APPLICATION OF NANO INSULATION MATERIALS IN THE SUSTAINABLE BUILT ENVIRONMENT

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Abstract: Nanotechnology is widely being used in the built environment for its advantages in many improved engineering properties of the nano materials. Nano insulating materials open up new possibilities for ecologically oriented sustainable infrastructure development. The most widely used nano material in built environment is for the purpose of insulation to improve the energy efficiency namely in the buildings and dwellings. Nanotechnology has now provided an effective and affordable means to increase energy efficiency in pre-existing buildings as well as new construction by increasing thermal resistance. The major advantage of nano insulation materials is its benefit of translucent coatings which increase the thermal envelope of a building without reducing the square footage. The intrinsic property of nano insulating material is it can be applied to windows to reduce heat transfer from solar radiation due it its thermal resistant property and the translucent property allows diffusing of day light. The nano insulating material has significant advantage in reducing the operational energy aspects of buildings due to its valuable insulating properties.

This paper examines applicable nanotechnology based products that can improve the sustainable development and overall competitiveness of the building industry. The areas of applying nano insulating material in building industry will be mainly focused on the building envelope. The paper also examines the potential advantages of using nanotechnology based insulating material in reducing the life cycle energy, reduction of material usage and enhancing the useable life span. The paper also investigates the operational energy by simulation methodology and compares the reduction of operational energy consumption.

Keywords – Built Environment, Nano Material, Thermal Resistance, Operational Energy, Green House Gas

1. Introduction

The construction and operation of buildings is responsible for significant environmental impacts, predominately through resource consumption, waste production and greenhouse gas emissions. Building insulation will be one of the main focuses, where the demand for more energy efficient buildings is expected to grow significantly in coming years. One of the main problems related to energy consumption in buildings is created by winter heating and summer cooling. The presence of glass surfaces and the insulating capacity of the outer cladding is the main reasons for heat loss and gain within the building envelope (Scalisi, 2009). Insulation is the most effective way to improve the energy efficiency of a home. Insulation of the building envelope helps keep heat in during the winter and keep solar heat away during summer to improve thermal comfort while saving energy. Insulation materials which are used for building insulation include mineral wool, cellulose batting, foam plastics and newly emerged materials like nonomaterial.

Numerous strategies have been adopted in an attempt to improve the operational energy efficiencies with relates building maintenance and to reduce green house gas emissions. Emerging fields like nanotechnology delivers outstanding insulation materials for more efficient, less toxic and environmental friendly insulation. Current applications are in the forms of paints, coatings, thin films or as solid materials. Nansulate® coating is a patented insulation technology that incorporates a nanocomposite called Hydro-NM-Oxide, a product of nanotechnology. It's an excellent insulator due to its low thermal conductivity and the nonomaterial used. It can be directly applied to the existing buildings without incurring any post-construction addition with conventional insulating, thus creates tremendous energy saving with existing buildings. Test results for Nansulate® from independent laboratory shows that thermal flow through the wall section coated with Nansulate® was reduced by 34.80% and thermal resistance (1/U) of the wall section coated with Nansulate® was increased by 28.98% (Test Method:UNI EN ISO 8990:1999 - similar to ASTM C236) (www.nansulate.com).

To reduce life cycle environmental impacts of buildings, their service life should be extended as much as possible (Aye *et al*. 2007). The durability of the structure plays an important role. Application of nanomaterials in to the building envelope will assist in lengthening the service life of building materials, thus reducing the carbon footprint. This study aims to study the impact on operational energy consumption of the building with the application of Nansulate, an insulation product of nanotechnology with compared to conventional cellulose insulation.

2. Methodology

A multi-residential building has been used as a case study to assess the operational energy performance of prefabricated steel construction. This section outlines the case study building that was analysed and the methods used to assess the operational energy requirements associated with both conventional concrete and prefabricated steel construction approaches for this building.

