Procedure for buildings' energy modelling suited for integrated control simulation

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Abstract

Numerical simulations are becoming more and more a key step in designing an integrated building + energy system. The use of a detailed numerical model and an accurate calculation algorithm permits us not only to study the influence of design parameters, but also to evaluate the building energy demand and indoor comfort conditions. The computational effort in modelling the building behaviour might become a limit in terms of simulation time, in particular in the case of complex systems. This is evident when an integrated control of building and thermal energy system is performed, because of the need of a short time step (1 to 5 minutes) for control purposes. In this sense, a clear edge between architectural and energy modelling has to be drawn. In this paper, a methodology for simplifying a detailed building model has been presented, by defining phases, quantitative figures, limits and uncertainty of the results. Such procedure is replicable and could be useful during any numerical modelling process. With reference to a three-story apartment building, the influence of (1) the algorithm for short- and long-wave radiation, (2) building and surrounding context's shadings, (3) different levels of geometric surface information have been investigated. For each phase, building's energy balance and simulation runtime has been reported. Additionally, the reliability and adherence of simulation outputs have been inspected by comparing the numerical model response with a whole year of monitoring data.

1. Introduction

Building models are being increasingly used for studying the influence of design parameters and for the evaluation of building energy demand and indoor comfort conditions. Accurate building modelling might require computational efforts during simulations. The developing of a good building model requires focussing on the building's most important features (weather file, building size, energy loads…), to minimize the number of thermal zones, to properly characterize HVAC and controls (IBPSA-USA bis, 2012). Building models are commonly used to predict the energy consumption, and their accuracy is related to the phase of the design process (IBPSA-USA, 2012). Less importance is given to the design and operation of an integrated building energy and control systems model. When the interaction between the energy plant and building model is investigated, a strong reduction of computational effort is required.

The model needs to be as complex as needed to achieve its purpose. Good work is done when a balance between accuracy and model complexity is found. For this reason, it is important to define priorities and to individuate the features which have a greater impact on performances.

The main aim of this work is the elaboration of a simplified building model to be used in the study of an integrated control between building and energy supply system. To this end, (1) a detailed model has been created; (2) the calibration of the ventilation mass flow rate and infiltration rate has been carried out for a better agreement between the model and real case; (3) a simplification procedure for the reduction of the computational effort of the detailed model has been developed. A satisfying approximation of the heating demand between the detailed and the simplified model has

been reached with a strong reduction of the simulation runtime.

2. Case study

The building under investigation is located in Bronzolo, Italy, and it was built by IPES (a local social housing institution), in 2006, according to the "CasaClima A Plus" standard (Direttiva Casaclima, 2011). It is a residential building with 8 apartments for a total of 577 m² of conditioned living area distributed over three storeys. The building is oriented along the north-west to south-east axis, with a façade oriented to the south.

Domestic Hot Water (DHW) and heating demand are covered by a 15 kW pellet boiler. The hot water is stored in a tank-in-tank puffer of 800 L and then distributed to each apartment. A recirculation water system is also used in order to provide DHW during peak hours. For the supply air, a forced ventilation system with a heat recovery unit is used. External air is pre-heated by geothermal probes, to avoid the freezing of the ventilation fan; an AHU acts as heat recovery from the exhaust air to the fresh air and the supply air is then divided in three ducts, for the distribution on the three floors. A post-heating in each apartment is then provided through coils fed by a pellet boiler.

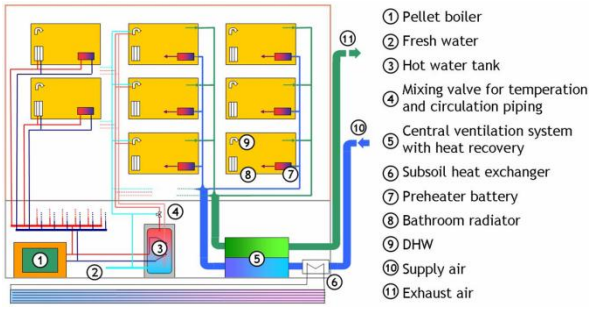

Fig. 1 – Ventilation and Domestic Hot Water (DHW) system (IPES, 2007)

A monitoring system has been installed and data of internal temperature, relative humidity and CO_2 levels, external temperature, relative humidity and solar radiation, electrical and thermal consumption have been collected for a whole year.

