5. RESULTS AND FINDINGS

5.1 Reflectivity

5.1.1 Figure 16 below shows the reflectance percentage for the three coatings, CP 40, CP65 and NP65.

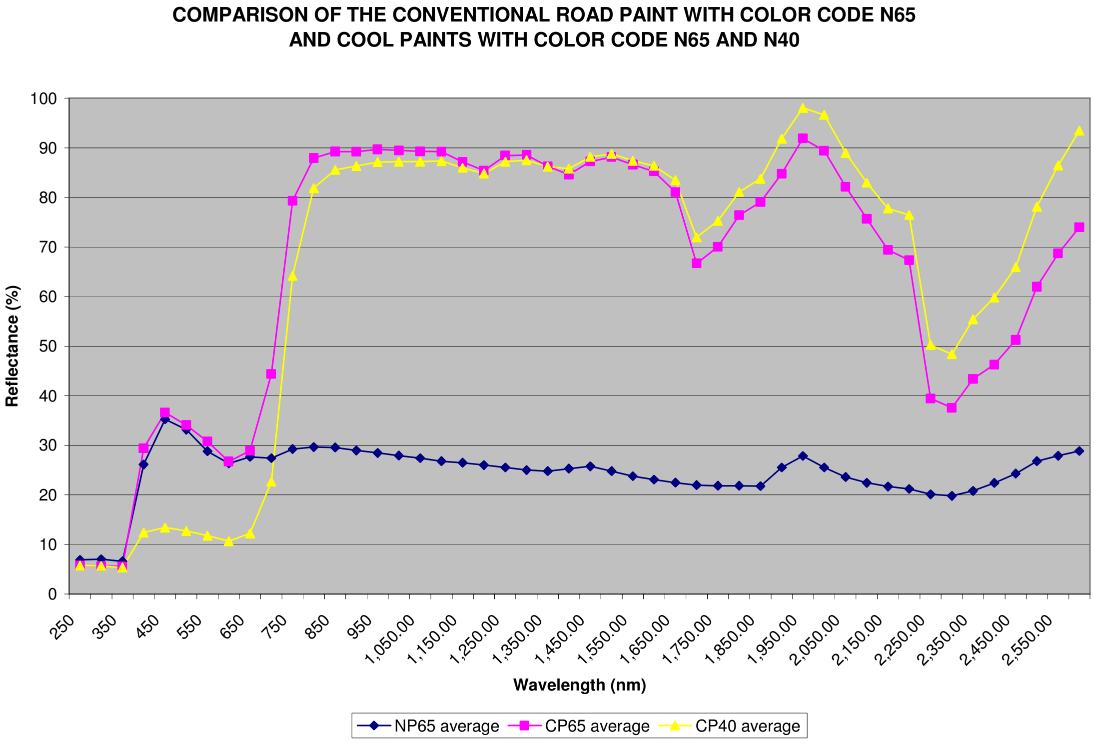

Figure 16. Graph comparing the percentage of reflectance between NP65, CP65 and CP40.

Table 1: Average reflectivity values at the ultraviolet, visible light and near infra-red region.

	UV (300-400nm)	VIS (400-700nm)	NIR (700-2600nm)
Acrylic substrate with NP65	7%	30%	25%
Acrylic substrate with CP65	6%	31%	77%
Acrylic substrate with CP40	6%	12%	81%

5.1.2 All three coatings are noted to have low reflectivity (less than 7%) for ultra-violet spectrum (300-400nm).

5.1.3 In the visible light spectrum (400-700nm), both CP65 and NP65 have similar reflectivity profile and average reflectance percentage. This indicates that their color is similar. As CP 40 is darker in color, it has a much lower reflectance percentage as compared to the other two coatings.

5.1.4 From 700nm onwards (near infrared-red spectrum), the reflectance percentage for NP65 remains consistently low, with a reflectance percentage of 25%. But CP65 jumps from a reflectance of 31% to 77%. Similar profile was also noted for CP40; reflectance percentage has jumped from 12% in the visible like spectrum to 81% in the near infrared-red spectrum.

5.2 Thermal Conductivity

5.2.1 Table 2 below shows the average conductivity results of the different coatings. The details of the conductivity are as in attached (Annex D, table 3). From the results, it can be observed that the thermal conductivities for *PerfectCool* coatings (both CP 40 and CP65) are much lower than the NP65.

Table 2: Summary of results for Conductivity measurement of the different coatings

Coating Type	Conductivity (W/mK)
CP40	0.264
CP65	0.252
NP65	0.422

5.3 Emissivity

5.3.1 Table 3 below shows the average emissivity of the three coatings. From the emissivity, it can be observed that CP40 has the highest emissivity. CP65 emissivity is similar to NP65.

Table 3: Summary of results for Emissivity measurement of the different coatings

Coating Type	Emissivity
CP40	0.828
CP65	0.692
NP65	0.680

5.4 Control Experiment

5.4.1 The results gathered from the experiment were consolidated and tabulated into graphical format.

5.4.2 From the results, it is observed that the surface temperature of CP65 was cooler than NP65. Throughout the entire duration of the test, the surface temperature of CP65 did not exceed 50℃, whereas NP65 has exceeded 50℃ on certain days and recorded the highest temperature. A thermal lag was also noted for the control slab as compared to the rest. This lag becomes more prominent on a cooler day.

5.4.3 From the 14 days test, 28th June, 30th June, 3rd July and 6th July have represented the days with the least rainfall. Out of these days, 28th June has the highest solar radiation and ambient air temperature. Therefore, it was selected as a typical hot day for further analysis.

5.4.4 On the typical hot day, the peak temperature of the control slab, CP65 and NP65 are noted to be 50.18℃, 45.78℃ and 49.6℃ respectively. It is also noted that CP65 cools down to a lower temperature than NP65 and unpainted concrete slab in the night.

5.4.5 Details of results are as attached (Annex D, figures 2 to 12).

5.5 On-Site Results

5.5.1 Basketball Courts at Vacant School (Boon Lay Secondary School)

5.5.1.1 The temperature results for the entire period were measured for the six different heights, 50mm below surface (hereinafter "-50mm"), 10mm below surface (hereinafter "-10mm"), 0mm on surface (hereinafter "0mm"), 10mm above surface (hereinafter "+10mm"), 300mm above surface (hereinafter "+300mm"), and 600mm above surface (hereinafter "+600mm"), measured throughout the entire period plotted at 5 minutes interval.

5.5.1.2 It is observed that all peak temperatures measured at all six different heights are higher than the reference ambient air temperature recorded at the National University of Singapore. From the graphs, it can be observed that the peak surface temperatures of the *PerfectCool* coatings have an average difference of about 15°C, when compared to the reference ambient air temperature. Ambient air temperatures measured above NP65 are noted to be only 4°C higher than the reference ambient air temperature.

