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REVIEW IN SOLAR CONCRETE THERMAL COLLECTORS

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ABSTRACT

In this review article ,we will appraise existing, relevant literature documenting investigations conducted by other researchers. The review will evaluate the methodology used in the other previous work as well as highlight the major findings of their investigations. By reviewing what other researchers have done with regard to the development of solar concrete connectors, in this study there was an ability to identify research gaps achieved by experimental experiments of this research stream seeking to fill. The following paragraphs summarize the most relevant scientific works that the study was able to review.The literature was reviewed in a chronological order just to capture the developments and advancements that have been realized over the years.

Keyords: solar , thermal, concrete , nano, ansys, numerical .

INTRODUCTION

(Nayak et al, 1989) the authors conducted several experiments to investigate the performance of varnished concrete roof solar energy collector mostly used to heat water and supply the hot water to various households for domestic purposes. In the experiments, the authors used black PVC tubes located approximately 10 mm underneath the layer of concrete. The colouring was chosen in order to improve the absorption rate of the concrete surface. Given the adjustments in the design of the concrete roof solar energy collectors in the experiments conducted by Nayak et al. (1989), it was established that—at a maximum ambient air temperature of 35^0 C and solar radiation intensity of $1000W/m^2$—the design were more efficient that other conventional solar energy collectors like the flat-plate collectors, hence more cost effective [1].

(Bopshetty et al, 1992) in this study, the researchers increased the amount of concrete between adjacent tubes from 0.06m to 0.15m in order assess factors that influence thermal storage of concrete solar energy collectors. From the parametric investigation, the researchers established that increasing the amount of concrete between the adjacent tubes through which the operating fluid flow results in improved thermal storage for the concrete solar energy collectors. However, increasing the concrete layer between adjacent tubes also let to an increase in the level of thermal resistance between solar radiation incident to the absorption surface and the tubes containing the operating fluid. Furthermore, the researchers investigated a two dimensional (radial and axial) transient model composed of solar energy collectors. In this model, a steel mesh reinforced PVC pipe was embedded in the concrete. Also the designed involved the covering of the top section of the model with glass, leaving air gaps of about 0.04m. Finally the model was varnished black to improve its absorption characteristics. Taking the ambient temperature of the air as the initial conditions, the researchers calculated the resistance in conduction of the PVC by used two computation methods: finite element analysis and symmetry conditions analysis. Linearly intercalated values recorded at ten minute intervals of climate data were assume constant. The final outcomes of the investigation revealed that, the increased the operating fluid temperature, the efficacy of the concrete solar collector linearly decreased. Additionally, the study established that step-wise decrement of the operating fluid entering the solar collector led to marked increases in the convective and the radiative losses, leading to lower useful energy gains by the entire system **[2].**

(Reshef and Sokolov, 1992) the authors designed a one dimensional transient model of a concrete solar collector. The model was considerably wide, of a circular cross-sectional area, and the concrete was reinforced by glass. The operating fluid in this case was water and the temperature gradient in the direction of the working fluid was much smaller in comparison to the temperature gradient in the direction incident to the flow, also the temperature downstream was neglected. The temperature distribution in the radial direction of the tubes was then computed through the use of the finite difference method. In order to perform the calculations, the researchers made some key assumptions such as no change in the physical characteristics of the system and laminar flow of the operating fluid. Also, the researchers were able to record coefficients of heat transfer from the middle of the concrete-tube structure, indicating the resistance due to contact at the boundary of the tubes and the concrete wall [3].

(Jubran et al., 1994) purposed to reduce the amount of energy lost by a concrete solar collector during the cold seasons. To realize this aim, the researchers opted to used glass to cover the concrete solar during cold seasons. The researchers developed several designs by using readily available window pane glass. The fundamental difference between the designs was air gap: a space left between the top surface of the collector plate and the glass covering. The air gap left in the designs ranged between 0.004m and 0.04m. After several experiments, they established that as the air gap was decreased, the heat transfer from one side of the air gap to the other through the three methods of heat transfer (convection, radiation, and conduction) was significantly suppressed. The spacing between adjacent solar collector plates, however, had no impact on the rate of heat loss from the collector to the surrounding cold environment. 0.5-meter thick insulators made from rock wool (thermal conductivity of 0.036W/m.C) were used by the investigators to prevent heat loss from the back and from ends of the solar collectors. The resultant design was a compact solar collector with the capability of trapping as much solar energy as possible in summer heat without leading to adverse heat gains across the roofs of buildings, especially when the collectors are embedded in the structure of the building **[4].**

