LABORATORY PROFILE

2023 Edition

Optical & Thermal Testing Laboratory

OTM Solutions Pte Ltd

ilac-MRA

Accredited Laboratory
SAC-SINGLAS
LA-2016-0610-G

SINGAPORE GREEN BUILDING COUNCIL MEMBER

OTM

Choose OTM.

Work with the expert in

Optical & Thermal Measurement solutions.

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Choose OTM. Work with the expert in Optical & Thermal Measurement solutions.

We focus on optical & thermal testing

OTM Solutions Pte Ltd was incorporated in 2013, with the vision of being Singapore's best optical & thermal testing laboratory.

We have dedicated personnel, equipment, quality system and expertise available to deliver accurate and reliable optical & thermal testing services to our customers.

2023 is the 10th year of our laboratory's operation. We look forward to working with you in 2023.

Key milestones

- 2013: Incorporated as OTM Solutions Pte Ltd
- 2014: Qualified for IGDB data submission
- 2016: Accredited by SAC-SINGLAS
- 2017: Joined as SGBC corporate member
- 2018: Qualified for CGDB data submission
- 2023: 10-year anniversary

Choose OTM. Work with the expert in Optical & Thermal Measurement solutions.

We are competent in optical & thermal testing

SAC-SINGLAS accreditation according to ISO 17025
Accredited in 2016

SGBC lab partner for SGBP certification
Qualified in 2017

NFRC/LBNL IGDB submission
Qualified in 2014

AERC/LBNL CGDB submission
Qualified in 2018

SAC-SINGLAS accreditation: the Singapore Laboratory Accreditation Scheme (SINGLAS) managed by Singapore Accreditation Council (SAC).
SGBC lab partner: lab partner of Singapore Green Building Council (SGBC) for Singapore Green Building Product (SGBP) certification.
IGDB submission: submission of glass product optical data to the International Glazing Database (IGDB) managed by National Fenestration Rating Council (NFRC) and Lawrence Berkeley National Laboratory (LBNL).
CGDB submission: submission of window attachment product optical data to the Complex Glazing Database (CGDB) managed by Attachments Energy Rating Council (AERC) and LBNL.

Choose OTM. Work with the expert in Optical & Thermal Measurement solutions.

SAC-SINGLAS accredited

Internationally recognized

Material Solar Reflectance Index (SRI) Test Report

Report number: OTM2104001

Client:

Company name
Address line 1
Address line 2
Address line 3
Attention: Name

Laboratory:

Optical & Thermal Testing Laboratory
OTM Solutions Pte Ltd
21 Woodlands Close
#07-05 Primz Bizhub
Singapore 737854

Tel: (+65) 6908 0126
WhatsApp: (+65) 8838 1374
Email: info@otm.sg
Web: www.otm.sg

View laboratory profile

The Optical & Thermal Testing Laboratory of OTM Solutions Pte Ltd is accredited to ISO/IEC 17025 under the Singapore Accreditation Council - Singapore Laboratory Accreditation Scheme (SAC-SINGLAS, Certificate No: LA-2016-0610-G).

The results reported herein have been performed in accordance with the terms of accreditation under the Singapore Accreditation Council.

What is SAC-SINGLAS accreditation?

We always highlight that our lab is SAC-SINGLAS accredited. The rationale is explained here.

No laboratory license

Operating a lab, including a third-party lab, does not require a license in Singapore (and in most parts of the world).

Voluntary SAC-SINGLAS accreditation

The Singapore Laboratory Accreditation Scheme (SINGLAS) managed by Singapore Accreditation Council (SAC) is a voluntary lab accreditation scheme based on ISO 17025.

The accreditation criteria are comprehensive and cover all essential parts of lab operation.

SAC audits the lab every year, to verify the compliance of the lab quality system to ISO 17025.

SAC accredited reports

An SAC-SINGLAS accredited lab is allowed to issue SAC accredited reports with the “ilac-MRA” and “SAC-SINGLAS” marks, for testing services conducted under the terms of accreditation.

SAC accredited reports are internationally recognized, thanks to the Mutual Recognition Arrangements (MRAs) signed by SAC.

Benefits of engaging an SAC-SINGLAS accredited lab

The annual audit by SAC verifies that the instruments are well maintained and calibrated, the personnel are qualified, the test accuracy is satisfying, and more other things.

A general lab customer usually does not have the knowledge and resources to thoroughly check a lab’s quality system. It is effortless and risk-free to select an SAC-SINGLAS accredited laboratory.

For decision makers, e.g. governments or buyers, SAC accredited reports are more trustworthy.

Laboratory instruments

UV/VIS/NIR spectrophotometer

FTIR spectrometer

Emissometer

Heat flow meter

Hot wire thermal conductivity meter

Drying & heating chamber

Choose OTM. Work with the expert in Optical & Thermal Measurement solutions.

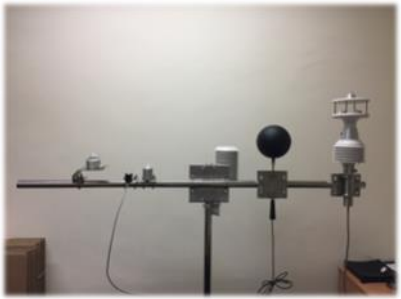
Handheld & on-site instruments

Portable spectrophotometers

Roller wave gauge

Standard colour tiles

Data loggers & sensors



Micro-climate station

Weather station

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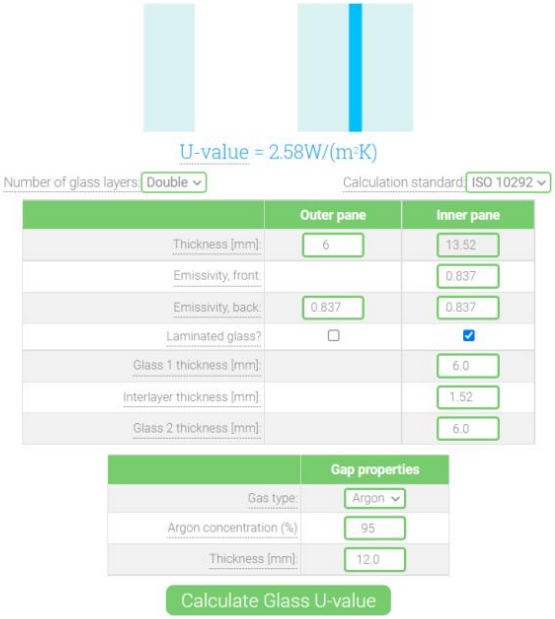
Online optical & thermal calculators

5 free and user-friendly online optical & thermal calculators were developed by us, for interested customers to perform their own calculations and experiment various possibilities.

Online ETTV U-value calculator



Online glass U-value calculator

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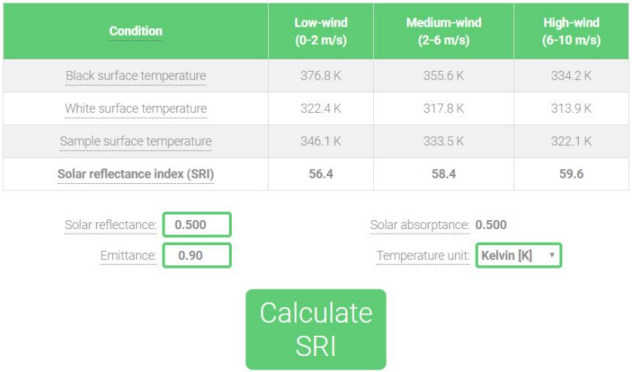
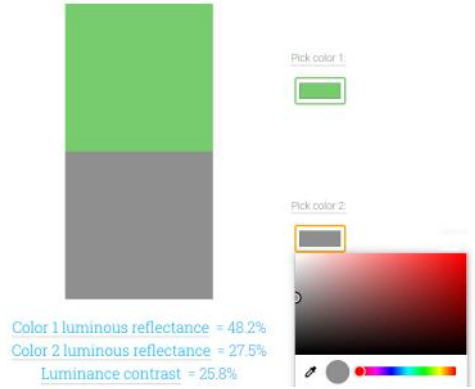
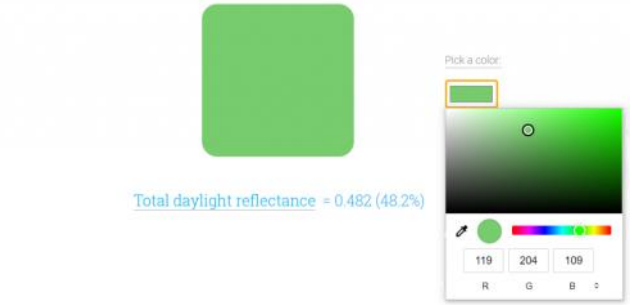
Online optical & thermal calculators



Online solar reflectance index (SRI) calculator



Online luminance contrast calculator



Online total daylight reflectance calculator

Scan me

Try online calculators

Choose OTM. Work with the expert in Optical & Thermal Measurement solutions.

Focus on one thing.

Do it well.

Focus on optical & thermal testing.

Be Singapore's best

optical & thermal testing laboratory.

We compare our results with external labs regularly

Testing quality is critical to both our customers and ourselves. At OTM, we've implemented a robust laboratory quality system based on ISO 17025 and are improving it continually.

