BEST6

Advanced Building Technology in Carbon-Free Smart City

Mahmoud Al-Theeb *CEO of Royal Commission in Jubail* P.O. Box: 10074, Jubail Industrial City Kingdom of Saudi Arabia, 31961 Email: <u>theebm@rcjy.gov.sa</u>



Presentation Outline

- Introduction
- Energy Efficiency in Buildings
- > THE LINE
- Assessments of Energy Efficiency in Buildings
- Numerical Modeling, Design and Evaluation Tools
- Future Work/Collaboration

> Summary

Introduction



Jubail Industrial City World-Class Manufacturing Hub Royal Commission for Jubail & Yanbu





WWW.RCJY.GOV.SA

Higher Education Support

Introduction

Jubail Industrial College



Higher Education Support

Introduction

Jubail University College



6

Higher Education Support

Introduction

Jubail Technical Institute



Introduction

Royal Commission cities use Building Code which is more advanced than the Saudi National Building Code

NEW CITY CENTER

Jubail Industrial City



March 19, 2024

Introduction

Carbon Capture Utilization and Storage

Saudi Aramco joined hands with the Kingdom's energy ministry to establish a carbon capture and storage hub in Jubail on the East Coast of Saudi Arabia. The plan for the hub is to have a storage capacity of up to <u>9 million tons</u> of carbon dioxide a year by 2027.



Jubail Industrial City

Energy Efficiency in Buildings

- ➢ Global warming is one of the problems that we currently face.
- ➢ Global warming has led to many environmental issues.
- Buildings are responsible for a large portion of the global and local impacts of climate change.
- ➢ Globally, buildings use 30−50% of the total energy demand.
- ➢ In Saudi Arabia, 70% of the total energy demand is used for cooling of buildings.
- Designing building envelopes to achieve energy savings not only will reduce energy consumption and hence energy demand over time, but also will contribute to the fight against global warming.

- Advanced building technology is being used to build a smart city in Saudi Arabia's Neom called "THE LINE"
- > THE LINE is 170 km (110 miles) long.
- > THE LINE will not have cars, streets or carbon emissions.
- THE LINE will have a population of nine million (25% of Saudi Arabia's current population).
- THE LINE population density will be 260,000 people/km² compared to a density of 44,000 people/km² of Manila, the world's most densely populated city.

- The 170 km (110 miles) length of THE LINE consists of two mirrored buildings having a total width of 200 m (660 ft) and a height of 500 m (1,600 ft) with an outdoor space in between.
- > THE LINE building is the third tallest building in Saudi Arabia.
- As THE LINE is a carbon free city, it will be entirely powered by various types of renewable energy. This will contribute in supporting the initiative "Carbon Capture Utilization and Storage"

NEOM

THE LINE EXHIBITION GOES ON TOUR



Assessments of Energy Efficiency in Buildings

Deanship of Research and Industrial Development at the Royal Commission in Jubail

Assessment of energy efficiency in buildings requires:

- > Testing
- Advanced validated model and tools









Numerical Modeling, Design and Evaluation Tools

- Validated 2D and 3D Model for Energy and Moisture Assessments
- White Roof Design Tool (WRDT)
- Airspace Reflective Tool (ART) for Different Building Applications
- Tool for Steel Framing with Various Types of Insulations
- Evaluation and Design Tool for Reflective Insulations in Roof Attics

Validated 2D and 3D model for energy and moisture assessment

All modules of the 2D and 3D model are fully coupled



Validated 2D and 3D Model for Energy and Moisture Assessments

- Solve the Heat , Air and Moisture (HAM) equations
- Validated for different building applications
- Currently being used in several projects
- Used to develop several user-friendly design and evaluation tools



White Roof Design Tool (WRDT)



White Roof Design Tool (WRDT)

- A user-friendly tool
- Applies only for Saudi roofing
- Evaluation mode: for given roof specifications and climate conditions, the tool determines the cooling and heating energy loads
- Design mode:
 - ✓ For given energy load (e.g., with black roof) and α_s , the tool determines the amount of insulations
 - ✓ For a given energy load and δ_{ins} , the tool determines the solar reflectivity and then select the type of cool roof coating/membrane
- For all modes, considerations were given to check whether risk of condensation and mold growth occur in the roof

