

MOBILE TEST CHAMBER FOR TESTING ENVIRONMENTAL PERFORMANCE OF AN INTERCHANGEABLE FAÇADE SYSTEM, AND TEST CHAMBER SYSTEM

5 FIELD OF INVENTION

The present invention generally relates to a mobile test chamber for testing environmental performance of an interchangeable façade system, and a test chamber system including one or more of the mobile test chambers.

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BACKGROUND

Building energy performance is greatly dependent on its exterior façade design. The façade of the building represents the separating interface for, e.g., thermal exchange
15 between the building and its surrounding environment. For example, the façade acts as a barrier control for air, water vapor, sound, heat, solar energy, and rain. The façade has been found to account for up to 70% of the building's energy consumption. Therefore, a poorly designed façade can result in a low building energy performance, meaning an energy inefficient building which consumes and wastes a lot of unnecessary energy.
20 Hence, it is important to assess the façade's design and energy efficiency to provide a measure of the energy performance of the building. However, assessing the energy performance of a façade system is often a difficult and expensive task, especially for a complex façade system. For example, architects are increasingly using full glass windows, integrated with external and internal shadings, as their preferred façade system due to the aesthetic view offered by transparent window glazing and the ease-of-
25 construction.

In a conventional approach, to assess the thermal efficiency and to determine the energy performance of a building, thermal parameters for window glazing such as heat-loss parameter (U-value) or solar-heat-gain parameter (G-value) are used. However, this
30 conventional approach does not provide a sufficiently accurate measure of the actual thermal efficiency or energy performance of the building. This is because U-value and G-

value are thermal parameters for a single window glazing component/element of a façade system (e.g., the single-glazed or double-glazed glass windows of the façade system), and such thermal parameters alone do not sufficiently represent the energy performance of the entire integrated façade system (e.g. a glass façade integrated with outdoor shadings and indoor blinds). Furthermore, when using “static” parameters like U-value and G-value, dynamic changes in climatic conditions cannot be accounted for.

In order to fully assess the thermal efficiency or energy performance of a façade system, assessors may resolve this either by constructing a permanent mock-up test chamber that mimics actual building conditions or by carrying out actual on-site testing in a real building environment. On-site field measurements in an actual building are often difficult due to the unpredictable changes in the test environment such as changes in the weather and movements of the human occupants. On the other hand, a mock-up test chamber offers a fully controlled environment that attempts to replicate the actual building with boundary conditions and parameters of influence under control. However, such a test chamber is limited in its ability to test and compare different façade or shading device systems. This is because the permanent test chamber does not allow its façade to be easily removed or interchanged. Therefore, such a permanent test chamber is generally limited to testing only one type of façade system.

Nowadays, façade systems are becoming more complex, and they come in a large variety and in different forms. For example, façade systems can be categorized under glazed façade or non-glazed façade, or a combination of both. Glazed façades come in different forms such as single, double, or triple-glazed and their glass dimensions may be in full-height or with a fixed wall-to-window ratio. Glazed façades may also be manufactured with different heat-reduction technologies, such as Low-E coated, thin-film protected, vacuum-insulated or IR-coated. Non-glazed façades are usually made of conventional opaque materials such as concrete, brickwall, insulated drywall or aluminium panels. Therefore, conventional test chamber that is generally limited to testing only one type of façade system is undesirably restrictive.

A need therefore exists to provide a test chamber with enhanced façade system performance testing capabilities which seeks to overcome, or at least ameliorate, one or

more of the deficiencies/limitations of the conventional arts mentioned above. It is against this background that the present invention has been developed.

SUMMARY

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According to a first aspect of the present invention, there is provided a mobile test chamber for testing environmental performance of an interchangeable façade system in a test environment, the test chamber comprising:

10 a testing enclosure having one or more side frames configured for releasably securing one or more façade specimens for testing,

a plurality of sensors arranged in the testing enclosure for measuring multiple environmental parameters associated with the testing enclosure in the test environment when the testing enclosure has the one or more façade specimens releasably secured thereto, and

15 a mobility system disposed on a base structure of the test chamber configured for allowing mobility and rotatability of the test chamber.

Preferably, the testing enclosure is configured to be enclosed by a ceiling structure, the base structure, and a plurality of side structures, and wherein said one or more façade specimens form one or more of the plurality of side structures, respectively, when
20 releasably secured to said one or more side frames.

Preferably, the ceiling structure, base structure, and one or more of the side structures which are not formed by any of the one or more façade specimen are thermally
25 insulated.

In an embodiment, at least one of the ceiling structure and the base structure has a securing mechanism formed therein configured for securing one or more secondary objects in the testing enclosure for testing together with the one or more façade specimens for determining the environmental performance of the façade system with the
30 one or more secondary objects.

Preferably, the securing mechanism comprises an arrangement of guiding channels for receiving a corresponding engaging member of the one or more secondary objects for releasably securing the secondary objects in the testing enclosure.