(Chaurasia, 2000) achieved a study about the solar concrete collectors which supplied the domestic hot water with aluminum tubes embedded over slab concrete without insulation at the back and without glazing on the upper surface. The area of absorbing surface was 1.06 m^2. The diameters of aluminum tubes were (12, 19, 25) mm. The better results were gotten at 19 mm. It was concluded the output hot water temperature gotten from the concrete collector was raised by 2^0C to 5^0C by using a single coating of the blackboard paint. Furthermore, the moderate temperature of hot water (36°C to 58°C) was obtained through the daytime in winter. the concrete collector performance was studied experimentally by using laying down a grid of tubes fabricated of aluminum in the roof of the building (without glazing at the top), the experiments done in India when the solar radiation and maximum air temperature was 650W/m^2 and 27°C respectively, to provide hot water for the domestic purposes. The authors noticed that the water temperature at the inlet was 15ºC to 28ºC, the temperature of hot water was 36ºC to 58ºC could be obtained during the day in the winter. **[5]**

(Bilgen et al., 2002) used horizontal slab concrete system in the solar energy collection device. The researchers conducted an experimental assessment of heat transfer mechanisms in the horizontal slab concrete system. The dimensions of length, width, and thickness of the slap adopted in this research were 0.78m, 0.04m, and 0.10m respectively. The researchers began the experiment by using an artificial source of heat to raise the heat flux in the system from $200W/m^2$ to $700W/m^2$. Thereafter, the investigators took measurements of the heat flux through free convection as well as the temperature readings at different spots over the surface of the horizontal slab concrete system. Several theoretical assumptions were used to be able to analyse the system theoretically. Researchers were able to demonstrate that with mathematical models that had been advanced satisfactorily foretold thermal properties of the solar energy collection system under diverse scenarios. The experimental investigation of free convection heat transfer mechanism over the horizontal slab concrete system also resulted in the derivation of an experiential correlation between the variables involved. also, the results obtained the amount of heat absorbed by the slab did not significantly depend on the angle of radiation. Heat losses by radiation and free convection accounted for all the energy loss from the slab (60% and 40% respectively) and energy compensation in the storage unit was at its peak within the first 3-4 hours.

In addition, they went a step further to investigate the variation of energy storage as well as thermal efficiency of the horizontal slab concrete system with various parameters. A correlation was done between the heat transfer of the concrete slab and other existing horizontal solar collection surfaces through free convection. It was discovered that the heat transfer of the concrete slap used in this investigation was approximately 18.5% lower than that of other existing horizontal surfaces. and the researchers attributed this disparity to relatively larger surface used in their experiment. Finally, a two dimensional temporary model was used to simulate how the horizontal slab concrete system would respond heat flux analogous radiation from the sun. Three insulated sides of the slab, except the top surface, were subjected to heat flux from an artificial heat source. The temperature variation across the top surface of the slab was then forecasted through the use of the finite element technique. The outcome of the experiment established that the exposure of the concrete slab to radiation flux resulted in the absorption of over 50% of the heat flux within the first three hours of heating [6].

(Kevin Cavanaugh et.al, 2002) this study focused on the thermal properties of masonry constituents, concrete, masonry units and the products which form the building components. This work contained passives solar design, the considerations for masonry and concrete besides the method to reduce condensation inside assemblages.

Buildings that contained solar passive presented a specialized application for retention, reradiating and the thermal mass of the solar heat storage. To achieve those goals, a certain thermal properties should be present in the storage medium. Thermal conductivity should be high to permit the heat to break through the storage material but not too high and led to be thermal lag or the storage time is shortened. In order to increase the quantity of solar energy that could be stored especially for the mass floors, the solar absorptivity should be high. High- emissivity properties should be in the thermal storage materials to enhance reradiate the stored energy back inside the occupied space. To raise the quantity of energy that could be stored in a given materials, the heat capacity and specific heat should be high. Masonry materials and concrete fulfill all these conditions for more effective thermal storage. In a passive solar building, these materials used with great success to prevent overheating, store collected solar energy and reradiate energy to the interior space **[7].**

(Ashley Burnett Abbott 2004) evaluated precast solar-based water warming system design majorly used to heat water for use in habitations with single families. The performance of the precast solar collector was evaluated and described by a model composed of segments arranged series the axial direction. The separate segments were connected by the working fluid which was designed to flow across pipes embedded in the precast solar collector. Every segment was represented by a two dimensional solid model whereas the boundary conditions on the plate covering the precast collector model were computed using a more traditional representation of a flat plate solar energy collector. The researchers used MATLAB together with Femalb code (a finite elements solver) to contrast the performance characteristics of their model to that of the usual air-to-air heat pumps. As a result of the contrast, the research was able examine diverse non-dimensional factors of operation to obtain various operational values from which the optimal or near optimal designs were developed. Furthermore, the research focused on assessing the annual costs of installation and operation as well as possible applications of the near optimal designs in specific regions such as Atlanta, Georgia, Chicago, and Illinois. The analysis included full life cycle cost projections of the entire system hence providing a good source to fully appraise the long-term economic benefits of the near optimal designs.

