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Department of Mechanical Engineering

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Presented by :

**ARAR LOKMAN & BADIDJA IBRAHIM**

Theme :

***Study of heat loss through the ground of residential building envelope in Ouargla soil.***

the jury composed of:

GUEBAILA MOUSSA	MCA ( UKM OUARGLA )	PRESIDENT
KHALFI MEHDI	MAA ( UKM OUARGLA )	EXAMINATEUR
KINA M.SALAH	MAA ( UKM OUARGLA )	ENCADREUR

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## ***Dedication***

*It is a great honor to dedicate this modest work  
To those who have encouraged and supported me  
morally and materially during the difficult moments of  
my life.*

*To my dear mother, who always gives me hope to live  
and has never stopped praying for me.*

*To my dear father.*

*To my dear ones:*

- To my dear sisters and brothers.*
- To all my uncles and aunts.*
- To my extended family: ARAR, BADIDJA.*
  - To my dear friends.*
- To all my friends everywhere, and in particular.*
- And without a doubt, to my dear friends at the  
University of Ouargla.*

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*Thanks and praises to God for giving me the faith and strength to accomplish this modest work. Prayers and salutations to our Prophet, his family, and his companions.*

*Our most sincere and heartfelt thanks go to our thesis supervisor, Kina Med Saleh, at the University of Ouargla for his help, wise guidance, and availability, as well as for the trust, patience, and understanding he has always shown us.*

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# Study of heat loss through the ground of residential building envelope in Ouargla soil.

## Summary

The study develops a coupled ground temperature model for residential construction of single zone in Ouargla, taking into account water evaporation, solar radiation, thermal radiation and heat transfer by convection. The model calculates heat gains and losses, revealing that solar radiation absorbs heat during the day, while water evaporation and thermal radiation lose it at night. The simplified ground temperature calculation equation predicts ground temperature as a function of solar radiation and outdoor air temperature, thereby providing temperature distribution and heat losses at different depth below grade.

## Résumé

L'étude développe un modèle couplé du bâtiment résidentielle de zone unique et le sol à Ouargla, prenant en compte l'évaporation de l'eau, le rayonnement solaire, le rayonnement thermique et le transfert de chaleur par convection. Le modèle calcule les gains et les pertes de chaleur, révélant que le rayonnement solaire absorbe la chaleur pendant la journée, tandis que l'évaporation de l'eau et le rayonnement thermique la perdent la nuit. L'équation simplifiée de calcul de la température du sol prédit la température du sol en fonction du rayonnement solaire et de la température de l'air extérieur, fournissant ainsi une répartition de la température et des pertes de chaleur à différentes profondeurs sous le niveau du sol.

## ملخص

طورت الدراسة نموذجًا مزدوجًا لدرجة حرارة الأرض للبناء السكني لمنطقة واحدة في ورقلة، مع الأخذ بعين الاعتبار تبخر الماء، الإشعاع الشمسي، الإشعاع الحراري وانتقال الحرارة بالحمل الحراري. وبحسب النموذج مكاسب وخسائر الحرارة، ويكشف أن الإشعاع الشمسي يمتص الحرارة نهارًا، في حين يفقدها تبخر الماء والإشعاع الحراري ليلاً. تنتبأ معادلة حساب درجة حرارة الأرض المبسطة بدرجة حرارة الأرض كدالة للإشعاع الشمسي ودرجة حرارة الهواء الخارجي، وبالتالي توفير توزيع درجة الحرارة وفقدان الحرارة على أعماق مختلفة تحت السطح السفلي للعمارة.

**Keywords:** Building envelope performance, Ground-coupled heat loss, Soil moisture, Soil conductivity, Thermal insulation.

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## Nomenclature

### *Symbols*

<i>A</i>	Area (m <sup>2</sup> )
<i>C</i>	Specific heat capacity (Jkg <sup>-1</sup> K <sup>-1</sup> )
<i>D</i>	Diameter (m)
<i>G</i>	Solar irradiance (Wm <sup>-2</sup> )
<i>Q</i>	Energy consumption (MJ)
<i>M</i>	Mass (kg)
<i>T</i>	Temperature (°K or °C)
<i>T*</i>	Predicted room air temperature (°K or °C)
<i>U</i>	Heat transfer coefficient (Wm <sup>-2</sup> .K <sup>-1</sup> )
<i>Db</i>	Dead band temperature (°C)
<i>dp</i>	Distance between pipes (m)
<i>hc</i>	Free convection coefficient (Wm <sup>-2</sup> .K <sup>-1</sup> )
<i>hcomb</i>	Combined heat transfer coefficient (Wm <sup>-2</sup> .K <sup>-1</sup> )
<i>hfc</i>	Forced convection heat transfer coefficient (Wm <sup>-2</sup> .K <sup>-1</sup> )
<i>hr</i>	Radiation heat transfer coefficient (Wm <sup>-2</sup> .K <sup>-1</sup> )
<i>hview</i>	Heat transfer coefficient outside surface (Wm <sup>-2</sup> .K <sup>-1</sup> )
<i>k</i>	Thermal conductivity (Wm <sup>-1</sup> K <sup>-1</sup> )
<i>ni</i>	Fluid mass flow rate (kgs <sup>-1</sup> )
<i>tins</i>	Insulation thickness (m)
<i>tf</i>	Floor thickness (m)
<i>tw</i>	Wall thickness (m)
<i>gc</i>	Glass cover of the collector
<i>gl</i>	Window glass
<i>gr</i>	Ground
<i>i</i>	Node number
<i>ifs</i>	Inside floor surface
<i>inf</i>	Air infiltration
<i>inletf</i>	Fluid inlet to the floor pipe
<i>inws</i>	Inside mass wall surface
<i>inw</i>	Inside north wall surface
<i>irf</i>	Inside roof surface
<i>iww</i>	Inside west wall surface
<i>j</i>	Construction component
<i>oc</i>	Occupants
<i>ows</i>	Outside wall surface
<i>r</i>	Room
<i>ra</i>	Room to outside air
<i>rgl</i>	Room to glazing
<i>rmw</i>	Room to mass wall
<i>rnw</i>	Room to north wall
<i>rrf</i>	Room to roof

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<i>a</i>	Percentage of solar irradiation (%)	<i>rww</i>	Room to west wall
		<i>set</i>	Set point
<i>Subscripts</i>		<i>si</i>	Inside surface
<i>amb</i>	Ambient	<i>so</i>	Outside surface
<i>cons</i>	Consumption	<i>sol</i>	Solar irradiation
<i>ec</i>	Electrical equipments		
<i>exitf</i>	Fluid exit	<i>Greek symbols</i>	
<i>ext</i>	External surfaces	$\Delta t$	Time step size (s)
<i>fl</i>	Floor	$\zeta$	Effectiveness
<i>fld</i>	Circulating fluid	$\vartheta$	Kinematic viscosity ( $\text{m}^{-2}\text{s}^{-1}$ )
<i>fr</i>	Inside floor surface to room	$\rho$	Fluid density ( $\text{kgm}^{-3}$ )

# *Generalities*

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## **G1. General introduction**

Residential buildings are one of the most important areas to take into account when discussing energy sustainability and environmental conservation. It's not just spaces of life, but rather places of daily interaction between people and the environment that surrounds them. Finding the balance between comfort thermal and environmental sustainability in buildings requires a thorough understanding of how they are designed and constructed. The study of heat losses in residential buildings is an essential step towards improving energy efficiency in these areas. By understanding how heat escapes from buildings, we can identify weak points and develop solutions strategies to reduce these losses and improve energy performance buildings. The importance of understanding heat loss in buildings residential also includes their positive impact on the comfort and health of their residents. Reducing thermal leaks means maintaining comfortable temperatures inside the building throughout the year, which helps to provide a healthy and comfortable indoor environment for residents.

The heat flow to the ground from a building depends on the complicated thermal process in the ground. However, most of the research on building heat loss via the ground is based on the coupling effects between soil heat and soil moisture transfer, soil thermal conductivity and capacity are presumed constant in space and time. Moreover, only thermal conduction is considered as soil heat transfer mechanism. It is furthermore mostly assumed that the heat transfer at the soil surface is governed solely by the air temperature, usually in combination with a constant heat transfer coefficient. By making these assumptions, building heat loss via the ground remains a linear thermal problem, and hence suitable for analytical or uncomplicated numerical analysis. Soil moisture does most of the case interact with soil heat transfer, through various mechanisms [1]:

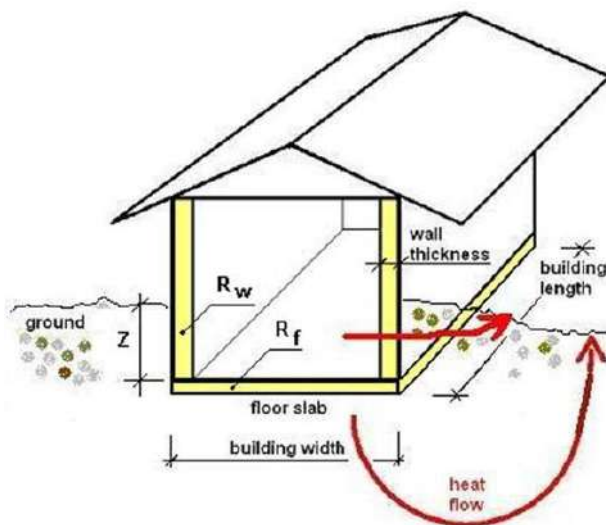
- (1) Soil thermal conductivity and capacity are highly dependent on soil moisture content,
- (2) The transfer, storage and/or phase change of moisture result in a concurrent transfer and/or storage of sensible and/or latent heat, and

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(3) Evapo-transpiration forms an integral part of the surface heat balance. These interactions do however turn 'building heat loss via the ground' into a non-linear coupled problem.

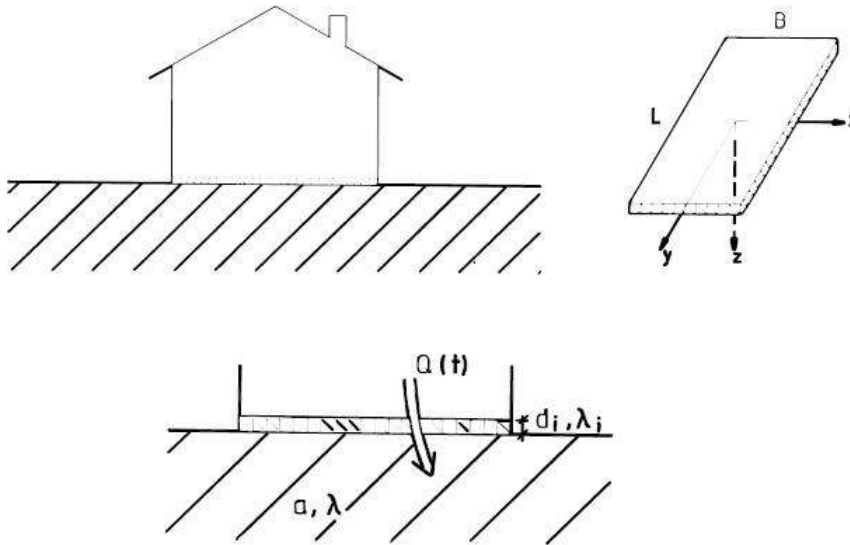
The ground can be treated as a system consisting of a subsurface layer, in which there are interactions related to changing weather conditions, and a deeper layer in which these impacts do not occur. The ground temperature, starting from a certain distance from the surface, is relatively stable. It is called the undisturbed ground temperature, which depends on climatic conditions, and is different in various places of the Earth. Below the depth at which the impact of atmospheric conditions disappears, small changes in the ground temperature result from the existence of geothermal flux.

✚ Different configurations of thermal heat exchange of residential buildings



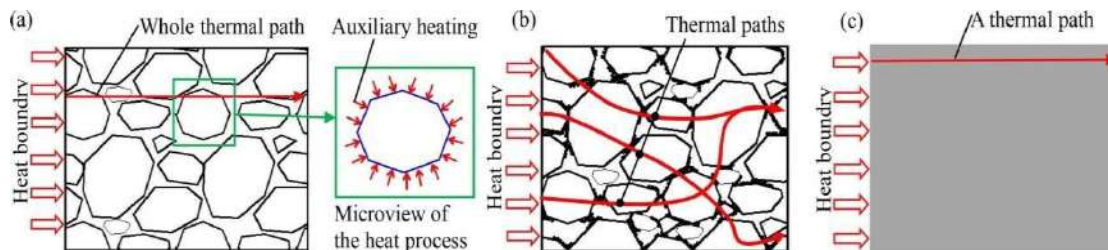
**Figure G01:** Heated basement (SS-EN ISO 13370:2007)

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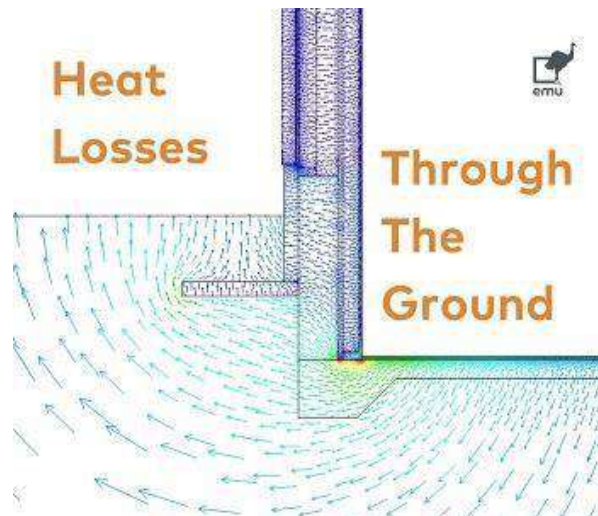
**Figure G02:** Building with foundation of the type slab on ground

(<https://www.buildingphysics.com/manuals/slab>).



**Figure G03:** Sketch-of-a-model-of-the-heat-balance-in-a-single-room-house-and-indications-of-notation

([https://www.google.com/search?sca\\_esv=905151fc136a1efd&sxsrf](https://www.google.com/search?sca_esv=905151fc136a1efd&sxsrf))

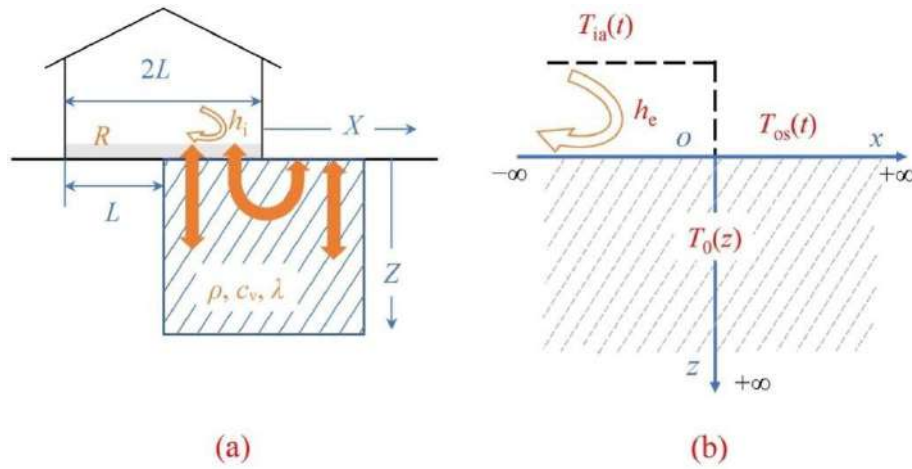


**Figure G04:** Heat Losses through the Ground.

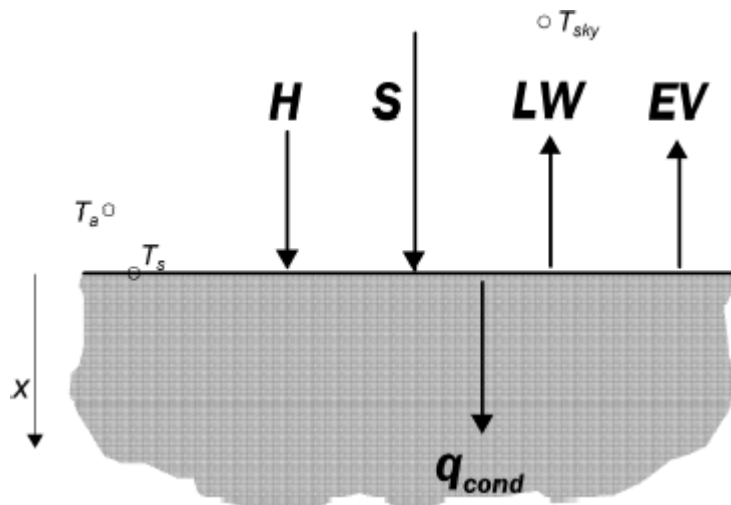
(ISO 10211:2017)

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**Figure G05:**Ground-couple floor model of: (a) heat transfer; (b) semi-infinite solid.  
(ISO 10211:2017)



**Figure G06:** The heat balance on the surface of the ground.  
(<https://www.google.com/search?sca>)

Where:

H= Convective heat flux

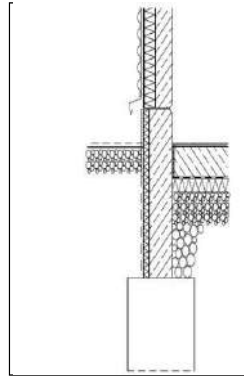
S =the solar radiation flux

LW= the daily average net flux of long-wave radiation

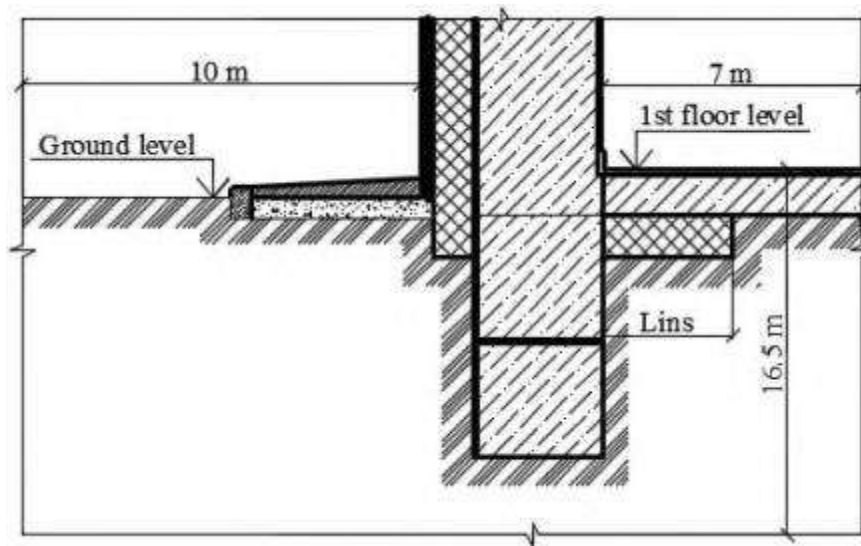
EV= Evaporative heat flux

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**Figure G07:** Vertical cut through the slab - wall connection.  
(<https://www.researchgate.net/publication/342850073>)



**Figure G08:** Insulation of the wall stripe of the floor on the ground.  
(<https://www.researchgate.net/publication/342850073>)

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## **G2. Conclusion**

Residential buildings play a crucial role in energy sustainability and environmental conservation, necessitating a balance between thermal comfort and environmental impact. Understanding and mitigating heat losses in these buildings are essential for enhancing energy efficiency and ensuring comfortable living conditions. While research has primarily simplified the complex interactions of soil heat and moisture transfer, a more nuanced approach is needed to address the non-linear nature of these processes. By considering the variable thermal conductivity and capacity of soil and the role of moisture and evapo transpiration, we can better understand and reduce heat loss through the ground. Recognizing the stability of undisturbed ground temperatures at certain depths can further aid in developing effective strategies for improving the energy performance of residential buildings.

