INVITATION TO SUBMIT A RESEARCH PROPOSAL ON AN ASHRAE RESEARCH PROJECT

1857-TRP, Improved simplified methodology for describing and calculating heat conduction between buildings and the ground

Attached is a Request-for-Proposal (RFP) for a project dealing with a subject in which you, or your institution have expressed interest. Should you decide not to submit a proposal, please circulate it to any colleague who might have interest in this subject.

Sponsoring Committee: TC 4.7 Energy Calculations
Co-sponsored by: TC 4.1 Load Calculation Data and Procedures, TC 4.4 Building Materials and Building Envelope Performance

Budget Range: $150,000 may be more or less as determined by value of proposal and competing proposals.

Scheduled Project Start Date: **April 1, 2023** or later.

All proposals must be received at ASHRAE Headquarters by AM, EST, Thursday, December 15, 2022.. NO EXCEPTIONS, NO EXTENSIONS. Electronic copies must be sent to rpbids@ashrae.org. Electronic signatures must be scanned and added to the file before submitting. The submission title line should read: 1857-TRP, Improved simplified methodology for describing and calculating heat conduction between buildings and the ground and *"Bidding Institutions Name"* (electronic pdf format, ASHRAE's server will accept up to 10MB)

If you have questions concerning the Project, we suggest you contact one of the individuals listed below:

For Technical Matters
Technical Contact
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For Administrative or Procedural Matters:
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Contractors intending to submit a proposal should so notify, by mail or e-mail, the Manager of Research and Technical Services, (MORTS) by Thursday, December 1st, 2022 in order that any late or additional information on the RFP may be furnished to them prior to the bid due date.

All proposals must be submitted electronically. Electronic submissions require a PDF file containing the complete proposal preceded by signed copies of the two forms listed below in the order listed below. **ALL electronic proposals are to be sent to rpbids@ashrae.org.**

All other correspondence must be sent to ddaniel@ashrae.org and mvaughn@ashrae.org. Hardcopy submissions are not permitted. **In all cases, the proposal must be submitted to ASHRAE by 8:00 AM, EST, December 15, 2022. NO EXCEPTIONS, NO EXTENSIONS.**

The following forms (Application for Grant of Funds and the Additional Information form have been combined) must accompany the proposal:

(1) ASHRAE Application for Grant of Funds (electronic signature required) and
(2) Additional Information for Contractors (electronic signature required) ASHRAE Application for Grant of Funds (signed) and

ASHRAE reserves the right to reject any or all bids.

State of the Art (Background)

Annual energy calculation and design load calculation methodologies for heat conduction through building foundations into the surrounding ground are inconsistent across ASHRAE literature. The basis for the calculations described in the Fundamentals volume of the Handbook (ASHRAE 2017c) 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 Fundamentals volume of the Handbook, 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." This is particularly true for design load calculations that historically are only performed for isolated design days, when the loads associated with ground-adjacent surfaces can require calculations of months or years to establish a realistic thermal history for the thermal state of the surrounding ground.

Each of the methods referenced in ASHRAE's Handbook suffers from some limitation of applicability (slab vs. basement, loads vs. energy, heating vs. cooling, number of configurations, etc.). None of them establish a basic performance characteristic describing the foundation insulation configuration that allows direct comparison of designs in a meaningful way, like the U-value allows comparison of wall structures.

There have been some efforts to modify the existing simplified algorithms (Rock 2005) and recent efforts to improve the quantification of heat flow into the ground using more sophisticated 2/3-D numerical methods include: ASHRAE Standard 140-2017 (ASHRAE 2017b), 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). A study by McDowell et al., showed differences in the annual cooling loads of up to 300% and in the annual heating loads of 60% between the existing simplified methods and more sophisticated methods (McDowell 2009). However, the sophisticated methods are impractical to use in most building simulations and there is still a need for reliable calculations that are simple enough to be communicated in the Fundamentals volume of the Handbook and referenced by ASHRAE 90.1.

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 empirical measurements or simulation to support better decisions. As above grade envelopes improve with pushes towards low load/net-zero buildings, the relative contribution to the overall heating and cooling load associated with foundations will only increase. Without a 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.

Justification and Value 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 2/3-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 simplified methods for calculating the heat transfer through slabs and basements will have an immediate impact in the design and evaluation of low-energy buildings.