Geometrical and physical characteristics from design have been employed to develop a detailed model which reproduces with high accuracy the real building. The large amount of monitored data have been used to define several boundary conditions and to calibrate the model.

3. Detailed model

The detailed model of the building was made in a previous work (Ecker, M., 2011) using Google SketchUp and Trnsys 3D plugin (Ellis, P., 2009). Walls and floors were defined according to the real geometry and orientation; for windows, a predefined window was used, whose characteristics reproduce the original ones. The envelope charac*teristics are reported in Table .

Due to calculation modes' requirements for running the detailed model, only convex zones have been accepted. Apartments 1, 2, 3, 5, 6 and 8 have a L-shape, so they have been divided in two zones. Fig. 2 shows the result of zone partitioning and the labels used to indicate the zones. The staircase has been modelled as a single zone with 4 stacked air-node, one for each storey. This zone is the only one not heated. In the 3D building model, self-building shadings and shadings due to the surrounding have been modelled with several shading groups. In Fig. 3, a picture of the real case and a view of the SketchUp model are shown.

3.1 Simulation boundary conditions

Simulations have been run with TRNSYS 17 (Klein S.A., 2009) and the following boundary conditions have been set:

- Weather: monitored weather file has been used. Data have been collected for one year with a timestep of 1 hour. The file format is an *.epw (Energy Plus format) and it has been read by Type 15.
- Infiltration: a yearly fixed value for each apartment has been defined after performing a building model calibration. It takes into account wind-driven leakages and average-users behaviour.

Wall type	U-value [W/m²K]
Exterior walls	0.14
Roof	0.08
Cellar ceiling	0.15
Entrance door	0.7
Windows	0.86

Table 1 – U values of the building envelope (design values)

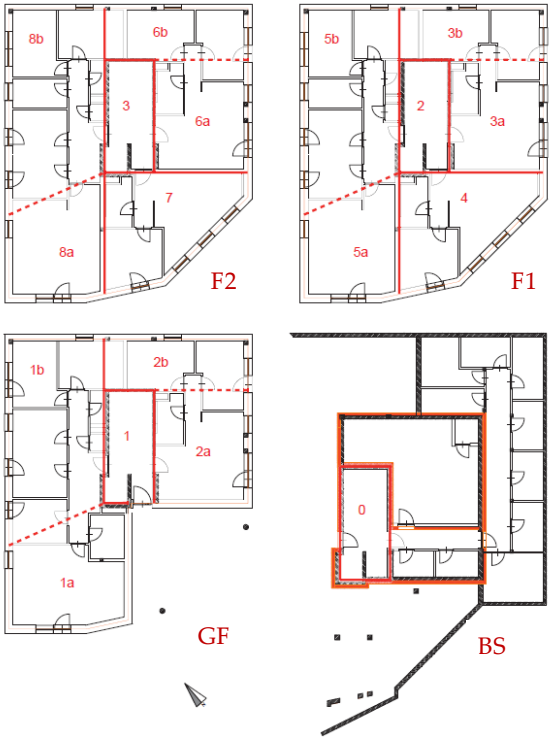

Fig. 2 – Zone partitioning of basement (BS), ground floor (GF), first (F1) and second (F2) floor

Fig. 3 – Picture of the real case (above) and view of SketchUp model (below)

- Ventilation: a fresh air supply flow rate has been defined for each apartment during the building model calibration. A heat recovery of the 85% has been applied between the exhaust and the fresh air.
- Internal gains: monitored data of electrical consumption have been used to model internal gains due to electrical devices, lighting and cooking. The measured value is split into radiative (40%) and convective (60%) parts. Monitored data have been collected during a whole year with a timestep of 1 hour. Monitored data for users' occupancy are not available, so a schedule based on standard EN ISO 7730 (EN ISO 7730, 2007) has been used. The occupancy profile is assumed to be in accordance with power consumption profile; different user's activities during the day are also taken into account (Ecker M., 2011).
- Heating: an indoor air setpoint of 21°C is defined; the heating season is fixed from October to April;
- Cooling: an indoor air setpoint of 26°C is defined; the cooling season is fixed from May to September.