5.5.1.3 From the graphs it is noted that *PerfectCool* coatings are effective in reducing the temperatures of the pavements. A difference of 5°C is noted between the peak temperatures between *PerfectCool* coating and the normal road paint at -50mm, -10mm and 0mm.

5.5.1.4 The results were further categorized and grouped into hours, for the entire measurement period. The highest average difference in temperatures between *PerfectCool* coatings and the normal road paint is noted was to be at -10mm. The biggest difference recorded is noted to be at 1700hrs.

5.5.1.5 It is noted that for temperature measurements at -50mm, the peak temperature for the ambient air is between 1200-1300hrs, but the sub-surface temperatures of the pavements peaked only between 1600-1700hrs. This time lag decreases as the measurements approaches the surface. The ambient air temperature profiles recorded at 300mm and 600mm above both pavement types are noted to be similar to the temperature measured at NUS.

5.5.1.6 It is also noted that there is a slight time lag in the temperature graphs of the ambient air above the pavements as compared to the reference temperature graph.

5.5.1.7 The results for the vacant school site are as attached (Annex D, figures 13 to 21).

5.5.2 Asphalt Road At Vacant JTC Site

5.5.2.1 The experiment was set on site for the duration of 23 days (from 30th June, 2008 to 22nd July, 2008). The temperature results recorded at an interval of 5 minutes was plotted into a line graph. The plotted temperature profiles of *PerfectCool* coating and the asphalt road at all six measuring heights were compared and studied.

5.5.2.2 It is observed that under a typical month, the road surface temperature (0mm) can be as high as 55℃ (Day 130708, see figure 17 below). This is much higher than the ambient air temperature of 30℃. It was noted that overall, the *PerfectCool* coating had a much lower surface temperature (0mm). On a similar day where the road temperature reached as high as 55℃ (Day 130708), *PerfectCool* coating peak temperature at 0mm, was 38℃, 17℃ lower than the peak temperature of the conventional asphalt road.

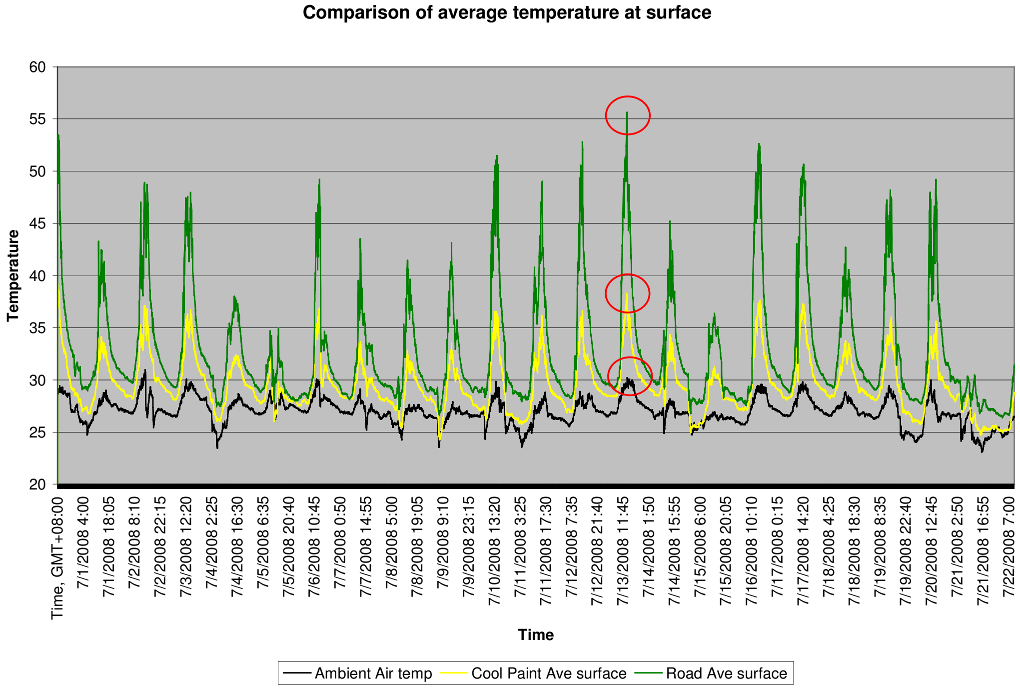

Figure 17. Comparison of average surface air temperatures between the Cool Paint and the asphalt Road on surface. Circled red from top to bottom are the peak temperatures of the Road surface, the cool paint surface and the ambient air respectively.

5.5.2.3 Similar observations were noted for sub-surface temperatures. Peak temperatures of conventional asphalt roads at -50mm and -10mm are noted to be consistently and distinctively higher than the peak temperatures of *PerfectCool* coatings at respective depths. Figure 15 below shows the temperatures of both the conventional asphalt road and *PerfectCool* coating at -50mm. On a similar day, (Day 130708) the peak sub-surface temperatures of a asphalt road and *PerfectCool* coating is 50℃ and 34℃ respectively.

