DINCEL STRUCTURAL WALLING

PART 1 – ENERGY EFFICIENCY IN BUILDINGS
EMBODIED ENERGY

9th October 2009

Dear Dincel Stakeholder

Re: Part 1 Energy Efficiency in Building materials – Embodied Energy

This letter represents the independent opinion of the National Centre for Sustainability (NCS) at Swinburne University of Technology of the findings presented within the paper developed by Dincel Construction System Pty Ltd titled: Part 1 Energy Efficiency in Building materials – Embodied Energy. The approach taken by the reviewer solely addresses the findings and assertions made within the document and does not address or include reference to related sustainability issues within the supporting industries.

The objectives of the peer review process were to ensure:

- assertions made in the report are accurate and complete
- calculations and supporting assumptions are correct
- the credibility of the findings are strengthened by providing an objective third party opinion
- recommendations for improvements were documented

The methodology followed by the reviewer included:

- a review of the complete report
- examination and assessment of calculations and supporting assumptions
- verification of citations and references
- a preliminary report of the reviewers findings to provide Dincel with the opportunity to correct the report prior to finalisation of the work

Based on the scope of the above process, it is the independent opinion of the reviewer that:

- our findings provide confidence in the information within the report
- the level of information and data accuracy was found to be high
- the report has been developed in a clear, factual, neutral and understandable manner, based on clearly documented citations and references

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EXECUTIVE SUMMARY

Australian construction engineers have developed a new building construction technology called Dincel Construction System (DCS).

DCS is a structural building system which consists of floor slabs supported by load bearing Dincel-Walls.

Dincel-Wall is a patented concrete forming technology with rigid polymer housing accommodating a concrete fill. The result is a waterproof, crack-free, non-load bearing or load bearing, fire and acoustic wall which is more cost effective than traditional wall systems, and installed faster and safer.

When Dincel-Walls are used as load bearing walls, a significant reduction in concrete and steel reinforcement use is achieved at **each floor slab level achieving 43% cost efficiency** when compared against the conventional construction system shown in this article **(Download – Costing Analysis)** from DCS Website. The reduction of material use at each floor level of building structures represents less embodied energy and related CO_2 emissions.

IMPACTS OF ENERGY CONSUMPTION

The majority of our energy needs are met by burning fossil fuels. Almost 60% of the total greenhouse gas emissions are carbon dioxide (CO_2) emissions which are generated from fossil fuel combustion and other carbon dioxide-emitting processes.[1]

Our reality is that we do not have adequate alternative energy sources to replace the fossil fuel burning, and hence to reduce CO_2 emissions. We can therefore only try to minimise the human expansion impact on the environment by increasing the use of more environmentally friendly energy sources, encouraging the use of long lasting building materials and recyclability, and maximising energy efficiency measures.

Buildings are responsible for 30% to 40% of global energy use and associated CO_2 emissions. In Europe, buildings account for 40% to 45% of energy consumption in society contributing significant amounts of CO_2 emissions.[2] The building's energy use and related CO_2 emissions are attributed to:

- Energy used for the construction of buildings.
- Energy used for building operations over building life.

ENERGY EFFICIENCY IN BUILDINGS

Residential and commercial buildings are responsible for a significant proportion (23%) of Australia's greenhouse gas emissions (CO_2) in both construction and operational use.[1 & 2] The CO_2 emissions are increasing at a rate of 1.3% p.a. for residential and 2.1% p.a. for commercial buildings.[1]

The following opportunities have been considered to reduce energy use and related CO_2 emissions in the building sector:

1 Garnaut Climate Change Review www.garnautreview.org.au

2 Centre for International Economics 2007

PART 1: Energy Efficiency In Building Construction – Embodied Energy

Embodied energy is the energy consumed by all of the processes associated with the production of a building, from the acquisition of natural resources to product delivery. This includes the mining and manufacturing of materials and equipment, the transport of the materials and the administrative functions.

It was thought until recently that the embodied energy content of a building was small compared to the energy used in operating the building over its life. Most effort was therefore put into reducing operating energy by improving the energy efficiency of the building envelope.

Research has shown that this is not always the case. In some cases, embodied energy can be the equivalent of many years of operational energy[4] and this paper will illustrate this with a comparison of Dincel Construction System and conventional construction.

The method of building, the durability of materials used and the building's effective life make a significant impact on energy consumption. Durability and recyclability of building materials are very important issues in terms of energy consumption.

Dincel Construction System when used as load bearing walls has the potential of significantly reducing construction material used in floor slabs by reducing concrete and steel use and thereby reducing embodied energy.

Dincel-Wall also eliminate up to 95% of wall reinforcement steel use and lessen the durability requirement of concrete walls. The normally specified 40 Mpa concrete strengths can easily be 20 Mpa concrete (even lower strengths down to 8 Mpa are possible depending on the structural use). Thus, providing up to 50% reduction in the cement content in the concrete mix is possible due to the permanent polymer protection offered by Dincel-Forms.

The document *'PART 1 Energy Efficiency In Building Construction – Embodied Energy'* highlights the importance of embodied energy and finds the following:

- The single most important factor in reducing the impact of embodied energy is to design long life, durable and adaptable buildings[4]. This paper demonstrates the importance of embodied energy savings. **The current Building Code of Australia (BCA 2009 – Section J) does not consider the embodied energy even though the related savings are significantly more than the energy saving provisions of the Building Code of Australia as demonstrated in Table 6 of this document.**
- A full life cycle assessment for Dincel-Walls has not been undertaken; however it is estimated that DCS provides at least 200 years of building life which is much longer than the life of conventional buildings and means less building replacement is required.[5]
- DCS only needs to use the shell of the apartment unit as the permanent load bearing structure. This means that all of the internal partition walls and services can be re-modelled at any time without affecting the structure, providing building adaptability over its life.
- **The embodied energy offered in residential apartment buildings by DCS is 42% lower compared to conventional building systems at the time of construction of the Case Study building, and as much as 62% lower when a 100 year building life cycle is taken.**
- **This embodied energy saving is equivalent to taking 20 cars off the road for every apartment built using Dincel Construction System, or a reduction of 75.8 tonnes of greenhouse gas emissions at the time of construction.**
- **The embodied energy savings by DCS represents 29.1 t-CO_2-e/person which is higher than the Australian CO_2 emission rate of 19.5 t-CO_2-e/person.**
- Embodied energy can be the equivalent of many years of operational energy[5]. **This paper shows that DCS embodied energy savings in comparison to conventional construction, at the time of completed construction, is the equivalent of the energy which would be consumed for heating and cooling of the building for the next 89 years or 16 years for total operational energy use.[6]**
- Re-use of building materials (i.e. recycling) commonly saves about 95% of embodied energy that would otherwise be wasted.[4] DCS offers full recyclability during manufacturing, construction and end of building life (i.e. 200 years for DCS)[5].

