

# **ASHRAE Standard 140-2020**

## **Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests**

Results for TRNSYS18.06.0002  
(TRNSYS18)  
vs.  
Informative Annex B8, Section B8.2 Example Results

Prepared By  
Thermal Energy System Specialists, LLC  
(TESS)

Results Developed  
19-Aug-2024

**ASHRAE Standard 140-2020**  
**Computer Programs, Program Authors, and Producers of Example Results for**  
**Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests**

The programs used to generate the example results are described in Table B11-2. Under the computer program column, the first entry in each cell is the proper program name and version number. The entries in parentheses are the abbreviations for the programs generally used in the tables and charts which follow.

The second column ("Authoring Organization") indicates the national research facility, university, or industry organization with expertise in building science that wrote the simulation software.

The third column ("Implemented By") indicates the national research facility, university, or industry organization with expertise in building science that performed the simulations. The majority of organizations that performed simulations either ran software written by their organization or otherwise ran other building energy simulation software in addition to that written by their organization.

See Standard 140, Annex B11 for further details.

**TABLE B11-2**  
**Ground-Coupled Slab-On-Grade Analytical Verification**  
**Participating Organizations and Models**

Analytical Solution, Case GC10a	Authoring Organization	Implemented by
Delsante, Stokes, and Walsh (1983)	Commonwealth Scientific and Industrial Research Organisation, Australia	NREL/JNA, <sup>a,b</sup> United States
<b>Verified Numerical Model</b>		
FLUENT 6.0.20	Fluent, Incorporated, United States	PAAET, <sup>c</sup> Kuwait
MATLAB 7.0.4.365 (R14)	The MathWorks, Inc., United States	Dublin Institute of Technology, Ireland
TRNSYS 16.1	University of Wisconsin/TESS, <sup>d</sup> United States	TESS, <sup>d</sup> United States
<b>Simulation Program</b>		
BASECALC V1.0e	CETC, <sup>e</sup> Canada	CETC, <sup>e</sup> Canada
EnergyPlus 2.0.0.025	LBNL/UIUC/DOE-BT, <sup>f,g,h</sup> United States	GARD Analytics, Inc., United States
ESP-r/BASESIMP	CETC/ESRU, <sup>e,i</sup> Canada/United Kingdom	CETC, <sup>e</sup> Canada
GHT	NREL, <sup>a</sup> United States	NREL, <sup>a</sup> United States
SUNREL-GC 1.14.01	NREL, <sup>a</sup> United States	NREL, <sup>a</sup> United States
VA114 2.20/ISO-13370	VABI Software BV, The Netherlands; CEN/ISO, <sup>j,k</sup>	VABI Software BV, The Netherlands

<sup>a</sup>NREL: National Renewable Energy Laboratory, United States

<sup>b</sup>JNA: J. Neymark & Associates, United States

<sup>c</sup>PAAET: Public Authority for Applied Education and Training, Kuwait

<sup>d</sup>TESS: Thermal Energy Systems Specialists, United States

<sup>e</sup>CETC: CANMET Energy Technology Centre, Natural Resources Canada, Canada

<sup>f</sup>LBNL: Lawrence Berkeley National Laboratory, United States

<sup>g</sup>UIUC: University of Illinois Urbana/Champaign, United States

<sup>h</sup>DOE-BT: U.S. Department of Energy, Office of Building Technologies, Energy Efficiency and Renewable Energy United States

<sup>i</sup>ESRU: Energy Systems Research Unit, University of Strathclyde, United Kingdom

<sup>j</sup>CEN: European Committee for Standardization, Belgium

<sup>k</sup>ISO: International Organization for Standardization, Switzerland

**ASHRAE Standard 140-2010 Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
 TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results  
 By Thermal Energy System Specialists, LLC (TESS), 19-Aug-2024**

**List of Tables**

<i>Table</i>	<i>Description</i>	<i>Sheet Tab</i>	<i>Cell Range</i>
B8.2-1	"a"-Series Case Summary, Numerical Model Verification	Tables 1	B7-L24
B8.2-2	Steady-State Conduction	Tables 2	B7-Q26
B8.2-3	Steady-State Supporting Information		B29-Q42
B8.2-4	Steady-Periodic Last-Simulation-Year Conduction		B46-Q83
B8.2-5	Steady-Periodic Last-Simulation-Year Peak-Hour Conduction	Tables 3	B7-AA62
B8.2-6	Time from Coldest Hour (Jan15, Hour 4) to Peak Conduction Occurrence	Tables 4	B7-Q33
B8.2-7	Steady-Periodic Supporting Information		B35-Q60
B8.2-8	Steady-Periodic Minimum ODB and Time of Occurrence	Tables 5	B8-AE38
B8.2-9	Delta Steady-State Conduction	Tables 6	B7-Q30
B8.2-10	Delta Steady-Periodic Annual Total Conduction		B32-Q56
B8.2-11	Delta Steady-Periodic Last-Year Peak Hour Floor Conduction		B58-Q82
B8.2-12	Delta Steady-Periodic Conduction v Coldest Hour Phase Shift		B84-Q108

**ASHRAE Standard 140-2010 Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
 TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results  
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**List of Figures**

<b>Figure</b>	<b>Title</b>	<b>Sheet Tab</b>
B8.2-1	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-State Floor Conduction	Fig B8.2-1 QFSS
B8.2-2	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-State Floor Conduction Sensitivity	Fig B8.2-2 dQFSS
B8.2-3	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-State Zone Heating Load	Fig B8.2-3 QZSS
B8.2-4	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-State Zone Heating Load Sensitivity	Fig B8.2-4 dQZSS
B8.2-5	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-State (Zone Heating Load) - (Floor Conduction)	Fig B8.2-5 QZ-FSS
B8.2-6	IEA BESTEST Ground Coupling: In-Depth Floor Slab Case GC10a Modeling Parameters	Fig B8.2-6 GC10Par
B8.2-7	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-State Zone Temperature	Fig B8.2-7 TZSS
B8.2-8	IEA BESTEST Ground Coupling: In-Depth Floor Slab, GC10a Steady-State Surface Temperatures (Y=0, thru edge center)	Fig B8.2-8 TempGC10a-Surf
B8.2-9	IEA BESTEST Ground Coupling: In-Depth Floor Slab, GC10a Steady-State Surface Temperatures (Y=X, thru corner)	Fig B8.2-9 TempGC10a-Surf-diag
B8.2-10	IEA BESTEST Ground Coupling: In-Depth Floor Slab, GC10a, GC30a Steady-State Near-Surface Temperatures (Y=0, thru center of edge)	Fig B8.2-10 TempGC10a-30a
B8.2-11	IEA BESTEST Ground Coupling: In-Depth Floor Slab, GC10a, GC30a Steady-State Near-Surface Temperatures (Y=X, thru corner)	Fig B8.2-11 TempGC10a-30a-diag
B8.2-12	IEA BESTEST: In-Depth Floor Slab, GC30b, GC60b, GC65b Steady-State Near-Surface Temperatures (Y=0, thru center of edge)	Fig B8.2-12 TempGC30b-65b
B8.2-13	IEA BESTEST: In-Depth Floor Slab, GC30b, GC60b, GC65b Steady-State Near-Surface Temperatures (Y=X, thru corner)	Fig B8.2-13 TempGC30b-65b-diag
B8.2-14	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-Periodic Annual Floor Conduction	Fig B8.2-14 QFSP
B8.2-15	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-Periodic Annual Floor Conduction Sensitivity	Fig B8.2-15 dQFSP
B8.2-16	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-Periodic Annual Zone Heating Load	Fig B8.2-16 QZSP
B8.2-17	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-Periodic Annual Zone Heating Load Sensitivity	Fig B8.2-17 dQZSP
B8.2-18	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-Periodic (Zone Heating Load) - (Floor Conduction)	Fig B8.2-18 QZ-FSP
B8.2-19	IEA BESTEST Ground Coupling: In-Depth Floor Slab Hourly Floor Conduction, GC40a	Fig B8.2-19 GC40aHourly-1
B8.2-20	IEA BESTEST Ground Coupling: In-Depth Floor Slab Hourly Floor Conduction, GC40b	Fig B8.2-20 GC40bHourly-2
B8.2-21	IEA BESTEST Ground Coupling: In-Depth Floor Slab Hourly Floor Conduction, GC40c	Fig B8.2-21 GC40cHourly-1
B8.2-22	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-Periodic Phase Shift, Time from Coldest ODB to Peak Floor Conduction	Fig B8.2-22 PhF
B8.2-23	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-Periodic Phase Shift Sensitivity, Floor Conduction v. ODB	Fig B8.2-23 dPhF

**ASHRAE Standard 140-2010 Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
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**List of Figures**

<b>Figure</b>	<b>Title</b>	<b>Sheet Tab</b>
B8.2-24	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-Periodic Phase Shift, Time from Coldest ODB to Peak Zone Load	Fig B8.2-24 PhZ
B8.2-25	IEA BESTEST Ground Coupling: In-Depth Floor Slab Delta Steady-Periodic Phase Shift Sensitivity, Zone Load v. ODB	Fig B8.2-25 dPhZ
B8.2-26	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-Periodic Annual Peak-Hour Floor Conduction	Fig B8.2-26 PFSP
B8.2-27	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-Periodic Annual Peak-Hour Floor Conduction Sensitivity	Fig B8.2-27 dPFSP
B8.2-28	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-Periodic Annual Peak-Hour Zone Heating Load	Fig B8.2-28 PZSP
B8.2-29	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-Periodic Annual Peak-Hour Zone Heating Load Sensitivity	Fig B8.2-29 dPZSP
B8.2-30	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-Periodic (Peak Zone Heating Load) - (Peak Floor Conduction)	Fig B8.2-30 PZ-FSP
B8.2-31	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-Periodic Zone Temperature	Fig B8.2-31 TZSP
B8.2-32	IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-Periodic Minimum ODB	Fig B8.2-32 ODBmin

**ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
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Note: The statistics in the tables below are based on the Standard 140 informative example results.  
 These statistics do not have any substantial importance and are not to be interpreted as acceptance criteria.

**Table B8.2-1. "a"-Series Case Summary, Numerical Model Verification**

	Analytical Solution CSIRO	Verified Numerical Models			Statistics			GHT/ NREL	GHT/ V.M.Mean <sup>a</sup> -1	TRNSYS18 TESS
		TRNSYS TESS	FLUENT PAAET	MATLAB DIT	Min	Max	(Max-Min) /Mean			
<b>Floor Conduction</b>										
GC10a (W or Wh/h)	<b>2433</b>	2427	2425	2432	2425	2432	0.3%	2415	-0.5%	
GC30a (W or Wh/h)		2642	2585	2695	2585	2695	4.2%	2457	-7.0%	
GC40a (kWh)		23033	22761	23609	22761	23609	3.7%	20812	-10.0%	
<b>Phase Shift for Floor Conduction Peak (hours)</b>										
GC40a		416	416	416	416	416	0.0%	487	17.1%	
<b>GC10a Modeling Parameters</b>										
E (depth, m)	infinite	40	40	300	40	300		30		
F (far-field, m)	infinite	40	40	150	40	150		20		
<b>Time Simulated (Years)</b>										
GC10a	s.s. soln.	8.0	s.s. model	s.s. model				6.0		
GC30a		7.0	s.s. model	s.s. model				6.0		
GC40a		6.0	5.0	10.0	5.0	10.0		6.0		

<sup>a</sup> "V.M.Mean" is average of verified numerical-model results.

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**Table B8.2-2. Steady-State Conduction**

	Verified Numerical Models				(Max-Min) /Mean	GHT NREL	SUNREL-GC NREL	EnergyPlus GARD	VA114/ ISO-13370 VABI	ESP-r/ BASESIMP NRCan	BASECALC NRCan	Statistics, Other Simulation Models			TRNSYS18 TESS
	TRNSYS TESS	FLUENT PAAET	MATLAB DIT									Min	Max	(Max-Min)/ (V.M.Mean) <sup>a</sup>	
<b>Floor Conduction (W or Wh/h)</b>															
GC30b	2533	2504	2570		2.6%	2341	2341	2652	2421			2341	2652	12.3%	2533
GC30c	2137	2123	2154		1.5%			2308	2092	1973	1973	1973	2308	15.7%	
GC60b	2113	2104	2128		1.1%		1999	2219	2069			1999	2219	10.4%	2113
GC65b	1994	1991	2004		0.7%		1895	1616	1920			1616	1920	15.3%	1994
<b>Zone Heating Load (W or Wh/h)</b>															
GC30b							2341	2652	2427			2341	2652	12.3%	2520
GC30c								2308	2098	2003	2003	2003	2308	14.3%	
GC60b							1999	2219	2075			1999	2219	10.4%	2113
GC65b							1895	1616	1925			1616	1925	15.5%	1994
<b>(Zone Heating Load) - (Floor Conduction), [W or Wh/h]</b>															
GC30b							0	0	6			0	6		-13
GC30c								0	6	30	30	0	30		
GC60b							0	0	6			0	6		0
GC65b							0	0	5			0	5		0

<sup>a</sup> "V.M.Mean" is average of verified numerical-model results; for zone load results the average of the floor conduction results is used.

**Table B8.2-3. Steady-State Supporting Information**

	Verified Numerical Models				(Max-Min) /Mean	GHT NREL	SUNREL-GC NREL	EnergyPlus GARD	VA114/ ISO-13370 VABI	ESP-r/ BASESIMP NRCan	BASECALC NRCan	Statistics, All Results			TRNSYS18 TESS
	TRNSYS TESS	FLUENT PAAET	MATLAB DIT									Min	Max		
<b>Zone Air Temperature (°C)</b>															
GC30b							30.0	30.0	30.0			30.0	30.0	0.0%	30.0
GC30c								30.0	30.0	30.0	30.0	30.0	30.0	0.0%	
GC60b							30.0	30.0	30.0			30.0	30.0	0.0%	30.0
GC65b							30.0	30.0	30.0			30.0	30.0	0.0%	30.0
<b>Simulation Duration (Years)</b>															
GC30b	6.0	s.s. model	s.s. model			5.0	5.0	7.0	1.0			0.0	7.0		6.0
GC30c	6.0	s.s. model	s.s. model					6.0	1.0	2.0	3.0	0.0	6.0		
GC60b	6.0	s.s. model	s.s. model				5.0	7.0	1.0			0.0	7.0		6.0
GC65b	6.0	s.s. model	s.s. model				5.0	8.0	1.0			0.0	8.0		6.0

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**Table B8.2-4. Steady-Periodic Last-Simulation-Year Conduction**

	Verified Numerical Models				GHT NREL	SUNREL-GC NREL	EnergyPlus GARD	VA114/ ISO-13370 VABI	ESP-r/ BASESIMP NRCan	BASECALC NRCan	Statistics, Other Simulation Models			TRNSYS18 TESS	
	TRNSYS TESS	FLUENT PAAET	MATLAB DIT	(Max-Min) /Mean							Min	Max	(Max-Min)/ (V.M.Mean) <sup>a</sup>		
<b>Floor Conduction (kWh)</b>															
GC40b	22099	21932	22513	2.6%	20513	20513	23204	21206				20513	23204	12.1%	22183
GC45b	32758	32456	33483	3.1%			33415	30856				30856	33415	7.8%	32524
GC50b	277923	277988	281418	1.3%			324257	289925				289925	324257	12.3%	278538
GC55b	35075	34879	35491	1.7%		33211	39932	31601				31601	39932	23.7%	35123
GC70b	17396	17434	17552	0.9%		16607	15553	16817				15553	16817	7.2%	17459
GC80b	6029	5939	6151	3.5%		5661	6059	5728				5661	6059	6.6%	6153
GC40c	18649	18598	18873	1.5%			20255	18330	17285	17285		17285	20255	15.9%	
GC45c	27004	26906	27392	1.8%			28707	26038	23849	23849		23849	28707	17.9%	
GC55c	20760	20714	20986	1.3%			22570	20172	20850	20850		20172	22570	11.5%	
GC80c	9192	9137	9314	1.9%			10073	8966	8635	8635		8635	10073	15.6%	
<b>Zone Heating Load (kWh)</b>															
GC40b	n/a	n/a				20513	23204	21260				20513	23204	12.1%	22073
GC45b	n/a	n/a					33415	30924				30924	33415	7.6%	32566
GC50b	n/a	n/a					324257	291502				291502	324257	11.7%	277302
GC55b	n/a	n/a				33211	39932	31654				31654	39932	23.6%	34944
GC70b	n/a	n/a				16607	15553	16865				15553	16865	7.5%	17460
GC80b	n/a	n/a				5661	6059	5778				5661	6059	6.6%	6129
GC40c	n/a	n/a					20255	18379	17545	17545		17545	20255	14.5%	
GC45c	n/a	n/a					28707	26101	24185	24185		24185	28707	16.7%	
GC55c	n/a	n/a					22570	20221	21111	21111		20221	22570	11.3%	
GC80c	n/a	n/a					10073	9013	8848	8848		8848	10073	13.3%	
<b>(Zone Heating Load) - (Floor Conduction) [kWh]</b>															
GC40b						0	0	54				0	54		-110
GC45b							0	68				0	68		42
GC50b							0	1577				0	1577		-1236
GC55b						0	0	53				0	53		-179
GC70b						0	0	48				0	48		2
GC80b						0	0	50				0	50		-24
GC40c							0	49	260	260		0	260		
GC45c							0	63	336	336		0	336		
GC55c							0	49	261	261		0	261		
GC80c							0	47	213	213		0	213		

<sup>a</sup> "V.M.Mean" is average of verified numerical-model results; for zone load results the average of the floor conduction results is used.