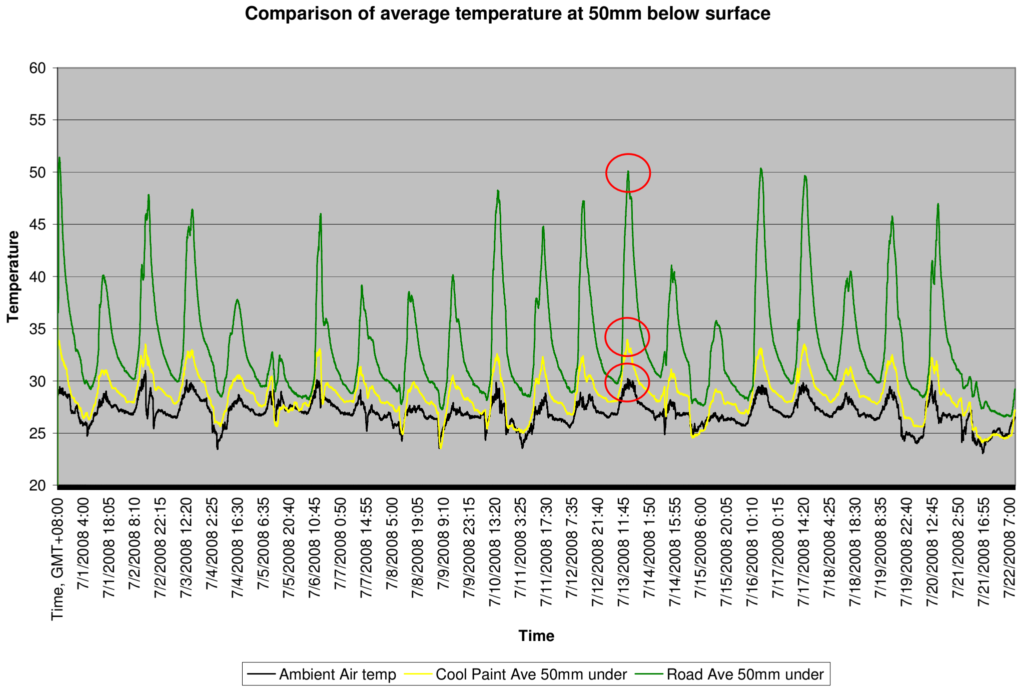

Figure 18. Comparison of average surface air temperatures between the Cool Paint and the asphalt Road at 50mm below surface. Circled red from top to bottom are the peak temperatures of the Road surface, the cool paint surface and the ambient air respectively.

5.5.2.4 Another notable observation from both figures 17 and 18 is, when compared to the asphalt road, the temperature graphs plotted for *PerfectCool* coating through out the entire measurement duration were consistently lower, even during the night. This observation is consistent for all measurements at -50mm, -10mm, 0mm, and +10mm (Annex D, figures 22 to 26).

5.5.2.5 The differences in the ambient air results are not as obvious as the sub/surface results. Only slight differences are noted between ambient air temperatures recorded above *PerfectCool* coating and the conventional asphalt road. Similar to the results noted in the vacant school site, a slight time lag between the conventional asphalt road and the *PerfectCool* coating is noted (Annex D, figure27).

5.5.2.6 Further details of results are as attached (Annex D, figures 22 to 27 and table 4).

5.6 Survey Questionnaire

5.6.1 The survey was conducted on the 16th of October, 2008, from 1200hrs to 1400hrs. 30 participants were brought down to both vacant school and JTC sites and were asked to individually complete the survey questionnaire. The results of the 30 participants for both the vacant school and JTC sites were consolidated and tabulated into graphic format.

5.6.2 As the selection criteria were not limited to any particular dress codes or gender, there were a good mix in dressing among the participants, ranging from T-shirt and jeans to office wear. Their footwear also ranges from high heels to sportswear.

5.6.3 Based on the consolidated results, it was observed that the all the participants ranked their thermal sensation, for questions 1 to 8, beyond the neutral rating of 4. The results for each question were then tallied and displayed into a graph. Figures 19 and 20 below are abstracts of the survey questionnaires results for both sites found in Annex D. Refer to Annex C for details of questions 1 to 8. Based on the results, it can be observed that the participants overall felt slightly cooler when they are above the *PerfectCool* coatings. It is worth noting that at the vacant school site, when asked to rank their sensation of their feet, it can seen that more participants ranked “5–warm” and lesser ranked “7–Very Hot”, when they were on the *PerfectCool* coating, as compared to the normal coating (compare Qn 1 to Qn 5 in figure19). Similar findings were observed for when the participants were asked to rank how they felt when they touched the pavements – the number of participants ranked “5–warm” increases, while the number which ranked “7–Very Hot” decreases (compare Qn 4 to 8 in figure 19).

5.6.4 The difference in thermal sensation felt by the participants become more obvious in the results gathered at the JTC site. Comparing similar questions, it can be seen that more participants ranked “7–Very Hot” when asked for their thermal sensation for their feet and hands. When the same group of participants was asked to rank their sensations when they are on the *PerfectCool* coating, there were dramatic improvements. No participants ranked “7–Very Hot” for sensation felt by their feet (question 5, figure 20), and the number of participants which ranked “7–Very Hot” for sensations felt by their hands dropped from 30 participants to only 2 (question 8, figure 20).

5.6.5 Further results are as attached (Annex D, figures 29 to 32).

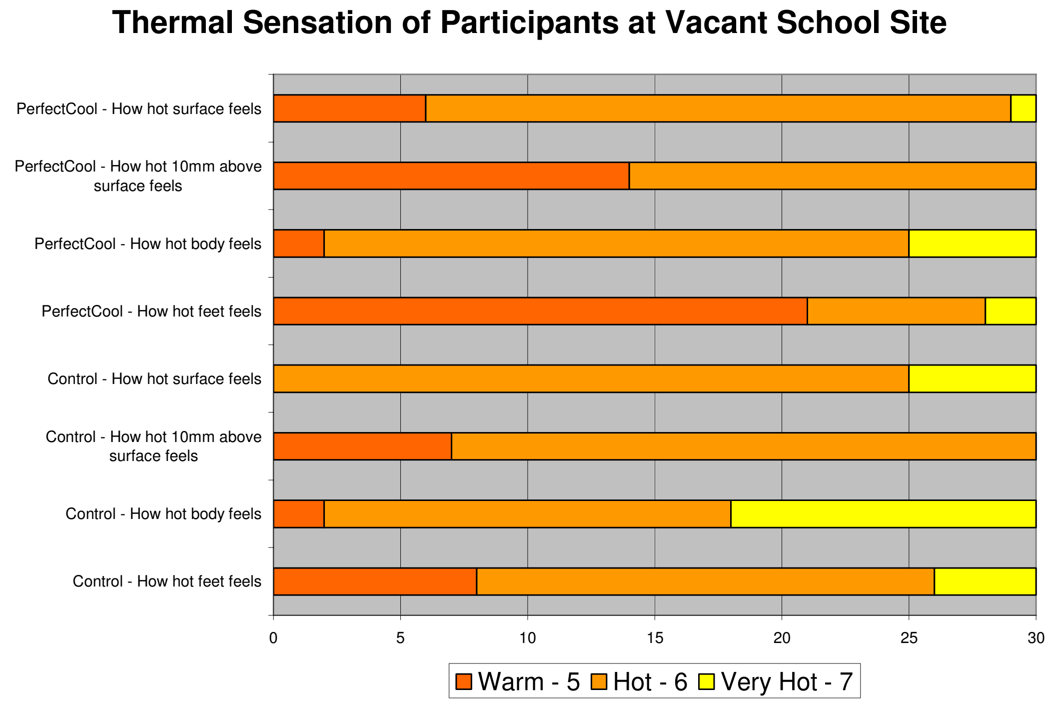

Figure 19. Results of survey questionnaire, from questions 1 to 8, completed by 30 participants at the vacant school site.