4. www.yourhome.gov.au/technical/fs52.html
5. Refer to the following: **(Download – FAQ, Answer No: 6 – Life/Sustainability)**
6. Refer Table 7 of this document. Architectural building design regulations such as solar access and cross ventilation are issues directly related to operational energy efficiency. **(Download – Information for Architects)** of DCS website.

PART 2: Energy Efficiency For Building Operational Use

If the following measures are not implemented efficiently, unnecessary energy wastage can accumulate over the life of the building.

- Improving the use of passive heating, cooling and lighting; and
- Enhancing insulation, thermal mass and air tightness of the building enclosures; and
- Avoidance of thermal bridging at the building enclosures, and
- Installing more efficient appliances; and
- Integrating generation systems into buildings, such as gas-fired co-generation plants and photovoltaic panels.

Information on the operational energy efficiency of Dincel Construction Systems and the savings which may be attributed to the use of DCS compared to conventional building is contained in this second paper **(Download – PART 2 – Energy Efficiency for Building Operational Use)** of DCS website.

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PART 1

ENERGY EFFICIENCY IN BUILDING CONSTRUCTION – EMBODIED ENERGY

Currently, a building structure's related energy efficiency is only represented by Section J of the Building Code of Australia. Section J only refers to walls having high insulation R value. Issues such as thermal mass, thermal bridging and air tightness which also significantly affects the energy efficiency, are not considered. The current Building Code of Australia also does not take into account that the embodied energy savings can be achieved by using less energy intensive, long life materials and engineering structural solutions which will result in reduced embodied energy.

Dincel Construction System (DCS) significantly reduces construction material use and at least doubles the building's life in comparison to conventional buildings by the DCS protection offered to concrete and steel reinforcement. The reduction of material consumption, use of materials with less embodied energy and use of durable materials are the most important factors for embodied energy savings.[7]

This article demonstrates that embodied energy savings for the entire building construction are much greater than the energy savings that can ever be achieved by only having insulated building façade walls. The Government ought to consider the embodied energy savings in buildings in addition to insulated façade walls to really assist energy related issues, including greenhouse gas emissions.

PURPOSE AND SCOPE

This document was prepared to highlight the importance of potential embodied energy savings by using Dincel Construction System. A full life cycle analysis for this study has not been undertaken however, the embodied energy figures in references 13 and 14 of Table 1 includes the energy required in the extraction/processing/manufacturing, etc. of the materials listed. This data is presented (refer Table 1, references 13 and 14) on DCS and a conventional building system to make a comparison and identify embodied energy characteristics of the two systems.

The minimum life of Dincel-Polymer is estimated as 200 years based on material durability. However, the embodied energy comparisons are shown in Tables 3 and 4 for 1, 50 and 100 years. Only post-disaster public buildings are engineered for 100 years. The remaining buildings including residential are not engineered beyond 50 years.

Embodied energy is defined as the energy consumed by all of the processes associated with the production of a building, from the acquisition of natural resources to product delivery. This includes the mining and manufacturing of materials and equipment, the transport of the materials and the administrative functions.

FACTORS REDUCING EMBODIED ENERGY IN BUILDINGS

1. Durability

The design life expectancy of conventional building structures is considered to be maximum 50 years for private buildings and 100 years for post-disaster public buildings by Australian engineering standards[8].

The design life expectancy refers to the life of the building structure for design conditions as required by the Australian Concrete Structures Code AS3600 – 2001. Designers assume that the structural life of the building will be 50 or 100 years depending on the importance of the building.

Dincel Construction System (DCS) uses Dincel-Wall which is a patented concrete forming technology with rigid polymer[9] housing accommodating a concrete fill. The result is a waterproof, crack-free, non-load bearing or load bearing, fire and acoustic wall. Dincel-Wall ensures that the concrete infill is protected by the presence of the permanent polymer skins[10]. This achieves the following:

- **Durability -** Dincel, as a permanent membrane system encapsulating concrete prevents external contamination from water, moisture, biological pests and termites entering into the building environment, thus eliminating environmental decay.
- **Longevity** – Even for corrosive and acidic environments, Dincel's permanent polymer enclosure provides a far greater life expectancy than any traditional type of building material due to the durability of the Dincel-Polymer.

  The design life expectancy, i.e. longevity of Dincel-Wall is at least 200 years because of the protection offered by Dincel-Forms[11]. However, Dincel-Polymer also offers at least one full recyclability for a further 200 years at the end of the building's life cycle, thus offering potentially 400 years of use from the same Dincel-Polymer material used originally[12].

  If buildings are constructed using Dincel load bearing walls, the building fabric consisting of Dincel-Wall at the basement and façade walls will protect the entire building structure against environmental decay. Thus, the presence of Dincel Construction System (DCS), under the worst conditions, will at least double the design life expectancy of the entire building structure.

The longevity of any material is one of the most important issues in the life cycle assessment. Even where the life cycle of DCS is adopted for 100 years in lieu of 200 years, and DCS recycling is ignored, the results still offer very significant energy efficiency and potential greenhouse gas emission reduction by using DCS.

7 www.yourhome.gov.au/technical/fs52.html

8 Australian Concrete Structures Code AS3600 – 2001

9 Dincel-Polymer is a heavy metal stabiliser and plasticiser free, rigid PVC.

10 (Download – Waterproof Walls)

11 (Download – FAQ, Answer No: 6 – Life/Sustainability)

12 (Download – FAQ, Answer No: 3 – Recyclable/Sustainability)

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2. Reduction In Material Use

The following case study compares DCS with conventional framed construction system consisting of masonry in-fills which is the most common technique throughout the world.

The examples are based on a single apartment consisting of 2 bedrooms and study and measuring 7m x 15m. A plan for the Case Study apartment is provided in Figure 1.