Quality control measures

In the lab, ISO 17025 is closely adhered to, with the following important practices:

- Impartiality in laboratory operation
- Regular instrument calibration & maintenance
- Detailed work instructions
- Competent personnel
- Traceable measurement results
- Minimized measurement uncertainties
- Regular performance verifications
- Regular quality assurance tests

Quality assurance tests

In order to ensure test result validity, the laboratory performs the following:

- Daily instrument performance verification with retained samples
- Quarterly internal quality assurance tests with retained samples
- Participation in proficiency tests (PTs) programs or inter-laboratory comparisons (ILCs)

Listed below are the PTs & ILCs participated by the lab:

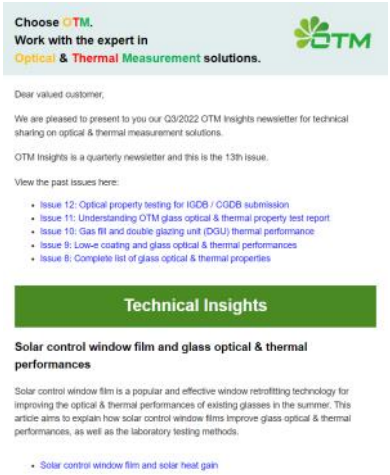
- 2014: ILC on glass testing, organized by LBNL
- 2015: ILC on glass testing, organized by LBNL
- 2017: ILC on complex glazing testing
- 2018: ILC on spectral reflectance testing
- 2019: PT on thermal conductivity testing
- 2020: ILC on glass testing, organized by LBNL
- 2021: PT on thermal conductivity testing

OTM insights newsletter

We release our OTM Insights newsletter quarterly since Q3/2019.

Listed below are the recent 10 issues of OTM Insights newsletter:

- Issue 13 (Q3/2022): Solar control window film and glass optical & thermal performances
- Issue 12 (Q2/2022): Optical property testing for IGDB / CGDB submission
- Issue 11 (Q1/2022): Understanding OTM glass test report
- Issue 10 (Q4/2021): Gas fill and double glazing unit (DGU) thermal performance
- Issue 9 (Q3/2021): Low-e coating and glass optical & thermal performances
- Issue 8 (Q2/2021): Complete list of glass optical & thermal properties
- Issue 7 (Q1/2021): 4 things to check when glass optical & thermal test results are different from manufacturer's specifications
- Issue 6 (Q4/2020): What are the differences between the NFRC, EN, and ISO glass optical & thermal test methods?
- Issue 5 (Q3/2020): How accurate are glass optical & thermal test results?
- Issue 4 (Q2/2020): How to test optical & thermal properties of glasses from existing buildings?


Choose OTM.
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Optical & Thermal Measurement solutions.

Dear valued customer,

We are pleased to present to you our Q3/2022 OTM Insights newsletter for technical sharing on optical & thermal measurement solutions.

OTM Insights is a quarterly newsletter and this is the 13th issue.

View the past issues here:

- Issue 12: Optical property testing for IGDB / CGDB submission
- Issue 11: Understanding OTM glass optical & thermal property test report
- Issue 10: Gas fill and double glazing unit (DGU) thermal performance
- Issue 9: Low-e coating and glass optical & thermal performances
- Issue 8: Complete list of glass optical & thermal properties

Technical Insights

Solar control window film and glass optical & thermal performances

Solar control window film is a popular and effective window retrofitting technology for improving the optical & thermal performances of existing glasses in the summer. This article aims to explain how solar control window films improve glass optical & thermal performances, as well as the laboratory testing methods.

- Solar control window film and solar heat gain

OTM Insights newsletter issue 13

OTM blog

We update our OTM Blog regularly, with technical tips and service updates.

Listed below are selected bog posts added in 2022:

- 03/10/2022: Water UV transmittance (UVT) measurement at 254 nm
- 19/09/2022: Full-size solar panel daylight reflectance test
- 05/09/2022: Import Optics user database into LBNL WINDOW
- 15/08/2022: Our instrument: heat flow meter
- 18/07/2022: ±0.001 rounding discrepancy in specular daylight reflectance calculation
- 04/07/2022: Preparing samples for luminance contrast test
- 20/06/2022: The difference between NFRC winter and summer U-values
- 17/05/2022: Acceptance criteria for solar reflectance index (SRI)
- 18/04/2022: Can daylight reflectance be tested with ASTM E903 only?
- 04/04/2022: How to get window film optical & thermal properties with different glass substrates?
- 21/03/2022: Our instrument: FTIR spectrometer
- 07/03/2022: On-site measurement of wall system U-value
- 03/01/2022: Sample thickness in ASTM C518 thermal conductivity testing

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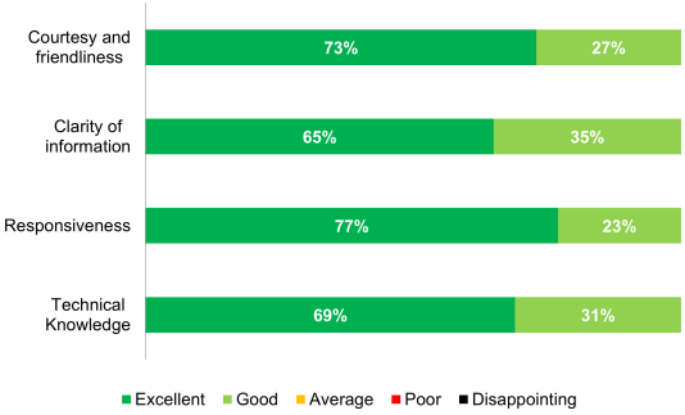
Visit OTM blog

Choose OTM. Work with the expert in Optical & Thermal Measurement solutions.

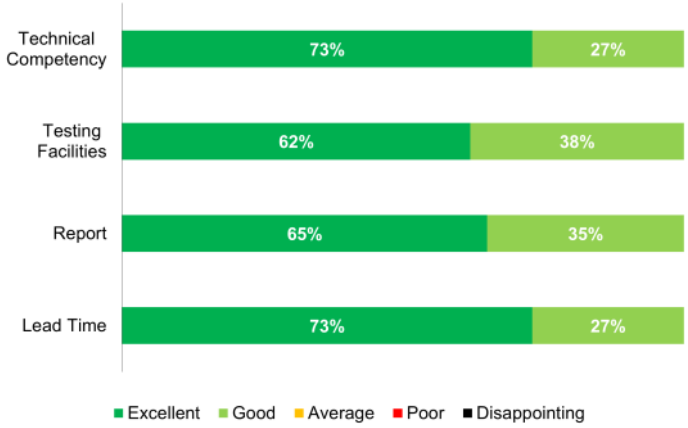
We do our best for high customer satisfaction

100% customers are satisfied with our customer services



Rating on customer services

100% customers are satisfied with our testing services



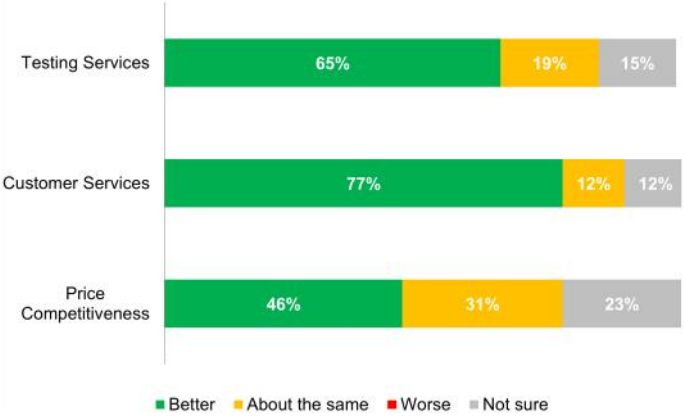
Rating on testing services

Source of data: customer satisfaction survey conducted between 01/2022 and 09/2022. 26 customers participated the survey.

Choose OTM. Work with the expert in Optical & Thermal Measurement solutions.

We do our best for high customer satisfaction

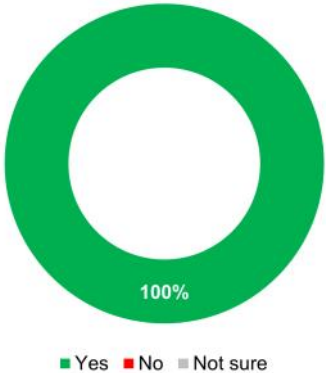
Most customers rated us better than or about the same as other labs.



Comparison with other labs

100% customers are willing to work with OTM again and recommend OTM to others

Work with OTM again in the future



Recommend OTM to others

Further efforts on price competitiveness:

- Uniform price to all
- Automatic volume discount
- Automatic loyalty discount

Source of data: customer satisfaction survey conducted between 01/2022 and 09/2022. 26 customers participated the survey.

Choose OTM. Work with the expert in Optical & Thermal Measurement solutions.

We serve regional & international customers

Our main customer base is the building and construction industry, from material manufacturers to construction companies. We welcome international customers. Our customers are from in total 32 countries, as of 2022.