# ***Chapter I***

## ***Introduction and Overview of Heat Loss in Residential Buildings***

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## **1. Introduction**

The problem of predicting heat losses from below grade surfaces in basements is a difficult one. In comparison, the heat losses from the upper floors of a residential dwelling are easily predicted. The above grade surfaces have well-defined boundaries, more easily determined boundary conditions, and high thermal resistances. Below grade surfaces, on the other hand, have boundaries which lose heat to the surrounding soil. In uninsulated basements the thermal resistance of the walls and floor are of the same order as that of the surrounding soil. Soil thermal conductivity is dependent on a number of factors, such as the mineral and organic material content, density, water content, and temperature. Estimating the soil thermal conductivity from soil content and density by analytical methods can at best be described, in the absence of a large number of measurement and chemical analyses, as more of an art than a science.

Furthermore, the temperature distribution within the surrounding soil is also dependent on a number of factors such as air temperature, solar radiation, vegetation and snow ground cover, and wind velocities. Finally, soil temperature distribution and heat transfer may also be affected by the movement of ground water through the soil and any phase change [2].

Ground-coupled envelopes are a major source of heat loss in overall building energy performance. Dynamic simulation of the underground heat transfer process and its integration with building energy models are pivotal in practical engineering applications.

### **1.1 Literature reviews**

Ground-coupled envelopes are a major source of heat loss in overall building energy performance. Dynamic simulation of the underground heat transfer process and its integration with building energy models are pivotal in practical engineering applications.

B. Larwa, K. Kupiec [3]. Study of temperature distribution in the ground, *Chem Process Eng.*, 2019, 40 (1), 123–137 have presented a model that considers annual changes in long-wave radiation flux, allowing for the determination of ground surface temperature, amplitude, and phase angle. It also explores the impact of heat transfer coefficient, air temperature amplitude, phase angle, and solar radiation flux on

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equation parameters. Results shows that ground temperature is influenced by various factors like latitude, weather, season, altitude, terrain, shading, buildings, surface coverage, land properties, and precipitation, making it unpredictable

Claesson. J , Hagentoft. CE [4]. have presented an extensive analysis of heat flow processes, aiming to obtain accurate and simple formulae for design purposes. Also Malyavina. , E .G and Gnezdilova [5]., Have focused on heat loss calculations for floor thermal protection using soil mass and annual thermal regime. Results show soil type, insulation width, and heat transfer resistance significantly impact resistance, concluding floor thermal insulation strips as the most effective structure.

Delsante.A.E[6]. Have used Fourier transforms to express heat flux from a surface region into a 2 or 3 dim. semi-infinite solid, with periodic quantities. These expressions are evaluated in 2-dim and 3-dim, and an explicit exact expression is obtained. Furthmore, Hans Janssen et. al, [7], have examine the impact of soil moisture transfer on ground-based building heat loss, comparing fully coupled and linear thermal simulations. Results show coupling influences include surface temperature amplitude, thermal conductivity variation, and sensible heat advection. For the same issue, Kang. X et. al [8], Have introduced a new co-simulation framework for dynamic underground heat transfer, integrating an XGB regression model with building energy models, improving computational speed and reducing simulation errors. Kissock.Kelly, et. al [9], Have presented a simplified method for calculating heat loss from slab-on-grade buildings. It uses a transient finite-difference model and a weighted average of annual average temperature and past three-month average temperature. The simplified model predicts heat loss using effective ground temperature using Kasuda's equation. A correction factor is added to account for heat loss from building ends. The method accurately accounts for variations in heat loss caused by temperature irregularities, enhancing its applicability.Chuangchid.P et al [10], have established a realistic model for heated concrete slab floors, focusing on heat transfer between slab and ground. It uses steady-state and steady-periodic solutions to determine ground heat loss/gain under design conditions.

**Pokorska-Silva. I [11]**, have explored soil temperature's impact on heat loss in a residential building in Poland, revealing that a proprietary geometric model overestimates heat flux due to lower ground temperatures.

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## **1.2 Objective**

Thermal properties of the ground are generally recognized to be the most important parameters that affect ground coupled heat transfer. Unfortunately, data for soil thermal properties are often very difficult to obtain. Indeed, soil thermal properties are influenced by a various factors such as soil type, soil density, soil moisture content, and even soil temperature and soil depth. This study explores methods for calculating ground heat loss through basement structures. It examines the impact of basement insulation on heat loss. Factors influencing heat loss include floor type, building geometry, insulation resistance, ambient temperature and the presence of insulation

It is expected that the results of this study will make a contribution significant to the transition towards a more sustainable and energy-efficient future residential buildings in Ouargla. By providing simplified dynamic models to reduce the loss of heat in residential buildings

## **1.3 Methodology**

For the sake of simplicity modeling for study of heat losses to ground through residential building basement, a model of a single zone type of residence or office buildings equipped with under-floor heating systems (Figure1) is considered describing the long- and short-term dynamic characteristics of the system. It was decided therefore to establish a coupled model which would provide a tool for ground heat losses study by choosing the commonly used method [12].

The modeling implies a simplification of the real physical processes that occurs in real buildings. These simplification are made through the use of assumptions that

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allow the problem of heat transfer mechanisms in the building to be solved more easily for example , simplified air infiltration and free convection heat exchange. Since the dynamic conditions of the model are being considered, the equations describing the heat transfer mechanism of the system are solved at every time step using the finite difference method.

The model are developed from the thermal characteristic of the building, and simulated for a heating period of six months

It uses one dimensional dynamic modeling and modular programming approach to simplify real world physical processes in buildings.

The temperature distribution and impact of the slab insulation are computed using program software AnThermversion 6.115 [13]. Concept of calculation is given by reference [14].

- Using three types of soil dry and wet : Sand; Earth; clay
- Implementing An ON/OFF controller for temperature regulation at set point 20 °C
- The input data including the hourly ambient temperature, solar irradiation (global and diffuse), wind velocity, precipitation of Ouargla weather conditions, type of soil and design parameters.
- The output data are the inside room, outside temperature of the slab, heat losses through the ground below grade.
- Considering uniform heat distribution for each layer depth of the ground below grade.

For considerable energy conservation, the knowledge of the temperature distribution in subsurface layers of the ground is important in the design, modeling and exploitation of a residential building envelope.

Our work deal with four chapters:Introduction; Simulation model of the coupled heated envelope to the ground;Results and discussions; Conclusion

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## **2.The Importance of Studying Heat Loss through the Ground in Residential Buildings**

### **2.1 Introduction**

Residential buildings are among the most significant sectors consuming substantial energy, and energy efficiency in these buildings plays a crucial role in enhancing environmental and economic sustainability. Heat loss through the ground is one of the primary factors affecting energy efficiency in buildings. Therefore, understanding and studying heat loss through the ground can have significant benefits.

### **2.2 The Importance of the Study**

Studying heat loss through the ground in residential buildings is essential for improving energy efficiency and achieving environmental and economic sustainability. By gaining a better understanding of this type of heat loss, we can develop more effective strategies and designs that contribute to creating more comfortable and healthy living environments for residents, protecting the environment, and conserving natural resources. Hence:

#### **I . Improving Energy Efficiency:**

- Reducing Energy Consumption: By understanding how heat loss through the ground occurs, design and construction measures can be taken to minimize this loss, leading to reduced reliance on artificial heating and cooling, thus saving energy.
- Cost Savings: Improving energy efficiency in residential buildings can lower energy bills for residents, making housing more economical in the long run.

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## **II . Achieving Environmental Sustainability:**

- Reducing Carbon Emissions: Lowering energy consumption translates to fewer greenhouse gas emissions from energy production, contributing to combating climate change and improving air quality.
- Conserving Natural Resources: Enhancing energy efficiency helps reduce dependence on non-renewable resources like coal, oil, and natural gas.

## **III. Enhancing Thermal Comfort and Health for Residents:**

- Achieving Thermal Comfort: Understanding heat loss can aid in designing buildings that maintain comfortable temperatures year-round, enhancing residents' well-being.
- Improving Indoor Air Quality: Reducing heat loss can minimize excess moisture and prevent mold growth, improving indoor air quality and reducing associated health risks.

## **IV. Guiding Policies and Regulations:**

- Setting Better Building Standards: Studies on heat loss can contribute to the development of stricter and more efficient building standards related to energy use.
- Encouraging Innovation in Building Materials and Techniques: Gaining more insight into heat loss can stimulate the development of new materials and technologies that reduce this loss.

## **V. Increasing Awareness and Knowledge:**

- Educating the Public and Professionals: Raising awareness about the importance of reducing heat loss can lead to the adoption of more efficient design and construction practices among engineers, architects, and homeowners.

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- Encouraging Research and Development: Highlighting this field can motivate more researchers to explore innovative solutions to improve energy efficiency in buildings.

### **2.3 Potential Benefits of Understanding This Type of Heat Loss**

- Identifying Weak Points: By studying heat loss, the most vulnerable points in buildings that require improvement can be identified.
- Developing Thermal Insulation Technologies: Understanding how heat loss occurs can lead to the development of more effective insulation materials and techniques, reducing thermal loss.
- Improving Foundation Designs: This knowledge can be used to enhance the design of building foundations and infrastructure to make them less susceptible to heat loss.

### **2.4 Conclusion**

In conclusion, predicting heat losses from below grade surfaces in basements presents significant challenges compared to the more straightforward predictions for upper floors of residential dwellings. This difficulty arises from the complex and variable nature of soil thermal conductivity, which depends on factors such as mineral and organic content, density, water content, and temperature. Additionally, the temperature distribution within the surrounding soil is influenced by external conditions like air temperature, solar radiation, vegetation, snow cover, and wind. The dynamic and multifaceted nature of soil-heat interactions, including the potential impact of groundwater movement and phase changes, further complicates the accurate estimation of heat losses. Therefore, understanding and integrating these complex factors into building energy models is crucial for improving the energy performance of buildings, particularly those with ground-coupled envelopes.

## ***Chapter II***

**(Numerical modeling of physical problems)**

## **1. Simulation model of the coupled heated envelope to the ground**

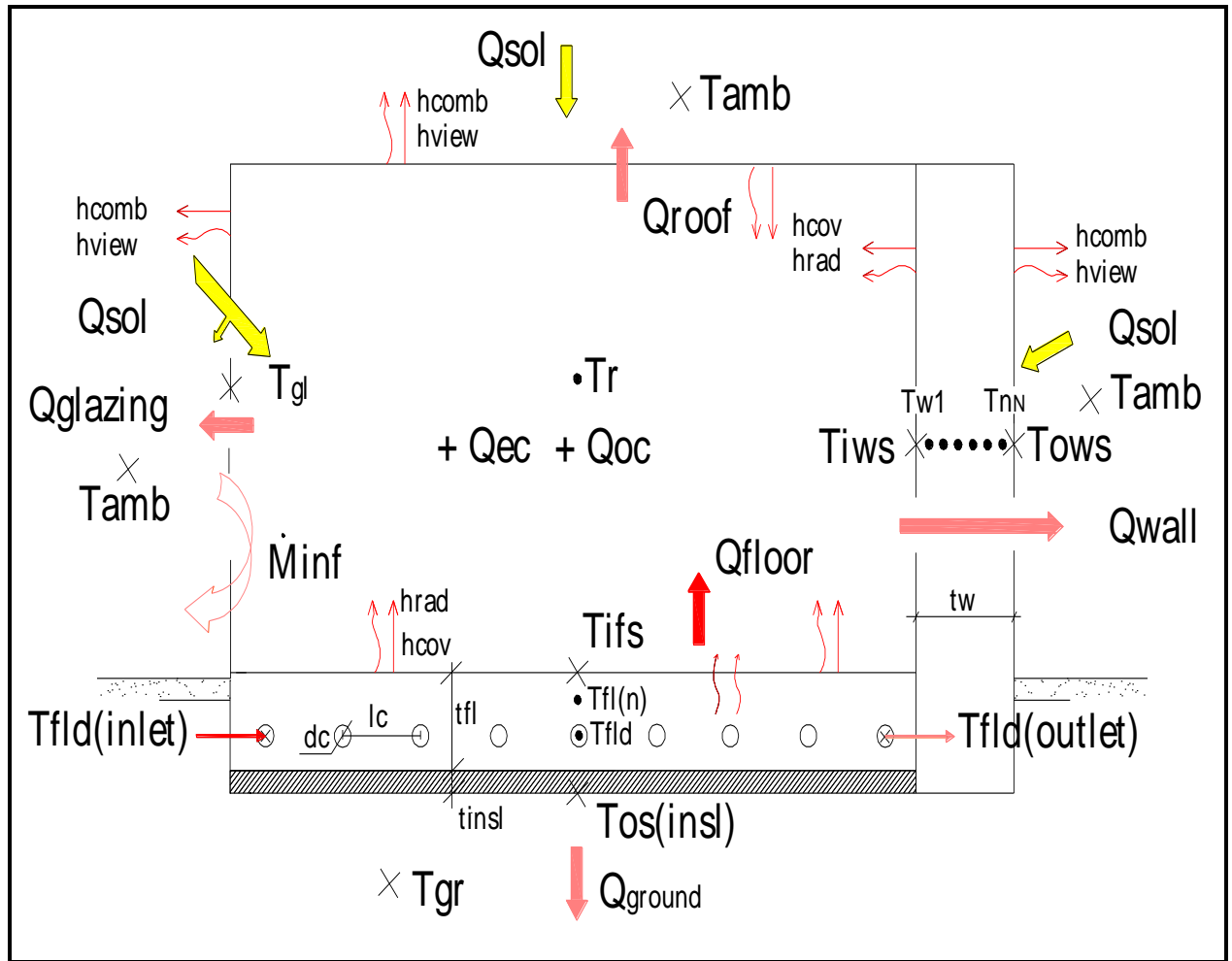
### ***1.1 Description of the model***

Building heating energy consumption is influenced by its envelope, heating plant efficiency, and control system quality, which connects the building to its heating system and inhabitants.

The model in Figure1, represent a single-zone building with solar under floor heating systems. The building's west and north walls are mass less, while the east wall forms a mass wall. Hot water circulates through pipes in the floor mass, insulated at its bottom. Energy is transferred through air infiltration, solar gains, and heat losses. The model describes the long- and short-term dynamic characteristics of the system. Thermo-Physique values of the building components are given by reference (Karlekar, and Desmond) [15].

The modelling approach involves creating a model for each system component based on its physical characteristics, calculating heat transfer using one-dimensional heat flow, and fitting parameter values for various configurations. The finite difference method is commonly used for simulating building models due to its flexibility and information availability.

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**Figure 2.1** General model of a heated envelope (Typical of residence or office building)

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## ***1.2 Model development and Assumptions***

The model is developed from the following assumptions:

- Considers long and short wave radiation heat exchange;
- Maintains thermal capacity for each air, mass floor, and wall;
- Accounts for conduction through walls, floors, roofs, and glazing separately;
- Accounts for air infiltration and ground heat losses;
- Doesn't account for heat released from occupants and electrical equipment;
- Assumes negligible thermal resistances of surface pipes in slab;
- The solar irradiation effects through the glazing are lumped on the inside surfaces, including the air of the room, whereby each surface or room air is assumed to receive a fixed percentage of the solar gain.

In order to simulate the heat and moisture transfer influence on the characteristics of the ground heat loss in unsaturated soil, the following simplifying assumptions are made in this study due to the soil transport phenomena are very complex:

- (1) The soil is homogeneous and the soil type does not change along the considered depth.
- (2) Natural convection of the fluid in porous medium satisfies Darcy's law.
- (3) There is no freezing in soil, and air in the soil is assumed to be ideal gas.

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### 1.3 Numerical modelling

#### 1.3.1 Temperature calculations

##### a. Node Temperatures

The fluid circulating through the embedded floor pipe, is treated as a point source represented by the single capacitive element whose temperature is  $T_{\text{fld}}$ . The mass floor and the mass wall are divided into layers of thickness  $\Delta x_{\text{fl}}$  and  $\Delta y_{\text{w}}$  respectively. An energy balance for the time interval can be expressed as: the heat flux from all neighbouring nodes towards node  $i$  during  $\Delta t$  is equal to the increase in internal energy of material associated with node  $i$ , i.e.:

$$Mcp_i \left( \frac{T_i^{n+1} - T_i^n}{\Delta t} \right) = UA_{(i-1,i)}(T_{i-1}^n - T_i^n) + UA_{(i,i+1)}(T_{i+1}^n - T_i^n) \quad (1)$$

Rearranging the above equation to :

$$\left( \frac{T_i^{n+1} - T_i^n}{\Delta t} \right) = \frac{UA_{(i-1,i)}T_{i-1}^n + UA_{(i,i+1)}T_{i+1}^n - (UA_{(i-1,i)} + UA_{(i,i+1)})T_i^n}{Mcp_i} \quad (2)$$

And letting :  $\lambda_i = (UA_{(i-1,i)} + UA_{(i,i+1)})T_i^n / Mcp_i$  (3)

$$\omega_i = T_i^{n+1} / \Delta t \quad (4)$$

$$S_i = (UA_{(i-1,i)}T_{i-1}^n + UA_{(i,i+1)}T_{i+1}^n) / Mcp_i \quad (5)$$

Equation (1) becomes:  $(T_i^{n+1} - T_i^n / \Delta t) = \omega_i = S_i - \lambda_i T_i^n$  (6)

This equation can be written as:  $T_i^{n+1} = (1 - \lambda_i \Delta t) T_i^n + S_i \Delta t$  (7)

The stability analysis, (Hirt 1968) [15], applied to this explicit solution leads to a restriction on the choice of the time step size. That is the term  $(1 - \lambda_i \Delta t)$  of the equation must be positive or equal to zero, Thus:  $\Delta t \leq \frac{1}{\lambda_i}$  (8)

For the case of the simulation model, the maximum permissible time step size is found equal 2.5 seconds, that is, too time consuming for a long-term simulation. However, an increase in permissible time step size can be achieved without loss of accuracy, by introducing a weighting factor  $\sigma_i$ , i.e choosing an implicit solution.