- **Dincel Construction System Apartment**
  - Consists of Dincel-Wall, concrete slabs and internal lightweight partition walls.
  - The protection offered by Dincel-Polymer is 200 years for all concrete and reinforcing steel elements.
  - A 50 year life cycle of the lightweight internal partition walls (timber and plasterboard) is assumed. Lightweight partitions are used because load-bearing structural walls are not required internally when using DCS.
  - No recyclability potential of Dincel-Polymer has been taken into account in the calculations below. The energy use of Dincel - Wall can be further minimised significantly if at least one additional recycle life is allowed at the end of building life.
  - The total mass of materials consumed in this example would be 73.4 tonnes. Dincel use 64% less steel than conventional building systems.
  - AS3600 – 2001 Concrete Structures Code requires 40 Mpa concrete use if the building is located within one (1) km from the coastal zone or 32 Mpa within 1 to 50kms zone. Dincel-Wall would not require more than 20 Mpa (or even 10 Mpa concrete up to 8 storey buildings) since durability protection of concrete is provided by permanent polymer membrane forms of DCS. Thus, significant reduction in cement use is achievable.

Figure 3 provides the plan and Material Mass Calculations for this apartment.

- **Conventional Building System Apartment**
  - The life of the conventional building is 50 years which is consistent with the Australian engineering design life standards for residential buildings (Australian Concrete Structures Code AS3600 – 2001).
  - Conventional frame system consists of non-load bearing brick party and partition infill walls, concrete slabs and concrete columns. When brick party walls with render finishes are used, the internal partition walls become brick as well in lieu of lightweight walls in majority of applications. There are many reasons for this, including acoustic performance at the party walls, consistency of wall finishing, construction economics. Refer **(Download – Costing Analysis)** from the DCS website.
  - The cost of recycling bricks especially if they are rendered will be cost prohibitive. Therefore, recycling of bricks is not included.
  - The total mass of materials consumed in this example would be 109.9 tonnes. Conventional system is 50% heavier than Dincel which is a substantial load and will result in additional construction costs for earthquake, transfer level(s) and footings (i.e. extra concrete and steel).

Figure 4 provides the plan and Material Mass Calculations for this apartment.

Figure 2 overpage shows the comparison in construction of a conventional frame system and DCS.

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Figure 1.