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**Table B8.2-5. Steady-Periodic Last-Simulation-Year Peak-Hour Conduction**

Verified Numerical-Model Results														Other Simulation Results														Statistics, Other Sim. Models																
TRNSYS				FLUENT				MATLAB				(Max-Min)/			GHT				SUNREL-GC				EnergyPlus				VA114/ISO-13370				ESP-r/BASESIMP				BASECALC				(Max-Min)/			TRNSYS18		
TESS				PAAET				DIT				/Mean			NREL				NREL				GARD				VABI				NRCan				NRCan				/V.M.Mean <sup>a</sup>			TESS		
Date	Hour			Date	Hour			Date	Hour						Date	Hour			Date	Hour			Date	Hour			Date	Hour			Date	Hour			Date	Hour			Min	Max		Date	Hour	
<b>Floor Conduction (W or Wh/h)</b>																																												
GC40a	3087	1-Feb	12	3042	1-Feb	12	3174	1-Feb	12	4.2%																																		
GC40b	2941	1-Feb	13	2914	3-Feb	13	3002	2-Feb	13	3.0%																																		
GC45b	4444	1-Feb	13	4396	2-Feb	13	4551	2-Feb	13	3.5%																																		
GC50b	34531	4-Feb	13	34510	3-Feb	13	35033	3-Feb	13	1.5%																																		
GC55b	4366	22-Jan	13	4336	21-Jan	13	4427	21-Jan	13	2.1%																																		
GC70b	2254	11-Feb	16	2259	11-Feb	15	2276	11-Feb	16	1.0%																																		
GC80b	776	7-Feb	20	763	8-Feb	19	794	7-Feb	19	4.0%																																		
GC40c	2454	7-Feb	14	2444	7-Feb	14	2487	6-Feb	14	1.7%																																		
GC45c	3634	4-Feb	14	3618	6-Feb	14	3691	6-Feb	14	2.0%																																		
GC55c	2710	4-Feb	14	2703	6-Feb	14	2744	6-Feb	14	1.5%																																		
GC80c	1190	9-Feb	17	1181	9-Feb	17	1207	8-Feb	17	2.2%																																		
<b>Floor Conduction (W or Wh/h)</b>																																												
GC40a	2758	4-Feb	11					3005	02/02	03:00	2899	21-Feb	2																	2710	3005	10.0%				2953	1-Feb	13						
GC40b	2710	4-Feb	13	2710	4-Feb	13					4415	02/02	04:00	4318	20-Feb	20													4318	4415	2.2%				4411	1-Feb	13							
GC45b								39570	01/01	01:00	36304	20-Feb	7													36304	39570	9.4%				34604	4-Feb	13										
GC55b				4102	22-Jan	14					4860	01/01	01:00	4085	20-Feb	24													4085	4860	17.7%				4374	22-Jan	13							
GC70b				2144	11-Feb	18					1906	02/03	08:00	2252	24-Feb	2													1906	2252	15.3%				2263	11-Feb	16							
GC80b				722	9-Feb	22					766	02/04	02:00	753	5-Mar	2													722	766	5.6%				792	7-Feb	19							
GC40c								2650	02/03	11:00	2472	24-Feb	5	2231	31-Jan	8	2224	Feb	0	2224	2650	17.3%																						
GC45c								3827	02/03	07:00	3606	25-Feb	1	3192	31-Jan	6	3178	Jan	0	3178	3827	17.8%																						
GC55c								2926	02/03	11:00	2682	24-Feb	22	2666	29-Jan	23	2659	Jan	0	2659	2926	9.8%																						
GC80c								1300	02/05	05:00	1187	1-Mar	24	1094	2-Feb	5	1091	Feb	0	1091	1300	17.5%																						
<b>Zone Heating Load (W or Wh/h)</b>																																												
GC40b				2710	4-Feb	13					3005	02/02	03:00	2907	22-Feb	4													2710	3005	10.3%				2938	1-Feb	13							
GC45b								4415	02/02	04:00	4328	22-Feb	4																	4328	4415	2.0%				4417	1-Feb	13						
GC50b								39570	01/01	01:00	36021	21-Feb	3													36021	39570	9.4%				34454	4-Feb	13										
GC55b				4102	22-Jan	14					4860	01/01	01:00	4093	22-Feb	3													4093	4860	17.6%				4351	22-Jan	13							
GC70b				2144	11-Feb	18					1906	02/03	08:00	2259	27-Feb	3													1906	2259	16.8%				2263	11-Feb	16							
GC80b				722	9-Feb	22					766	02/04	02:00	760	8-Mar	4													722	766	5.8%				789	7-Feb	21							
GC40c								2650	02/03	11:00	2479	26-Feb	3	2273	1-Feb	20.0	2261	Feb	0	2261	2650	16.1%																						
GC45c								3827	02/03	07:00	3616	26-Feb	3	3246	31-Jan	4.0	3228	Jan	0	3228	3827	17.2%																						
GC55c								2926	02/03	11:00	2690	25-Feb	4	2708	28-Jan	4.0	2698	Jan	0	2690	2926	8.6%																						
GC80c								1300	02/05	05:00	1194	4-Mar	3	1128	31-Jan	4.0	1122	Feb	0	1122	1300	15.0%																						
<b>(Zone Heating Load) - (Floor Conduction), [W or Wh/h, may not be for same hour]</b>																																												
GC40b				0				0				8								0	8							0	8					-15										
GC45b								0				10								0	10							0	10					6										
GC50b								0				-283								-283	0							-283	0					-150										
GC55b				0				0				8								0	8							0	8					-22										
GC70b				0				0				7								0	7							0	7					0										
GC80b				0				0				7								0	7							0	7					-3										
GC40c								0				7				42				0	42							0	42															
GC45c								0				10				54				0	54							0	54															
GC55c								0				8				42				0	42							0	42															
GC80c								0				7				34				0	34							0	34															

<sup>a</sup> "V.M.Mean" is average of verified numerical-model results; for zone load results the average of the floor conduction results is used.

**ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
 TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results  
 By Thermal Energy System Specialists, LLC (TESS), 19-Aug-2024**

Note: The statistics in the tables below are based on the Standard 140 informative example results.  
 These statistics do not have any substantial importance and are not to be interpreted as acceptance criteria.

**Table B8.2-6. Time from Coldest Hour (Jan 15, Hour 4) to Peak Conduction Occurrence**

	Verified Numerical Models				(Max-Min) /Mean	GHT NREL	SUNREL-GC NREL	EnergyPlus GARD	VA114/ ISO-13370 VABI	ESP-r/ BASESIMP NRCan	BASECALC NRCan	Statistics, Other Simulation Models			TRNSYS18 TESS
	TRNSYS TESS	FLUENT PAAET	MATLAB DIT									Min	Max	(Max-Min)/ (V.M.Mean) <sup>a</sup>	
<b>Phase Shift for Floor Conduction Peak (hours)</b>															
GC40b	417	465	441		10.9%	489	489		886			489	886	90.0%	417
GC45b	417	441	441		5.5%				880			880	880	0.0%	417
GC50b	489	465	465		5.1%				867			867	867	0.0%	489
GC55b	177	153	153		14.9%		178		884			178	884	438.5%	177
GC70b	660	659	660		0.2%		662		958			662	958	44.9%	660
GC80b	568	591	567		4.2%		618		1174			618	1174	96.6%	567
GC40c	562	562	538		4.3%				961	388		388	961	103.4%	
GC45c	490	538	538		9.2%				981	386		386	981	114.0%	
GC55c	490	538	538		9.2%				978	355		355	978	119.3%	
GC80c	613	613	589		4.0%				1100	433		433	1100	110.2%	
<b>Phase Shift for Zone Load Peak (hours)</b>															
GC40b							489		912			489	912	95.9%	417
GC45b									912			912	912	0.0%	417
GC50b									887			887	887	0.0%	489
GC55b							178		911			178	911	455.3%	177
GC70b							662		1031			662	1031	55.9%	660
GC80b							618		1248			618	1248	109.5%	569
GC40c									1007	424		424	1007	105.2%	
GC45c									1007	384		384	1007	119.3%	
GC55c									984	312		312	984	128.7%	
GC80c									1151	384		384	1151	126.8%	

<sup>a</sup> "V.M.Mean" is average of verified numerical-model results; for zone load results the average of the floor conduction results is used.

**ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
 TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results  
 By Thermal Energy System Specialists, LLC (TESS), 19-Aug-2024**

Note: The statistics in the tables below are based on the Standard 140 informative example results.  
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**Table B8.2-7. Steady-Periodic Supporting Information**

	Verified Numerical Models			GHT NREL	SUNREL-GC NREL	EnergyPlus GARD	VA114/ ISO-13370 VABI	ESP-r/ BASESIMP NRCan	BASECALC NRCan	Statistics, All Results			TRNSYS18 TESS	
	TRNSYS TESS	FLUENT PAAET	MATLAB DIT							Min	Max	(Max-Min) /Mean		
<b>Mean Annual Zone Air Temperature (°C)</b>														
GC40b					30.0	30.0	30.0				30.0	30.0	0.0%	30.0
GC45b						30.0	30.0				30.0	30.0	0.0%	30.0
GC50b						30.0	30.0				30.0	30.0	0.0%	30.0
GC55b					30.0	30.0	30.0				30.0	30.0	0.0%	30.0
GC70b					30.0	30.0	30.0				30.0	30.0	0.0%	30.0
GC80b					30.0	30.0	30.0				30.0	30.0	0.0%	30.0
GC40c						30.0	30.0	30.0	30.0		30.0	30.0	0.0%	
GC45c						30.0	30.0	30.0	30.0		30.0	30.0	0.0%	
GC55c						30.0	30.0	30.0	30.0		30.0	30.0	0.0%	
GC80c						30.0	30.0	30.0	30.0		30.0	30.0	0.0%	
<b>Simulation Duration (Years)</b>														
GC40b	5.0	6.0	10.0	5.0	5.0	7.0	1.0				1.0	10.0		5.0
GC45b	5.0	3.0	10.0			7.0	1.0				1.0	10.0		4.0
GC50b	8.0	8.0	10.0			8.0	1.0				1.0	10.0		8.0
GC55b	3.0	3.0	10.0		2.0	3.0	1.0				1.0	10.0		2.0
GC70b	6.0	3.0	10.0		5.0	7.0	1.0				1.0	10.0		5.0
GC80b	10.0	3.0	10.0		5.0	16.0	1.0				1.0	16.0		5.0
GC40c	5.0	3.0	10.0			6.0	1.0	2.0	3.0		1.0	10.0		
GC45c	5.0	3.0	10.0			6.0	1.0	2.0	3.0		1.0	10.0		
GC55c	3.0	3.0	10.0			3.0	1.0	2.0	3.0		1.0	10.0		
GC80c	8.0	4.0	10.0			10.0	1.0	2.0	3.0		1.0	10.0		

**ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests**  
**TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results**  
**By Thermal Energy System Specialists, LLC (TESS), 19-Aug-2024**

Note: The statistics in the tables below are based on the Standard 140 informative example results.  
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**Table B8.2-8. Steady-Periodic Minimum ODB and Time of Occurrence**

Verified Numerical-Model Results																													
	TRNSYS				FLUENT				MATLAB																				
	TESS	Date	Hour	ODBmin	PAAET	Date	Hour	ODBmin	DIT	Date	Hour	ODBmin																	
<b>Outdoor Dry-Bulb Temperature (°C)</b>																													
GC40a	2.1	8-Jan	4.0	30.0					2.0	8-Jan	4.0	15.0																	
GC40b	2.1	8-Jan	4.0	30.0					2.0	8-Jan	4.0	15.0																	
GC45b	2.1	8-Jan	4.0	30.0					2.0	8-Jan	4.0	15.0																	
GC50b	2.1	8-Jan	4.0	30.0					2.0	8-Jan	4.0	15.0																	
GC55b	2.1	8-Jan	4.0	30.0					2.0	8-Jan	4.0	15.0																	
GC70b	2.1	8-Jan	4.0	30.0					2.0	8-Jan	4.0	15.0																	
GC80b	2.1	8-Jan	4.0	30.0					2.0	8-Jan	4.0	15.0																	
GC40c	2.1	8-Jan	4.0	30.0					2.0	8-Jan	4.0	15.0																	
GC45c	2.1	8-Jan	4.0	30.0					2.0	8-Jan	4.0	15.0																	
GC55c	2.1	8-Jan	4.0	30.0					2.0	8-Jan	4.0	15.0																	
GC80c	2.1	8-Jan	4.0	30.0					2.0	8-Jan	4.0	15.0																	
Other Simulation Results																													
	GHT				SUNREL-GC				EnergyPlus				VA114/ISO-13370				ESP-r/BASESIMP				BASECALC				TRNSYS18				
	NREL	Date	Hour	ODBmin	NREL	Date	Hour	ODBmin	GARD	Date	Hour	ODBmin	VABI	Date	Hour	ODBmin	NRCan	Date	Hour	ODBmin	NRCan	Date	Hour	ODBmin	TESS	Date	Hour	ODBmin	
<b>Outdoor Dry-Bulb Temperature (°C)</b>																													
GC40a	2.0	8-Jan	4.0	15.0																									
GC40b	2.0	8-Jan	4.0	15.0	2.0	8-Jan	4.0	15.0	2.0	01/08 04:00	15.0	2.0	8-Jan	4.0	16.0										2.1	8-Jan	4.0	30.0	
GC45b									2.0	01/08 04:00	15.0	2.0	8-Jan	4.0	16.0											2.1	8-Jan	4.0	30.0
GC50b									2.0	01/08 04:00	15.0	2.0	8-Jan	4.0	16.0											2.1	8-Jan	4.0	30.0
GC55b					2.0	8-Jan	4.0	15.0	2.0	01/08 04:00	15.0	2.0	8-Jan	4.0	16.0											2.1	8-Jan	4.0	30.0
GC70b					2.0	8-Jan	4.0	15.0	2.0	01/08 04:00	15.0	2.0	8-Jan	4.0	16.0											2.1	8-Jan	4.0	30.0
GC80b					2.0	8-Jan	4.0	15.0	2.0	01/08 04:00	15.0	2.0	8-Jan	4.0	16.0											2.1	8-Jan	4.0	30.0
GC40c									2.0	01/08 04:00	15.0	2.0	8-Jan	4.0	16.0	2.0	8-Jan	4.0	15.0	4.0	Jan	0.0	744.0						
GC45c									2.0	01/08 04:00	15.0	2.0	8-Jan	4.0	16.0	2.0	8-Jan	4.0	15.0	4.0	Jan	0.0	744.0						
GC55c									2.0	01/08 04:00	15.0	2.0	8-Jan	4.0	16.0	2.0	8-Jan	4.0	15.0	4.0	Jan	0.0	744.0						
GC80c									2.0	01/08 04:00	15.0	2.0	8-Jan	4.0	16.0	2.0	8-Jan	4.0	15.0	4.0	Jan	0.0	744.0						

**ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
 TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results  
 By Thermal Energy System Specialists, LLC (TESS), 19-Aug-2024**

Note: The statistics in the tables below are based on the Standard 140 informative example results.  
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**Table B8.2-9. Delta Steady-State Conduction**

	Verified Numerical Models				VA114/ ESP-r/ Statistics, Other Simulation Models						TRNSYS18 TESS			
	TRNSYS TESS	FLUENT PAAET	MATLAB DIT	(Max-Min) /Mean	GHT NREL	SUNREL-GC NREL	EnergyPlus GARD	ISO-13370 VABI	BASESIMP NRCan	BASECALC NRCan		Min	Max	(Max-Min)/ (V.M.Mean) <sup>a</sup>
<b>Floor Conduction (W or Wh/h)</b>														
GC30a-GC10a	214	160	263	48.5%	42						42	42	0.0%	
GC40a <sup>b</sup> -GC30a	-12.4	13.2	0.1	8227.4%	-80.9						-80.9	-80.9	0.0%	
GC40b <sup>b</sup> -GC30b	-10.3	-0.1	0.0	-297.9%	0.5	0.5	-3.6	-0.2			-3.6	0.5	-117.7%	-0.6
GC40c <sup>b</sup> -GC30c	-7.9	0.2	0.0	-314.3%			4.3	0.5	0.2	0.2	0.2	4.3	-160.0%	
GC30a-GC30b	109	81	125	41.7%	116						116	116	0.0%	
GC30a-GC30c	505	462	541	15.6%										
GC30b-GC60b	420	400	442	10.0%		342	434	352			342	434	21.8%	420
GC60b-GC65b	120	114	125	9.3%		104	603	149			104	603	418.5%	120
GC30b-GC65b	539	513	566	9.9%		446	1037	501			446	1037	109.5%	539
GC70b <sup>b</sup> -GC65b	-7.9	-0.4	0.0	-284.9%		0.5	160.0	-0.3			-0.3	160.0	-5797.5%	-0.6
<b>Zone Load (W or Wh/h)</b>														
GC40b <sup>b</sup> -GC30b						0.5	-3.6	-0.1			-3.6	0.5	-117.7%	-0.6
GC40c <sup>b</sup> -GC30c							4.3	0.1	-0.1	-0.1	-0.1	4.3	-172.4%	
GC30b-GC60b						342	434	352			342	434	21.8%	407
GC60b-GC65b						104	603	150			104	603	418.5%	120
GC30b-GC65b						446	1037	502			446	1037	109.5%	527
GC70b <sup>b</sup> -GC65b						0.5	160.0	0.2			0.2	160.0	-5780.2%	-0.6

<sup>a</sup> "V.M.Mean" is average of verified numerical-model results; for zone load results the average of the floor conduction results is used.