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Preferably, the one or more secondary objects comprise shading devices configured for reducing environmental exposure in the testing enclosure from the outside test environment.

- 10 In an embodiment, the side frame comprises a securing mechanism for releasably securing the façade specimen for testing, the securing mechanism comprising a plurality of sliding bars, each adjustable between a lock position for securing the façade specimen in the side frame during testing and a release position for allowing the façade specimen to be removed from the side frame.

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In an embodiment, the mobile test chamber further comprises a processing enclosure having one or more information handling devices located therein processing data, including data received from the plurality of sensors.

- 20 In an embodiment, the mobile test chamber further comprises a wireless network device for communicating with one or more other mobile test chambers testing environmental performance of one or more other façade systems so as to utilize the mobile test chamber in a wireless test chamber network for testing environmental performances of façade systems at multiple locations.

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In an embodiment, the mobile test chamber further comprises one or more systems configured for setting conditions in the testing enclosure, the conditions include heating, ventilation, air conditioning, humidity and lighting.

- 30 Preferably, the plurality of sensors are selected from a group consisting of a thermal sensor, a humidity sensor, a lux sensor, an infra-red sensor, a radiant thermometer, a rain sensor, a wind sensor, an air-quality sensor, a sound sensor, a dust sensor, a solar irradiance sensor, an environmental sensor, a chemical sensor, a power sensor and a GPS sensor.

In an embodiment, multiple sensors from the plurality of sensors are integrated as one sensor having multiple sensing functionalities.

- 5 In an embodiment, the test chamber is rotatable about a vertical axis for adjusting an orientation of the one or more façade specimens releasably secured thereto.

According to a second aspect of the present invention, there is provided a test chamber system comprising:

- 10 a mobile test chamber according to the above-described first aspect of the present invention; and
a computer device having stored therein an executable application configured for remotely controlling one or more systems in the mobile test chamber, including setting conditions in the testing enclosure, and receiving data sensed by the plurality of sensors
15 for processing, logging and/or remotely monitoring the data sensed, via a wireless communication.

Preferably, said conditions include heating, ventilation, air conditioning, humidity, and lighting.

- 20 According to a third aspect of the present invention, there is provided a wireless network of mobile test chambers comprising a plurality of the mobile test chambers according to the above-described first aspect of the present invention communicatively coupled to one another for data communication.

25 **BRIEF DESCRIPTION OF THE DRAWINGS**

- Embodiments of the present invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of
30 example only, and in conjunction with the drawings, in which:

Fig. 1 depicts an exemplary mobile test chamber according to an example embodiment of the present invention for testing environmental performance of an interchangeable façade system in a test environment;

Figs. 2A to 2D are schematic drawings depicting a perspective view, a top view, a front view, and a side view of the example test chamber;

5 Fig. 3 illustrates the interchanging of a façade specimen secured to the example test chamber;

Fig. 4 illustrates various shading devices which may be installed or mounted in the example test chamber together with the façade specimens;

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Fig. 5 schematically illustrates the example test chamber integrated with multiple sensors for multifunctional sensing of different environmental parameters;

15 Figs. 6A to 6D illustrate various states of test chamber when securing or releasing a façade specimen from the front side frame;

Figs. 7A to 7D illustrate various states of the test chamber when securing or releasing a façade specimen from the right side frame;

20 Fig. 8 illustrates an exemplary securing mechanism in the base structure of the example test chamber for securing shading devices therein;

Fig. 9 depicts a test chamber system including the example mobile test chamber and a computer device;

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Fig. 10 illustrates a user interface of an application displaying the data sensed by the sensors in the example test chamber; and

30 Fig. 11 depicts a wireless network of mobile test chambers including a plurality of the example mobile test chambers communicatively coupled to one another for data transmission.

DETAILED DESCRIPTION

Embodiments of the present invention seek to provide a test chamber with enhanced façade system performance testing capabilities. In an embodiment, there is provided a test chamber having one or more side frames configured for releasably securing one or more façade specimens. That is, the test chamber has one or more interchangeable façade sides to facilitate testing of various types of façade configurations. In a further embodiment, the test chamber is also mobile such that it can be moved or transported and can be rotated. This provides flexibility in façade system testing since the test chamber can be moved to various desired testing locations (e.g., at the planned building site or at the roof of a building) and can be turned to face a particular direction desired for testing purposes (e.g., towards the sun or aligned with the planned building). In yet a further embodiment, the test chamber is configured to have multiple sensors for enabling multiple environmental parameters to be measured during each test. This maximizes data collection during each test which enables a better and more detailed assessment of the environment performance of the test chamber in an efficient manner. Details of the test chamber according to exemplary embodiments of the present invention will now be described.