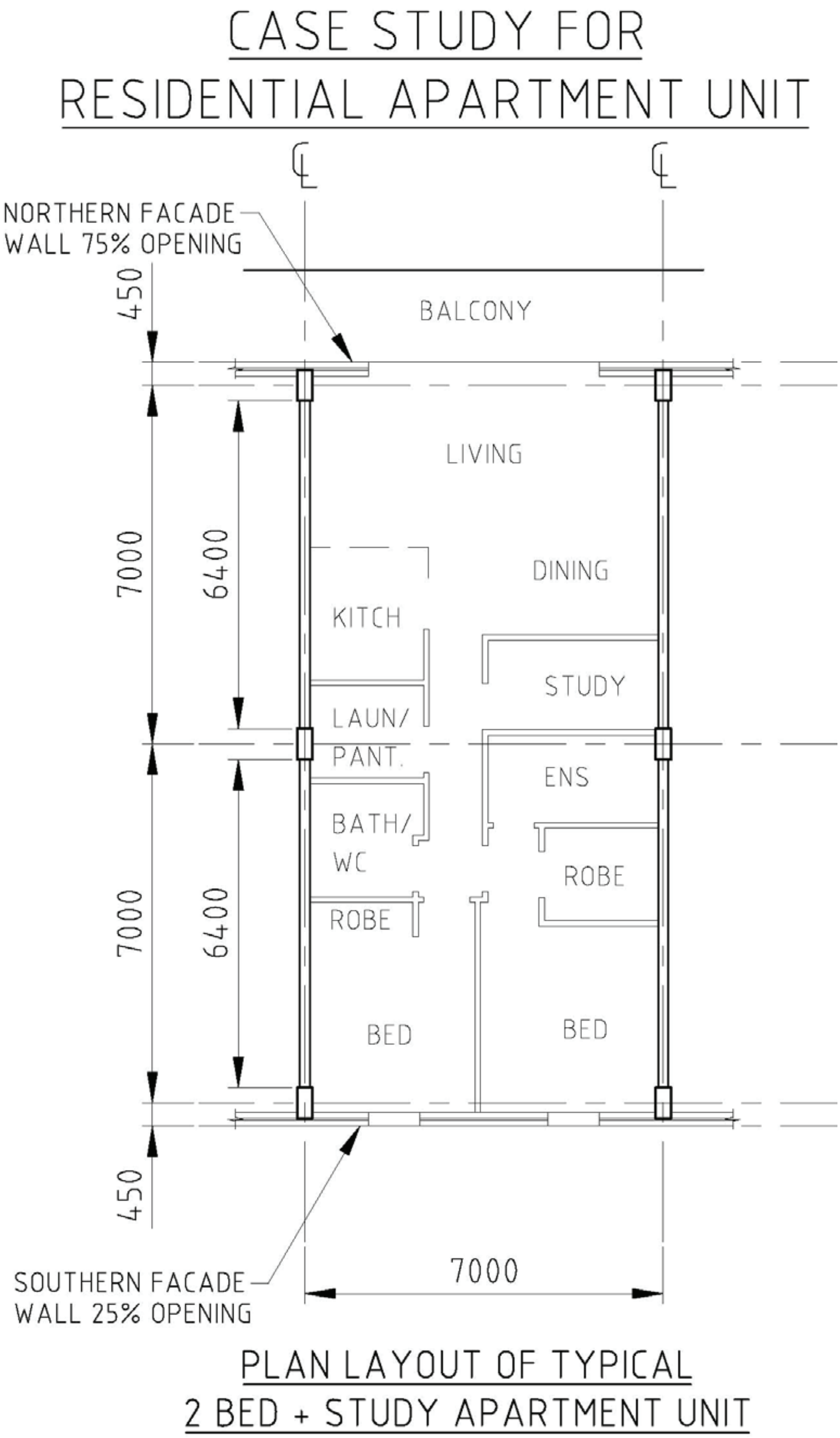

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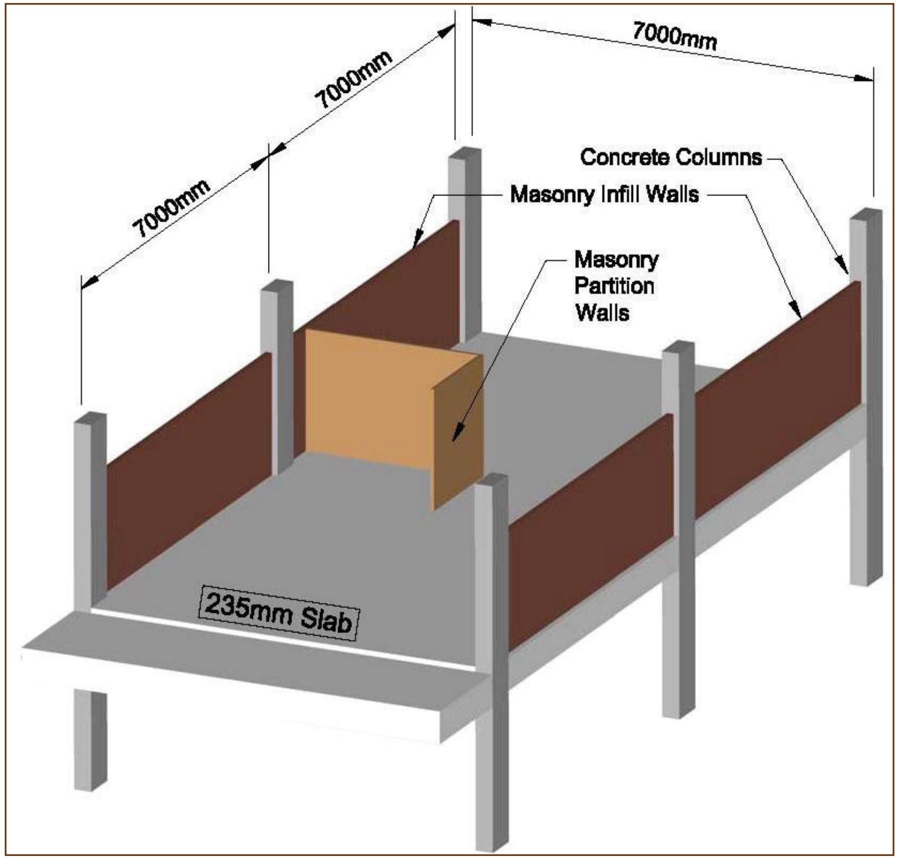
Figure 2. COMPARISON BETWEEN CONVENTIONAL FRAME AND DINCEL SYSTEMS FOR TWO BEDROOM + STUDY APARTMENT UNIT



