3D MODELING OF ESTP CACHAN, FRANCE BY 3D SCANNER FOR THE ASSESSMENT OF THERMAL EFFECTS AND ENERGY DISSIPATION

A DISSERTATION

Submitted in partial fulfillment of the requirements for the award of the degree

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MASTER OF TECHNOLOGY

in

CIVIL ENGINEERING

(With Specialization in Geomatics Engineering)

By

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in this thesis, entitled, **"3D Modeling of ESTP Cachan, France by 3D Scanner for the Assessment of Thermal Effects and Energy Dissipation"**, in partial fulfilment of the requirements for the award of the Degree of **Master of Technology in Civil Engineering** with specialization in **Geomatics** submitted to the Department of Civil Engineering, Indian Institute of Technology Roorkee, Roorkee, and FIT / ESTP/ Constructibility Research Institute Cachan France, is the authentic record of my own work carried out under the supervision of **Prof. Sanjay K. Ghosh,** Civil Engineering Department, Indian Institute of Technology Roorkee, Roorkee, India and **Prof. David Bassir,** Director of Research, FIT / ESTP/ Constructibility Research Institute Cachan France.

The matter embodied in this dissertation has not been submitted by me for the award of any other degree or diploma.

Date :- 30 June 2010

Place: - IIT Roorkee

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CERTIFICATE

This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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(Mudit Kapoor)

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ABSTRACT

Now a day there is a need to assess the thermal effect and the energy dissipation of the building before construction. This thesis is about the Energy Diagnosis with thermal photography of the ESTP Cachan campus building. In this report, the thermal analysis is done on the 3 dimensional view of the ESTP, Cachan campus. In this study, the 3D modeling is done with the help of the 3D laser scanner, total station and DesignBuilder has been done and the results so obtained are compared. To obtain an accurate estimate of the geometry of the vaults, 3D-laser scanning was performed. Based on the 3D-point cloud, a 3D-model of the vault sallow's determining the lines of thrust in the structure. Thermography is also performed on the 3D model by the different techniques like Thermograms, DesignBuilder and contours. So the comparisons of these techniques are also done in this thesis. The reader could also realize the usefulness of the thermal photography analysis in order to locate areas of energy leakage. The resultant model is enriched with many points in space like co-ordinates, temperature, and humidity for the analysis. In the model, the laser scanning method is very fast and accurate. The other method like Total Station and DesignBuilder are also very fast but it is very quick to get the models by laser scanner. Various defects are obtained in the buildings with the help of these techniques and we also verified them. Most common defects are obtained on the corners, under-wall and in the beams. In the thermal analyses, DesignBuilder has given accurate results with the accuracy of 0.5°C. The Thermohygrometer is used to draw contours of the temperature and showed the same results as from DesignBuilder.

Keywords: 3D laser scanning, Total Station, DesignBuilder, Thermography, GPS, Contours

Chapter- 1

INTRODUCTION

1.0 Introduction

Various society fields demand realistic 3D models. For urban planning, analyzing in a 3D virtual reality world is much more efficient than imaging the 2D information on maps. For public security, accurate 3D building models are indispensable to make strategies during emergency situations. Navigation systems and virtual tourism also benefit from realistic city models.

Manual creation of city models is undoubtedly a rather slow and expensive procedure, because of the enormous number of buildings and complexity of building shapes. The rapid development of cities also adds to the cost of manual city model updating.3-Dimensional model of the ESTP building is done with the help of different techniques like 3D Laser Scanner, DesignBuilder and Total Station. The Thermal analysis and Energy dissipation is done with the help of the Thermograms, DesignBuilder and Contours.

3D model is built by the three techniques then the comparison is done on the model so obtained, based on the meshed networked and the accuracy of the co-ordinates. Thermal analysis and Energy is done with the help analysis of the results of the Thermograms, DesignBuilder and contours by the Covadis (AutoCAD).

The rapid collection of 3D information serves several purposes

i) Historical documentation, ii) Facility condition documentation, iii) Construction as-built development, iv) Building Information Model (BIM) development

This study discusses the application of the visualization capabilities of IR in conjunction with three-dimensional models of buildings. Three-dimensional modeling is a powerful tool for visualizing and representing building conditions that is used by architects, builders, and contractors. Also, a three-dimensional model is better understandable than a more abstract two-dimensional representation (like a floor plan or an image).

1.1 Techniques Available

A 3D scanner is a device that analyzes a real-world object or environment to collect data on its shape and possibly its appearance (i.e. color). The collected data can then be used to construct digital, three dimensional models useful for a wide variety of applications. These devices are used extensively by the entertainment industry in the production of movies and video games. Other common applications of this technology include industrial design, orthotics and prosthetics, reverse engineering and prototyping, quality control/inspection and documentation of cultural artifacts.

Total Station is used to generate the CAD data used to get spatial information of the structure. In order to generate accurate 3D models control points need to be placed in the structure, the control points will also appear in the photographs and are used for the software. Measurements of the building are taken to generate an accurate 3D model. Control points and the Total Station are used to generate spatial information to create a 3D model.

3D models can also be created by software. To add those buildings on visualization projects is with a few useful scripts that create procedural buildings. Different software available to create 3D model:

i) Create a 3D Scene with DesignBuilder, Maya, Photoshop, 3ds Max and Blender 3D

Thermal analysis is done with the help of the thermograms by the FLIR camera. The images show the temperature at each point. Infrared imagery is often a grayscale whose scales (or shades of gray) represent the differences in temperature and emissivity (opposite of reflectivity) of objects in the image. As a general rule, objects in the image that are lighter in colour are warmer, and darker objects are cooler. No object is detected in visible light wavelength (400-700 nm) rather, it detects infrared wavelength (3000-5000 nm & 8000-14000 nm).

Thermal analysis and energy dissipation can also be done with the help of the software like DesignBuilder, AutoDesk, etc. DesignBuilder provides Energy Modeling/Simulation services for whole buildings and building component analysis. It is the developer of quality software tools and solutions in building science field.

1.2 Need of the Problem

Proper insulation, durability, air and moisture tightness are key elements for a comfortable and energy efficient building. As a result, it is important to have a continuous, stable, and integral boundary between the conditioned interior spaces and the unconditioned outdoors spaces. It is common today for many professional home inspectors and energy auditors to use infrared imaging technology to evaluate the performance of this "thermal envelope" in the process of conducting energy auditing of homes and buildings.

Common drawbacks of the current application of infrared thermography are that while it provides usable temperature data and renders false-color images, these images are only two-dimensional and in most cases of a very low resolution. In presenting the thermography images to a client, they can be confusing to an untrained eye. Also, the three-dimensionality of a building cannot fully be captured by individual images.

1.3 Principles of Thermal Imaging

The measurement of temperature remotely and assigning a colour based on the temperature. Thermal radiation is the process by which the surface of an object radiates its thermal energy in the form of electromagnetic waves. Infrared radiation from a common household radiator or electric heater is an example of thermal radiation, as is the light emitted by a glowing incandescent light bulb. Thermal radiation is generated when heat from the movement of charged particles within atoms is converted to electromagnetic radiation.

It is a science of seeing temperature patterns using special electronic cameras. Rather than seeing light, these remarkable instruments create pictures of heat and cold. They measure infrared (IR) energy and convert to data to images corresponding to the temperature.

1.3.1 Thermography in buildings

i) Missing compressed or improperly insulation.

ii) Shrinkage or setting of various insulating materials.

iii) Excessive thermal bridging in joints between walls and tops or bottom plates.

iv) Moisture damages to insulation and building materials.

v) Heat loss through multi plane windows with a broken or improperly fitted seal.

vi) Leaks in water pipes. Damaged heat ducts.

vii) Location of or leaking in buried stream links, water line or underground sprinklers.

1.3.2 European norms on building inspection:

i) The ISO/ EN 13187: 1998 is a norm that specify what and how needs to be done to perform a thermographic building inspection in buildings.
ii) It is started in Europe but is today accepted as an international ISO norm to several European countries for example: France, United Kingdom, Sweden, etc.
iii) There is also the recent EPBD (European Performance for Buildings Directive) that is presently being implemented in all European Union countries and regulates minimum requirements for building construction within European Union.

1.3.2.1 Thermographic examination EN 13187: 1998 [Source: 20]

In order to define the actual test requirements and in particular the side of the building envelop (outdoors and indoors) from which the thermographic examination is to be performed, the following factors need to be considered:

i) The specifications and capabilities of the thermographics equipment.
ii) The characteristics of the building envelop, i.e. the respective types and locations of heating systems, structural elements and insulating layers;
iii) The radiative properties of the surface example the cladding materials
iv) Climate factors, Accessibility for easy inspection, Influences of the environment, Other factors of importance.

1.3.2.2 The directive

i) General framework for a methodology of calculation of the integrated performance of buildings
ii) Setting of minimum standard in new and existing buildings.
iii) Energy certification of Buildings
iv) Inspection and assessment of heating and cooling installations.

1.3.2.3 Scope of EN13187

In this standard two forms (these two adaptations different mainly with regard to the reporting and presentation of the results) of thermography are specified

i) Testing with an IR camera is primarily integrated for the inspection of the overall performance of new buildings or the result after a rebuilding operation.

ii) Simplified testing with an IR camera is suitable when carrying out audits, example at the site of a rebuilding project or at production control or other routine inspection.

1.3.3 Thermal Radiation's characteristics

Consider now a more dense and opaque object (doesn't transmit light), like a star or a person.

i) Photons of Light within such an object will bounce around from atom to atom exchanging energy (being absorbed and emitted).

ii) Light behaves the same as how the atoms themselves bounce around exchanging energy with each other.

iii) Collisions among atoms randomize their kinetic energies and we can characterize the average kinetic energy by the Temperature of the object.

iv) The "bouncing around" of light in an opaque body also randomizes its radioactive energy in a similar way that only depends on the body's temperature.

v) It helps find problems before they become visible. It is non contact. It is intrusive.

vi) It can scan large areas quickly to identify areas of concern.

vii) Quickly identifies specific locations for detailed inspection/ intrusion.

viii) It can be used on the building envelop as well as installations (plumbing, electrical and HVAC).

1.4 Concept of 3D modeling

In 3D computer graphics, 3D modeling is the process of developing a mathematical representation of any 3 dimensional surface of object (either inanimate or living) via specialized software. The product is called a 3D model. It can be displayed as a two-dimensional image through a process called 3D rendering or used in a computer simulation of physical phenomena. The model can also be physically created using 3D Printing devices.

The scale space of 3D buildings is essentially a linear continuum, along which an arbitrary number of milestones can be said to exist referred to as Levels of Detail (LoD). Each LoD corresponds to a certain degree of generalization. Unlike the 2D topographic maps that have standard official scale series, there are no generally agreed LoDs for 3D buildings. As exemplified in the following list, the currently available LoDs are mainly determined in relation to the resolution of sensor data, the precision of semantic information and the relevant application.3D modeling is done to have the following aspects:

i) Flexibility, ability to change angles or animate images with quicker rendering of the changes;
ii) Ease of rendering, automatic calculation and rendering photorealistic effects rather than mentally visualizing or estimating;
iii) Accurate photorealism, less chance of human error in misplacing, overdoing, or forgetting to include a visual effect.
iv) High Quality, Reduction in cost, Quick Turnaround Time, Edge on the competition -- without capital investment.
v) Adaptable to our Standards, A better-managed e-business infrastructure
vi) More concentration on business development, Confidentiality and Security

1.5 Objective

The following are the objectives of the study:

i) Energy Diagnosis with thermal photography of the ESTP Cachan campus building
ii) Thermal analysis is done on the 3 dimensional view of the ESTP, Cachan campus
iii) Comparison of the 3D modeling Techniques.
iv) Comparison of the Thermal analysis techniques.

1.6 Thesis layout

The layout of the thesis is discussed in the following steps:

i) Starting with the previous and current studies related to the work.
ii) Methodology of the work is defined.
iii) Study area and the need of this type of study.
iv) Pre-processing and data analysis by different approaches.
v) Data analysis of the results.
vi) Conclusion and future work

Chapter- 2

LITERATURE REVIEW

2.0 Past and Recent Studies

In cultural heritage documentation, choosing the appropriate technology (sensor, hardware, software), the appropriate procedures, designing the workflow and assuring that the final output is in accordance with the set of technical specifications is always a challenging matter (Patias et al., 2008). The leading parameters are the size and the complexity of the object and the level of accuracy required. These are some of the major factors which may influence the procedure to be adopted. Result from photogrammetry based studies (Grussenmeyer et al., 2002) and guidance to users on laser scanning in archaeology and architecture (English Heritage, 2007) promote the use of these techniques appropriately and successfully.

Generally, 3D data acquisition as well as 3D modeling of cultural heritage monuments can be performed by different approaches, such as analysis of existing plans and elevation drawings, surveying, laser scanning, photogrammetry or computer vision methods (Gonzo et al., 2004). Indeed, whereas several authors advise the use of photogrammetry as an image based method (e.g. Hanke and Oberschneider, 2002; Mayer et al. 2004; Kersten, 2006, El- Hakim et al. 2007), others recommend laser scanning (e.g. Allen et al., 2003).

Advantages of imaging methods are their level of details, economic aspects, portability, handling in spatial limited environment and a short data collection time. Disadvantages remain in the post processing when the texture of the object is poor. Advantages by using an active sensor system like terrestrial laser scanners are 3D survey capacities and the 3D surface acquisition. Nevertheless, this technology is not optimal for capturing linear elements and produces a large amount of data which implies to be reduced for further processing. Consequently, in most cases a combination of the above mentioned methods regarding their benefits may be the best solution (e.g. Fuchs et al., 2004, Gonzo et al., 2004).

Due to the complex structures of medieval castles, commonly used assumptions made on standard architecture, like parallelism, perpendicularity or symmetry are not applicable. Thus, the recording of such sites results in a huge amount of data and consequently the question of automation comes up. Whereas classical photogrammetry implies a heavy amount of manual and very time consuming interaction (e.g. Hanke and Oberschneider, 2002; Grussenmeyer and Yasmine, 2003), unfortunately the automation around laser scanning acquisition and data processing is really developed.

Several parameters effect thermographic measurements namely emissivity, reflectivity, environmental conditions, colour, etc. To evaluate the influence of some of these parameters, simple tests are carried out using the LFCs thermography equipment, both in laboratory and ''in situ''.

One of the laboratory tests consists of partially immersing two identical specimens of cellular concrete in water followed by a drying period. The tests are performed under steady-state conditions, in two climatic chambers with different temperatures and relative humidity. Thermal images were obtained during each test, using four different values of emissivity: 0.62, 0.85, 0.91 and 0.95.

As expected, the results showed that emissivity variation induced changes in the thermal images, during both absorption and drying. By looking at the thermal images it was possible to say that the images obtained with emissivity 0.62 were quite different from the remaining ones. The differences between the other thermograms (emissivity 0.85, 0.91 and 0.95) were not very significant. However, thermal images obtained with emissivity 0.85 were generally clearer. Thus, if the study aims for a qualitative evaluation of the results, that is, an analysis of superficial temperature differences, the selected emissivity value is not very important. Never the less, a judiciously selected emissivity value may simplify the interpretation of the thermal image.

Li S., Isele J., Bretthauer G. (2008) has done a work with objective: An approach designed by the German Research Center in Karlsruhe (Forschungszentrum Karlsruhe) to create an IFC (Industry Foundation Classes) compatible building information model from laser range images. The methodology through the entire process from data acquisition to the IFC compatible product model was proposed in his paper. In addition, IFC-Models with different level of details (LoDs) were introduced and discussed within the work. Methodology used is shown in the figure.