4. Detailed model calibration

The detailed model has been developed following all building characteristics available and monitoring data. Nevertheless, ventilation mass flow rate and infiltration rate needed to be further fixed through a model calibration because they are not directly measurable. The calibration process consists in an iterative process to match observed and simulated behaviours.

4.1 Ventilation

The coils' numerical model has been calibrated considering as boundaries the coil itself and using monitored data collected for one year with a time step of 1 hour: temperature and relative humidity of the supply air, air speed, water flow rate, inlet and outlet water temperature have been employed to this end. For each coil, an UA coefficient has been defined (Incropera et all., 2007). Rated values are available for fixed inlet air temperature (17°C), water flow-rate (180 m^3/h) and inlet water temperature (70°C). Because of off-rated conditions of the air mass and fluid flow rate, the following expression can be adopted:

$$UA_{coil} = UA_{160} \cdot \left(1 + \left(\frac{\dot{m}_{water}}{\dot{m}_{design}} \right)^{0.8} \right) \quad (1)$$

Coils have been modelled as a counter-flow heat exchanger (Type 5) with water in the source side and air in the load side. The total air flow rate has been calculated from monitored air velocity in the channels; then the estimated air flow rate of each apartment has been defined multiplying the total air flow rate for design fractions (case VEN_1).

The discrepancy of the exchanged heat in each coil, between monitored consumption and VEN_1, is quite high in some apartments than in others. In apartments 1, 3, 6 and 8 the difference is less than 10%, whereas in apartments 4 and 7 (the smaller ones), the difference between the monitored and the simulated exchanged heat in the coils achieves 50%. This discrepancy is due to the wrong position of the sensor for the measurement of the air velocity. To solve such a discrepancy, the calibration of the air flow rate has been made with the process explained above. A corrective value of the guess rate (designed with Y) has been iteratively calculated up to obtain a match of simulated and monitored heat in each coil. The correct air flow rate has been calculated for each time step as follows:

$$\dot{m}_{air,calibrated} = \dot{m}_{air,guess}(1+Y) \quad (2)$$

A constant yearly corrective value for each apartment has been individuated; in particular, the most frequent value has been chosen rather than an average value because not affected by measurements in transient conditions.

The yearly heating demand has been re-calculated with the corrected air fractions (case VEN_2) and a satisfactory approximation of the exchanged heat in the coils has been reached (Fig. 4).

An increase of 22% of the measured air mass flow is made, nevertheless, the total air flow still remains within the design value of 1440 m³/h (Castagna M., 2009).

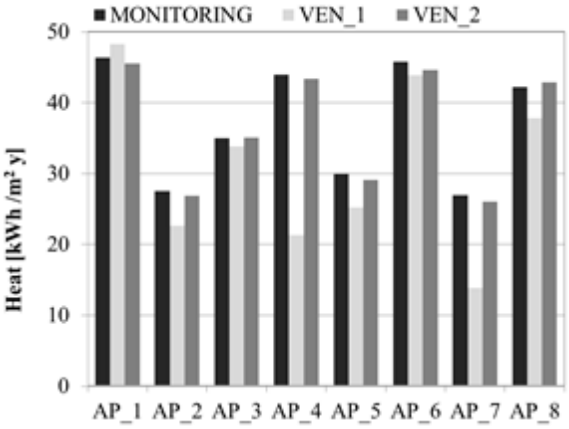

Fig. 4 – Comparison of ventilation rate from monitoring (MONITORING), before (VEN_1) and after calibration (VEN_2) in terms of exchanged heat

4.2 Infiltration

From monitoring, measurements on the instantaneous infiltration rate were not available, so the n_{50} value from the blower-door test has been assumed (case INFIL_1) as first attempt. In this case, the n_{50} value is equal to 0.8 h^{-1} (IPES, 2006). Commonly, to calculate the infiltration rate from the n_{50} value, the Sherman equation is used (Sherman, 1987):

$$n = \frac{n_{50}}{20} = 0.04 \quad (3)$$

where n_{real} [h^{-1}] is the infiltration rate.