<sup>b</sup> Values for GC40a, GC40b, GC40c and GC70b are: annual total × 1000 (W/kW) / 8760 (h/y)

**ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
 TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results  
 By Thermal Energy System Specialists, LLC (TESS), 19-Aug-2024**

Note: The statistics in the tables below are based on the Standard 140 informative example results.  
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**Table B8.2-10. Delta Steady-Periodic Annual Total Conduction**

	Verified Numerical Models				(Max-Min) /Mean	GHT NREL	SUNREL- NREL	GC GARD	EnergyPlus ISO-13370 VABI	ESP-r/ BASESIMP NRCan	BASECALC NRCan	Statistics, Other Simulation Models			TRNSYS18 TESS
	TRNSYS TESS	FLUENT PAAET	MATLAB DIT									Min	Max	(Max-Min)/ (V.M.Mean) <sup>a</sup>	
<b>Floor Conduction (kWh)</b>															
GC40a-GC40b	933	829	1096	28.1%	299							299	299	0.0%	
GC45b-GC40b	10659	10524	10971	4.2%				10211	9650			9650	10211	5.2%	10341
GC40b-GC50b <sup>c</sup>	15846	15677	16181	3.2%				15908	14683			14683	15908	7.7%	15916
GC55b-GC40b	12976	12947	12978	0.2%			12698	16728	10395			10395	16728	48.8%	12940
GC40b-GC70b	4704	4498	4961	9.8%			3906	7650	4389			3906	7650	79.3%	4725
GC40b-GC80b	16071	15993	16362	2.3%			14852	17145	15478			14852	17145	14.2%	16030
GC45c-GC40c	8355	8309	8519	2.5%				8452	7708	6564	6564	6564	8452	22.5%	
GC55c-GC40c	2111	2117	2113	0.3%				2315	1842	3565	3565	1842	3565	81.5%	
GC40c-GC80c	9457	9461	9559	1.1%				10182	9364	8650	8650	8650	10182	16.1%	
<b>Zone Conduction (kWh)</b>															
GC45b-GC40b								10211	9664			9664	10211	5.1%	10493
GC40b-GC50b <sup>c</sup>								15908	14701			14701	15908	7.6%	15834
GC55b-GC40b							12698	16728	10394			10394	16728	48.8%	12871
GC40b-GC70b							3906	7650	4395			3906	7650	79.3%	4613
GC40b-GC80b							14852	17145	15482			14852	17145	14.2%	15944
GC45c-GC40c								8452	7722	6640	6640	6640	8452	21.6%	
GC55c-GC40c								2315	1842	3566	3566	1842	3566	81.6%	
GC40c-GC80c								10182	9366	8697	8697	8697	10182	15.6%	

<sup>a</sup> "V.M.Mean" is average of verified numerical-model results; for zone load results the average of the floor conduction results is used.

<sup>c</sup> GC50b with normalized floor area: GC50b / (80 x 80) x (12 x 12)

**ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
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 By Thermal Energy System Specialists, LLC (TESS), 19-Aug-2024**

Note: The statistics in the tables below are based on the Standard 140 informative example results.  
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**Table B8.2-11. Delta Steady-Periodic Last-Year Peak Hour Floor Conduction**

	Verified Numerical Models				VA114/ ESP-r/ GHT SUNREL-GC EnergyPlus ISO-13370 BASESIMP BASECALC						Statistics, Other Simulation Models			TRNSYS18 TESS
	TRNSYS TESS	FLUENT PAAET	MATLAB DIT	(Max-Min) /Mean	NREL	NREL	GARD	VABI	NRCan	NRCan	Min	Max	(Max-Min)/ (V.M.Mean) <sup>a</sup>	
<b>Floor Conduction (W or Wh/h)</b>														
GC40a-GC40b	145	128	171	29.1%	48						48	48	0.0%	
GC45b-GC40b	1503	1482	1549	4.4%			1410	1419			1410	1419	0.6%	1458
GC40b-GC50b <sup>c</sup>	2164	2138	2214	3.5%			2115	2082			2082	2115	1.5%	2174
GC55b-GC40b	1425	1422	1425	0.2%		1391	1855	1186			1186	1855	47.0%	1421
GC40b-GC70b	687	655	726	10.2%		566	1099	647			566	1099	77.3%	690
GC40b-GC80b	2166	2151	2208	2.6%		1988	2239	2146			1988	2239	11.5%	2161
GC45c-GC40c	1180	1173	1205	2.7%			1176	1134	961	954	954	1176	18.7%	
GC55c-GC40c	256	258	258	0.9%			275	210	435	435	210	435	87.4%	
GC40c-GC80c	1265	1264	1279	1.2%			1351	1285	1137	1133	1133	1351	17.1%	
<b>Zone Conduction (W or Wh/h)</b>														
GC45b-GC40b							1410	1421			1410	1421	0.7%	1478
GC40b-GC50b <sup>c</sup>							2115	2097			2097	2115	0.8%	2163
GC55b-GC40b						1391	1855	1186			1186	1855	47.0%	1413
GC40b-GC70b						566	1099	648			566	1099	77.3%	675
GC40b-GC80b						1988	2239	2147			1988	2239	11.5%	2149
GC45c-GC40c							1176	1137	973	967	967	1176	17.6%	
GC55c-GC40c							275	211	435	437	211	437	87.8%	
GC40c-GC80c							1351	1285	1145	1139	1139	1351	16.7%	

<sup>a</sup> "V.M.Mean" is average of verified numerical-model results; for zone load results the average of the floor conduction results is used.

<sup>c</sup> GC50b with normalized floor area: GC50b / (80 x 80) x (12 x 12)

**ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
 TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results  
 By Thermal Energy System Specialists, LLC (TESS), 19-Aug-2024**

Note: The statistics in the tables below are based on the Standard 140 informative example results.  
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**Table B8.2-12. Delta Steady-Periodic Conduction v Coldest Hour Phase Shift**

	Verified Numerical Models				VA114/ ESP-r/ GHT SUNREL-GC EnergyPlus ISO-13370 BASESIMP BASECALC						Statistics, Other Simulation Models			TRNSYS18 TESS
	TRNSYS TESS	FLUENT PAAET	MATLAB DIT	(Max-Min) /Mean	NREL	NREL	GARD	VABI	NRCan	NRCan	Min	Max	(Max-Min)/ (V.M.Mean) <sup>a</sup>	
<b>Floor (Hours)</b>														
GC40a-GC40b	-1	-49	-25	-192.0%	-2						-2	-2	0.0%	
GC45b-GC40b	0	-24	0	-300.0%				-6			-6	-6	0.0%	0
GC40b-GC50b <sup>c</sup>	-72	0	-24	-225.0%				19			19	19	0.0%	-72
GC55b-GC40b	-240	-312	-288	-25.7%		-311		-2			-311	-2	-110.4%	-240
GC40b-GC70b	-243	-194	-219	-22.4%		-173		-72			-173	-72	-46.2%	-243
GC40b-GC80b	-151	-126	-126	-18.6%		-129		-288			-288	-129	-118.4%	-150
GC45c-GC40c	-72	-24	0	-225.0%				20	-2		-2	20	-68.8%	
GC55c-GC40c	-72	-24	0	-225.0%				17	-33		-33	17	-156.3%	
GC40c-GC80c	-51	-51	-51	0.0%				-139	-45		-139	-45	-184.3%	
<b>Zone (Hours)</b>														
GC45b-GC40b								0			0	0	0.0%	0
GC40b-GC50b <sup>c</sup>								25			25	25	0.0%	-72
GC55b-GC40b						-311		-1			-311	-1	-110.7%	-240
GC40b-GC70b						-173		-119			-173	-119	-24.7%	-243
GC40b-GC80b						-129		-336			-336	-129	-154.1%	-152
GC45c-GC40c								0	-40		-40	0	-125.0%	
GC55c-GC40c								-23	-112		-112	-23	-278.1%	
GC40c-GC80c								-144	40		-144	40	-360.8%	

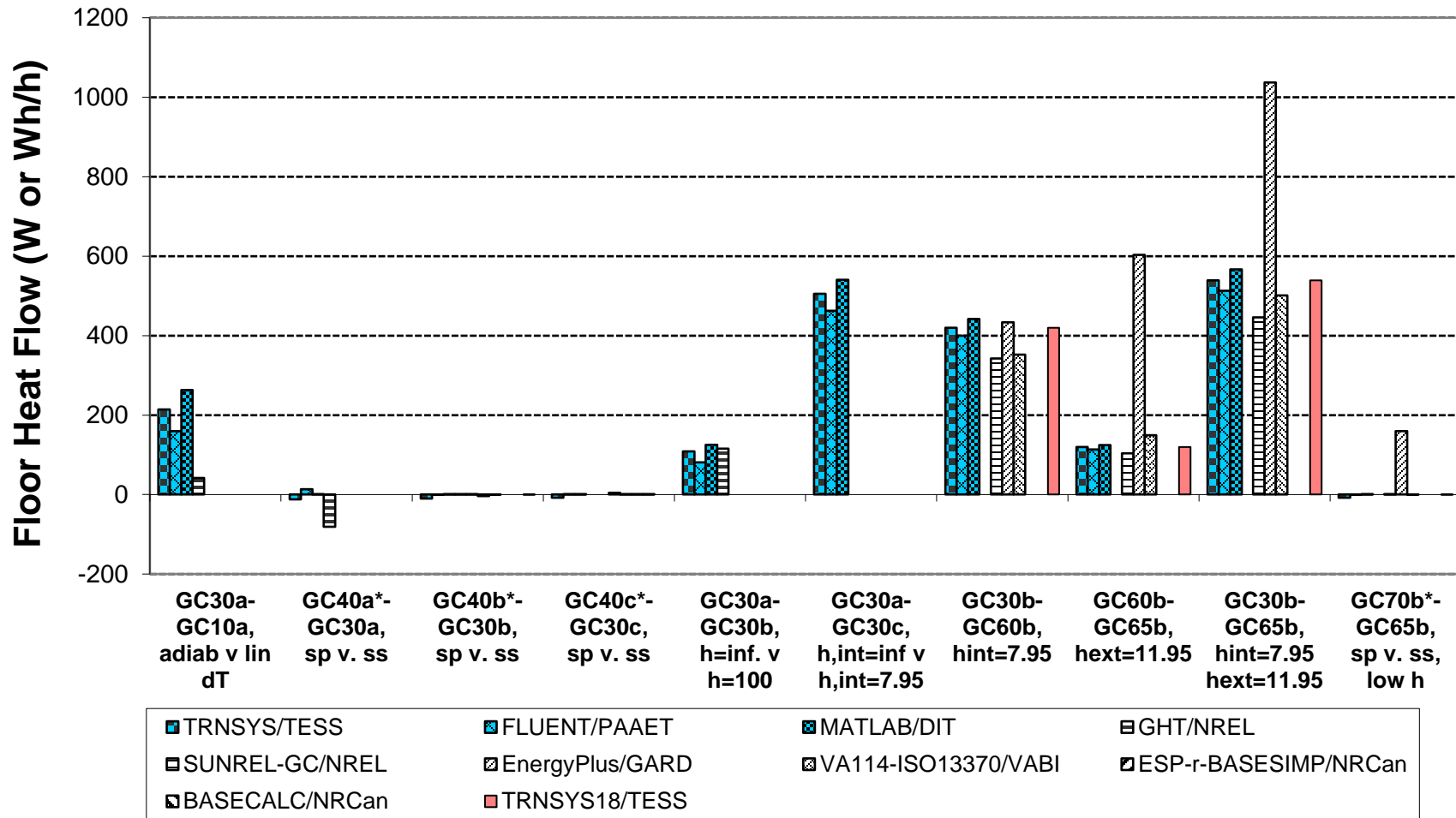
<sup>a</sup> "V.M.Mean" is average of verified numerical-model results; for zone load results the average of the floor conduction results is used.

<sup>c</sup> GC50b with normalized floor area: GC50b / (80 x 80) x (12 x 12)



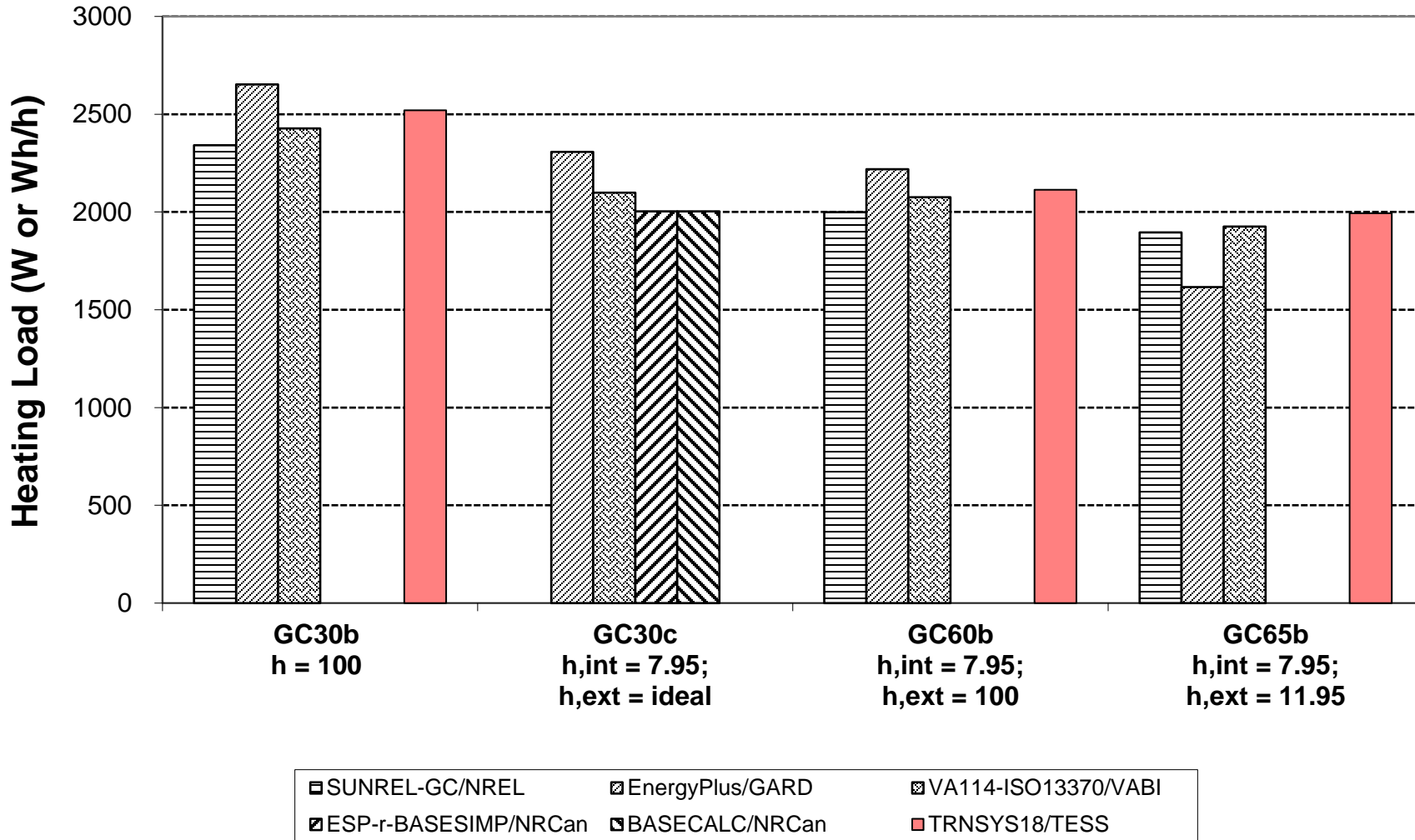


**Figure B8.2-2. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
 Steady-State Floor Conduction Sensitivity**

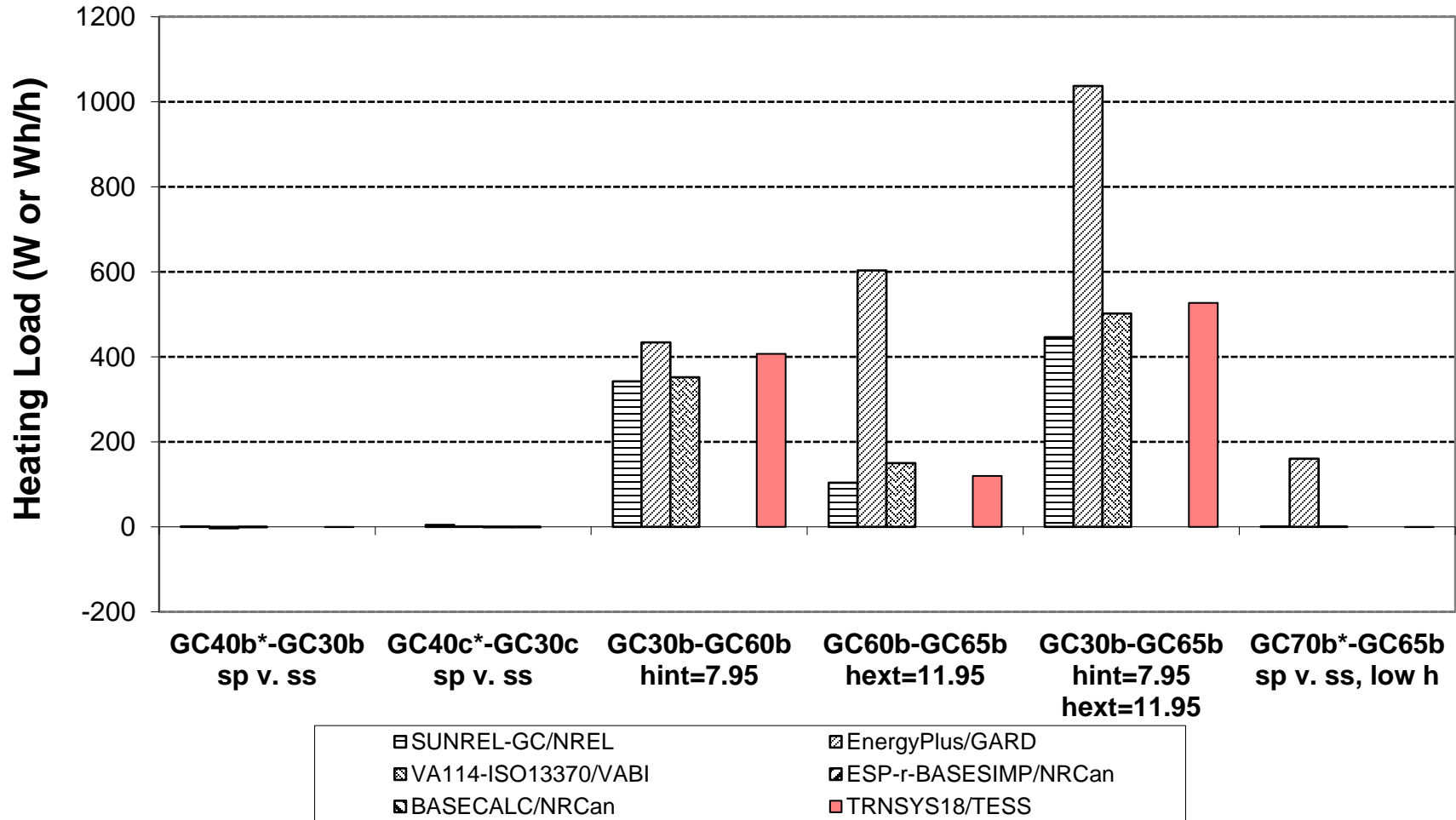


\* Values for GC40a, GC40b, GC40c, and GC70b are: annual total x 1000 (W/kW) / 8760 (h/y)