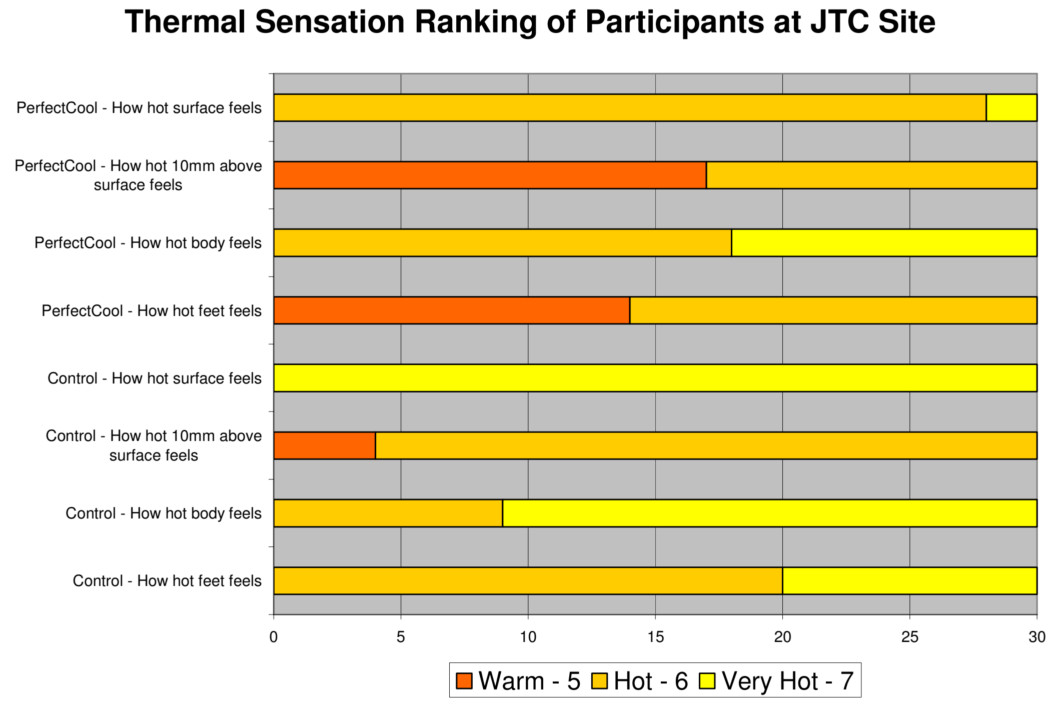

Figure 20. Results of survey questionnaire, from questions 1 to 8, completed by 30 participants at the JTC site.

5.7 Energy Simulation

5.7.1 A 3-D massing model of a typical factory, 45m by 30m by 8m high, was created for the energy simulation. Images of the model can be found in Annex D (figures 33 to 35). The factory modeled is generally divided into 2 areas: a two story office, 10m by 30m by 8m high, and a double volume working area, 35m by 30m by 8m high. The external wall is assumed to be a standard wall construction, the internal wall is assumed to be a 105mm thick brick wall with 13mm thick plaster on both sides, and the external glazing is assumed to be low-e double glazing (6mm+6mm). The factory was completed with a pitch roof top and a 20m wide asphalt road along the perimeter of the factory.

5.7.2 Two typical scenarios were modeled: the typical factory surrounded with the asphalt pavement, and with the pavements coated with CP40. The following parameters were taken as the inputs for both scenarios: asphalt is taken to have the an albedo (solar reflectance) of 0.15 (Lovell *et al*, 2005), and an emissivity of 0.93 (source: website “Cole-Parmer”); CP40 is taken to have an albedo of 0.46 and an emissivity of 0.828. The albedo of CP 40 is calculated with by prorating the reflectivity results with the proportion of spectral energy distribution of solar radiated at ground level as simulated from IEC 60068-2-5:1975. The occupancy and lighting consumption kept as constant for both scenarios.

5.7.3 Through the energy simulation, the yearly electrical consumption for the factory surrounded with pavement made with asphalt and coated with CP40 were 354.82 MWh and 342.5376MWh. This computes to a saving in electrical by 3.46% for the factory with its pavements coated with CP40.

5.7.4 The energy simulation has also identified that the peak electrical consumption to fall in the month of June. The total electrical consumption and chiller load consumption were tabulated and the percentage savings possibly achieved through the application of CP40 was 4.88% and 7.69% respectively.

5.7.5 The external wall surface temperatures of the factory for both scenarios, during the period of when the peak electrical consumption was identified, were tabulated into a graph for comparison. It was observed that the external wall surface temperatures of the factory surrounded with CP40 was consistently lower as compared to the factory surrounded with asphalt pavements.

5.7.6 Details are as attached (Annex D, figures 32 to 39 and tables 5 to 7).

5.8 Discussion

5.8.1 *PerfectCool* coatings have a direct influence on the transfer of heat from the sun to the medium (asphalt roads, basketball courts, etc.), and back into the environment. The transfer of thermal energy (heat) from one medium to another only occurs via three methods: conduction, convection and radiation. Conventionally, mediums such as roads, basketball courts, etc., absorb a huge amount of solar radiation from the sun and builds up its internal heat. This built up thermal energy is transferred back into the environment, thus raising the overall temperature. *PerfectCool* coatings serves as a barrier, not only protecting the mediums from direct sunlight, it also limits the transfer of thermal energy from the sun to the mediums and back into the environment.

5.8.2 *PerfectCool* coatings limit the transfer mainly by being highly reflective in the infrared-red *region*. This is clearly seen in the laboratory reflectivity test results, between the comparisons of two paint types with similar color. With reference to the report's figure 13, *PerfectCool* coating (CP65) is very reflective in the NIR region (700-2600nm), with an average value of 77%, which is 52% higher than a normal paint with similar color (NP65 – 25% reflective in NIR region). The high reflectivity is able to directly reduce the amount of heat transferred to a medium through radiation. This is clearly substantiated from the reduced sub-surface temperatures graphs plotted for the vacant school site (see Annex D figures 13 and 14). The sub-surface temperatures plotted for *PerfectCool* coating at -50mm and -10mm were significantly lower than the normal road paint. As *PerfectCool* coating is able to reflect away 80% of the thermal energy, less thermal energy is able to reach the surface and warm it. The high reflectivity of *PerfectCool* coating thus is also able to significantly reduce the surface temperature (see Annex D, figure 15).

5.8.3 The effects and benefits of *PerfectCool* coatings due to their high reflective in the NIR range are clearly demonstrated in the controlled experiment. Two similar colored coatings, where one is highly heat reflective and the other is not, when exposed to the similar conditions demonstrate different effects. The peak surface temperature of CP65 is about 4℃ lower than the NP65 (see figure 21 below). With all other parameters kept constant, this reduction in surface temperature can be concluded to be mainly due to the high reflectivity properties of the *PerfectCool* coatings.