The calculated airtightness value gives an idea of the infiltration rate, but it does not take into account the building exposure to the wind direction, the ventilation strategy and occupants' behaviour. For this reason, a survey on the infiltration rate has been done, in order to fix an overall value for each apartment.

In the staircase, the infiltration rate has been assumed to be 0.35 h^{-1} (Diamond R.C. et all, 1996) for considering the opening of the doors in the basement, in the ground floor and an air intake on the third floor. No calibration for the staircase infiltration rate has been done, because monitored data were not available.

For the definition of yearly fixed infiltration rate, the same procedure used for the ventilation rate has been applied. The calibration has been made by comparing simulated and monitored heating demand in each apartment. Monitored data have

been collected during a year with a time step of 1 hour. The iterative process individuated a corrective infiltration value (designed with X) for each time step up to obtain the match between simulated and monitored heating demand.

$$n_{calibrated} = n(1+X) \quad (4)$$

Also in this case, the most frequent X value has been chosen for the definition of the constant yearly infiltration rate for each apartment. In particular, for apartments 3, 4 and 7, an infiltration rate of 0.34 h^{-1} has been individuated, while 0.44 h^{-1} has been taken for apartments 1, 2, 5, 6 and 8. These values are related to the apartment's size or to the occupancy.

New infiltration rate values have been set in the detailed model (case INFIL_2) and heating demands have been compared with case INFIL_1 and with the measured consumption.

The discrepancy in the heating demand, for the whole building, between monitored and calibrated case (INFIL_2) has been reduced to 1% (see Fig. 5). A slight difference between monitoring and simulation still remains due to the fact that (1) the occupancy profile is assumed (Ecker M., 2011); (2) the thermostat set point temperatures have been deduced from monitored indoor air temperature; (3) the infiltration rate value has been defined to be constant during the year. As a consequence, higher or lower heating demand with respect to the monitored consumption might occur.

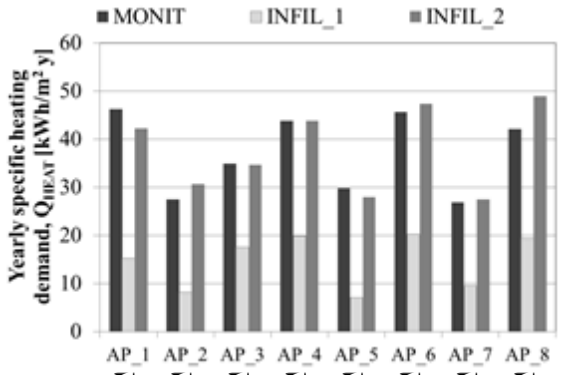

Fig. 5 – Specific heating demand calculated in each apartment from monitoring (MONIT), before (INFIL_1) and after (INFIL_2) calibration

5. Simplification procedure

The detailed model has been simulated with TRNSYS 17 (Klein S.A., 2009) for a whole year (8760 hours) with a time-step of 5 minutes. Although the real case has been reproduced with high accuracy, on the other hand, the complete simulation required 2.7 hours to run. In order to study the energy building model integrated with the supply energy system, a simplified model is therefore necessary. For this reason, a procedure has been individuated (see Table 2) starting from a detailed model and moving towards a simplified one. This process consists of three steps that analyze the main issues influencing the energy balance and the simulation runtime in a building model developed with TRNSYS. The impact of 1) radiation mode, 2) geometry mode and 3) shadings elements on building performance and simulation runtime have been analysed. Finally, a model, with reduced computational efforts which maintains sufficient accuracy, has been created. The analysed cases are reported in Table 2 where the used radiation mode, geometry mode and shading elements are specified.