Equation (7) becomes:  $T_i^{n+1} = T_i^n + \sigma_i \omega_i \Delta t$  (9)

Solving for  $\omega_i$ , we get  $\omega_i = \frac{S_i - \lambda_i T_i^n}{1 + \lambda_i \sigma_i \Delta t}$  (10)

The weighting factor  $\sigma_i$  is found from matching the analytical and the implicit numerical equations of  $\omega_i$

Namely:  $\frac{(1 - e^{-\lambda_i \Delta t}) S_i - \lambda_i T_i^n}{\lambda_i T_i^n} = \frac{S_i - \lambda_i T_i^n}{1 + \lambda_i \sigma_i \Delta t}$  (11)

Solving for  $\sigma_i$  we get :  $\sigma_i = \frac{1}{(1 - e^{-\lambda_i \Delta t})} - \frac{1}{\lambda_i \Delta t}$  (12)

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From this equation,  $\sigma_i$  always takes values in the range [0,1] what ever the value of the product  $(\lambda_i \Delta t)$ . Once  $\omega_i$  is computed, the predicted temperature of nod i for a time step size  $\Delta t$  is given as:

$$T_i^{n+1} = T_i^n + \omega_i \Delta t \quad (13)$$

The same procedure outlined above is used to calculate each nodal temperature for the working fluid, the mass floor, the mass wall, and the air of the room.

The model simulation of the system is implemented into a computer code using modular programming approach. The initial value for each of all temperatures is taken 12 °C.

### **b. Surface temperatures**

A steady state energy balance on each of the inside and the outside building is used to calculate their temperatures. The surface temperature equation can be expressed in terms of conductive, convective and radiation heat exchange, including the solar heat gain on outside envelope surfaces. The inside surfaces or the room air are assumed to receive a fixed percentage of the gain. The glazing is assumed to have only one surface temperature since its thickness is chosen small.

$$T_{is} = \frac{\sum(UA_j T_j) + a_{sol} G}{\sum UA_j} \quad (14)$$

$$T_{os} = \frac{\sum(UA_j T_j) + G}{\sum UA_j} \quad (15)$$

### **c. Room air temperature**

The room air temperature is defined as the process output that has to be controlled. This temperature is the result of the heat input through the floor, the solar irradiation and the heat losses (gains) through the mass wall, the glazing, the roof, the remaining walls, and air infiltration. Therefore the variation of the room air temperature can be seen as dependant on the following physical quantities which are defined as process inputs: the inlet fluid temperature or the fluid mass rate that enters the heating element, the outside air temperature, the solar irradiation, the wind velocity. The existence of non-measurable disturbances is not take into account.

$$S_r = (UA_{(fl,r)} T_{ifs} + UA_{(r,mw)} T_{imws} + UA_{(r,rf)} T_{irf} + UA_{(r,gl)} T_{gl} + UA_{(r,nw)} T_{irnww} + UA_{(r,ww)} T_{iww} + \dot{m}_{inf} c p_{air} T_{amb} + a_{sol} G + Q_{oc} \nearrow^0 + Q_{ec} \nearrow^0) / M c p_{air} \quad (16)$$

$$\lambda_r = (UA_{(fl,r)} + UA_{(r,w)} + UA_{(r,rf)} + UA_{(r,gl)} + UA_{(r,nw)} + UA_{(r,ww)} + \dot{m}_{inf} c p_{air}) \quad (17)$$

$$\sigma_r = \frac{1}{(1 - e^{-\lambda_r \Delta t})} - \frac{1}{\lambda_r \Delta t} \quad (18)$$

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$$\omega_r = \frac{S_r - \lambda_r T_r^n}{1 + \lambda_r \sigma_r \Delta t} \quad (19)$$

$$T_r^{n+1} = T_r^n + \sigma_r \omega_r \cdot \Delta t \quad (20)$$

Where the gains by the occupants and electrical applications are neglected for the sake of simplicity.

### *d. Temperature output of fluid from embeded pipes:*

The heat input to the floor can be expressed as :

$$Q_{cons} = \zeta \dot{m} c p_{fld} (T_{in(fld)} - T_{fl(1)}) \quad (21)$$

Where  $\zeta$  is the effectiveness of heat element given by

$$\zeta = 1 - e^{-NTU} \quad (22)$$

$$NTU = \frac{UA_{(fld,fl)}}{\dot{m} c p_{fld}} \quad (23)$$

$Q_{cons}$  can also be expressed as:

$$Q_{cons} = \dot{m} c p_{fld} (T_{in(fld)} - T_{out(fld)}) \quad (24)$$

By matching the two expression of  $Q_{cons}$  , we get the temperature of the fluid as a function of the inlet temperature and the temperature of the first floor

$$\text{node: } T_{out(fld)} = \zeta T_{fl(1)} + (1 - \zeta) T_{in(fld)} \quad (25)$$

### **1.3.2 Heat transfer coefficient calculations**

- Linearization assumption is used for long wave radiation heat transfer between internal surfaces and surrounding surfaces.
- Correlations used for free convection heat transfer in real-sized three-dimensional enclosures given by (Khalifa, and Marshall) [16].

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### 1.4 *Theoretical analysis of ground temperature changes:*

For theoretical analysis of ground temperature changes with location and time the following assumptions are made:

- The ground is a homogeneous heat conducting medium,
- The ground can be treated as a semi-infinite medium with constant thermal diffusivity,
- The surface temperature of the ground is variable periodically over time,
- The geothermal gradient is zero.

The daily average temperature of the ground  $T$  can be computed by using Carslaw–Jaeger equation:

$$T = T_{sm} - A_s \cdot \exp\left(-\frac{x}{L}\right) \cdot \cos\left(\omega t - P_s - \frac{x}{L}\right) \quad (26)$$

The parameters of the above relationship are:  $T_{sm}$ ,  $A_s$ ,  $P_s$  and  $L$ . Damping depth  $L$  is defined as follows:

$$L = \sqrt{\frac{2a}{\omega}} \quad (27)$$

For phenomena occurring in the annual cycle, the frequency is equal to  $\omega = 2\pi/365$  days<sup>-1</sup> =  $0.199 \times 10^{-6}$  s<sup>-1</sup>.

The average value of the geothermal gradient on Earth is approx. 0.03 K/m, whereas the average value of the thermal conductivity of the ground is of the order of 1.5 W/(m K). Thus, the average geothermal heat flux density is  $0.03 \times 1.5 = 0.045$  W/m<sup>2</sup>. It is a much smaller value than the other heat fluxes on the surface of the ground, which means geothermal flux can be neglected in balancing heat fluxes.

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Due to neglecting the geothermal flux, the value of the annual average temperature of the ground practically does not depend on the location, i.e. the undisturbed ground temperature and the average temperature of the ground surface are the same.

The phase angle  $P$  is related to time elapsed from the beginning of the calendar year until the daily average value (temperature or flux) reaches the minimum, as follows:

$$P = \omega t_{min} \quad (28)$$

the type of soil and hygrometric conditions, thermal properties vary. Very dry soil will not have the same properties as very wet soil. As a result, heat dissipation underground will be different. The two main properties to observe are therefore the thermal conductivity and thermal resistance of the soil (inversely proportional quantities).

As the results obtained show, the thermal conductivity of soils varies significantly depending on their water content. Therefore, it is important to know the thermal properties and hygrometric conditions of the land where you wish to carry out civil engineering work. Depending on these parameters, you will not have the same conditions for heat propagation. This will allow you to put in place the necessary means for a long-lasting installation (choice of materials, etc.). TEMPOS was designed for this type of measurement and allows you to obtain very quickly ( $\sim 3$ min) and with great precision ( $< 10\%$ ) the thermal conductivity of dry and wet soils.

### **1.5 Thermal conductivity of dry and wet soils**

The following application example concerns the measurement of thermal conductivity of dry and wet soils with the TEMPOS portable thermal analyzer. The humidity level of the soil (or hygrometry) is an important parameter to take into account when undertaking, for example, road work or installation of pipes. Indeed, depending on the type of soil and the hygrometric conditions, the thermal properties vary. Very dry soil will not have the same properties as very wet soil. As a result, heat dissipation underground will be different. Cables and pipes buried in ground with low thermal conductivity can overheat and potentially burn. Conversely, hot water pipes buried in ground with too high thermal conductivity will suffer considerable heat loss, which could harm the profitability of the installation. The two main properties to observe are therefore the thermal conductivity and the thermal resistance of the soil

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(inversely proportional quantities). In the literature the given values to fit three type of Ouargla soil are given **Table 1**.

**Table 1.** Thermal conductivity of dry and wet soils.

Soil type	Thermal Conductivity of dry soil (W/m.K)	Thermal Conductivity of soil of 10% waater(W/m.K)	Thermal Conductivity saturated soil (W/m.K)
Earth	0.321	0.912	1.307
Sand	0.396	2.224	2.402
Clay	0.543	1.298	1.715

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## 1.6 Portable thermal conductivity analyzer

The TEMPOS, a compact and portable measuring device developed by METER, was designed to carry out measurements directly in the field (in situ), or in the laboratory on samples taken. Precise and fast, the TEMPOS meet the requirements of international standards ASTM D5334 and IEEE 442.



**Figure 2.2** Portable thermal conductivity analyzer

## 1.7 Numerical application

Considering numerical tests of the heating systems of the residential building built on dry and humid soil of sand, earth, and clay separately for different depths below grade namely: 1.2 m, 2.0 m. The thermal conductivities are taken from Table 1 (standard values).

Establishing a simulation for six months under Ouargla climate conditions, and the month of January is seen as the coldest period to be analysed through the temperature distributions and heat losses. Below grade ground layers at different depths are supposed to homogenous.

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### **1.8 . Conclusion :**

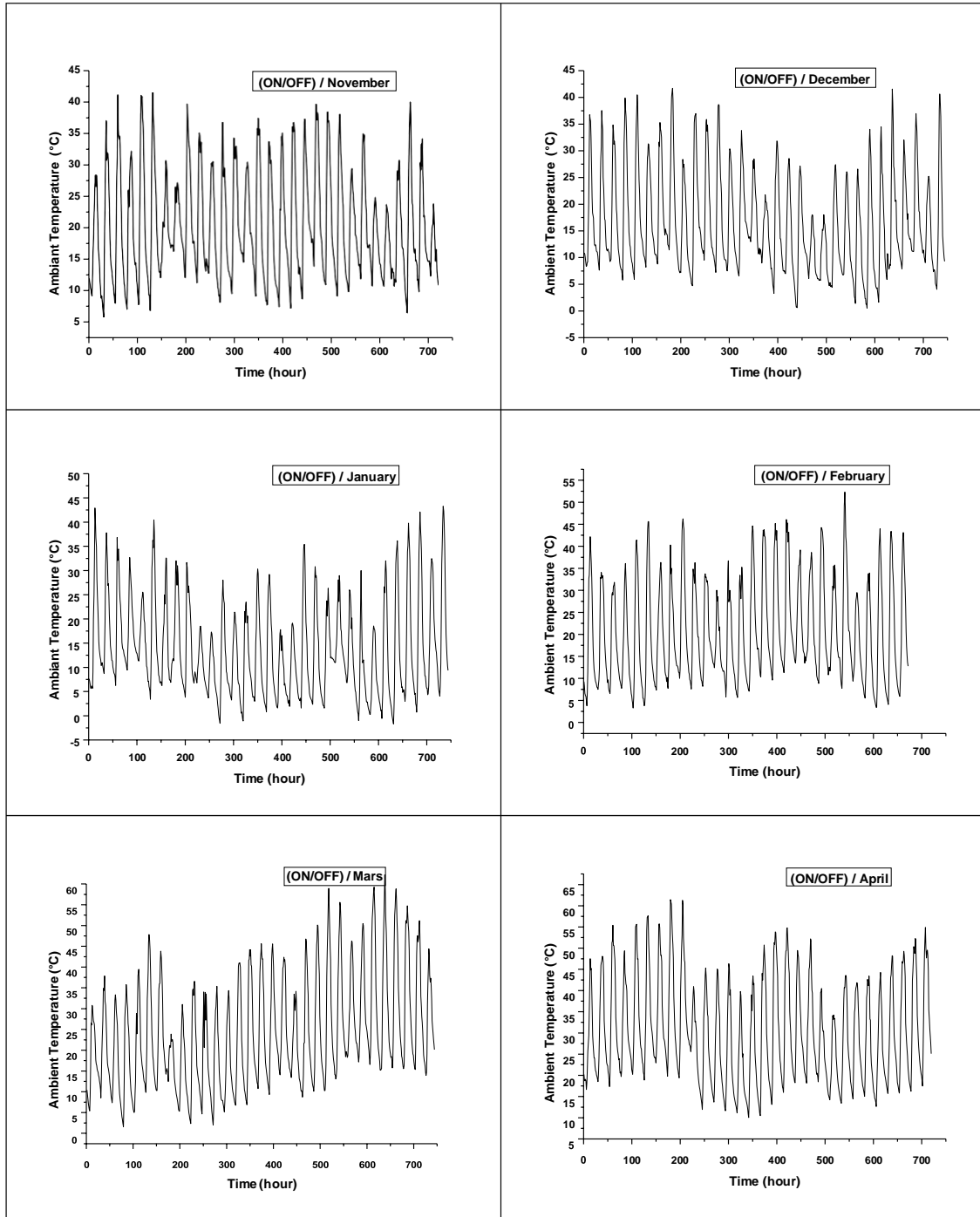
Predicting heat losses from below grade surfaces in basements presents significant challenges compared to the more straightforward predictions for upper floors of residential dwellings. This difficulty arises from the complex and variable nature of soil thermal conductivity, which depends on factors such as mineral and organic content, density, water content, and temperature. Additionally, the temperature distribution within the surrounding soil is influenced by external conditions like air temperature, solar radiation, vegetation, snow cover, and wind. The dynamic and multifaceted nature of soil-heat interactions, including the potential impact of groundwater movement and phase changes, further complicates the accurate estimation of heat losses. Therefore, understanding and integrating these complex factors into building energy models is crucial for improving the energy performance of buildings, particularly those with ground-coupled envelopes.

# **Chapter III**

*( Results and discussions )*

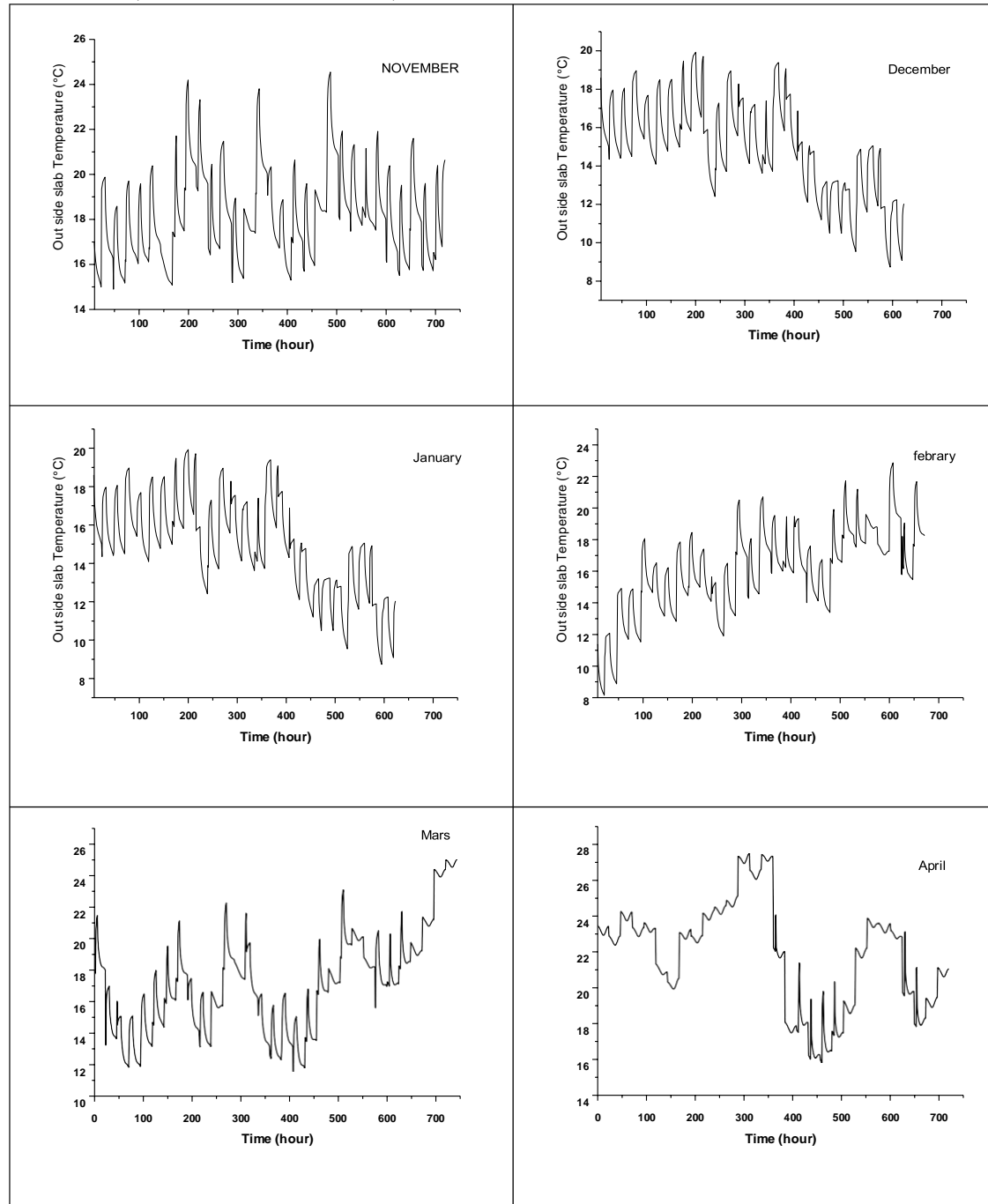
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**Graph 1:** Indoor temperatures using ON/OFF control.  
(Six month simulations).



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**Graph 2:** Outside insulated slab Temperature using ON/OFF control, (Six month simulations).



