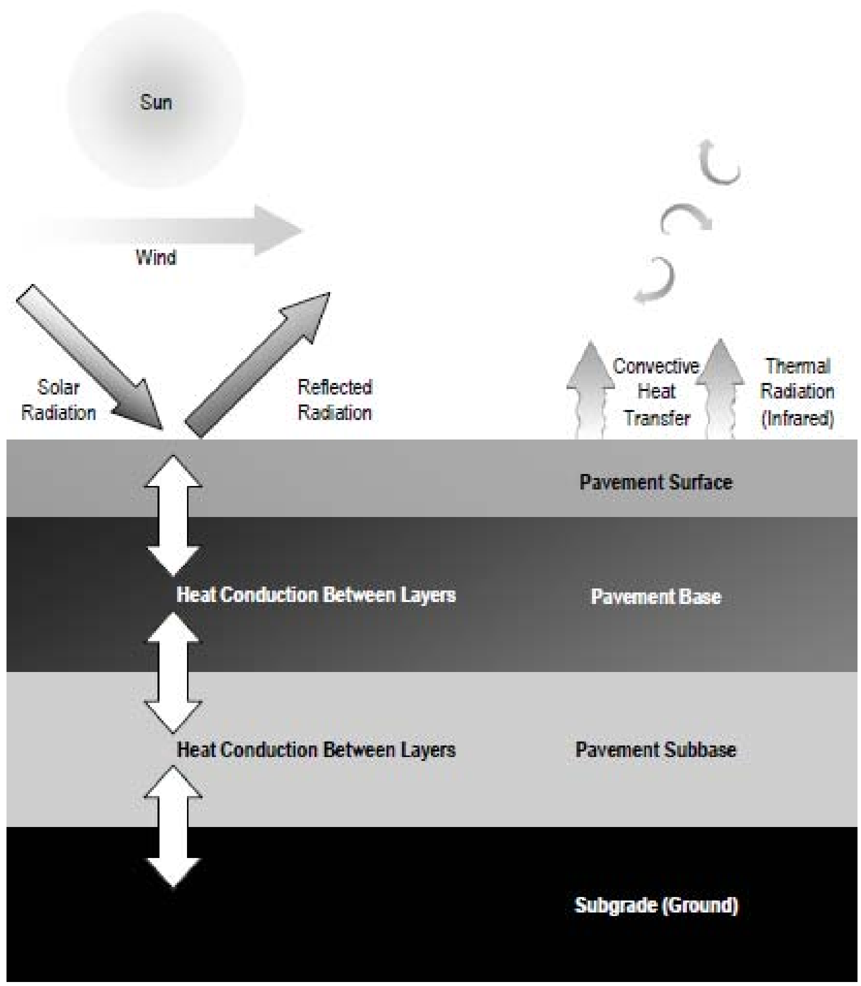


**Figure 5. Heat-related characteristics and processes in a pavement [1].**

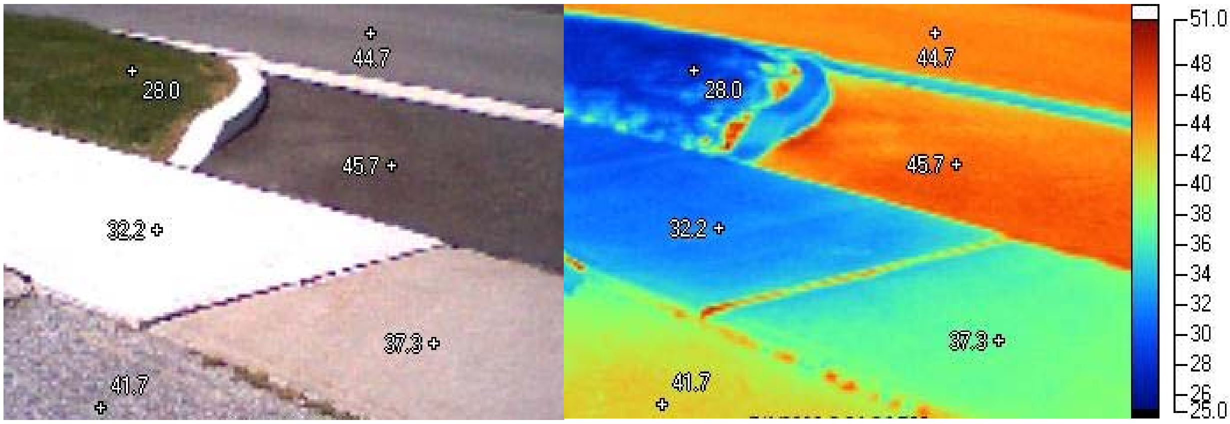


**Figure 6. Thermal image of five adjacent surfaces at Golder Mississauga office.**

**Figure 7. Example of investigated aggregates.**

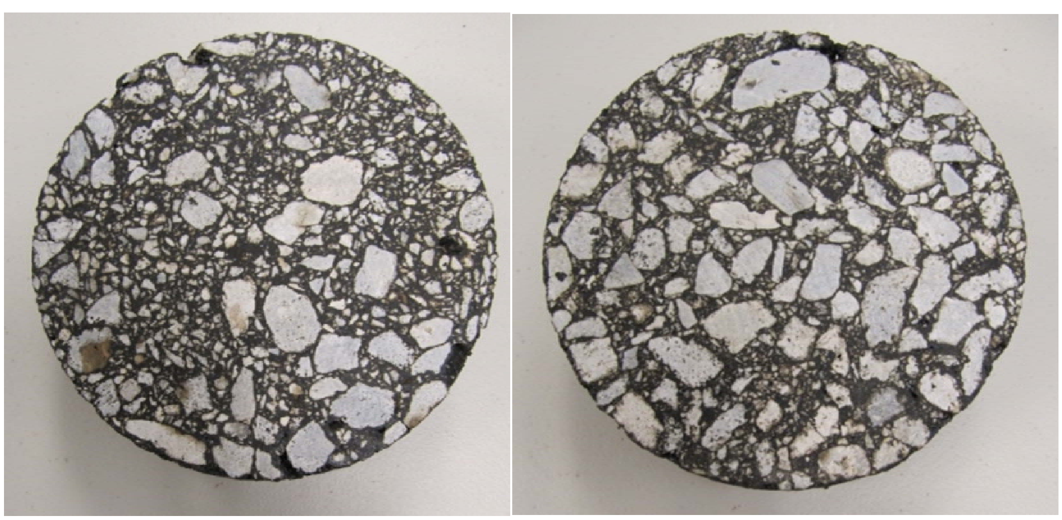

**Figure 8. Example of investigated mixes.**

**Figure 9. First asphalt sample prepared by Coco Paving.**

**Figure 10. The second asphalt sample prepared by Coco Paving.**