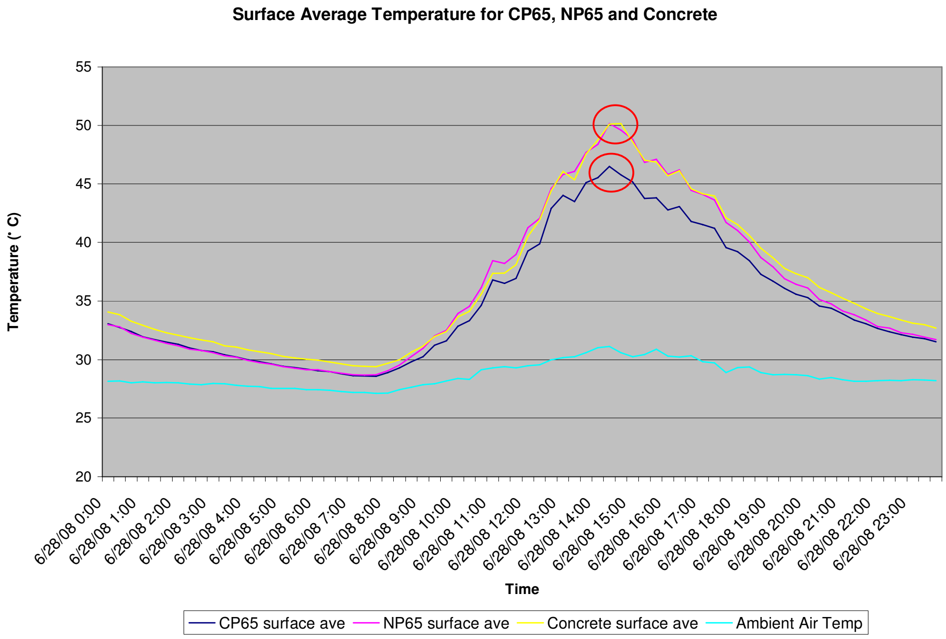

Figure 21. Comparison of average surface temperature of control slab, CP65 and NP65. Note peak temperature of CP65 is about 4℃ lower than NP65 and control.

5.8.4 The reflective technology in *PerfectCool* coatings allows the coatings to still be highly reflective to heat despite being dark in color. Dark colored surfaces are typically preferred for roads because they cause less discomfort glare to road users. Traditionally, darker color would generally mean lower reflectivity in the infrared-red region. The hollow spheres integrated into the *PerfectCool* coatings are able to overcome this limitation. In the reflectivity test results, *PerfectCool* coatings were able to have low reflectivity in the visible light region (see report, table 1; reflectivity - 12%) and yet maintain high reflectivity in the NIR region (see report table 1; reflectivity - 81%). The on site experiment results clearly shows the dark colored *PerfectCool* coating consistently had lower sub-surface and surface temperatures when compared to the asphalt road surface. Peak temperature differences between the two surfaces goes up to as high as 10℃.

5.8.5 Figure 22 and 23 below shows the temperature profile for 24 hours duration for JTC site and the school site. The temperature profiles between the control and the *PerfectCool* coatings were compared at the heights of -50mm, -10mm, 0mm and +10mm. The graphs clearly demonstrated that *PerfectCool* coatings are much cooler.

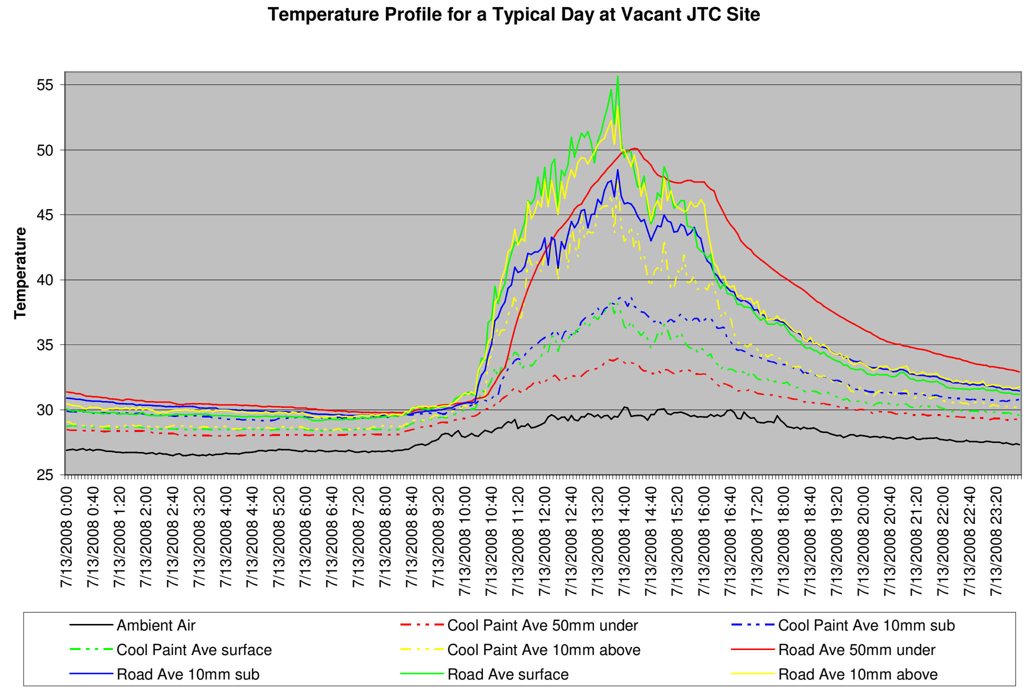

Figure 22. A 24-hour temperature profile of a typical day at the JTC site.