**Figure B8.2-3. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
 Steady-State Zone Heating Load**



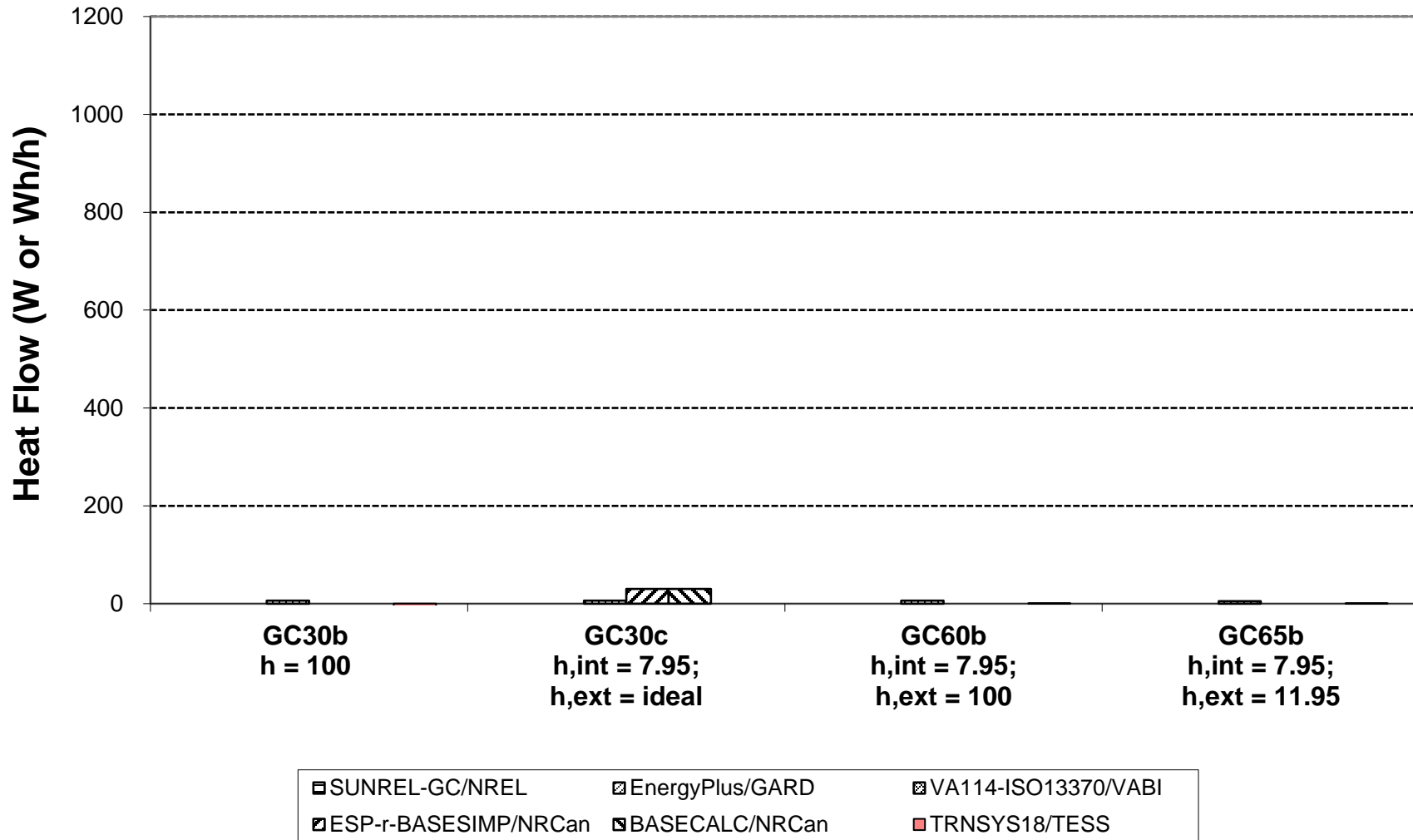
**Figure B8.2-4. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
 Steady-State Zone Heating Load Sensitivity**



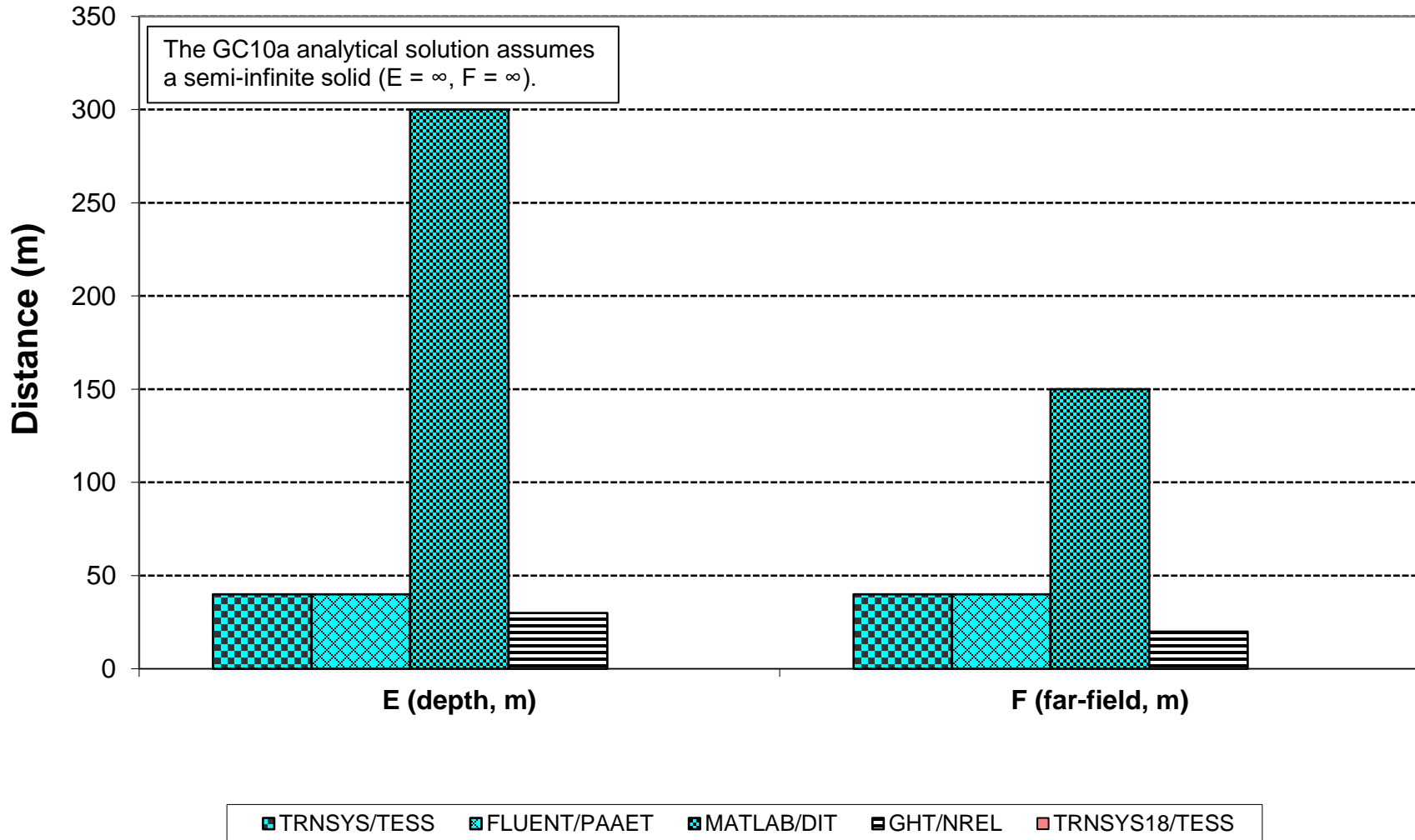
\* Values for GC40b, GC40c, and GC70b are: annual total x 1000 (W/kW) / 8760 (h/y)

ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
 TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results, by Thermal Energy System Specialists, LLC (TESS), 19-Aug-202

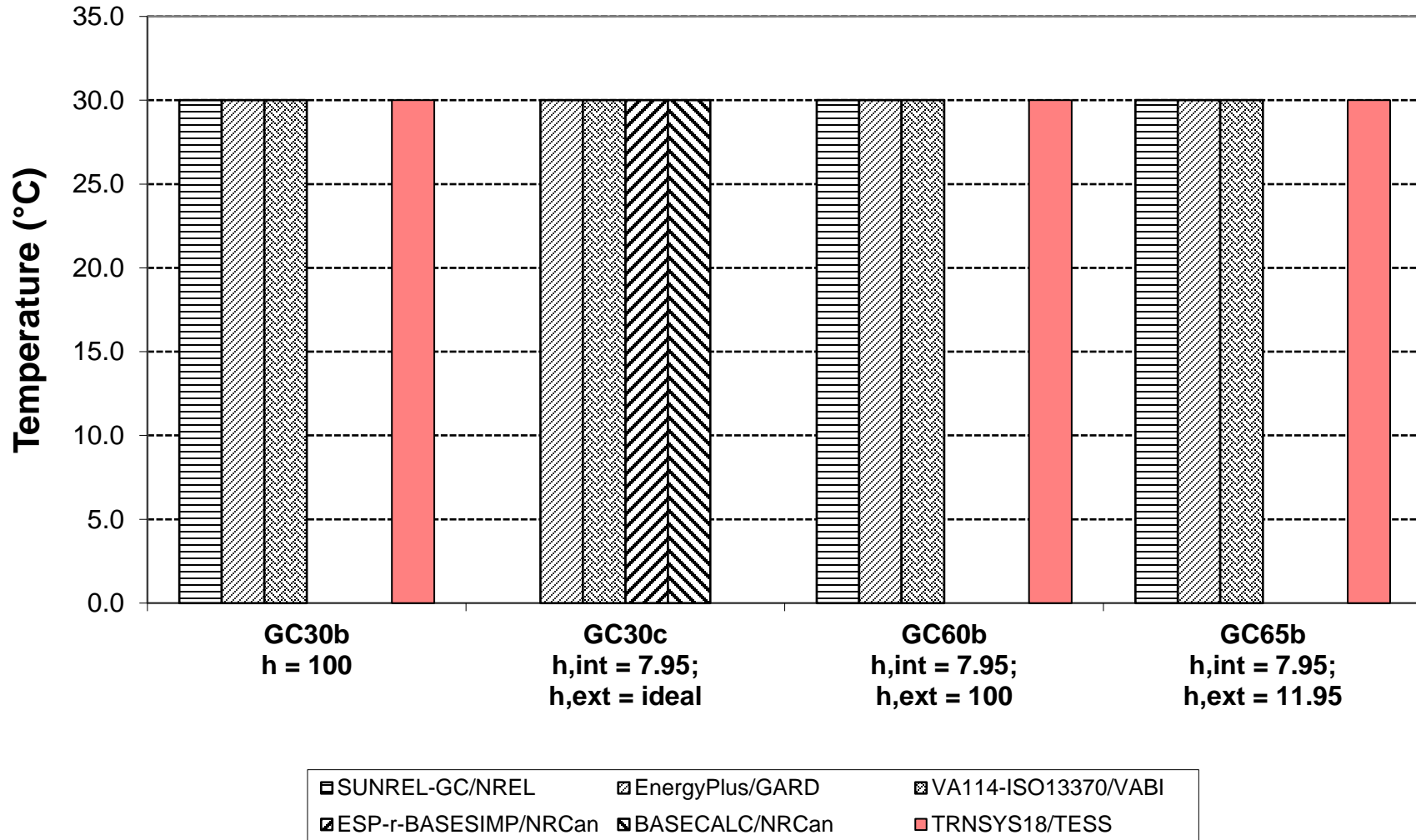
**Figure B8.2-5. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
 Steady-State (Zone Heating Load) - (Floor Conduction)**



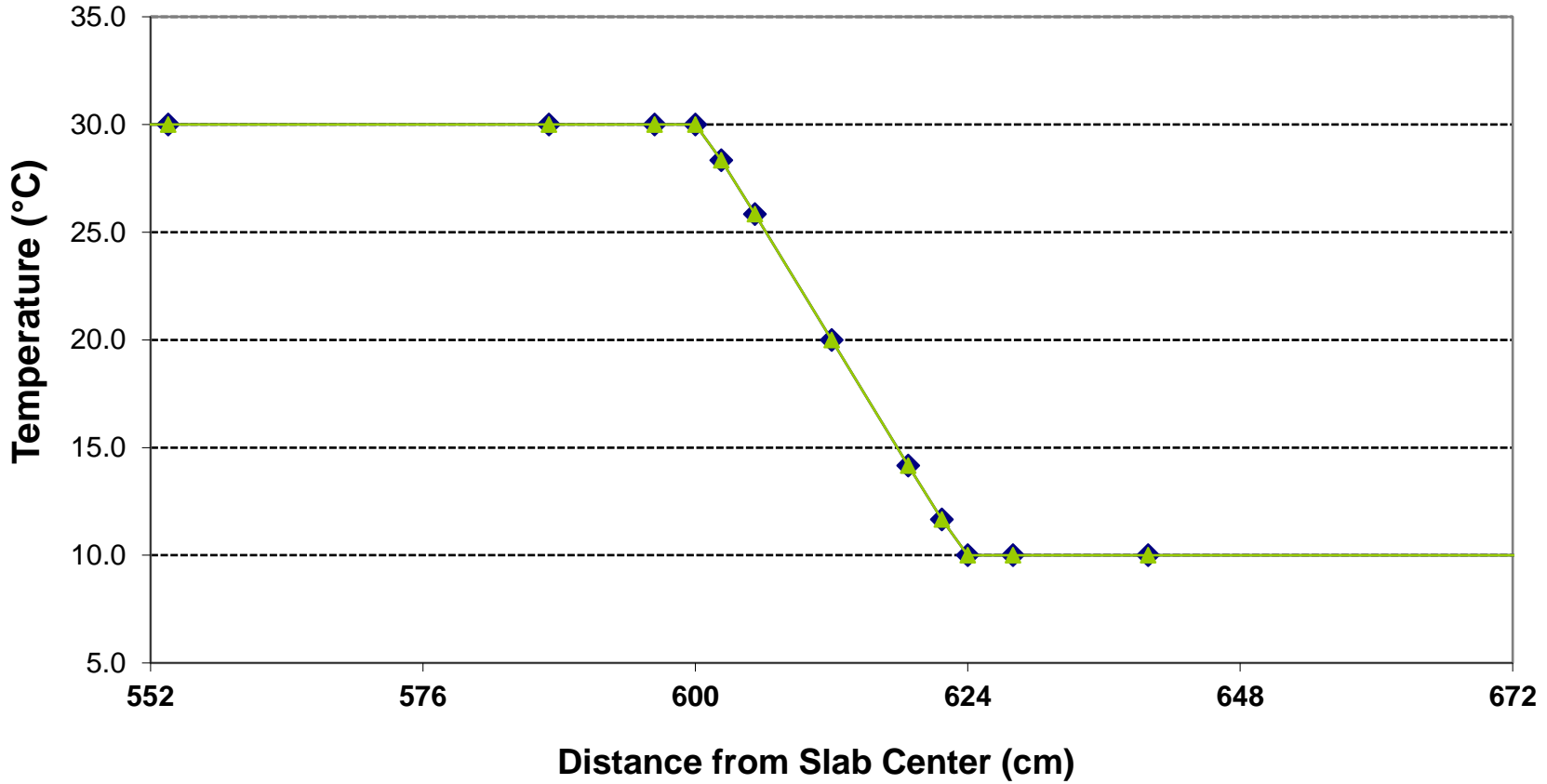
**Figure B8.2-6. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
Case GC10a Modeling Parameters**