2.1. Case study building

This study involved an assessment of the operational energy associated with a multi-residential building, for two varying construction approaches, a prefabricated modular steel structure and a conventional concrete structure, used for comparative purposes. The building modelled has a gross floor area of 3,943 m^2 with a total of 63 apartments consisting of 58 single-storey and five double-storey apartments. The first six floors of the building each consist of 9 single-storey apartments (Figure 1) and the seventh floor consists of four single-storey and five double-storey apartments. The floor area of the single-storey and double-storey apartments is 63 and 118 m^2, respectively. The ground floor consists of seven tenancies together with other utilities. The ground floor and the sub-structure were not considered in this study. The details of the external/internal walls and the floor/ceiling panels are for each scenario by element is given in Figure 2.

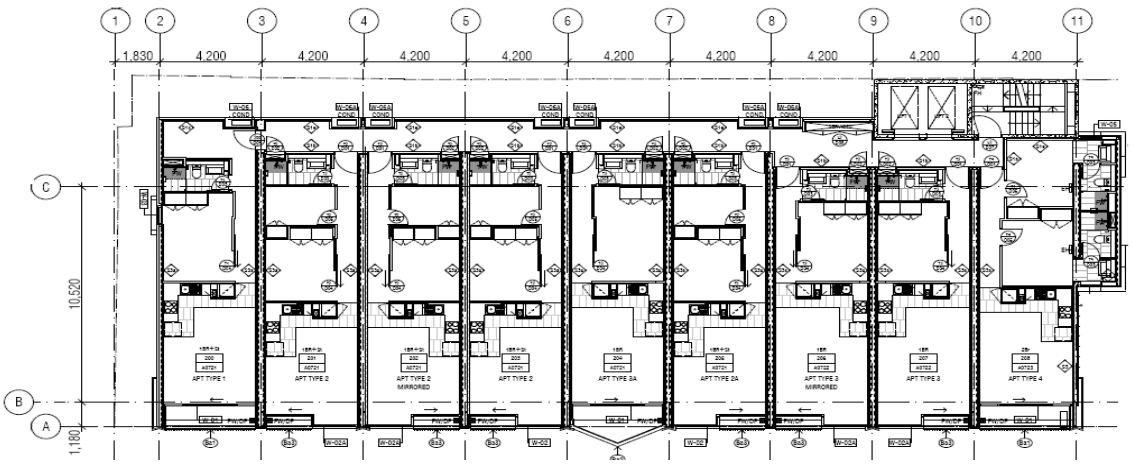


Fig. 1: Standard floor plan for single-storey apartments (FKA 2009)

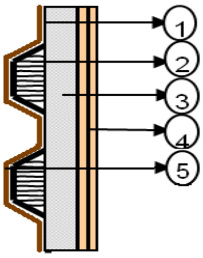
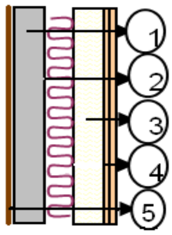
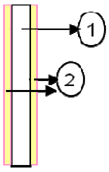
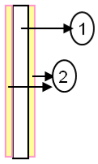
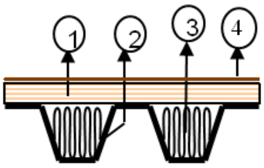
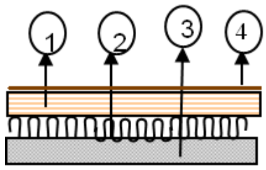
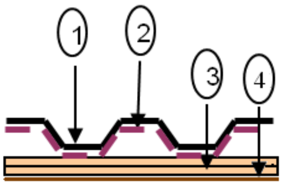
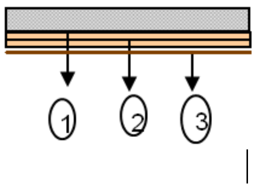
Steel		Concrete	
Exterior wall			
	1) 1.6mm thk Corten steel panel 2) 80mm thk Cellulose Insulation 3) 50mm studs 4) Plaster boards(13mm) 5) Nansulate Coating (4mm)		1) Precast Concrete 2) 80mm thk Cellulose Insulation 3) Timber Frame 4)Plaster boards(13mm) 5) Nansulate Coating (4mm)
Internal wall			
	1) Stud wall (50x50x3 SHS) 2) Plaster boards(13mm)		1)Timber frame (50x50 Sections) 2) Plaster boards(13mm)
Floor			
	1) Plywood flooring(19mm) 2) 2.4mm thk Corten steel panel 3) 100mm thk cellulose Insulation 4) Nansulate Coating (4mm)		1) Plywood flooring(19mm) 2) 100mm thk Cellulose Insulation 3) Reinforced Concrete slab (32Mpa) 4) Nansulate Coating (4mm)
Ceiling			
	1) 1.6mm thk Corten steel panel 2) Spray type "Body defender" 3) 16mm thk Plaster Boards 4) Nansulate Coating (4mm)		1)Reinforced Concrete slab (32Mpa) 2) 16mm thk Plaster Boards 3) Nansulate Coating (4mm)