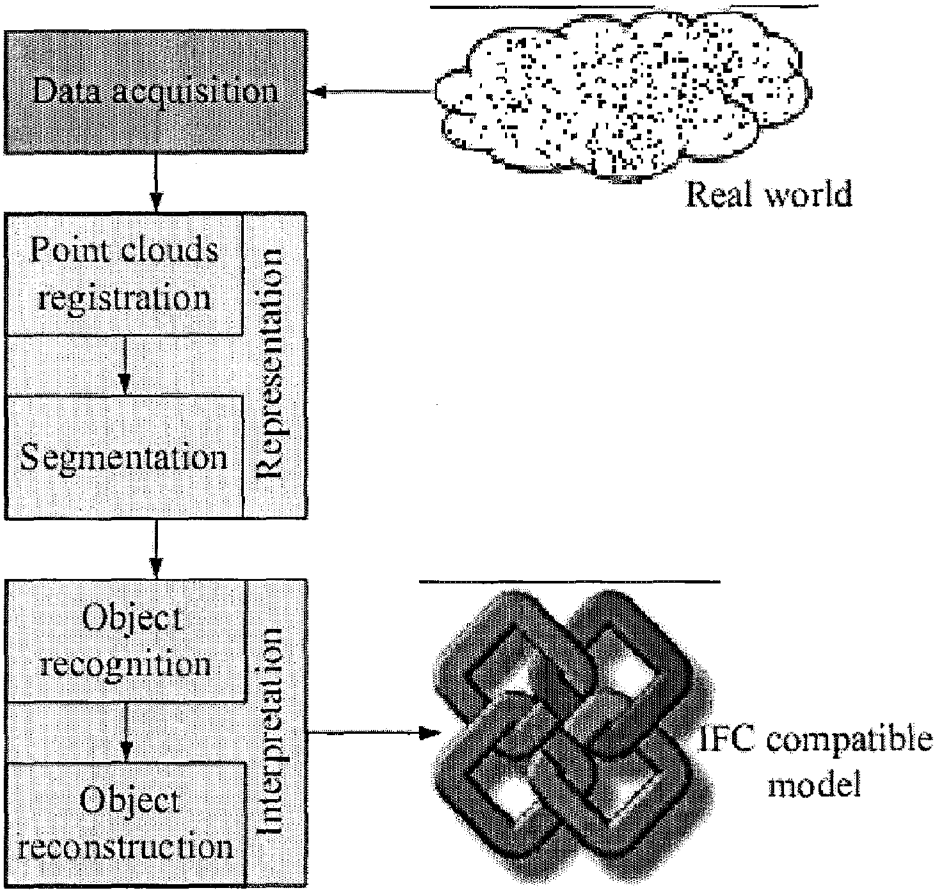


Figure 2.1- From Point Cloud to IFC Model

The conclusion of this study is an overall methodology to solve the problem of generation of IFC compatible building information models with laser scanning. The methodology through the entire process from data acquisition to the IFC compatible product model was proposed in this paper. In addition, IFC-Models with different LoDs within the work were introduced. Generation of IFC models with LoD0 and LoD1 were also demonstrated.

Pu S. and Vosselman G. (2009) presented an automatic method for reconstruction of building façade models from terrestrial laser scanning data. Important facade elements such as walls and roofs are distinguished as features. Knowledge about the features' sizes, positions, orientations, and topology is then introduced to recognize these features in a segmented laser point cloud.

Methodology used is reconstruction of buildings starts with recognition of structures in the raw data. Usually, the recognized structures are geometry features such as points, lines, or planes. In their approach, a higher level feature, the semantic feature, is defined, because we believe that understanding the meaning of each segment will support the façade reconstruction in several aspects.

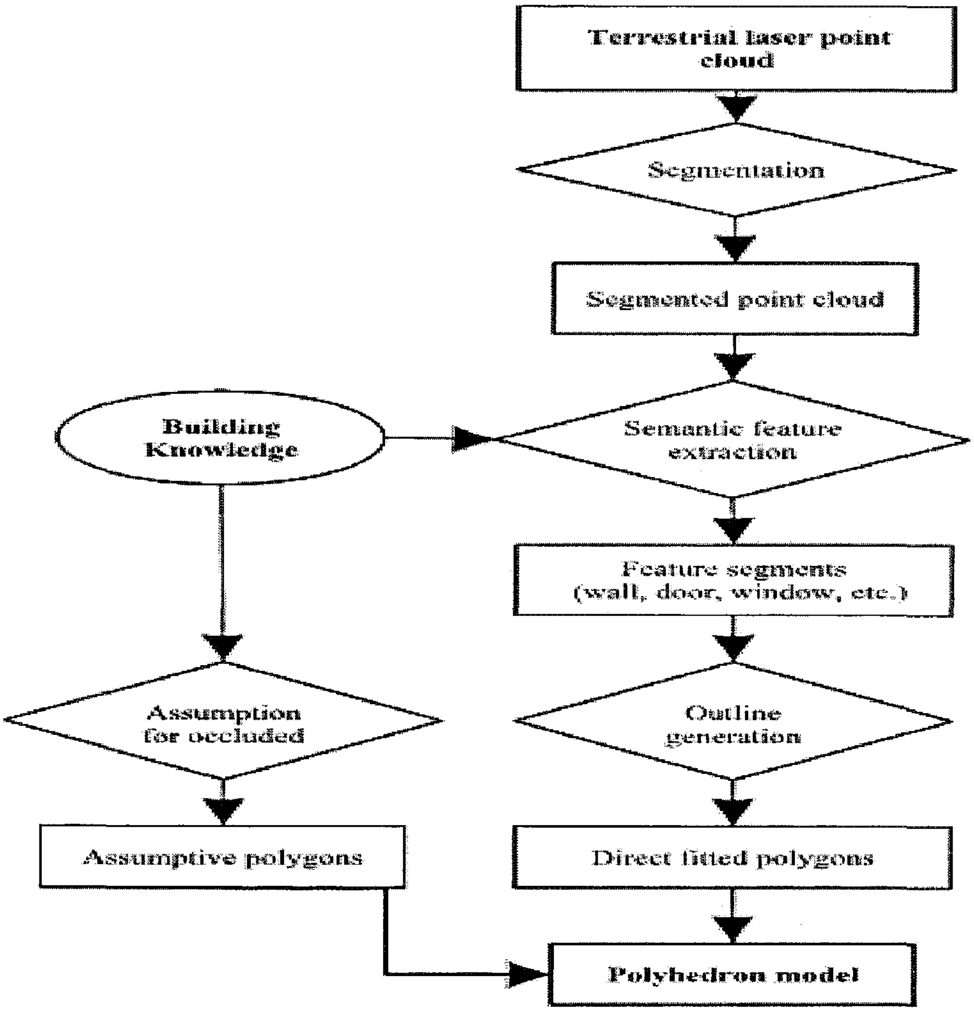


Figure 2.2- Building Reconstruction Process

First, a point cloud often contains points which do not belong to the building façade (for example people walking by), or points of objects on the building which we do not want to include in the final model (for example flower pots behind windows). These points can be filtered out if we know that they do not belong to the building.

Second, laser scanning can hardly scan a building completely. There are always occluded areas which cannot be reached by the laser beams. Knowledge can be used to fill these gaps by understanding the relations between the features surrounding the gaps, and guarantee a water-tight model.

Third, a semantically labeled building model enables better visualization ability, by sharing the same texture in all polygons with the same feature, or assigning a pre-defined texture to a certain semantic type. Finally, a semantic labeled building model can be associated with more attributes (name, owner, floor, etc) according to the semantic types, which helps integration with object based geo-databases.

In conclusion, it is foreseen that the method will fail in detecting correct building outlines for complex building structures, such as curved walls and curved protrusions, or non-vertical walls. More complete building knowledge will help to understand and reconstruct more complex buildings. The outline generation algorithm should also be improved to minimize offset errors. The current models are still un-textured wireframe models. The combination of digital images with laser data is considered to improve the outline generation in a later stage, and to produce textured building models.

Hu Z., Zhang J., and Deng Z.(2008) have done work on the building information model (BIM) and four-dimensional (4D) technology, this work proposes an improves structure analysis method, which can generate structural geometry, resistance model, and loading conditions automatically by a close interlink of the schedule information, architectural model, and material properties. The method was applied to a safety analysis during a continuous and dynamic simulation of the entire construction process.

With the data supports, a BIM was established. All the information needed in architectural model, structural model, construction process, resistance model, and loading conditions could be extracted from the BIM. Based on these models, a 4D construction management platform was developed as a conjunction of a visualization environment and a structural analysis system. As an application of 4D information platforms, the SABIC (Safety Analysis of Building In Construction), which has functions of 4D construction management and safety analysis for time dependent building, was presented.

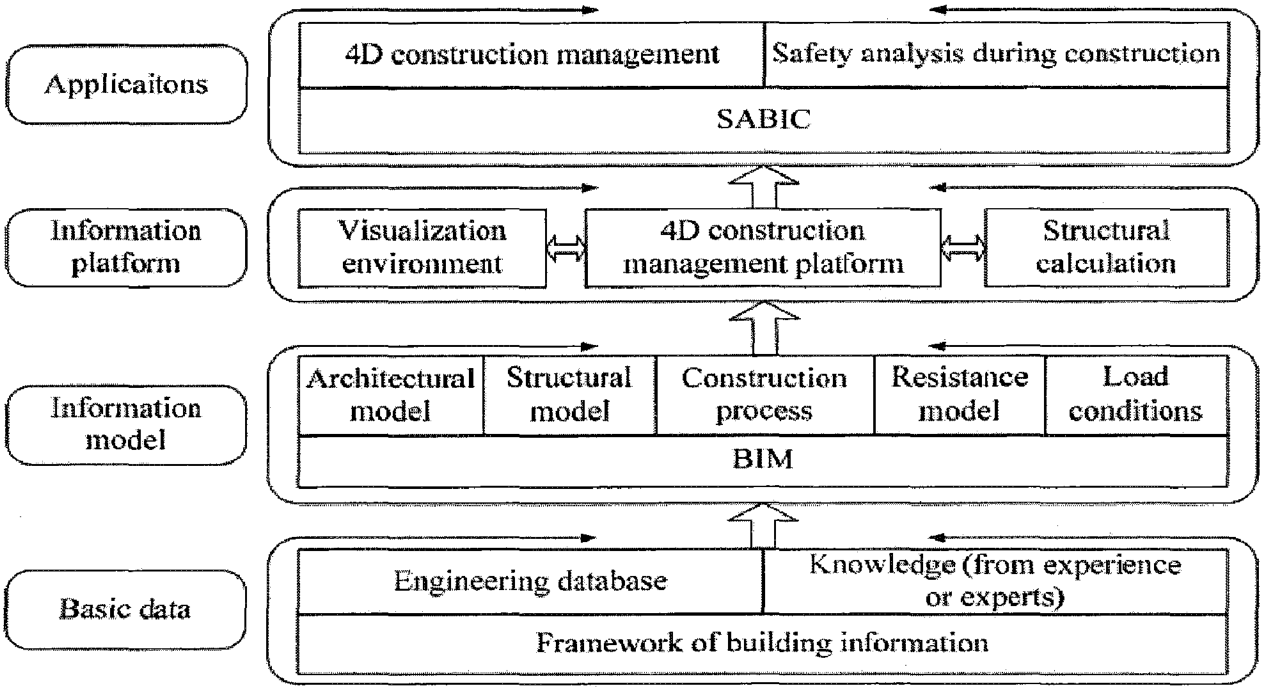


Figure 2.3- Logic Organization of the Sabic

The working flow chart of SABIC is given in Fig. 2.3. In this figure, 4D modeling including 3D architectural model and relationship between building elements and schedule or resources are the indispensable conditions of the process. 4D simulation and management, along with the calculation of safety performance index are the two most important works.

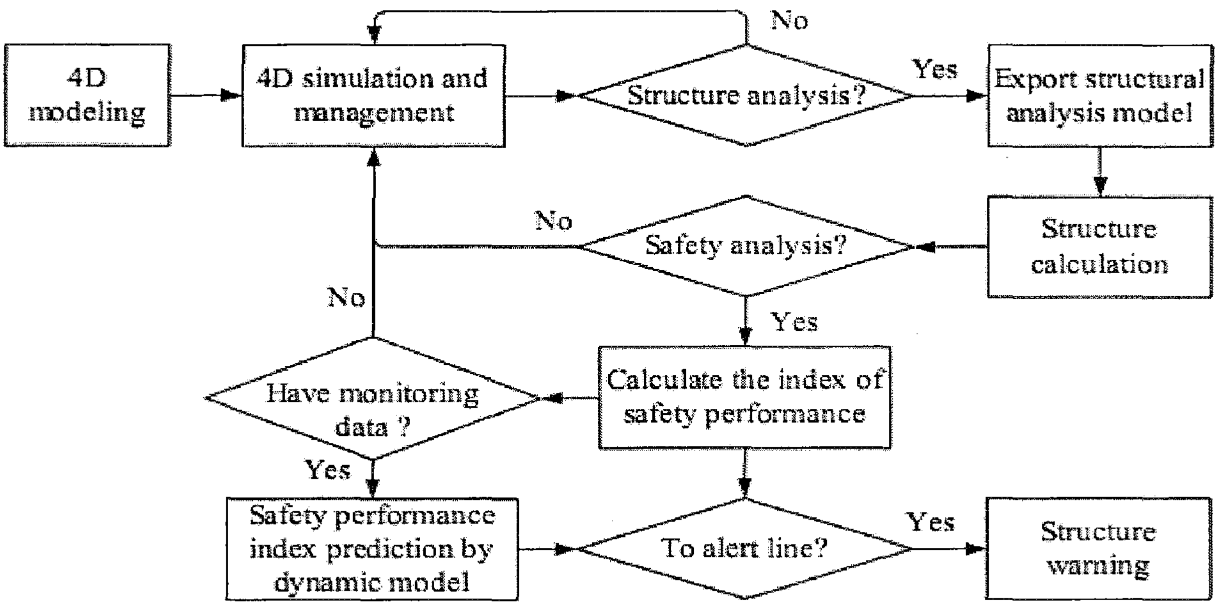


Figure 2.4- Flow-chart of the SABIC

Result of this work is the improved time-dependent structure analysis performs quite well on a safety analysis system named SABIC. It overcomes the disadvantages of current structure analysis method during construction, i.e., too much artificial intervention.

Shi Y., Chen H., Xu Q., Li D., Wang Z. and Fang X. (2008) have done work, which includes selecting the temperature range, setting emissivity values, setting the number of averaged frames, selecting auto or manual focus adjustment and temperature tracking, recording thermographic image and measuring position of equipment, visible light photo, temperature of appointment, outdoor temperature, outdoor air speed, and the angle of gradient.

Modern infrared thermography has more functions. The major key includes manual focus adjustment key, auto focusing key, manual temperature tracking key, auto temperature tracking key, freeze thermographic image key, recording thermographic image key and so on. When in use, we must set the temperature range and the emissivity of the surface.

Infrared thermography is the major equipment to test the heat defect of building envelope; it will greatly enhance in-field test technology in building energy conservation. Based on the practical application, we generalize the following experience for existing residential buildings: start the testing after 7:00 pm, considering the change of environmental condition, spend short time shooting the building; record the position of instrument; the corresponding photo with the thermographic image, single-point modified temperature; outdoor temperature; wind velocity and so on, and record the angle of gradient of instrument when shooting upper part.

In this chapter, various techniques were used which are: photogrammetry as an image based method, Industry Foundation Classes (IFC), terrestrial laser scanning data. Laser scanning can hardly scan a building completely. There are always occluded areas which cannot be reached by the laser beams. A semantically labeled building model enables better visualization ability, by sharing the same texture in all polygons with the same feature. Infrared thermography is the major equipment to test the heat defect of building envelope; it will greatly enhance in-field test technology in building energy conservation. In the next chapter, methodology is being discussed in detail.

Chapter- 3

METHODOLOGY

3.0 Introduction

In 3D computer graphics, 3D modeling is the process of developing a mathematical representation of any 3 dimensional surface of object (either inanimate or living) via specialized software. The product is called a 3D model. It can be displayed as a two-dimensional image through a process called 3D rendering or used in a computer simulation of physical phenomena. The model can also be physically created using 3D Printing devices.

In this report the three techniques are used to do a comparison in them. Three techniques used are which are as follows:

1. 3D Laser Scanner HDS 6100 Leica
2. DesignBuilder Software
3. AutoCAD software

3.1 3D Laser Scanner Modeling

Now a day, thanks to the computer power, highly complex matching algorithms automatically detect matches and create a 3D-model of the building. The problem with this technique is that it requires good lighting and sufficient texture. If these requirements are not fulfilled, the automatic matching algorithms fail to compute proper corresponding points. Therefore, this technique is not useful when working in an interior with low-light conditions.

Recently, laser scanning is getting great interest for its relevant simplicity and speed. Laser scanning analyzes a real-world or object environment by measuring thousands of points with high accuracy in a relatively short period of time. Some scanners even have a built-in camera to acquire color information that can be superimposed onto the geometric data. After an extensive processing phase, the collected data can be used to construct digital, two-dimensional drawings or 3D-models useful for a wide variety of applications. Laser scanning is like taking a photograph with depth information. Like cameras, they are line-of-sight instruments, so to ensure complete coverage o f a structure, multiple scan positions are required. Different laser scanner principles exist, i.e. triangulation based, time of flight based and phase-difference based.