**Figure B8.2-7. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
Steady-State Zone Temperature**



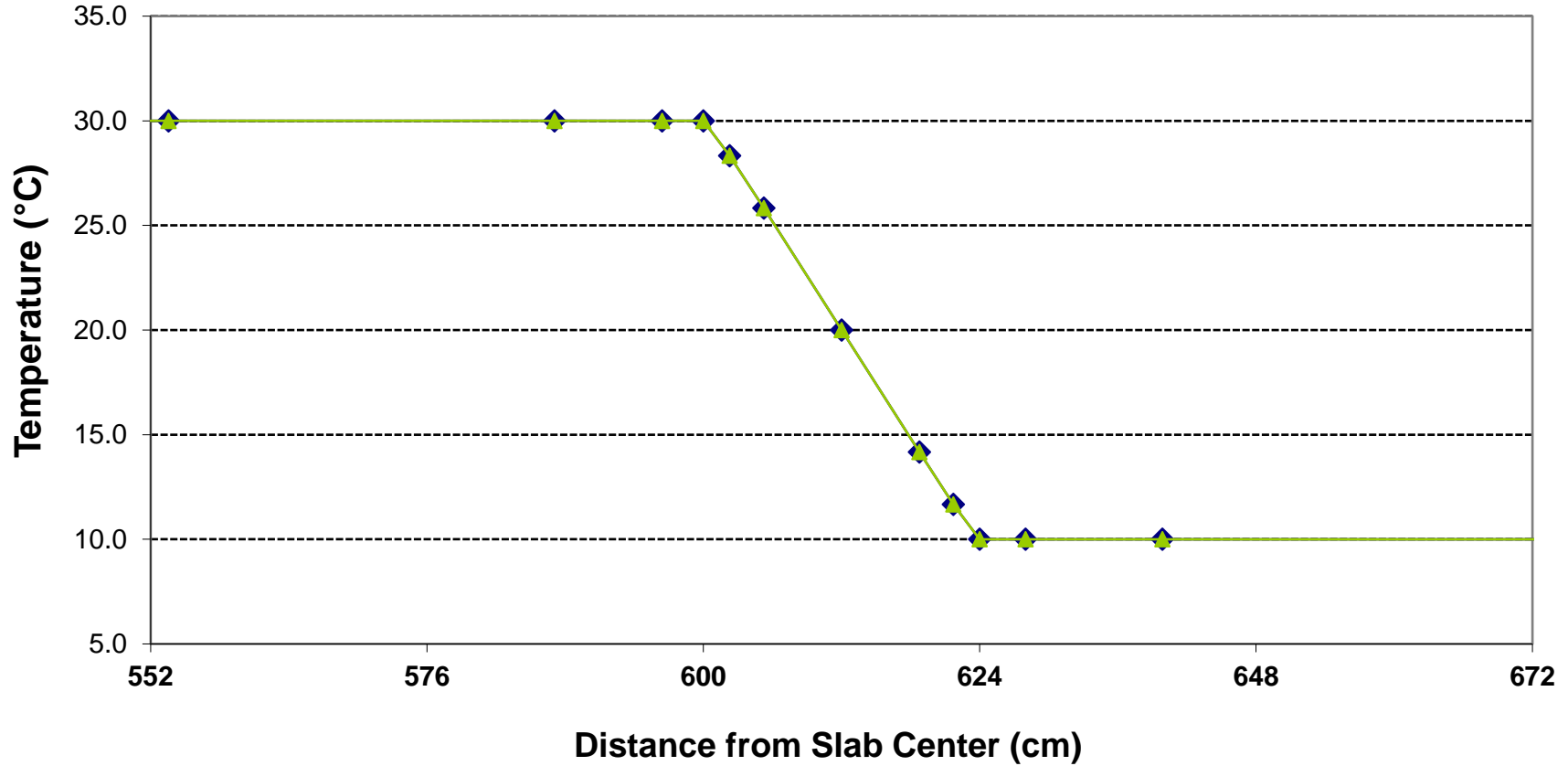
**Figure B8.2-8.**  
**IEA BESTEST Ground Coupling: In-Depth Floor Slab, GC10a**  
**Steady-State Surface Temperatures (Y=0, thru edge center)**



—◆— TRNSYS/TESS-GC10a    —▲— MATLAB/DIT-GC10a    —●— TRNSYS18/TESS-GC10a



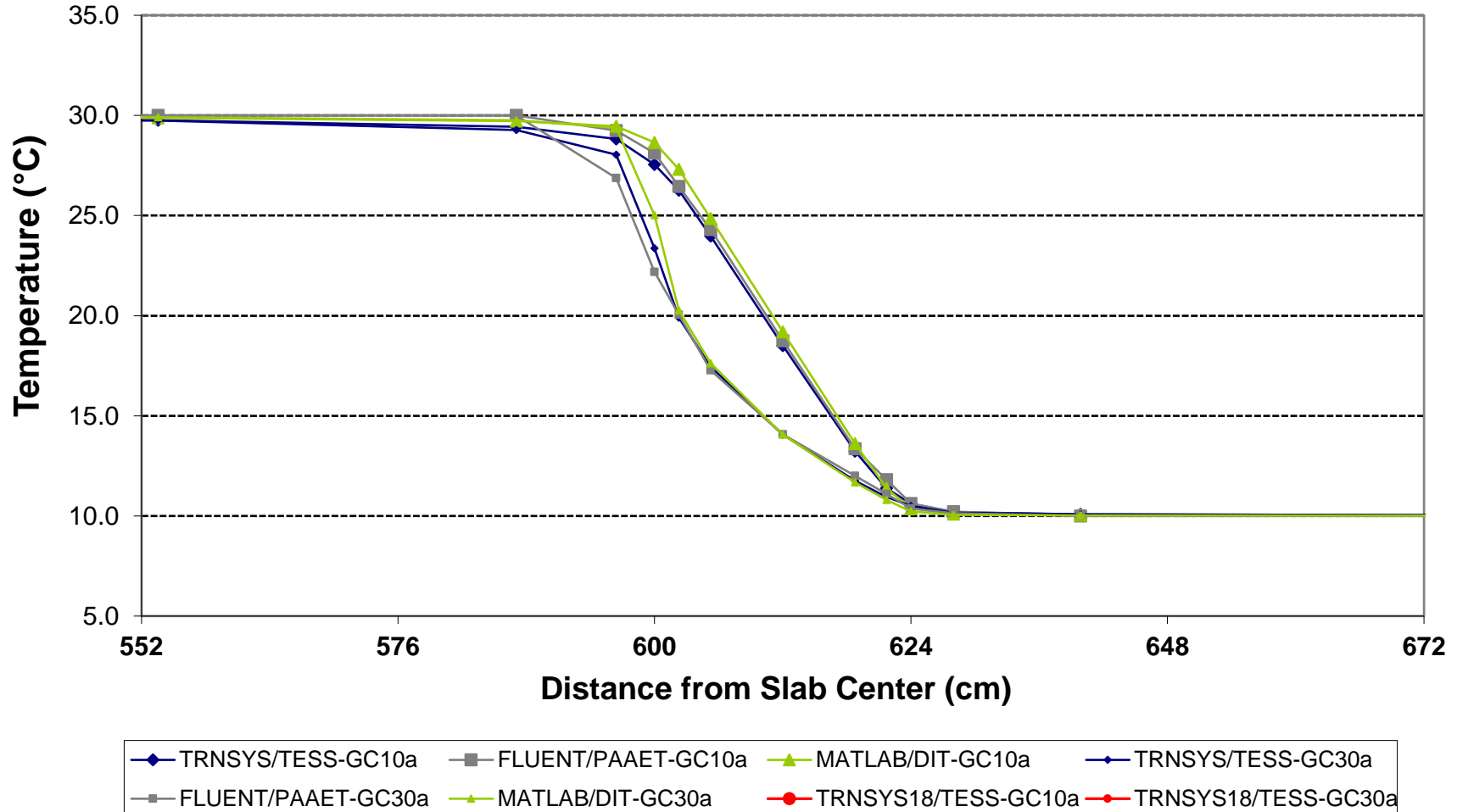
**Figure B8.2-9.**  
**IEA BESTEST Ground Coupling: In-Depth Floor Slab, GC10a**  
**Steady-State Surface Temperatures (Y=X, thru corner)**



—◆— TRNSYS/TESS-GC10a    —▲— MATLAB/DIT-GC10a    —●— TRNSYS18/TESS-GC10a

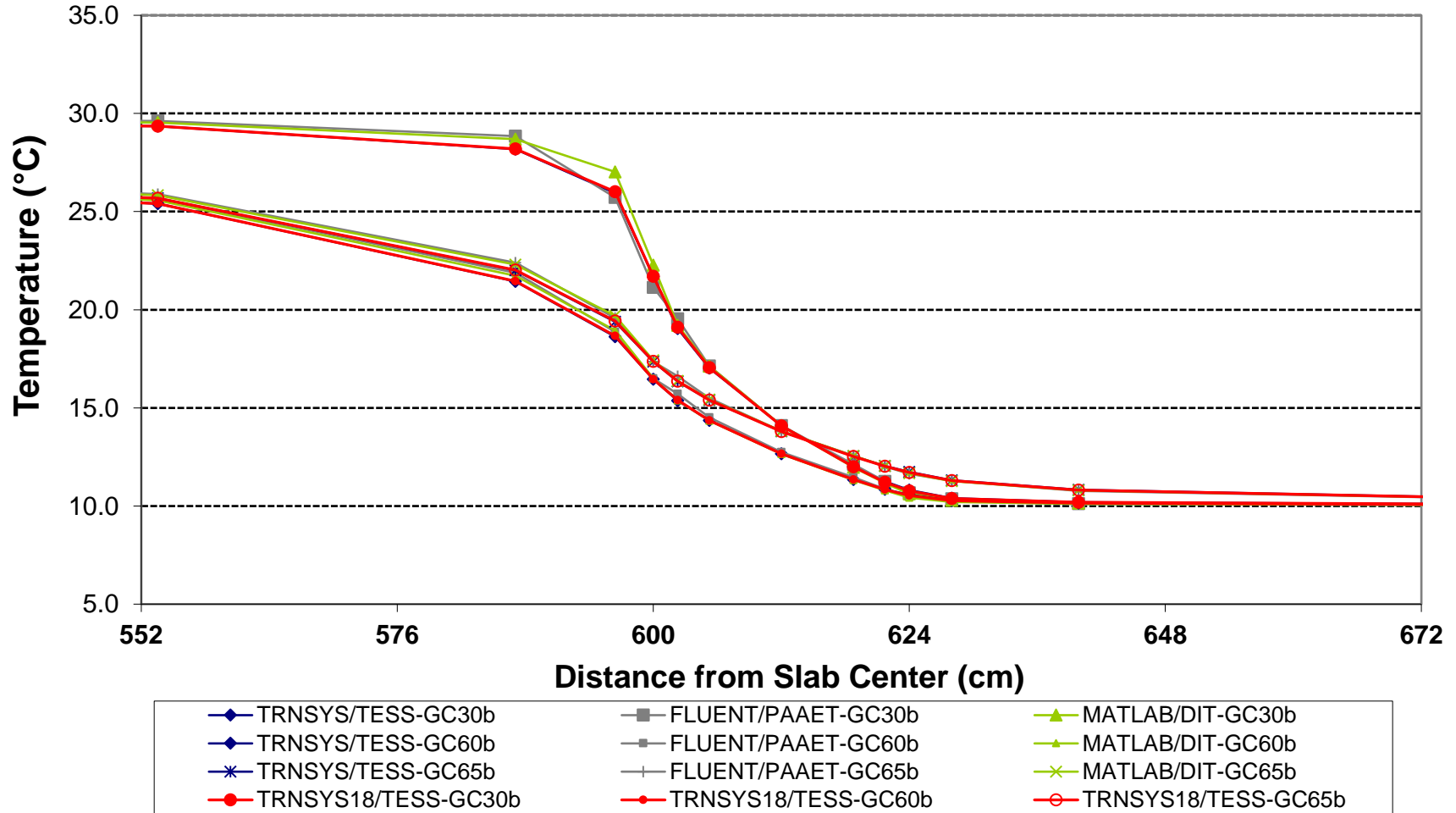


**Figure B8.2-11.**  
**IEA BESTEST Ground Coupling: In-Depth Floor Slab, GC10a, GC30a**  
**Steady-State Near-Surface Temperatures (Y=X, thru corner)**



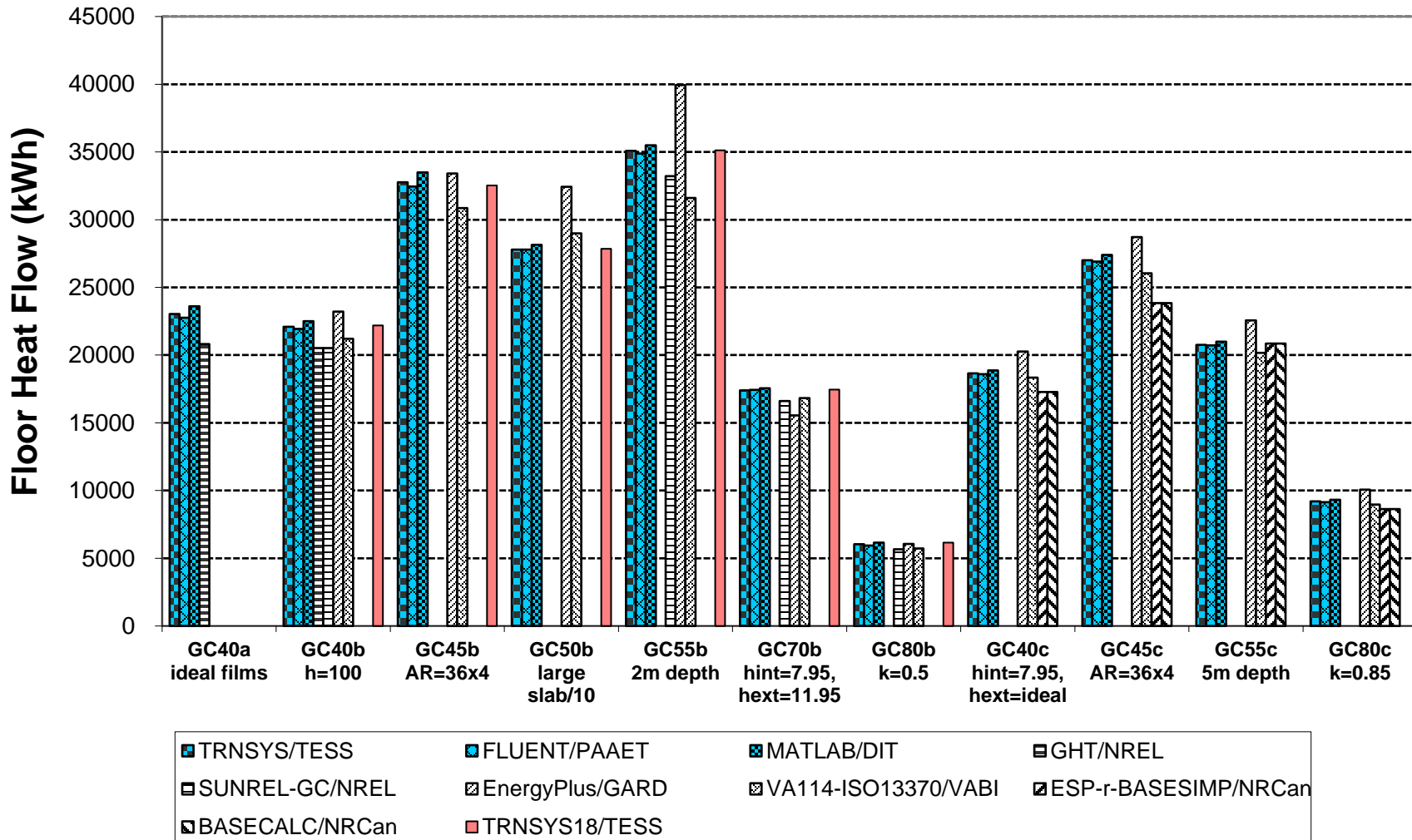


**Figure B8.2-13.**  
**IEA BESTEST: In-Depth Floor Slab, GC30b, GC60b, GC65b**  
**Steady-State Near-Surface Temperatures (Y=X, thru corner)**



ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
 TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results, by Thermal Energy System Specialists, LLC (TESS), 19-Aug-202

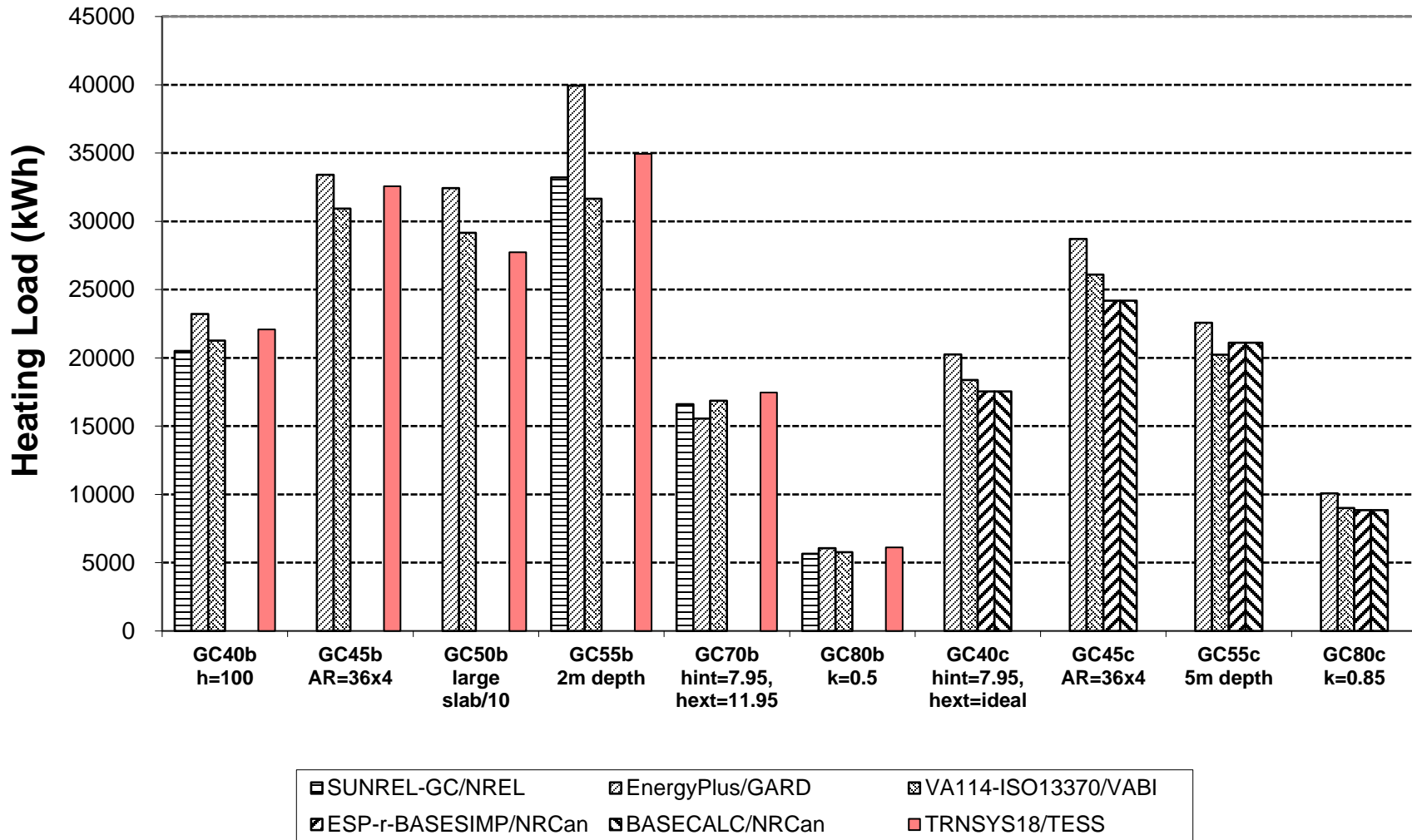
**Figure B8.2-14. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
 Steady-Periodic Annual Floor Conduction**