A-G

- Australia
- Cambodia
- Canada
- China
- Costa Rica
- Egypt
- France
- Germany

H-N

- Hong Kong
- Hungary
- India
- Ireland
- Israel
- Japan
- Korea
- Malaysia
- Mauritius
- Netherland
- New Zealand

O-T

- Oman
- Philippines
- Qatar
- Saudi Arabia
- Singapore
- South Africa
- Sri Lanka
- Taiwan
- Tanzania
- Thailand
- Turkey

U-Z

- USA
- Vietnam

We understand the physics in optical & thermal testing

Publications

Chen, F. and Wittkopf, S. K. (2012) Summer condition fenestration thermal transmittance measurement using calorimetric hot box. 53, Energy and Buildings.

Chen, F. and Wittkopf, S. K. (2012) Solar heat gain coefficient measurement with indoor calorimetric hot box and solar simulator. 53, Energy and Buildings.

Chen, F., Choo, T. S. and Ouyang, J. (2013) The effects of fenestration systems on occupant thermal and visual comfort in the tropics. SB13 Singapore Conference.

Chen, F. (2013) Annual equivalent shading coefficient (AESC) index for thermal performance rating of fenestration in Singapore. SB13 Singapore Conference.

Presentations

Chen. F. (2012) SERIS' approach towards a standard calorimetric method for solar heat gain coefficient (SHGC) measurement. 2012 International Collaboration Seminar: Development of Evaluation Method for G-value, Korea.

Chen. F. (2012) SERIS' experience on calorimetric G-value measurement. The 2nd International Seminar Regarding G-value Measurement Method, China.

Chen, F. (2013) The ABCs of fenestration system U-value and G-value. Seminar on Energy Efficient Facades and Fenestrations in the Tropics, Singapore.

Chen, F. (2013) Fenestration: the New Focal Point of Tropical Green Building Innovations. SGBC and SIBL Joint Seminar: Holistic Approach to Sustainable Development, Singapore.

Chen, F. (2013) The ABCs of Facades in the Tropical Climate. 2nd Seminar on High Performance Façades in the Tropics, Singapore.

Chen, F. (2013) Fenestration System Thermal Performance Rating for Summer Condition. APEC Policy Workshop for Energy Efficient Envelopes, Thailand.

Chen, F. (2015) New Perspectives on Energy Efficient Fenestrations in Tropical Climate. Fenestration Days China, China.

Chen, F. (2017) Accurate Measurement of Transmittance and Reflectance for Engineering Applications. PerkinElmer INTour Seminar 2017, Singapore.

Your premium optical & thermal testing laboratory:

- Broadest scope
- Best accuracy
- Fastest delivery
- Friendliest price

Full services optical & thermal testing laboratory

Glass properties

IGDB / CGDB submission

Frame U-value & SHGC

Solar reflectance index (SRI)

Daylight reflectance

Thermal conductivity

Emissivity

Colour

Luminance contrast

On-site monitoring

Choose OTM. Work with the expert in Optical & Thermal Measurement solutions.

Laboratory test of glass optical & thermal properties

Test methods

There are 3 major glass test methods. It is important to select an appropriate test method for fair comparison:

- NFRC method: NFRC 100/200/300/301
- EN method: EN 410/673
- ISO method: ISO 9050/10292

We support all 3 methods, with the NFRC method as the default.

Sample types

All general glass types: laminated glass, glass with window film, insulating glazing unit and partially fritted glass.

Instruments

- PerkinElmer Lambda 950 spectrophotometer
- PerkinElmer Spectrum Two spectrometer

Standard result set

- Visible light transmittance
- Visible light reflectance (front & back)
- Solar energy transmittance
- Solar energy reflectance (front & back)
- Solar heat gain coefficient (SHGC)
- Shading coefficient
- U-value (winter & summer)

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More information at otm.sg

Choose OTM. Work with the expert in Optical & Thermal Measurement solutions.

Expert in glass optical & thermal property testing

Extended results

Upon a customer's request, we can report selected additional results favoured by the industry, particularly the window film sector:

- UV transmittance & rejection
- Infrared transmittance & rejection
- Total solar energy rejection
- Light-to-solar gain (LSG) ratio
- Luminous efficacy
- Colour (transmitted & reflected)
- Colour rendering index (CRI)
- CIE damage factor
- Skin damage factor

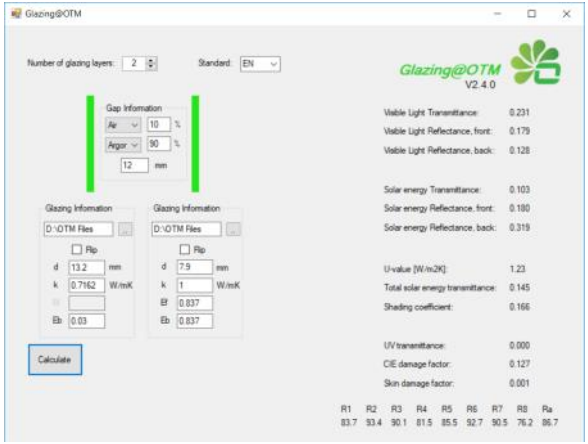
Advanced calculations

Upon a customer's request, we can perform the following advanced calculations

- Extract low-e layer optical properties and construct new low-e glass.
- Extract PVB/SGP interlayer optical properties and construct new glass laminate.
- Extract window film optical properties and attach it to a different glass.

Home-made calculation software

We code our own glass calculation software from scratch, for the best capabilities and flexibilities.



Glazing@OTM software

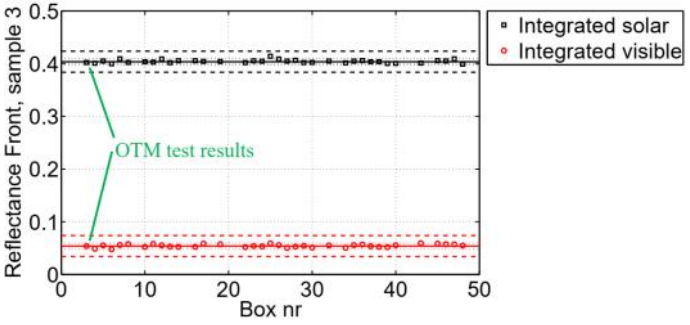
Choose OTM. Work with the expert in Optical & Thermal Measurement solutions.

Our results are as accurate as world's best laboratories

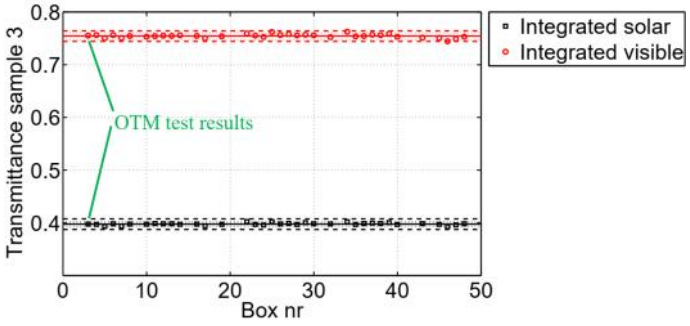
We participate in the inter-laboratory comparison (ILC) organized by the Lawrence Berkeley National Laboratory (LBNL) regularly.

Shown below are the result comparisons of the ILC conducted in 2015. The results measured by OTM are accurate, among the 36 participating labs.

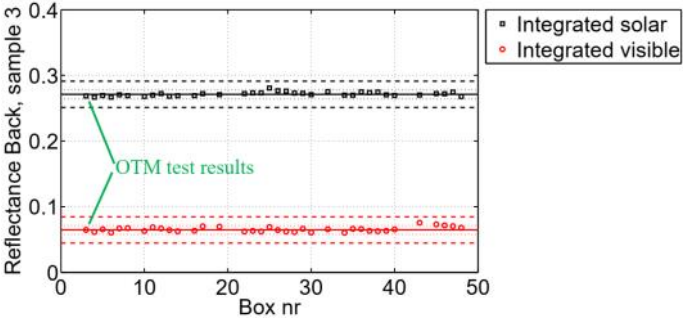
We participated in the LBNL ILC in 2019 again, with excellent accuracy demonstrated.



Comparison of reflectance results (front side)



Comparison of transmittance results



Comparison of reflectance results (back side)

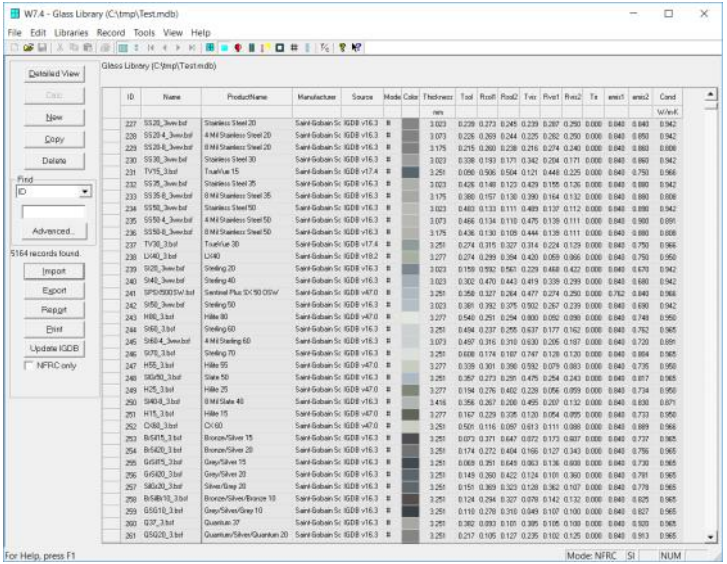
Choose OTM. Work with the expert in Optical & Thermal Measurement solutions.