In this review, the results obtained revealed that electrical energy requirements of regions with long winter seasons hence longer artificial heating periods could be reduced by over 50% if the near optimal designs of the precast solar energy collector were to be applied in conjunction with typical solar energy heat pumps. However, the cost of construction and installation could not be justified in regions or states with shorter cold seasons. With regards to the technical specifications of the near optimal designs, the study established that a total of 23 pipes were needed to efficiently and reliably supply the energy requirements of a single household in the coldest month. Also the outcomes determined that the pipes required in the near optimal design had to be considerably large whereas the solar energy collectors had to be designed with large enough surface areas for maximum absorption of solar radiation, although the maximum surface area of the collector were subject to practical restraints. The other finding by the researchers is that, whereas the thickness of the design had no significantly strong impact on performance or efficiency, the optimal thickness to width proportion should be about 0.1875. Generally, the study proposed the use of thin concrete sections with the above mention thickness to width ratio. Also, the research noted that temperature distribution within the model varied downstream, with the rate of variation increasing with time [8].

(Sullivan et al., 2007) connected concrete-based solar energy collectors to typical heat pumps utilized for the heating and cooling of buildings and homes. Afterwards, different assessments were conducted in order to investigate the potential damaging impacts of embedded tubes on the life of pavements as well as to establish how compaction operations affect plastic pipes used in these solar collection devices [9].

(Watchara Wongpanyoa at el., 2008) presented the temperature distribution for concrete storage system, the temperature of oil inlet for charging purpose was 250ºC. according to the climatic circumstances of Phitsanulok province this study carried out. The ratios of the local materials volumetric were sand (1.5): water (1): rock (3): cement (1) which was suitable for use in a concrete storage system. The prediction of heat capacity and the distribution of temperatures could be done by using the determination of heat transfer and the case simulation analysis of the system to enhance the efficiency of the storage system. It could be concluded from the results that **:**

1- The specific heat capacity affected on the concrete storage system.

2- for the parabolic trough, the thermal energy storage system with using local materials in Thailand for the first sample volumetric ratio were cement (1): rock(3) :sand(1.5) water(1) suitable for concrete storage system due to the specific heat capacity and thermal conductivity were higher than other samples.

3- For the concrete storage , the prediction for the distribution of temperatures carried out by using the characteristics of sample 1 with DLR developed (high temperature concrete) were close while the price of the local materials were lower.

4- The node of the first sample which was lower than high temperature concrete, the solution of this problem led to decrease the average distance for the heat pipes inside the storage system **[10]**.

(Majdi Hazami et al., 2010) presented an experimental analysis of a cheap integrated solar storage collector ISSC with entire area of aperture was 2 m^2, which was used in order to supply domestic hot water. An absorber matrix fabricated of a thin cement concrete slab which achieved the function for the two absorbing and storing of the solar thermal energy so that the ISSC could be characterized. A copper tubes network was embedded into the concrete absorber. For several days under different environment circumstances during three months (from November 2007 to February 2008), the outdoor experiments were accomplished. In order to calculate temperatures in different parts of the collectors, water mass flow rates and measuring the climate variables, the tests achieved. The analysis of the system behavior was done by heat losses, contrast exit temperatures and useful energy. To calculate the efficiency for ISSC, energy losses, the optical and thermal performance below given operating circumstances, the energy analysis was carried out. The results showed that integrated solar storage collector had energetic efficiencies of 32%, which could supply acceptable stored thermal heat rate by providing about 80% in domestic hot water for a family includes 5 persons. The study presented an economic calculation which took in the consideration the investment time recovery across the system. The results obtained from a high quality thermo syphon solar system contained a flat-plate collector (with the entire area of aperture was $2m^2$) were contrast to the results gotten from the ISSC system. The results of experimental investigations could be summarized as below **:**

1-The ISSC system provided a huge potential to use in the integrated solar storage collector in Tunisia for public sectors and for modest rural families. In order to decrease the country dependence on foreign oil and provide a protection from the price increases and from future fuel shortages, the installation of this passive water heating was used. One of the major advantages of ISSC that could provide cost saving for several years with little request for maintenance.

2- It possible to supply about 140-180 l hot water with moderate temperature (42-46 ^{0}C) and efficiency of 32% until the winter and that occurred by using ISSC system. When the ISSC system contrast with the conventional solar system SDHW, it is clear the use of this system is promising. Actually, the ISSC could produce efficiency approximately the same to SDHW (34%).