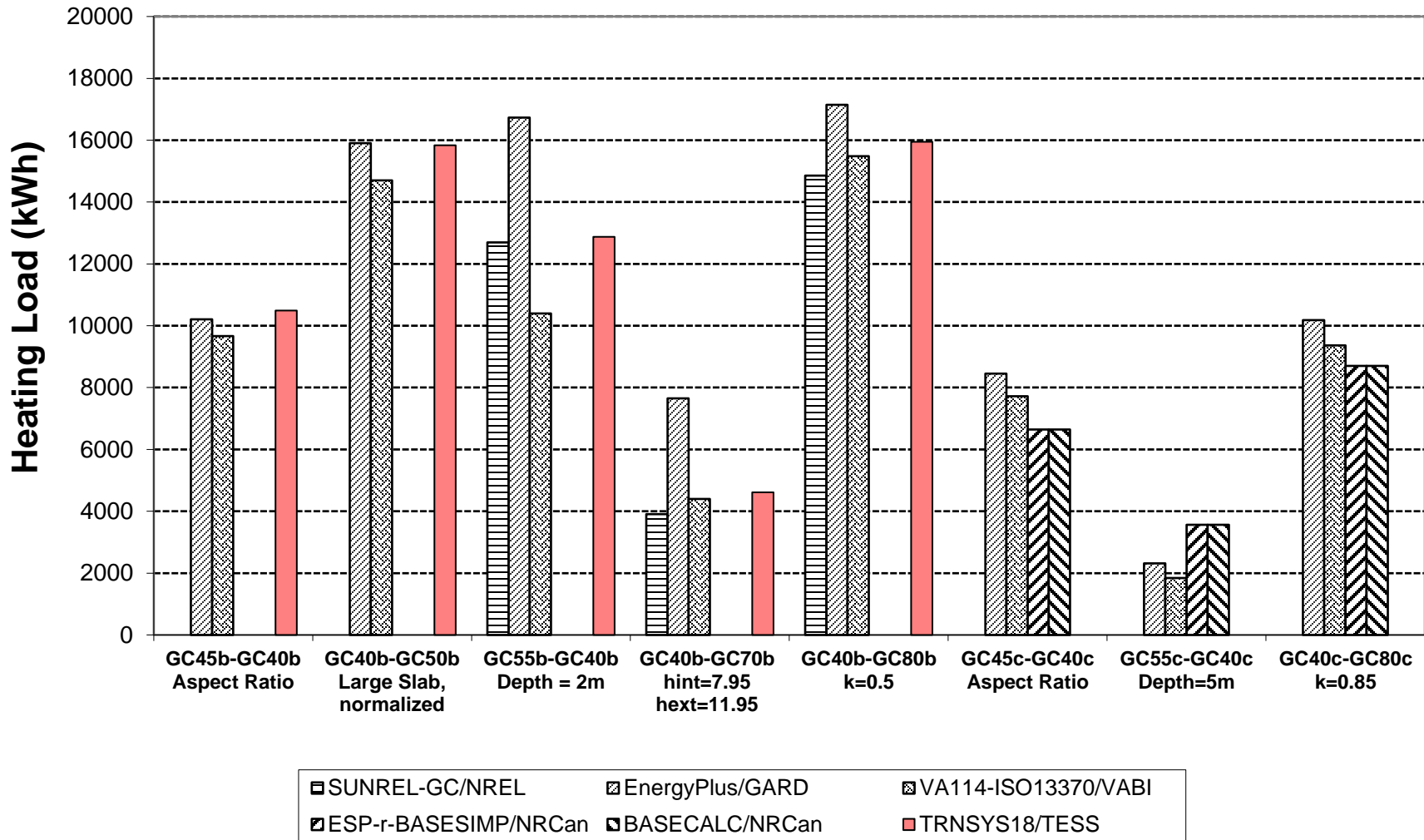
ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
 TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results, by Thermal Energy System Specialists, LLC (TESS), 19-Aug-202

**Figure B8.2-16. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
 Steady-Periodic Annual Zone Heating Load**



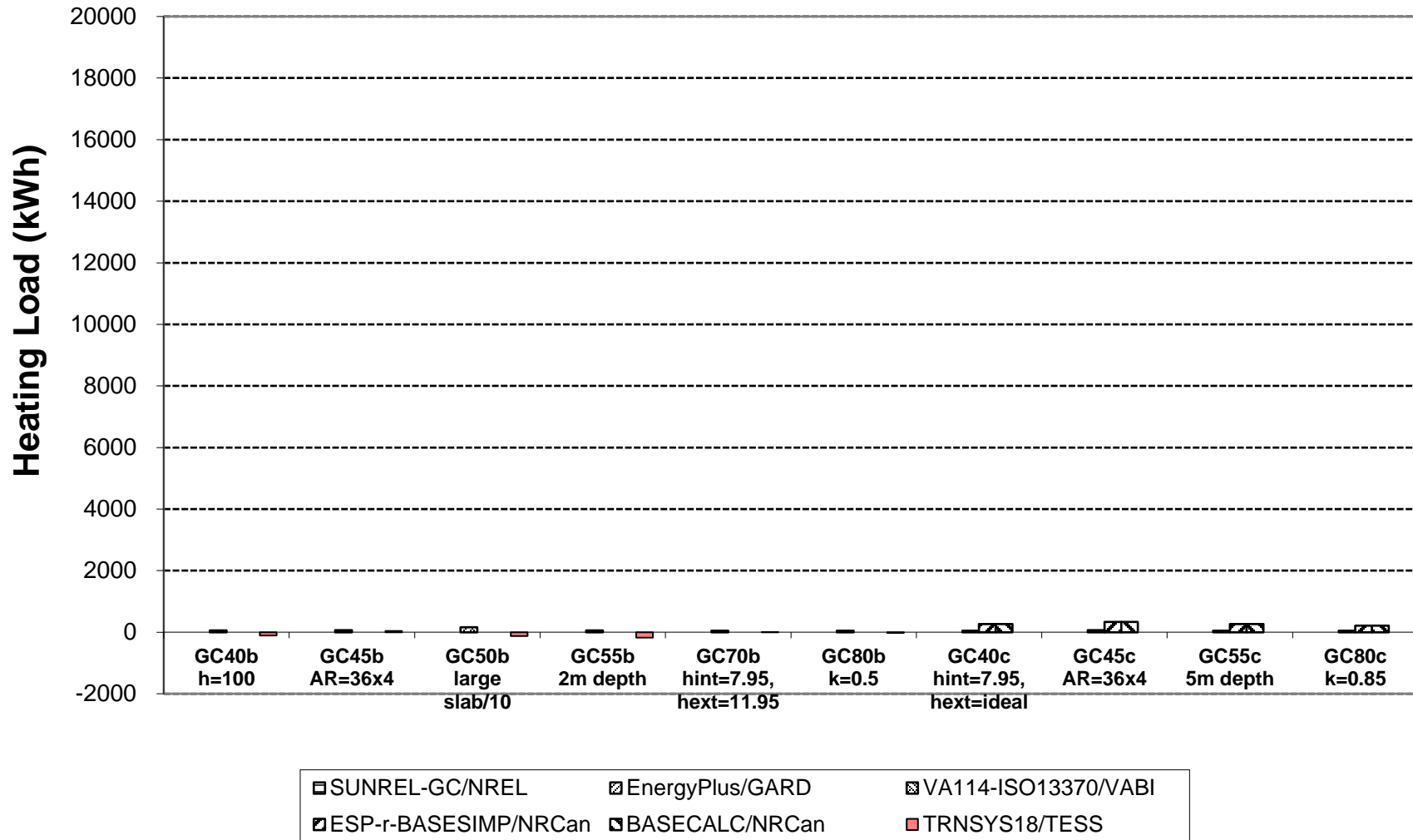


**Figure B8.2-17. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
 Steady-Periodic Annual Zone Heating Load Sensitivity**



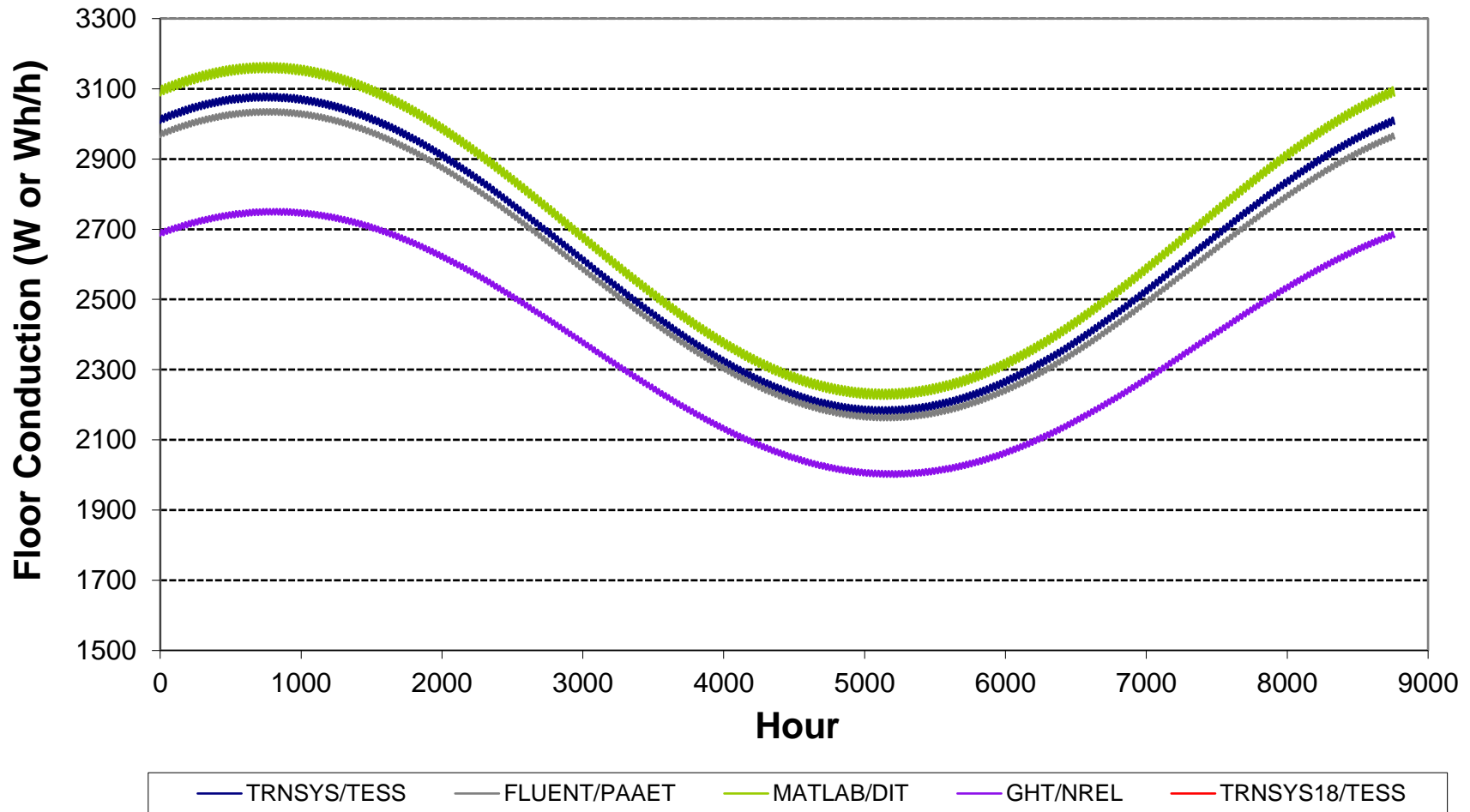
ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
 TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results, by Thermal Energy System Specialists, LLC (TESS), 19-Aug-2022

**Figure B8.2-18. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
 Steady-Periodic (Zone Heating Load) - (Floor Conduction)**



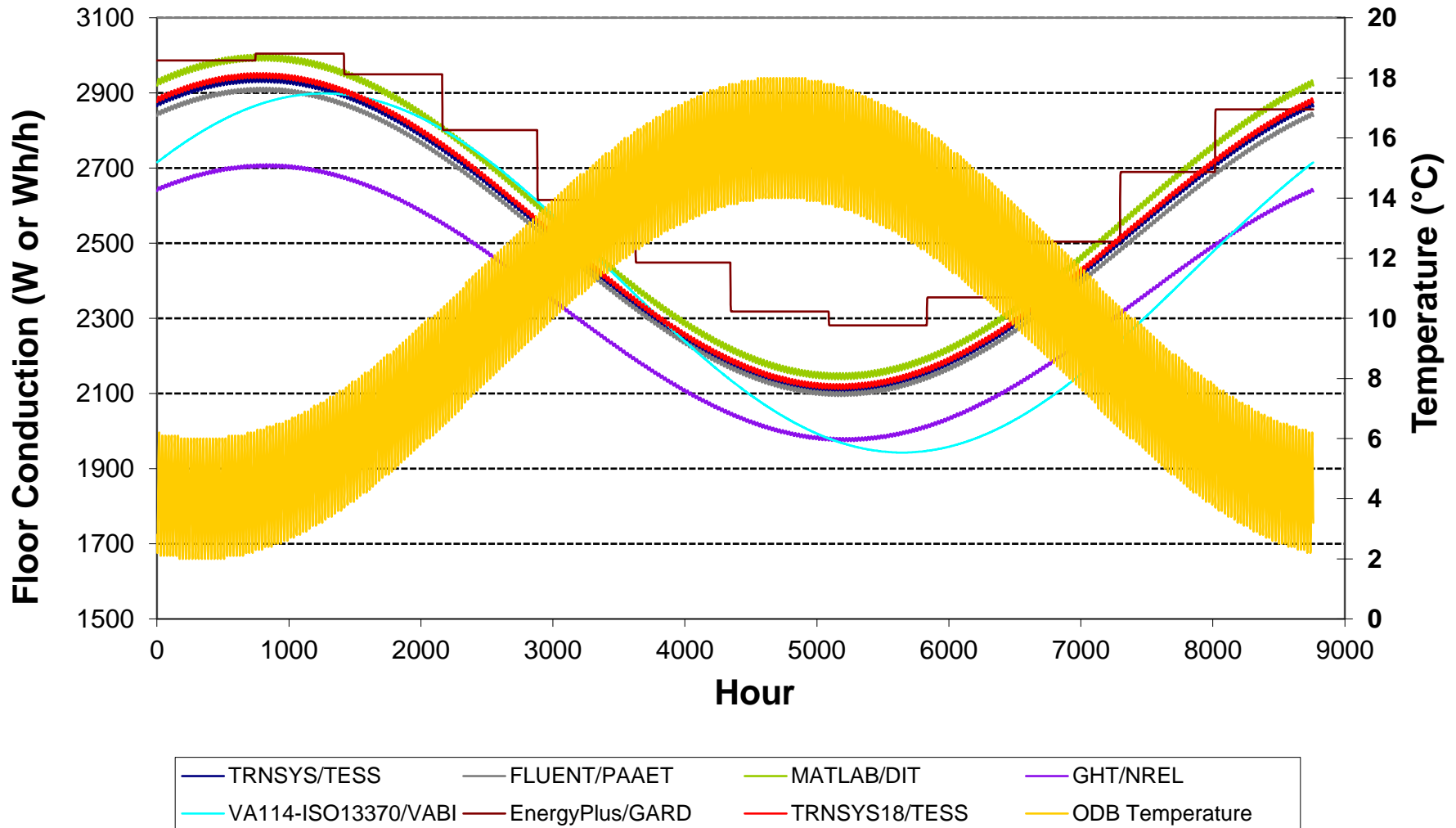
ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results, by Thermal Energy System Specialists, LLC (TESS), 19-Aug-202