We are eligible for IGDB submission

OTM is qualified to submit data to the IGDB, the world's largest glass optical property database, managed by NFRC and LBNL.

When you are using the famous LBNL WINDOW software, the optical data were probably tested by OTM.

Furthermore, OTM is also qualified to submit data to the CGDB managed by AERC and LBNL.



LBNL WINDOW software

IGDB: International Glazing Database
CGDB: Complex Glazing Database
NFRC: National Fenestration Rating Council
AERC: Attachments Energy Rating Council
LBNL: Lawrence Berkeley National Laboratory

Choose OTM. Work with the expert in Optical & Thermal Measurement solutions.

How are glass optical & thermal properties tested?

Curious about the glass testing procedures? The important concepts are explained here.

No direct measurement

In contrast to the common assumptions, the U-value & SHGC of a glass are not directly measured in an instrument with controlled temperature difference and solar radiation.

Only spectral optical properties are physically tested

In the lab, we only test the spectral transmittance/ reflectance in the 300 nm – 2500 nm range (ultraviolet, visible light and near infrared) and the spectral reflectance in the 5 μm – 25 μm range (infrared).

Broadband optical properties are calculated

Weighted averaging is performed, with the standard AM1.5 solar spectrum or the standard room temperature blackbody emission spectrum as the weights, to get the following broadband optical properties:

- Visible light transmittance/reflectance
- Solar energy transmittance/reflectance
- Emittance

Thermal properties are calculated

According to the standard environmental conditions and mathematical models defined in the standards, the following thermal properties are calculated:

- U-value
- SHGC and shading coefficient

Detailed testing procedures

The step-by-step testing procedures of the following glass types are available at our website:

- Single glazing testing procedures
- Double glazing unit (DGU) testing procedures
- Partially fritted glazing testing procedures

What are U-value, SHGC and shading coefficient?

U-value, SHGC and shading coefficient are the 3 important thermal results influencing building envelope energy efficiency. The basic concepts are explained here.

U-value

$$U\ [W/(m^2K)] = \frac{\text{Heat transmitted through a glass [W]}}{\text{Area [m}^2\text{]} \times \text{Temperature difference [K]}}$$

U-value represents the insulation performance of a glass under an indoor/outdoor temperature difference. Smaller U-value means better thermal insulation.

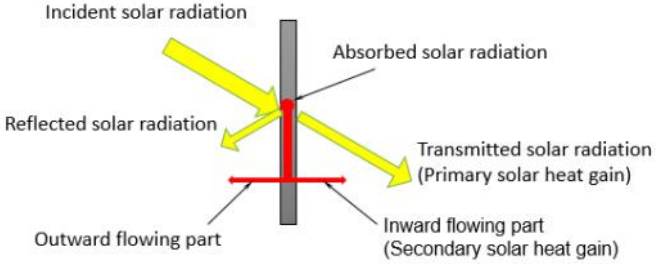
U-value is dependent on the environmental conditions, e.g. indoor/outdoor wind speed. Therefore, the summer condition and winter condition U-values are different.

Solar heat gain coefficient (SHGC)

$$SHGC\ [-] = \frac{\text{Solar heat transmitted through a glass [W]}}{\text{Solar heat incident on a glass [W]}}$$

SHGC represents the solar heat gain performance of a glass. Smaller SHGC means better solar heat gain control.

As shown below, SHGC consists of two components, the primary and secondary solar heat gains.



Shading coefficient

$$SC\ [-] = \frac{SHGC\ [-]}{0.87}$$

Shading coefficient is the same as SHGC in physical meaning. Shading coefficient is the SHGC divided by 0.87 (the nominal SHGC of a clear glass).

The differences between NFRC, EN & ISO methods

There are three widely adopted glass test methods:

- NFRC method: NFRC 100/200/300/301
- EN: EN 410/673
- ISO: ISO 9050/10292

The differences between them are explained here.

Measurement principles: same

The measurement principles in the 3 methods are the same. The same types of instruments are used.

Testing: NFRC method is more detailed

The requirements in the NFRC method on the testing procedures are detailed and specific, whereas the EN/ISO methods are brief in the testing part.

The test results obtained according to the NFRC method can be directly used for the EN/ISO calculations, but not vice versa.

Calculation: different solvers & conditions

The differences in the calculation parts are substantial:

- Solver: the NFRC method uses a numerical solver, whereas the EN/ISO method uses an analytical solver.
- Environmental conditions: different solar spectrum, temperature and wind speed etc.

Results: large difference in SHGC

The visible light transmittance/reflectance results are the same.

The winter condition U-value results are close, but there is no summer condition U-value in the EN/ISO method.

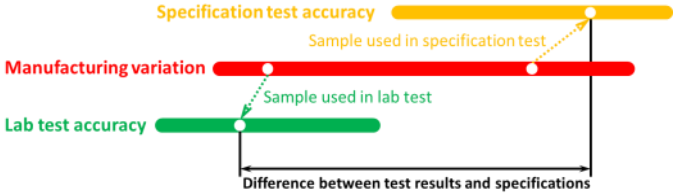
The difference in the SHGC results could be large (e.g. 0.02), due to the differences in the environmental conditions.

Which method is recommended?

It depends on your project requirements. If it is not explicitly specified, the NFRC method is recommended, due to the more detailed requirements and the wide adoption by the industry.

Why are test results different from specifications?

It is impossible for our test results to be the same as the manufacturer's specifications. Some explanations are provided here.



It is normal and inevitable

As depicted above, there are 3 possible factors:

- Specification test uncertainty
- Production variation
- OTM test uncertainty

It is impossible to eliminate all uncertainties and variations. Some differences are inevitable.

Production variation

Two different samples are used in the specification test and in OTM test.

The two samples are not identical, especially when they are produced in different lots, different years or different plants.

Specification test uncertainty

The specifications are with certain uncertainty. It is also important to know the test methods used to obtain the specifications.

OTM test uncertainty

Our results are with certain uncertainty, as specified in the test report. We will be fully responsible to our result accuracy. We will re-test for free or refund the full price if our results are not accurate.

Project suggestions

- Understand your project requirements
- Check with your glass supplier for their typical production variation and specification accuracy
- Check with OTM for the measurement uncertainty

Factors affecting glass U-value

Glass U-value represents the insulation performance of a glass under an indoor/outdoor temperature difference. The factors affecting glass U-value are discussed here.

Glass surface emissivity

A low emissivity surface has a reduced radiative heat exchange with its surroundings. Glasses with low-emissivity (low-e) coating are with lower U-values.

An uncoated glass surface has a nominal emissivity of 0.84. Due to this high emissivity, the U-value of an uncoated glass is high.

For single glazing glasses, hard low-e coating, which can withstand scratches and moisture, is used. It has a typical emissivity of 0.1 - 0.3 and greatly reduces the glass U-value.

Soft low-e coating with better performance is often used for double glazing units (DGUs), as the coating is encased in the DGU gas gap and protected. Its typical emissivity ranges 0.02 - 0.1, superior to hard low-e coating.

DGU gas fill

DGU gas fill (gap size and gas type) affects the convective heat transfer rate in the DGU gas gap.

The gap size cannot be too small or too large. There exists an optimum gap thickness, depending on the low-e coating and environmental conditions. In Singapore, 12 mm air gap is most commonly used.

DGUs filled with argon gas have substantially lower U-values than those filled with air, due to the smaller thermal conductivity and greater density of argon.

Glass thickness

Glass thickness affects the heat conduction rate. As glass is a good conductor of heat and glass thickness can only vary in a narrow range, increasing the thickness of a glass has little effect on its U-value.

Because PVB interlayer is a poor conductor of heat, laminated glasses have slightly smaller U-value than monolithic glasses.

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Online glass U-value calculator

U-value = 2.58W/(m²K)

Number of glass layers: Double

Calculation standard: ISO 10292

	Outer pane	Inner pane
Thickness [mm]:	6	13.52
Emissivity, front:		0.837
Emissivity, back:	0.837	0.837
Laminated glass?	☐	☑
Glass 1 thickness [mm]:		6.0
Interlayer thickness [mm]:		1.52
Glass 2 thickness [mm]:		6.0

	Gap properties
Gas type:	Argon
Argon concentration (%)	95
Thickness [mm]:	12.0

Calculate Glass U-value

How to use this calculator?

- Select the number of glass layers
- Select the calculation method
- If applicable, toggle the laminated glass option
- Input the glass and interlayer thicknesses
- Input the emissivity values
- If applicable, set the gas type and gap thicknesses

The glass U-value is calculated and updated immediately when there are input changes.

Calculation principle

The calculator follows ISO 10292 or EN 673.

Try the calculator

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Laboratory testing for IGDB & CGDB submission

IGDB test methods

- NFRC 300
- NFRC 301

IGDB sample types

All sample types in the scope of IGDB submission, e.g. glasses or window films, except diffuse samples, e.g. fritted glasses.

Instruments for IGDB testing

- PerkinElmer Lambda 950 spectrophotometer
- PerkinElmer Spectrum Two spectrometer

Results for IGDB submission

- A text file in the IGDB data format

Refer to the pages 20 - 29 for more information on our glass testing services.

CGDB test methods

- AERC 1.1

CGDB sample types

All samples types in the scope of CGDB submission, e.g. fabrics.