CONVENTIONAL FRAME SYSTEM

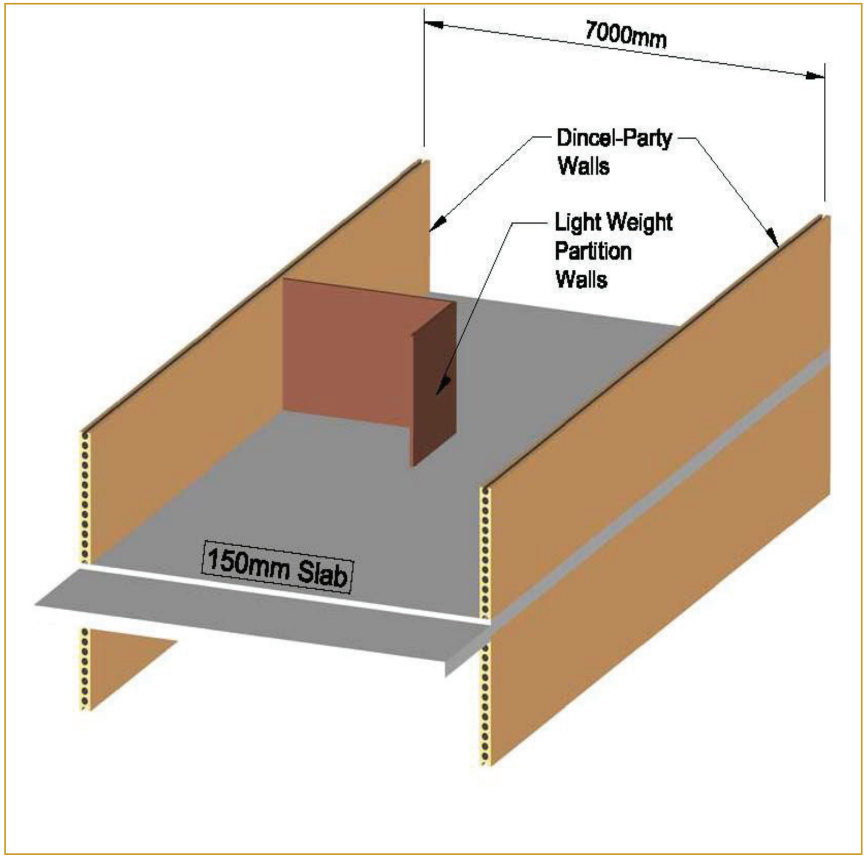


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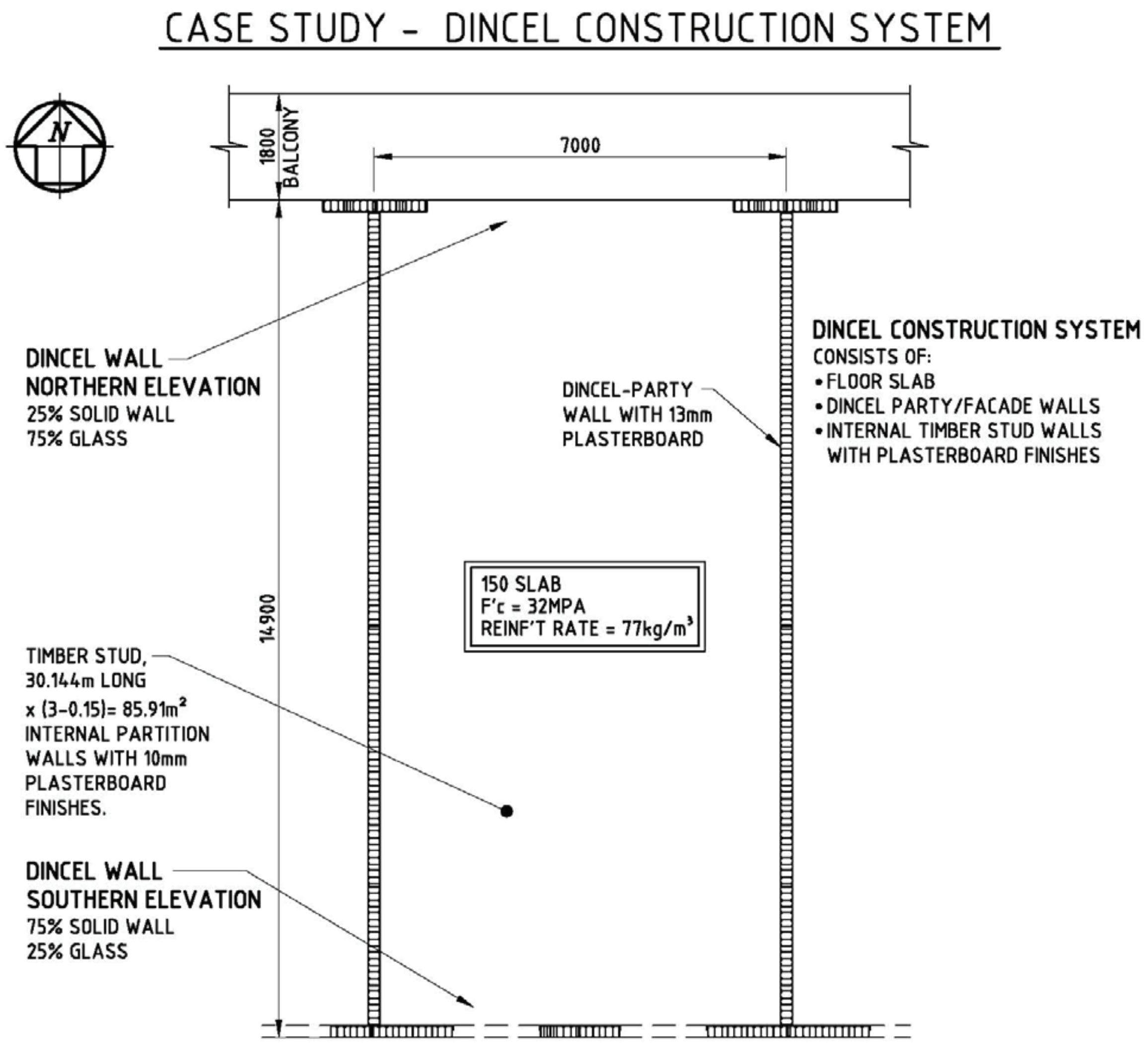
Figure 3



MATERIAL MASS CALCULATION
7m x 14.9m RESIDENTIAL MODULE (3m FLOOR TO FLOOR)

COMPONENT	CONCRETE 2400kg/m^3	STEEL REINF'T	CLAY BRICK	DINCEL-POLYMER 13.5kg/m^2	PLASTER-BOARD	TIMBER FRAME 7.1kg/m^2
SINGLE FLOOR SLAB 150 THICK	32 MPa ($17.5m^3$) 42000kg	500 MPa 1351kg	N/A	N/A	N/A	N/A
DINCEL PARTY WALLS (1 OFF EACH APARTMENT)	20 MPa ($7.51m^3$) 18032kg	500 MPa 21kg	N/A	($41.3m^2$) 558kg	(2 x $41.3m^2$) 702kg	N/A
PERIMETER WALL (DINCEL WALL)	20 MPa ($3.63m^3$) 8712kg	500 MPa 10kg	N/A	($20m^2$) 269kg	($20m^2$) 130kg	N/A
PARTITION WALLS	N/A	N/A	N/A	N/A	($166m^2$) 1083kg	($85.91m^2$) 610kg
TOTAL	($28.64m^3$) 68744kg	1382kg	N/A	($61.3m^2$) 827kg	($268.6m^2$) 1915kg	($85.91m^2$) 610kg

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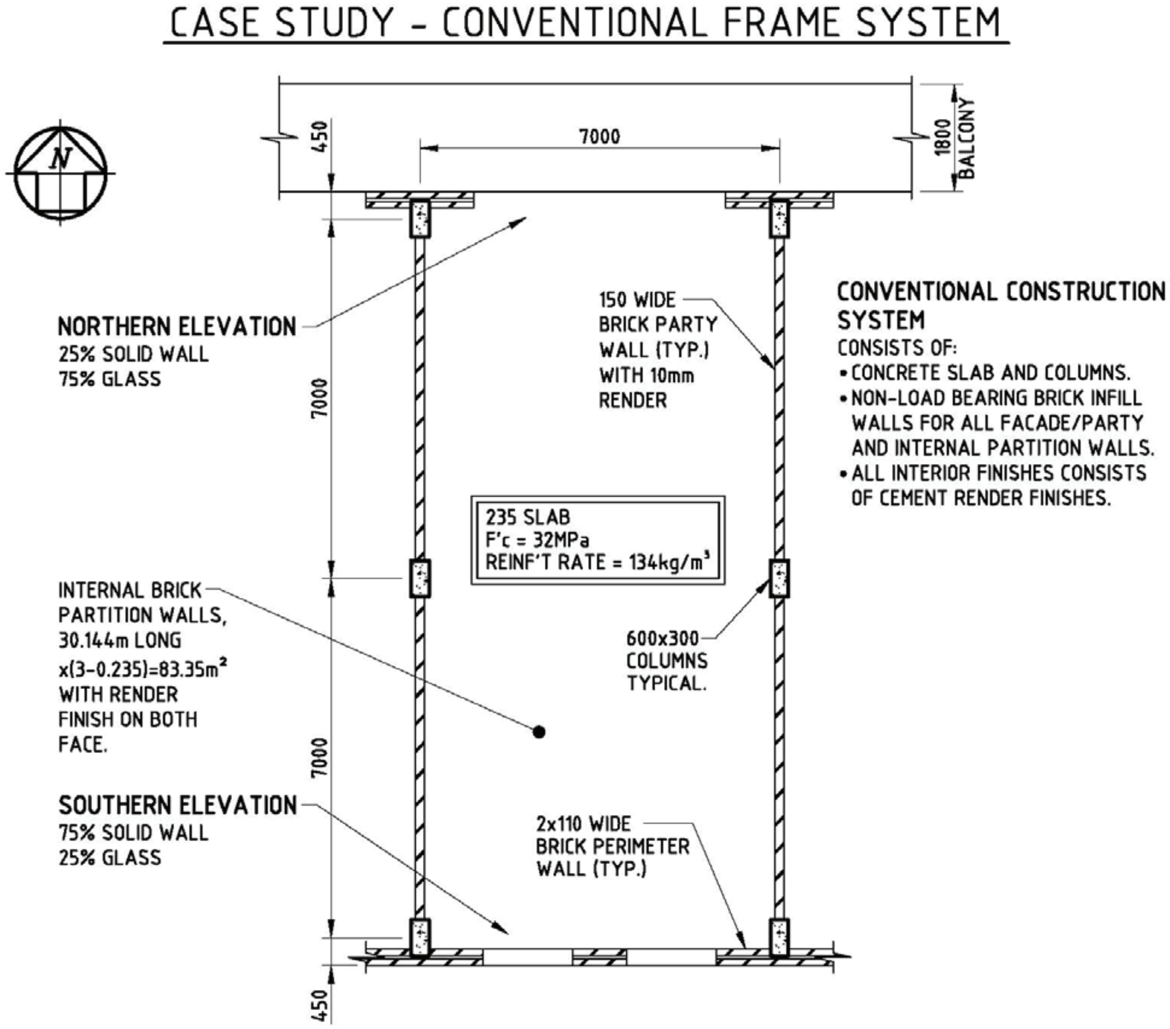
Figure 4