Fig. 1 depicts an exemplary mobile test chamber 100 according to an example embodiment of the present invention for testing environmental performance of an interchangeable façade system in a test environment. The test chamber 100 comprises a testing enclosure 110 having one or more side frames 120 configured for releasably securing one or more façade specimens (forming the interchangeable façade system) for testing. The test chamber 100 shown in Fig. 1 has three side frames 120 configured for releasably securing three façade specimens, in particular, a front side frame 122, a left side frame 124, and a right side frame 126. The test chamber 100 also comprises a plurality of sensors 130 (schematically shown in Fig. 1) arranged in the testing enclosure 110 for measuring multiple environmental parameters associated with the testing enclosure 110 in the test environment when the testing enclosure 110 has the one or more façade specimens releasably secured thereto. In addition, the test chamber 100 comprises a mobility system 150 (e.g., see Fig. 2) disposed on a base structure 154 of the test chamber 100 configured for allowing mobility and rotatability of the test chamber 100. For example, with the

mobility system 150, the test chamber 100 is rotatable about a vertical axis for adjusting an orientation of the one or more façade specimens releasably secured thereto.

With the interchangeable façades, multiple environmental parameters sensing, and mobility/rotatability, the test chamber 100 advantageously enables enhanced façade system performance testing capabilities. In another embodiment, the mobile test chamber 100 is further configured to enable an interchangeable shading system such that various shading system configurations can be tested in the test chamber 100 together with the interchangeable façade system to measure the environmental performance of various façade and shading systems configurations. The interchangeable shading system will be described later below in further detail.

Conventional test chambers do not provide such capabilities and versatility. For example, a conventional approach is to construct a permanent test chamber fixed in location at a testing site to replicate a single type of façade system desired to be tested. Once constructed, the façade (e.g., glazed, concrete, bricks or insulation boards) is permanently fixed to the test chamber and is not configured to be interchangeable. For example, in the case of a glazed façade, the glass panes (whether they are single, double, or triple glazed) cannot be interchanged after the test chamber is constructed. Such a conventional test chamber is limited in façade testing capability and does not cater for architect's increasing use of a large variety of complex facades especially for commercial buildings. For example, complex glazed façade systems come in various types (such as low-E coated, thin-film protected, vacuum-insulated, IR-coated, etc.) to reduce heat transfer. They also come in a large range of thicknesses, colours, transmittances and reflectivity values. Hence, a permanent test chamber, which does not allow its façade system to be easily removed and interchanged, is generally limited to testing only one type of façade system and various types of façade systems cannot be easily tested. In order to test another type of façade system, a new test chamber would need to be constructed, which is very costly and highly inefficient.

With the mobility system 150, the test chamber 100 is advantageously mobile such that it can be moved or transported and rotated. This provides façade system testing flexibility since the test chamber can be moved to various desired testing locations (e.g., at the actual building site or at the roof of a building) and can be turned to face a

particular desired direction (e.g., towards the sun or aligned with the planned building). In contrast, as described above, the conventional approach is to construct a permanent test chamber which is fixed in location and direction at a testing site since they are purposely built to replicate one type of façade system.

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Exemplary schematic drawings of the test chamber 100 are depicted in Figs. 2A to 2D. Specifically, Figs. 2A to 2D depict a perspective view, a top view, a front view, and a side view of the test chamber 100, respectively. As shown, the mobility system 150 has a plurality of wheels (e.g., 8 wheels as shown in Fig. 2) affixed to the base structure 154 at
 10 suitable locations. In an embodiment, each wheel may further be configured with an anchoring member (not shown) thereby allowing mobility while maintaining mechanical stability when stationary. Preferably, each wheel and/or anchoring member is capable of supporting at least 250kg in weight. As an example only and without limitation, an example dimension of the test chamber 100 may be about 2.3m in height (h), 1.5m in
 15 width (w) and 2.1m in depth (d). It will be appreciated that the dimension of the test chamber 100 can be varied as desired or as appropriate.

As shown in Fig. 1, the exemplary test chamber 100 has a testing enclosure (or front compartment) 110 in which the environmental parameters are measured and a
 20 processing enclosure (or back compartment) 160 in which one or more information handling devices are located for processing data including data received from the sensors 130. More specifically, the front compartment 110 is configured for testing and data collection, and is equipped with façade specimens, secondary objects (e.g., shading devices), the sensors 130, split air-conditioning front unit, and so on. The back
 25 compartment 160 is configured to house devices and systems (not shown) for data processing, system control, data storage and data transmission. For example, the back compartment 160 is equipped with information handling devices (e.g., computers), displays, communication devices (e.g., capable of wireless communication such as via Wi-Fi and 3G/4G mobile network and/or wired communication such as via LAN), split air-
 30 conditioning back unit, etc. The testing enclosure 110 and the processing enclosure 160 may be positioned side by side such that they share a common inner side wall (i.e., a rear side 162 of the testing enclosure 110). Furthermore, the front side of the processing enclosure 160 and/or the common inner side wall has a door 161 to allow access to the processing enclosure 160. As an example only and without

limitation, the depth (d1) of the testing enclosure 110 may be 1.5m and the depth (d2) of the processing enclosure 160 may be 0.6m.

