Shaping Tomorrow's Built Environment Today

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TO: Chris Balbach, Chair TC 4.7, cbalbach@psdconsulting.com
Jeff Haberl, Research Subcommittee Chair TC 4.7, jhaberl@tamu.edu
CC: Michael Pouchak, Research Liaison Section 4.0, mike.pouchak@honeywell.com

FROM: Michael Vaughn, MORTS, mvaughn@ashrae.org

DATE: November 6, 2018

SUBJECT: Research Topic Acceptance Request (1857-RTAR), "Improved simplified methodology for describing and calculating heat conduction between buildings and the ground"

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During their fall meeting, the Research Administration Committee (RAC) reviewed the subject Research Topic Acceptance Request (RTAR) and voted to accept it with comments for further development into a work statement (WS) provided that the key comment(s) and question(s) below are addressed to the satisfaction of your Research Liaison, Michael Pouchak, mike.pouchak@honeywell.com, or RL4@ashrae.net, in the work statement draft.

1. The RTAR does not state the problems of the each simplified method and is difficult to be understand the proposed research.
2. A further check of literature is needed. US and European to make sure nothing has emerged in this field that may have been missed.
3. Assure that the number of required building models is aligned with the budget.

The work statement draft must be approved by the Research Liaison prior to submitting it to RAC.

An RTAR evaluation sheet is attached as additional information and it provides a breakdown of comments and questions from individual RAC members based on specific review criteria. This should give you an idea of how your RTAR is being interpreted and understood by others. Some of these comments may indicate areas of the RTAR and subsequent WS where readers require additional information or rewording for clarification.

The first draft of the work statement should be submitted to RAC no later than **August 15, 2020** or it will be dropped from display on the Society's Research Implementation Plan. The next likely submission deadline for a new work statement on this topic is **May 15, 2019** for consideration at RAC's 2019 Annual meeting. The submission deadline after that for work statements is **August 15, 2019** for consideration at the RAC's 2019 fall meeting.

| | | |
|---|---|---|
| **Project ID** | **1857** | |
| **Project Title** | **Improved simplified methodology for describing and calculating heat conduction between buildings and the ground** | |
| **Sponsoring TC** | TC 4.7 Energy Calculations | |
| **Cost / Duration** | $75,000/ 18 Months | |
| **Submission History** | **1st Submission** | |
| **Classification: Research or Technology Transfer** | Basic/Applied Research | |
| **RAC 2018 Fall Meeting Review** | | |
| **Essential Criteria** | **Voted NO** | **Comments & Suggestions** |
| **Background:** The RTAR should describe current state of the art with some level of literature review that documents the importance/magnitude of a problem. References should be provided. If not, then note it in your comments. | | **2** - There are two factors of heat conduction. One is building side and the other is ground side. There are few descriptions of how mode both of two. The modeling of the ground will be difficult. The RTAR can explain the modeling of ground. **9** - The problem is recognized and is positioned within the literature. This is a well-understood area of concern, that would benefit from clarity, **8** - good. |
| **Research Need:** Based on the background provided is the need for additional research clearly identified? If not, then the RTAR should be rejected. | | **2** - The RTAR describes nothing of the simplified methods and is difficult to be evaluated. **9** - A new metric or methodology would result. **8** - good discussion |
| **Relevance and Benefits to ASHRAE:**<br>Evaluate whether relevance and benefits are clearly explained in terms of:<br>a. Leading to innovations in the field of HVAC & Refrigeration<br>b. Valuable addition to the missing information which will lead to new design guidelines and valuable modifications to handbooks and standards.<br>Is this research topic appropriate for ASHRAE funding? If not, Reject. | | **9** - Will lead to a consistent simplified approach across all ASHRAE documentation. **8** - will benefit under and oversizing calculations |
| **IF ABOVE THREE CRITERION ARE NOT ALL SATISFIED - MARK "REJECT" BELOW & CONTINUE REVIEW BELOW** | | |
| **Other Criteria** | **Voted NO** | **Comments & Suggestions** |
| **Project Objectives:** Based on the background and need, evaluate whether the project objectives are:<br>1. Aligned with the need<br>2. Specific<br>3. Clear without ambiguity<br>4. Achievable<br>If not, then appropriate feedback should be provided. | | **9** - These are clearly stated and achievable. **10** - The authors should be more specific and detail the criteria for accepting the result of one or more simple methods. How will the evaluation be carried out? How will the more detailed 2/3-D methods be assessed to establish them as a reference? What is the criterion to establish that a simple method adequately represents the effect of heat transfer? |
| **Expected Approach and Budget:** Is there an adequate description of the approach in order for RAC to be able to evaluate the appropriateness of the budget? If not, then the RTAR should be returned for revision.<br>Anticipated funding level and duration: | | **7**- Work Statement should include enough details on the type of building constructions and climates so that potential contractors know how many models they need to develop. **9** - Computation by 2D / 3D models versus current simplified methods. **10** - he authors should specify a minimum number of building types, climate zones, etc. to be analyzed. The project lacks the experimental validation of the results. |
| **References:** Are the references provided? | | |
| **Decision Options** | **Initial Decision?** | **Final Approval Conditions** |
| ACCEPT AS-IS | | **2**- The RTAR does not state the problems of the each simplified method and is difficult to be understand the proposed research. **4** - It is unclear whether 2/3-D results for annual simulation create sufficient benchmark against which the simple methods are compared. **7** - RL to work with TC to assure that the number of required building models is aligned with the budget. **9** - use ask the team for a further check of literature, US and European, to make sure nothing has emerged in this field that may have been missed. **10**- The authors should be more specific and detail the criteria for accepting the result of one or more simple methods. How will the evaluation be carried out? How will the more detailed 2/3-D methods be assessed to establish them as a reference? What is the criterion to establish that a simple method adequately represents the effect of heat transfer? An experimental validation would increase the reliability of the project's findings. **8**- meets criteria |
| ACCEPT W/COMMENTS | | |
| REJECT | | |