Fig. 2: Details of the main material used in the building for prefabricated steel and concrete structural scenarios, by element

2.2 Operational energy analysis

The operational energy associated with the case study building was calculated using TRNSYS simulation software. Based on the characteristics of the building as well as assumed heating and cooling schedules, TRNSYS was used to simulate the thermal behaviour of the building.

The simulation was performed using the most recent weather data for Melbourne, Australia published by the Australian Bureau of Meteorology The simulation was performed on an hourly basis for a period of one year maintaining a steady temperature range of 20-26 degrees Celsius within the building. The detailed occupational schedules and gains were not considered in this study. The simulation was carried out with and without the nansulate application on the exterior wall, ceiling and floor of the building.

The COP (Coefficient of Performance) values of COP $_{Heating}$ = 3.0 and COP $_{Cooling}$ = 2.2 were used in converting the heating and cooling load outputs from the TRNSYS simulation to energy requirements in kWh.

3. Results and Discussion

This section presents the results and discussion of the operational energy analysis of the case study building for both prefabricated steel and concrete construction approaches.

3.1 Operational energy analysis

This section details the annual operational energy requirements associated with the case study building for both concrete and prefabricated steel construction types.

The TRNSYS simulation performed to determine the operational energy required for each Zone to maintain a temperature between 20-26^0 C. The TRNSYS simulation output on temperature control is illustrated in Figure 3.

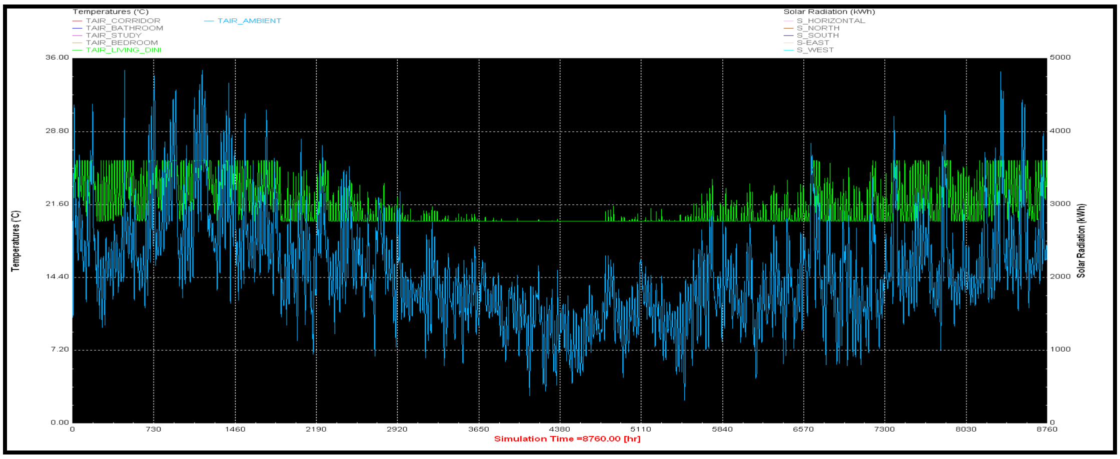


Fig. 3: TRANSYS out put on temperature control between 20-26^0 C vs ambient temperature of Melbourne weather

The simulated monthly distribution patterns of heating and cooling loads for a period of one year is given in Figure 4 and 5, without and with nansulate insulation respectively. All the data was based on Melbourne's weather data. The heating and cooling load patterns behave similarly for both concrete and prefabricated steel construction types.