5 In the example embodiment, the testing enclosure 110 has three interchangeable façade sides (i.e., a front side 164, a left side 166, and a right side 168) to facilitate testing of various types of façade specimens or façade system configurations. It will be appreciated that more or less interchangeable façade sides may be provided as desired or as appropriate. For example, the testing enclosure 110 is not limited to having a rectangular cross-section as shown in Fig. 1 and that more or less
10 interchangeable façade sides may be provided depending on the cross-sectional shape of the testing enclosure 110. As shown in Fig. 1, the testing enclosure 110 is configured to be enclosed by a ceiling structure 170, a base structure 154, and a plurality of side structures 162, 308, and 312 (e.g., see Fig. 3). Specifically, one or more of the façade specimens 308, 312 form one or more of the plurality of side structures, respectively, when releasably secured to the one or more side frames 120.
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By way of example only, Fig. 3 illustrates an example whereby the clear glazed façade specimens 304 initially secured to the three side frames 120 are released and
interchanged with non-glazed façade specimens 308 (e.g., made of concrete, brick
20 and/or aluminium) in one example, or interchanged with coated glazed façade specimens 312 (e.g., low-E coated, thin-film coat or IR-coated) in another example. Details of the securing mechanism at the side frames 120 for releasably securing the façade specimens for testing will be described later with reference to Figs. 6 and 7.

25 As the test chamber 100 has multiple interchangeable façade sides in embodiments of the present invention, it will be appreciated that any combination of the same type or different types of façade specimens may be releasably secured to the interchangeable side frames 120 of the test chamber 100 as desired to test the environmental performance of various façade system configurations. As described hereinbefore, façade
30 systems are becoming more complex, and they come in a large variety and in different forms. Therefore, the test chamber 100 according to embodiments of the present invention advantageously provides the ability for the assessors to test various façade system configurations with ease. Any type of façade specimens may be tested by the test chamber 100, including but without limitation, glazed facades, metallic façades (e.g.,

aluminium, steel, etc.), non-metal façades (e.g., concrete composites, brick, etc.), cool paint coated façades, switchable glazed façades (e.g., switchable colour), coloured glazed façades, insulative façades, solar thin-films coated façades, low-E coated façades, double-skin façades, solar-responsive façades, thermo-responsive façades, 5 electro-responsive façades, PCM-embedded façades, motorized shutter devices, solar-shading systems (e.g., drape, blind, louvered lamellas, curtain rollers, shutters), façades with air-ventilation openings, vertical-green façades, and so on.

As described hereinbefore, in an embodiment, the mobile test chamber 100 is further 10 configured to enable an interchangeable shading system such that various shading system configurations can be tested in the test chamber 100 together with the interchangeable façade system to measure the environmental performance of various façade and shading systems configurations. In this regard, in an example embodiment, the test chamber 100 further comprises securing mechanism in the base structure 154 15 and/or the ceiling structure 170 for securing one or more secondary objects in the testing enclosure 110 for testing together with the one or more façade specimens to determine the environmental performance of the façade system as a whole (i.e., with the secondary objects). For example, the secondary objects comprise shading devices for reducing environmental exposure in the testing enclosure 110 from the outside test environment. 20 For example, the shading devices may include, but not limited to, blinds, curtains, drapes, roller sheets, shutters, laminates, louvered lamellas, thin-films, thermochromic shading devices, electrochromic shading devices, etc. Similarly to the façades specimens, it will be appreciated that any combination of the same type or different types of shading device specimens may be releasably secured to the test chamber 100 25 as desired to test the environmental performance of the façade system with various shading device system configurations.

Table 1 below lists various types of exemplary specimens which may be installed or interchangeably secured to the test chamber 100 according to embodiments of the 30 present invention for testing. It will be appreciated that the lists provided in Table 1 are non-exhaustive and other types of specimens not mentioned in Table 1 may also be tested by the test chamber 100 as desired.

Façade systems	Roof systems	Interior walls/floor/ceilings
- Glazed-façades - Metallic façades (e.g., Al, steel, etc) - Non-metallic façades (e.g., concrete composites, brick) - Cool-paint coatings - Switchable glazed façades - Colored glazed façades - Insulative façades - Solar thin-films - Low-E glass-coatings - Solar glass-coatings - Double-skin façades - Solar-responsive façades - Thermo-responsive façades - Electro-responsive façades - PCM-embedded façades - Motorized shutter devices - Solar-shading systems (e.g., drape, blind, louvered lamellas, curtain, rollers, shutters) - Air-ventilation openings - Vertical-green façades	- Green roof systems - Reflective paint coatings - Insulative paint coatings - Solar-panels	- Chilled beams walls - Insulated walls - PCM-embedded walls - Thermal energy storages - Desiccant systems

Table 1 – Various types of exemplary specimens which may be tested by the test chamber 100