Instruments for CGDB testing

- PerkinElmer Lambda 950 spectrophotometer
- Devices and Services AE1 RD1 emissometer

Results for CGDB submission

- A homogeneity report
- A text file in the CGDB data format

For both IGDB & CGDB submissions, the submission will be performed by the customer and OTM will provide necessary technical support to the customer.

What are the procedures of CGDB submission testing?

If you are new to CGDB submission, the testing procedures are explained here.

Homogeneity test

The purpose of the homogeneity test is to understand the consistency of a product and select a representative sample.

18 samples need to be sampled from different lots and different positions. The visible light transmittances or reflectances of the 18 samples are measured for the calculation of material product homogeneity.

Based on the homogeneity test results, a representative sample is selected for more detailed optical property test.

If there are multiple products in a product family, simplified procedures are available for the homogeneity test. Please refer to our website for more details.

Optical property test

In the optical property test, the following properties of the representative sample are tested:

- Direct-hemispherical and diffuse spectral transmittance in the 300 nm – 2500 nm range
- Direct-hemispherical and diffuse spectral reflectance in the 300 nm – 2500 nm range
- Thermal emissivity and infrared (IR) transmittance

Result compilation

Based on the test results, two result files are compiled:

- A homogeneity test report in the MS Excel format
- A text file in the CGDB data format containing the optical property test results

The two files shall be submitted together by the customer.

Frame U-value & SHGC calculation service

Calculation methods

- NFRC 100/200
- NFRC Simulation Manual

Solar reflectance test method

- ASTM E903

Frame and fenestration types

- All general frame types: aluminium frame, aluminium frame with thermal break, and uPVC frame
- All general fenestration types: window and curtain wall system

Calculation software

- LBNL WINDOW/THERM

Solar reflectance test instrument

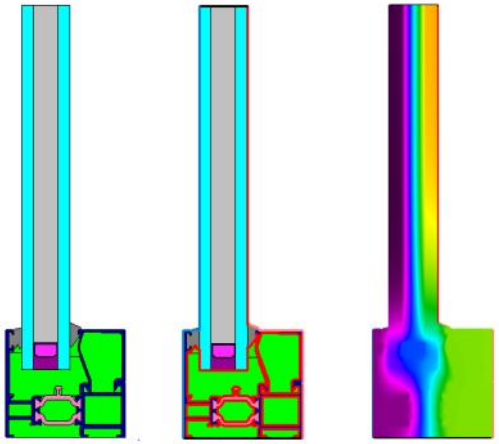
- PerkinElmer Lambda 950 spectrophotometer

Standard calculation result set

- Frame U-value and SHGC
- Edge-of-glazing U-value and SHGC
- Centre-of-glazing U-value and SHGC
- Fenestration system U-value and SHGC

Standard solar reflectance test results

- Solar reflectance and absorptance



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Why are frame U-value & SHGC important?

The importance of frame U-value and SHGC in the tropical climate is being more recognized by the industry recently. The background information is explained here.

Frame U-value is important in winter conditions

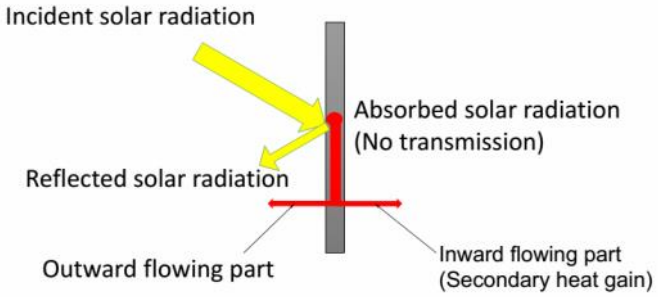
Due to the large indoor/outdoor temperature difference, the overall fenestration U-value is important in winter conditions.

As the U-value of frames, particularly aluminium frames, are typically greater than the U-value of low-e insulating glazing units, frame U-value is important in winter conditions.

Frame SHGC is important in summer conditions

Due to the large solar heat gain, the overall fenestration SHGC is important in summer conditions.

The solar heat gain through a frame could be large. Shown below is the heat transfer mechanism.



Frame U-value influences SHGC

The secondary heat gain through a frame is dependent on the solar absorptance and the U-value of the frame.

Frames with lower solar absorptance and U-value are with lower SHGC.

4 reasons to engage OTM for frame U-value & SHGC calculation

- We are a neutral and independent third-party lab
- We are technically competent
- We use the NFRC method consistently
- We offer a special bundle price when both frame and glass are evaluated by OTM

How are frame U-value and SHGC calculated?

Curious about the frame U-value and SHGC calculation procedures? The important concepts are explained here.

Physical property test not required

The thermal conductivity and emissivity of common fenestration materials are available in a standard material database.

It is not required to test the materials, unless your material is not available in the database.

Solar reflectance test optional

The default solar reflectance of all materials is 0.3. It is optional to test your material solar reflectance for better accuracy.

Frame cross-section drawing needed

Frame cross-section drawing in CAD format is needed. The bill of materials (BOM) of the fenestration is also needed.

2D modelling in THERM

A 2D model is built in the LBNL THERM software, with the standard environmental conditions applied. The frame and edge-of-glazing U-values and SHGCs are calculated.

Area-weighted averaging in WINDOW

In the LBNL WINDOW software, the overall fenestration system U-value and SHGC are calculated based on area-weighted averaging of frame, edge-of-glazing and centre-of-glazing U-values and SHGCs.

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Roof material solar reflectance index (SRI) test

Test methods

- ASTM E903
- ASTM C1371 (with TN 11-2)
- ASTM E1980

Sample types

All general materials with flat surface: roof materials, pavement materials and façade cladding materials.

Instruments

- PerkinElmer Lambda 950 spectrophotometer
- Devices and Services AE1 RD1 emissometer

Standard result set

- Solar reflectance & absorptance
- Thermal emittance
- SRI at 3 wind conditions

For non-roof materials, it is possible to test the solar reflectance only.

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We are familiar with all sample types

PVDF coated metal plate

Waterproofing membrane

Concrete

Ceramic tile

Granite

Wood

Paint

Roof tile

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What is solar reflectance index (SRI)?

SRI is an important parameter in urban heat island mitigation applications. Materials with higher SRI are with lower surface temperature under solar radiation. The basic concepts are explained here.

Surface temperature under solar radiation

The temperature of a surface under solar radiation is dependent on both the surface properties and the environmental conditions.

Solar reflectance and emittance are the two properties affecting surface temperature.

Under the standard environmental conditions, the surface temperatures at three wind speeds can be calculated.

Reference white and black surfaces

A surface with solar reflectance = 0.80 and emittance = 0.9 is defined as the reference white surface.

A surface with solar reflectance = 0.05 and emittance = 0.9 is defined as the reference black surface.

Solar reflectance index (SRI)

The surface temperatures of the reference white surface (T_{white}), of the reference black surface (T_{black}), and of a sample (T_{sample}) can be calculated. An SRI can then be calculated from the 3 temperature results.

$$SRI = \frac{T_{black} - T_{sample}}{T_{black} - T_{white}} \times 100$$

As there are three standard wind speeds, there are 3 SRIs at different wind speeds.

It is possible for a SRI to be greater than 100 or less than 0.

For horizontal or low-sloped surfaces only

Strictly speaking, the concept of SRI is not applicable to façades, as the temperature calculation model is for horizontal and low-sloped surfaces only.

In LEED, only solar reflectance is required for non-roof areas.

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How is solar reflectance index (SRI) tested in the lab?

Curious about the SRI testing procedures? The important concepts are explained here.

SRI is calculated

SRI is calculated from the tested solar reflectance and thermal emittance, according to ASTM E1980.

Solar reflectance and thermal emittance are tested separately, with two different instruments.

Thermal emittance is directly measured

Thermal emittance is directly measured with the instrument emissometer, according to ASTM C1371.

Three methods for solar reflectance testing

There are three acceptable solar reflectance measurement methods:

- ASTM E903
- ASTM C1549
- ASTM E1918

The 3 methods are equivalent essentially. The differences are mainly on the solar radiation source, detector and optical geometry.

ASTM E903 is the most accurate one, as it uses a spectrophotometer.

At OTM, ASTM E903 is employed. The spectral reflectance of a sample in the solar spectrum range (300 nm – 2500 nm) is measured. Weighted averaging, with the standard AM1.5 spectrum as the weights, is performed to get the solar reflectance.

Initial and aged SRI

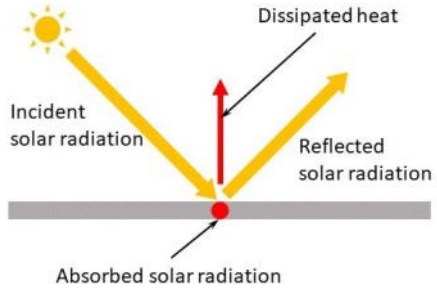
Due to soiling and weathering, the SRI becomes lower when a material is aged. The aged SRI is a more realistic representation than the initial SRI in the lifetime of a building.

At this moment, we can test the initial SRI only. If the aged SRI is needed, the aging process should be performed by the customer.

Factors affecting solar reflectance index (SRI)

solar reflectance index (SRI) can be understood as a scaled surface temperature, with reference to the reference white and black surfaces. The factors affect SRI are explained here.