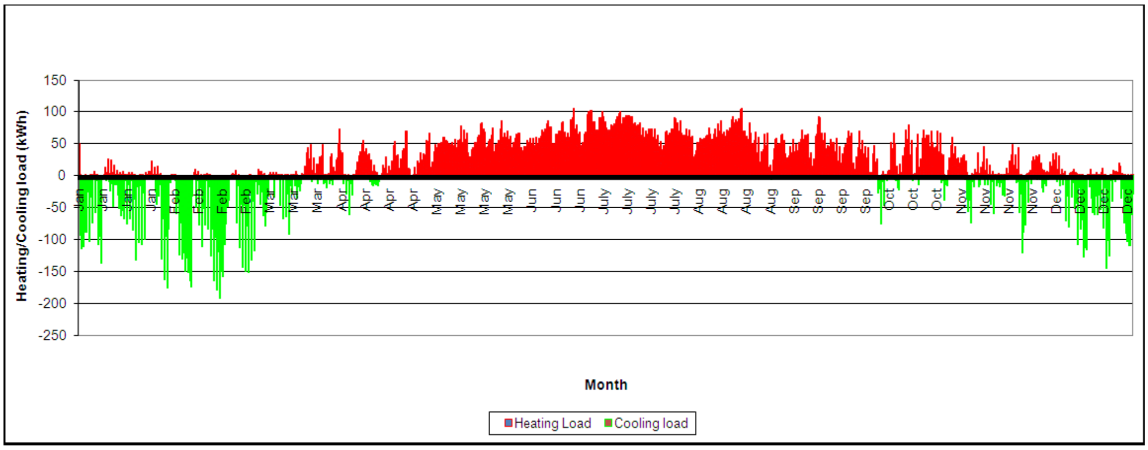


Fig. 4: Heating and cooling load distribution pattern for the case study building- without Nansulate

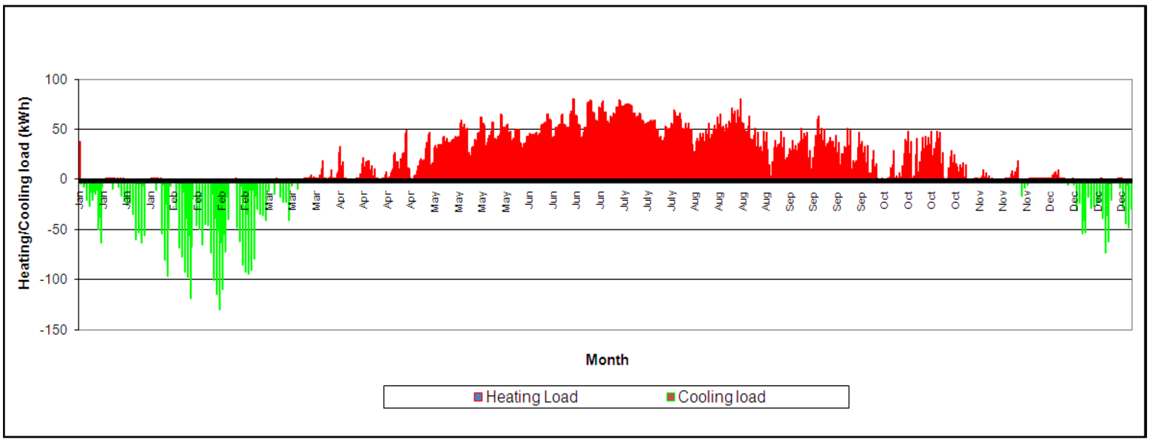


Fig. 5: Heating and cooling load distribution pattern for the case study building- with Nansulate outside

The application of Nansulate in to the exterior of the building shows a saving in the energy consumption through reducing heating and cooling loads. As of figure 4, the heating and cooling loads fluctuate between +100 to -200 without the application of Nansulate. With the application of Nansulate this range reduces up to +80 to -130 as shown in figure 5.