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**Table 2:** Ground heat loss below grade of soil type at 1.2mdepth below grade.  
(Six months of simulation)

<b>Soil type Dry</b>	<b>Thermal conductivity (W/m. K)</b>	<b>Depth below grade (m)</b>	<b>Heat loss (MJ)</b>
Sand	0.381	1.2	530.1
Earth	0.321	1.2	1.247
Clay	0.543	1.2	109.2

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**Table 3:** Ground heat loss below grade of soil type at 2mdepth below grade.  
(Six months of simulation)

<b>Soil type Dry</b>	<b>Thermal conductivity (W/m.K)</b>	<b>Depth below grade (m)</b>	<b>Heat loss (MJ)</b>
Sand	0.381	2,0	213.1
Earth	0.321	2,0	0.988
Clay	0.543	2,0	1.672

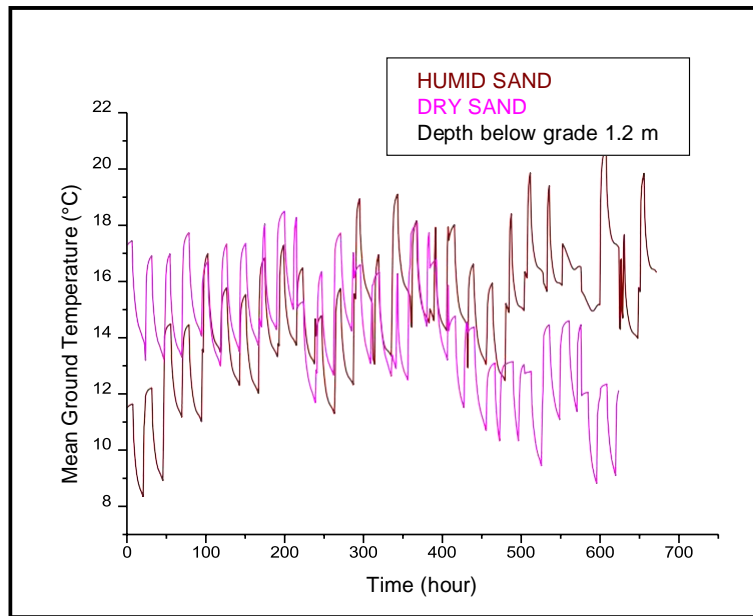
**Table 4:** Ground heat loss below grade of soil type at 1.2mdepth below grade.  
(Six months of simulation)

<b>Soil type Wet )10%)</b>	<b>Thermal conductivity (W/m.K)</b>	<b>Depth below grade (m)</b>	<b>Heat loss (MJ)</b>
Sand	2.224	1,2	8.700
Earth	0.912	1,2	3.542
Clay	1.298	1,2	5.041

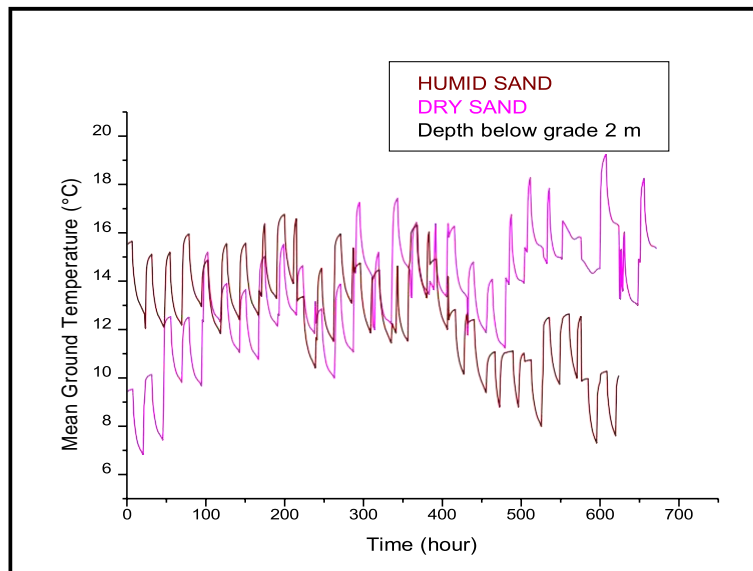
**Table 5:**Ground heat loss below grade of soil type at 1.2 m depth below grade.  
(Six months of simulation)

<b>Soil type Wet )10%)</b>	<b>Thermal conductivity (W/m.K)</b>	<b>Depth below grade (m)</b>	<b>Heat loss (MJ)</b>
Sand	2.224	2,0	6.85
Earth	0.912	2,0	2.808
Clay	1.298	2,0	3.997

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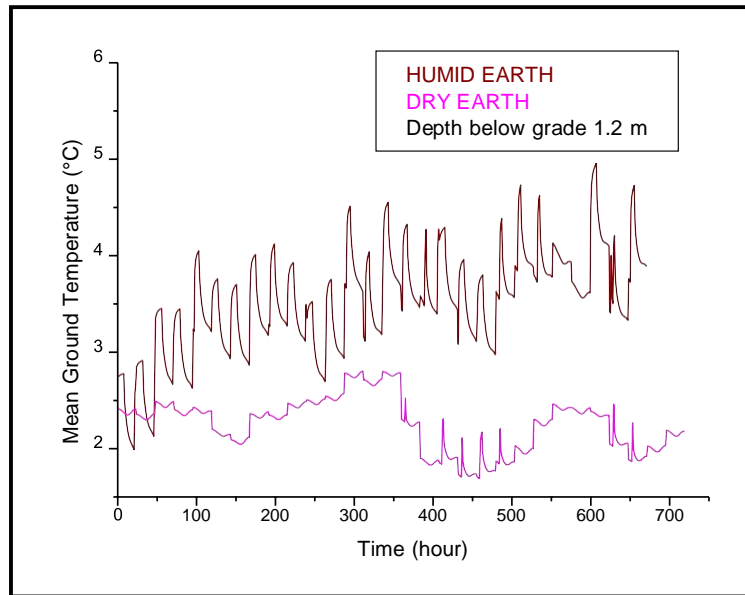


**Graph 3:** Temperature distribution of dry and humid sand (Month of January at 1.2 m depth below grade)

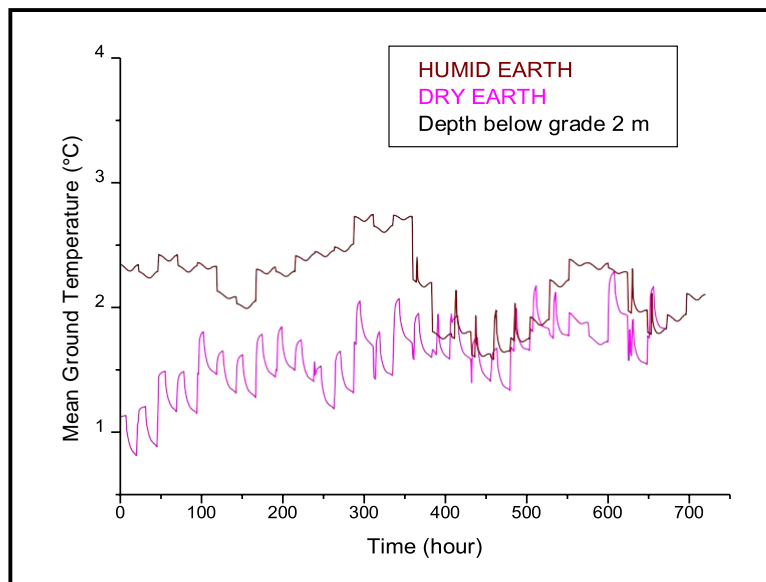


**Graph 4:** Temperature distribution of dry and humid sand (Month of January at 2 m depth below grade)

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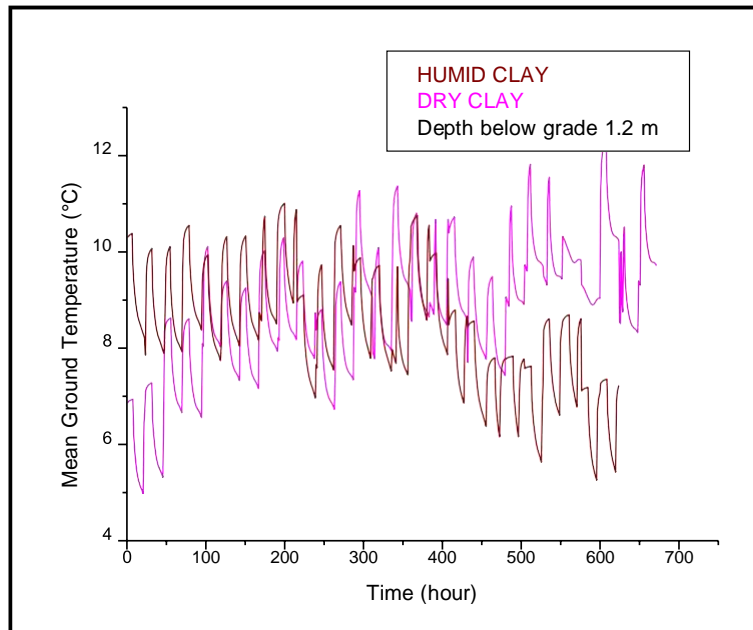


**Graph 5:** Temperature distribution of dry and humid earth (Month of January at 1.2 m depth below grade)

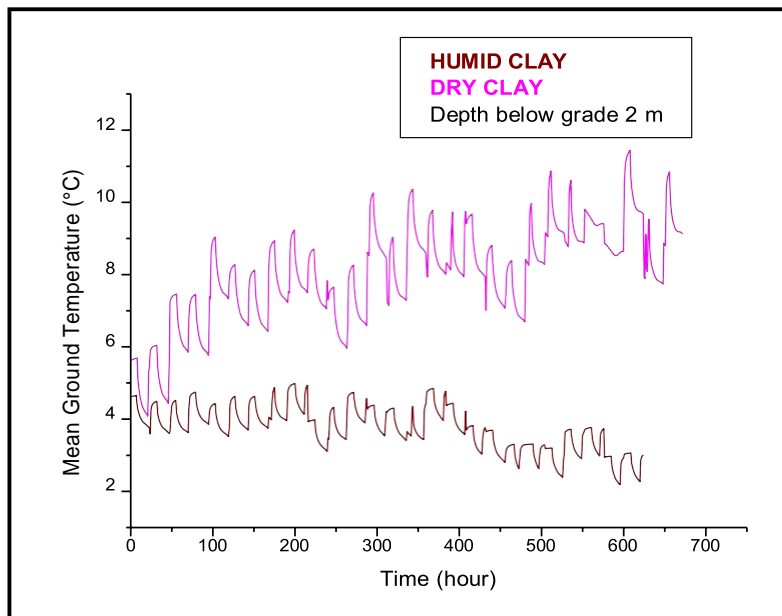


**Graph 6:** Temperature distribution of dry and humid earth (Month of January at 2 m depth below grade)

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**Graph 7:** Temperature distribution of dry and humid clay (Month of January at 2 m depth below grade)



**Graph 8:** Temperature distribution of dry and humid clay (Month of January at 2 m depth below grade)

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## 1. Results and discussions

- Simulations output for six months of the indoor temperatures with on/off control are shown in Graph 1, where the value of the mean lowest temperatures does not exceed 5 °C during of the heating season.
- The average outside temperature of the insulated slab on the ground below grade of sand, during consecutive six months is seen in Graph 2 to be 7 °C during the month of January
- Using three different soil types for the ground mass, and for 1.20 m, and 2.0 m depth
  - It seen from Table 2 that a dry clay has 27 % heat loss more in comparison to dry sand and 41% to dry earth at 1.2 m depth, and the output temperature distributions for layer is shown in graph 03.
  - It seen from Table 3 that a dry clay has 41 % heat loss more in comparison to dry earth and 27 % to the dry sand at 2 m depth,
  - It seen from Table 4 that a dry clay has 30 % heat loss more in comparison to dry earth and 42 % less than the dry sand at 1.2 m depth,
  - It seen from Table 5 that a dry clay has 59 % heat loss less in comparison to dry earth and 42 % less than the dry sand at 2 m depth,
  - The output temperature distributions of layers for various types dry and humid at different depth and conditions are shown in graph 2 to 8. Where the thermal amplitude from combinations to other, significantly indicate that ground mass below grade is favourable for conservative energy waste through the ground with earth material rather than sand or clay.

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In conclusion, the simulation results demonstrate the significant impact of soil type and depth on heat loss from below grade surfaces. The findings indicate that dry clay has substantially higher heat losses compared to dry sand and dry earth at a depth of 1.2 meters, with a 27% and 41% increase respectively. At a depth of 2 meters, dry clay still exhibits higher heat losses, though the differences vary, showing a 41% increase compared to dry earth and 27% to dry sand. However, at different conditions, dry clay can also show significantly lower heat losses, indicating a complex relationship between soil properties and heat transfer. The output temperature distributions reveal that using earth material below grade is more favorable for reducing energy waste compared to sand or clay. These results underscore the importance of considering soil composition and depth in the design and construction of energy-efficient buildings.

# `Study of heat loss through the ground of residential building envelope in Ouargla soil.

## **Conclusions**

A simulation model is established to determine the actual heat loss through the ground soil from an insulated slab in a low temperature floor heating system. The main study was achieved by numerical tests on Ouargla soil for three different types for different thermo values, basement depths, and weather conditions. The thermal analyze indicates that the soil of Ouargla is less sensitive to outside ambient temperature and more sensitive to solar radiation gains. Consequently this type of soil elucidates and contributes to the economic building design of foundations.

# Study of heat loss through the ground of residential building envelope in Ouargla soil.

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## ANNEXE

### Main Program

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DIMENSION TW(20),TF(20),OMEGAW(20),OMEGAF(20),UAE(20),UAW(20),
& UAB(20),UAV(20),ISTADAY(12),IENDAY(12)
CHARACTER*10 MONTH(12),NANUAL(1)
REAL INSLK,INSLT,LAMBD,MASFL,NAC,NTU,PI,LAMBDF,PR,INCIDE,INCIDT
& ,INCNEXT,ITGRAL,MASCAP,LAT,LGTUD,LGCPL,LGCCAP,PUTIL,MASAIR
REAL NRMANS,NRJMOIS,MASABS,MASVIT,PMCAP,INSLCAP
PARAMETER (PI=3.1416)
PARAMETER(ZERO=1.0E-9)
DATA MONTH/'NOVEMBRE','DECEMBRE','JANVIER','FEVRIER','MARS',
& 'AVRIL','MAY','JUIN','JULIET','AOUT','SEPTEMBRE',
& 'OCTOBRE'/
DATA NANUAL(1)'/ANNUELLE'/
DATA ISTADAY(1),ISTADAY(2),ISTADAY(3),ISTADAY(4),ISTADAY(5),
& ISTADAY(6),ISTADAY(7),ISTADAY(8),ISTADAY(9),ISTADAY(10),
& ISTADAY(11),ISTADAY(12)/305,335,1,32,60,91,121,
& 152,182,213,244,274/
DATA IENDAY(1),IENDAY(2),IENDAY(3),IENDAY(4),IENDAY(5),
& IENDAY(6),IENDAY(7),IENDAY(8),IENDAY(9),IENDAY(10),IENDAY(11),
& IENDAY(12)/334,360,31,59,90,120,151,181,212,243,273,304/
DATA X,Y,Z,RT,AGL,RNWT,WT,FT,H/2.5,2.5,2.5,0.15,5.0,
& 0.15,0.25,0.30,0.05/
DATA DITUBE,DEXTUB/0.018,0.020/
DATA DPTH,DFBG,INSLT,INSLK,FTUHE/2.1,2.1,0.10,0.05,0.02/
DATA GLT,GLK/0.005,0.76/
DATA DA,CPA,DYV,AK/1.164,1012,18.24E-6,0.0251/
DATA FK,DFLD,VIS,PR,CPFD/0.624,995.33,0.7E-6,4.68,4178.8/
DATA DW,CPW,WK,EWI,EWE/1810.0,840.0,0.52,0.2,0.01/
DATA DF,CPF,FLOK,EFL/2307.0,878.0,1.40,0.95/
DATA RK,EROFI,EROFE,ABSGLE,EGLE,EV/0.8,0.2,0.01,0.05,0.9,0.9/
DATA TOFS,TFLD,TFDCH,TFLOR,TIFS,TR,TGL,TIWS,TIRS,
1TIRNWS,TOWS,TORS,TORNWS,TWALL,TIRNWOS,TORNWOS,TRDT,TMC/18*285.16/
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C DATA TCM /293.16/

DATA KABS,EPABS,EABS,ABSOR,TUBDIS,DEXTUBC,W,ESODU,SOUK,DITUBC,  
& SOUDL,SOUK/386.0,0.002,0.14,0.95,0.018,0.02, 0.1,0.005,5.0,  
& 0.018,0.02,5.0/

DATA INSLCAP,EGAP,EPSV,EINSBAS/0.05,0.02,0.005,0.10/

CC DATA CAPLG,NCONDC/1.0,10.0/

DATA COEFF,EXM,EXN,QOC,QEC/0.023,0.8,0.4,0.0,0.0/

DATA ALFAFL,ALFARM,ALFAWL/0.15,0.10,0.75/

DATA NODFLO,NODWAL/10,10/

DATA DT/180.0/

DATA C1,C2,C3/0.150,0.088,0.00483/

DATA ANVTAMB,AMPL,PHASE/283.36,-6.7,7.39/

DATA TINFMAX,TINFMIN,TINF,TSORC/313.16,303.16,285.16,285.16/

DATA TABS,TAIR,TV/285.16,285.16,285.16/

DATA FLMART,FLMRMAX/0.04,0.04/

DATA TSET,TRAV,TOUF,TEXIT,TENC/293.16,285.16,285.16,285.16,285.16/

DATA OMEGAR,QDES,UABULD,UAFDRM,UAMBT/0.0,1500.0,75.0,2.0,6.7/

DATA F1,F2,F3,F4/1.0,1.0,1.0,1.0/

DATA ALFAC,TAU,BETACAP/0.8,0.9,30.0/

DATA LAT,LGTUD/37.0,116.0/

DATA BETAHZ,BETA VR/0.0,90.0/

AW=X\*Z

AR=Y\*X

ARNW=Y\*Z

AF=AR

WMAS=DW\*AW\*WT/FLOAT(NODWAL)

FMAS=DF\*AF\*FT/FLOAT(NODFLO)

C MASFL=DFLD\*H\*X\*Y

DISCON=0.20

CAPLG=1.00

CAPLAG=2.0

SC=(CAPLG\*CAPLAG)

NCONDP=Y/DISCON

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```
NCONDC=CAPLAG/TUBDIS
LGCPL=X*NCONDP+DISCON*(NCONDP-1)
LGCCAP=CAPLG*NCONDC+TUBDIS*(NCONDC-1)
VFLD=(3.14*DITUBE*DITUBE* LGCPL)/4.0
VCAP=(3.14*DITUBC*DITUBC*LGCCAP)/4.0
MASFL=VFLD*DFLD
MASCAP=VCAP*DFLD
AIRMAS=DA*X*Y*Z*CPA
```

C.....