**Figure B8.2-19. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
Hourly Floor Conduction, GC40a**



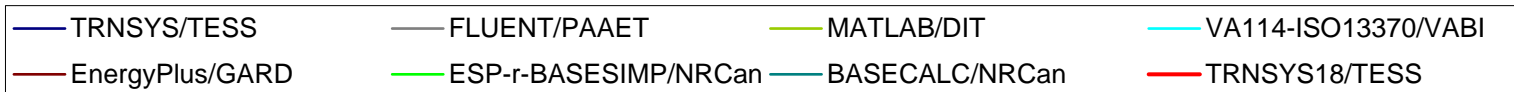
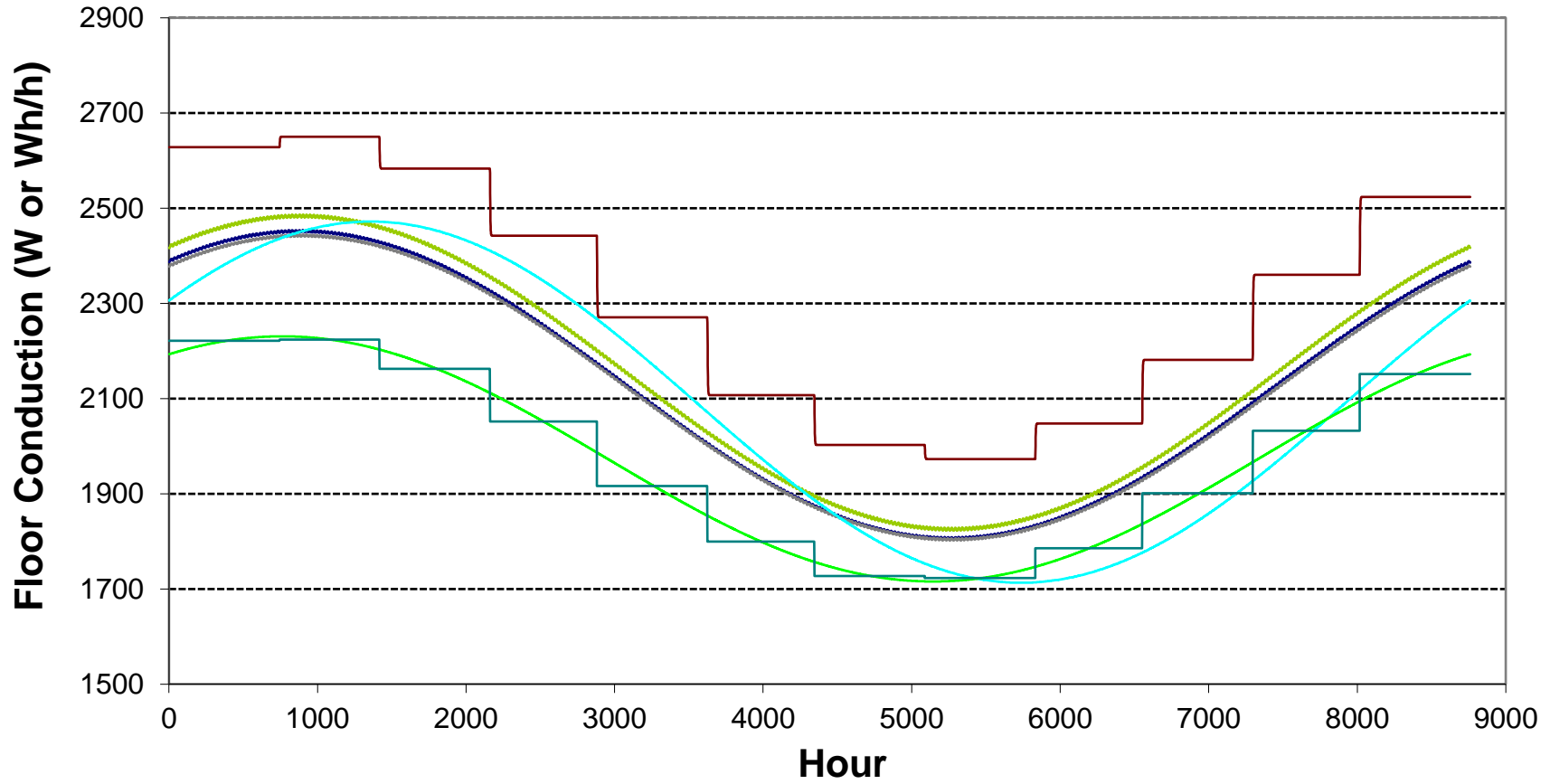
ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results, by Thermal Energy System Specialists, LLC (TESS), 19-Aug-202

**Figure B8.2-20. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
Hourly Floor Conduction, GC40b**

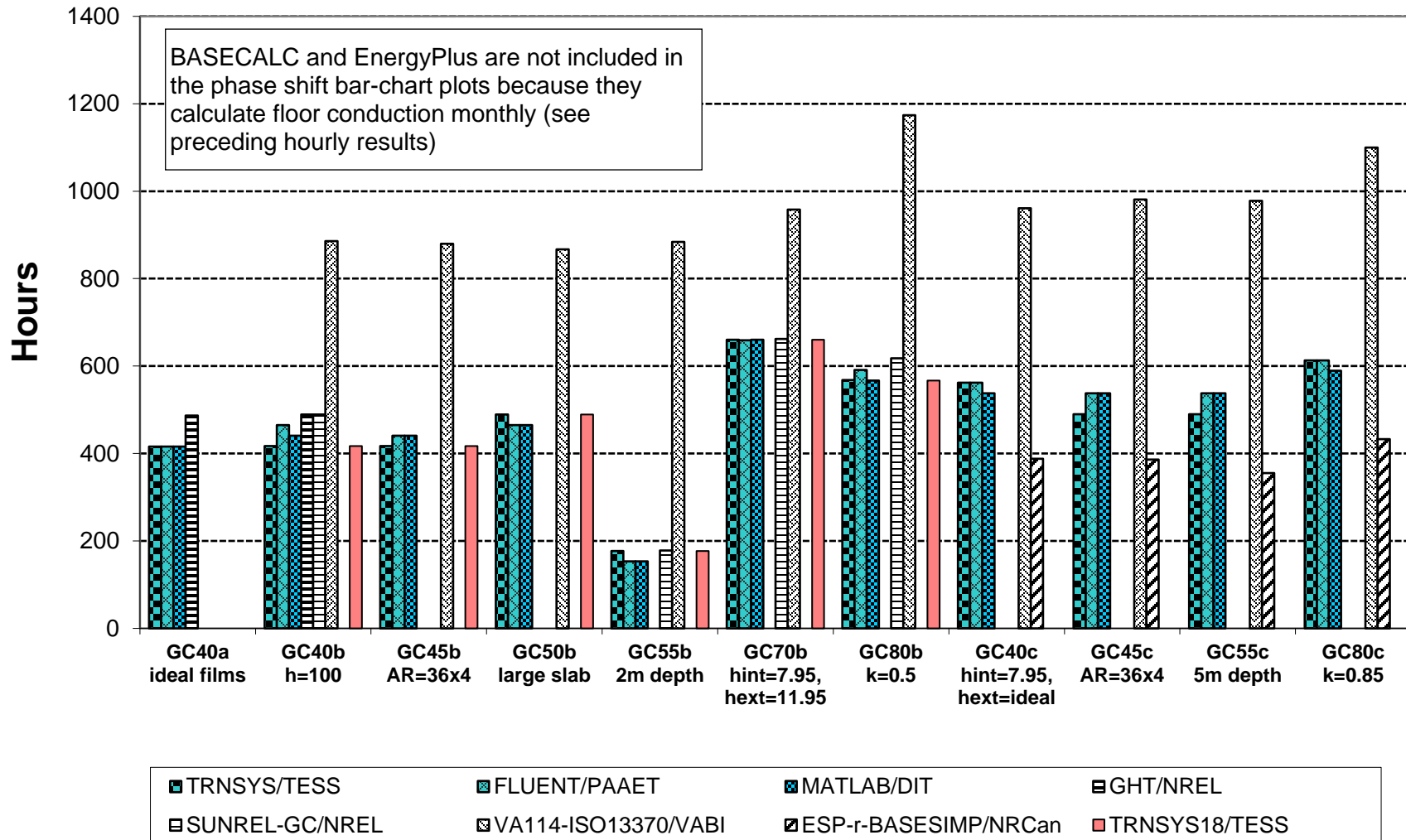


ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results, by Thermal Energy System Specialists, LLC (TESS), 19-Aug-202

**Figure B8.2-21. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
Hourly Floor Conduction, GC40c**

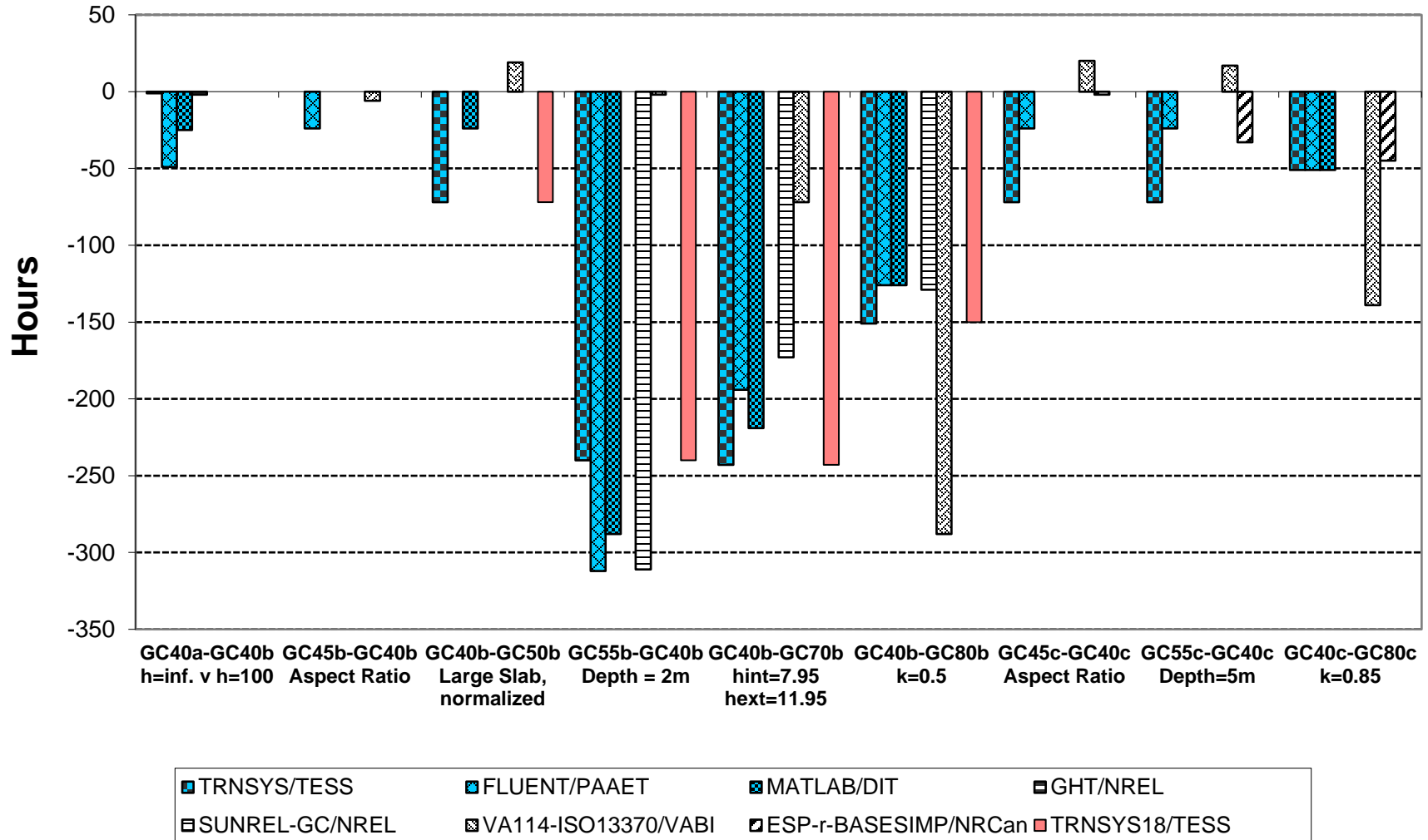


**Figure B8.2-22. IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-Periodic Phase Shift, Time From Coldest ODB to Peak Floor Conduction**

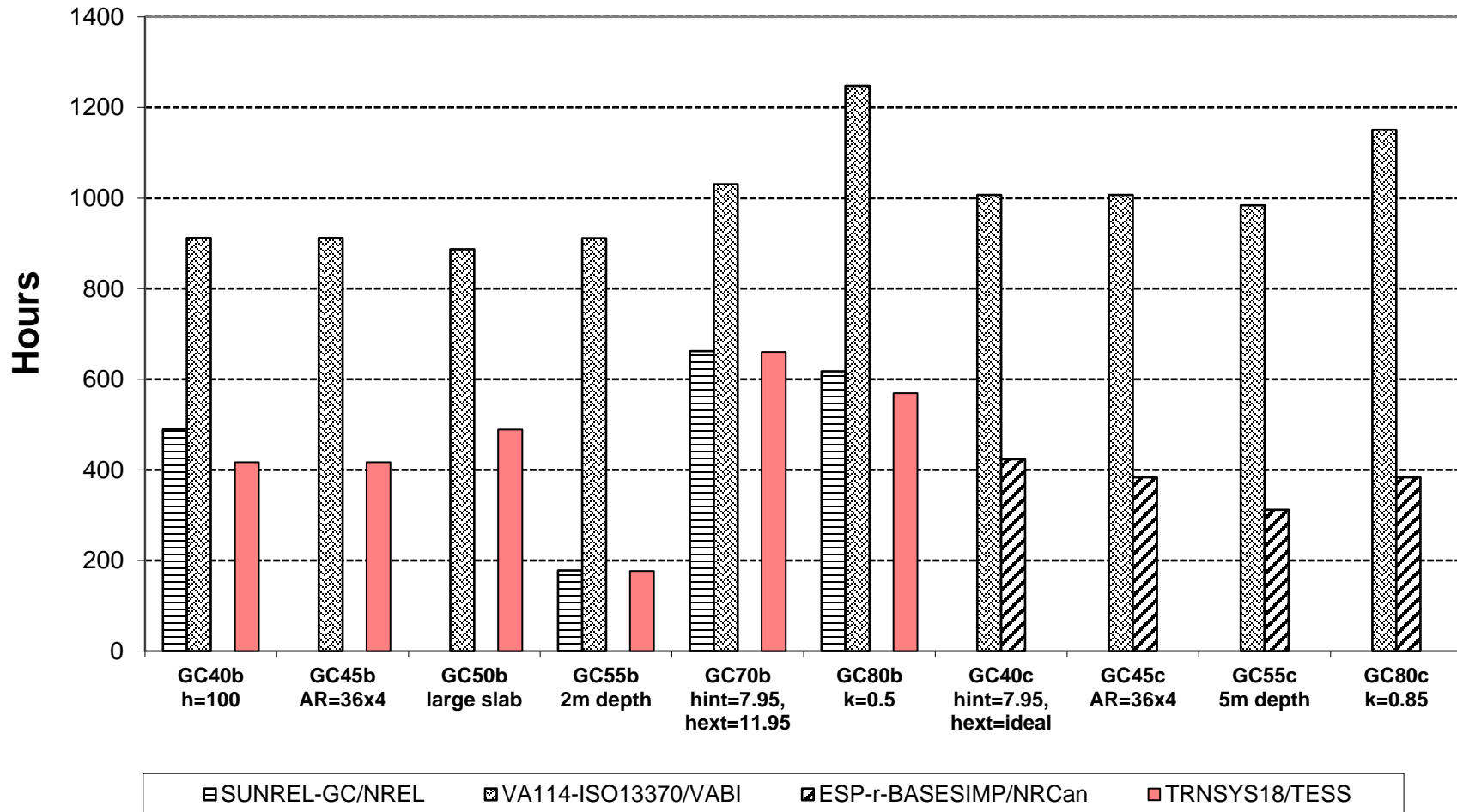


ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
 TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results, by Thermal Energy System Specialists, LLC (TESS), 19-Aug-202

**Figure B8.2-23. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
 Steady-Periodic Phase Shift Sensitivity, Floor Conduction v. ODB**



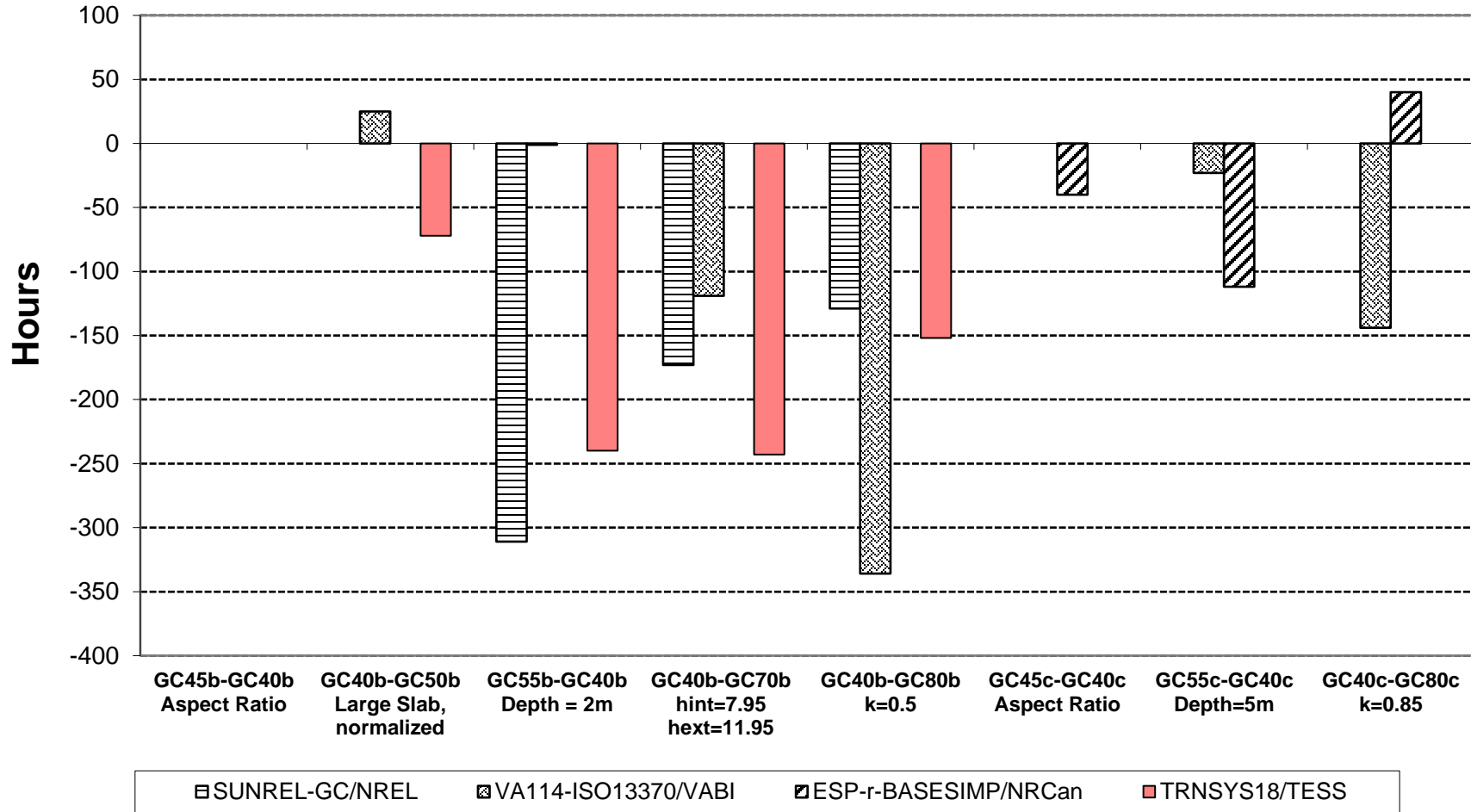
**Figure B8.2-24. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
 Steady-Periodic Phase Shift, Time from Coldest ODB to Peak Zone Load**





ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
 TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results, by Thermal Energy System Specialists, LLC (TESS), 19-Aug-202

**Figure B8.2-25. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
 Delta Steady-Periodic Phase Shift Sensitivity, Zone Load v. ODB**

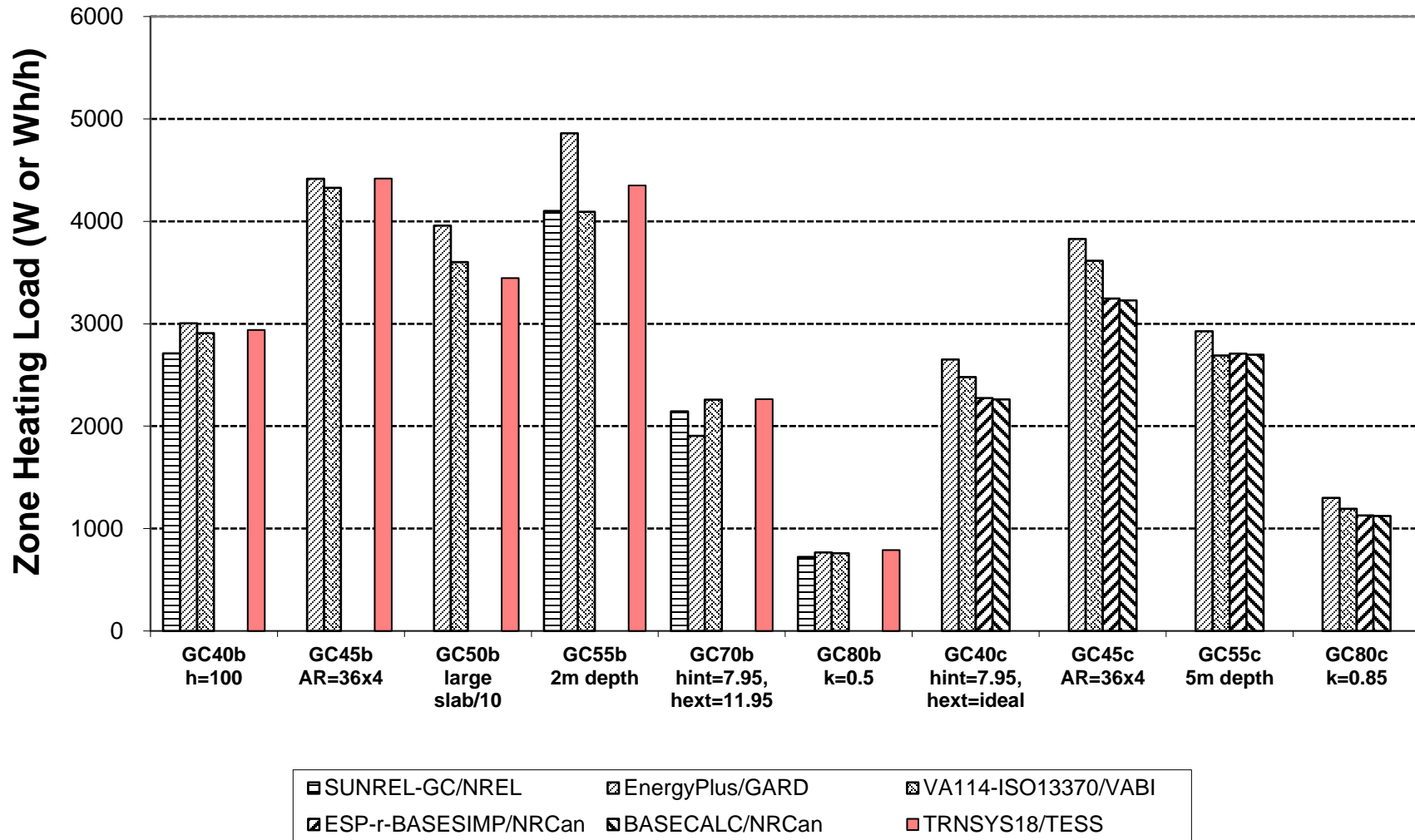




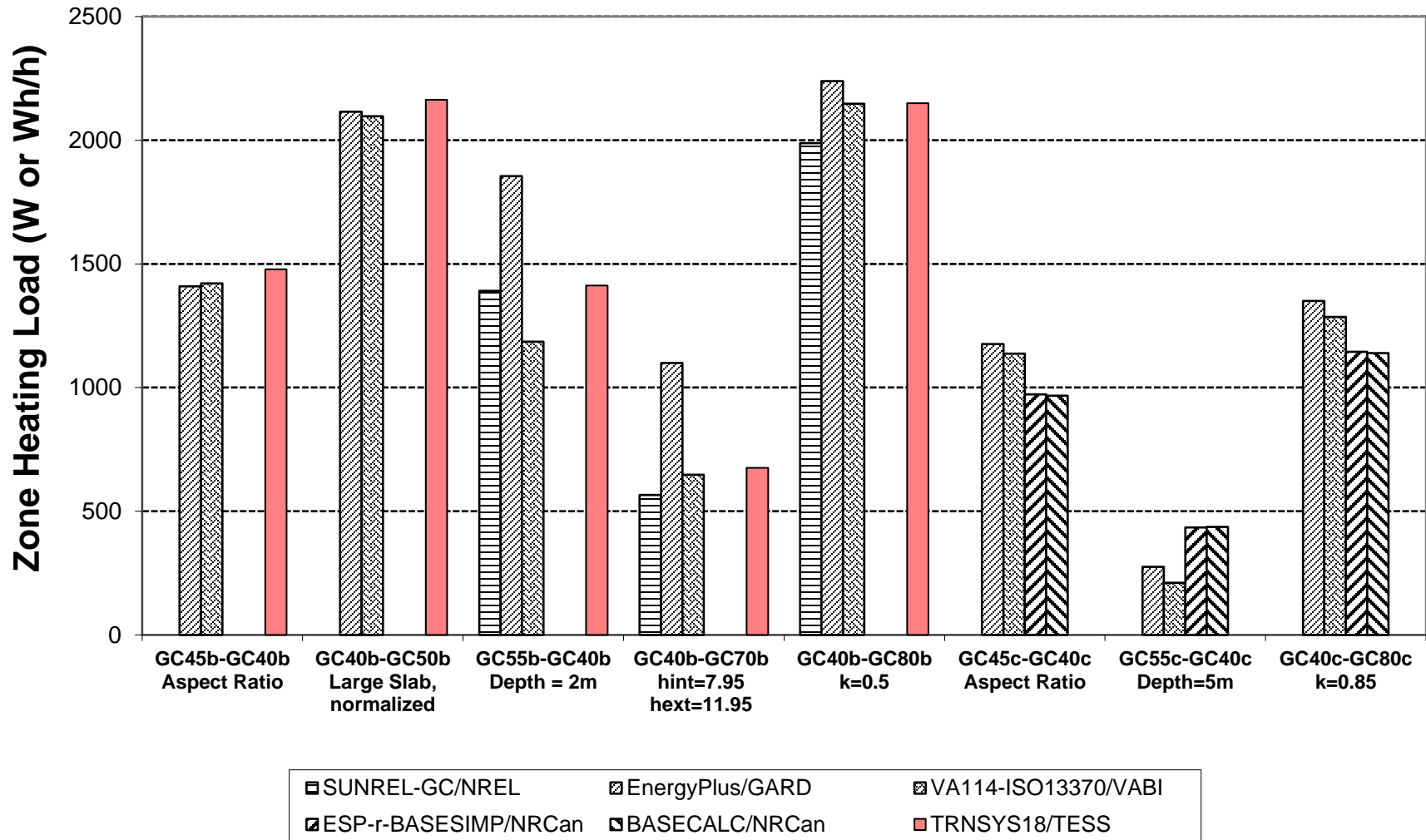


ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
 TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results, by Thermal Energy System Specialists, LLC (TESS), 19-Aug-202

**Figure B8.2-28. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
 Steady-Periodic Annual Peak-Hour Zone Heating Load**

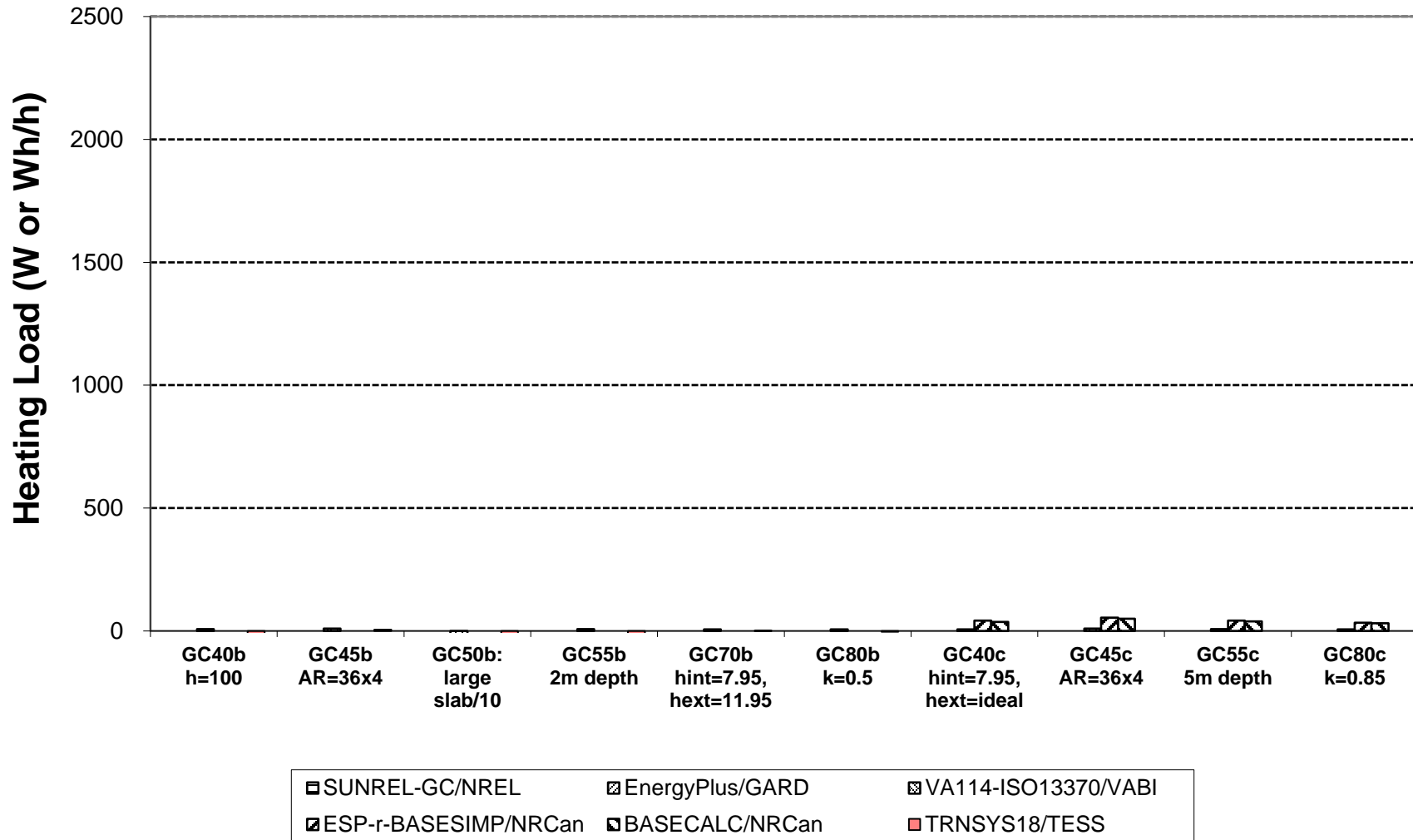


**Figure B8.2-29. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
 Steady-Periodic Annual Peak-Hour Zone Heating Load Sensitivity**

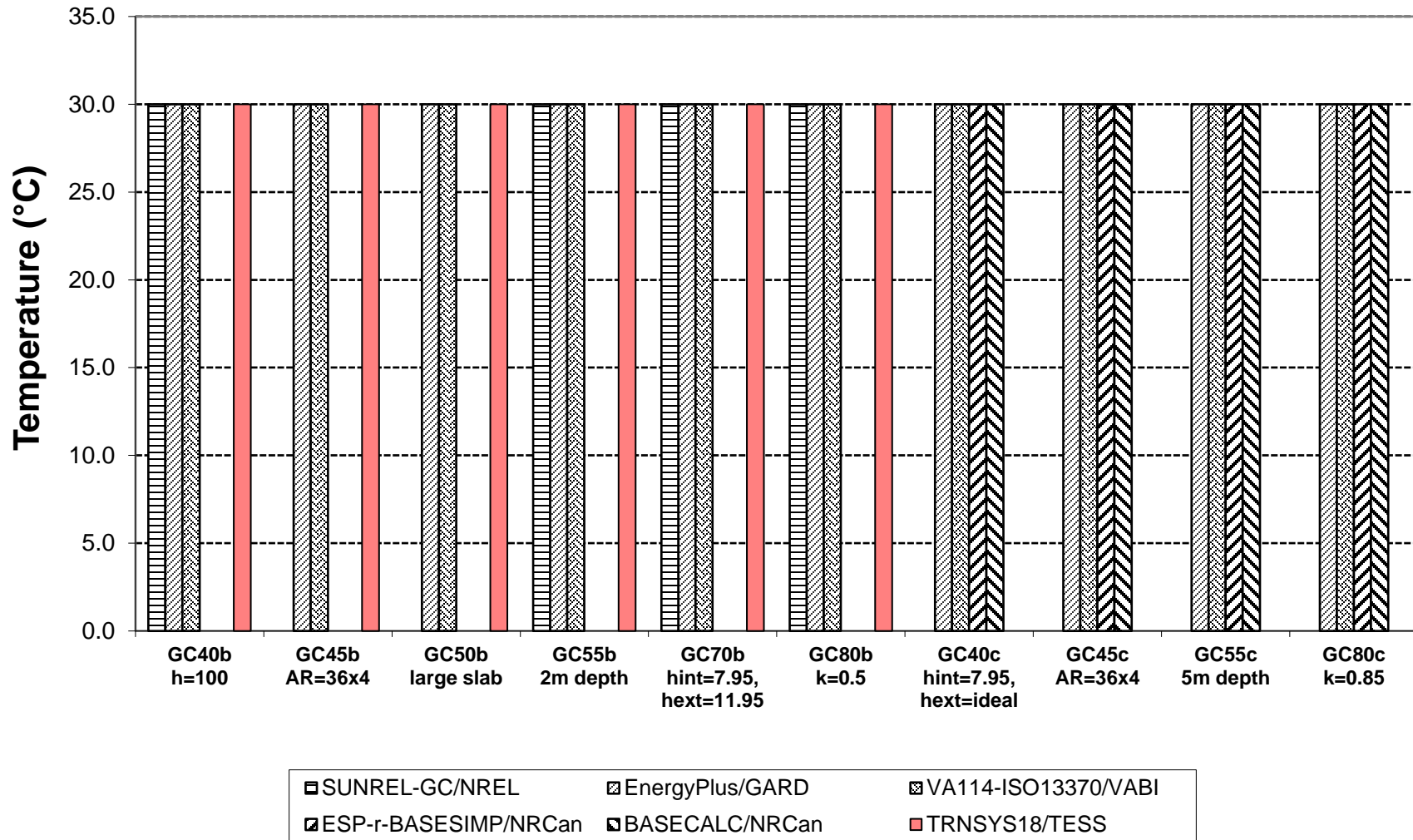


ASHRAE Standard 140-2020 Results Comparison for Section 5.2.4 - Ground Coupled Slab-On-Grade Analytical Verification Tests  
 TRNSYS18.06.0002 (TRNSYS18) vs. Annex B8, Section B8.2 Example Results, by Thermal Energy System Specialists, LLC (TESS), 19-Aug-2022

**Figure B8.2-30. IEA BESTEST Ground Coupling: In-Depth Floor Slab Steady-Periodic (Peak Zone Heating Load) - (Peak Floor Conduction)**



**Figure B8.2-31. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
 Steady-Periodic Zone Temperature**



**Figure B8.2-32. IEA BESTEST Ground Coupling: In-Depth Floor Slab  
 Steady-Periodic Minimum ODB**