The tool will be submitted to the Saudi Building Code Authority for upgrading of the building code to allow use of less roof insulation when cool roofing systems are installed



THE LINE buildings contain steel framing







Tool Modes:

✓ Evaluation

✓ Design

 ✓ Research and optimization

For all modes, the tool provides the results in few seconds (< 5 sec)

March 19, 2024



For all modes, the tool provides the results in few seconds (< 5 sec) Steel Framing Evaluation and Design Tool Mode SI Units Thermal Conductivity Effective Emittance Filled Actual **R** Value nsulation Thickness Compute Effective 0.725 W/m K Ocold Side 0.02889 63.5 0.03 Clear m².K/W **IP Units** Hot Side **Evaluation Mode:** ✓ Obtain R-value for given input **Excel** Exit R vs Thermal Conductivity R vs Insulation Thickness R vs Effective Emittance PDF Overlay plot

Design Mode:

 ✓ Obtain the value of a design parameter to meet specified R-value by the user

Research and optimization mode to investigate the effect of various parameters on the thermal performance of steel framing systems



Research and optimization mode to investigate the effect of various parameters on the thermal performance of steel framing systems



DESIGN GUIDE does not include reflective insulations

GUIDE DESIGN Thermal Design and Code Compliance for Cold-Formed Steel Walls

2015 Edition

Steel Framing Alliance 25 Massachusetts Avenue, NW Suite 800 Washington, DC 20001





🔿 Steel Framing Alliance

The tool can be used to upgrade the "Thermal Design and Code Compliance for Cold-Formed Steel Walls" to include reflective insulations in steel framing systems

Airspace Reflective Tool for Different Building Applications (ART)

THE LINE buildings contain enclosed airspaces





Examples of enclosed airspace applications













Airspace Reflective Tool (ART) for Different Building Applications



33

Airspace Reflective Tool (ART) for Different Building Applications



Building Enclosure Science and Technology 34

Airspace Reflective Tool (ART) for Different Building Applications



Airspace Reflective Tool (ART) for Different Building Applications



Airspace Reflective Tool (ART) for Different Building Applications







Airspace Reflective Tool (ART) for Different Building Applications

Most recently, ART was extended for up to three airspaces



Evaluation and Design Tool for Reflective Insulations in Roof Attics

Attic Tool was developed to assess the thermal performance of home attics with and without reflective insulations or radiant barriers

- A user-friendly tool
- Can be used in evaluation mode for determining the thermal resistance at a wide variety of conditions
- Can be used in design mode for determining the value(s) of design parameter(s) to achieve specified thermal resistance by the user
- Can be in research mode to investigate the effect of different parameters on the performance of attics.



Evaluation and Design Tool for Reflective Insulations in Roof Attics

Details of Attic Tool will be presented in Science 3: Increasing Performance on Tuesday, March 19, 2024, 3:45 pm – 5:00 pm



Future Work/Collaboration

- Use the available numerical models and tools, and testing as needed to develop the "Whole Building Energy Rating, WBER"
- For a given climate and type of building (residential or commercial), determine the percentage contributions to the energy performance from various building envelope parts:
 - ✓ R → for Roof
 - $\checkmark \mathsf{W} \rightarrow \mathsf{for Walls}$
 - ✓ F → for Fenestrations (Windows, Curtain Walls, Skylight Devices)
 - ✓ Use R, W and F to obtain WBER

WBER will be used for:

- Designing new buildings
- Determining the cost-effective retrofitting strategy for old buildings

Old Building







- Designing buildings with high-energy efficiency can contribute to the fight against global warming
- ✓ Advanced building technologies are currently being used in Saudi Arabia, for example, THE LINE
- ✓ To support the field of building science and technology:
 - More test facilities will be built
 - More user-friendly design and evaluation tools will be developed

Thank You

Get in touch

National institute of Building Sciences 1090 Vermont Avenue NW, Suite 700 Washington, DC 20005 (202) 289-7800 nibs@nibs.org