```
CPVIT=840
CPABS=383.0
DABS=8954.0
DVITR=2700.0
MASVIT=DVITR*EPSV*CAPLG*CAPLAG
MASAIR=DA*EGAP*CAPLG*CAPLAG
MASABS=DABS*EPABS*CAPLG*CAPLAG
EPCAP=EPSV+EGAP+EPABS+ EINSBAS
```

C     RATIO=SC/AF

C

```
DO 1 IUAWALL=1,NODWAL
UAW(IUAWALL)=WCOD
UAE(IUAWALL)=WCOD
1CONTINUE
UAW(1)=WCOD*2.0
UAE(NODWAL)=WCOD*2.0
FCOD=AF*FLOK*FLOAT(NODFLO)/FT
DO 2 IUAFLOR=1,NODFLO
UAB(IUAFLOR)=FCOD
UAV(IUAFLOR)=FCOD
2CONTINUE
UAB(1)=FCOD*2.0
UAV(NODFLO)=FCOD*2.0
DO 3 IFLOR=1,NODFLO
```

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```
TF(IFLOR)=TFLOR
3 CONTINUE
DO 4 IWALL=1,NODWAL
TW(IWALL)=TWALL
4 CONTINUE
C  ER=TSET-TR
NSTEP=3600/INT(DT)
C  INTERIURES DU BATIMENT
CALL GEOSHAPE(X,Y,Z,2,SFA2)
SHFLMW=SSHAPE(SFA2,AF,AW,EFL,EWI)
SHFLGL=SSHAPE(SFA2,AF,AGL,EFL,EGL)
SHFLNW=SSHAPE(SFA2,AF,AW,EFL,EWI)
C
SHGLFL=SSHAPE(SFA2,AGL,AF,EGL,EFL)
SHGLRF=SSHAPE(SFA2,AGL,AR,EGL,EROFI)
SHGLNW=SSHAPE(SFA2,AGL,AW,EGL,EWI)
C
SHMWFL=SSHAPE(SFA2,AW,AF,EWI,EFL)
SHMWNW=SSHAPE(SFA2,AW,AW,EWI,EWI)
SHMWRF=SSHAPE(SFA2,AW,AR,EWI,EROFI)
C
SHRFGL=SSHAPE(SFA2,AR,AGL,EROFI,EGL)
SHRFMW=SSHAPE(SFA2,AR,AW,EROFI,EWI)
SHRFNW=SSHAPE(SFA2,AR,AW,EROFI,EWI)
C
SHNWRF=SSHAPE(SFA2,AW,AR,EWI,EROFI)
SHNWMW=SSHAPE(SFA2,AW,AW,EWI,EWI)
SHNWFL=SSHAPE(SFA2,AW,AF,EWI,EFL)
SHNWGL=SSHAPE(SFA2,AW,AGL,EWI,EGL)
C
CALL GEOSHAPE(X,Y,Z,1,SFA1)
SHFLRF=SSHAPE(SFA1,AF,AR,EFL,EROFI)
SHGLMWS=SSHAPE(SFA1,AGL,AW,EGL,EWI)
```

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SHRFFL=SSHAPE(SFA1,AR,AF,EROFL,EFL)

SHMWGL=SSHAPE(SFA1,AW,AGL,EWI,EGL)

SHMWMWO=SSHAPE(SFA1,AW,AW,EW,EWI)

SHMWOMW=SSHAPE(SFA1,AW,AW,EW,EWI)

C.....

CALL GEOSHAPE(EPCAP,CAPLAG,CAPLG,1,SFA1)

SHVABS=SSHAPE(SFA1,SC,SC,EV,EABS)

SHABSV=SSHAPE(SFA1,SC,SC,EABS,EV)

C

C OPEN(UNIT=30,FILE='CLM1.DATA',STATUS='OLD')

ITGRAL=0.0

QGROUD=0.0

QRADT=0.0

QCONV=0.0

DO 5 NYEAR=1,1

C NYEAR=1

QANUAL=0.0

QVENT=0.0

Q=0.0

ENSOLC=0.0

ANUABEL=0.0

ANHOBEL=0.0

ANUABV=0.0

ANHOBV=0.0

DO 5 MTH=1,6

DTT=0.0

HOURABV=0.0

HOURBEL=0.0

ABOVSET=0.0

BELSET=0.0

QMONTH=0.0

NSTAR=ISTADAY(MTH)

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```
C  NSTAR=ISTADAY(1)
   NEND=IENDAY(MTH)
   NRJMOIS=0
C  NEND=IENDAY(1)
C  QGROUD=0.0
   PUTIL=0.0
   RDICAP=0.0
   DO 5 NDAY=NSTAR,NEND
   TJ=0.0
   TP=0.0
   NRJMOIS=NRJMOIS+1
C  CALL QUTFLC(RDI,TAU,ALFAC,SC,TAMB,TCM,UL)
   DO 5 IHOUR=1,24
C  IF(IHOUR.GE.12) TINF=TEXIT
C  OPEN(UNIT=36,FILE='RESULAT.DATA',STATUS='UNKNOWN')
C  WRITE(36,*)TR-273.16,TSORC-273.16,TEXIT-273.16,RDI
C  I=I+1
C  TA=18.0
C  RDI=0.0
C  WRITE(*,*) TR-273.16 ,SOLRAD,TA
C  WRITE(6,*)DECHSOL

   IF(MTH.EQ.1) THEN
   OPEN(UNIT=12,FILE='NOVB1.DATA',STATUS='UNKNOWN')
C  WRITE(12,*)HDTT,TR-273.16
   WRITE(12,*)HDTT,QGROUD
C  OPEN(UNIT=14,FILE='TDELY.DATA',STATUS='UNKNOWN')
C  WRITE(14,*)TRDELY-273.16
   ELSE IF(MTH.EQ.2) THEN
   OPEN(UNIT=21,FILE='DECB1.DATA',STATUS='UNKNOWN')
C  WRITE(21,*)HDTT,TR-273.16
   WRITE(21,*)HDTT,QGROUD
C  OPEN(UNIT=15,FILE='TRODEL.DATA',STATUS='UNKNOWN')
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```
C  WRITE(15,*)HDTT,TRDELY-273.16
    ELSE IF(MTH.EQ.3) THEN
    OPEN(UNIT=22,FILE='JANV1.DATA',STATUS='UNKNOWN')
C  WRITE(22,*)HDTT,TR-273.16
    WRITE(22,*)HDTT,QGROUD
    ELSE IF(MTH.EQ.4) THEN
    OPEN(UNIT=28,FILE='FVR1.DATA',STATUS='UNKNOWN')
C  WRITE(28,*)HDTT,TR-273.16
    WRITE(28,*)HDTT,QGROUD
    ELSE IF(MTH.EQ.5) THEN
    OPEN(UNIT=11,FILE='MARS1.DATA',STATUS='UNKNOWN')
C  WRITE(11,*)HDTT,TR-273.16
    WRITE(11,*)HDTT,QGROUD
    ELSE
    OPEN(UNIT=25,FILE='AVRL1.DATA',STATUS='UNKNOWN')
C  WRITE(25,*)HDTT,TR-273.16
    WRITE(25,*)HDTT,QGROUD
    ENDIF
C  GDIFUS=0.0
C  GBEAM=0.0
    OPEN (UNIT=5,FILE='KN.DATA',STATUS='OLD')
    READ (5,*)AN,DJR,SOL,TA,V
    WRITE(6,*)AN,DJR,SOL,TA,V
C  IF(TR.GT.TSET) THEN
C  A=0.01774532925*90.0)
    DNJOUR=AN
    NRMANS=MTH
    TL=IHOURL
    RD=0.017453
C  IF(IHOURL.EQ.24) THEN
C  TL=0.0
C  ENDIF
    CALL INCLSOL(DNJOUR,LAT,LGTUD,BETACAP,TL,DECHSOL,ANGHSOL,CSI)
```

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```
CALL INCLHZ(DNJOUR,LAT,LGTUD,BETAHZ,TL,CSHZ)
CALL INCLVRE(DNJOUR,LAT,LGTUD,BETA VR,TL,CSIVRE)
CALL INCLVRO(DNJOUR,LAT,LGTUD,BETA VR,TL,CSIVRO)
CALL INCLVRN(DNJOUR,LAT,LGTUD,BETA VR,TL,CSIVRN)
CALL INCLVRS(DNJOUR,LAT,LGTUD,BETA VR,TL,CSIVRS)
HAUTSOL=ABS((COS(LAT*RD)*COS(DECHSOL*RD)*COS(ANGHSOL*RD))+
1SIN(LAT*RD)*SIN(DECHSOL*RD))
CALL SOLDIFU(NRJMOIS,NRMANS,HAUTSOL,BETACAP,DIFUCAP)
CALL SOLDIFU(NRJMOIS,NRMANS,HAUTSOL,BETAHZ,DIFUHZ)
CALL SOLDIFU(NRJMOIS,NRMANS,HAUTSOL,BETA VR,DIFUVR)

CALL TEMSOL(LAT,DECHSOL,TSLEV,TSCOU,DENSOL)
C BR=23.45*SIN(0.980*0.0174532925*335)
C UNV=DOS(0.5)

IF(FLOAT(IHOUR).LT.TSLEV.OR.FLOAT(IHOUR).GT.TSCOU) THEN
CSI=0.0
CSHZ=0.0
CSIVRE=0.0
CSIVRO=0.0
CSIVRN=0.0
CSIVRS=0.0
DIFUCAP=0.0
DIFUHZ=0.0
DIFUVR=0.0
ELSE IF(FLOAT(IHOUR).GE.TSLEV.OR.FLOAT(IHOUR).LE.TSCOU) THEN
CSI=ABS(CSI)
CSHZ=ABS(CSHZ)
CSIVRE=ABS(CSIVRE)
CSIVRO=ABS(CSIVRO)
CSIVRN=ABS(CSIVRN)
CSIVRS=ABS(CSIVRS)
ENDIF
```

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```
C  WRITE(6,*) I HOUR,FLMART
C  WRITE(6,*) CSI, CSIHZ,CSIVRE, CSIVRO ,CSIVRN,CSIVRS
C  DIFUVR=0.0
C  DIFUHZ=1000.000
C  IF(CSIVRO.GE.0.0) THEN
C  CSIVRO=0.0
C  ELSE
C  CSIVRO=ABS(CSIVRO)
C  ENDF
      RDI=(SOL*ABS(CSI)+DIFUCAP)*SC
C  IF(CSIVRE.LE.0.0) CSIVRE=0.0
      TJ=TJ+TA
TP=TP+1.0
      IF(IHOUR.EQ.24) THEN
      DAVTAMB=(TJ/TP)+273.16
      ENDF
C  READ (22,*)A
C  OPEN(UNIT=13,FILE='DECRAD2.DATA',STATUS='UNKNOWN')
C  WRITE(13,*)I,SOLRAD
C  OPEN(UNIT=11,FILE='DECTEMP2.DATA',STATUS='UNKNOWN')
C  WRITE(11,*)I,TA
C  OPEN(UNIT=11,FILE='MIN2.DATA',STATUS='OLD')
C  READ(11,*)S1
C  OPEN(UNIT=23,FILE='WTH2.DATA',STATUS='OLD')
C  READ(23,*)AD1,AD2,GDI,TA,V,AD3
C  OPEN(UNIT=13,FILE='TEMP2.DATA',STATUS='OLD')
C  READ(13,*)S3
C  OPEN(UNIT=14,FILE='VENT2.DATA',STATUS='OLD')
C  READ(14,*)S4
C  OPEN(UNIT=17,FILE='TER2.DATA',STATUS='OLD')
C  READ(17,*)S5
C  OPEN(UNIT=19,FILE='R10.DATA',STATUS='UNKNOWN')
C  WRITE(19,*)S,S1,S2,S3,S4,S5
```

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TAMB=TA+273.16

SOLRAD=(SOL\*CSIVRS+DIFUVR)\*AGL

SOLRADC=(SOL\*CSIVRS+DIFUVR)\*SC

SOLHZ=(SOL\*CSIHZ+DIFUHZ)\*AR

SOLVRO=(SOL\*CSIVRO+DIFUVR)\*ARNW

SOLVRE=(SOL\*CSIVRE+DIFUVR)\*ARNW

SOLVRN=(0.0+DIFUVR)\*AW

C WRITE(6,\*)RDICAP

C NAC=C1+C2\*V+C3\*(TAMB-TR)

C AINF=DA\*X\*Y\*Z\*NAC/3600.0

DO 5 MINT=1,NSTEP

DTT=DTT+DT

HDTT=DTT/3600.0

C TENC=TEXIT

TFDCH=TFLD

NAC=C1+C2\*V+C3\*(TAMB-TR)

AINF=DA\*X\*Y\*Z\*NAC/3600.0

C

PMCAP=(CAPLG+CAPLAG)\*2.0

CINSC=0.048

EINSC=0.05

ESINSBA=0.10

NV=1

C IF(FLOAT(IHOUR).LT.TSLEV.OR.FLOAT(IHOUR).GT.TSCOU) FLMART=0.0

C IF(FLOAT(IHOUR).GE.TSLEV.AND.FLOAT(IHOUR).LE.TSCOU) FLMART=0.04

NRMANS=MTH

C VISFLP=5.449-0.1067\*TFDCH+0.0007325\*TFDCH\*\*2.0

C VISDFL=5.449-0.1067\*TFLD+0.0007325\*TFLD\*\*2.0

VISFLP=VIS

VISDFL=VIS

HW=HWIND(V)

C CALL ULCAP(MTH,NDAY,IHOUR,NV,SC,BETACAP,CINSC,EINSC,EPCAP,

C 1PMCAP,HW,TENC,TAMB,UGCAP)

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```
C  UGCAP=4.0
C  CALL RENDCAP(KABS,SOU DK,EPABS,ESOU D,SOU DL,TUBDIS,DEXTUBC,
C  1UGCAP,TAU,ALFAC,TENC,TAMB,SC,DITUBE,FLMART,CPFD,HFLDCA,RDI,QUTIL,
2IHOUR,TSLEV,TSCOU,RENDINC)
C
  PUTIL=PUTIL+QUTIL*DT
  RDICAP=RDICAP+RDI*DT
  RENDMJC=PUTIL/RDICAP
C  IF(IHOUR.EQ.INT(TSCOU)) WRITE(6,*)RENDMJC,IHOUR
C  CALL TSORTIE(FLMART,MASCAP,CPFD,TENC,TAMB,DT,SC,
C  1RDI,UGCAP,TMC,TSORC)
C  WRITE(6,*)IHOUR,TSORC-273.16
  CALL HCNHA(AK,CAPLAG,BETACAP,TV,TAMB,DA,DYV,CPA,HCVA)
  HCOBV=HCOMB(HCVA,HW)
  UCOMBV=HCOBV*SC
  HVIEWV= VIEW(EV,TV,TSKY)
  UVIEWV=HVIEWV*SC
  CALL HCNHA(AK,CAPLAG,BETACAP,TV,TABS,DA,DYV,CPA,HCVABS)
  UCVABS=HCVABS*SC
C  HVIEWVA=VIEW(EV,TV,TABS)
  URVABS=HRAD(SHVABS,TV,TABS,SC)
  CALL HCNHB(AK,CAPLAG,BETACAP,TV,TAIR,DA,DYV,CPA,HCVAIR)
  UCVAIR=HCVAIR*SC
  CALL HCNHA(AK,CAPLAG,BETACAP,TABS,TAIR,DA,DYV,CPA,HCABSA)
  UCABSA=HCABSA*SC
C  HVIEWAV=VIEW(EABS,TABS,TV)
  URABSV= HRAD(SHABSV,TABS,TV,SC)
  ULATGAP=(INSLCAP/EINSC)*EGAP*CAPLG*2.0
  ULATV=(INSLCAP/EINSC)*EPSV*CAPLG*2.0
  UPABS= (INSLCAP/ESINSBA)*EPCAP*CAPLAG*2.0
  CALL HCVFL(FLMART,DFLD,VISFLP,VISDFL,DITUBC,DEXTUBC,LGCCAP,FK,
1PR,CPFD,HFLDCA)
  UABSFLD= HFLDCA*3.14*DITUBC*LGCCAP/2.0
```

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```
C  UVIEWV=7.0
C  COMBV=2.5
C  URVABS=2.6
C  UCVAIR=1.5
C  ULATV=0.03
CALL TVITRE(SOLRAD,DT,UVIEWV,UCOMBV,URVABS,UCVAIR,ULATV,TSKY,
1 TAMB,TABS,TAIR,MASVIT,CPVIT,SC,TV)
C  UCABSA=1.4
C  ULATGAP=1.8
CALL TAIRGAP(DT,UCVAIR,UCABSA,ULATGAP,TV,TABS,TAMB,
1 MASAIR,CPAIR,SC,TAIR)
C  URVABS=1.2
C  UPABS=0.4
CALL TABSOR(SOLRAD,DT,URVABS,UCABSA,UABSFLD,UPABS,TV,TAIR,
1 TSORC,TAMB,MASABS,CPABS,SC,TABS)
CALL SORCAP(FLMART,DT,UABSFLD,TABS,TAIR,
1 TENC,MASCAP,CPFD,SC,TSORC)
TINF=TSORC
C  AA=COS(45.0)          L
C  QUTFLC=SC*(RDI*TAU*ALFAC-(UL*(TCM-TAMB)))
C  IF (RDI.EQ.0.0) THEN
C  RENDMC=0.0
C  DA,EGAP,EPCAP,CAPLAG
C  QUTFLC=0.0
C  ELSE
C  QUTFLC=FLMART*CPFD*(((TAU*RDI/UL)-
C  1TENC+TAMB)*(1.0-EXP(-UL*SC/FLMART*CPFD)))
C  RENDMC=QUTFLC/(0.8*RDI*SC)
CALL ROMODEL(ALFARM,SOLRAD,UAFDRM,UAMBT,TAMB,TINF,TRDELY)
ER1=TSET-TRDELY
ER=ER1+ER2
CC  ER=TSET-TR
ERSIGN=ERMIN*ER
```

## 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