For each step of Table 2, the incoming (denoted as positive terms) and the out-coming (denoted as negative terms) energy fluxes of each zone have been studied. Yearly energy losses and gains have been then calculated for the whole building according to the boundary conditions presented above.

CASE	Radiation mode	Shadings	Geometry mode
RAD_1	Detailed	Shad group	3D data
RAD_2	Standard	Shad group	3D data
SHD_1	Standard	Shad Factor	3D data
SHD_2		Type 34	3D data
GEO_1	Standard	Type 34	3D data
GEO_2			Manual

Table 2 – Steps of the simplification process

5.1 Radiation mode

In TRNSYS 17, two different modes for the distribution of the radiation within a zone are available, the standard and the detailed mode. In the case of the standard mode, the direct short-

wave radiation, is proportionally divided fixing a constant user-defined fraction (GEOSURF values), while the detailed mode calculates the distribution of the entering direct radiation according to shading and insolation matrices generated by an auxiliary program called TRNSHD (Hiller et all., 2000). The standard mode bases the diffuse radiation distribution on absorption-transmission weighted area ratios for all surfaces of a zone, while the detailed mode considers the multi-reflection too, thanks to the use of view factor matrix generated by an auxiliary program known as TRNVFM. Finally, the standard mode treats the long-wave radiation with the star-node approach (Seem, J.E., 1987). This approach takes into account no user defined emissivity of inside surfaces nor radiation exchange over more than one air-node. This aspect will be important for further considerations. For the treatment of long-wave radiation, the detailed radiation mode considers the multi-reflection too, using the view factor matrix generated by TRNVFM.

Comparing the energy balance for cases RAD_1 and RAD_2 (see Table 3), a difference in infiltration losses (Q_{INF}), ventilation gains (Q_{VENT}), transmission losses (Q_{TRANS}), heating (Q_{HEAT}) and cooling demand (Q_{COOL}) is shown.

		RAD_1	RAD_2
Q_{HEAT}	[kWh/m²y]	37.6	34.1
Q_{COOL}	[kWh/m²y]	-4.7	-6.9
Q_{INF}	[kWh/m²y]	-35.0	-35.4
Q_{TRANS}	[kWh/m²y]	-41.8	-34.8
Q_{GINT}	[kWh/m²y]	41.9	41.9
Q_{SOL}	[kWh/m²y]	23.8	23.7
Q_{VENT}	[kWh/m²y]	-21.8	-22.6

Table 3 – Yearly energy gains and losses for the whole building in RAD_1 and RAD_2 cases

In order to understand the reason for this discrepancy, the radiation absorbed by all the apartments' walls has been analysed. The total radiation absorbed (and transmitted) in all inside (Q_{ABSI}) and outside (Q_{ABSO}) surfaces has been investigated. For the sake of clarity, the control volume is assumed to be the zone, so the term "inside" is referred to the radiation coming from the zone, while the term "outside" concerns the radiation coming from outside the zone (Klein S.A. et all, 2009). In cases RAD_1 and RAD_2, the Q_{ABSI} differs less than 2%, while higher difference is verified in the Q_{ABSO} (see Table 4). Labels "EXT", "BND", "ADJ" are referred to the surface's categories, external, boundary or adjacent, respectively. The radiation mode refers to the inner radiation distribution, in fact the total external radiation absorbed at external surfaces (Q_{ABSO_EXT}) is the same in both cases. For the detailed mode, negative values indicate the absorption of radiation on a surface, whereas positive heat flux means a net emission. The main differences between standard and detailed mode have been pointed out by adjacent surfaces. In fact, all apartments border with an unconditioned multi air-node zone (the staircase and the lift), which influences the external absorbed radiation for adjacent walls. In particular, lower apartments are more affected by the exchange with staircase zone than higher.