3-It could save for the homeowner about 65% of his annual heat bill and decrease the need for non-renewable energy , besides that the amount of withdrawal water presents 80% of the building hot water during the year. The results showed that the system worked satisfactory even in cold seasons.

On the other hand, the major disadvantage of ISSC is the high overnight heat loss coefficient $14W/m^2.C$ **[11].**

(Zhiyong Yang at el., 2011) achieved a design for a solar heat pump SAHP that used in solar collector especially in the integrated roof as the evaporator. To predict the space heating load, a building energy simulation was used besides 3D theoretical model to analyze the performance of the solar roof collector. In order to decrease the energy demand, a floor radiant heating unit was done. The results showed that through the winter the system could supply a comfortable living space, when the average temperature of the room about 18.9%. The average COP for the system was 2.97 with peak around 4.16. [12]

(Rangsit arachittia et al., 2011) studied the thermal performance for two rooms, the first room with roof-integrated solar concrete collector with PVC tubes embedded in it while the second room with reinforced cement concrete slab, with no insulation and no glazing on the top. The results illustrated that the room with concrete solar collector slab produced up to 40 litres of hot water for every day at temperature varied from 40 to 50ºC , also the heat gain to the house decreased and the economic study showed that the payback period was swift**[13].**

(Namrata Sengar et al., 2011) made a study about the BMHSWH for the collector with trapezoidal shape and insulation of two layers, the results showed that the system had the capability to provide approximately 65 liters of hot water at 40ºC above the ambient temperature for every day and the area of collector was 1.14m^2 in winter circumstances. The researchers proved that payback period of BMHSWH for different fuel was small and save efficiency, and single glass was 57% while in double glaze was 62% **[14].**

(P. BLECICH et al., **2012)** investigated the domestic hot water heating system with solar concrete collector. The main elements of the system were: storage tank, a serpentine tubes and auxiliary heating source like a gas burner or an electric resistance heat. The serpentine tubes could be put into roof slabs, walls and concrete pavements. In order to solve transient 3D heat conduction in the concrete element with the serpentine tubes inside, a numerical model according to the finite volume approach has been improved. By using the mixed convection – radiation boundary conditions, heat transfer at the exposed surface of concrete element was discussed. The numerical models provided the results: storage tank temperatures, water temperature across the serpentine tubes and the solar concrete collector heating system. It could be noticed that the serpentine tube could heat water up to 40-50ºC during the summer season when the temperature reached to 30-40ºC. The average efficiency (i.e. solar fraction) is 50-70% in Rijeka (Croatia) during the period from May to September, in other words less than half of the required energy was provided by using the auxiliary heating source. The efficiency of solar concrete collector systems were effected by many parameters such as; tilt angle of the concrete, tube depth, tube spacing, tube length and solar absorbance. In order to avoid tube-tube thermal influence, the spacing between tubes bends should be less than 15 cm.

This research presented a study about the performance of solar concrete collector system for heating domestic hot water. A large heating collecting potential was offered by the concrete surfaces during the sunny summer days when the temperature reached to more than 65ºC. Even though the solar thermal collectors could not contrast by the solar concrete collectors, the solar concrete collectors have many advantages. Solar concrete collectors could be installed into manmade structures such as; roads, pavement, parking areas, roofs, walls and so on. The results concluded that the 40% to 70% of the required energy for DHW heating in the summer season could be provided by the solar concrete collector. The shape of the serpentine tube and the concrete slab properties affected on the system efficiency and the exact value of the solar fraction.

Large quantity of heat could not provide by the solar concrete collectors during the summer season because of the low temperatures in the concrete slab. In order to de-ice the surface of pavements, streets and concrete sideways during the winter season, the hot water pumped across the serpentine tube of solar concrete collector.

The flow velocity of water has to be less than 3m/s and the length of the serpentine pipe approximately 100m because of the weak density of heat conduction flux which reached serpentine pipe from concrete surface. The serpentine tubes of the solar concrete collectors should be put near the exposed surface to ensure high efficiency of the solar concrete system. Also to prevent mutual thermal influence, neighboring tube bonds should be put with the spacing at least 15 cm. for the maximum efficiency in the summer season, the optimum inclination of the concrete slab was 30º. The efficiency of the solar concrete collector system decreased with bigger or smaller inclinations because of reduced solar irradiation on the surface of concrete slab **[15]**.