The new simplified method, that is more complete and accurate than the existing simplified methods, will replace the different methods used in the ASHRAE Handbook of Fundamentals Chapters 17, 18 and 19.

Objectives

There are two main research objectives:

1. Establish a simplified method for calculating the heat transfer through slabs and basements that accurately represents the multi-dimensional nature of heat transfer from the building into the surrounding ground. This

method should account for a reasonable range of foundation insulation designs and apply to both design load and annual energy calculations.

2. Determine a performance metric for the relative characterization of foundation insulation designs.

The objective of this work is NOT to validate detailed or simplified methods with empirical, measured data.

Scope:
This project focuses solely on evaluating and developing simplified methods of the heat transfer through slabs and basement versus well-established detailed computational methods of estimating heat transfer from ground-contact building surfaces. While empirical validation of these results is important for quantifying the accuracy of simplified methods, this research will focus on comparative testing of the simplified method. Empirical validation would be a valuable follow up research project once a simplified method is established.

Task 1: Evaluate Detailed Methods
The Contractor will review detailed ground-building heat transfer methods currently available, such as TRNSYS (McDowell, 2009) and Kiva (Kruis, 2015). Their strengths and weaknesses should be documented including how they compare to analytical test suites or other documented tests like ASHRAE 140 Section 5.2.4. Comparisons to existing measured data are encouraged, but collection of empirical data is not included in this project. This review should also identify any input parameters (e.g., domain properties and boundary conditions) impactful enough to be included in any simplified methods. The contractor will select one detailed method to use to evaluate the simplified methods in consultation with the Project Monitoring Subcommittee.

Deliverable: Summary of existing detailed methods including strengths and weaknesses and comparison to test suites

Task 2: Evaluate Simplified Methods
The Contractor will review simplified ground-building heat transfer methods currently available in various ASHRAE sources like the Fundamentals volume of the Handbook and Standard 90.1, as well as sources from outside of the United States. The strengths and weaknesses of the simplified methods will be detailed. The evaluation should include factors such as the accuracy of the results versus the more detailed 2/3-D method selected in Task 1 across various building types, soil types, and climates; ease-of-use; and availability of inputs. The evaluation should include the ability of the methods to cover a wide range of potential foundation designs (both high-efficiency and existing buildings), whether the method is simple enough to be described within a subsection of a chapter in the Fundamentals volume of the Handbook, and whether the method is applicable to both annual energy and design load calculations (including the thermal mass effect of the ground adjacent to the building). The number of test cases should be adequate to cover the breadth of building types, climates, ground conditions, foundation constructions, and any other parameters that may influence the heat transfer from the ground to the building that are typically found in the US. At a minimum this should include 3 building types, 5 climates, 5 ground conditions (soil and moisture), and 10 foundation constructions with and without insulation. While moisture migration can be an important factor in ground-building heat transfer in some locations, quantifying this effect is still an area of research that has not been added into the current detailed 2/3-D methods. As such, it is not expected that those effects will be quantified in the simplified method.

Deliverable: Summary of existing simplified methods including strengths and weaknesses and comparison to detailed methods

Task 3: Improve existing simplified method or develop new simplified method
Based on the evaluation of the simplified methods in Task 2, the Contractor (in consultation with the Project Monitoring Subcommittee) will select a method to modify to better model the building-ground heat transfer. If none of the simplified models can reproduce the results from the detailed 2/3-D methods with reasonable accuracy or are not able to be extended to cover all of the parameters that were tested in Task 2, develop a new simplified method that is easy-to-use, applies readily available inputs, and reasonably matches the detailed method results. The new or modified method must meet the following conditions to be acceptable (as determined in consultation with the Project Monitoring Subcommittee):

- be simple enough to be fully described in the Fundamentals volume of the Handbook

- include only parameters that are readily available and easy to determine
- work for both design load calculations as well as annual energy consumption calculations
- agree with the results from the detailed method with reasonable accuracy
- provide for a metric to be developed that provides for a qualitative assessment of the relative efficiency for different foundation insulation configurations, similar to the U-value for wall constructions.

Deliverable: Fully documented improved or new simplified method

Task 4: Evaluate new method for multiple building types and climates
The new or modified simplified method will be evaluated versus the detailed method for multiple foundation configurations, soil conditions, and climate types. At a minimum this will include all of the parameter space used to evaluate the simplified methods in Task 2, as well, as heated and unheated slabs. The evaluation of methodology results should include both heating and cooling for both design load and annual energy calculations. Any deficiencies identified when evaluating the new method will be addressed by refining the method or by thoroughly documenting its limitations.