Surface temperature under solar radiation



For a surface under the sun, its surface temperature is affected by two factors:

- The fraction of solar radiation reflected back. It is characterized by its solar reflectance.
- The fraction of absorbed solar radiation dissipated back. It is characterized by its thermal emittance.

Solar reflectance & SRI

Materials with high solar reflectance are able to reflect more incident solar radiation back to the sky and absorb less.

As solar reflectance is correlated to colour, in general, the lighter the colour, the higher the SRI.

Additionally, materials with high reflection to near-infrared (NIR) radiation are with relatively higher solar reflectance too.

Thermal emittance & SRI

Materials with high thermal emittance can dissipate more absorbed solar radiation back to the environment.

However, most materials are with high thermal emittance, typically in the range of 0.8 - 0.95. There are not much room and technology available to increase the thermal emittance of a surface.

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Online solar reflectance index (SRI) calculator

Condition	Low-wind (0-2 m/s)	Medium-wind (2-6 m/s)	High-wind (6-10 m/s)
Black surface temperature	376.8 K	355.6 K	334.2 K
White surface temperature	322.4 K	317.8 K	313.9 K
Sample surface temperature	346.1 K	333.5 K	322.1 K
Solar reflectance index (SRI)	**56.4**	**58.4**	**59.6**

Solar reflectance: 0.500

Emittance: 0.90

Solar absorptance: 0.500

Temperature unit: Kelvin [K]

Calculate SRI

How to use?

Input the solar reflectance and emittance values.

The surface temperatures and SRIs (at 3 wind speed conditions) are automatically displayed.

Calculation principle

The calculator follows ASTM E1980.

Try the calculator

Fulfil BCA daylight reflectance requirements with ease

Test methods for non-glass materials

- ASTM E903
- ASTM E971
- CIE 130

Test methods for glass materials

- ASTM E903
- NFRC 300

Sample types

All general façade and roof materials with flat surface: aluminium cladding, concrete, roof tile and glass.

Instrument

- PerkinElmer Lambda 950 spectrophotometer

Standard result set for non-glass materials

- Total daylight reflectance
- Diffuse daylight reflectance
- Specular daylight reflectance

Standard result set for glass materials

- Daylight reflectance

Glass materials are with specular reflection only. The concept of total/diffuse/specular reflection is not applicable to glasses.

Glasses with ceramic frit are considered non-glass materials.

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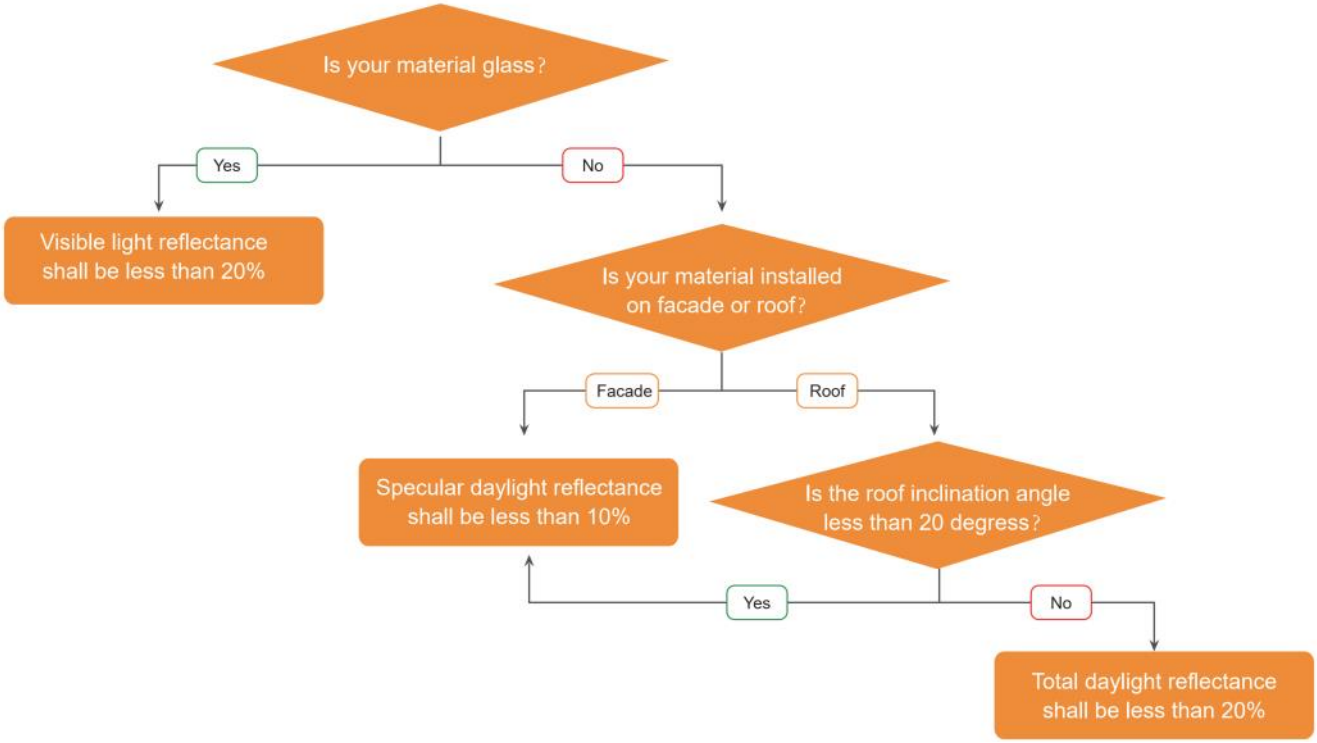
BCA daylight reflectance requirements

Use the flow chart below to check if your material can meet the BCA daylight reflectance requirements.

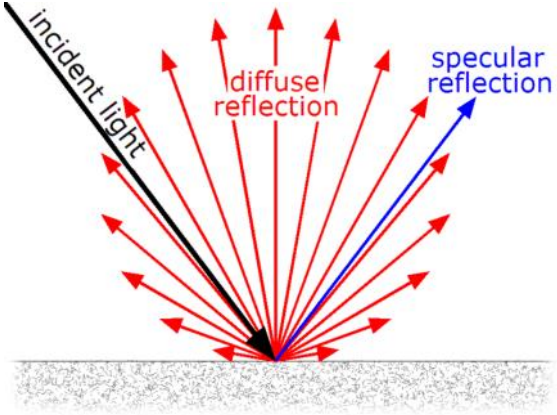


Is daylight reflectance correlated to colour & gloss?

Instruments for colour and gloss measurement are available in many companies. The relationship between daylight reflectance, colour and gloss is explained here.

What is daylight reflectance?

Daylight reflectance is the fraction of natural daylight reflected by a surface.



The specularly reflected portion is the specular daylight reflectance .

The diffusely reflected portion is the diffuse daylight reflectance.

The sum of the specular and diffuse daylight reflectances is the total daylight reflectance.

Daylight reflectance and colour

For colour measurement instruments with integrating spheres, the Y results in the Yxy colour space (with D65 illuminant and 10 degree observer) is close to the daylight reflectance results.

- The Y result in the SCI mode is equivalent to the total daylight reflectance.
- The Y result in the SCE mode is equivalent to the diffuse daylight reflectance.
- The difference between them is equivalent to the specular daylight reflectance.

Daylight reflectance and gloss

The gloss result is proportional to the specular daylight reflectance, though they are not equivalent.

How is daylight reflectance tested in the lab?

Curious about the daylight reflectance testing procedures? The important concepts are explained here.

No simple handheld device

BCA requires the measurements to be performed according to the ASTM E903 method with 150 mm integrating sphere.

Most handheld devices cannot meet this requirement.

Instrument measured spectral reflectance

The instrument (UV/VIS/NIR spectrophotometer) measures the spectral reflectance in the visible light range (380 nm – 780 nm).

When the instrument is in the specular-component-included (SCI) mode, the total spectral reflectance is measured.

When the instrument is in the specular-component-excluded (SCE) mode, the diffuse spectral reflectance is measured.

The specular spectral reflectance is the difference between the above two.

Calculation of broadband results

The broadband results (total/diffuse/specular daylight reflectance) are calculated from the spectral results (total/diffuse/specular spectral reflectance), by weighted averaging, with the standard daylight spectrum and human vision sensitivity as the weights.

At OTM, a home-made software (DLR@OTM) is used for the calculations and it also generates test reports automatically.

How to meet BCA daylight reflectance requirements?

Some tips on meeting BCA daylight reflectance requirements are discussed here.

Less than 10% specular daylight reflectance

The less than 10% specular reflectance requirement is applicable to façades, horizontal and low-sloped roofs (less than 20 degrees of inclination).