MATERIAL MASS CALCULATIONS
7m x 14.9m RESIDENTIAL MODULE (3m FLOOR TO FLOOR)

COMPONENT	CONCRETE 2400kg/m³	STEEL REINF'T	STANDARD BRICK 150kg/m²	STANDARD BRICK 200kg/m²	RENDER 28kg/m²	MORTAR 25.2kg/m²
SINGLE FLOOR SLAB 235 THICK	32 MPa (27.47m³) 65928kg	500 MPa 3681kg	N/A	N/A	N/A	N/A
3 OFF COLUMNS 600x300	32 MPa (1.49m³) 3576kg	500 MPa 195kg	N/A	N/A	N/A	N/A
PERIMETER WALLS 2x110 THICK BRICK	N/A	N/A	(2x19.35m²) 5805kg	N/A	(1x19.35m²) 542kg	(2x19.35m²) 975kg
1 OFF PARTY WALL FOR EACH APARTMENT	N/A	N/A	N/A	(35.4m²) 7080kg	(2x35.4m²) 1982kg	(35.4m²) 892kg
110 INTERNAL BRICK PARTITIONS	N/A	N/A	(83.35m²) 12502kg	N/A	(2x83.35m²) 4667kg	(83.35m²) 2100kg
TOTAL	28.96m³ 69504kg	3876kg	122.05m² 18307kg	35.4m² 7080kg	256.85m² 7191kg	3967kg

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EMBODIED ENERGY COEFFICIENTS

For The Building Products of This Study

It is important to consider the source of energy of a building product and its components in calculating the embodied energy. The type of energy used (coal, oil, gas, hydro, wind, nuclear sources) and its costs significantly affect the embodied energy calculation of a building product and the building as a whole.

In this case study, the embodied energy coefficients of locally manufactured building products has been used where possible. It is arguable that not all construction materials are necessarily produced locally in Australia. This case study uses clay brick, concrete, steel, wood, plasterboard and Dincel-Forms (vinyl). All these materials, with the exception of some quantity of imported vinyl and cement used in concrete manufacturing are produced in Australia.

Concrete 20 Mpa (240 kg/m³ - cement) Concrete 30 Mpa (320 kg/m³ - cement)	2.38 MJ/kg 2.70 MJ/kg
Framing Timber	
Dincel-Polymer (vinyl)	
Insulation	
Plasterboard	
Brick Wall • Standard Brick • Mortar • Plaster	 5.44 MJ/kg 2.38 MJ/kg 8.94 MJ/kg
Steel Reinforcement	55.5 MJ/kg

Table 1 – Embodied Energy Coefficients 13 14

13 The Environmental Impacts of Residential Development:
Case Studies of 12 Estates in Sydney, by Bill Randolph, Darren Holloway, Stephen Pullen, Patrick Troy
Faculty of Built Environment University of New South Wales July 2006 (updated March 2007) – Refer Appendix 5 for energy coefficients.

14 Appendix 2 – Evaluation of hybrid embodied energy and emissions (CO_2-e) coefficients – PhD Study by Stephen Pullen
http://digital.library.adelaide.edu.au/dspace/bitstream/2440/47584/1/04ref-append.pdf.

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TABLE 2 EMBODIED ENERGY CALCULATIONS FOR CASE STUDY OVER 100 PERIOD		Concrete 2400 kg/m³		Steel 7850 kg/m³	Standard Brick	Brick Mortar 25.2 kg/m²	Brick Render 28kg/m³	Plasterboard 10mm – 6.5 kg/m² 13mm – 8.5 kg/m²	Framing Timber 7.1 kg/m²	Dincel-Polymer 13.5 kg/m²	Total
		32Mpa	**20Mpa**								
Embodied Energy Coefficients (MJ/kg)		2.70	2.38	55.5	5.44	2.38	8.94	13.3	22.61	74.9	
DINCEL CONSTRUCTION SYSTEM (assumes 100 year building lifespan)	Material Mass (kg)	42 000	26 744	1382	N/A	N/A	N/A	1 915 kg	610	827	73 478 kg 628.5 kg/m²
	Embodied Energy (MJ) Building Life at Year 1	113 400	63 650	76 701	N/A	N/A	N/A	25 469	13 792	61 942	354 954 (MJ)
	At 50 Years (replacement of internal partitions)	113 400	63 650	76 701	N/A	N/A	N/A	2 x 25 469	2 x 13 792	61 942	394 215 (MJ)
CONVENTIONAL FRAME SYSTEM (assumes 50 year building lifespan)	Material Mass (kg)	69 504	N/A	3 876	(18 307 + 7 080)	3 967	7 191	N/A	N/A	N/A	109 925 kg 940.3 kg/m²
	Embodied Energy (MJ) Building Life at Year 1	187 660	N/A	215 118	138 105	9 441	64 287	N/A	N/A	N/A	614 611 (MJ)
	At 50 Years (building replaced)	2 x 187 660	N/A	2 x 215 118	2 x 138 105	2 x 9 441	2 x 64 287	N/A	N/A	N/A	1 041 562 (MJ)
ENERGY EFFICIENCY OF DCS	AT YEAR 1 (614 611 – 354 954) + 614 611 X 100 = 42% FOR 100 YEARS (1 041 562 – 394 215) ÷ 1 041 562 x 100 = 62%										