(A. A. Keste et al., 2012) focused on the literature produced until now on the concrete collector. The authors planned to use metal fiber reinforced concrete in order to store cum insulator base of solar collector. The thermal conductivity increased because of inclusion of metal fibers. The aim of this study was to discover the average temperatures and daily efficiency of the output hot water. Thermal conductivity of the hot water at moderate temperature up to 54ºC, metal fiber reinforced concrete and storage capacitance could be gotten during the daytime in the building in winter by using reinforced cement concrete slabs or by using developing roof structure and put a network of tubes fabricated from copper over it which could provide a cheap passive solar water heating system. The heat technique of passive solar water was easy to manufacture and the worker can achieve this kind of job with little training. For the further enhancement in heat transfer rate, solar collector with dimple surface could be used for this goal **[16].**

(Larry A. Bellamya, 2012) carried out the experimental measurements to assess the energy performance for a solar heated stratified concrete wall panel for a twelve month trials. The panel included the exterior layer of insulating concrete that embedded with a solar thermal collector which was covered 10% of the panel face while the interior layer was a high thermal mass concrete. the results concluded that for the stratified concrete panel, the energy performance enhanced by the collector more than 15%. The tests were achieved by using the solar heated stratified concrete panel that has a high U- factor with an embedded mini solar collector covered just 10% of the face of the panel. The energy performance comparing with lightweight panel was better than double quantity of insulation. The superior performance of the concrete collector could be large because of its thermal mass. On the other hand, the mini solar collector embedded in the panel had an important contribution to the performance. The unwanted solar heating still produces which delivers solar heat to the interior face of the wall panel too early in the day during the summer. To study performance gain, the optimizing collector shape should be produce with great concern **[17].**

(Adeyanju A., 2013) presented the economic analysis for solar collector system and combined packed bed energy storage by using the operation factors such as; cylindrical cross section area, concrete bed size, air flow rate, void fraction and concrete size. This was achieved by studying the effects of the previous factors on the blower cost and the total energy stored in addition to the daily storage system per unit energy in the concrete under the winter circumstances of Trinidad. In this analysis a spherical shaped concrete of three various sizes were used over different air flow rate. It was found that spherical shaped concrete of size 0.065m has the maximum blower cost at 0.045m^3/sec because of high pressure drop and low porosity. while concrete with size 0.11m diameter has the minimum blower cost at 0.0094m^3/s. moreover, to concrete with size 0.11m diameter has the minimum daily cost at 0.0094m^3/sec while the spherical shaped concrete of size 0.065m diameter has the maximum storage system daily cost at 0.045m^3/s. The running time was taken as 9 hours/day and 300 days/year. The cost of the solar collector and the combined packed energy storage should be evaluation, which permits the gross income determination. For the maintenance and the annual running, the additional costs were taken into account **[18].**

(D'Antoni et al., 2013) utilized bare concrete buildings as solar energy harvesters all through the warm season and their potential to harvest energy appraised. Moreover, to the researchers evaluate the design of CSC—a type of MSTC which resembles a bare, free standing construction with tube heat exchangers embedded in massive matrices of concrete. Numerical models and simulation factors were used to establish the energy potential of the CSC design in diverse climatic conditions experienced across regions in Europe. The models determined that, for the climate of Stuttgart, Germany, the winter heat flux rate was about 93.07W/m^2, yielding energy of 460.77kWh/m^2. This yield resulted from an operating fluid flow rate of 45kg/h/m^2 and entry temperature of 5^0C. To better understand how design parameters determine overall energy output of CSC design, the researchers developed the rudimentary impact method as sensitivity analysis approach. The study further demonstrated that the influence of environmental sources of energy was nearly constant in diverse climatic circumstances as long as 62% of the solar radiation was reaching the surface and the ambient air was covering at least 25% of the design. In these conditions, latent and radiated energy gains were nearly equivalent, ranging from 5% to 7%.

What is more, he performed a sensitivity-based inquiry combined with the rudimentary impact approach to determine the most influential solar collector parameters. The outcomes from the inquiry established that thickness of the absorber, the diameter of the tube, and the spaces between the tubes were the most influential factors on the overall yield of energy from a solar collector. Nonetheless, this inquiry was incomplete as the combination of the rudimentary impact approach and the sensitivity analysis only focused on the parameters that have the greatest impact on the energy yield of solar collectors. Since the performance of the CSC design presents a multivariable problem, dependent on time and various thermal behaviours, a compromise between storage of heat and heat transfer through conduction has to be looked into further. The researchers, therefore, conducted further research by selecting the yield of energy as the targeted quantity when the designed is applied to usual applications requiring maximization. The quantity of the energy yield as well as the quality of the yielded energy (fluid energy content) were considered, particularly in applications involving relatively lower operating temperatures. Finally, the researchers assessed the importance of system configuration not only on energy yield but also on the reduction of installation costs. The assessment revealed that low-quality solar energy accumulators could be efficiently combined with compression-type heat pumps to save on space, reduce heating loads required of each device, and cover DHW. However, the efficiency and economic benefits are only to a certain limit, as the study establishes [19].