Deliverable: Comparison of the simplified method versus the detailed methods for multiple foundation configurations and climates.

Task 5: Report findings and document method
The final simplified method and its evaluation will be fully documented for inclusion in the Fundamentals volume of the Handbook. The documentation should be ready for reference by Standard 90.1 and other ASHRAE literature. Test cases that can be used to assess implementations of the simplified method will be prepared. Such test cases will be prepared in a fashion such that they can be considered for possible inclusion in Standard 140. (The number and form of the test cases will be developed with consultation of the Project Monitoring Subcommittee and SSPC 140.) A comprehensive final report will be developed that details all of the project findings.

Deliverable: Final report including recommendations for Handbook and Standard 90.1 and test cases for possible inclusion in Standard 140

Deliverable: A research or technical paper, submitted for peer review and publication in the ASHRAE Transactions or Science and Technology for the Built Environment and conference presentation

Deliverables:

1. Summary of existing detailed methods including strengths and weaknesses and comparison to test suites (Task 1, Month 3)
2. Summary of existing simplified methods including strengths and weaknesses and comparison to detailed methods (Task 2, Month 6)
3. Fully documented improved or new simplified method (Task 3, Month 12)
4. Comparison of the simplified method versus the detailed methods for multiple foundation configurations and climates. (Task 4, Month 18)
5. Final report including recommendations for Handbook and Standard 90.1 and test cases for possible inclusion in Standard 140 (Task 5, Month 24)
6. A research or technical paper, submitted for peer review and publication in the ASHRAE Transactions or Science and Technology for the Built Environment and conference presentation (Task 5, Month 30)
7. Quarterly progress and financial reports to MORTS (to be reviewed by the Project Monitoring Subcommittee (PMS)).
8. Any data obtained from the research in electronic format
9. A project summary

In addition, Progress, Financial and Final Reports, Technical Paper(s), and Data shall constitute the deliverables ("Deliverables") under this Agreement and shall be provided as follows:

Progress, Financial and Final Reports, Technical Paper(s), and Data shall constitute the deliverables ("Deliverables") under this Agreement and shall be provided as follows:

a. Progress and Financial Reports

Progress and Financial Reports, in a form approved by the Society, shall be made to the Society through its Manager of Research and Technical Services at quarterly intervals; specifically on or before each January 1, April 1, June 10, and October 1 of the contract period.

The following deliverables shall be provided to the Project Monitoring Subcommittee (PMS) as described in the Scope/Technical Approach section above, as they are available:

Furthermore, the Institution's Principal Investigator, subject to the Society's approval, shall, during the period of performance and after the Final Report has been submitted, report in person to the sponsoring Technical Committee/Task Group (TC/TG) at the annual and winter meetings, and be available to answer such questions regarding the research as may arise.

b. Final Report

A written report, design guide, or manual, (collectively, "Final Report"), in a form approved by the Society, shall be prepared by the Institution and submitted to the Society's Manager of Research and Technical Services by the end of the Agreement term, containing complete details of all research carried out under this Agreement, including a summary of the control strategy and savings guidelines. Unless otherwise specified, the final draft report shall be furnished, electronically for review by the Society's Project Monitoring Subcommittee (PMS).

Tabulated values for all measurements shall be provided as an appendix to the final report (for measurements which are adjusted by correction factors, also tabulate the corrected results and clearly show the method used for correction).

Following approval by the PMS and the TC/TG, in their sole discretion, final copies of the Final Report will be furnished by the Institution as follows:

-An executive summary in a form suitable for wide distribution to the industry and to the public.
-Two copies; one in PDF format and one in Microsoft Word.

c. *Science & Technology for the Built Environment* or ASHRAE Transactions Technical Papers

One or more papers shall be submitted first to the ASHRAE Manager of Research and Technical Services (MORTS) and then to the "ASHRAE Manuscript Central" website-based manuscript review system in a form and containing such information as designated by the Society suitable for publication. Papers specified as deliverables should be submitted as either Research Papers for HVAC&R Research or Technical Paper(s) for ASHRAE Transactions. Research papers contain generalized results of long-term archival value, whereas technical papers are appropriate for applied research of shorter-term value, ASHRAE Conference papers are not acceptable as deliverables from ASHRAE research projects. The paper(s) shall conform to the instructions posted in "Manuscript Central" for an ASHRAE Transactions Technical or HVAC&R Research papers. The paper title shall contain the research project number (1857-RP) at the end of the title in parentheses, e.g., (1857-RP).