	CASE	Q_{ABSO} [kWh]			
		TOT	EXT	BND	ADJ
AP_1	RAD_1	**42495**	42927	0	-432
	RAD_2	**44004**	42927	0	1077
AP_2	RAD_1	**31353**	32098	0	-745
	RAD_2	**33164**	32098	0	1066
AP_3	RAD_1	**21297**	21990	-	-693
	RAD_2	**23691**	21990	-	1701
AP_4	RAD_1	**27831**	27505	-	326
	RAD_2	**28497**	27505	-	993
AP_5	RAD_1	**24763**	25098	-	-335
	RAD_2	**26902**	25098	-	1804
AP_6	RAD_1	**79724**	79693	-	32
	RAD_2	**80535**	79693	-	843
AP_7	RAD_1	**61442**	61261	-	181
	RAD_2	**61865**	61261	-	604
AP_8	RAD_1	**113303**	113091	-	213
	RAD_2	**114060**	113091	-	969

Table 4 – Absorbed radiation on external walls

Maintaining all the boundary conditions unvaried and changing only the distribution of the radiation, the effect of the different heat transfer with multi air-node zones can be observed with the Mean

Radiant Temperature (T_{MR}) within the zone. This measure takes into account the area weighted mean temperature of all walls of the zone, so a variation in the air-node temperature might come out analyzing the different T_{MR}.

The cumulative frequency of the Mean Radiant Temperature for apartments 2 (situated in the GF) and 8 (situated in the F2) is shown in Fig. 6. The graph represents the yearly frequency distribution of the T_{MR} in the zones for cases RAD_1 and RAD_2. In apartment 2, the T_{MR} differs of about 0.7°C for the 40% of the year, while in apartment 8, there is a good overlapping of the two curves.

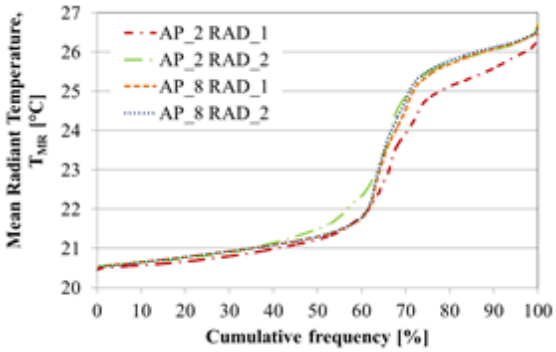

Fig. 6 – Cumulative distribution during a year of the Mean Radiant Temperature in apartment 2 and 8.

A different distribution of the radiation within the zone influences the ventilation load, the heating and cooling supply energy and the infiltration load. In particular, a discrepancy of about 9% is observed on the whole building heating load.

The radiation mode does not influence only internal air temperature within the zones, but also the simulation runtime. In fact, computational efforts are strongly affected and a reduction of 86% of runtime passing from the detailed to the standard radiation mode is observed.

In light of this, the choice of the radiation mode is very important for the reduction of computational effort, but attention should be paid when multi air-node zones are adjacent to single air-node zones.

5.2 Shading elements

External or internal shading elements may be defined for any transparent surface of a zone. To implement external shaders and self-shading of the building in the SketchUp building model, several "shading groups" have been used. At the beginning of the simulation, TRNBuild generates a shading matrix which takes into account the presence of shading elements or surrounding structures. During the simulation, Type 56 determines the actual sunlit fraction of surfaces thanks to the use of the shading matrix file with respect to the sun's current position for each time step. If no shading group is present in the building model, external shadings might be modelled in TRNBuild itself. For an external window, the user can select an internal and/or external shading device, specifying its shading factor, which indicates the shaded fraction of the window element.

In this work, the effect of two different external shaders and self-shading of the building model have been investigated and compared with the case with the shading groups (RAD_2). A building with no shading elements has been modelled and the shadings' effect has been reproduced by External Shading Factors. An external file with shading factor obtained by the detailed model (case SHD_1) and a TRNSYS component, Type 34, (case SHD_2) have been used to determine the External Shading Factor inputs.

The use of both shading factors and Type 34 produces a difference of the yearly heating demand of the whole building, Q_{HEAT}, of 1% with the case of shading groups (case RAD_2). The use of Type 34 increases the cooling demand of the building, Q_{COOL}, of around the 8%.