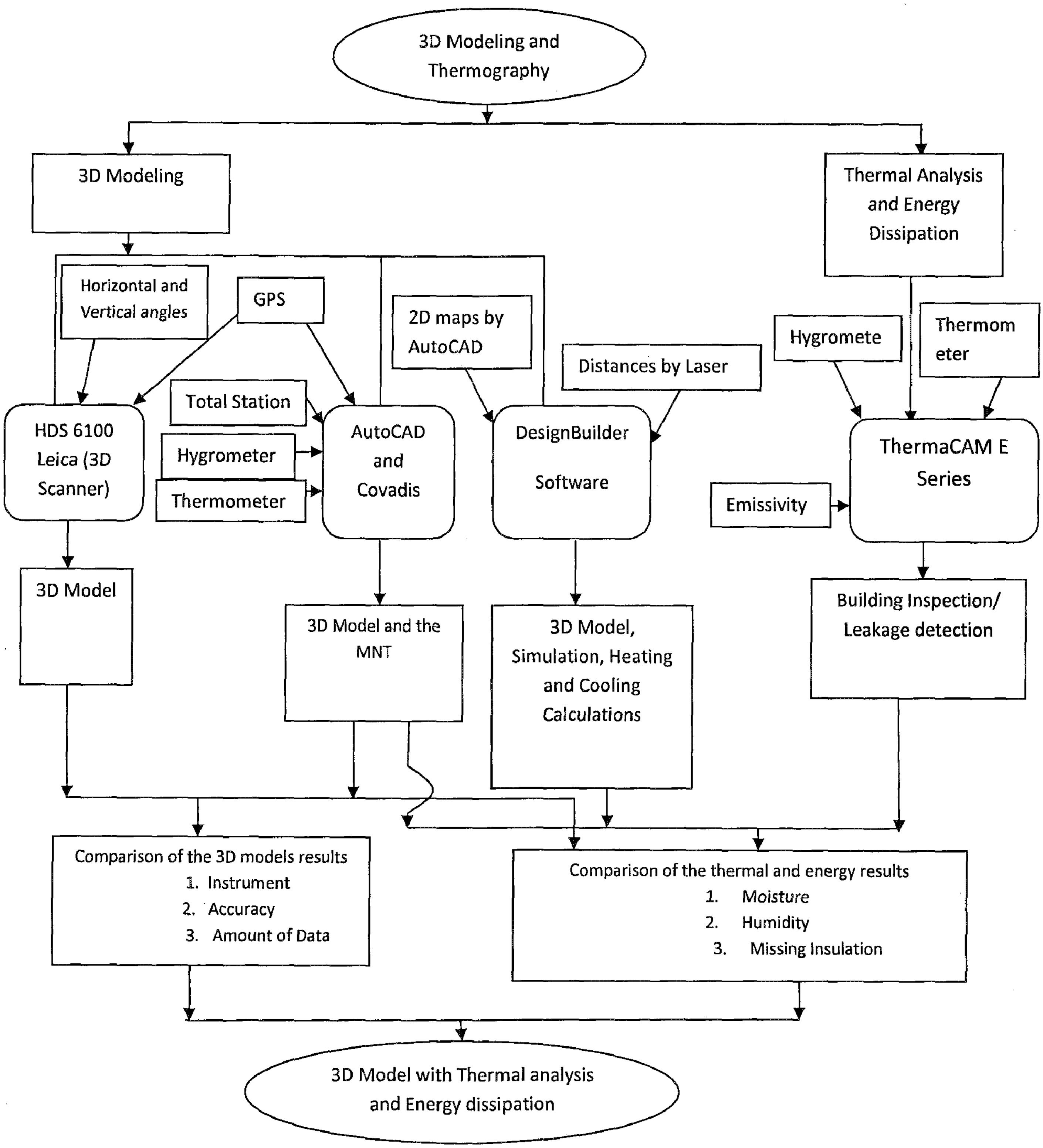


Figure 3.1- Methodology

Triangulation scanners (Figure.3.2) are the devices that project a laser line or pattern onto an object and measure the deformation of that pattern using a visible sensor to determine the objects' geometry. The sensor, the pattern projector and the object being measured are configured in a triangle, hence the name triangulation scanner. Since the length of the baseline between the sensor and the projection device is limited by the field of view of the sensor, this type of scanners can only be used to measure objects up to a range of maximum 5 meters.

Time of flight scanners compute distances by measuring the timeframe between sending a short laser pulse and receiving its reflection from an object. Since the laser pulse travels with a constant speed, the speed of light, the distance between the scanner and the object can be determined. These types of scanners are relatively slow (10,000 points/s), but can measure points up to 1 k m from the scanner without loss of accuracy. Phase-based scanners use a modulated continuous laser wave instead o f laser pulses allowing for faster measuring (500,000 points/s).

Because of the laser power required t o modulate the beam to certain frequencies, the range o f these scanners is limited t o approximately 50–80 m.

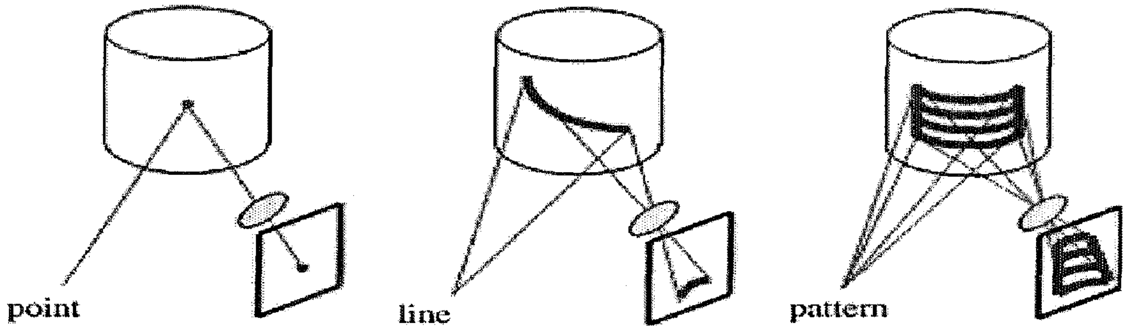


Figure 3.2- Triangulation Scanner Principle

For this thesis, the high-precision Leica HDS 6100 laser scanner was used. This midrange scanner uses the phase-based principal to measure the distance of a point to the scanner. It has a full field of view (360° × 310°) and a guaranteed accuracy of 9 mm per point up to a range of 50m. With its low beam divergence (9mm at 50m) it is one of the best mid-range scanners in the market. The most important technical specifications of the system are summarized in Table 2.

Table 3.1- Specifications of the 3D Laser Scanner

Scanner	**HDS 6100 Leica**
Instrument type	Compact, phase-based, dual-axis sensing, ultra high-speed laser
	scanner, with survey-grade accuracy and full field-of-view
User interface	Onboard touch panel, or external notebook or Tablet PC, or PDA
Scanner drive	Servo motor
Data storage	Integrated hard drive
Camera	No integrated camera; Cyclone SCAN supports use of external camera
Accuracy of single measurement	
Position	5 mm, 1 m to 25 m range;
	9 mm to 50 m range
Distance	= 2 mm at 90% albedo up to 25 m;
	= 3 mm at 18% albedo up to 25 m
	= 3 mm at 90% albedo up to 50 m;
	= 5 mm at 18% albedo up to 50 m
Modeled surface	1 mm at 25 m; 2 mm at 50 m for 90% albedo, one sigma;
Precision / noise	2 mm at 25m; 4 mm at 50m, for 18% albedo, one sigma
Target acquisition	2mm std. deviation
Dual-axis sensor	Selectable on/off; 3.6” resolution
Data integrity Monitoring	Self-check at start-up; optional checks using Cyclone-SCAN
Field-of-view	
Horizontal	360° (maximum)
Vertical	310° (maximum)

Laser Scanning System	
Type	Phase-shift
Laser Class	3R (IEC 60825-1)
Range	79 m ambiguity interval
	79 m @90%; 50 m @18% albedo
Scan rate	Up to 508,000 points/sec, maximum instantaneous rate

3.2 DesignBuilder Software 3D Modeling

3.2.1 Introduction

DesignBuilder is a state-of-the-art software tool for checking building energy, CO2, lighting and comfort performance. Developed to simplify the process of building simulation, DesignBuilder allows you to rapidly compare the function and performance of building designs and deliver results on time and on budget.

Design Builder is a user-friendly modeling environment where you can work (and play) with virtual building models. It provides a range of environmental performance data such as: annual energy consumption, maximum summertime temperatures and HVAC component sizes.

Some typical uses are:

i) Environmental performance data is displayed without needing to run external modules and import data and any simulations required to generate the data are started automatically.

ii) EnergyPlus 'Compact HVAC' descriptions provide an easy way into detailed analysis of commonly used heating and cooling systems.

iii) Natural ventilation can be modeled with the option for windows to open based on a ventilation set point temperature.

iv) Day lighting - models lighting control systems and calculates savings in electric lighting.

v) Shading by louvers, overhangs and side fins as well as internal and mid pane blinds.

vi) A comprehensive range of simulation data can be shown in annual, monthly, daily, hourly or sub-hourly intervals:

a) Energy consumption broken down by fuel and end-use.

b) Internal temperatures

c) Weather data

d) Heat transmission through building fabric including walls, roofs, infiltration, ventilation etc.

e) Heating and cooling loads.

f) CO2 generation.

vii) Heating and cooling plant sizes can be calculated using design weather data.

viii) Parametric analysis screens allow you to investigate the effect of variations in design parameters on a range of performance criteria.

ix) Generate EnergyPlus IDF files and work with these outside DesignBuilder to access EnergyPlus system functionality not provided by DesignBuilder.

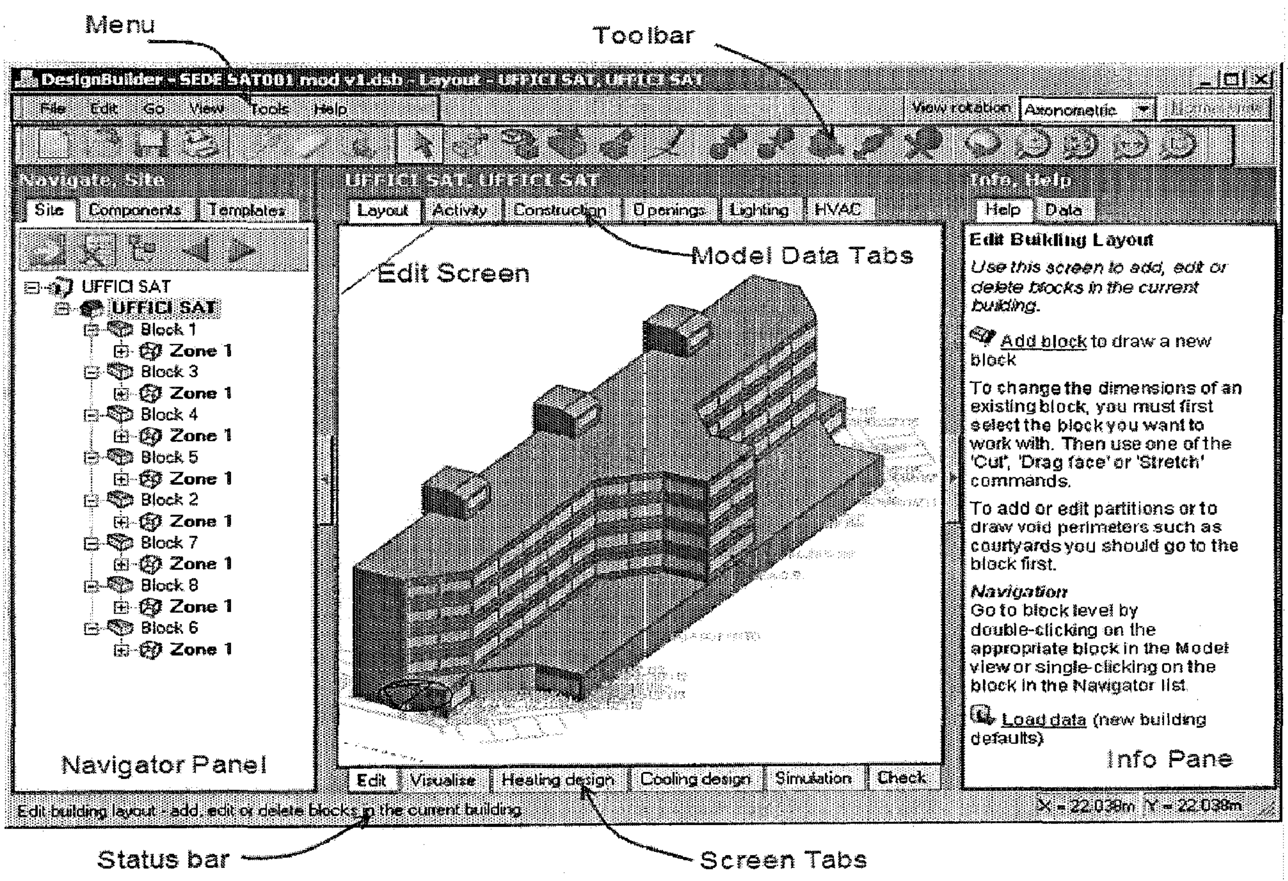


Figure 3.3- Snapshot of the Designbuilder

x) Minimum Requirements

a) Windows 7, Vista, XP or Windows 2000 running on
b) 1000 MHz processor
c) 800x600 pixel screen
d) 1 GB RAM
e) 200 MB free disk space
f) Pointing device
g) 100% OpenGL compatible 3D graphics adapter with hardware acceleration running in 32-bit color mode

3.2.2 Software features

DesignBuilder SBEM gives us all the functionality we need to produce EPCs and Part L2 Compliance reports with minimum time and effort:

i) Check building designs for compliance with Building Regulations (France)

ii) Produce Building Regulations Compliance Reports for Building Control.

iii) Import 2-D CAD floorplans, scanned paper drawings or 3-D CAD models.

iv) Fast, accurate and reliable data entry using the state-of-the-art DesignBuilder 3-D modeler. Draw buildings in 3-D with blocks which can be copied, sliced, stretched and partitioned up into zones.

v) Internal arrangements of zones can be easily changed without having to redraw large sections of the model.

vi) Constructions, glazing, lighting and HVAC data can be applied to multiple areas of the building in a single action using the powerful data inheritance function. This allows you to make global settings at building, block, and zone levels.

vii) Enter data for constructions using any data that is available in 4 different ways:

a) Enter layers of materials and automatically calculate U-value and Km using the approved calculation method.

b) Enter known U-value and Km data, where using early stage U-value estimates or if the data has been calculated in an external application like the BRE U-value calculator.

c) Select from a list of descriptions in the NCM library for existing buildings.

d) Use the NCM Inference procedures for an existing building when you only know the sector, age and construction type.

viii) You can generate impressive rendered images and AVI movies of the building model at any time without any extra work (requires separate purchase of Visualization module). These images can be valuable in client reports and presentations. Also 3-D DXF data can be exported for importing into other CAD programs.

DesignBuilder SBEM calculations work from the same 3-D building model data as the other DesignBuilder modules. One can switch at any time between SBEM and Simulation modes to obtain the design performance data you require. So once you have finished your SBEM calculation you can generate overheating data (hours where the temperature is over 28°C) to check the building against Criteria 3 of ADL2. One can readily investigate design alternatives to find cost-effective options giving the best overall performance

The laser distance meter is used to draw a 2D map of the building. The 2D map is transferred to the DesignBuilder software. The heights of the objects are calculated with the help of the laser meter and the 3D model is created in the DesignBuilder. DesignBuilder showed the results in the form of 3D model, heating and cooling calculations and simulation results.

3.3 AutoCAD Software 3D Modeling

3.3.1 To Model the building in 3D (AutoCAD)

The information required to create a computer representation of a building can therefore be separated into• the geometry information, which holds for instance the dimension, the orientation, and the connections of a component; and the construction information, which holds the physical properties of the constituting material(s), such as the density and environmental impacts. Separating the geometry topology model and the material composition has several advantages in terms of data consistency, model extensibility and maintenance. For example, to update some aspect of its composition, it is necessary to find each occurrence of that property in the model, which can be a time-consuming process in cases where the data model is large.

With separate geometry and composition models, where the details of the material properties are stored in one place, the modification needs to be done only once.