By way of example only, Fig. 4 illustrates various shading devices which may be installed or mounted in the test chamber 100 together with the clear glazed façade specimens 304 initially secured to the test chamber 100. As illustrated in the example of Fig. 4, the shading devices may be window blinds 404, thin films 408, thermochromic shading devices 412, and/or window curtains 416. In an embodiment, the shading devices may be automated by a control loop such that they are adjustable between various states (e.g., between an open/on state and a close/off state) to dynamically simulate a predicted usage of the shading devices in real life. This can achieve a dynamic and more accurate measurement of the environment performance of the façade system. For example, the control loop may be pre-programmed to adjust between the various states based on a predetermined time of the day or predetermined time intervals. In another embodiment, the shading devices may be configured to be responsive to an input command signal or to certain environmental conditions. For

example, the shading devices may be adjusted to open or close by detecting whether it is day or night. Accordingly, in this embodiment, the shading devices in the testing chamber 100 may advantageously be automated and/or responsive to dynamically simulate real life conditions during testing. Details of the securing mechanism in the base structure 154 and/or the ceiling structure 170 will be described later with reference to Fig. 8.

Fig. 5 schematically illustrates the example test chamber 100 integrated with multiple sensors 130, which render its ability to carry out multifunctional sensing for different environmental parameters. It will be appreciated to a person skilled in the art that multiple sensors 130 for measuring multiple environmental parameters may be integrated as one integrated sensor for measuring such multiple environmental parameters. Therefore, multiple sensors 130 described herein also cover such an integrated sensor. By way of example, Fig. 5 schematically illustrates six exemplary environmental parameters capable of being measured by the multiple sensors (or integrated sensor) 130, namely, humidity, rainfall, temperature, solar radiation, daylight illuminance, and power consumption. Further sensing parameters may include, but not limited to, wet/dry bulb ambient temperature, mean radiant temperature, glare, direct and diffused daylighting, real-time thermal imaging, wind, sound, air quality, sun-path tracking, and GPS location. Accordingly, the sensors 130 may include, but not limited to, a Pt100 thermal sensors, a humidity sensor, a lux sensor, an IR sensor, a radiant thermometer, rain sensor, wind sensor, air-quality sensor (e.g., CO, CO₂, NOX and SOX sensors), a noise/sound sensor, a dust sensor, a solar irradiance sensor, a GPS sensor, an environmental sensor (e.g., PM_{2.5} etc.), a physical and chemical sensor (e.g., dust, pesticides, herbicides, methane, etc.), and a power sensor (e.g., power consumption monitoring device). The multiple sensors 130 enable multi-functional sensing capability which allows simultaneous testing of many environmental parameters. This allows a better and more detailed assessment of the environment performance of the test chamber in an efficient manner.

Preferably, the testing enclosure 110 is airtight, corrosion proof, water proof. For example, to achieve such properties, the inner structure of the test chamber (including the side frames 120) is made of aluminum and the exposed parts of the inner structure facing outward are covered with insulation materials and stainless steel. Further, the

securing mechanism at the side frames 120 are configured to releasably secure the façade specimens in a manner such that the testing enclosure 110 is airtight and water proof when the façade specimens are secured thereto. It will be appreciated that the testing enclosure 110 being airtight means that the testing enclosure does not exchange
5 air with the outside environment unless through the air-conditioner, exhaust fan or the like intentionally installed therein. Accordingly, the example test chamber 100 is suitable for outdoor testing environment since it can withstand rain and corrosion. In an embodiment, the ceiling structure 170, the base structure 154 and one or more of the side structures which are not formed by any of the one or more façade specimen (i.e.,
10 the rear side structure 162 in the example of Fig. 1) are thermally insulated so as to minimise influence from the outside environment to the conditions in the testing enclosure 110 due to such structures.

Details of the securing mechanism at the side frames 120 for releasably securing the
15 façade specimens for testing will now be described with reference to Figs. 6 and 7 according to an example embodiment of the present invention. However, it will be appreciated to a person skilled in the art that the present invention is not limited to this type of securing mechanism described and other types of securing mechanism are within the scope of the present invention as long as they can releasably secure the
20 façade specimens to the side frames 120 in a manner which preserves the above-mentioned airtight and water proof properties.

Fig. 6A depicts the test chamber 100 at an original or initial state whereby the specimen façades are not yet installed or mounted to the test chamber 100. As shown, the side
25 frames 120 are protected by metallic covers 610, preferably made of stainless steel, to enhance the corrosion resistance of the structure and for weather proofing (e.g., airtight and water proof). The metallic cover 610 is generally elongated in shape and is configured to be fastened to a corresponding section of the side frame 120 so as to cover the section.