Most materials can meet this requirement easily, with the following typical specular daylight reflectance:

- Rough surfaces (e.g. concrete and tile): close to 0% specular daylight reflectance
- Painted surfaces (e.g. PVDF coated aluminium plate): around 1 - 2%
- Glossy non-metal surfaces (e.g. polished granite): less than 5%
- Shiny metal surfaces (e.g. bare stainless steel): more than 10% possible

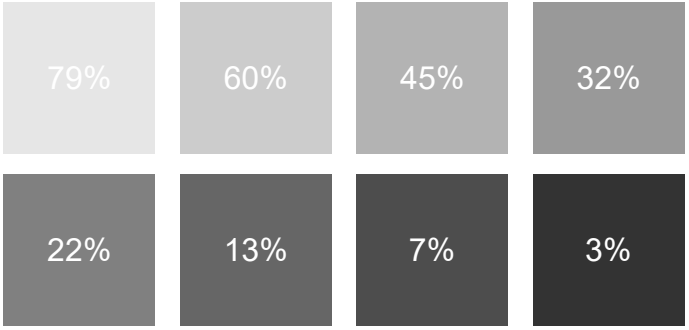
Due to the strong specular daylight reflection, shiny metal surfaces should be used with caution.

Less than 20% total daylight reflectance

The less than 20% total daylight reflectance requirement is applicable to steep-sloped roofs only (more than 20 degrees of inclination).

The total daylight reflectance is correlated to surface colour. To lower the total daylight reflectance, dark colours shall be used. It is impossible to lower the total daylight reflectance without colour change.

A total daylight reflectance calculator is available on our website. Shown below are the calculated total daylight reflectances of typical grey colours.



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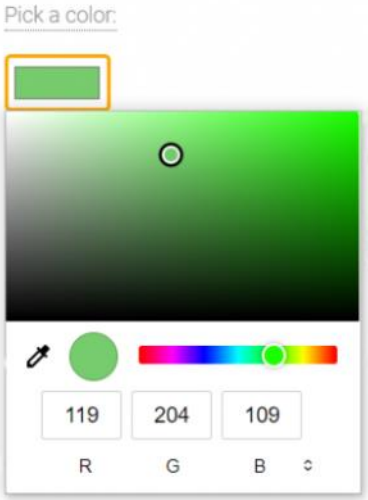
Online total daylight reflectance calculator

Total daylight reflectance = 0.482 (48.2%)



How to use?

Pick an colour with the colour picking tool.

The total daylight reflectance of the colour is automatically displayed.

Calculation principle

The calculator essentially calculate the luminance value (equivalent to the total daylight reflectance) of the screen displayed sRGB colour.

Try the calculator

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Thermal conductivity of solid, powder, liquid & paste

Unlike other tests, the selection of test method for thermal conductivity testing is dependent on the sample type.

For thick solid samples with two flat surfaces

- Test method: ASTM C518
  - Up to 2.5 W/(m·K)
  - Mean temperature: -15 °C to 65 °C
  - With external thermocouple kit for materials with large thermal conductivity
- Sample types: insulation materials, concrete panels, composite panels
- Instrument: Thermtest HFM100 heat flow meter

For homogeneous solid, powder, paste and liquid samples

- Test method: ASTM C1113, D5930 or D7896 with manufacturer's instructions
  - Up to 10 W/(m·K)
  - At room temperature only
- Sample types: general solid, powder, paste and liquid samples
- Instrument: Xiatech TC3000E hot wire thermal conductivity meter

Standard result set

- Thermal conductivity

Upon request, the results of thermal resistance and U-value can be calculated and included.

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Two instruments, more capabilities

Feature comparison

Instrument	Heat flow meter	Hot wire thermal conductivity meter
Method	ASTM C518	ASTM C1113, D5930 or D7896 with manufacturer's instructions
Measurement principle	Steady state measurement • Typical measurement time: 1 h • Calibration required	Transient measurement • Typical measurement time: 1 min • Calibration not required
Sample type	Both homogeneous materials and layer-by-layer composite materials, solid only	Homogeneous materials only; solid powder, paste and liquid
Solid sample size	Typically: 300 mm x 300 mm, with maximum 100 mm thickness Both sides shall be flat and parallel.	For solid samples, typically 50 mm x 50 mm x 5 mm Two samples are needed, at least one side shall be flat.

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Thermal conductivity, thermal resistance & U-value

They are different properties to describing material insulation performance. The differences are explained here.

Thermal conductivity

Thermal conductivity represents the ability of a material to conduct heat.

Its unit is W/(m·K) and it is independent of material thickness. Typically, thermal conductivity is used for homogeneous materials only.

Thermal resistance

$$\text{Thermal resistance } [(m^2K)/W] = \frac{\text{Thickness [m]}}{\text{Thermal conductivity } [W/(m \cdot K)]}$$

Thermal resistance is calculated from thickness and thermal conductivity. It is dependent on thickness and its unit is (m²K)/W.

For a typical wall system consisting of multiple wall layers, the total thermal resistance is simply the sum of the thermal resistances of all layers.

Typically, thermal resistance is used for materials with known thickness or with multiple layers.

U-value

$$U\ [W/(m^2K)] = \frac{1}{\text{Sum of thermal resistance of all solid \& air layers } [(m^2K)/W]}$$

U-value is the reciprocal of the sum of the thermal resistances of all solid and air layers in a wall system. Its unit is W/(m²K). U-value is also called thermal transmittance.

Typically, U-value is used for a complete wall system. If only a few layers of a wall is considered, the concept of U-value is not applicable.

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How is thermal conductivity tested in the laboratory?

Curious about the thermal conductivity testing procedures? The important concepts are explained here.

With heat flow meter

A steady state temperature difference is maintained on the two sides of a sample (e.g. 20°C). The heat flux through the sample is measured with heat flux transducers. The thermal conductivity is calculated from the heat flux, temperature difference and sample thickness.

As it is challenging to measure heat flux accurately, a comparison method is used. A reference material with known thermal conductivity is measured to get a correction factor. The correction factor is used to correct the sample measurement result.

Calibration is always required for the heat flow meter method.

With hot wire thermal conductivity meter

The hot wire probe is sandwiched between two pieces of solid samples and it is heated up by a short pulse of current. The heat from the hot wire is dissipated to the sample. The dissipation rate is correlated to the material thermal conductivity.

The temperature variation history is analysed to get the thermal conductivity.

For solid samples, it is important to maintain good thermal contact between the sample surfaces and the hot wire probe.

Calibration is not required for the hot wire method. The method is fast, as it is not required to attain a steady state.

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Sample thickness in ASTM C518 testing

In thermal conductivity testing according to ASTM C518, a test sample is clamped between two plates and compressed.

Some customers are concerned if thermal conductivity results are affected by the compression.

3 thicknesses

Conceptually, there are 3 thicknesses of a sample:

- Uncompressed thickness: the thickness of a sample in the free state without compression;
- Installation thickness: the thickness of a sample in the intended installation.
- Testing thickness: the thickness of a sample during thermal conductivity testing.

Testing thickness & thermal conductivity

When a sample is compressed to a smaller thickness, its density increases and the increased density affects the thermal conductivity.

A sensitivity study was performed by OTM in 2020. In this study, when the sample was compressed by 10%, the result variation was less than 1.7%.

Thermal conductivity result is not sensitive to testing thickness variation. If the compression is small (e.g. less than 5%), the result variation is negligible for general engineering applications.

Testing thickness of soft samples

For soft samples, the customer should declare the installation thickness, if it is significantly different from the uncompressed thickness. Otherwise, the installation thickness is assumed the same as the uncompressed thickness.

In both scenarios, the sample is compressed slightly to the testing thickness (within 5% variation from the installation thickness) for good thermal contact.

Thermal resistance not reported

By default, the thermal resistance of a sample is not reported, as the instrument measured thermal resistance is smaller due to sample compression.

Online ETTV U-value calculator

Number of material layers: 4 Wall/Roof type: Vertical Wall

Material	Source	Name	Color	Thermal conductivity [W/(m·K)]	Thickness [mm]		Thermal resistance [(m²K)/W]
1	Library	Metal: aluminium alloy		211	2	Edit	0.000
2	Library	Plaster: perlite		0.115	10	Edit	0.087
3	Library	Brick, dry (covered by plaster/tile)		0.807	80	Edit	0.099
4	Library	Concrete (2400 kg/m^3)		1.442	100	Edit	0.069
						Outside surface film resistance:	0.044
					Inside surface type: High emissivity	Inside surface film resistance:	0.120

R-value = 0.255 (m²K)/W U-value = 2.38 W/(m²K)

Calculate U-value

How to use?

- Select the number of layers
- Select the wall/roof type
- Set the properties of each layer
- Select the inside surface type

The wall/roof U-value is calculated and updated immediately when there are input changes.

Calculation principle

The calculator follows BCA Guidelines on Envelope Thermal Transfer Value for Buildings.

Try the calculator

Choose OTM. Work with the expert in Optical & Thermal Measurement solutions.

Material emittance / emissivity testing

The words emittance and emissivity are used inter-changeably. Emittance is the standard term used in the standards.

Test method

- ASTM C1371 (with TN 11-2)

Sample types

All general materials with flat surface, excluding glasses.

For glass materials, the NFRC 301 method is recommended.

Instrument

- Devices and Services AE1 RD1 emissometer

Standard result set

- Emittance

Why is emittance important to insulation performance?

Emittance is an important property of material insulation performance. The basic concepts are explained here.

Three heat transfer modes

There are three heat transfer modes, namely conduction, convection and radiation.

To reduce conduction, materials with low thermal conductivity should be used.

To reduce convection, air cavities with appropriate thickness should be used.

To reduce radiation, materials with low emittance should be used.

Emittance is related to the radiative heat transfer.

Emittance & radiative heat transfer

All surfaces emit infrared radiation. They also reflect and absorb infrared radiation emitted by the surrounding surfaces.