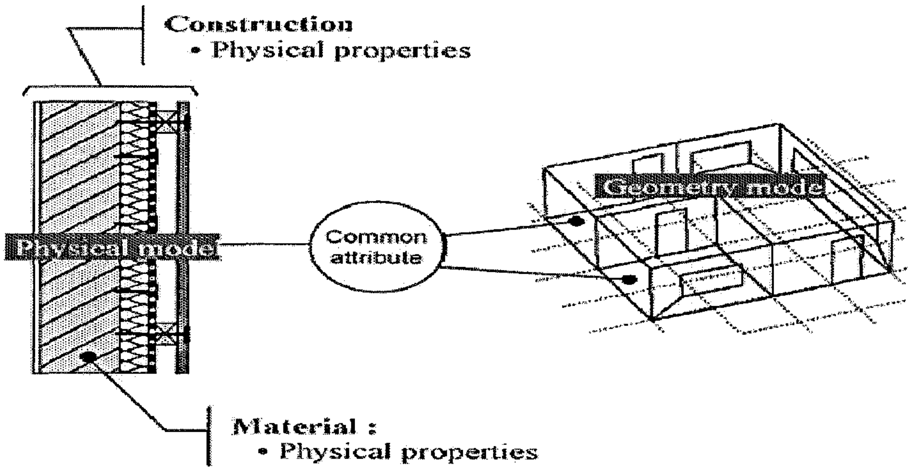


Figure 3.4 -Abstract Representation of the Separation Between Geometry and Physical Model

In this chapter, methodology of 3D modeling is discussed with the help of the three techniques that is Laser scanner, DesignBuilder and AutoCAD and Thermal analysis and energy dissipation is done with the help of the three techniques that are: Thermograms, DesignBuilder and Contours. In the next chapter the study area of the study is discussed in detail.

Chapter- 4

STUDY AREA

4.0 Metadata of the data used

2D maps and photo of a Research Building

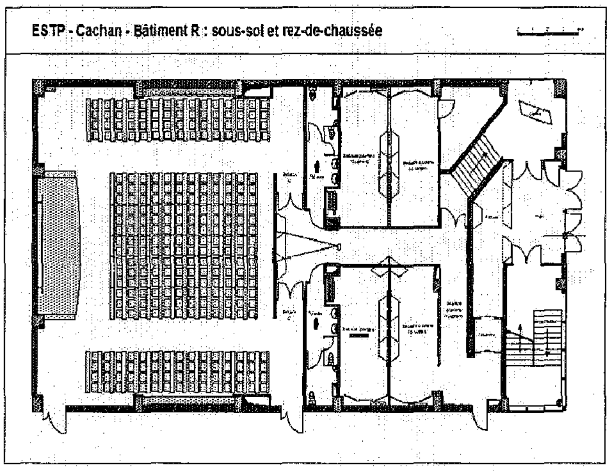


Figure 4.1-2D Map of a Ground Floor of Research Building

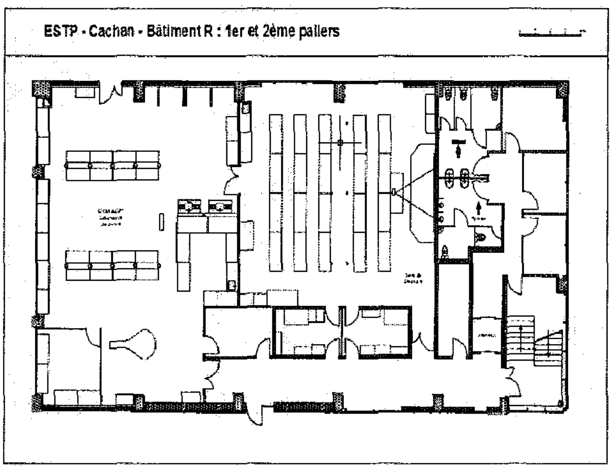


Figure-4.2 -2D Map Of A First Floor Of Research Building

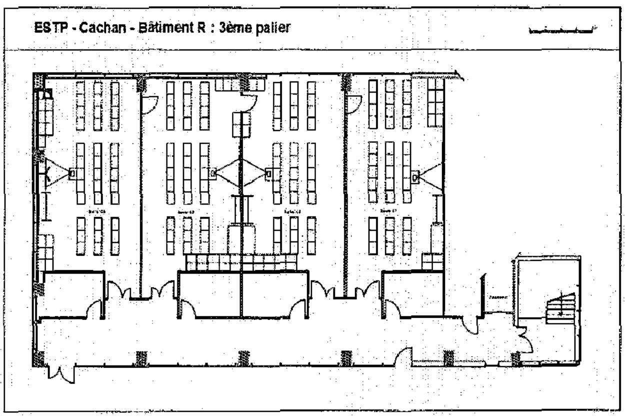


Figure-4.3- 2D Map of a Second Foor of Research Building

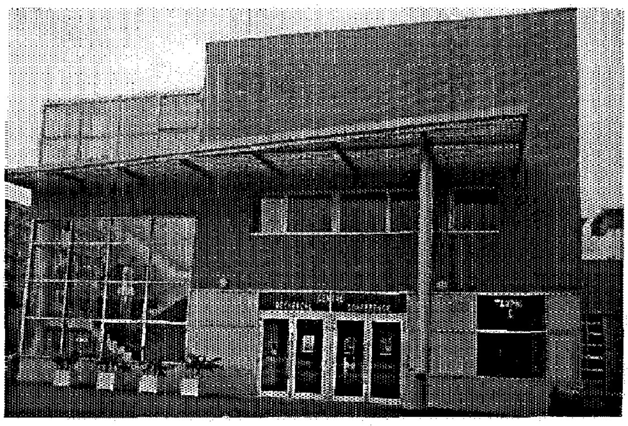


Figure 4.4- Photo of Research Building

Dimensions of Research Building

Length : 35.090 meters

Breadth : 16.924 meters

Height : 10.242 meters

4.1 Need of this Study

Adding the third dimension has dramatically increased the complexity of a building model in both a geometric and a semantic sense. While a large-scale 2D building is represented by its cadastral ground plan, the appearance of a 3D building is characterized by a lot more surface elements. Consequently, it can take many possible forms. The meaning of a 2D building is usually expressed by a number of semantic attributes attached to its ground plan. In 3D space, however, every surface element of a building can be described by special semantic attributes in addition to its more general attributes.

As an example the relationship between two individual 2D buildings can be judged by relative location, form and relative size of ground plan, orientation, proximity, and horizontal alignment, whereas two individual 3D buildings are related additionally by vertical alignment, roof form, relative height or surface texture. Beating in mind the complexity of a 3D building model, cartographers are confronted with the challenging task of deriving constraints for model generalization from the interdependencies among building parts, neighborhood relationships among individual buildings, and spatial structures of settlement blocks. So far the knowledge and conceptual models necessary to support these structures are still largely missing.

With regard to the graphic generalization needed for 3D visualization, cartographers face the challenge of acquiring knowledge of users and their tasks. In comparison to 2D visualization which is traditionally constrained to a plan view, 3D visualization is inherently moreover oriented in terms of viewing point, eye level and vision field. Although the central perspective view of a 3D building model gives a naturalistic impression, the observer experiences it differently from reality. For example, an observer typically has difficulties in estimating distances and orientations in the virtual space due to the varying scale of the presented model objects.

In computer graphics, the surface of an irregular 3D object can be generally represented by a wire frame that consists of triangles or quadrilaterals as typical mesh elements. By successively simplifying the mesh elements, a coarser resolution of the wire frame can be derived. However, this approach is very inefficient, if not impossible at preserving the semantic and structural characteristics of building objects. In current 3D visualization systems, building objects are typically rendered at three pre-determined LoDs. During a fly-through, the three

LoDs are dynamically switched over from one to another according to predefined distance thresholds. This leads to two main problems: (1) each building regardless of its size and position in the vision field preserves a uniform LoD, so discontinuity is inevitable between adjacent buildings, and (2) abrupt changes or "popping" effects in the shape of the building occur simultaneously to many objects in a rather unforeseen manner. In order to achieve a smooth graphic transition while preserving the visual clarity of important objects, a building needs to be examined at its geometric primitives, with each being rendered at a LoD according to the distance to the viewer, whilst a sufficiently large number of intermediate morphing steps are inserted between adjacent LoDs. Such an approach requires both a thorough understanding of the meaning of the individual primitives and their relationships in the context of use and, the availability of a 3D MRDB. Both requirements are difficult to satisfy. Moreover, too little is known about how many LoDs an observer really desires for their personal convenience, how well they will recognize the characteristics of a 3D building model at different abstraction levels, what kind of impacts their task will have on their perception and cognition and what kind of interactions make sense.

Another challenge lies in the relative immaturity of existing 3D systems. Although many GIS vendors tend to expand their tool kits to include 3D interactions, users are usually only allowed to change a subset of the visualization parameters (camera position, light source, texture and colour). Often the individual 3D objects or object parts and their associated attributes are inaccessible due to the absence of necessary analytical and interaction methods in spite of their acknowledged importance (Hedley, 2003). Over recent years, efforts have been made to develop a range of intuitively operable 3D widgets that allow the direct manipulation of 3D data, such as selection by virtual pointer, modification and deformation of various spatial entities (Leiner et al., 1997; Rahman and Khuan, 2003; Yang et al., 2004).

In the above chapter, 3D widgets are often incompatible with each other (often due to a lack of standards). Without the support of 3D interactive functions, both developers of generalization methods and users have to invest considerable effort in understanding the behavior of 3D objects and their generalized forms. In the next chapter, data processing is done with the methodology developed.

Chapter- 5

DATA PROCESSING

5.0 3D Digitalization

Five steps plus one global post-processing step are necessary to create a complete digital volumetric 3D model:

I. **Data acquisition.** During the gagging of the range image the surface of parts of the scene is scanned.

II. **Registration.** Each range image is registered in a common coordinate system. The odometer based robot pose serves as a first estimate and is corrected by registration.

III. **Planning.** The next best view is calculated and a collision free path is planned in 3D to that pose. Hereby, the information gain is optimized considering the cost of travel and turning.

IV. **Robot control.** The robot moves to the target pose using the path computed in the previous step including dynamic collision avoidance.

V. **Iteration.** The process continues with the next data acquisition until the complete environments is digitalized.

VI. **Integration.** The acquired data are post-processed, e.g., 3D meshes are generated and stored.

5.1 Laser Scanning Technique

Once the point clouds have been acquired, they have to be processed and converted into useable information. Since the required input to the structural calculation phase consists of a number of slices, each slice deployed into a number of 2D point coordinates, a strategy had to be set up on how to get to these deliverables in the most efficient way.

Using the Cloudworx software (every point cloud was filtered for noise removal, redundant points were removed, a mesh was created and small holes were filled using a curvature-based filling algorithm. Then a point grid, aligned to this new coordinate system, was projected onto the meshed model and the coordinates of these projected points were exported to a DXF-file that can be read by CAD software. As a compromise between manual post-processing time and computation accuracy, the size of the grid was chosen to be 10 cm providing 21 slices for each shell in one direction and 39 slices in the other direction. To help automate the point extraction slice by slice and convert their coordinates into a two-dimensional frame a CloudWorx (AutoCAD) application was written that fits a plane to a number of selected points and exports the coordinates of the points in the plane to a text file.

5.2 Modeling in DesignBuilder

The laser distance meter is used to draw a 2D map of the building in AutoCAD. The 2D map is transferred to the DesignBuilder software. The heights of the objects are calculated with the help of the laser meter and the 3D model is created in the Designbuilder. Designbuilder showed the results in the form of 3D model, heating and cooling calculations and simulation results.

Steps to create a Building in the DesignBuilder

i) Open the DesignBuilder software.

ii) Select a template or open a new file.

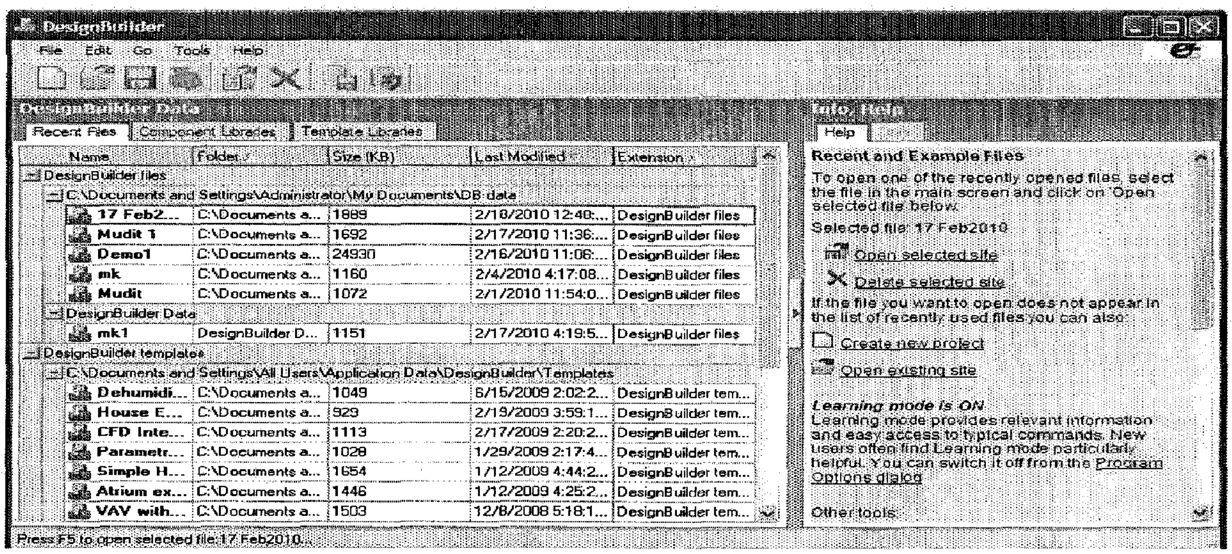


Figure 5.1- To open a File in DesignBuilder

iii) Select a title, location and the analysis type of the building.

iv) Click on the button i.e. add new building.

v) Now define the Model Type, Project Details, Assessor Details and Occupier Details.

vi) It will show three axes in different colours X axis is in red colour, Y is in green colour and the Z axis is in blue colour. As one draw a line if this line has the same colour as of the axis then this means that the line is parallel to that axis. One gives the direction with the mouse and then enters the length by keyboard. So that it will be exact as user want.

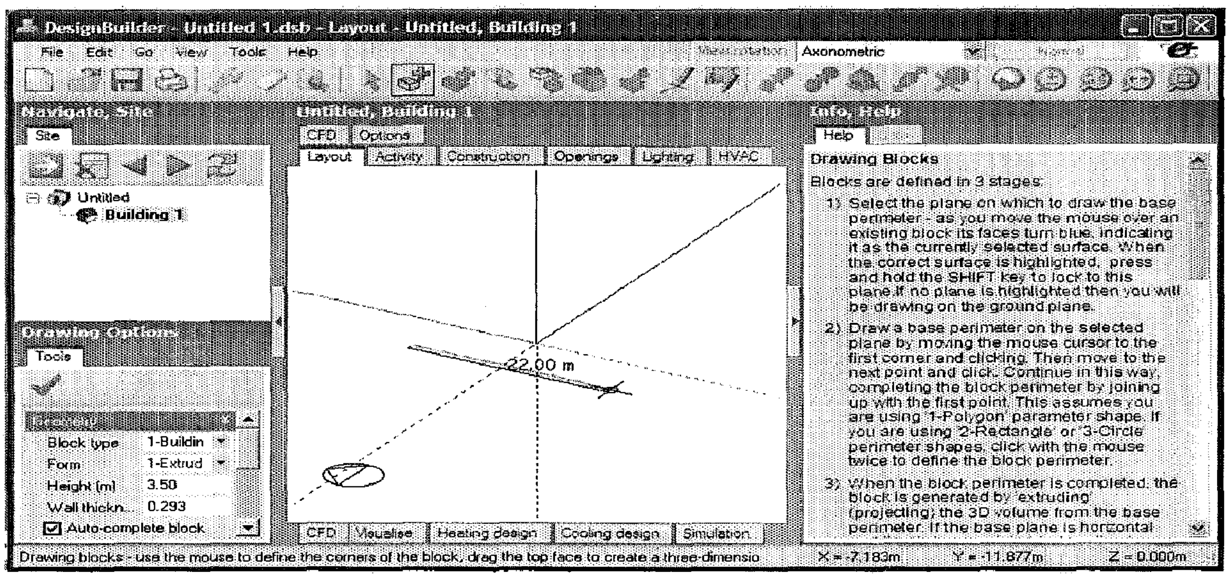


Figure 5.2 -Drawing a Boundary of the Building

In the given figure, the line has the same colour as of the Y-axis, so it is parallel to the Y axis.

vii) Now the whole building is designed. Ground floor is prepared.

viii) Create the second floor on the ground floor. Useful information: red points show the edges, cyan points show the middle points and the green points show the end points in the buildings.