**ACCEPT Vote** - Topic is ready for development into a work statement (WS).
**ACCEPT W/COMMENTS Vote** - Minor Revision Required - RL can approve RTAR for development into WS without going back to RAC once TC satisfies RAC's approval condition(s)
**REJECT Vote** - Topic is not acceptable for the ASHRAE Research Program

## Research Topic Acceptance Request Cover Sheet

Date: 6/8/2018

(Please Check to Insure the Following Information is in the RTAR)

Title:

| | |
|---|---|
| A. Title | X |
| B Executive Summary | X |
| C. Background | X |
| D. Research Need | X |
| E. Project Objectives | X |
| F. Expected Approach | X |
| G. Relevance and Benefits to ASHRAE | X |
| H. Anticipated Funding Level and Duration | X |
| I. References | X |

Improved simplified methodology for describing and calculating heat conduction between buildings and the ground.

RTAR # 1857
(To be assigned by MORTS)

Results of this Project will affect the following Handbook Chapters, Special Publications, etc.:

Handbook of Fundamentals, Chapters 17, 18 and 19
Standard 90.1

Research Classification:

| | |
|---|---|
| Basic/Applied Research | X |
| Advanced Concepts | |
| Technology Transfer | |

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Responsible Committee: TC 4.7 Energy Calculations

Date of Vote: 1/23/2018

| | | |
|---|---|---|
| For | | 8 |
| Against | * | 0 |
| Abstaining | * | 1 |
| Absent or not returning Ballot | * | CNV |
| Total Voting Members | | 10 |

RTAR Authors

Lead: Neal Kruis and Timothy McDowell

Others:

Co-sponsoring TC/TG/MTG/SSPCs (give vote and date)

Expected Work Statement Authors

Lead: Neal Kruis and Timothy McDowell

Others:

Potential Co-funders (organization, contact person information):

| | Yes | No |
|---|---|---|
| Has an electronic copy been furnished to the MORTS? | X | |
| Has the Research Liaison reviewed the RTAR? | X | |

* Reasons for negative vote(s) and abstentions

One voting member was also a RTAR author

**RTAR # __1857_____**

**Title:**

Improved simplified methodology for describing and calculating heat conduction between buildings and the ground.

