

**OPTIMIZATION OF BUILDING ENVELOPE FOR
SIMULTANEOUS THERMAL, DAYLIGHT, AND NOISE
INSULATION PERFORMANCE, IN TROPICAL
CLIMATES**

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**DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY DELHI
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by

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DEPARTMENT OF CIVIL ENGINEERING

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CERTIFICATE

This is to certify that the thesis entitled "**Optimization of building envelope for simultaneous thermal, daylight and noise insulation performance, in tropical climates**" by **Mr. Nabeel Ahmed Khan**, to the Indian Institute of Technology, Delhi for the award of the degree of "**Doctor of Philosophy**" is a record of bona fide research work carried by him under my guidance and supervision. The research material and results contained in the present form of the thesis have not been submitted in part or fully to any other University or Institute for the award of any other degree or diploma to the best of our knowledge.

(Prof. B. Bhattacharjee)

Department of Civil Engineering

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Nabeel Ahmed Khan

ABSTRACT

Thermal, visual, and acoustic comfort are among the major parameters of overall occupant comfort and indoor environmental quality in buildings. Early-stage design and selection of building envelope parameters require due consideration to all these three aspects of comfort to enhance envelope performance, productivity, and wellbeing of occupants. Several methodologies have been proposed by researchers for optimization of thermal and visual performance of the envelope, both individually and simultaneously, but the acoustic performance, i.e. mainly noise insulation, has remained largely disregarded or left to be dealt with at a later stage. The lack of a proper methodology for simultaneous optimization of thermal and visual performance of building envelope with acoustic performance has led to degradation of the acoustic environment inside green buildings. The present study proposes a methodology for simultaneous optimization of the thermal, daylight insertion, and noise insulation performance of building envelope to minimize operational energy consumption and enhance thermal, visual, and acoustic comfort for the occupants. The proposed methodology makes the use of a multi-objective optimization algorithm, Non-Dominated Sorting Genetic Algorithm-II (Deb, Pratap, Agarwal, and Meyarivan 2002a), combined with thermal, daylight, and sound energy transfer models to arrive at a set of optimized building envelope parameters for early-stage design. The admittance method proposed by Milbank and Harrington-Lynn (Milbank and Harrington-Lynn, 1974) is used to assess the thermal performance of the building envelope. The daylight insertion through the windows is estimated making the use of the Perez sky model (Perez, Seals, and Michalsky 1993) and inverse square law (Koenigsberger, 1984). The noise insulation property of the envelope construction and glazing is estimated through the transfer matrix method (Brouard, 1995) and the performance is assessed using the OITC rating (ASTM, 2016). The efficacy of the proposed methodology is assessed by using it for the early-stage

design of a hypothetical case study building and studying the set of optimal design solutions thus obtained. An adequate sky luminance prediction model for Indian tropical climatic conditions is proposed through comparative between measured sky luminance data and widely used sky luminance prediction models (Perez and CIE sky model (Darula and Kittler, 2002)).

As an end-user or a decision-maker, every person is not skilled enough to carry out whole building simulation optimization himself for the selection of building envelope parameters for the desired objectives. For global and mass adoption of such green building solutions, a set of climate-specific ready-to-use guidelines are required that can be readily used by the architects or decision-makers in the design stage of building for the reduction in energy consumption and enhancement of comfort levels inside the building. Therefore a set of guidelines are also proposed using the developed methodology for low-rise commercial buildings which when implemented in design will enhance thermal, visual, and noise insulation performance for the building envelope leading to minimum energy consumption while ensuring thermal, visual, and noise insulation comfort for the occupants in different climatic zones of tropical climate.

The proposed methodology was also used to develop design guidelines for envelopes in multi-unit residential buildings. A modified form of the proposed methodology was used to develop design guidelines for multi-unit residential building envelopes in major climatic zones of the Indian tropical climate.