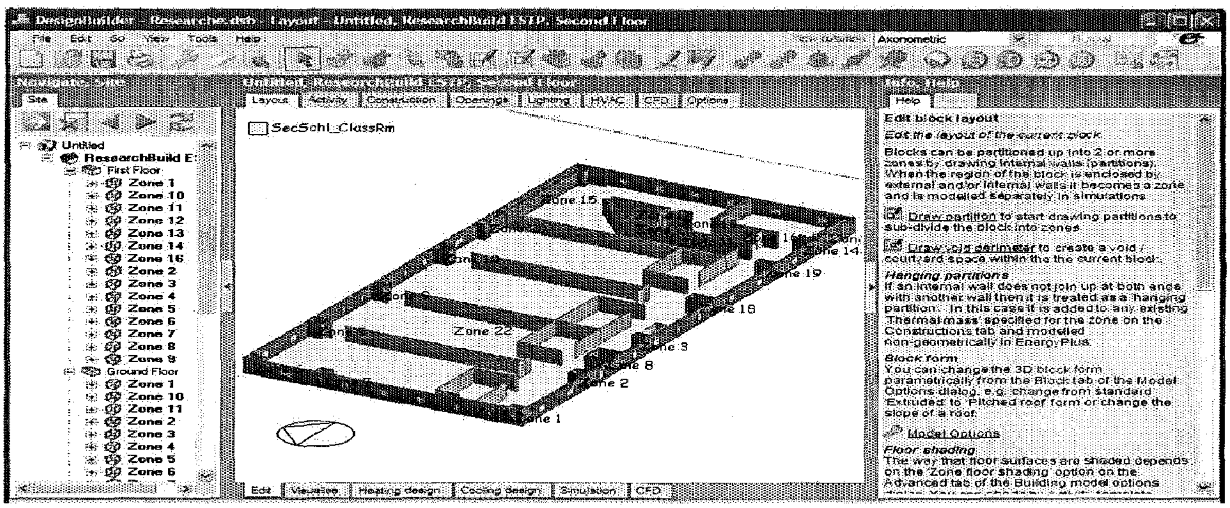


Figure 5.3- Drawing a Partitions in a Building

ix) Now the Heating and Cooling calculations can be done on the 3D model. According to the calculations, the ventilation system, openings and glazing can be set.

x) Simulation is done after that to see the model in the movie format.

xi) CFD can be applied to find out the boundary conditions of the building.

5.3 Modeling in Total Station

Geographical Positional System is used to get the co-ordinates of the some prominent points. By using these control points, the position of the total station is found out. The points on the building are taken with the help of the total station.

Co-ordinates of the points have been calculated by GPS on. Total Station is used on that control points to find out the other points to map the building in the 3D.

To find the azimuth of the points calculated from the Total Station

i) Calculation of the azimuth of all the GPS control points (points that you are able to see). The azimuth is the angle formed by the oriented direction AB with the parallel axis to the axis of the ordered representation. The azimuth positively is counted of 0 to 400 ranks in the direction of the aiguilles of a watch.

$$V_{St-Pt} = 2 \times \arctan\left(\frac{X_{Pt}-X_{St}}{Y_{Pt}-Y_{St}+\sqrt{((X_{Pt}-X_{St})^2+(Y_{Pt}-Y_{St})^2)}}\right)$$

ii) After finding the azimuth of all the GPS control points, calculation of the horizontal angles of all the GPS control points.

iii) Then calculate the $V_0 = G_{St \to Pt1} - h_z$(for example).

iv) Calculated the average of all the V_0 is called as$V_{0\,(average)}$.

v) $V_{any\,point} = V_{0\,(average)} + h_{z\,any\,point}$

Now $V_{any\,point}$ and distance with the laser in total station. So we can calculate the 3 dimensional co-ordinates of the buildings.

A Total Station is an electronic/optical instrument used in modern surveying. The total station is an electronic theodolite (transit) integrated with an electronic distance meter (EDM) to read distances from the instrument to a particular point.

All the calculations have been done in the Microsoft excel or other software like Decatop, Covadis. For saving the file in the AutoCAD format, open it in the Microsoft excel by separating the values by the comma. Then the Decatop software is used to find all the points with respect to the ellipsoid. Then the points are exported to the AutoCAD to make a 3D model of the building.

Then open the file supported by AutoCAD in the AutoCAD to create the 3D model of the building.

Hygrometer and thermometer is used to find the humidity and the temperature of the points in the building at a distance of 1 meter each. The contours are created with these points in the AutoCAD to find the thermal analysis of the building. It is like contours which show the difference of the temperature with the distance.

5.4 Thermal analysis and Energy Dissipation

Thermal analysis is done with the help of the FLIR E series camera. The photos are clicked with this camera. Then the analysis is done on the thermograms to find the defects and leakages in the building. As liquids evaporate they draw heat from their surroundings. Therefore wet/ damp spots are typically colder than their surroundings. The thermal imager sees those temperatures differences, even if it is less than 0.1°Celcius. Cold air can contain less moisture than warm air. Moisture always condenses on the coldest place/ spot. A cold spot will be an indicator that damp might be present. When the water dries in a wet piece of clothing the piece becomes colder than the ambient around it from where it takes the energy for the evaporation process to takes place.

In this chapter 3D model is created with the thermal and energy analysis. This model contains the temperature at each point. So it can be used for the analysis purpose. Now the 3D model is enriched with many points in space and temperature and humidity also. The temperature points are like contours, it is contours of temperature and humidity for the analysis. Next chapter is about the results obtained from this chapter.

Chapter- 6

ANALYSIS OF RESULTS

6.0 Comparison and Quality Assessment

Aim of this section is to compare the models derived from the different techniques. For comparing laser and surveying data, a point to point comparison makes no sense, since laser scanning technique does not allow choosing the point to be measured. That's why wireframes obtained independently via each technique constitute a first comparison basis.

6.1 Comparison of the Three Techniques Based On Wireframes

Each wireframe is composed of 19 windows which contour lines have been digitized on each data set. Thus, a wireframe produced by point cloud digitizing has been compared to tacheometric data.

6.1.1 3D Mesh model by laser scanner

In the same way, the photogrammetric model has been compared to laser scanning model and to surveying model.

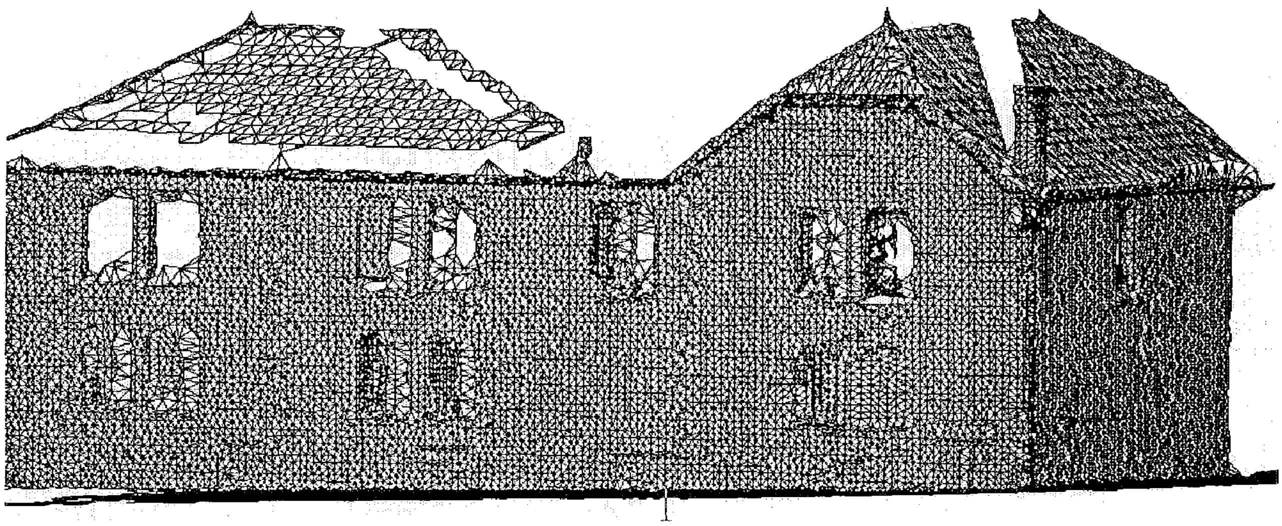


Figure 6.1 - 3D Model of a Student Building by Laser Scanner Mesh Format

Then, the 3D distances between each wireframe have been computed and analyzed. Results showed that the detection quality or the similarity between models must be related to the type of window. More particularly, laser scanning and survey models show the lowest deviations for rectangular reveal windows.

6.1.2 3D Surface model by AutoCAD

The main reason is the difficulty to measure the circular and chamfered parts of that kind of windows by tacheometry. On the other hand, the laser scanning enables to acquire each little detail, like for instance the sandstone linings of the windows.

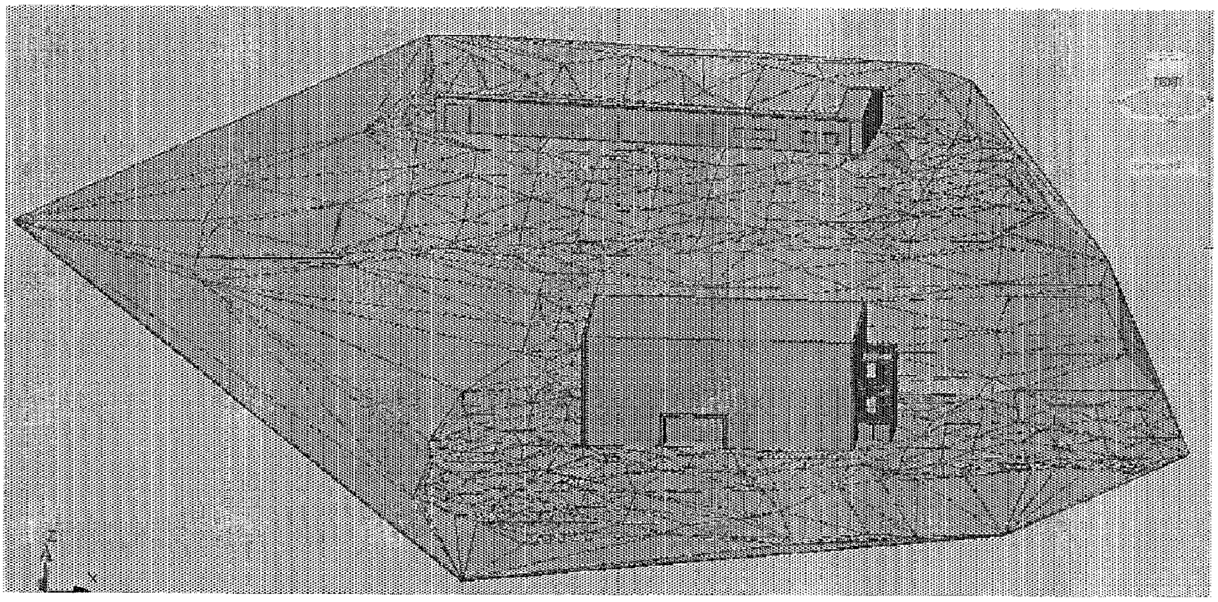


Figure 6.2 - 3D Model of A Building In Autocad

6.1.3 3D Surface model by DesignBuilder

Globally, the absolute accuracy of every model is in agreement with the inherent accuracy of the geodetic network, i.e. +/- 5cm. Additionally six object edges have been analyzed to compare photogrammetric and laser scan recording.