All papers or articles prepared in connection with an ASHRAE research project, which are being submitted for inclusion in any ASHRAE publication, shall be submitted through the Manager of Research and Technical Services first and not to the publication's editor or Program Committee.

d. Data

Data is defined in General Condition VI, "DATA"

e. Project Synopsis

A written synopsis totaling approximately 100 words in length and written for a broad technical audience, which documents 1. Main findings of research project, 2. Why findings are significant, and 3. How the findings benefit ASHRAE membership and/or society in general shall be submitted to the Manager of Research and Technical Services by the end of the Agreement term for publication in ASHRAE Insights

The Society may request the Institution submit a technical article suitable for publication in the Society's ASHRAE JOURNAL. This is considered a voluntary submission and not a Deliverable. Technical articles shall be prepared using dual units; e.g., rational inch-pound with equivalent SI units shown parenthetically. SI usage shall be in accordance with IEEE/ASTM Standard SI-10.

Level of Effort
Funding Amount Range: $ 150,000 Professional Months – Principal Investigator: 3
Professional Months – Total: 18 Duration in Months: 30

Proposal Evaluation Criteria:

No.	Proposal Review Criterion	Weighting Factor
1	Contractors understanding of Work Statement as revealed in proposal.	**25**
2	Quality of personnel for this project ● Experience of modeling ground/building heat transfer ● Experience of evaluating model performance	**30**
3	Quality of methodology proposed for conducting research. ● Approaches for implementing and validating the models ● Approaches for evaluating the model over different building types and climates ● Organization and management plan	**30**
4	Probability of contractor's proposal meeting objectives ● Detailed work plan with major tasks and key milestones ● Capability to effectively communicate with the PMS ● Reasonableness of project schedule	**5**
5	Past performance on ASHRAE projects • Quality of work on previous ASHRAE projects • Meeting schedule on previous ASHRAE projects	**5**
6	Student involvement ● Extent of student participation on contractor's team ● Likelihood that involvement in project will encourage entry into HVAC industry	**5**

Project Milestones:

No.	Major Project Completion Milestone	Deadline Month
1	Summary/evaluation of detailed methods	3
2	Summary/evaluation of simplified methods	6
3	Development of new/improved simplified method	12
4	Evaluate new/improved simplified method for multiple slab configurations and climates	18
5	Documentation/Test Cases/Final Report	24
6	ASHRAE Transactions article and conference presentation	30

References

1. ASHRAE 2019. “ANSI/ASHRAE/IES Standard 90.1-2019 Energy Standard for Buildings Except Low-Rise Residential Buildings”, ASHRAE, 2019.
2. ASHRAE 2017a. “ANSI/ASHRAE/ICC/USGBC/IES Standard 189.1-2017 Standard for the Design of High-Performance Green Buildings”, ASHRAE 2017.
3. ASHRAE 2017b. “ANSI/ASHRAE Standard 140-2017 Standard Method of Test for the Evaluation of Building Energy Analysis Computer Programs”, ASHRAE 2017.
4. ASHRAE 2017c. “ASHRAE Handbook of Fundamentals”, ASHRAE 2017.
5. ASHRAE 2018. “ANSI/ASHRAE/IES Standard 90.2-2018 Energy-Efficient Design of Low-Rise Residential Buildings”, ASHRAE, 2018.
6. 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.
7. J. Latta and G. Boileau, “Heat Losses from House Basements,” Can. Build., vol. XIX, no. 10, pp. 39–42, 1969.
8. 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.
9. 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.
10. M. Krarti and S. Choi, “Simplified Method for Foundation Heat Loss Calculation,” ASHRAE Trans., vol. 102, no. 1, pp. 140–152, 1996.
11. 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.
12. 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-onGrade Construction,” Golden, Colorado, 2008.
13. 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.
14. N. Kruis, “Development and Application of a Numerical Framework for Improving Building Foundation Heat Transfer Calculations,” University of Colorado, 2015.
15. B. Rock, “"A User-Friendly Model and Coefficients for Slab-on-Grade Load and Energy Calculations." ASHRAE Transactions, vol. 111(2), pp. 122-136, 2005