```
IF(ERSIGN.LT.0.0) ITGRAL=0.0
ITGRAL=ITGRAL+ER*DT
IF(FLOAT(IHOUR).GE.TSLEV.AND.FLOAT(IHOUR).LE.TSCOU) THEN
CALL ONOFF(SOL,TSLEV,TSCOU,IHOUR,TR,FLMRMAX,FLMART )
C  WRITE(6,*)IHOUR,FLMART,TR-273.16
C  WRITE(6,*)FLMART,TR-273.16
C  Q=Q+(FLMART*15.0)
C  CONKCAP=389.0
C  CALL HFLUID(FK,VIS,H,Y,FLMART,DFLD,COEFF,EXM,EXN,PR,HFLD )
CALL HCVFL(FLMART,DFLD,VISFLP,VISDFL,DITUBE,DEXTUB,LGCPL,FK,
1 PR,CPFD,HFLD)
C  CALL HCVFL(FLMART,DFLD,VISFLP,VISDFL,DITUBC,DEXTUBC,LGCCAP,FK,
C  1PR,CPFD,HFLDCA)
UAFLD=HFLD*AF
UAFDL=UAB(1)*UAFLD/(UAB(1)+UAFLD)
IF(FLMART.EQ.0.0) THEN
EFCTV=1.0
ELSE
NTU=UAFDL/(FLMART*CPFD)
EFCTV=1.0-EXP(-NTU)
ENDIF
C
UAFDGR=AF*HFLD*FLOK*INSLK/(FLOK*INSLK+HFLD*INSLK*FTUHE+
1HFLD*FLOK*INSLT)
C  UAINS=(INSLK*FTUHE+FLOK*INSLT)*AF/(INSLT+FTUHE)
C  UAFDIS=HFLD*UAINS*AF/(HFLD*AF+UAINS)
C CALL FLUTEMP(FLMART,CPFD,TINF,TF(1),TOFS,UAFDGR,UAFDL,TFLD)
CALL TFLCH(FLMART,MASFL,UAFDL,UAFDGR,TF(1),DT,CPFD,TINF,
1TOFS,TFLD)
C  WRITE(6,*)TSORC-273.16,TFLD-273.16
CALL UGRD(DPTH,DFBG,AF,X,Y,UWP,UGA)
DAVTAMB=ANVTAMB+AMPL*COS((NDAY-PHASE)*2.0*PI/366.0)
```

## 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

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```
CALL OUFLOST(UWP,UGA,UAFDGR,DAVTAMB,ANVTAMB,TFLD,TOFS)
C OPEN(27,FILE=FLMART.DATA,STATUS='UNKNOWN')
C WRITE(27,*)TIFS-273.16,FLMART
UAEFCT=FLMART*CPFD*EFCTV
C
CALL TFNODE(NODFLO,UAFDFL,UAB,UAV,TFLD,DT,FMAS,CPF,TIFS,TF)
CALL HCONHA(AK,Y,TR,TIFS,DA,DYV,CPA,HCOHA1)
UAFR=HCOHA1*AF
UHFLGL=HRAD(SHFLGL,TIFS,TGL,AF)
UHFLMW=HRAD(SHFLMW,TIFS,TIWS,AF)
UHFLRF=HRAD(SHFLRF,TIFS,TIRS,AF)
UHFLNW=HRAD(SHFLNW,TIFS,TIRNWS,AF)
UHFLNWO=HRAD(SHFLNW,TIFS,TIRNWS,AF)
CALL INSURFT(UAFR,UAV(NODFLO),UHFLGL,UHFLMW,UHFLRF,UHFLNW,UHFLNWO,
1TR,TF(NODFLO),TGL,TIWS,TIRS,TIRNWS,TIRNWS,ALFAFL,SOLRAD,TIFS)
C CALL INSURFT(UAFR,UAV(NODFLO),0.0,0.0,0.0,UHFLNW,TR,TF(NODFLO),
C 1TGL,TIWS,TIRS,TIRNWS,ALFAFL,SOLRAD,TIFS)
C WRITE(*,*)TIFS-273.16,TR-273.16,TGL-273.16,TIWS-273.16,
C 1TIRS-273.16,TIRNWS-273.16
C WRITE(*,*)TR-273.16,FLMART
C WRITE(*,*)TR-273.16,TIFS-273.16,TF(1)-273.16,TFLD-273.16,
C 1TEXTIT-273.16,TOFS-273.16
CALL HCONVT(AK,Z,TR,TIWS,DA,DYV,CPA,HCOV1)
UARW=HCOV1*AW
CALL HCONVT(AK,Z,TR,TIRNWS,DA,DYV,CPA,HCOV6)
UARRNW=HCOV6*ARNW
CALL HCONVT(AK,Z,TR,TIRNWS,DA,DYV,CPA,HCOV8)
UARRNWO=HCOV8*ARNW
CALL HCONVT(AK,Z,TR,TGL,DA,DYV,CPA,HCOV2)
UARGL=HCOV2*GLK*AGL/(GLK+0.5*HCOV2*GLT)
CALL HCONHA(AK,Y,TR,TIRS,DA,DYV,CPA,HCOHA2)
UARRF=HCOHA2*AR
CALL ROOMTEMP(UAFR,UARW,UARGL,UARRF,UARRNW,UARRNWO,TIFS,
```

## 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

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```
1TIWS,TGL,TIRS,TIRNWS,TIRNWOS,TAMB,CPA,AINF,QOC,QEC,DT,ALFARM,
2SOLRAD,AIRMAS,TRAV,OMEGAR,TR)
UHMWFL=HRAD(SHMWFL, TIWS, TIFS, AW)
UHMWGL=HRAD(SHMWGL, TIWS, TGL, AW)
UHMWNW=HRAD(SHMWNW, TIWS, TIRNWS, AW)
UHMWRF=HRAD(SHMWRF, TIWS, TIRS, AW)
UHMWNWO=HRAD(SHMWNW, TIWS, TIRNWOS, AW)
CALL INSURFT(UARW, UAW(1), UHMWFL, UHMWGL, UHMWRF, UHMWNW, UHMWNWO, TR,
1TW(1), TIFS, TGL, TIRS, TIRNWS, TIRNWOS, ALFAWL, SOLRAD, TIWS)
CALL TWNODE(NODWAL, UAW, UAE, TIWS, DT, WMAS, CPW, TOWS, TW)
CALL HCONVT(AK, Z, TOWS, TAMB, DA, DYV, CPA, HCOV3)
C   TSKY=277.16
TSKY=TEMPSKY(TAMB)
HVIEW1=VIEW(EWE, TOWS, TSKY)
HCOB1=HCOMB(HCOV3, HW)
UAWA=HCOB1*AW
UAVIEW1=HVIEW1*AW
CALL OUTSURFT(UAE(NODWAL), UAWA, UAVIEW1, SOLVRN, TW(NODWAL),
1 TAMB, TSKY, TOWS)
C   WRITE(*,*)TOWS-273.16
C
UAROOF=AR*RK/RT
UHRFFL=HRAD(SHRFFL, TIRS, TIFS, AR)
UHRFMW=HRAD(SHRFMW, TIRS, TIWS, AR)
UHRFGL=HRAD(SHRFGL, TIRS, TGL, AR)
UHRFNW=HRAD(SHRFNW, TIRS, TIRNWS, AR)
UHRFNWO=HRAD(SHRFNW, TIRS, TIRNWOS, AR)
CALL INSURFT(UARRF, UAROOF, UHRFFL, UHRFMW, UHRFGL, UHRFNW, UHRFNWO, TR,
1TORS, TIFS, TIWS, TGL, TIRNWS, TIRNWOS, 0.0, SOLRAD, TIRS)
C
HVIEW2=VIEW(EROFE, TORS, TSKY)
CALL HCONHB(AK, Y, TORS, TAMB, DA, DYV, CPA, HCOMB2)
C
```

## 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

---

HCOB2=HCOMB(HCOMB2,HW)

UARFA=HCOB2\*AR

UAVIEW2=HVIEW2\*AR

CALL OUTSURFT(UAROF, UARFA, UAVIEW2, SOLHZ, TIRS, TAMB, TSKY, TORS)

CALL HCONVT(AK,Z,TGL,TAMB,DA,DYV,CPA,HCOV5)

C

HVIEW3=VIEW(EGL,TGL,TSKY)

HCOB3=HCOMB(HCOV5,HW)

UAVIEW3=HVIEW3\*AGL

UAGLA=HCOB3\*GLK\*AGL/(GLK+0.5\*GLT\*HCOB3)

UHGLRF=HRAD(SHGLRF,TGL,TIRS,AGL)

UHGLFL=HRAD(SHGLFL,TGL,TIFS,AGL)

UHGLNW=HRAD(SHGLNW,TGL,TIRNWS,AGL)

UHGLMW=HRAD(SHGLMW,TGL,TIWS,AGL)

UHGLNWO=HRAD(SHGLNW,TGL,TIRNWOS,AGL)

CALL GLAZTEM(UARGL,UAGLA,UHGLFL,UHGLMW,UHGLRF,UHGLNW,UHGLNWO,

1UAVIEW3,TR,TAMB,TIFS,TIWS,TIRS,TIRNWS,TIRNWOS,TSKY,

2ABSGL,SOLRAD,TGL)

C WRITE(\*,\*) UARGL,UAGLA,UHGLFL,UHGLRF,UHGLNW

C WRITE(\*,\*)TGL-273.16,TR-273.16,TIFS-273.16,TIWS-273.16,

C 1TIRS-276,TIRNWS-273.16,TSKY-273.16

UARNW=WK\*ARNW/RNWT

UAROW=WK\*ARNW/RNWT

UARNWO=WK\*ARNW/RNWT

UHNWOF=HRAD(SHNWOF,TIRNWOS,TIRS,ARNW)

UHNWOGL=HRAD(SHNWOGL,TIRNWOS,TGL,ARNW)

UHNWOMW=HRAD(SHNWOMW,TIRNWOS,TIWS,ARNW)

UHNWOFL=HRAD(SHNWOFL,TIRNWOS,TIFS,ARNW)

UHNWONW=HRAD(SHNWOFL,TIRNWOS,TIRNWS,ARNW)

C

UARNW=WK\*ARNW/RNWT

UHNWRF=HRAD(SHNWRF,TIRNWS,TIRS,ARNW)

UHNWGL=HRAD(SHNWGL,TIRNWS,TGL,ARNW)

## 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

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```
UHNWMW=HRAD(SHNWMW,TIRNWS,TIWS,ARNW)
UHNWFL=HRAD(SHNWFL,TIRNWS,TIFS,ARNW)
UHNWNWO=HRAD(SHNWNW,TIRNWS,TIRNWOS,ARNW)
CALL INSURFT(UARRNW,UARNW,UHNWFL,UHNWGL,UHNWRF,UHNWMW,UHNWNWO,
1TR,TORNWS,TIFS,TGL,TIRS,TIWS,TIRNWOS,0.0,SOLRAD,TIRNWS)
CALL INSURFT(UARRNWO,UARNWO,UHNWOFL,UHNWOGL,UHNWORF,UHNWOMW,
1UHNWONW,TR,TORNWOS,TIFS,TGL,TIRS,TIWS,TIRNWS,0.0,SOLRAD,TIRNWOS)
C
CALL HCONVT(AK,Z,TORNWS,TAMB,DA,DYV,CPA,HCOV7)
HVIEW4=VIEW(EWE,TORNWS,TSKY)
HCOB4=HCOMB(HCOV7,HW)
UAVIEW4=HVIEW4*ARNW
UARNWA=HCOB4*ARNW
CALL OUTSURFT(UARNW,UARNWA,UAVIEW4,SOLVRE,TIRNWS,TAMB,TSKY,TORNWS)
CALL HCONVT(AK,Z,TORNWS,TAMB,DA,DYV,CPA,HCOV9)
HVIEW5=VIEW(EWE,TORNWOS,TSKY)
HCOB5=HCOMB(HCOV9,HW)
UAVIEW5=HVIEW5*ARNW
UARNWOA=HCOB5*ARNW
CALL OUTSURFT(UARNWO,UARNWOA,UAVIEW5,SOLVRO,TIRNWOS,TAMB,TSKY,
1 TORNWOS)
UAVENT=AINF*CPA
QVENT=QVENT+UAVENT*(TAMB-TR)
C WRITE(*,*)ANVTAMB-273.16
C WRITE(*,*)DAVTAMB-273.16
ANVTAMB=291.66
QGROUD=QGROUD+((UGA*(TOFS-ANVTAMB))+UWP*(TOFS-DAVTAMB))/(10**6.)
C WRITE(*,*)QGROUD
FLORC=FCOD/FLOAT(NODFLO)
UAFLOR=UAFR*FLORC/(UAFR+FLORC)
WALCON=WCOD/FLOAT(NODWAL)
UAWALL=UAWA*UARW*WALCON/(UAWA*UARW+UAWA*WALCON+UARW*WALCON)
UAROFA=UAROOF*UARRF*UARFA/(UAROOF*UARRF+UAROOF*UARFA+UARRF*UARFA)
```

# 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

```
UAGLAZ=UAGLA*UARGL/(UAGLA+UARGL)
URWALL=UARNW*UARNWA*UARRNW/(UARNW*UARNWA+UARNW*UARRNW+
1UARNWA*UARRNW)
UAMBT=UAWALL+UAROF+A+UAGLAZ+URWALL*2.0+UAVENT
UAFDRM=UAEFCT*FLORC*UAFR/(FLORC*UAFR+UAEFCT*UAFR+UAEFCT*FLORC)
C   TINF=TSORC
   TEXTIT=EFCTV*TF(1)+((1.0-EFCTV)*TINF)
   TENC=TEXTIT

C   WRITE(*,*)TINF-273.16,TEXTIT-273.16,TFLD-273.16,TF(1)-273.16,
C   1 TOFS-273.16
C   WRITE(*,*)TFLD-273.16,TF(1)-273.16,TF(2)-273.16,
C   1 TF(9)-273.16,TF(10)-273.16,TIFS-273.16
C   QMONTH=QMONTH+(UAEFCT*(TINF-TF(1))*DT/(10**6.0))
C   QANUAL=QANUAL+(UAEFCT*(TINF-TF(1))*DT/(10**6.0))
C   IF(FLOAT(IHOUR).GE.TSLEV.AND.FLOAT(IHOUR).LE.TSCOU) THEN
   QMONTH=QMONTH+(FLMART*CPFD*(TINF-TEXTIT)*DT/(10**6.0))
   QANUAL=QANUAL+(FLMART*CPFD*(TINF-TEXTIT)*DT/(10**6.0))
ENSOLC=ENSOLC+SOL/(10**6.0)
C   ENDIF
   QRADT=QRADT+(UHFLGL*(TIFS-TGL)+UHFLRF*(TIFS-TIRS)+
1UHFLNW*(TIFS-TIRNWS)+
2UHFLNWO*(TIFS-TIRNWOS)+UHFLMW*(TIFS-TIWS))*DT/(10**6.0)
QCONV=QCONV+UAFR*(TIFS-TR)*DT/10**6.0
C   Q=Q+(FLMART*CPFD*(TINF-TEXTIT)*DT/(10**6.0))
C   WRITE(*,*)TFLD-273,16
C   WRITE(*,*) TEXTIT-273.16
C   WRITE(*,*)Q
C   QMONTH=0.
C   WRITE (6,*)TINF-273.16
   IF(TR.GT.293.66) THEN
   ABOVSET=ABOVSET+(TR-TSET-0.5)*DT
   HOURABV=HOURABV+DT
```

## 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

---

```
ANUABV=ANUABV+(TR-TSET-0.5)*DT
ANHOBV=ANHOBV+DT
ELSE IF(TR.LT.292.66) THEN
BELSET=BELSET+(TSET-0.5-TR)*DT
HOURBEL=HOURBEL+DT
ANUABEL=ANUABEL+(TSET-0.5-TR)*DT
ANHOBEL=ANHOBEL+DT
ENDIF
C WRITE(*,*)TGL-273.16,TOWS-273.16,TORS-273.16,TORNWS-273
ER2=TRDT-TR
TRDT=TR
ERMIN=ER
TROOM=TCELC(TR)
C WRITE(*,*)TF(1)-273.16,TFLD-273.16,TOFS-273.16
OPEN(UNIT=50,FILE='CONTR.DATA',STATUS='UNKNOWN')
C WRITE(50,*)IHOURL,FLMART,SOL,TENC-273.16,TSORC-273.16,TR-273.16
C WRITE(50,*)IHOURL,TR-273.16,TSORC-273.16,TABS-273.16,TV-273.16
C WRITE(50,600)IHOURL,FLMART,SOL,TA,TENC-273.16,TSORC-273.16,
C 1TFLD-273.16,TR-273.16
C WRITE(50,600)TENC-273.16,
C 1TFLD-273.16,TF(1)-273.16,TF(2)-273.16,TF(3)-273.16,TF(4)-273.16
C 2,TF(5)-273.16,TF(6)-273.16,TF(7)-273.16,TF(8)-273.16,
C 3TF(9)-273.16,TF(10)-273.16
WRITE(50,600)SOL,FLMART,TSORC-273.16,TIFS-273.16,TR-273.16
1,TGL-273.16,TIWS-273.16,TIRS-273.16,TIRNWS-273.16,TIRNWOS-273.16
600 FORMAT(10(1X,F6.2))
C 1TW(4)-273.16,TW(5)-273.16,TIWS-273.16,TR-273.16
C
C IF(MINT.EQ.NSTEP) WRITE(*,*)HDTT,TROOM
C IF(NDAY.EQ.NEND.AND.IHOURL.EQ.24.AND.MINT.EQ.NSTEP) THEN
C CALL PRINTS(QMONTH,MONTH(MTH),ABOVSET,BELSET,HOURABV,HOURBEL,
C 1TROOM,TA)
C ENDF
```

# 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

---

```
IF(MTH.EQ.6.AND.NDAY.EQ.NEND.AND.IHOUR.EQ.24.AND.MINT.EQ.NSTEP)
1 THEN
CALL PRINTS(QANUAL,NANUAL(NYEAR),ENSOLC,ANUABV,ANUABEL,
1 ANHOBV,ANHOBEL,TROOM,TA,QGROUD,QRADT,QCONV)
ENDIF
5 CONTINUE
STOP
END
C.....
C      FIN DU PROGRAMME
C.....
SUBROUTINE HCONVT(AK,L,TR,TIS,DA,DYV,CPA,HCOV)
REAL L,L2,L3,PR
PARAMETER (R4=1.0E9)
TM=(TR+TIS)*0.5
C=AK/L
L2=L*L
L3=L2*L
GR=(9.81*ABS(TR-TIS)*L3*DA*DA)/(TM*DYV*DYV)
PR=DYV*CPA/AK
RA=GR*PR
IF(RA.LT.R4) THEN
HCOV=C*0.590*RA**0.250
ELSE
HCOV=C*0.129*RA**0.333
ENDIF
RETURN
END
C.....
SUBROUTINE HCONHA(AK,L,TR,TIS,DA,DYV,CPA,HCOHA)
REAL L,L2,L3,PR
PARAMETER(R3=1.0E7)
TM=(TR+TIS)*0.5
```

## 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

---

```
C=AK/L
L2=L*L
L3=L2*L
GR=(9.81*ABS(TR-TIS)*L3*DA*DA)/(TM*DYV*DYV)
PR=DYV*CPA/AK
RA=GR*PR
IF(RA.LT.2*R3) THEN
  HCOHA=C*0.540*RA**0.250
ELSE
  HCOHA=C*0.140*RA**0.333
ENDIF
RETURN
END
C.....
SUBROUTINE HCONHB(AK,L,TR,TIS,DA,DYV,CPA,HCOHB)
REAL L,L2,L3,PR
C  PARAMETER(R2=1.0E5,R3=1.0E7)
TM=(TR+TIS)*0.5
  C=AK/L
  L2=L*L
  L3=L2*L
  GR=(9.81*ABS(TR-TIS)*L3*DA*DA)/(TM*DYV*DYV)
  PR=DYV*CPA/AK
  RA=GR*PR
HCOHB=C*0.440*RA**0.125
  RETURN
  END
C.....
FUNCTION HWIND(V)
  HWIND=5.7+3.8*V
  RETURN
  END
C.....
```