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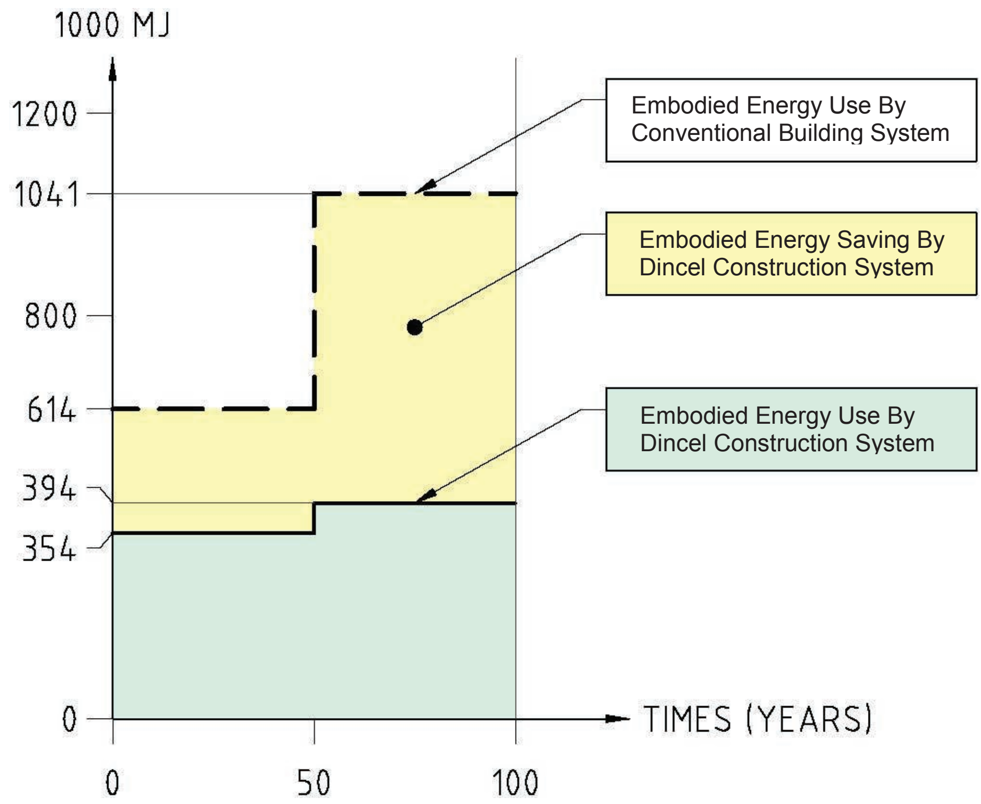
FIGURE 5 – ENERGY SAVING FOR THE CONSTRUCTION OF ONE (1) APARTMENT UNIT/YEAR

The Figure below represents the total embodied energy savings for one (1) apartment unit per year over a range of time periods.



ENERGY SAVING CALCULATIONS* **1kwh = 3.6 MJ**

(A) 1st Year	= (614 611 – 354 954) x 1	= 259 657 MJ =	72 127 kwh
(B) 1 Unit/Year for 50 Years (i.e. 50 Apartments)	= (614 611 – 354 954) x 50 Years	= 12 982 850 MJ =	3 606 347 kwh
(C) 1 Unit/Year for 100 Years (i.e. 100 Apartments)	= (1 041 562 – 394 215) x 50 Years + (B)	= 45 350 200 MJ =	12 597 277 kwh

* Refer Table 2 for energy values.

The embodied energy calculations of this study for the building construction are based on the demand generated by the population growth. The population growth occurs on an exponential basis. For the purpose of this study an annual population increase of 1.6% of the base population of 21 282 600 in Australia (refer reference 20) on a linear basis for 50 and 100 year periods was adopted. The non-accounting of exponential growth for simplicity purposes provides a conservative result.

An ongoing construction activity is required to cater for the population growth. This is the reason why the above calculations show that one apartment is required to be built for each year of the considered 50 and 100 years time periods (refer Table 4). This is not a study for one apartment over 50, 100 years period. This is then multiplied with the annual apartment demand to determine the entire embodied energy savings shown in Table 5.

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CARBON DIOXIDE (CO_2-e) EMISSION CALCULATIONS

The relevant carbon dioxide emission (kg CO_2-e/kWh) of a building product can significantly change depending on the type of energy used for the production. For example, 78% of Australian electricity is energy generated by burning mainly coal. As a result, significant kgCO_2-e/kwh is produced. However, New Zealand achieves the majority of power from hydro sources and France achieves 70% of its power from nuclear energy. Therefore, their relative CO_2 emission quantity will vary from the product produced in Australia.

This paper only considers the quantity of CO_2-e produced per kWh of electricity production by Australian NGA factors as explained below.

Table 3: CO_2-e Emission Factor For Australian Electricity (i.e. Energy Production) www.climatechange.gov.au/workbook/pubs/workbook-nov2008.pdf (National Greenhouse Accounts (NGA) Factors – November 2008 – Table 39)	
New South Wales and ACT	1.06 kg CO_2-e/kwh
Victoria	1.31 kg CO_2-e/kwh
Queensland	1.04 kg CO_2-e/kwh
South Australia	0.98 kg CO_2-e/kwh
Western Australia	0.98 kg CO_2-e/kwh
Average of 5 states	1.074 kg CO_2-e/kwh

Another reference states the Australian average is 1.051 kg CO_2-e/kwh[15].

This case study adopts this factor of 1.051 kg CO_2-e/kwh as it is the lower value referenced for Australian use, and therefore more conservative for the purposes of this paper. This conservative approach may underestimate the actual CO_2-e emissions in Australia; however the purpose of this paper is to demonstrate the benefit of Dincel Construction System to our environment and economics even if the lowest emission factors are used.