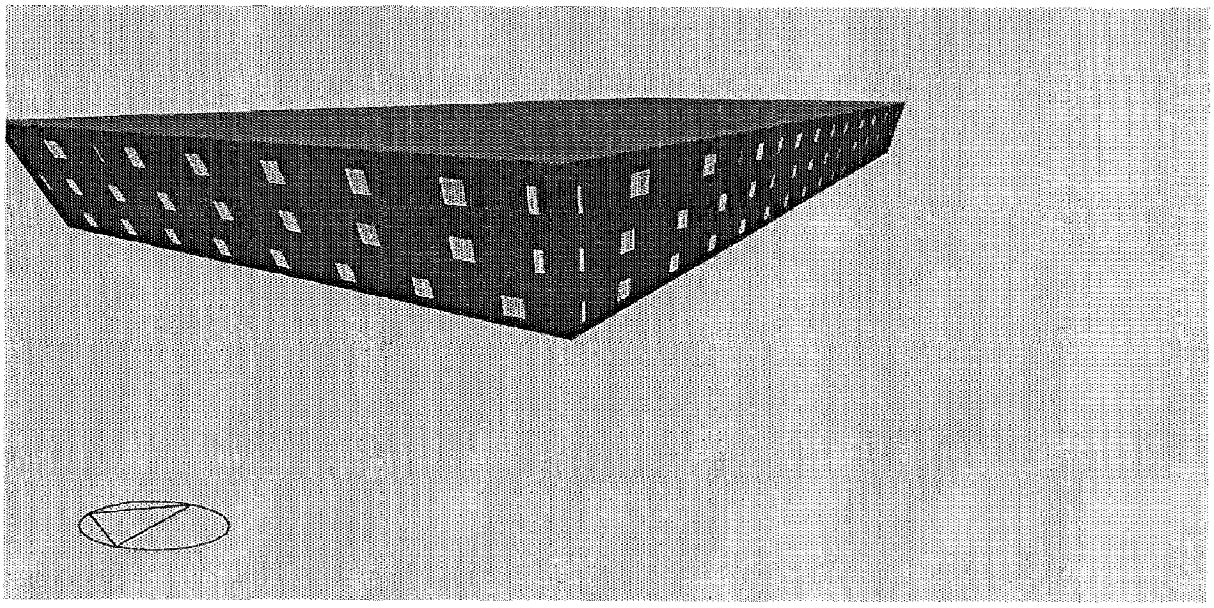


Figure 6.3 - 3D Model of Research Building by DesignBuilder

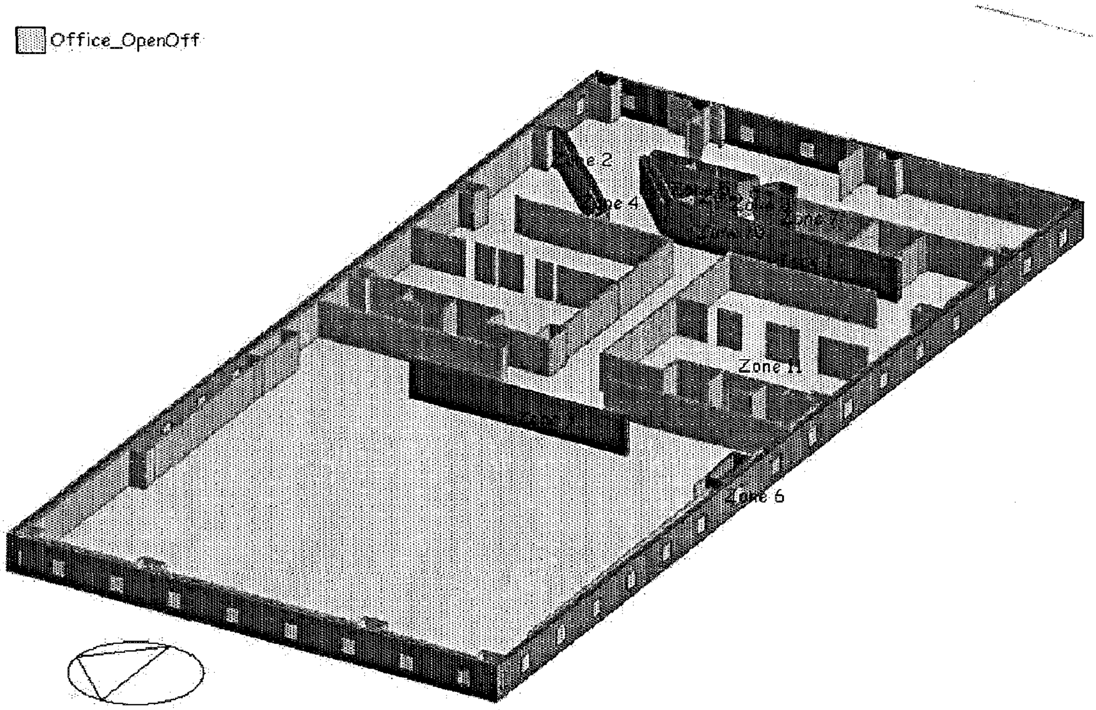


Figure 6.4 - Ground Floor of Research Building by Designbuilder

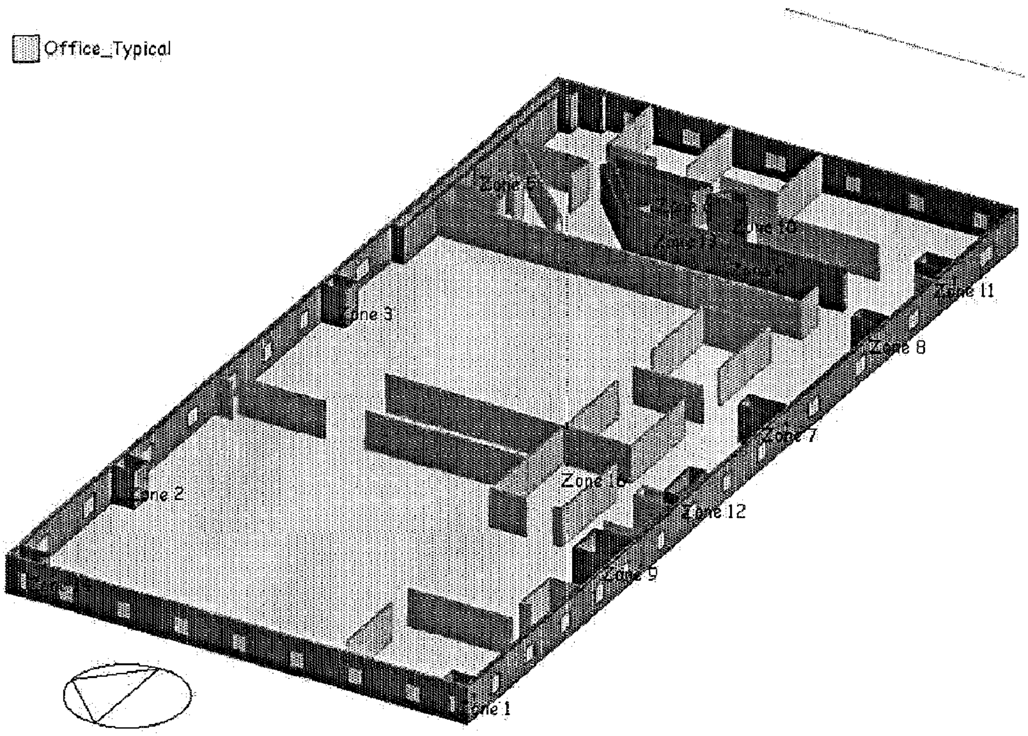


Figure 6.5 - First Floor of Research Building by Designbuilder

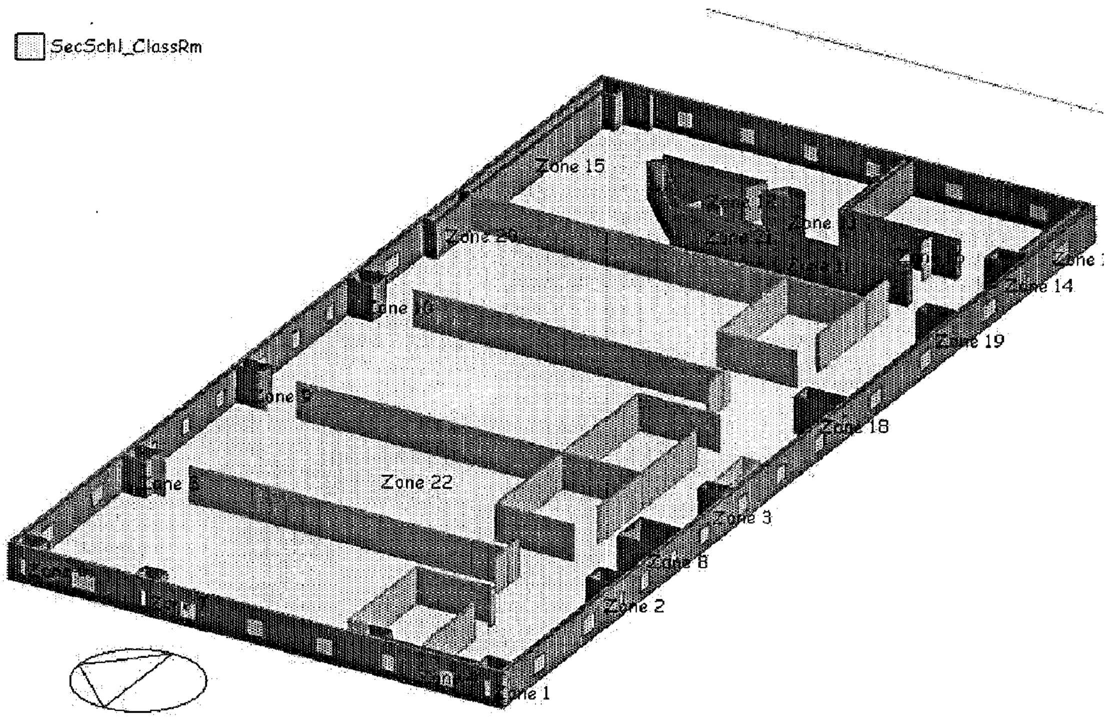


Figure 6.6 - Second Floor of Research Building by Designbuilder

To derive the edges from the TLS point cloud, adjusted planes had to be estimated in a local area left and right of the edge. By intersection of these two planes the particular edge can be determined and compared to the corresponding edge in the photogrammetric restitution.

To determine the deviations, the mean distance between the photogrammetric edge points and the laser derived edge has been calculated. Dependent on the regularity of the edge the mean distances vary between ± 2.0 cm and ± 3.7 cm.

Due to the typical characteristic of the edges of a medieval building the photogrammetric edge points lie closer to the object than the laser derived edges which lie slightly outside the building.

Globally the 3D distances calculated between the three models are similar with respect to the tolerances fixed by the specifications (± 5 cm in X, Y, Z). So, the results of this wireframes comparison confirm that the 3 techniques –conventional surveying, laser scanning, photogrammetry are in accordance to the accuracy required for the documentation of the building.

6.2 Limitations of the Involved Terrestrial Laser Scanning

The biggest part of the buildings as well as the surrounding gaps and the main parts of the fortifications have been captured by TLS via 6 stations. The scanner has been set up and oriented over known geodetic points belonging to a 3D network of about 25 points.

Therefore, the point clouds were directly geo-referenced and can already be visualized in the field.

Table 6.1 Overview of the Instruments Used for Acquisition and Summary of the Amount of Data Recorded

Data	Instrument	Amount Of Data	Accuracy
Laser Scanner	HDS 6100 Leica	25 million points all around the building	5 mm, 1 m to 25 m 9 mm to 50 m range
Total Station & GPS	Trimble M3 3" DR	100 points (1 day); Eastern façade (windows), Doors	2"Prism ±(2+2 ppm × D) mm 2"Reflectorless ±(3+2 ppm x D) mm 3",5" Prism ±(3+2 ppm × D) mm 3",5" Reflectorless±(3+2 ppm × D) mm
	Leica GPS 1200+	30 Control Points	6/7 mm in E,N and 15 mm in h
DesignBuilder	Laser Meter Leica DISTO A5	-	Range 5cm-200m. Accuracy ±2mm.
	Thermohygrometer Testo 625		Meas. Range -10 to +60 °C Accuracy ±1 digit ±0.5 °C

6.3 Limitations of the Surveying Data

Of course tacheometric measurements were indispensable not only for providing a geodetic network, but also for acquiring control points on the façade. Moreover, especially the windows have been captured by this technique, in order to provide a skeleton plan representing the outlines of significant objects or contours (windows, doors, etc.).

6.4 Comparison of the Three Techniques on Thermography

The measurement of temperature remotely and assigning a colour based on the temperature. Thermal imaging is a science of seeing temperature patterns using special electronic cameras. Rather than seeing light, these remarkable instruments create pictures of heat and cold.

6.4.1 Thermography by thermograms

They measure infrared (IR) energy and convert to data to images corresponding to the temperature. Here is the illustration of the application of thermography of housing particularly related to energy performance. Something inconceivable for the perfect beginner: the thermograph goes into campaign "thermography to see" around his home with his camera in hand. Its winter and overcast day, or better, the sky is clear at night. This explains the actions of "thermography inventory" or "thermography awareness.

Does this mean that work is to carry everywhere to improve energy efficiency? However, there are priorities to be defined, and an increase in the yards. This is the "before renovation thermography before and renewable energy", which will grow in size if the charlatans during exploration did not destroy any confidence in this technique .

Then there will be "Thermography in reception work, it will eventually and gradually necessarily required." Beware, this is not the camera that decides, the thermograph, and does not deserve this name as the thermograph trained and controlled, which is taking place right now.

6.4.1.1 Thermal insulation

This is the crucial point to consider in a building. The points below may be of origin in new or under renovation.

i) no insulation
ii) degradation of the insulation

iii) poor implementation of the insulation

iv) insufficient thickness of insulation: the only way now to control this serious point is to check the supply to its implementation.

a. Lack of insulation in wall

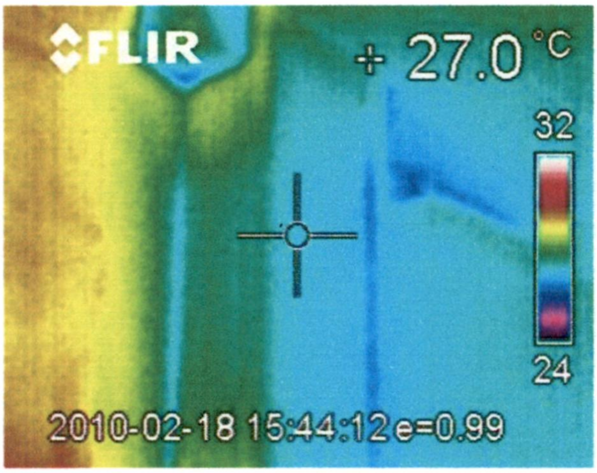


Figure 6.7-Research Building, Thermogram **Figure 6.8-Research Building Optical Photo**

After partial renovation, this home still consumes too much electricity for heating. Among other defects embodiment, the thermal imager detects immediately the absence of insulation on the full height of the room. It is a defect with absence of voluntary control over the site.

b. Lack of insulation in roof

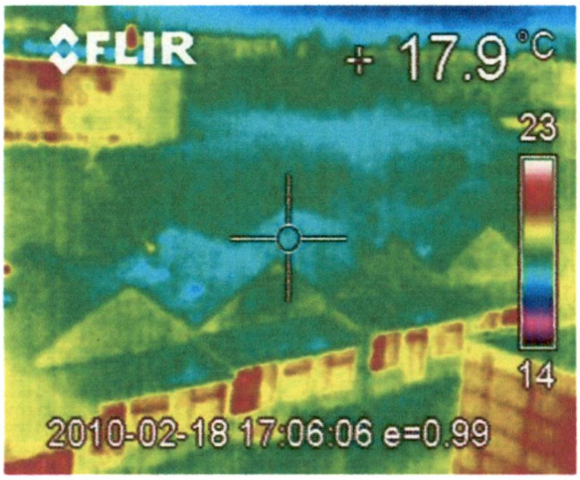


Figure 6.9- ESITC Buildings, Thermogram **Figure 6.10- ESITC Buildings Optical Photo**

c. Degradation of insulation wall

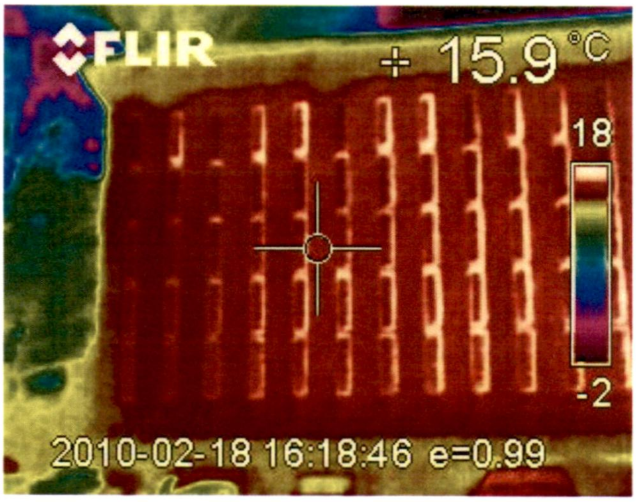


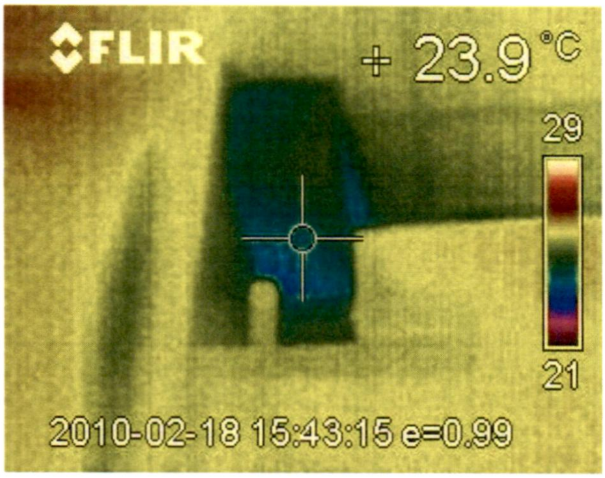
Figure 6.11-Bibliotheque Building, Thermogram **Figure 6.12-Bibliotheque Building Optical Building**

Wood construction: The strip insulation rolls do not fully plastered to the wall on both sides of the floor above.

6.4.1.2 Thermal bridges

It is the delicate point of construction in France since the first thermal regulations in 1974. The thermal bridge occurs mainly at the junction of concrete slabs and vertical walls. The insulation inside the housing is the primary cause of these thermal bridges that do not exist in the former.

a. Thermal-time



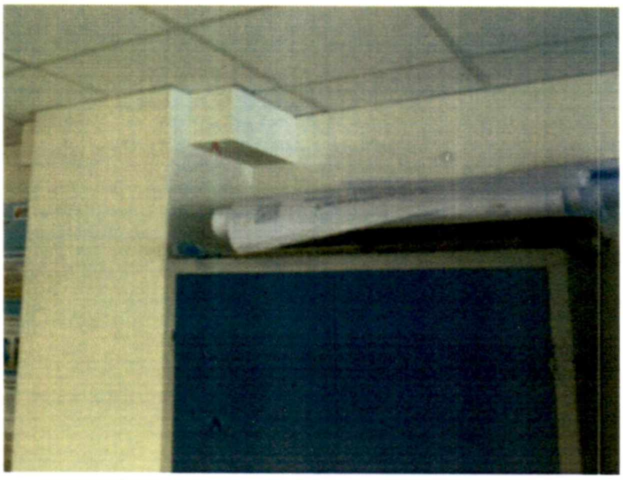


Figure 6.13 - Research Building Thermogram **Figure 6.14 Research Building Optical Photo**

Pavilion Concrete beams: Vertical wall isolation. The right side of the ceiling is topped by a terrace (no insulation) and presence of a little winter sun, which one benefits while he is there. The left side of the cap includes a heated room. The beam directly on the outside edge and creates a thermal-time, which would be in "hot" thermography from outside.

b. Thermal metal carpentry

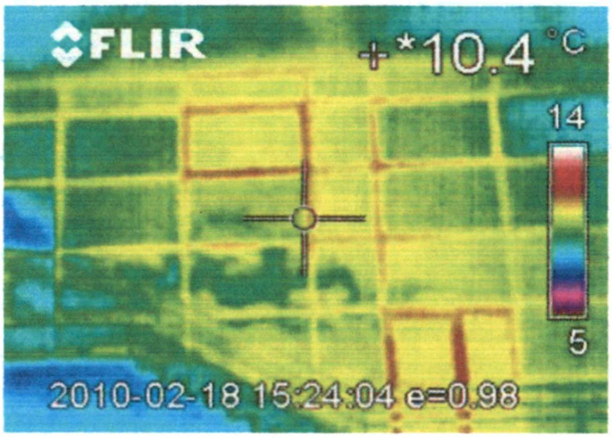


Figure 6.15 - Research Building Thermogrm

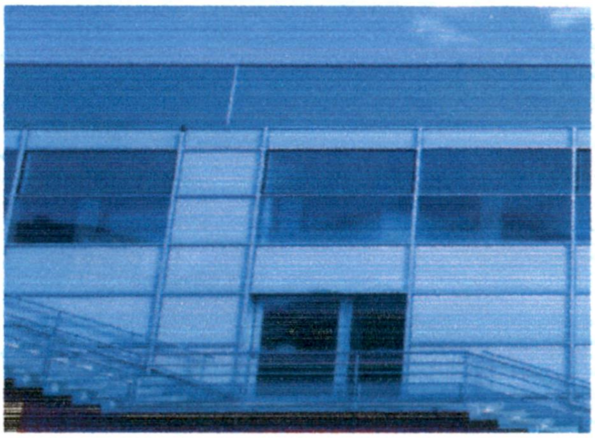


Figure 6.16- Research Building, Optical Photo

Aluminum joinery (no thermal break). Chassis sliding, thus posing problems of air-tightness (Can we guess the top right of the window). Inner side, the woodwork is the seat of condensation in cold weather.