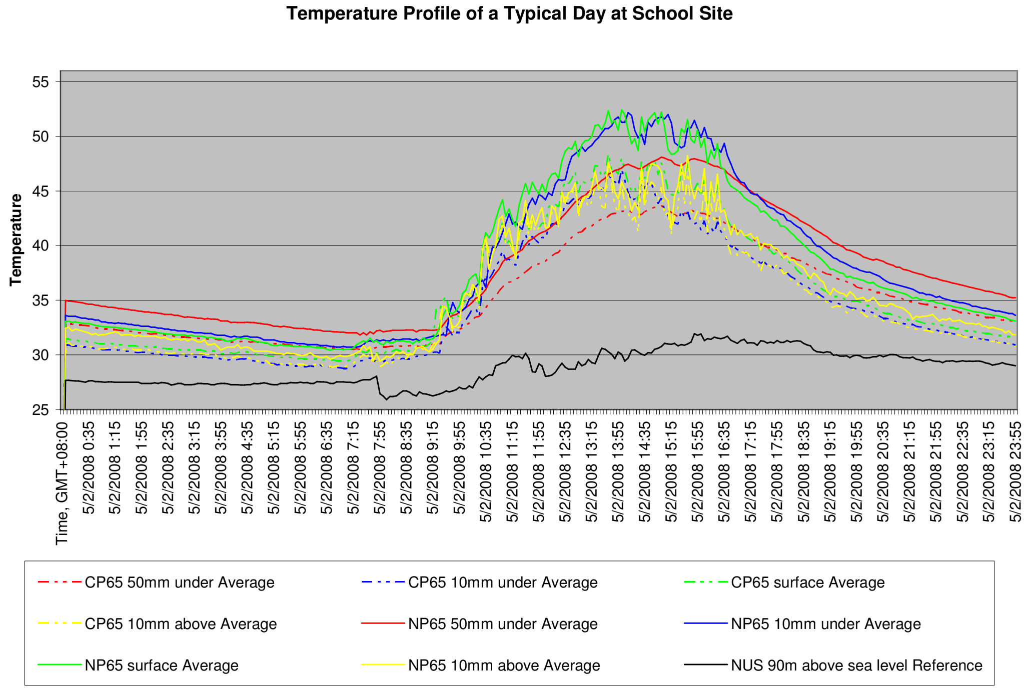

Figure 23. A 24-hour temperature profile of a typical day at the school site.

5.8.6 Another notable observation was that for the JTC site, the temperature profile graphs for the asphalt road at 0mm and +10mm were similar. This indicates that the rate and the amount of thermal energy which the asphalt road absorbs, is similar and as high as the rate and amount which the road is dissipating. But after the application of *PerfectCool* coating, the temperature graph at +10mm was noted to be higher (see figure 22). The main contribution to the increased heat gain is likely due to the high reflectivity of *PerfectCool* coatings in the infrared-red region; Heat transfer from the roads to the layer of air by conduction and convection can be considered negligible. The conductivity of *PerfectCool* coatings are too small to create any significant differences, while Heat transferred via convection can be deemed negligible as the air layer is close to still. The highly reflective *PerfectCool* coatings reflect a huge portion of the heat back into the environment, heating up the thin layer of air via radiation.

5.8.7 Although the temperature of the layer of air just above the *PerfectCool* coating's surface was higher, it was still significantly lower than all the temperature graphs plotted for the asphalt road (see figure 22).

5.8.8 Through the actual site readings, the degree of impact *PerfectCool* coatings has on the ambient air temperature was inclusive due to the small difference between ambient air temperatures measured for both sites at +300mm and +600mm was very small. This is because the scale which the *PerfectCool* coatings were applied was too small to cause any significant impact to its immediate surrounding. Other exterior influences, such as wind conditions, could have also influenced the data.

5.8.9 Although the ambient air temperature results were inclusive, the temperature reduction caused by the cool paint can still be felt by its users. This is because humans are more sensitive to sensible heat. The cool paint is able to give a cooler sensation as compared to the asphalt roads through the mitigated heat conduction through the feet and the upward long wave radiation (Kinouchi, 2004). Results to the survey questionnaire clearly demonstrate this. When the participants are asked to compare their thermal sensation felt at the JTC site, all the participants felt cooler when they were standing on the *PerfectCool* coatings (see Annex D, figures 30 and 32). Out of a total of 60 responses (30 responses each for vacant school and JTC sites), only 2 responded that their feet didn't feel any difference, and 3 responded that their bodies were not able to feel the difference (see figure 24 below). It is also noted that benefits of *PerfectCool* coatings. Although at the vacant school site, three participants were indifference in their thermal sensation when they stood on both the normal coated and *PerfectCool* coated basketball courts, it is suspected that what limits them in feeling the difference is due to their dressing during the time of the survey. One of the factors which influence thermal comfort is clothing insulation (source: Health and Safety Executive website). It is possible that the three participants were too heavily clothed to be able to feel any difference caused by *PerfectCool* coatings.

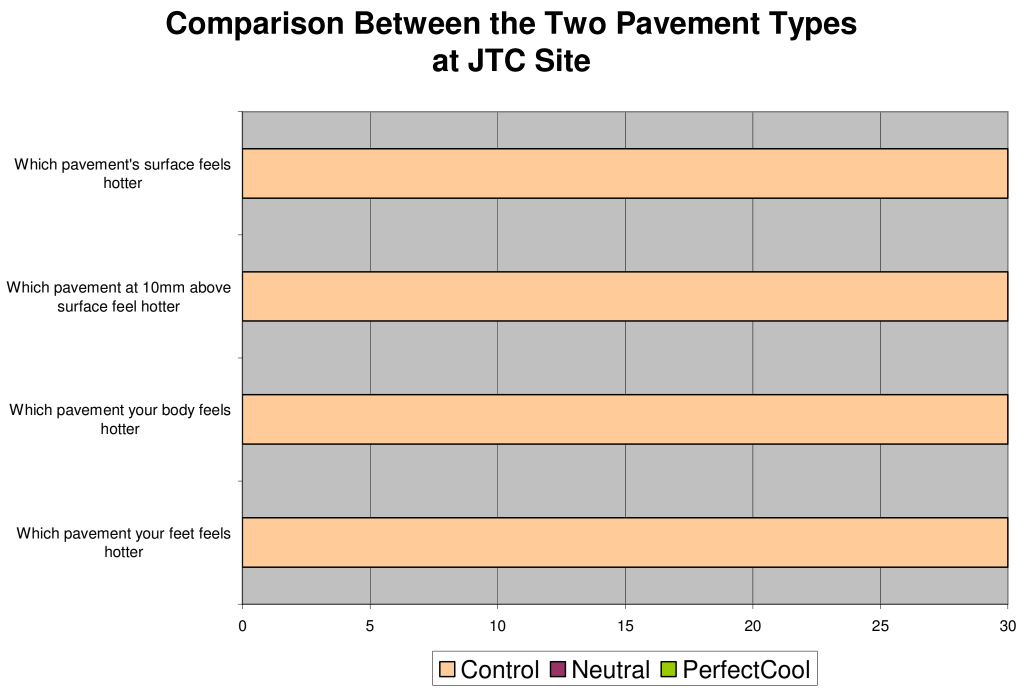

Figure 24. Survey questionnaire results question 9 to 12 of JTC site. All responded that they feet, hands and body felt hotter when they stood on the asphalt road as compared to the *PerfectCool* coatings

5.8.10 The application of *PerfectCool* coatings also leads to possible monitory benefits. Through the energy simulation, it has been identified that the possible electrical yearly savings derived from the application of *PerfectCool* coatings onto the roads is 3.46%. The percentage savings is related to the external temperature: the hotter the day, the bigger the savings. This is clearly evident in the higher percentage savings derived from the peak load electrical consumption as simulated. During the summer solstice, which occurs in the month of June, where the ambient air temperature is the highest, the possible savings derived through the application of *PerfectCool* coatings was calculated to be 4.88%. The reason why *PerfectCool* coatings have an impact on the total energy consumption is because they are able to reduce the overall ambient air temperature. This lowered ambient air temperatures is translated into a lower solar load entering into the building, thus reducing the overall cooling load of the building. The results from the energy simulation clearly support this. The wall surface temperatures of the factory surrounded with pavements coated with CP40 were generally lower as compared to its counterpart. On a typical hot day, the possible reduction of chiller load can be up to 7.69%.