## 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

---

```
FUNCTION HCOMB(HCON,HW)
HCOMB=((HCON**3.460)+(HW**3.460))**(1.0/3.460)
RETURN
END
C.....
FUNCTION VIEW(E,T1,T2)
VIEW=(5.678E-8)*E*(T1*T1+T2*T2)*(T1+T2)
C WRITE(6,*)VIEW
RETURN
END
C.....
SUBROUTINE GEOSHAPE(DIM1,DIM2,DIM3,ITYPE,GSHF)
REAL PI
PI=3.1416
R1=DIM1/DIM2
R2=DIM3/DIM2
R12=R1*R1
R22=R2*R2
RR=R12+R22
GO TO (10,20),ITYPE
10 A=(1.0/(R1*R2))+ALOG((1.0+R12)*(1.0+R22)/(1.0+RR))
B=2.0*(ATAN(R2))/R1
C=2.0*(ATAN(R1))/R2
D=2.0*SQRT(1.0+(1.0/R12))*ATAN(R2/SQRT(1.0+R12))
E=2.0*SQRT(1.0+(1.0/R22))*ATAN(R1/SQRT(1.0+R22))
GSHF=(A-B-C+D+E)/PI
20 A=R1*ATAN(1.0/R1)
B=R2*ATAN(1.0/R2)
C=SQRT(RR)*ATAN(1.0/SQRT(RR))
D=(1.0+R12)*(1.0+R22)/(1.0+RR)
E=((R22*(1.0+RR))/((1.0+R22)*RR))**R22
F=((R12*(1.0+RR))/((1.0+R12)*RR))**R12
DEF=D*E*F
```

## 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

---

```
GSHF=(1.0/(PI*R1))*(A+B-C+0.25*ALOG(DEF))
RETURN
END
C.....
FUNCTION SSHAPE(GSHF,A1,A2,E1,E2)
C  SSHAPE=(1.0/GSHF+(1.0/E1-1.0)+((A1/A2)*(1.0/(E2-1.0))))**(-1)
SSHAPE=(1.0/GSHF+1.0/E1-1.0+(A1/A2)*(1.0/E2-1.0))**(-1)
RETURN
END
C.....
FUNCTION HRAD(SF,T1,T2,AE)
HRAD=5.678E-8*SF*(T1*T1+T2*T2)*(T1+T2)*AE
RETURN
END
C.....
FUNCTION TEMPSKY(TAMB)
TEMPSKY=(0.876*(TAMB**4.0)+14.25)**0.250
C  TEMPSKY=0.0552*TAMB**1.5
RETURN
END
C.....
SUBROUTINE UGRD(DPTH,DFBG,AF,X,Y,UWP,UGA)
UW1=0.698
UW2=0.378
UW3=0.264
UW4=0.203
UW5=0.164
UW6=0.150
UW7=0.118
UWW1=UW1
UWW2=UWW1+UW2
UWW3=UWW2+UW3
UWW4=UWW3+UW4
```

## 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

---

```
UWW5=UWW4+UW5
UWW6=UWW5+UW6
UWW7=UWW6+UW7
IF(DPTH.LE.0.3) THEN
  UW=UWW1
ELSE IF(DPTH.LE.0.6.AND.DPTH.GT.0.3) THEN
  UW=UWW2
ELSE IF(DPTH.LE.0.9.AND.DPTH.GT.0.6) THEN
  UW=UWW3
ELSE IF(DPTH.LE.1.2.AND.DPTH.GT.0.9) THEN
  UW=UWW4
ELSE IF(DPTH.LE.1.5.AND.DPTH.GT.1.2) THEN
  UW=UWW5
ELSE IF(DPTH.LE.1.8.AND.DPTH.GT.1.5) THEN
  UW=UWW6
ELSE
  UW=UWW7
ENDIF
IF(DFBG.LE.1.5) THEN
  UG=0.148
ELSE IF(DFBG.LE.1.8.AND.DFBG.GT.1.5) THEN
  UG=0.142
ELSE
  UG=0.131
ENDIF
UWP=UW*(X+Y)*2.0
UGA=UG*AF
RETURN
END
```

C.....

```
SUBROUTINE HFLUID(FK,VIS,H,Y,FLMART,DFLD,COEFF,EXM,EXN,PR,HFLD)
```

```
  REAL PE,PR
```

```
  DEQUIV=2.0*H*Y/(H+Y)
```

## Study of heat loss through the ground of residential building envelope in Ouargla soil.

```
RE=FLMART*2.0/(VIS*DFLD*(Y+H))
C RE=FLMART*4.0*DFLD/(3.14*(H**2)*VIS)
C WRITE(*,*)RE
C PR=CPFD*VIS*DFLD/FK
CST=FK/DEQUIV
IF(RE.LT.2300.0) THEN
PE=RE*PR*DEQUIV/Y
HFLD=CST*3.660+(CST*0.0668*PE/(1.0+0.040*PE**0.667))
ELSE IF(RE.GT.4000.0) THEN
HFLD=CST*COEFF*(RE**EXM)*(PR**EXN)
ENDIF
RETURN
END
C.....
SUBROUTINE FLUTEMP(FLMART,CPFD,TINF,TFLOR,TOFS,UAFDGR, UAFDFL,T)
FLUIDE=FLMART*CPFD+UAFDFL+UAFDGR
T=(FLMART*CPFD*TINF+UAFDFL*TFLOR+UAFDGR*TOFS)/FLUIDE
RETURN
END
C.....
SUBROUTINE TFNODE(NODFLO,UAFDFL,UAB,UAV,TPFSV,DT,FMAS,CPF,TIFS
1,TF)
DIMENSION UAB(20),UAV(20),OMEGA(20),TF(20)
REAL LAMBD,LAMBD1,LAMBDN
THCP=FMAS*CPF
S1=(UAFDFL*TPFSV+UAV(1)*TF(2))/THCP
LAMBD1=(UAFDFL+UAV(1))/THCP
RHS1=S1-LAMBD1*TF(1)
SIGMA1=(1.0/(1.0-EXP(-LAMBD1*DT)))-(1.0/(LAMBD1*DT))
OMEGA(1)=RHS1/(1.0+SIGMA1*LAMBD1*DT)
DO 155 I=2,(NODFLO-1)
S=(UAB(I)*TF(I-1)+UAV(I)*TF(I+1))/THCP
LAMBD=(UAB(I)+UAV(I))/THCP
```

## 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

```
RHS=S-LAMBD*TF(I)
SIGMA=(1.0/(1.0-EXP(-LAMBD*DT)))-(1.0/(LAMBD*DT))
OMEGA(I)=RHS/(1.0+SIGMA*LAMBD*DT)
155 CONTINUE
SN=(UAB(NODFLO)*TF(NODFLO-1)+UAV(NODFLO)*TIFS)/THCP
LAMBDN=(UAB(NODFLO)+UAV(NODFLO))/THCP
RHSN=SN-LAMBDN*TF(NODFLO)
SIGMAN=(1.0/(1.0-EXP(-LAMBDN*DT)))-(1.0/(LAMBDN*DT))
OMEGA(NODFLO)=RHSN/(1.0+SIGMAN*LAMBDN*DT)
DO 160 IS=1,NODFLO
TF(IS)=TF(IS)+DT*OMEGA(IS)
160 CONTINUE
RETURN
END
C.....
SUBROUTINE ROOMTEMP(UAFR,UARW,UARGL,UARRF,UARRNW,UARRNWO,
1TIFS,TIWS,TGL,TIRS,TIRNWS,TIRNWOS,TAMB,CPA,AINF,QOC,QEC,DT,
2ALFARM,SOLRAD,AIRMAS,TRAV,OMEGA,TR)
REAL LAMBD
PARAMETER(ZERO=1.0E-9)
G=ALFARM*SOLRAD
S=(UAFR*TIFS+UARW*TIWS+UARRF*TIRS+UARGL*TGL+UARRNW*TIRNWS+
1UARRNWO*TIRNWOS+AINF*CPA*TAMB+G+QOC+QEC)/AIRMAS
LAMBD=(UAFR+UARW+UARRF+UARGL+UARRNW+UARRNWO+AINF*CPA)/AIRMAS
IF(LAMBD.EQ.0.0) THEN
SIGMA=(1.0/(1.0-EXP(-(LAMBD+ZERO)*DT)))-(1.0/((LAMBD+ZERO)*DT))
ELSE
SIGMA=(1.0/(1.0-EXP(-LAMBD*DT)))-(1.0/(LAMBD*DT))
ENDIF
OMEGA=(S-LAMBD*TR)/(1.0+SIGMA*LAMBD*DT)
TRAV=TR+OMEGA*DT*1.0
TR=TR+OMEGA*DT
```

# Study of heat loss through the ground of residential building envelope in Ouargla soil.

```
RETURN
END
C.....
SUBROUTINE TWNODE(NODWAL,UAW,UAE,TIWS,DT,WMAS,CPW,TOWS,TW)
DIMENSION UAW(20),UAE(20),OMEGA(20),TW(20)
REAL LAMBD,LAMBD1,LAMBDN
THCP=WMAS*CPW
S1=(UAW(1)*TIWS+UAE(1)*TW(2))/THCP
LAMBD1=(UAW(1)+UAE(1))/THCP
RHS1=S1-LAMBD1*TW(1)
SIGMA1=(1.0/(1.0-EXP(-LAMBD1*DT)))-(1.0/(LAMBD1*DT))
OMEGA(1)=RHS1/(1.0+SIGMA1*LAMBD1*DT)
DO 140 I=2,(NODWAL-1)
S=(UAW(I)*TW(I-1)+UAE(I)*TW(I+1))/THCP
LAMBD=(UAW(I)+UAE(I))/THCP
RHS=S-LAMBD*TW(I)
SIGMA=(1.0/(1.0-EXP(-LAMBD*DT)))-(1.0/(LAMBD*DT))
OMEGA(I)=RHS/(1.0+SIGMA*LAMBD*DT)
140 CONTINUE
SN=(UAW(NODWAL)*TW(NODWAL-1)+UAE(NODWAL)*TOWS)/THCP
LAMBDN=(UAW(NODWAL)+UAE(NODWAL))/THCP
RHSN=SN-LAMBDN*TW(NODWAL)
SIGMAN=(1.0/(1.0-EXP(-LAMBDN*DT)))-(1.0/(LAMBDN*DT))
OMEGA(NODWAL)=RHSN/(1.0+SIGMAN*LAMBDN*DT)
DO 150 I=1,NODWAL
TW(I)=TW(I)+DT*OMEGA(I)
150 CONTINUE
RETURN
END
C.....
SUBROUTINE INSURFT(UA1,UA2,UA3,UA4,UA5,UA6,UA7,T1,T2,T3,
1T4,T5,T6,T7,ALFA,SOLRAD,TS)
REAL LAMBDA
```

# 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

---

```
G=ALFA*SOLRAD
SOURCE=UA1*T1+UA2*T2+UA3*T3+UA4*T4+UA5*T5+UA6*T6+UA7*T7+G
LAMBDA=UA1+UA2+UA3+UA4+UA5+UA6+UA7
TS=SOURCE/LAMBDA
RETURN
END
C.....
SUBROUTINE OUFLOST(UA1,UA2,UA3,T1,T2,T3,TS)
TS=(UA1*T1+UA2*T2+UA3*T3)/(UA1+UA2+UA3)
RETURN
END
C.....
SUBROUTINE OUTSURFT(UA1,UA2,UA3,G,T1,T2,T3,TS)
TS=(UA1*T1+UA2*T2+UA3*T3+G)/(UA1+UA2+UA3)
RETURN
END
C.....
SUBROUTINE GLAZTEM(UA1,UA2,UA3,UA4,UA5,UA6,UA7,UAVIEW3,
1T1,T2,T3,T4,T5,T6,T7,T8,ABSGL,SOLRAD,TGL)
G=ABSGL*SOLRAD
TGL=(UA1*T1+UA2*T2+UA3*T3+UA4*T4+UA5*T5+UA6*T6+UA7*T7+UA8*T8+G)/(
1UA1+UA2+UA3+UA4+UA5+UA6+UA7+UA8)
RETURN
END
C ON-OFF CONTROL
SUBROUTINE ONOFF(SOL,TSLEV,TSCOU,IHOUR,TRAV,FLMRMAX,FLMART)
TSET=293.16
DBAND=0.5
OVER=TSET+DBAND
UNDER=TSET-DBAND
IF(FLOAT(IHOUR).GE.TSLEV.AND.FLOAT(IHOUR).LE.TSCOU.
1 AND.SOL.GT.0.0) THEN
IF(TRAV.GT.OVER.AND.FLMART.GT.0.03) THEN
```

## 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

---

```
FLMART=0.0
ELSE IF(TRAV.LT.UNDER.AND.FLMART.LT.0.01) THEN
FLMART=FLMRMAX
    ELSE IF(TRAV.LE.OVER.AND.TRAV.GE.UNDER) THEN
FLMART=0.0
C   FLMART=0.0
    ENDIF
    ELSE
FLMART=0.0
    ENDIF
C   OPEN(UNIT=49,FILE='CHAUF.DATA',STATUS='UNKNOWN')
C   WRITE(49,*)IHOOR,TRAV-273.16,FLMART
RETURN
END
C.....
SUBROUTINE ROMODEL(ALFARM,SOLRAD,UAFDRM,
1UAMBT,TAMB,TINF,TRMODEL)
    G=ALFARM*SOLRAD
    TRMODEL=(UAFDRM*TINF+UAMBT*TAMB+G)/(UAFDRM+UAMBT)
RETURN
    END
C.....
    TCELC=TKELV-273.16
RETURN
    END
SUBROUTINE TSORTIE(FLMART,MASCAP,CPFD,TENC,TAMB,DT,SC,
1RDI,UL,TMC ,TSORC)
    REAL LAMBD,MASFL,MASCAP
    PARAMETER(ZERO=1.0E-9)
    G=0.88*RDI
    S=(FLMART*CPFD*TENC+UL*SC*TAMB+G)/(MASCAP*CPFD)
    LAMBD=(FLMART*CPFD+SC*UL)/(MASCAP*CPFD)
    IF(LAMBD.EQ.0.0) THEN
```

## 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

```
SIGMA=(1.0/(1.0-EXP(-(LAMBDA+ZERO)*DT)))-(1.0/((LAMBDA+ZERO)*DT))
```

```
ELSE
```

```
SIGMA=(1.0/(1.0-EXP(-LAMBDA*DT)))-(1.0/(LAMBDA*DT))
```

```
ENDIF
```

```
OMEGA=(S-LAMBDA*TSORC)/(1.0+SIGMA*LAMBDA*DT)
```

```
TMC=TSORC+OMEGA*DT*0.5
```

```
TSORC=TSORC+OMEGA*DT
```

```
RETURN
```

```
END
```

C.....

```
SUBROUTINE ULCAP(MTH,NDAY,IHOUR,NV,SC,BETA,CINSC,EINSC,EPCAP,
```

```
IPMCAP,HW,TMC,TAMB,UG)
```

```
IF(BETA.GT.0.0.AND.BETA.LT.70.0) THEN
```

```
C=520.0*(1.0-0.000051*BETA*BETA)
```

```
ELSE IF(BETA.GE.70.0.AND.BETA.LE.90.0) THEN
```

```
C=520.0*(1.0-0.000051*70.0*70.0)
```

```
ENDIF
```

```
F=(1.0+0.089*HW-0.1166*HW*EABS)*(1.0+0.07866*NV)
```

```
E=0.43*(1.0-(100.0/TMC))
```

```
EABS=0.15
```

```
EVER=0.88
```

```
A3=((TMC-TAMB)/(NV+F))*E
```

```
A4=C/TMC
```

```
A1=NV/(A4*A3)
```

```
A2=1.0/HW
```

```
A=1.0/(A1+A2)
```

```
B1=5.678E-8*(TMC+TAMB)*(TMC*TMC+TAMB*TAMB)
```

```
B2=1.0/((EABS+0.00591*NV*HW))
```

```
B3=(2.0*NV+F-1.0+(0.133*EABS))/EVER
```

```
B=B1/(B2+B3-NV)
```

```
UAV=A+B
```

```
ULAT=CINSC*EPCAP*PMCAP/(EINSC*SC)
```

```
UARR=CINSC/EINSC
```

# 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

UG=UAV+ULAT+UARR

RETURN

END

C FUNCTION QUTFLC(RDI,TAU,ALFAC,SC,TAMB,TCM,UL)

C QUTFLC=SC\*(RDI\*TAU\*ALFAC-(UL\*(TCM-TAMB)))

C RETURN

C END

C.....

SUBROUTINE RENDCAP(KABS,SOU DK,EPABS,ESOUD,SOU DL,TUBDIS,DEXTUB,

1UL,TAU,ALFAC,TENC,TA,SC,DITUBE,FLMART,CPFD,HCTUFL,G,QUTIL,

2IHOUR,TSLEV,TSCOU,RENDMC)

REAL M

RD=0.017453

M=SQRT(UL/(KABS-EPABS))

C ATANH M=(EXP(M)-EXP(-M))/(EXP(M)+EXP(-M))

EFCAILT=(TANH((M\*((TUBDIS-DEXTUB)/2.0))\*RD)/

1(M\*((TUBDIS-DEXTUB)/2.0))

A=1.0/(UL\*TUBDIS)

B1=1.0/(UL\*(DEXTUB+((TUBDIS-DEXTUB)\*EFCAILT)))

B2=ESOUD\*DEXTUB/SOU DL\*SOU DK

B3=1.0/(DITUBE\*HCTUFL)

EFTRANS=A/(B1+B2+B3)

FR=(FLMART\*CPFD\*(1.0-(EXP(-EFTRANS\*UL\*SC/FLMART\*CPFD))))/(UL\*SC)

QUTIL=FR\*SC\*((TAU\*ALFAC\*G)-(UL\*(TENC-TA)))

IF(FLOAT(IHOUR).LT.TSLEV.OR.FLOAT(IHOUR).GT.TSCOU) RENDMC=0.0

IF(FLOAT(IHOUR).GT.TSLEV.AND.FLOAT(IHOUR).LT.TSCOU) THEN

IF(QUTIL.LT.0.0) QUTIL=0.0

ENDIF

RENDMC=QUTIL/G

C WRITE(6,\*) (TAU\*ALFAC\*G)/(UL\*(TENC-TA))

RETURN

END

C.....