6.4.1.3 The air-tightness

This is a subject very strange. As if housing was to be airtight! Well yes, the cold air intakes and heat vents are not controlled the source of a large share of energy consumption of building. Mastery of the subject, check the air-tightness of the building envelope so that the mechanisms of controlled ventilation (MCV) are working properly. Neither more nor less.

i) cold air intake by the woodwork, between frame and masonry
ii) hot air outlet by the woodwork, between opening and sleeping
iii) entry of cold air through the electrical conduits
iv) cold air from the bottom wall

This technique can be used in detecting problems of air-tightness thermography, when the atmospheric pressure difference between inside and outside is too low. But the primary purpose of the blower door to measure air permeability of building envelope, which gives a numerical result: thermography is not involved in this measure.

a. Joinery between frame and masonry

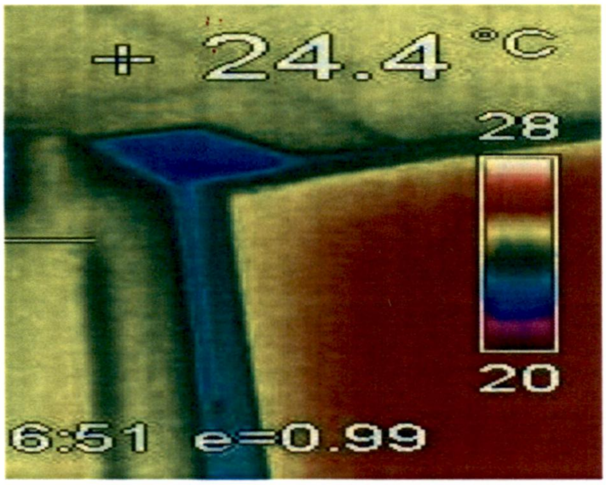


Figure 6.17- Research Building, Thermogram **Figure 6.18- Research Building, Optical Photo**

Thermography from inside shows that air penetrates between the masonry and the frame (detail right) - natural ventilation - and the window is not in question. Silicone sealant to correct the structural deficiency: non compliance with DTU. This problem is extremely common.

b. Joinery between opening and sleeping

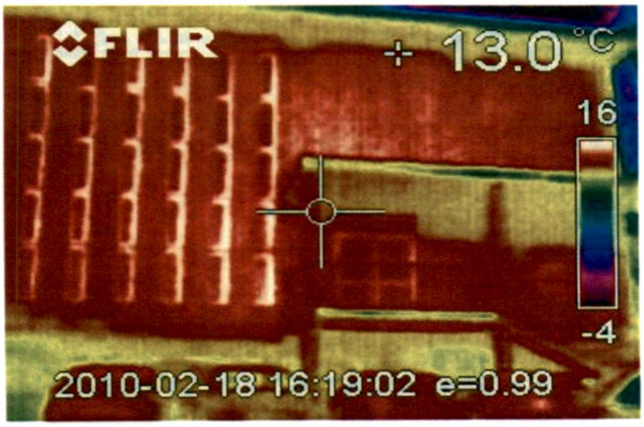


Figure 6.19- Bibliotheque Building, Thermogram **Figure 6.20- Bibliotheque Building, Optical Photo**

Shooting a wooden window from outside. There exits of hot air coming warm opening.

c. Electrical conduit

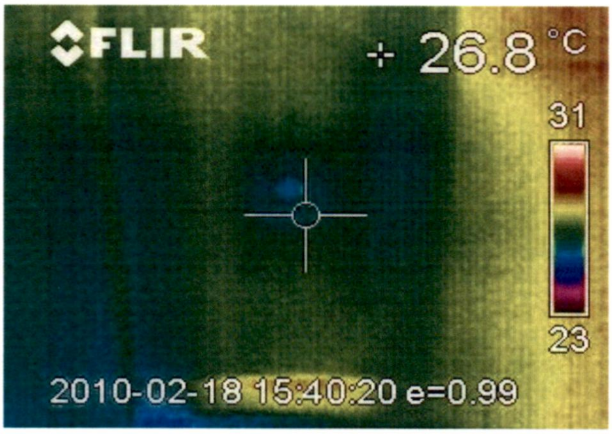


Figure 6.21- Research Building Thermogram

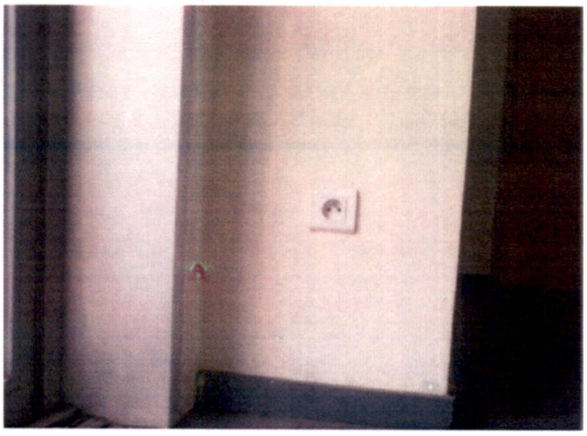


Figure 6.22- Research Building, Optical Photo

Salon nine (in the extension of a flag) heated, but not yet occupied. Failure classic made by the electrician entry of cold air through an outlet. The door did not show such a failure while this is more than one would expect to see from air intakes natural ventilation.

d. Low walls

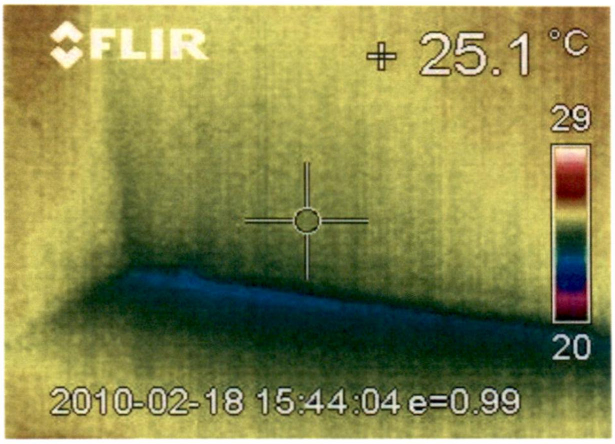


Figure 6.23- Research Building, Thermogram

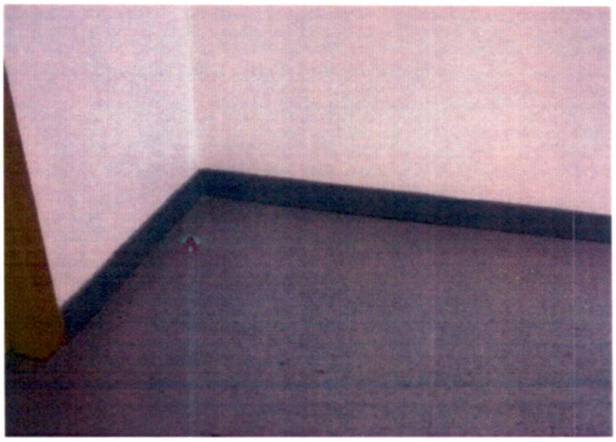


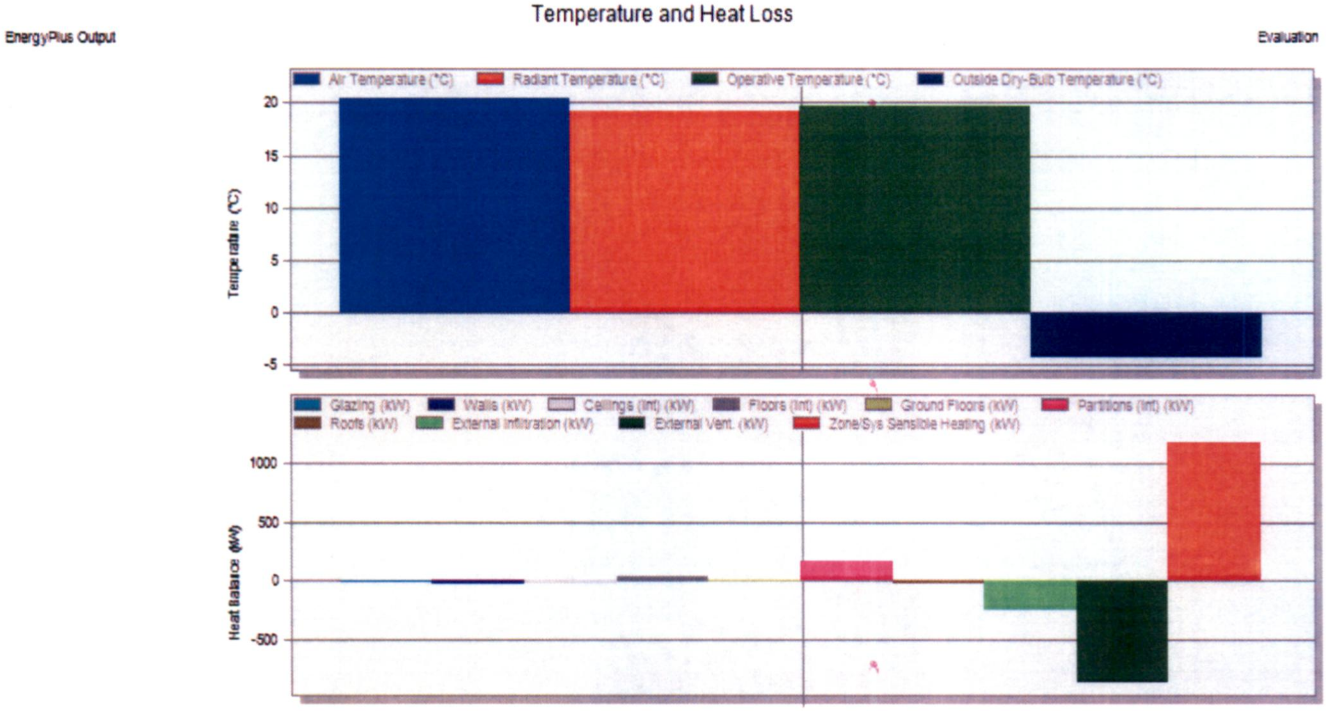
Figure 6.24- Research Building, Optical Photo

This finding need for housing depression by the technique of "blower door" became a classic control habitat for awarding the label "low-energy building. The air intake under the front door is important, but more surprising is the air intake under the wall itself.

6.4.2 Thermography and Energy dissipation by DesignBuilder

DesignBuilder also has given many results like heating and cooling calculations and simulation results.

The heating calculation is done by considering 12 march 2010. Determine the size of heating equipment required to meet the coldest winter design weather conditions



Air Temperature (°C)	20.37
Radiant Temperature (°C)	19.25
Operative Temperature (°C)	19.81
Outside Dry-Bulb Temperature (°C)	-4.20
Glazing (kW)	-15.11
Walls (kW)	-20.98
Ceilings (int) (kW)	-34.22
Floors (int) (kW)	34.25
Ground Floors (kW)	-6.18
Partitions (int) (kW)	156.83
Roofs (kW)	-21.98
External Infiltration (kW)	-246.43
External Vent. (kW)	-864.42
Zone/Sys Sensible Heating (kW)	1174.74

Figure 6.25 - Heating Calculations Research Building

The cooling calculation is done by considering 12 march 2010.To determine the capacity of mechanical cooling equipment required to meet the hottest summer design weather conditions.

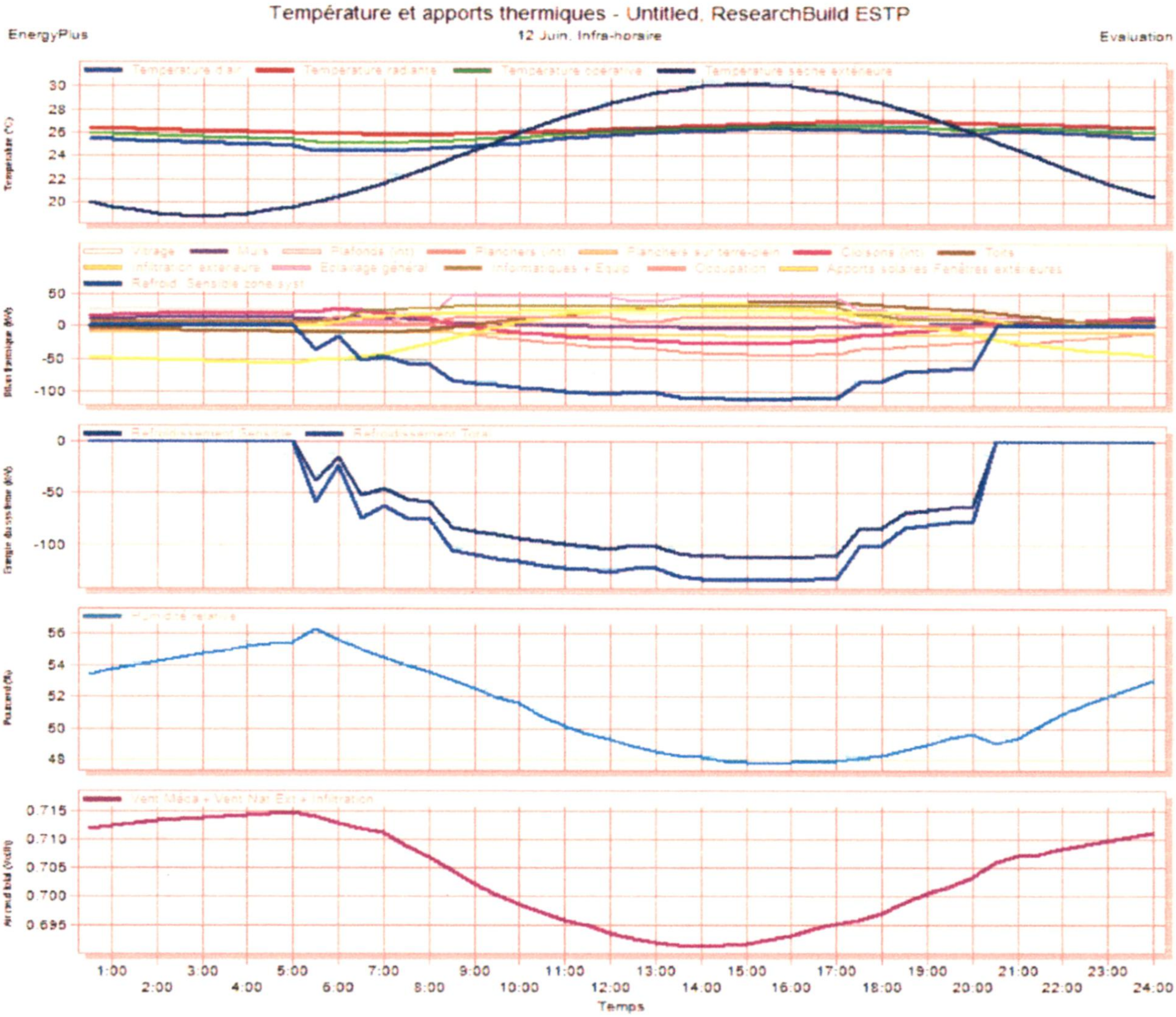


Figure 6.26 - Cooling Calculations Research Building

Weather data comes from Hourly weather data file. It includes consideration of heat conduction and convection between zones of different temperatures. It includes solar gain through windows. Includes one or more 'warm-up' days to ensure correct distribution of heat in building thermal mass and the start of the simulation. Warm-up continues until temperatures/ heat flows in each zone have converged.