5.8.11 With the reduced surface temperatures of the roads, it is expected that the life span of the roads can be extended due to increase in durability. High temperatures soften the surfaces of the roads, which increases the rate of rutting and shoving of surfaces, eventually leading to the unevenness of pavement surfaces. High temperatures also accelerate fatigue damages, such as gradual cracking of surfaces, bleeding of asphalts, etc. Cool paint is able to reduce significantly the surface temperatures of the roads and the asphalts remains less soften (Loustalot et al, 1995). It was identified, in a rutting experiment conducted by Pomerantz et al, that when the surface temperatures of roads were reduced by 10℃ to 42℃, the lifespan of the pavements increased by more than 10 folds. With reduced surface temperatures, rutting, shoving and other fatigue damages are less likely to occur, thus increasing the lifespan of the roads, reducing the cost of repaving.

5.8.12 The lifespan of the roads can also be increased with the reduction of the internal temperatures. Analysis also shows that cooler asphalt road slows down the chemical reactions which make them brittle, thereby maintaining their flexibility for a longer period (Monismith et al, 1994). As the internal temperature of the pavement builds up, the pavement loses its flexibility and becomes brittle. Cool paint is able to prevent this internal built up of heat, slowing down the chemical reactions, thus increasing the overall lifespan of the roads.

5.8.13 With the increase lifespan of the roads, the cyclical maintenance of the roads can be extended. Rosenfeld et al estimated that a resulting potential saving of $1.08/ m2 can be achieved.

5.9 Urban Heat Matrix

5.9.1 The concept of UHI (Urban Heat Island) and its effects have been researched intensively throughout the world. Locally, intensive researches have been conducted to identify the “hot spots” of Singapore. All the researches conducted although intensive, they were conducted independent of one another. The development of the UHM (Urban Heat Matrix) aims to propose a method to help planners/developers plan and estimate the impact their masterplan has on UHI and the impact of their heat mitigating implementations. The development of the UHM will use literature reviews to substantiate various contributing factors.

5.9.2 The input and output of the UHM aims to be as simplistic as possible. Thus, the UHM will be developed into an equation format. This format is independent of computer simulation and complex algorithms, making it simple and easy to use. The outcome of the UHM aims to be in this format:

$$\text{Temp}_{UHM} = T - aZ - bY - cX - \ldots.$$

Where,
T = Initial Temperature decided by location.
Z, Y, X, … = Temperature reduction caused by parameters Z, Y, X, …
a, b, c, … = Possible factors which influence parameters X, Y, Z, …

5.9.3 T (initial temperature), is heavily dependent on the geographical location and locality of the place. The temperature at various countries varies, depending on whether it is closer to the equator or beyond the tropics. Thus to localize the UHM, only locally conducted studies will be used. Wong and Yu conducted a mobile survey from 0200hrs to 0400hrs to investigate the night temperatures of various areas in Singapore. Based on their survey, they were able to identify that different areas in Singapore has different night temperature (see figure 25 below). Night temperature profiles are important because they clearly display the effects due to urbanization. This is clearly seen from figure 25. CBD (Central Business District) area is so much more urbanized, as compared to areas such as Lim Chu Kang. As the temperature measurements are not affected by solar radiation, and the time of measurement was done at a time where there are close to minimum activities at both areas, it can be concluded that the difference in temperature is contributed by the re-radiating heat by the urbanized areas. As CBD is densely developed, more heat is re-radiated back into the environment. Conversely, Lim Chu Kang is not as densely developed as compared to the CBD area, thus less heat re-radiated back into the environment, resulting in lower midnight temperature. The initial temperature, T will be based on the temperatures gathered from the urban heat profile of various locations in Singapore.

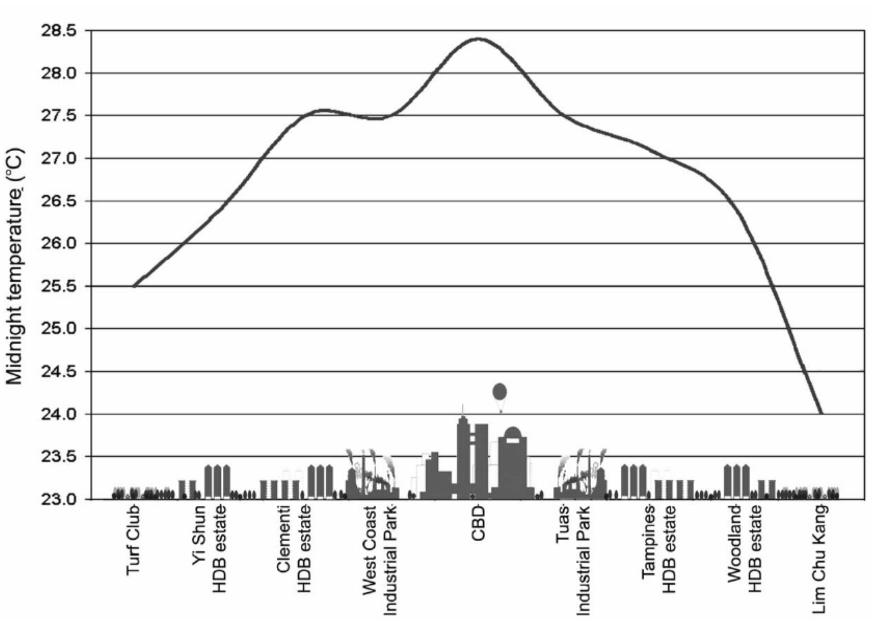

Figure 25. Sketch of UHI profile at various prominent location in Singapore. Source: "Study of Green Areas and Urban Heat Island in a Tropical City" by Wong and Yu, 2005.