30 An example of mounting a specimen façade to the front side 164 of the test chamber 100 will now be described. First, the metallic covers 610 at the front side 164 are removed to expose the front side frame 122. Specifically, in the case of a rectangular front side frame 122 as shown in Fig. 6A, the two vertical covers and the bottom

horizontal cover fastened to the front side frame 122 are removed. Fig. 6B illustrates a perspective close up view of the front side frame 122 looking from the left side 166. To detach the metallic covers 610 from the front side frame 122, fasteners (e.g., screws or bolts) are removed from the preformed fastener holes 620 shown in Fig. 6B. Fig. 6C depicts the test chamber 100 at a state whereby the two vertical covers have been removed from the front side 164 to expose the front side frame 122 underneath. This leaves the bottom horizontal cover to be removed. Fig. 6D depicts the test chamber 100 at a state whereby the bottom horizontal cover has also been removed.

After the metallic covers 610 have been removed from the front side frame 122 as shown in Fig. 6D, the front side frame 122 is thus exposed, along with the plurality of sliding bars 630 formed on the front side frame 122 which constitutes the securing mechanism. For example, the sliding bar 630 may extend substantially along an entire length of a section of the front side frame 122 (such as the vertical section), or a plurality of sliding bars 630 may be formed at intervals along a section of the front side frame 122 (such as the bottom section) as shown in Fig. 6D. The sliding bars 630 are each adjustable between a lock position for securing the façade specimen to the front side frame 122 for testing and a release position for allowing the façade specimen to be removed from the front side frame 122. The sliding direction of the sliding bars 630 from a lock position to a release position is illustrated by the arrows 634 in Fig. 6D. The sliding bar 630 may be held in its lock position by a fastener (not shown) which needs to be unfastened in order for the sliding bar 630 to be adjustable. Once all of the sliding bars 630 have been adjusted to the release position, the façade specimen for the front side 164 may then be mounted to the front side frame 122. To secure the façade specimen to the front side frame 122, the sliding bars 630 are adjusted back to their lock position so as to hold the façade specimen inserted/placed on the front side frame 122 and under/behind the sliding bars 630. The fastener is fastened to hold the sliding bars in the lock position. On the other hand, to remove the façade specimen from the front side frame 122, the sliding bars 630 are simply adjusted to the release position to allow the façade specimen to be removed since the façade specimen would no longer be held under/behind the sliding bars 630.

In generally the same manner as described above for the front side frame 122, a façade specimen can also be mounted to the left and right side frames 124, 126. An example of

installing the façade specimen to the right side frame 126 will now be described. First, the metallic covers 610 at the right side 168 as shown in Fig. 7A are removed to expose the right side frame 126, in particular, the two vertical covers and the bottom horizontal cover. Fig. 7B depicts a state of the test chamber 100 where the vertical cover adjacent the front side 164 is removed, Fig. 7C illustrates a state of the test chamber 100 where the bottom horizontal cover has also been removed, and Fig. 7D illustrates a state of the test chamber 100 where the other vertical cover adjacent the back compartment 160 has further been removed. It will be appreciated that the vertical cover adjacent the front side 164 removed in Figs. 7A and 7B is a common vertical cover for the front side frame 122 and the right side frame 126. Fig. 7D illustrates the right side frame 126 exposed after the metallic covers 610 have been removed. As shown, the right side frame 126 also has a plurality of sliding bars 630 formed thereto which constitutes the securing mechanism. Each sliding bar 630 is configured to be adjustable between a lock position for securing the façade specimen to the right side frame 126 for testing and a release position for allowing the façade specimen to be removed from the right side frame 126 in the same manner as described hereinbefore for the front side frame 122 with respect to Figs. 6A to 6D and thus will not be repeated for conciseness. In the example embodiment, the left side frame 124 has the same structure as the right side frame 126 and thus will not be repeated for conciseness.

As mentioned hereinbefore, in an embodiment, at least one of the ceiling structure 170 and the base structure 154 has a securing mechanism formed therein configured for securing one or more secondary object/device specimens in the testing enclosure 110 for testing together with the one or more façade specimens for determining the environmental performance of the specimen façade system. An example of the securing mechanism 806 formed in the base structure 154 will now be described. As shown, the securing mechanism 806 comprises an arrangement of guiding channels 810 (e.g. embedded/integrated with fasteners, such as nuts) for receiving a corresponding engaging member (not shown) of the one or more secondary object specimens for releasably securing the secondary object specimens in the testing enclosure 110. Although not illustrated, it will be appreciated that the ceiling structure 170 may also have a same corresponding securing mechanism formed therein. For example, the shading device specimen is configured to have engaging members (e.g., fasteners) protruding from a bottom portion and a top portion to be inserted in the appropriate

channels 810 in the base and ceiling structures 154, 170 and slide therein to position the shading device specimen in the testing enclosure 110. For example, Fig. 8 schematically illustrates three shading device specimens 814 mounted to the base structure 154 adjacent the three interchangeable sides of the testing enclosure 110.