In order to understand the different cooling demands needed in the two cases, single apartments have been analysed. As already seen, the detailed radiation mode does not consider irradiation from shade projected on exterior surfaces other than windows. For this reason, the incident radiation on windows only is taken into account.

Case SHD_1 has been considered to find out the difference of the simulation runtime when an external file with the sunlit portion area is used. Regarding the energy building balance, as the external file here used corresponds to the external shading factor of the RAD_2 case, no difference is shown.

The accuracy of the shadings modelled with Type 34 influences the agreement between cases SHD_2 and RAD_2. In Table 5, the incident radiation on all

apartments' windows for cases RAD_2 and SHD_2 is reported. The third column indicates the difference, in percentage, of incident radiation between the two cases.

CASE	**RAD_2**	**SHD_2**	$\Delta_{RAD_2,\ SHD_2}$
	[MWh]	[MWh]	[MWh]
AP_1	6.2	6.2	-0.3%
AP_2	5.9	6.7	-12.8%
AP_3	7.2	6.7	7.6%
AP_4	3.6	4.9	-30.8%
AP_5	5.9	5.7	4.7%
AP_6	8.5	7.4	13.2%
AP_7	4.0	3.6	10.2%
AP_8	6.0	6.2	-3.6%

Table 5 – Incident radiation on all apartments' windows in RAD_2 and SHD_2 cases

Type 34 has been set to model the roof's overhangs and balconies, while surrounding contributions and the building's shadings (wall thickness, balconies on the adjacent sides) have not been reproduced. A high effect of this modelling is shown in apartment 4, where the difference with case RAD_2 is 31%, or in those apartments oriented to south-east, where the difference amounts to 8-13%.

Regarding the simulation runtime, the use of external file for the external shading factor (case SHD_1) reduces the simulation runtime of 6%, while the use of Type 34 (SHD_2) increases it by about 4%. The result of case SHD_2 also depends on the number of Type 34 units used into the model.

5.3 Geometry mode

For each zone, TRNBuild supports different levels of geometric surface information, known as "manual" and "3D data" mode. In the manual mode, the geometry of the building is individuated according to the definition of walls and floors and their boundary conditions. The advantage of modelling directly in TRNBuild is that no detailed shape definition is requested. Defining the area and the boundary conditions for each surface, the software automatically calculates the interactions between the surfaces and the zone. The walls' categories used in this case are external, boundary and adjacent. "External" is referred to walls which border the outside, "boundary" is a wall in which boundary conditions of the first type can be specified and "adjacent" is a wall which borders another air-node.

The "3D data" mode provides, for all surfaces of the zone, three dimensional coordinates. Geometry model is designed in Google SketchUp with the Trnsys3D plugin and then an *.idf file is imported to the TRNBuild environment. If the detailed radiation mode is used, radiative zones must be convex polyhedrons.

Looking at yearly energy gains and losses in cases GEO_1 and GEO_2, no differences have been observed. For both cases, the simulation runtime is also unvaried.

For the calculation of the shadings' effects, the manual geometry mode does not use a shadings matrix. In fact, even if shading elements are inserted in the building model, the geometry mode does not consider this information. For this reason, if this mode is used, external inputs for modelling the shadings are required.

6. Simplified model

The steps analysed above have been used as a guide for the definition of a simplified building model. This new model has been conceived following the criteria of reducing the efforts during the numerical modelling design phase and the computational efforts:

- manual geometry mode has been applied in order to create zones in a flexible way because the walls' geometry and category are specified directly in the TRNBuild environment;
- standard radiation mode has been used to run the model, in order to reduce the simulation runtime and to draw the zones with any shape not necessarily convex;
- the use of Type 34 has allowed to model shading elements without any previous calculation for the definition of the sunlit portion area of the windows.

Building energy gains and losses of the simplified model have been compared with the reference case in order to verify the accuracy of the results.

With the use of standard radiation mode and manual geometry mode, a single zone for each apartment has been created. The staircase zone has been created as in the detailed model. All the characteristics and boundary conditions of the detailed mode have been set in the simplified model, too. The only exception has been the definition of windows because the total amount of glazed surface for each external wall has been taken into account.