**Executive Summary**

The current simplified methods used to estimate heat conduction between the ground and buildings are limited, incomplete, or inaccurate according to ASHRAE literature. This research will assess the various simplified methods against more accurate, multi-dimensional numerical methods to determine a suitable simplified approach to be adopted in ASHRAE energy standards.

**Background**

Annual energy calculation and design load calculation methodology for heat conduction through building foundations into the surrounding ground is inconsistent across ASHRAE literature. The basis for the calculations described in the Handbook of Fundamentals and ASHRAE 90.1 are often dated and/or limited in application. For example, the article used as a basis for the development of the F- and C-Factor approach (Baylon and Kennedy, 2007) in ASHRAE 90.1, the society's energy standard for non-residential buildings, concludes with the statement: "The application of these factors to non-residential buildings has several significant issues. Slab sizes are typically much larger with a much higher area to perimeter ratio."

In the Handbook of Fundamentals, different simplified approaches are referenced in the cooling and heating load calculations chapters (Latta and Boileau, 1969; Wang, 1979) than those described in the energy estimating chapter (Beausoleil-Morrison, 1996; Krarti and Choi, 1996; Winkelmann, 2002). In fact, the handbook states: "For cooling calculations, heat flow into the ground is usually ignored because it is difficult to quantify."

Recent efforts to improve the quantification of heat flow into the ground using more sophisticated 2/3D numerical methods include: ASHRAE Standard 140, with its addition of the "In-Depth Diagnostic Cases for Ground Coupled Heat Transfer Related to Slab-On-Grade Construction" (Neymark and Judkoff, 2008), and developments in specific tools such as TRNSYS (McDowell, 2009) and Kiva (Kruis, 2015). However, there is still a need for reliable calculations that are simple enough to be communicated in the Handbook of Fundamentals and referenced by ASHRAE 90.1.

**Research Need**

Because heat conduction through the ground is difficult to quantify, typically little effort goes into the design of foundation insulation. There is not strong evidence from experiment or simulation to support better decisions. As above grade envelopes improve with pushes towards low/net-zero buildings, the relative contribution to the overall heating and cooling load associated with foundations will only increase. Without better methodology to calculate conduction through the ground, designers risk undersizing equipment serving foundation adjacent zones (resulting in uncomfortable occupants) and/or overdesigning foundations by positioning excessive amounts of insulation where it has minimal impact. There is a need for a unified, simple method for calculating conduction through building foundation surfaces for consistent use throughout ASHRAE literature. The same methodology can cover: heating and cooling, slab and basement foundations, heated and unheated slabs, a wider range of insulation configuration designs, and design load and annual energy calculations. Like U-factors, the F- and C-factor values defined in ASHRAE 90.1 serve as a rough proxy for the relative efficiency of foundation insulation design. However, unlike U-factors they lack a formal definition that would make the metrics useful in the context of design load calculations or annual energy analysis. There is a need for a new relative metric that can better characterize the performance of foundation insulation designs that is also congruous with the simplified methods used for calculations and analyses.

**Project Objectives**

This project will evaluate the various simple methods versus the more detailed 2/3-D methods for both annual simulation results as well as design load calculations. The evaluations will be performed for multiple building types, in multiple climate zones, and with various slab/side/footer insulation configurations.

If there is a simple method which adequately represents the effect of heat transfer through the slab/basement then this method can be used to replace the methods currently in use in various places in ASHRAE literature and standards. If not, a new simple method will be proposed that can best represent the effect of heat transfer for both design load calculations and annual simulation of building energy use. The method should, if at all possible, provide a physical equivalence for the quick evaluation of different insulation configurations.

**Expected Approach**

Describe in a manner that may be used for assessment of project viability, cost, and duration, the approach that is expected to achieve the proposed objectives (200 words maximum).