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Fig. 9 depicts a test chamber system 900 comprising a mobile test chamber 100 as described herein and a computer device 906 having stored therein an executable application configured for remotely controlling one or more systems (not shown) in the mobile test chamber 100, including setting conditions in the testing enclosure 110, and receiving data sensed by the plurality of sensors 130 for processing, logging, and/or remotely monitoring the data sensed. For example, the received sensed data may be displayed to a user on a display screen 912 of the computer device 906. The computer device 906 comprises a processor 907 capable of executing the executable application, a storage medium 908 for storing various data such as the executable application and the data received from the sensors 130, and a communication module 909 for receiving and transmitting data. The communication between the control device 906 and the mobile test chamber 100 is preferably via wireless communication 910, such as via Wi-Fi or 3G/4G mobile network. Preferably, the above-mentioned one or more systems in the testing enclosure 110 are configured for setting conditions, including heating, ventilation, air conditioning, humidity and lighting. By way of an example, Fig. 10 illustrates a user interface 1010 of an application displaying data sensed by the sensors 130 to a user. For example, the computer device 906 may be any device capable of communicating with the test chamber 100 and capable of executing an application designed to control the one or more systems in the mobile test chamber 100, such as a computer, a laptop, and a mobile wireless device (e.g., a smartphone, a tablet, etc.). Such a computer device 906 is known in the art and thus need not be described in detail herein. A person skilled in the art would also be able to program various executable applications executable by the processor 907 of the computer device 906 to perform various functions as described herein and thus need not be described in detail herein.

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Fig. 11 depicts a wireless network of mobile test chambers 100 according to an embodiment comprising a plurality of the mobile test chambers 100 communicatively coupled to one another for data transmission.

Accordingly, embodiments of the present invention provide one or more of the following exemplary advantages.

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 - Mobility and global positioning – The test chambers 100 are mobile, allowing accurate data from several GPS locations to be taken so that data can be verified and corrected with respect to desired location (versus fixed immobile chambers);
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 - Consistency – Consistency of sensing data, e.g., via 3-chamber 6-sensors configuration: 3 chambers' sensors are interlinked, data-sharing and compared real-time online (versus single-sensor standalone chamber);
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 - Reliability – Strong baseline formation e.g., via 3-chamber 6-sensors configuration Strong baselines are formed by taking readings from three chambers at same location and same time. Sensing begins by taking three baselines first (all the test chambers are identical, only the façade and shading devices specimens are different and interchangeable) (versus conventional chambers and facades which are permanently fixed and cannot be changed);
- 20

 - Rotatability – Rotatability of chambers allows changes of façades and shading devices facing direction (versus fixed chambers that cannot change facing direction, in which only one set of limited data is collected);
- 25

 - Robust – The test chamber 100 can monitor and prevent sensor drifting, sensor errors and sensor defects via cross-comparison (e.g., 3 chambers 6-sensors configuration for cross comparison, IR cameras supporting) (versus single-sensor standalone chamber that offers no cross-comparisons);
- 30

 - Online data storage – For example, data-clouding uploading and real-time backups of data (versus localized storage);
- Diffusive sensing – Mobile sensing networks-enabled data communication via 3G/4G, mobile wireless device (e.g., smartphone), internet, or social media (e.g., via FACEBOOK or TWITTER control) (versus offline systems);

- Security – 24hrs online security cameras monitoring chambers (versus most chambers are not secured);
- 5 • Interactive control – For example, façade/shading/lighting/air conditioning and mechanical ventilation (ACMV) Samples-Sensors-Environment-Enduser Integrated Interactive Control (SSEIIC), where façades and shading devices are controlled by sensors and controllers which react to changes to environment (versus standalone façade systems that are separate from shading systems and ACMV systems);
- 10 • End users control – End users can easily control façade/shading/lighting/ACMV samples real-time via online internet or mobile wireless device (e.g., smartphones) (versus on-site standalone systems);
- 15 • Real-time remote monitoring – Cross-boundary sensing and remote-control of systems, e.g., from overseas (versus localised systems);
- 20 • High data quality – Data-sensing and database-creation carried out in the test chamber that is designed specifically for interchangeable facades and shading devices, completed with ACMV and lighting controls (versus chambers that are not designed for facades and shading devices);
- 25 • One-stop universal sensing – One-stop universal sensing in a single-chamber for multiple types of environmental, physical and chemical parameters (versus chambers that have only one-type of sensors e.g. thermal sensors); and/or
- 30 • Actual outdoor weather condition sensing – Actual climate conditions (versus indoor-chambers that are limited in weather conditions, sunlight is simulated using solar lamps, no rain, etc.)

Accordingly, according to embodiments of the present invention, interchangeable mechanical and structural designs are devised into the test chamber 100, which give end users access to change and test different façade and shading device systems. The test chamber 100 design enables an interchangeable façade system (e.g., three-faced

façade system), whereby multiple (e.g., three) façade surfaces can be removed and exchanged. This advantageously enables simultaneous testing of different façade systems. This also enables the end users to test different permutations of shading specimens under different façade configurations. In addition, the test chamber 100 with
5 interchangeable façade surfaces in embodiments is designed to maximize the climate effects (e.g. direct and diffused solar radiation) on the shading device specimens, thereby optimizing specimens testing under outdoor climatic conditions.