The difference of heating demand of the whole building between reference case and the simplified case is around 8% (Fig. 7). Higher differences are observed in those apartments in which the constant infiltration value approximates with lower accuracy the real infiltration rate or in which the incident solar radiation differs more from the reference case (see Table 5).

Comparing the simulation runtime in the two cases, a strong reduction of 89% is observed decreasing from 2.7 hours to 20 minutes. This result is due to the fact that the standard radiation mode has been used and 9 zones (apartment zones + staircase zone) versus the 15 of the Reference case have been modelled.

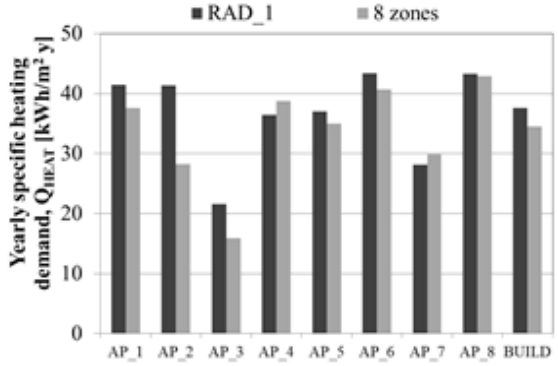

Fig. 7 – Yearly specific heating demand in the reference case (RAD_1) and in the 8 zones case

7. Conclusions

Building modelling integrated in supply energy systems are more and more challenging for the interdisciplinary of the treated aspects and the complexity of the model itself. A simplification procedure of a detailed building model has been presented in this work. The starting point has been a detailed model which has been calibrated with monitored data to obtain an accurate model. The impact of radiation mode, geometry mode and shading elements on building performance and simulation runtime have then been analysed. A model with sufficient accuracy and reduced computational effort has been developed.

Simulations have been run in TRNSYS 17 and the following considerations have been made according to the calculation modes used by this simulation tool.

The use of the manual or 3D data geometry mode makes no changes in both simulation runtime and building energy response. An important reduction of computational efforts is instead observed in moving from a detailed radiation mode to a standard mode (around 85%). This simplification leads to a change in the air-node temperature in those zones which border with unconditioned multi air-node zones. When the standard mode is used, the building's heating and cooling demand differs by about 9% with respect to the detailed mode.

The modelling of External Shading Factor with external inputs does not significantly reduce the simulation runtime, which might have variations of around ± 5%. The influence on energy gains and losses using Type 34 depends on the apartment's orientation. Type 34 models shadings taking into account only overhangs or wing-walls of the building and not the shading effect of the surrounding.

The use of standard radiation mode leads to a significant reduction of simulation runtime maintaining the same solar radiation arriving on walls and windows, but neglecting the effect of multi-reflection within the zone. Differences might be observed in those cases in which conditioned zones border with unconditioned multi air-node zones. If a detailed radiation mode is used and the shadings' shape is not complex to be modelled, there are no advantages in using external inputs for the definition of the sunlit portion area. Indeed, if the geometry characteristics of the building are defined directly on TRNBuild and the manual geometry mode is set, the use of inputs for the External Shading Factor is requested. In particular, better results can be achieved with an external file which defines the sunlit portion area considering all

the shadings effects (for example obtained by a shader program (Nathaniel L. et all, 2006). If this information is not available, a good approximation of shading effect on windows can be made by Type 34.

A unique solution for the reduction of computational efforts does not exist because it is strictly related to the aim of the simulation and the parameters which have to be analysed. The main aim of the work presented here is the definition of a final building model which reproduces as well as possible the real building behaviour, reducing computational efforts and the time consumed during the design phase.

For this purpose, standard radiation mode, manual geometry mode and Types 34 have been selected for the simplified model.

The final simplified building model runs in 20 minutes with a reduction of the simulation runtime of 89%. A discrepancy of the heating demand of 9% has been found and, for the aim of the work, this might be considered suitable.

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