5.9.4 Based on various literature reviews, there are a lot of factors which contributes to UHI. Factors such as material choices, building-street layouts and orientation, heat rejection from air-conditioning systems, green areas and their locations, etc. were all found to impact on the built up heat in urbanized areas. For this study, the choice of materials used for roads, and green areas will be included as parameters. Other factors such as air-conditionings and building materials are not included as they are not “dictatable” by the urban planners. As it was mentioned that the UHM will not consider the influence of wind and time because they are not controllable by planners (see 3.6.1), factors such as building layout and location will not be considered.

5.9.5 The UHM intends to investigate the intensity of the effect caused by various parameters. The intensity of effect, as defined by Honjo and Takakura, is the temperature difference between the maximum of the urban area and the minimum of the green area. As the initial temperature is an average value, in the UHM case, the intensity of effect is the defined as the “difference between the average temperature of the urban area and the minimum of the green area”. In the study conducted by Wong *et al* (2007) at various areas of the NUS campus, they found varying temperature profiles at different location of the school. The maximum, minimum and average night temperatures of the various locations are as shown in figure below.

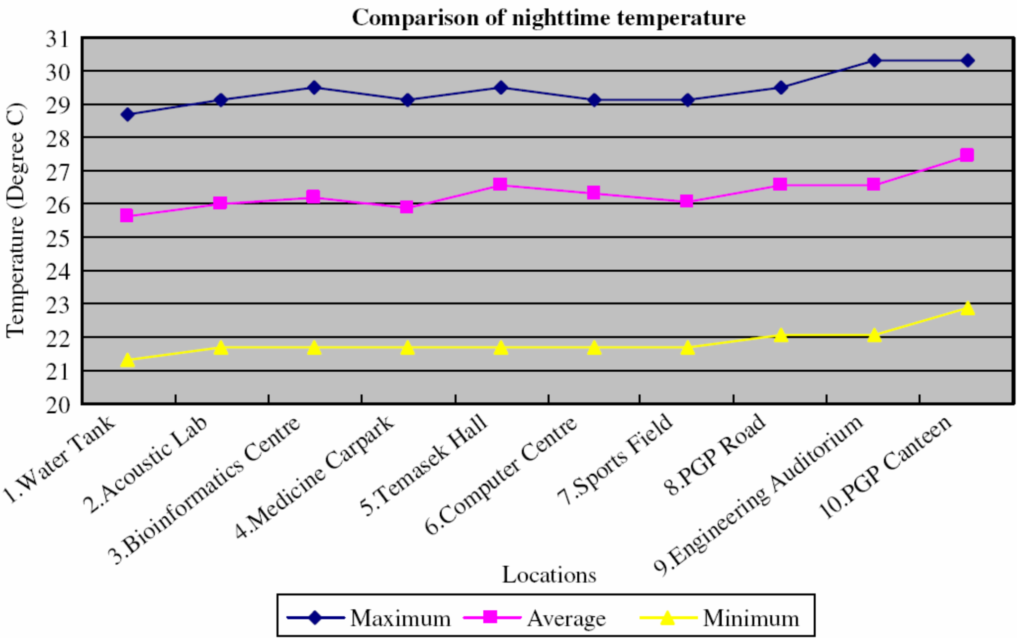

Figure 26. Comparison of night time temperatures at various locations within the NUS campus, Singapore. Source: “Environmental Study of the Impact of Greenery in an Institutional Campus in the Tropics” by Wong *et al*, 2007.

5.9.6 In the study, the locations 1, 2, 3 are classified as “dense greenery”, 4, 5, 6, 7 are “less dense greenery”, while 8,9,10 are “sparse greenery”. These three areas can symbolize as “dense greenery” are areas under the trees; “less dense greenery” are turf area; while, “sparse greenery” areas are urbanized areas. From the graphs, the average minimum temperature of the “dense greenery” is 21.6℃ and “less dense greenery” is 21.8℃. These figures indicates that when an entire area is totally shaded under the tree or are turf with grass, the night time temperature can go as low as 21.6℃ and 21.8℃ respectively.

5.9.7 Jauregui, in his study of the influence of the parks on temperature of the city indicated that although a single tree can moderate the climate, but is limited to the microclimate. Locally, a study was conducted in 2006 by Chen and Wong to investigate the thermal benefits of city parks. It found that although parks have cooling impact on the surrounding, it is limited by distance. In another study by Wong *et al* (2007) investigating on the thermal performance of extensive rooftop greenery systems in the tropical climate, they have concluded that the thermal performance of greenery is related to how extensive vegetation is planted. All these findings indicate that the benefits of greenery is limited to how much area it is implemented. Thus, area is a factor which dictates the extend of how the development is able to benefit from the implementation of various heat mitigating strategies.

5.9.8 Thus, the final formula is:

$$\mathrm{Temp}_{UHM} = \frac{A_{Total} \times T_{Inital} - A_{p}(T_{Inital} - T_{P}) - A_{Tree}(T_{Inital} - 21.6) - A_{Turf}(T_{Inital} - 21.8)}{A_{Total}}$$

Where,

A_{Total} = Total area of Development

T_{Inital} = Initial ambient temperature selected depending on location

A_p = Area of pavement

T_P = Ambient temperature above pavement

A_{Tree} = Area under the crown of tree

A_{Turf} = Area above turf areas

5.9.9 Taking an example of an hypothetical site located at Tuas, where it has a total site area of 2500m^2, with the building area of 1400m^2 pavement area of 900m^2, turf area of 190m^2, and tree area of 10m^2. The UHM of the site will be:

$$Temp_{UHM} = \frac{2500 \times 27.3 - 900(27.3 - 27.3) - 10(27.3 - 21.6) - 190(27.3 - 21.8)}{2500}$$

$$= 26.88°C$$

5.9.10 This means that the intensity of effect the heat mitigating strategies implemented into this development will be 26.88°C. The ambient air temperature above the pavements were taken to be 27.3°C because it was assumed that the initial temperature have already taken that into consideration. Based on table 4 in Annex D, it was noted that the minimum night temperature of *PerfectCool* coatings was 23.68°C. If *PerfectCool* coatings were to be applied onto all the pavements, than the UHM will be:

$$Temp_{UHM} = \frac{2500 \times 27.3 - 900(27.3 - 23.68) - 10(27.3 - 21.6) - 190(27.3 - 21.8)}{2500}$$

$$= 25.53°C$$

5.9.11 With the *PerfectCool* coating (CP40), the intensity of the effect of the heat mitigating strategies improved from 26.88°C to 25.53°C. This is because although the temperature difference between the *PerfectCool* coating (CP40) and the road was only 3.62°C, its area of implementation is bigger than the areas dedicated to greenery.