# 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

```
SUBROUTINE HCVFL(FLMART,DFLD,VISFLP,VISDFL,DITUBE,DEXTUB,LC,FK,
1PR,CPFD,HFLD)
    REAL PR,LC,NU
    EPCD=DEXTUB-DITUBE
    C   TFLHC=308.
    C   VISDFL=5.449-0.1057*TFLD+0.0007325*(TFLD**2.0)
    RE=FLMART*4.0/VISDFL
    GZ=RE*PR*(DITUBE/LC)
    IF(RE.LT.2100.0.AND.GZ.LT.100.0) THEN
        NU=3.66+(0.085*GZ/(1.0+0.047*(GZ**0.667)))*
        1 ((VISDFL/VISFLP)**0.14)
        ELSE IF(RE.LT.2100.0.AND.GZ.GT.100.0) THEN
            NU=1.08*(GZ**0.333)*((VISDFL/VISFLP)**0.14)+
            10.87*(1.0+0.015*(GZ**0.333))
            ELSE IF(RE.GT.2100.0.AND.RE.LT.10000.0) THEN
                NU=0.116*((RE**0.67)-125.0)*(PR**0.33)*((1.0+(DITUBE/LC)**0.667)*
                1(VISDFL/VISFLP)**0.14)
                ELSE IF(RE.GT.10000.0) THEN
                    NU=0.023*(RE**0.8)*(PR**0.33)*(VISDFL/VISFLP)**0.14
    ENDIF
    HFLD=NU*FK/DITUBE
    RETURN
END
C.....
SUBROUTINE INCLSOL(DNJOUR,LAT,LGTUD,BETA,TL,DECHSOL,ANGHSOL,CSI)
REAL LAT,LGTUD
    RD=0.017453
    DNJ=DNJOUR
    WS=0.984
    DECHSOL=23.45*SIN(0.986*RD*(DNJ+284.0))
    C   ANGHSOL=ACOS(-ATAN(LAT*RD)*ATAN(DECHSOL*RD))
    ET=-(-0.0002-0.4797*COS(WS*RD*DNJ)+3.2265*COS(2*WS*RD*DNJ)+
    &0.0903*COS(3*WS*RD*DNJ)+7.3509*SIN(WS*RD*DNJ)+
```

## 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

---

```
&9.391*SIN(2*WS*RD*DNJ)+0.3361*SIN(3*WS*RD*DNJ))
C   TS=TL-(-5.0)+(ET/60.0)+((0.0+LGTUD))/15.0
C   ANGHSOL=15.0*(TS-12.0)
      ANGHSOL=15.0*((TL-5.0)+(LGTUD/15.0)+ET-12.0)
CSI=COS(DECHSOL*RD)*COS(ANGHSOL*RD)*COS((LAT-BETA)*RD)+
& SIN(DECHSOL*RD)*SIN((LAT-BETA)*RD)
C   WRITE(6,*)ANGHSOL
      RETURN
      END
C.....
      SUBROUTINE INCLVRO(DNJOUR,LAT,LGTUD,BETA,TL,CSI)
      REAL LAT,LGTUD
      RD=0.017453
      DNJ=DNJOUR
      WS=0.984
      DECHSOL=23.45*SIN(0.986*RD*(DNJ+284.0))
C   ANGHSOL=ACOS(-ATAN(LAT)*ATAN(DECHSOL))
ET=0.0002-0.4797*COS(WS*RD*DNJ)+3.2265*COS(2*WS*RD*DNJ)+
&0.0903*COS(3*WS*RD*DNJ)+7.3509*SIN(WS*RD*DNJ)+
&9.391*SIN(2*WS*RD*DNJ)+0.3361*SIN(3*WS*RD*DNJ)
C   TS=TL-(-5.0)+(ET/60.0)+((0.0+LGTUD))/15.0
C   ANGHSOL=15.0*(TS-12.0)
      ANGHSOL=15.0*((TL-5.0)+(LGTUD/15.0)+ET-12.0)
CSI=COS(DECHSOL*RD)*SIN(ANGHSOL*RD)
      RETURN
      END
C.....
      SUBROUTINE INCLVRE(DNJOUR,LAT,LGTUD,BETA,TL,CSI)
      REAL LAT,LGTUD
      RD=0.017453
      DNJ=DNJOUR
      WS=0.984
      DECHSOL=23.45*SIN(0.986*RD*(DNJ+284.0))
```

# 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

```
C  ANGHSOL=ACOS(-ATAN(LAT)*ATAN(DECHSOL))
ET=0.0002-0.4797*COS(WS*RD*DNJ)+3.2265*COS(2*WS*RD*DNJ)+
&0.0903*COS(3*WS*RD*DNJ)+7.3509*SIN(WS*RD*DNJ)+
&9.391*SIN(2*WS*RD*DNJ)+0.3361*SIN(3*WS*RD*DNJ)
C  TS=TL-(-5.0)+(ET/60.0)+((0.0+LGTUD))/15.0
C  ANGHSOL=15.0*(TS-12.0)
  ANGHSOL=15.0*((TL-5.0)+(LGTUD/15.0)+ET-12.0)
CSI=-COS(DECHSOL*RD)*SIN(ANGHSOL*RD)
RETURN
END
```

```
C.....
  SUBROUTINE INCLVRS(DNJOUR,LAT,LGTUD,BETA,TL,CSI)
  REAL LAT,LGTUD
  RD=0.017453
  DNJ=DNJOUR
  WS=0.984
  DECHSOL=23.45*SIN(0.986*RD*(DNJ+284.0))
C  ANGHSOL= ACOS(-ATAN(LAT)*ATAN(DECHSOL))
ET=0.0002-0.4797*COS(WS*RD*DNJ)+3.2265*COS(2*WS*RD*DNJ)+
&0.0903*COS(3*WS*RD*DNJ)+7.3509*SIN(WS*RD*DNJ)+
&9.391*SIN(2*WS*RD*DNJ)+0.3361*SIN(3*WS*RD*DNJ)
C  TS=TL-(-5.0)+(ET/60.0)+((0.0+LGTUD))/15.0
C  ANGHSOL=15.0*(TS-12.0)
  ANGHSOL=15.0*((TL-5.0)+(LGTUD/15.0)+ET-12.0)
CSI=SIN(LAT*RD)*COS(ANGHSOL*RD)*COS(DECHSOL*RD)-
1 SIN(DECHSOL*RD)*COS(LAT*RD)
RETURN
  END
```

```
C.....
  SUBROUTINE INCLVRN(DNJOUR,LAT,LGTUD,BETA,TL,CSI)
  REAL LAT, LGTUD
  RD=0.017453
  DNJ=DNJOUR
```

# 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

```
WS=0.984
DECHSOL=23.45*SIN(0.986*RD*(DNJ+284.0))
C  ANGHSOL= ACOS(-ATAN(LAT)*ATAN(DECHSOL))
ET=0.0002-0.4797*COS(WS*RD*DNJ)+3.2265*COS(2*WS*RD*DNJ)+
&0.0903*COS(3*WS*RD*DNJ)+7.3509*SIN(WS*RD*DNJ)+
&9.391*SIN(2*WS*RD*DNJ)+0.3361*SIN(3*WS*RD*DNJ)
C  TS=TL-(-5.0)+(ET/60.0)+((0.0+LGTUD))/15.0
C  ANGHSOL=15.0*(TS-12.0)
  ANGHSOL=15.0*((TL-5.0)+(LGTUD/15.0)+ET-12.0)
CSI= SIN(DECHSOL*RD)*COS(LAT*RD)-
1 COS (DECHSOL*RD)*COS(ANGHSOL*RD)*SIN(LAT*RD)
  RETURN
  END
  SUBROUTINE INCLHZ(DNJOUR,LAT,LGTUD,BETA,TL,CSI)
  REAL LAT, LGTUD
  RD=0.017453
  DNJ=DNJOUR
  WS=0.984
  DECHSOL=23.45*SIN(0.986*RD*(DNJ+284.0))
  C  ANGHSOL=ACOS(-ATAN(LAT)*ATAN(DECHSOL))
  ET=0.0002-0.4797*COS(WS*RD*DNJ)+3.2265*COS(2*WS*RD*DNJ)+
&0.0903*COS(3*WS*RD*DNJ)+7.3509*SIN(WS*RD*DNJ)+
&9.391*SIN(2*WS*RD*DNJ)+0.3361*SIN(3*WS*RD*DNJ)
  C  TS=TL-(-5.0)+(ET/60.0)+((0.0+LGTUD))/15.0
  C  ANGHSOL=15.0*(TS-12.0)
    ANGHSOL=15.0*((TL-5.0)+(LGTUD/15.0)+ET-12.0)
  CSI=COS(DECHSOL*RD)*COS(ANGHSOL*RD)*COS(LAT*RD)+
  1 SIN(DECHSOL*RD)*SIN(LAT*RD)
  RETURN
  END
  C.....
  SUBROUTINE SOLDIFU(NRJMOIS,NRMANS,HAUTSOL,BETA,DIFUS)
  REAL IC,I0,PHY0,PHY1,PHY2,NRMANS,NRJMOIS
```

# 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

```
RD=0.017453
I0=1367.0
ALBEDO=0.07
IC=I0*(1.0+0.0034*COS(((30.0*(NRMANS-1.0))+NRJMOIS)*RD))
PHY0=IC*HAUTSOL*(0.271-0.2939*EXP(-0.26/HAUTSOL))
PHY1=PHY0*((1.0+COS(BETA*RD))/2.0)
PHY2=ALBEDO*(I0*HAUTSOL+PHY0)*((1.0-COS(BETA*RD))/2.0)
DIFUS=PHY1+PHY2
RETURN
END
```

```
C.....
SUBROUTINE TEMSOL(LAT,DECHSOL,TSLEV,TSCOU,DENSOL)
```

```
REAL LAT
RD=0.017453
WL=ACOS(-TAN(LAT*RD)*TAN(DECHSOL*RD))/RD
WC=ACOS(+TAN(LAT*RD)*TAN(DECHSOL*RD))/RD
TSLEV=12.0-(WL/15.0)
TSCOU=12.0+(WC/15.0)
DENSOL=TSLEV-TSCOU
RETURN
END
```

```
C.....
SUBROUTINE TFLCH(FLMART,MASFL,UAFDFL,UAFDGR,TF,DT,CPFD,TINF,
ITOFS,TFLD)
REAL LAMBDA,MASFL
S=(FLMART*CPFD*TINF+UAFDFL*TF+UAFDGR*TOFS)/MASFL*CPFD
LAMBDA=(FLMART*CPFD+UAFDFL+UAFDGR)/MASFL*CPFD
RHS=S-LAMBDA*TFLD
SIGMA=(1.0/(1.0-EXP(-LAMBDA*DT)))-(1.0/(LAMBDA*DT))
OMEGA=RHS/(1.0+SIGMA*LAMBDA*DT)
TFLD=TFLD+OMEGA*DT
RETURN
END
```

## 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

---

```
C.....
SUBROUTINE TVITRE(SOLRAD,DT,UVIEWV,UCOMBV,URVABS,UCVAIR,ULATV,
1 TSKY,TAMB,TABS,TAIR,MASVIT,CPVIT,SC,TV)
REAL LAMBD,MASVIT
PARAMETER(ZERO=1.0E-9)
S=(UVIEWV*TSKY+ UCOMBV*TAMB+URVABS*TABS+UCVAIR*TAIR+ULATV*TAMB+
1 0.95*SC*SOLRAD)/MASVIT*CPVIT
LAMBD=(UVIEWV+UCOMBV+URVABS+UCVAIR+ULATV)/MASVIT*CPVIT
IF(LAMBD.EQ.0.0) THEN
SIGMA=(1.0/(1.0-EXP(-(LAMBD+ZERO)*DT)))-(1.0/((LAMBD+ZERO)*DT))
ELSE
SIGMA=(1.0/(1.0-EXP(-LAMBD*DT)))-(1.0/(LAMBD*DT))
ENDIF
OMEGA=(S-LAMBD*TV)/(1.0+SIGMA*LAMBD*DT)
TV=TV+OMEGA*DT
RETURN
END
```

```
C.....
SUBROUTINE TAIRGAP(DT,UCVAIR,UCABSA,ULATGAP,TV,TABS,TAMB,
1 MASAIR,CPAIR,SC,TAIR)
REAL LAMBD, MASAIR
PARAMETER(ZERO=1.0E-9)
S=( UCVAIR*TV+UCABSA*TABS+ULATGAP*TAMB)/MASAIR*CPAIR
LAMBD=( UCVAIR+UCABSA+ULATGAP)/ MASAIR*CPAIR
IF(LAMBD.EQ.0.0) THEN
SIGMA=(1.0/(1.0-EXP(-(LAMBD+ZERO)*DT)))-(1.0/((LAMBD+ZERO)*DT))
ELSE
SIGMA=(1.0/(1.0-EXP(-LAMBD*DT)))-(1.0/(LAMBD*DT))
ENDIF
OMEGA=(S-LAMBD*TAIR)/(1.0+SIGMA*LAMBD*DT)
TAIR=TAIR+OMEGA*DT
RETURN
END
```

# 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

---

```
C.....
  SUBROUTINE TABSOR(SOLRAD,DT,URVABS,UCABSA,UABSFLD,UPABS,TV,TAIR,
1 TSORC,TAMB,MASABS,CPABS,SC,TABS)

  REAL LAMBD,MASABS
  PARAMETER(ZERO=1.0E-9)
  S=(URVABS*TV+UCABSA*TAIR+UABSFLD*TSORC+UPABS*TAMB+
1 0.95*SOLRAD*SC)/ MASABS*CPABS
  LAMBD=(URVABS+UCABSA+UABSFLD+UPABS)/ MASABS*CPABS
  IF(LAMBD.EQ.0.0) THEN
    SIGMA=(1.0/(1.0-EXP(-(LAMBD+ZERO)*DT)))-(1.0/((LAMBD+ZERO)*DT))
  ELSE
    SIGMA=(1.0/(1.0-EXP(-LAMBD*DT)))-(1.0/(LAMBD*DT))
  ENDIF
  OMEGA=(S-LAMBD*TABS)/(1.0+SIGMA*LAMBD*DT)
  TABS=TABS+OMEGA*DT
  RETURN
  END
```

```
C.....
  SUBROUTINE SORCAP(FLMART,DT,UABSFLD,TABS,TAIR,TENC,MASFLD,CPFD
1 ,SC,TSORC)
  REAL LAMBD,MASFLD
  PARAMETER(ZERO=1.0E-9)
  S=(FLMART*CPFD*TENC+UABSFLD*TABS)/MASFLD*CPFD
  LAMBD=(FLMART*CPFD+UABSFLD)/MASFLD*CPFD
  IF(LAMBD.EQ.0.0) THEN
    SIGMA=(1.0/(1.0-EXP(-(LAMBD+ZERO)*DT)))-(1.0/((LAMBD+ZERO)*DT))
  ELSE
    SIGMA=(1.0/(1.0-EXP(-LAMBD*DT)))-(1.0/(LAMBD*DT))
  ENDIF
  OMEGA=(S-LAMBD*TSORC)/(1.0+SIGMA*LAMBD*DT)
  TSORC=TSORC+OMEGA*DT
  RETURN
  END
```

## 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

---

```
C.....  
  SUBROUTINE HCNHB(AK,L,BETA,TR,TIS,DA,DYV,CPA,HCOHB)  
  REAL L,L2,L3,PR  
  C  PARAMETER(R2=1.0E5,R3=1.0E7)  
  TM=(TR+TIS)*0.5  
  C=AK/L  
  L2=L*L  
  L3=L2*L  
  GR=(9.81*COS(BETA)*ABS(TR-TIS)*L3*DA*DA)/(TM*DYV*DYV)  
  PR=DYV*CPA/AK  
  RA=GR*PR  
  HCOHB=C*0.440*RA**0.125  
  RETURN  
  END
```

```
C.....  
  SUBROUTINE HCNHA(AK,L,BETA,TR,TIS,DA,DYV,CPA,HCOHA)  
  REAL L,L2,L3,PR  
  PARAMETER(R3=1.0E7)  
  TM=(TR+TIS)*0.5  
  C=AK/L  
  L2=L*L  
  L3=L2*L  
  GR=(9.81*COS(BETA)*ABS(TR-TIS)*L3*DA*DA)/(TM*DYV*DYV)  
  PR=DYV*CPA/AK  
  RA=GR*PR  
  IF(RA.LT.2*R3) THEN  
    HCOHA=C*0.540*RA**0.250  
  ELSE  
    HCOHA=C*0.140*RA**0.333  
  ENDIF  
  RETURN  
  END
```

```
C.....
```

## 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

---

```
SUBROUTINE PRINTS(QAUXIL,MONTDUM,ENSOLC,ABOVE,BELOW,AV,BE,
ITROOM,TA,QGROUD,QRADT,QCONV)
CHARACTER*10 MONTDUM
PARAMETER(ZERO=1.0E-9)
C  OPEN(UNIT=1,FILE='PLSOL.DATA',STATUS='UNKNOWN')
C  IF(MTH.EQ.12) THEN
C  WRITE(*,*)'      Q ANNUELLE'
C  ELSE
WRITE(*,*)'----- '
WRITE(*,*) MONTDUM
WRITE(*,*)'----- '
WRITE(*,*) ' '
C  WRITE(*,*)'TEMPERATURE EXTERIURE=',TA,'C'
C  WRITE(*,*)'TEMPERATURE INTERIEURE=',TROOM,'C'
WRITE(*,*) ' '
WRITE(*,601)ABOVE/3600
601 FORMAT(1X,'MAGNITUDE AU DESSUE TCONS      =',F9.2,' °C HEURE')
WRITE(*,*) ' '
WRITE(*,602)AV/3600
602 FORMAT(1X,'NOMBRE DES HEURES AU DESSUE TCONS =',F9.2,' HEURE')
WRITE(*,*) ' '
IF(AV.EQ.0.0) THEN
TABOVE=ABOVE/((AV+ZERO)*1.0)
ELSE
TABOVE=ABOVE/(AV*1.0)
ENDIF
WRITE(*,603)TABOVE
603 FORMAT(1X,'TEMP MOYENNE MAX AU DESSUE TCONS =',F9.2,' °C')
WRITE(*,*)'.....'
WRITE(*,605)BELOW/3600.0
605 FORMAT(1X,'MAGNITUDE AU DESSOUS TCONS      =',F9.2,' °C HEURE')
WRITE(*,*) ' '
WRITE(*,606)BE/3600.0
```

## 'Study of heat loss through the ground of residential building envelope in Ouargla soil.

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```
606 FORMAT(1X,'NOMBRE DES HEURES AU DESSOUS TCONS =',F9.2,' HEURE')
WRITE(*,*)'
      IF(BE.EQ.0.0) THEN
      TBELOW=BELOW/((BE+ZERO)*1.0)
      ELSE
      TBELOW=BELOW/(BE*1.0)
ENDIF
      WRITE(*,607)TBELOW
607 FORMAT(1X,'TEMP MOYENNE MAX AU DESSOUE TCONS =',F10.2,' °C')
WRITE(*,*)'.....'
      WRITE(*,608)QAUXIL
608 FORMAT(1X,'Q TOTALE ANULLE=',F10.2,' MEGAJOULES ')
WRITE(*,*)'.....'
      WRITE(*,*)' '
WRITE(*,609)QGROUD
609FORMAT(1X,'Q TERRE   =',F10.2,' MEGAJOULES')
      WRITE(*,610)QRADT
610 FORMAT(1X,'Q RADATION =',F10.2,' MEGAJOULES')
      WRITE(*,611)QCONV
611 FORMAT(1X,'Q CONVECTION =',F10.2,' MEGAJOULES')
      WRITE(*,612)ENSOLC
612 FORMAT(1X,'Q SOLAIRE =',F10.2,' MEGAJOULES')
      WRITE(*,613)(ENSOLC /QAUXIL)*100.0
613 FORMAT(1X,'TAUX =',F5.2 )
RETURN
      END
```