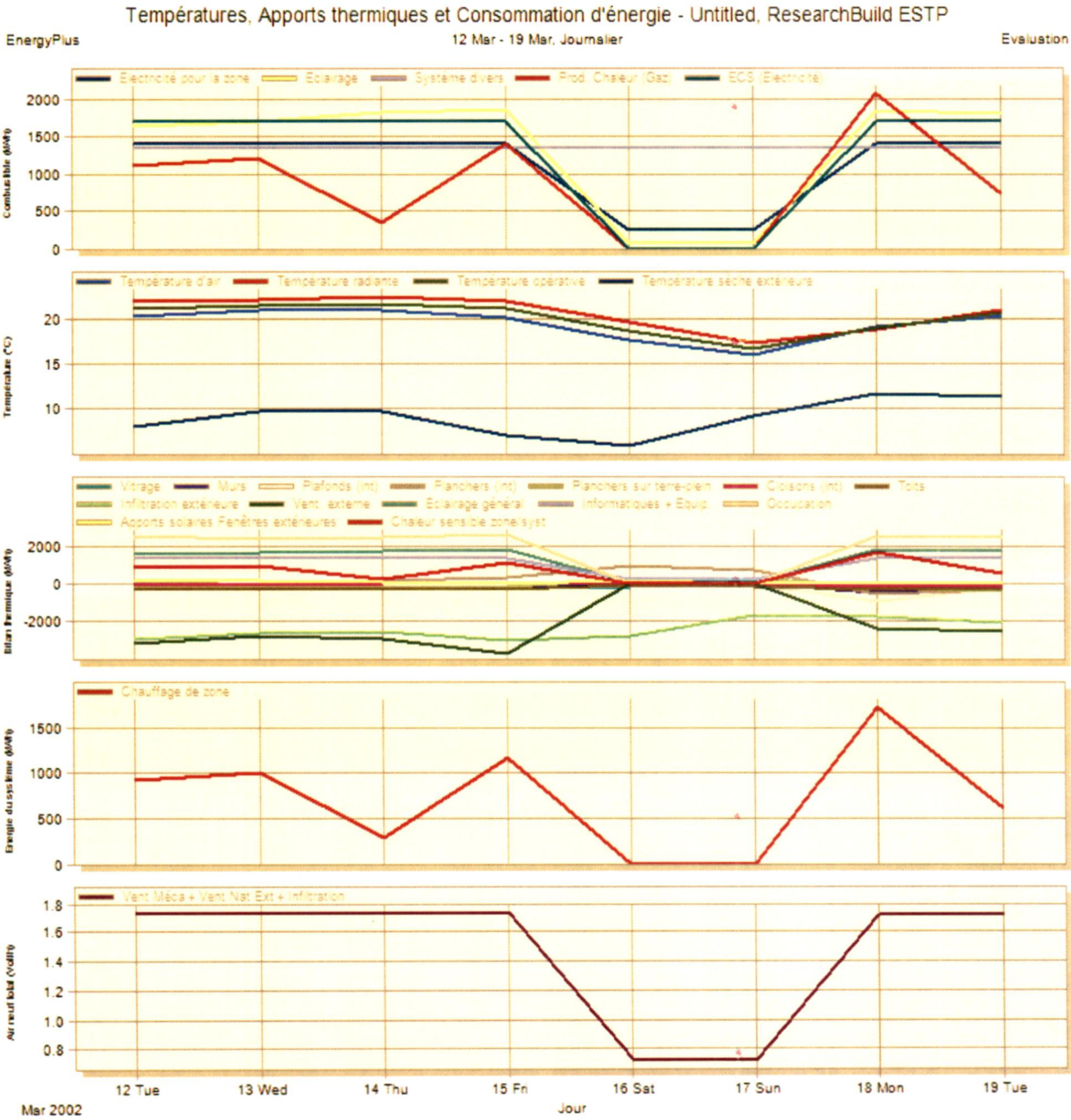


Figure 6.27 - Simulation Calculations Research Building

6.4.3 Thermography by AutoCAD

The contours are created with the Covadis 3D(AutoCAD). It shows the variation of the temperature inside with the help of the contours. It shows the defect in the building if it is present in it.

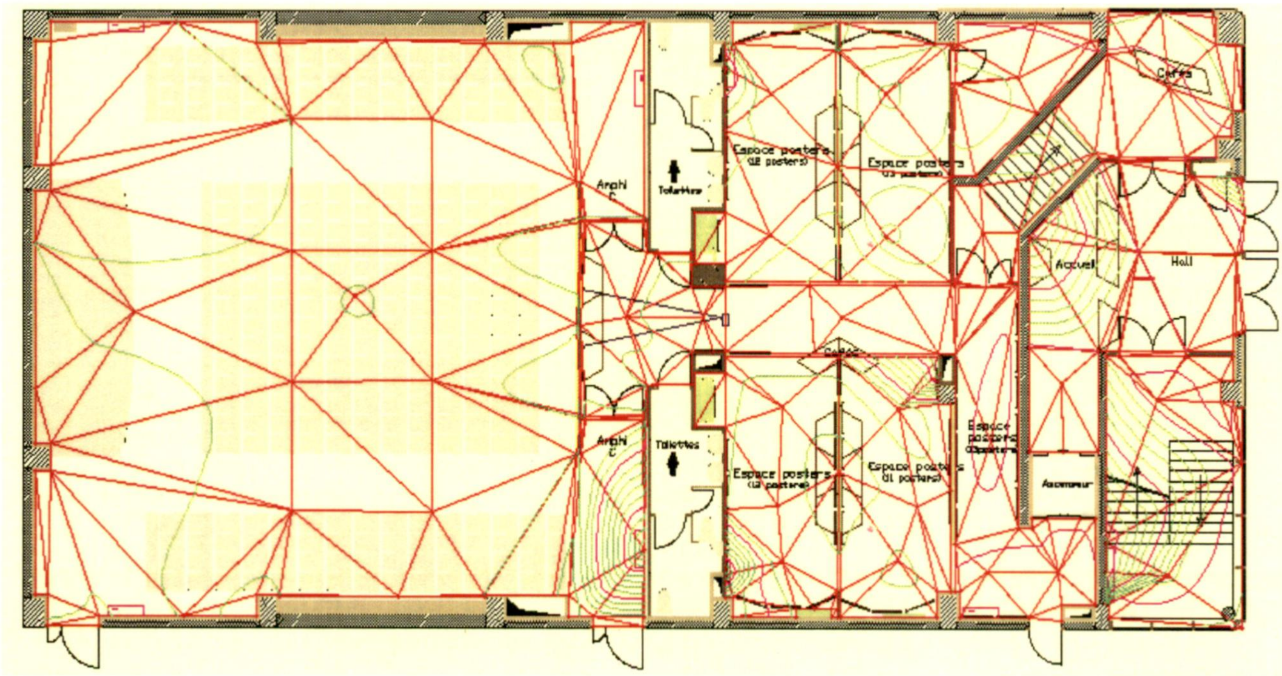


Figure 6.28 - Contours of the Ground Floor of the Research Building

In the Fig. 6.28, the contour lines are drawn with the interval of .2°C. After each 5°C, there is one different colour line of contour. So if there is irregular line of contours it shows the fault. This can be seen in the conference hall of the ground floor in Figure 19.

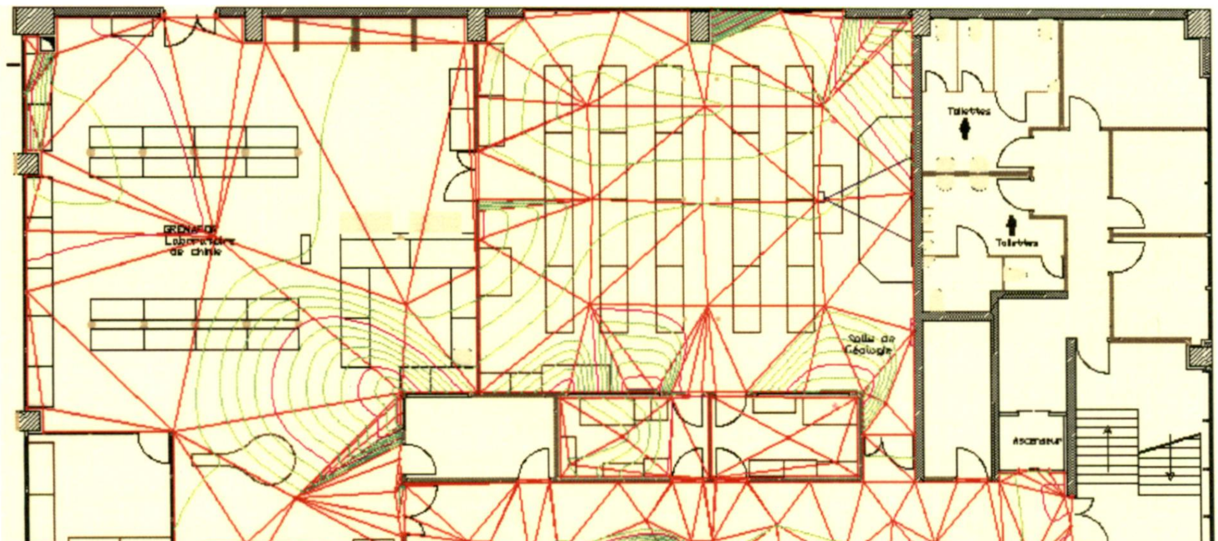


Figure 6.29 - Contours of the First Floor of the Research Building

In the Figure 6.29, the fault can be seen in the laboratory area. It is just in the left most cabin.

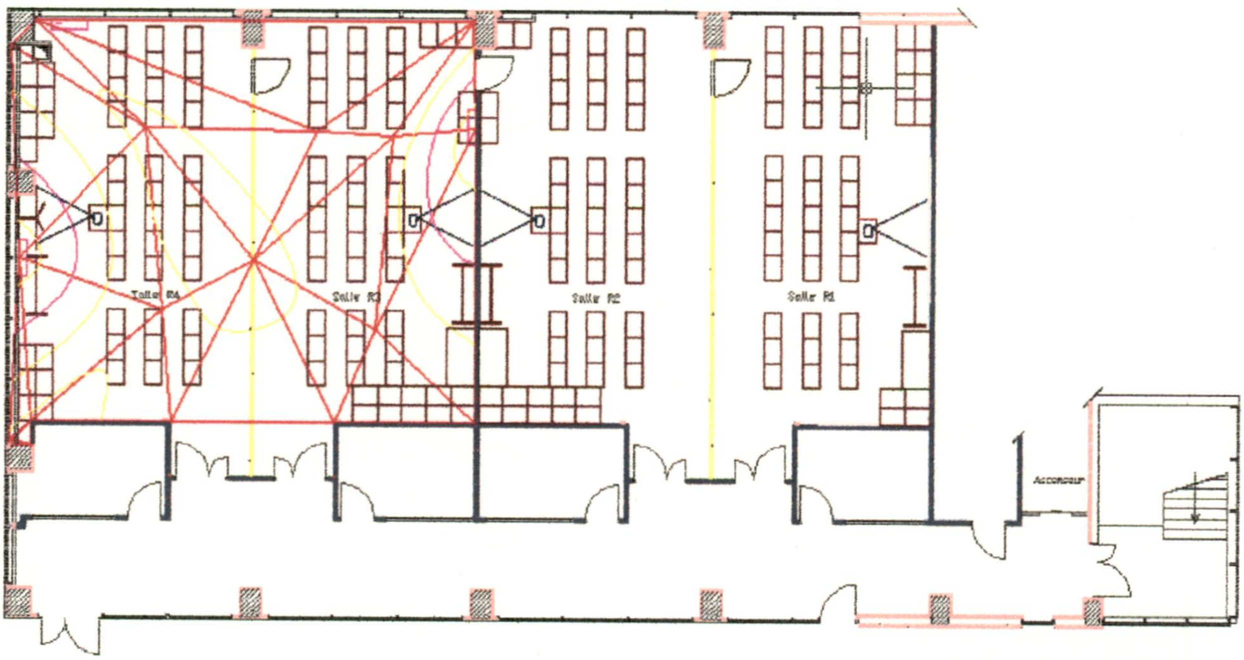


Figure 6.30 - Contours of the Second Floor of the Research Building

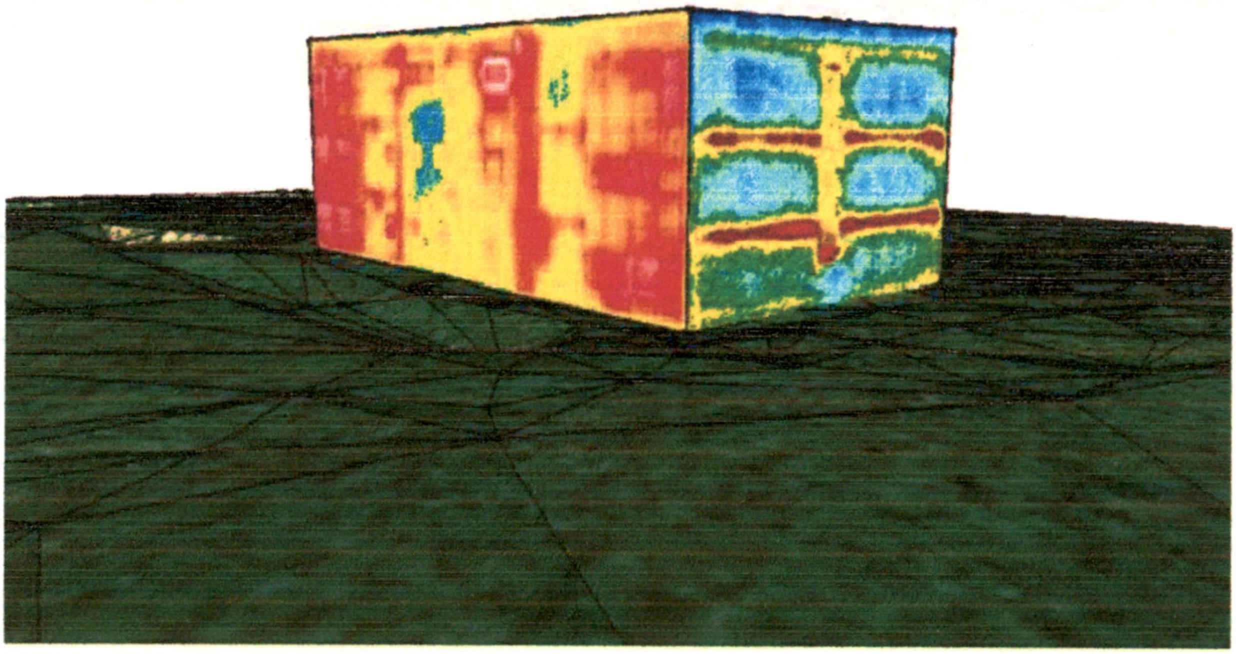


Figure 6.31 - 3D Model with Surface Temperature of a Building

This is the 3D model of a building with surface temperature. It is used for finding different defects in the building.

Chapter - 7

CONCLUSIONS AND FUTURE SCOPE OF WORK

7.0 Conclusions

1) Various defects like low walls, electrical conduit, lack of insulation in walls, have been found by the thermal analysis.
2) These defects are represented by the analysis of the thermograms. The best thermal analysis can be done by thermograms.
3) 3D model gives different views to analyze the building.
4) The temperature of all the points can be find out by 3D modelling and thermography.
5) In the model, the laser scanning method is very fast and accurate. The other method like Total Station and DesignBuilder are also very fast but laser scanner is very quick to get the models.
6) In the thermal analyses, DesignBuilder, given a very accurate results with the accuracy of 0.5°C.
7) The Thermohygrometer is also used to draw MNT of the temperature and it shows the same results as from DesignBuilder.

7.1 Future Work

1) Many future challenges exist, e.g., a safety analysis system based on four dimensional (4D) technology will be developed for dynamically safety analysis during the entire process of construction, improving the accuracy and efficiency when generating a structural model from complicated architectural model.

2) Analysis of support system and automatic alteration of construction plan according to the results are also expected in the future.

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2. A scientific paper's abstract has been accepted on the topic "**Comparison of Techniques for the 3D Modeling and Thermal Analysis**" for the X Congreso Internacional Expresión Gráfica aplicada a la Edificación Graphic Expression applied to Building International Conference in Alicante, Spain, 02-04 Dec 2010 for the journal of **Graphic Expression in Building.**

3. A poster on "**3D Modeling of the ESTP campus for the Thermal analysis and Energy dissipation**" has been presented on the **Innovation Day** by ESTP, Cachan France on 06 May 2010.