(V. Krishnavel et al., 2014) focused on the simultaneous testes for three various kinds of concrete collector design. The first design thermal conductive material was added to the concrete, the second design collector manufactured of concrete embedded with aluminum tubes, and the third design included PVC tubes were used. It could be noticed that slab of aluminum tubes and metal scrap was most efficient; moreover to the building integrated solar water heat system with inexpensive PVC tube was able to provide moderate hot water temperature which was suitable for various house applications **[20]**.

(Aruna Karunarathne, 2013) described the simulation of the temperatures difference and corresponding deformation for concrete slab by using 3D finite elements model. The pavement was designed like a thin isotropic plate which was resting on a Winkler-type elastic foundation. Because of the 2D plate elements were limited to linear distribution of temperatures across the thickness, and to get the temperatures difference across the thickness and surface, 8 nodes brick element type in ANSYS 12 were used for the FEM analysis. An experimental study was achieved to obtain the temperature difference for a concrete slab subjected to solar radiation. The solar heat flux on the slab and the daily temperatures difference through the depth of the slab were measured by solar meter, IR filter and thermocouples. There a direct relationship between the ambient temperature differences with daily temperature difference inside a ground concrete slab. On the other hand, the temperature inside the slab was always more than the temperature of the surrounding environment. Through the day, the concrete slab top surface absorbed solar heat flux and tried to make accumulation heat energy into the slab according to its thermal properties. The dissipation of energy by the concrete slab happened in the night convection factors such as; ambient temperature and the heat transfer coefficient controlled the energy dissipation by the heat concrete slab. Based on these values, the slab was not able to dissipate the entire energy before the sun rises in the next day. So that, the temperature into the concrete slab has a maximum value in contrast with ambient at any time.

The bottom center of the slab has the maximum temperature during the night and the top center point has the maximum temperature in the day that occurred when the top surface of the concrete slab subjected to solar heat flux. The thermal properties of concrete were governed the previous values more than the input heat flux.

The slab has the minimum temperature of 28^{o}C at 6.00 hours while the maximum temperature of 46^{o}C at 14.00 hours. So that, there was a difference about 18^{o}C in a daily cycle occurred in the slab. The upward and downward curling of the slab occurred due to the difference in temperatures. Through the day time, the bottom surface has lower temperature than the top surface. The maximum difference was 9^{o}C so that the upward curling happened at day time. During the night time, the bottom surface has a higher temperature values with maximum difference of 2^{0}C on the bottom surface. That variation led to a downward curling during the night time **[21]**.

(Waghmare et al., 2015) is essentially an appraisal of the performance of a 2m^2 concrete solar energy collector tested for energy potential in winter, rainy season, as well as the summer heat. The performance appraisal is based on consistent recordings of the entry and exit temperature of the operating fluid as well as the intensity of radiation recorded for five consecutive days in any particular month [22].

(Sangram Patil et al., 2016) investigated the ability of using building materials such as concrete for fabricating liquid flat plate solar collector. the concrete collector with dimensions of 2m * 1m was designed For various mass flow rates and different months. Manufactured and examined. It was noticed for the summer season the average temperature of the hot water collector was 56^{o}C to 80^{o} C, for winter season was 48^{o} C to 59^{o} C and for the rainy season the range was 47^{o} C to 57^{o} C. so that, the concrete collector was suitable to supply the demanded quantity of hot water for domestic uses. The main conclusions for this study could be summarized as below:

1- 50^{o} C of temperature water which was demanded for the bathing was supplied by the concrete collector for most of the year and this could be used for different domestic applications

2- To decrease cost of setup to supply hot water, the cement concrete collector could be integrated inside the inclined roof which faced south or even flat roof of building. Moreover the heat gain could be decreased by using this setup supplying space cooling.

3- The low cost of concrete collector would be more effective in remote areas or rural areas where there were no enough provide of electricity.