सार

थर्मल, विजुअल और ध्वनिक आराम इमारतों में समग्र अधिभोगी आराम और इनडोर पर्यावरणीय गुणवत्ता के प्रमुख मापदंडों में से हैं। लिफाफा के प्रदर्शन, उत्पादकता और रहने वालों की भलाई को बढ़ाने के लिए आराम के इन सभी तीन पहलुओं पर प्रारंभिक चरण के डिजाइन और लिफाफा मापदंडों के चयन की आवश्यकता है। लिफाफे के थर्मल और दृश्य प्रदर्शन के अनुकूलन के लिए शोधकर्ताओं द्वारा कई तरीके प्रस्तावित किए गए हैं, व्यक्तिगत रूप से और एक साथ, लेकिन ध्वनिक प्रदर्शन, यानी मुख्य रूप से शोर इन्सुलेशन, को बाद के चरण में बड़े पैमाने पर अवहेलना या छोड़ दिया गया है। ध्वनिक प्रदर्शन के साथ इमारत के लिफाफे के थर्मल और दृश्य प्रदर्शन के एक साथ अनुकूलन के लिए एक उचित पद्धति की कमी के कारण हरित भवनों के अंदर ध्वनिक वातावरण का हास हुआ है। वर्तमान अध्ययन परिचालन ऊर्जा खपत को कम करने और रहने वालों के लिए थर्मल, दृश्य और ध्वनिक आराम को बढ़ाने के लिए थर्मल, डेलाइट सम्मिलन, और भवन लिफाफे के शोर इन्सुलेशन प्रदर्शन के एक साथ अनुकूलन के लिए एक पद्धति का प्रस्ताव करता है। प्रस्तावित कार्यप्रणाली एक सेट पर पहुंचने के लिए थर्मल, डेलाइट और साउंड एनर्जी ट्रांसफर मॉडल के साथ संयुक्त एक बहु-उद्देश्यीय अनुकूलन एल्गोरिथ्म, गैर-डोमिनेटेड सॉर्टिंग जेनेटिक एल्गोरिथ्म- II (देब, प्रताप, अग्रवाल और मेयारिवन 2002ए) का उपयोग करती है। प्रारंभिक चरण के डिजाइन के लिए अनुकूलित भवन लिफाफा मापदंडों का। मिलबैंक और हैरिंगटन-लिन (मिलबैंक और हैरिंगटन-लिन, 1974) द्वारा प्रस्तावित प्रवेश पद्धति का उपयोग भवन लिफाफे के थर्मल प्रदर्शन का आकलन करने के लिए किया जाता है। खिड़कियों के माध्यम से दिन के उजाले सम्मिलन का अनुमान पेरेज़ स्काई मॉडल (पेरेज़, सील्स, और माइकल्स्की 1993) और व्युत्क्रम वर्ग कानून (कोएनिग्सबर्गर, 1984) का उपयोग करके किया गया है। लिफाफा निर्माण और ग्लेज़िंग की शोर इन्सुलेशन संपत्ति का अनुमान स्थानांतरण मैट्रिक्स विधि (ब्रौर्ड, 1995) के माध्यम से किया जाता है और प्रदर्शन का मूल्यांकन ओआईटीसी रेटिंग (एएसटीएम, 2016) का उपयोग करके किया जाता है। प्रस्तावित कार्यप्रणाली की प्रभावकारिता का आकलन एक काल्पनिक केस स्टडी बिल्डिंग के प्रारंभिक चरण के

डिजाइन के लिए इसका उपयोग करके और इस प्रकार प्राप्त इष्टतम डिजाइन समाधानों के सेट का अध्ययन करके किया जाता है। भारतीय उष्णकटिबंधीय जलवायु परिस्थितियों के लिए एक पर्याप्त स्काई ल्यूमिनेंस भविष्यवाणी मॉडल का प्रस्ताव मापा स्काई ल्यूमिनेंस डेटा और व्यापक रूप से उपयोग किए जाने वाले स्काई ल्यूमिनेंस भविष्यवाणी मॉडल (पेरेज़ और सीआईई स्काई मॉडल (दारुला और किटलर, 2002)) के बीच तुलनात्मक के माध्यम से किया जाता है।

एक अंतिम-उपयोगकर्ता या निर्णय-निर्माता के रूप में, प्रत्येक व्यक्ति वांछित उद्देश्यों के लिए भवन लिफाफा मापदंडों के चयन के लिए पूरे भवन सिमुलेशन अनुकूलन को स्वयं करने के लिए पर्याप्त कुशल नहीं है। इस तरह के हरित भवन समाधानों को वैश्विक और बड़े पैमाने पर अपनाने के लिए, जलवायु-विशिष्ट रेडी-टू-यूज़ दिशानिर्देशों के एक सेट की आवश्यकता होती है, जिसका उपयोग वास्तुकारों या निर्णय निर्माताओं द्वारा ऊर्जा की खपत में कमी के लिए भवन के डिजाइन चरण में आसानी से किया जा सकता है और इमारत के अंदर आराम के स्तर में वृद्धि। इसलिए कम वृद्धि वाले वाणिज्यिक भवनों के लिए विकसित पद्धति का उपयोग करके दिशानिर्देशों का एक सेट भी प्रस्तावित किया जाता है, जो डिजाइन में लागू होने पर थर्मल, दृश्य और शोर सुनिश्चित करते हुए न्यूनतम ऊर्जा खपत के लिए इमारत के लिफाफे के लिए थर्मल, दृश्य और शोर इन्सुलेशन प्रदर्शन को बढ़ाएगा। उष्णकटिबंधीय जलवायु के विभिन्न जलवायु क्षेत्रों में रहने वालों के लिए इन्सुलेशन आराम।

प्रस्तावित पद्धति का उपयोग बहु-इकाई आवासीय भवनों में लिफाफों के लिए डिजाइन दिशानिर्देश विकसित करने के लिए भी किया गया था। भारतीय उष्णकटिबंधीय जलवायु के प्रमुख जलवायु क्षेत्रों में बहु-इकाई आवासीय भवन लिफाफों के लिए डिजाइन दिशानिर्देश विकसित करने के लिए प्रस्तावित कार्यप्रणाली का एक संशोधित रूप इस्तेमाल किया गया था।

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