The annual operational energy for the building clearly indicates that for Melbourne the heating energy requirements are much greater than energy requirements for cooling (by at least 180 per cent). There is also a significant difference in operational energy requirements between the concrete and prefabricated steel construction types.

Table 1: Annual operational energy requirements for steel and concrete structural scenarios by square metre of floor area (NLA = 3943m^2)

Structure type	Annual operational energy (kWh/m^2)			Annual operational energy (GJ/m^2)		
	Heating	Cooling	Total	Heating	Cooling	Total
Steel	40.0	12.5	52.5	0.14	0.05	0.19
Concrete	36.8	8.7	45.5	0.13	0.03	0.16

The total operational energy for heating and cooling calculated was 45.5 and 52.5 kWh/m^2/yr for concrete and prefabricated steel respectively (table 1). The difference shown in operational energy due to the difference in the thermal mass of the two construction materials selected. Steel having a high heat storage capacity but it also has a very high rate of thermal conductivity which means that heat is absorbed and released too quickly for any meaningful thermal mass efficiency. Concrete with their high heat capacity and density but moderate thermal conductivity offers a good balance and therefore concrete requires a lower operational energy.

3.2 Insulation with Nansulate

With the application of Nansulate, it is clearly shows that the annual operational energy required for the building is less compared to the cellulose insulation. It is evident that presence of Nansulate without cellulose gives the best energy consumption as illustrated in Table 2.

Table 2: Operational Energy consumed comparison with respect to different insulation options

Insulation Options	Operational Energy over a year					
	Steel			Concrete		
	Heating	Cooling	Total	Heating	Cooling	Total
	(kWh/m^{2}yr)					
Base with 100mm Cellulose	40.0	12.5	52.5	36.8	8.7	45.5
Base w/o 100mm Cellulose	42.2	12.6	54.8	36.9	5.9	42.8
Nansulate Inside with cellulose	37.4	11.5	48.9	35.8	7.7	43.4
Nansulate Inside no cellulose	39.5	12.2	51.6	36.1	6.7	42.8
Nansulate Outside with cellulose	36.3	10.3	46.6	34.8	6.6	41.4
Nansulate Outside no cellulose	36.6	8.9	45.5	34.7	5.0	39.6

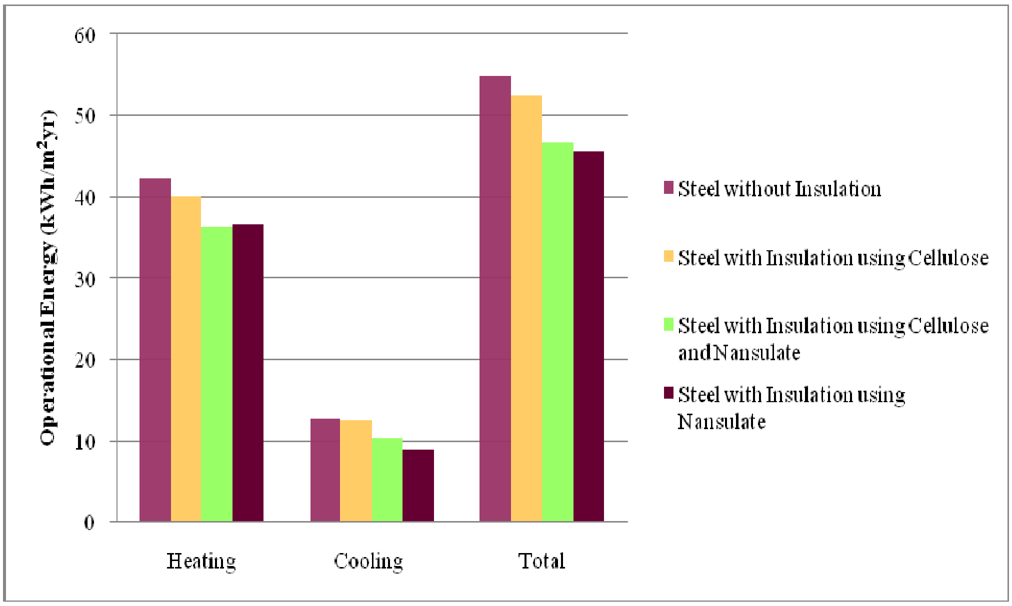


Fig. 6: Operational energy over one year for steel.