4- Furthermore, the concrete collector could be used as pre-heater for any water heating system and for commercial applications where water up to 70^o C is demanded **[23].**

(**Diana S.N.M. Nasir et al., 2016)** explained the optimizing of the RPSC system according to four different factors (water temperature, water speed, and tube depth and tube diameter) and contrast the performance of the system in expressions of (STR), (PTC) and Delta T of inlet-outlet. Two kinds of external environmental circumstances were taken into the account (i) flat surface like a low density or rural areas (ii) urban domain like a road canyon. "De-coupled" CFD approach was used according to the authors' previous works by modeling the effect of the external environment (macro domain) on the RPSC system (micro domain) in two CFD simulations. Both of the domains were compared with experimental and numerical information from previously published papers. In contrast the RPSC application in rural domain and urban domain, it was observed that the adjustment of the system according to the low and high circumstances of water speed supplied the best performance enhancement with more 28% in expressions of STR and PTC compared with other factors in the simulations. However, Delta T (less than 5 C) was gotten with values 0.25m/s water speed and above 0.02 m diameter of the tube. The main conclusions of this study were:

1- The evaluated STR and PTC for the RPSC system were 27.11% and 36.08% on average higher in urban domain in contrast with rural domain.

2- PTC and Delta T values were still gotten in the high inlet temperatures and deep tube embedment.

According to the previous results, it could be concluded that the urban environment and buildings had effectiveness on the RPSC performance and should be taken in the consideration when performing the RPSC simulation and optimization factors **[24].**

(Richard O'Hegarty et al., 2016) the influential factors of concrete solar collectors were studied in this study. Beside the external circumstances, the concrete solar collector performance was influenced by thermal characteristics of concrete matrix, fluid and tubing network. the performance of the concrete solar collector also affected by the fluid flow and geometry. The numerical simulation included one dimension tube flow network coupled with heat transfer in three dimension concrete domain. This research focused on the physical factors which were defined the concrete solar collector, thus constant temperature of the surface was used as the exposed surface boundary circumstances with all other surfaces being insulated. The different factors have been studied; concrete conductivity, tube embedment depth and tube spacing were among the six factors which had the major effect on the performance of the collector. Six physical factors (tube conductivity, tube embedment depth, concrete conductivity, mass flow rate, tube diameter and tube spacing) have been highlighted like potential effective factors on the heat transfer from the surface of the concrete solar collector to fluid outlet.

The concrete conductivity had the most effectiveness between the previous factors. Most of the research focused on the decrease of the conductivity of concrete facades, in the situation of concrete solar collector an increase in conductivity is desirable. Minimum value of conductivity was 2 W/m.K must be carrying out to supply a useful temperature difference. A major temperature difference happened when the tubes were closer to the surface, yet the exposure circumstances and the type of concrete limited this. It was very important from an aesthetic point of view, the embedding the concrete to a specific depth and in order to preserve the durability of collector, the distance from the surface was limited by the exposure circumstances of the concrete face.

Decreasing the distance among the individual tubes also showed a positive effectiveness on the performance. More tubes mean a major heat transfer area among the heat transfer fluid (in the case of water) and the concrete domain, yet the minimum distance was limited by the kind of tubing used.

The material of tube showed a little effectiveness over a broad range of values but, highlight a 3.9° C reduce in temperature difference when PVC tubes instead of metal tubes. The price of plastic tubes would decrease the entire price of the collector and that mean the money could be spent in more effectiveness areas like the tube spacing or concrete conductivity.

The diameter of the tube displayed very small effectiveness on the performance of the collector less than 1.2° C.

The most complex factor was the mass flow rate. The output energy increased by increasing the mass flow rate, on the other hand decrease the temperature difference. The low mass flow rate was suitable in the case of high temperature difference was desirable. Moreover, the required pumping power could be decreased by using a lower mass flow rate **[25].**