Check all that apply: Lab testing ☐, Computations ( ), Surveys ☐, Field tests ☐, Analyses and modeling ☐, Validation efforts ☐ Other (specify) ( ) ☐

1) Identify the various simple methods for calculating slab/basement heat transfer available in ASHRAE and other standards and literature.
2) Select a 2/3-D calculation program like Kiva or TRNSYS for calculating the target design loads and annual energy consumption values.
3) Identify building types (conditioned/semi-conditioned, different A/P ratios, at least one non-rectangular shape), climate zones, and insulation configurations for comparison.
4) Evaluate simple methods vs. detailed 2/3-D results for annual simulation and design loads.
5) If there is not an adequate simplified methods, propose changes or a new method
6) Establish a relative metric to indicate relative performance of foundation insulation designs (similar to U-factor for above grade surfaces)

**Relevance and Benefits to ASHRAE**

As buildings have gotten more and more efficient, the heat transfer through slabs and basements can no longer be discounted for being significantly lower than the other heat transfer components. Detailed methods for calculating this heat transfer using 2-d and 3-d methods have been created and integrated into building energy modeling software. However, these methods require detailed input that may not be readily available for the designer. The development of improved or new simple methods for calculating the heat transfer though slabs and basements will have an immediate impact in the design and evaluation of low-energy buildings.

This project would fit in the ASHRAE Strategic Plan in many ways:

1) Maximize the actual operational energy performance of buildings and facilities – provide a better tool for evaluating the insulation configurations for buildings to select the most efficient configuration for a new building.
2) Progress toward Advanced Energy Design Guides (AEDG) and cost-effective net-zero-energy (NZE) buildings – the new method could be included in the AEDG to provide guidance and evaluation for slab/basement constructions for low-energy performance.
3) Support the development of ASHRAE energy standards and reduce effort required to demonstrate compliance – the new method could be incorporated into many ASHRAE standards including 90.1, 90.2 and 189 to replace the existing simple methods for calculating heat transfer through the slab/basement that currently are different, poorly documented and or questionable accuracy.
4) Support development of tools, procedures and methods suitable for designing low-energy buildings – slab/basement heat transfer becomes more important as the other heat transfer components are reduce and the new simple method would provide an immediate improvement in the calculation of the performance of low-energy buildings

The new method could be used in the ASHRAE handbooks to replace the different methods available in different chapters with one more accurate method.



**Proposed Budget and Duration:**

**Anticipated Funding Level and Duration**

Funding Amount Range: $ 75,000

Duration in Months: 18

**References**


D. Baylon and M. Kennedy, "Calculating the Impact of Ground Contact on Residential Heat Loss," in *Proceedings of Thermal Performance of the Exterior Envelopes of Buildings X*, 2007.

J. Latta and G. Boileau, "Heat Losses from House Basements," *Can. Build.*, vol. XIX, no. 10, pp. 39–42, 1969.

F. Wang, "Mathematical Modeling and Computer Simulation of Insulation Systems in Below Grade Applications," in *Proceedings of Thermal Performance of the Exterior Envelopes of Buildings I*, 1979, pp. 456–471.

I. Beausoleil-Morrison, "BASECALC(TM): A Software Tool for Modelling Residential-Foundation Heat Loss," in *Proceedings of the Third Canadian Conference on Computing in Civil and Building Engineering*, 1996.

M. Krarti and S. Choi, "Simplified Method for Foundation Heat Loss Calculation," *ASHRAE Trans.*, vol. 102, no. 1, pp. 140–152, 1996.

F. Winkelmann, "Underground Surfaces: How To Get A Better Underground Surface Heat Transfer Calculation In DOE-2.1E," *DOE-2 Artic. from Build. Energy Simul. User News*, vol. 23, no. 5, pp. 5–14, 2002.

J. Neymark and R. Judkoff, "International Energy Agency Building Energy Simulation Test and Diagnostic Method ( IEA BESTEST ): In-Depth Diagnostic Cases for Ground Coupled Heat Transfer Related to Slab-on-Grade Construction," Golden, Colorado, 2008.

T. McDowell, J. Thornton, and M. Duffy, "Comparison of a Ground-coupling Reference Standard Model to Simplified Approaches," in *Proceedings of Building Simulation 2009*, 2009, pp. 591–598.

N. Kruis, "Development and Application of a Numerical Framework for Improving Building Foundation Heat Transfer Calculations," University of Colorado, 2015.


**Feedback to RAC and Suggested Improvements to RTAR Process**

Now that you have completed the RTAR process, RAC is interested in getting your feedback and suggestions here on how we can improve the process.