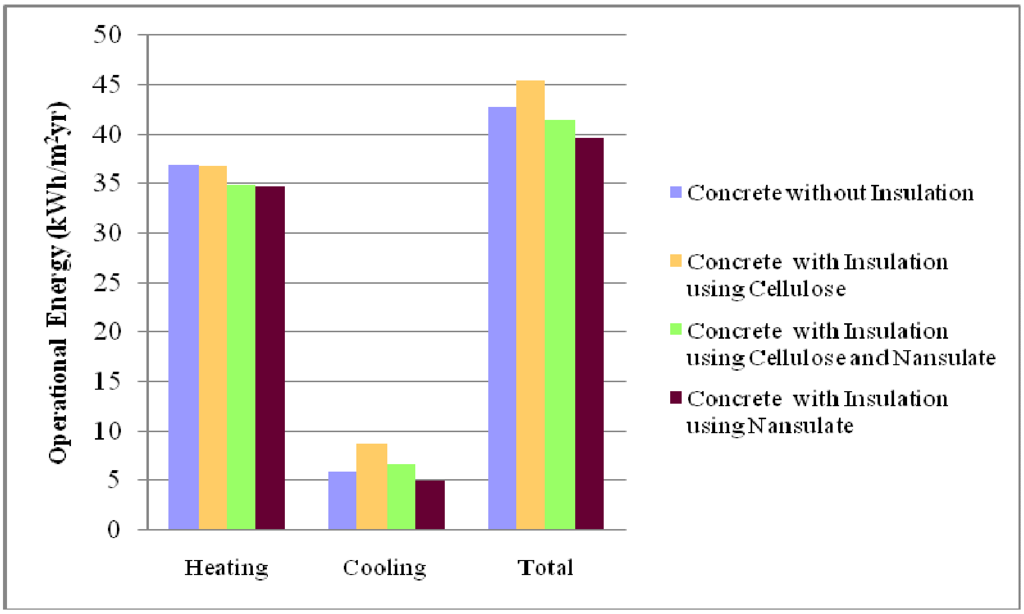


Fig. 7: Operational energy over one year for concrete.

The results in Figure 6 & 7 indicate that the application of Nansulate in the exterior of the building results a significant operational energy reduction compared to conventional insulation material like cellulose resulting saving of 7.47% in operational energy consumption. The removal of cellulose insulation result a saving of 5.9% of the total floor area of the building when Nansulate is applied to the building. The Nansulate insulation coating when applied to the exterior of the walls, it will be less hazardous to the occupants of the building.

4. Conclusion

The study has considered two forms of construction for a multi-residential building, conventional concrete construction and prefabricated steel construction. The results have shown a significant difference in the operational energy requirements associated with the two construction types due to their specific thermal masses. This study has further assessed an operational energy savings of 7.47% with the application of insulation material Nansulate, a product of nanotechnology. With the results obtained from the operational energy analysis through TRANSYS, it was shown that Nansulate provides an effective insulation for both construction methods used against the conventional insulation material cellulose. As the Nansulate coating requires a space of few mm's the results show a saving of 5.9% of the total floor area as a replacement for cellulose.

Further research need to be carried out to determine the impact of thermal mass of concrete on cellulose insulation especially with regards to operational energy required for cooling. The insulation properties of cellulose, high heat capacity and moderate thermal conductivity of concrete needs to be further evaluated on its impact on energy required for cooling of buildings.

As a super insulation product Nansulate provides combined performance qualities of thermal insulation and corrosion prevention which lead to an environmentally safe, water-based coating formulation. Nansulate is a product of nanotechnology that reduces the operational energy consumption of the buildings to a considerably. Thus, it is quite evident that nanotechnology hold a promising results in building insulation applications and the products are yet to come.

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