The emittance of most natural surfaces is around 0.9. For a surface with 0.9 of emittance, the infrared heat emitted by it is 90% of that by a perfect black body. It also absorbs 90% of incident infrared heat and only reflects 10% back.

For some low-emittance surfaces, the emittance is around 0.05. For a surface with 0.05 of emittance, the infrared heat emitted by it is only 5% of that by a perfect black body. It also only absorbs 5% of incident infrared heat and reflects 95% back.

Low-emittance surfaces can effectively reduce the radiative heat transfer and improve the insulation performance. They are typically applied on the indoor side topmost layer of a wall or on the surface facing an air cavity.

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Laboratory or on-site colour difference testing

Test methods

There are numerous test methods for colour & colour difference testing. We can support almost all of them. Typically:

- ASTM E1331
- ASTM D2244

Sample types

All general materials; it is possible to measure samples in powder or granular form

Instruments

- PerkinElmer Lambda 950 spectrophotometer
- Konica Minolta CM-2500d spectrophotometer

Standard result set

Depending on the test methods used. Typically:

- Color in CIELAB colour space
- Colour difference in CIELAB colour space

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Can colour results be used for colour matching?

Though colours can be instrumentally measured, it is advised to use physical colour standards to transfer colour. The reasons are explained here.

Absolute colour & relative colour measurement

CIELAB colour space is the most commonly used colour space in the building and construction sector.

The colour measurement results, i.e. L*ab, can be considered the absolute colour, as it is not compared with any other reference colours.

The colour difference measurement results, i.e. ΔE*ab, can be considered the relative colour, as it is compared with a reference colour.

Higher accuracy in relative colour measurement

In relative colour measurements, as both the reference colour and the test colour are measured by the same instrument (many uncertainty sources are cancelled out), the accuracy is very high (e.g. accuracy of ΔE*ab is better than ±0.05).

Lower accuracy in absolute colour measurement

In absolute colour measurements, the test colour is not compared to a reference colour (many uncertainty sources are applicable), the accuracy is lower (accuracy of L*ab is around ±1.5).

Use physical colour standards for colour matching

When different instruments are used in colour matching, it is preferred to use a physical colour standard to transfer the colour.

There are multiple relative colour measurements with respect to the same physical colour standard. The overall uncertainty is much smaller than using different instruments to perform independent absolute colour measurements.

Luminance contrast & luminous reflectance testing

Test methods

- AS 1428.1
- AS/NZS 1428.4.1

Sample types

- All general materials: flooring tiles, pavement materials, Tactile Ground Surface Indicators (TGSIs)
- Always two samples in a pair

Instruments

- Konica Minolta CM-2500d spectrophotometer

Standard result set

- Luminous reflectance
- Luminance contrast

Example applications

- To determine if there is sufficient luminance contrast between adjacent building elements for the safety of building users

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What are luminous reflectance & luminance contrast?

Sufficient luminance contrast is critical in the selection of Tactile Ground Surface Indicators (TGSIs). The luminance contrast between two surfaces is calculated from the luminous reflectances of them.

The basic concepts of the two properties are explained here.

Luminous reflectance

Luminous reflectance is the reflectance of a surface to visible light.

It is equivalent to visible light reflectance and daylight reflectance. The luminous reflectance of a perfect white surface is 100 (100% reflectance) of a perfect black surface is 0 (0% reflectance).

The luminous reflectance can be measured by a portable or benchtop spectrophotometer.

Luminance contrast

Luminance contrast is a measure of the difference between two luminous reflectances.

Below is the calculation equation:

$$\text{Luminance contrast} = \frac{125 \times (LR_1 - LR_2)}{LR_1 + LR_2 + 25}$$

Here, LR_1 and LR_2 are the luminous reflectances of surface 1 and surface 2, respectively

Luminance contrast is a calculated quantity and it is always in terms of two surfaces in a pair.

Luminance contrast is different from colour contrast. Surface pairs with large colour contrast may be with small luminance contrast.

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How to prepare samples for luminance contrast test?

Luminance contrast is always in terms of two samples in a pair. The sample preparation methods of 3 typical scenarios are explained here.

Side-by-side flat surfaces

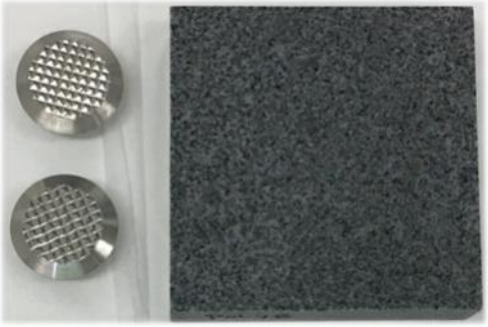
For this scenario, two flat-panel samples need to be submitted.

A flat surface with integrated TGSI studs

For this scenario, an integrated sample can be submitted.

A flat surface with loose TGSI studs

For this scenario, a flat surface sample and a few TGSI studs can be submitted separately.



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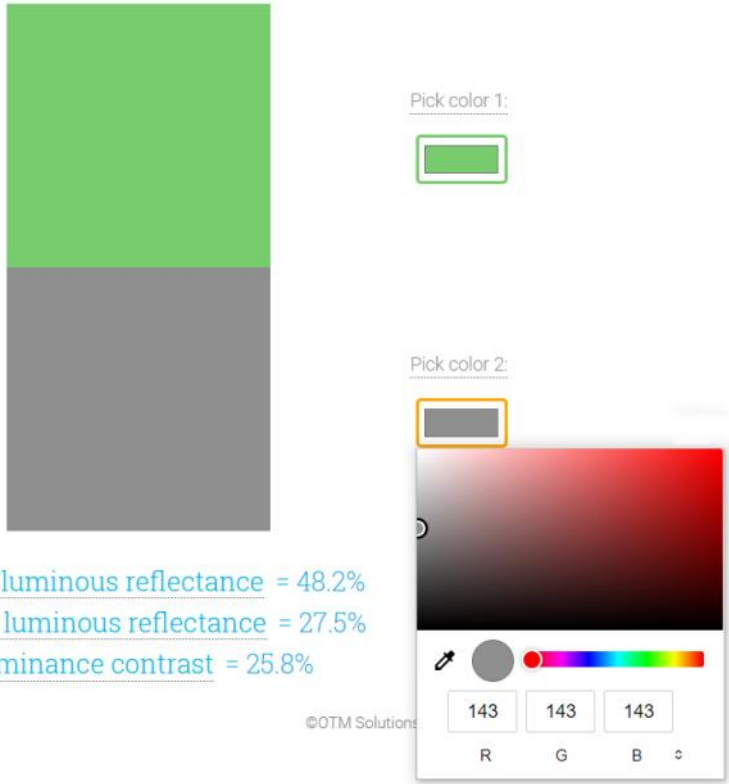
Online luminance contrast calculator



How to use?

Pick two colours with the colour picking tools.

The luminous reflectances of the two colours and the luminance contrast between them are displayed.

Calculation principle

The calculator essentially calculate the luminance values (equivalent to the luminous reflectances) of the screen displayed sRGB colours.

Try the calculator

On-site testing & monitoring

Standard on-site testing methods

- Glass colour uniformity: ASTM C1376
- Glass roller wave: ASTM C1651
- Glass edge lift: EN 1863-1
- Wall U-value: ISO 9869 -1

Custom methods for on-site monitoring

For custom on-site monitoring, proposals will be prepared based on the project requirements. We can monitor the following for your decision making:

- Weather: wind speed/direction, solar irradiance, air temperature/humidity
- Façade performance: surface temperature, heat flux, transmitted solar irradiance & visible light
- Thermal comfort: indoor air speed, temperature & humidity, globe temperature

Instruments

We have a wide collection of instruments for on-site testing & monitoring. New instruments can be added when there are special needs.

Reference projects

A number of on-site testing & monitoring projects have been performed by us:

- Glass colour uniformity measurements
- Façade cladding colour matching
- Thermochromic glass performance monitoring in 4 HDB flats
- Low-e glass performance comparison in 4 EC flats
- Thermal micro-climate monitoring in 5 sites of a commercial building
- Frame thermal performance monitoring at the BCA Skylab
- Frame thermal performance monitoring at a new commercial building

Reference projects

Cladding colour uniformity

Glass colour uniformity

Monitoring at BCA Skylab

Thermochromic glass monitoring

Low-e glass comparison

Micro-climate monitoring

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On-site glass performance monitoring system

An on-site glass optical & thermal performance monitoring system was customized by OTM.

Outdoor measurement system

On the outdoor side, the following quantities were measured:

- Incident daylight illuminance [lux]
- Incident solar irradiance [W/m^2]
- Air temperature [°C]

Indoor measurement system

On the indoor side, the following quantities were measured:

- Transmitted daylight illuminance [lux]
- Transmitted solar irradiance [W/m^2]
- Air temperature and glass surface temperature [°C]

Wireless data logging system

The data logging system is wireless and battery powered. Hole drilling and AC power supply are not required.

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Optical & Thermal Measurement solutions.

Contact OTM for professional optical & thermal testing services

www.otm.sg

(+65) 6908 0126

info@otm.sg

(+65) 8838 1374

21 Woodlands Close, #07-05 Primz Bizhub, Singapore 737854

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Visit www.otm.sg