In addition, multiple sensors 130 are designed into the test chamber 100, and they are
10 preferably integrated into a single user interface. The real-time data on numerical environment parameters such as solar, daylighting, rain, air, humidity, power consumption, energy efficiency can be collected simultaneously and are ready for further processing. Moreover, these sensors 130 are integrated with the HVAC, humidity and lighting control via a feedback system (not shown).

15 Therefore, it can be appreciated that the test chamber 100 according to embodiments of the present invention enables the testing of different kinds of shading devices. As more shading devices become electronically operated and more intelligent, the test chamber 100 allows testing of both automated and non-automated shading devices. These
20 shading devices are also integrated with the HVAC, humidity and lighting control via a feedback system (not shown).

It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific
25 embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

1. A mobile test chamber for testing environmental performance of an interchangeable façade system in a test environment, the test chamber comprising:

5 a testing enclosure having one or more side frames configured for releasably securing one or more façade specimens for testing,

a plurality of sensors arranged in the testing enclosure for measuring multiple environmental parameters associated with the testing enclosure in the test environment when the testing enclosure has the one or more façade specimens releasably secured thereto, and

10 a mobility system disposed on a base structure of the test chamber configured for allowing mobility and rotatability of the test chamber.

2. The mobile test chamber according to claim 1, wherein the testing enclosure is configured to be enclosed by a ceiling structure, the base structure, and a plurality of side structures, and wherein said one or more façade specimens form one or more of the plurality of side structures, respectively, when releasably secured to said one or more side frames.

20 3. The mobile test chamber according to claim 2, wherein the ceiling structure, base structure, and one or more of the side structures which are not formed by any of the one or more façade specimen are thermally insulated.

4. The mobile test chamber according to claim 2 or 3, wherein at least one of the ceiling structure and the base structure has a securing mechanism formed therein configured for securing one or more secondary objects in the testing enclosure for testing together with the one or more façade specimens for determining the environmental performance of the façade system with the one or more secondary objects.

30 5. The mobile test chamber according to claim 4, wherein the securing mechanism comprises an arrangement of guiding channels for receiving a corresponding engaging member of the one or more secondary objects for releasably securing the secondary objects in the testing enclosure.

6. The mobile test chamber according to claim 5, wherein the one or more secondary objects comprise shading devices configured for reducing environmental exposure in the testing enclosure from the outside test environment.

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7. The mobile test chamber according to any one of claims 1 to 6, wherein the side frame comprises a securing mechanism for releasably securing the façade specimen for testing, the securing mechanism comprising a plurality of sliding bars, each adjustable between a lock position for securing the façade specimen in the side frame during testing and a release position for allowing the façade specimen to be removed from the side frame.

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8. The mobile test chamber according to any one of claims 1 to 7, further comprising a processing enclosure having one or more information handling devices located therein processing data, including data received from the plurality of sensors.

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9. The mobile test chamber according to claim 8, further comprising a wireless network device for communicating with one or more other mobile test chambers testing environmental performance of one or more other interchangeable façade systems so as to utilize the mobile test chamber in a wireless test chamber network for testing environmental performances of façade systems at multiple locations.

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10. The mobile test chamber according to any one of claims 1 to 9, further comprising one or more systems configured for setting conditions in the testing enclosure, the conditions include heating, ventilation, air conditioning, humidity and lighting.

25

11. The mobile test chamber according to any one of claims 1 to 10, wherein the plurality of sensors are selected from a group consisting of a thermal sensor, a humidity sensor, a lux sensor, an infra-red sensor, a radiant thermometer, a rain sensor, a wind sensor, an air-quality sensor, a sound sensor, a dust sensor, a solar irradiance sensor, an environmental sensor, a chemical sensor, a power sensor and a GPS sensor.

30

12. The mobile test chamber according to claim 11, wherein multiple sensors from the plurality of sensors are integrated as one sensor having multiple sensing functionalities.

5 13. The mobile test chamber according to any one of claims 1 to 12, wherein the test chamber is rotatable about a vertical axis for adjusting an orientation of the one or more façade specimens releasably secured thereto.

14. A test chamber system comprising:

10 a mobile test chamber according to any one of claims 1 to 13; and
a computer device having stored therein an executable application configured for remotely controlling one or more systems in the mobile test chamber, including setting conditions in the testing enclosure, and receiving data sensed by the plurality of sensors for processing, logging and/or remotely monitoring the data sensed, via a wireless
15 communication.

15. The mobile test chamber system according to claim 14, wherein said conditions include heating, ventilation, air conditioning, humidity, and lighting.

20 16. A wireless network of mobile test chambers comprising a plurality of the mobile test chambers according to any one of claims 1 to 13 communicatively coupled to one another for data communication.