(**Richard O'Hegarty et al., 2017)** investigated experimentally the performance of a facade integrated concrete solar collector system in a mid-latitude European weather (Dublin). Three dimensions model was improved in order to predict the performance of the system in other European weathers. The relationship between the performance of the system to the solar fraction and output energy was analyzed in this study. In order to present a south facing façade installation, the experimental set up for the concrete solar collector was manufactured. The results concluded the experimentally that by using 1m^2 of concrete solar collector could supplied one quarter of annual hot water required for a single house while in the Fall and Spring seasons producing the maximum outputs energy because of the vertical orientation of the system. A three dimensions simulation for the system was improved by using COMSOL software and contrasted the numerical results with experimental results. The numerical results showed that the performance of the system was affected by several factors such as flow rate, tube length, collector area and the solar absorptance. By using a façade integrated concrete solar collector for a small house, the annual solar fractions were 24% (Dublin), 30 % (Sofia) and 20% (Helsinki). The concrete solar collector showed that there was no influence on the interior environment supplied a good insulation which was located at back of the concrete absorber. The potential energy output assessment for various CSCs and CSC system, three dimensions model was improved. This model contained a storage tank which was presented the experimental CSC. The mean absolute error was 5.6% between the simulation outlet temperature and the experimental test. For a clear day in Spring season in Dublin (25th of March 2017), a solar fraction was 37.8%. The CSC performance was not affected by the CSC area and the embedded tube length. The solar fraction was increased from 37.8% to 44.4% by increasing the CSC surface area from 1m^2 to 2m^2 when keeping the same length of the tube. In this study, the experimental analysis referred to a black painted concrete solar collector. The solar faction for six days decreased from 37.8% to 29.3% if the surface was left uncompleted with no black coating. A solar fraction was 36.1% for a black pigmented concrete. The tank temperature reduced but the outlet temperature increased by decreasing the flow rate. Also, increasing the flow rate more than 0.02Kg/s, the reference concrete solar collector had not considerable energy could be harnessed. A high initial tank temperature produced in a greater solar fraction with a lower daily efficiency. The performance of the concrete solar collector was not changed by using different tube diameter while keeping the same distance between the exposed surface and the outer part of the tube. The solar fraction decreased to 31.1% if antifreeze of 50% water and 50% glycol was used because of the thermal characteristics of the water glycol mixture. By employing a well-designed drain back system, the freeze protection could be evaluated. Based on the parametric analysis, the model was optimized and a 2m^2 area of black pigmented concrete with 100 mm of an extra interior layer of thick concrete was used in order to achieve the simulation process for the performance of the two European weathers (Sofia and Helsinki). The maximum annual average solar fraction was about 30% and obtained in Sofia. The maximum energy potential was obtained in Dublin and Sofia for spring and fall seasons. While for Helsinki, the maximum energy potential obtained in the summer season with solar fraction 30.5% **[26].**

(**Richard O'Hegarty et al., 2017)** the real advantages of the concrete solar thermal collectors were determined in this work. By decreasing the energy demands for the heating system which was carried out by providing input water with temperatures (5-20 ^{o}C) over main temperature, the assessment process for the potential of energy saving was done in this work. The cost payback and the energy were evaluated for the weather of Ireland. Concrete solar collector showed a good potential for energy saving. The collectors installed vertically and insulated at the back. The main conclusions of this study that the collectors could not reach the maximum temperatures which were carried out by other solar thermal collectors, however, they offered many other benefits. It could increase the mains by (15^{o}C) on winter day by using 1m^2 of concrete solar collector, designed within practical and economic limits. For the fall and winter months, the outlet water temperatures were (32^{o} C and 25^{o}C) respectively. The results showed that energy savings for the system explained in this research was (225) KWh/year [**27].**

(A. Chiarelli et al., 2017) An analysis of convection powered asphalt solar collector prototype was presented in this study which was achieved by the experimental tests with computational fluid dynamics (CFD) simulations in order to calculate how to optimize the design so that to decrease a high temperature of the urban pavement. Due to the energy harvesting setup included a series of tube which were buried inside the pavement; the arrangement of these tubes was experimentally investigated and contrasted to the possible construction technique contained of concrete corrugations that pursue at replacing the tubes. To optimize the air collection room which was put before the heated air left the asphalt solar collector prototype, CFD simulation was carried out. The data obtained was analyzed in expressions of energy harvested. The results showed that the tubes should be put in an individual row beneath the pavement wearing course for an entire optimal performance. This helped to decrease the temperature of the surface up to 5.5^{o} C in the pavement prototype. Moreover, the CFD simulations displayed that it was very necessary to care the optimal size and geometry for the air collection room because they had a major influence on the behavior of the system the conclusions of this work that the minimum surface temperature obtained due to the arrangements of the tubes with the maximum air velocity. It was possible to use the concrete corrugations instead of tubes and get a pavement cooling influence. However, this supplied a decreasing in cooling performance **[28].**

ABBREVIATION

PVC : Polyvinyl chloride
COP : Coefficient of Performance
FEM : Finite Element Method
CFD : Computational Fluid Dynamics

2D : Two Dimension
3D : Three Dimension
RPCS : Road pavement solar collector
ISSC : Integrated solar storage collector
SAHP : Solar assisted heat pump
BMHSWH : building materials housing solar water heater
DHW : Domestic Hot Water
CSC : Concrete solar collector
Delta T : Variance in average water outlet temperature and average water inlet Temperature, K
PTC : Potential thermal collection, %
STR : Surface temperature reduction, %
UHI : Urban Heat Island

LIST OF SYMBOLS

A : Surface area (m^2)
hc :Convective heat transfer coefficient (W/m^2. K)
k :Thermal conductivity (W/m .K)
L: length (m)
Q : Radiation Heat flux (W/m^2)
T: Temperature (°C)
m·: Mass flow rate (kg/s)
V·:Volume flow rate m^3/ s

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