15 Sustainable living by Nalanie Mithroratne, Brenda Vale and Robert Vale, September 2007 by publishers Butterworth Heinemann, page 16

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TABLE 4: Embodied Energy or Equivalent Other Savings Achieved By Using Dincel Construction System (DCS) To Replace Conventional Construction for a Typical Apartment Unit

	Saving after 1 Year OF DCS USE	**Saving for 1 APARTMENT/YEAR FOR 50 YEARS OF DCS USE**	**Saving for 1 APARTMENT/YEAR FOR 100 YEARS OF DCS USE**
 Energy[16]	239 657 MJ = 72 127 kwh	12 982 850 MJ = 3 606 347 kwh	45 350 200 MJ = 12 597 277 kwh
 Equivalent Carbon Dioxide $t\text{-}CO_2\text{-}e$[17]	75.8 tonnes CO_2-e	3 790 tonnes CO_2-e	13 239 tonnes CO_2-e
 Equivalent Coal Use[18]	81.5 tonnes Brown Coal OR 37 tonnes Black Coal	4 075 tonnes Brown Coal OR 1 848 tonnes Black Coal	14 236 tonnes Brown Coal OR 6 458 tonnes Black Coal
 Equivalent Passenger Car Use[19]	20	1 031	3 604

Example Year (1):

CO_2-e	= 72 127 kwh x 1.051 kgCO_2-e/kwh = 75 805 kg = 75.8 t
Brown Coal	= 75.8 t-CO_2-e ÷ 0.93 t-CO_2-e/t = 81.5 t
Black Coal	= 75.8 t-CO_2-e ÷ 2.05 t-CO_2-e/t = 37 t
Car	= 75.8 t-CO_2-e ÷ 3.673 t-CO_2-e/year = 20 cars

16 Energy conversion factor 3.6 MJ = 1 kWh

17 t-CO_2-e: tonnes of CO_2 equivalent emissions

18 www.ccsd.biz/pse_Handbook/5/3/ : 0.93 kg CO_2 /kg Brown Coal and average (1.72+2.32)÷2=2.05 CO_2 / kg Black Coal

19 Australian Bureau of Statistics Survey of Motor Vehicles Use, Australia 12 months ended 31st October 2007 Catalogue 9208.0. Assumes average 11.5litres /100 km and 13700km/year for an average passenger car. Average car produces 11.5 x 13700 x 2.331kgCO_2/L = 3673 kgCO_2/year, 3,673 t CO_2/year.

TABLE 5: Embodied Energy Or Equivalent Other Savings Achieved By Using Dincel Construction System (DCS) To Replace Conventional Construction in All Australian Apartment Units (129 230 units/year) [20]

	Saving after 1 Year OF DCS USE	Savings after 50 YEARS OF DCS USE	Savings after 100 YEARS OF DCS USE
 Energy[21]	72 127 x 129 230 = 9 321 million kwh	3 606 347 x 129 230 = 46 604 million kwh	12 597 277 x 129 230 = 1 627 946 million kwh
 Equivalent Carbon Dioxide t-CO_2-e[22]	9.796 million tonnes CO_2-e	464.7 million tonnes CO_2-e	1710.9 million tonnes CO_2-e
 Equivalent Coal Use[23]	10.533 million tonnes Brown Coal OR 4,778 million tonnes Black Coal	526.6 million tonnes Brown Coal OR 238.9 million tonnes Black Coal	1839 million tonnes Brown Coal OR 834 million tonnes Black Coal
 Equivalent Passenger Car Use[24]	2.66 million	133.3 million	465.8 million

NOTE:

(1) The above findings are for residential building construction only. DCS is also used for buildings other than residential buildings.

(2) The above table assumes that the growth in Australian population is accommodated in apartment buildings.

20 The population of Australia is 21 282 600 and increasing at a rate of 1.6% annually including migration to Australia, that is, 336 000 persons p.a. (31st March 2008, www.abs.gov.au) The Australian average occupancy rate is 2.6 persons per dwelling. If the entire Australian population increase is assumed to be accommodated in apartment units: 336 000 persons ÷ 2.6 persons per dwelling = 129 230 dwellings/year.

21 Energy conversion factor 3.6 MJ = 1 kWh

22 t-CO_2-e: tonnes of CO_2 equivalent emissions

23 www.ccsd.biz/pse_Handbook/5/3/ : 0.93 kg CO_2 /kg Brown Coal and average (1.172+2.32)÷2=2.05) CO_2 / kg Black Coal

24 Australian Bureau of Statistics Survey of Motor Vehicles Use, Australia 12 months ended 31st October 2007 Catalogue 9208.0. Assumes average 11.5litres /100 km and 13700 km/year. Average car produces 11.5x13700x2.331kgCO_2/L=3,673 kg CO_2/year, 3,673 t CO_2/year.

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WHAT DOES EMBODIED ENERGY SAVING MEAN TO THE PUBLIC?

Using data available at http://www.energysave.energyaustralia.com.au/energy_calculators, it can be determined that insulation in buildings with conventional walls results in energy savings of between 4.3% and 7.9% for a typical apartment25.

A typical apartment using gas hot water, and electricity for the remainder of its energy requirements, with insulated walls, consumes an estimated average of 4,470 kWh/year of energy. The above source of information assumes 18% of the energy is used for heating and cooling purposes.

EXAMPLE:

Assuming a typical apartment25:

- Option 1 All gas use
- Option 2 Gas hot water and cooking, remainder electricity
- Option 3 Gas hot water, remainder electricity
- Option 4 All electricity

TABLE 6	ELECTRICITY ENERGY – kwh / YEAR			
	OPTION 1	OPTION 2	OPTION 3	OPTION 4
* Insulation at walls YES	3,578	3,930	4,470	7,398
* Insulation at walls NO	3,787	4,267	4,807	7,735
* Effect of insulation on energy saving	209 (5.5%)	337 (7.9%)	337 (7.0%)	337 (4.3%)
** Ratio of Embodied Energy Saving by Dincel to Energy Saved by insulated building walls	72 127 ÷ 209 **= 345**	72 127 ÷ 337 **= 214**	72 127 ÷ 337 **= 214**	72 127 ÷ 337 **= 214**

* Energy Australia's web-link for energy calculations assumes a type of conventional wall and energy efficiency is based on whether the wall is installed with or without insulation. The insulated walls are assumed to be air tight; otherwise the nominated benefits can be ignored.

** Refer Table 4 for 72 127 kwh/year embodied energy saving by Dincel Construction System.

Interpretation of Table 6

Option 1 is likely to be unusual in Australia. Option 2 and Option 3 are more likely to be used in Australia. All electricity use (Option 4) is inefficient use of power. A significant number of Australian buildings use Option 2. Option 3 has been chosen for the purpose of Table 7 to obtain the most conservative results.

The Building Code of Australia (BCA) Section-J requires the use of wall insulation for energy efficiency purposes. However, as per Table 6 above the 214 times more efficient embodied energy saving opportunity is not considered by the current BCA 2009.

25 2 Bedroom + study, air conditioned, occupied by 3 persons in NSW – Australia, no swimming pool, no green power accreditation, no energy saving bulbs are allowed. Hot water tariff: Off Peak 1

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Table 7 below shows the total operational energy use and the DCS embodied energy savings for one apartment for the given periods. The embodied energy saving from using DCS of 72 127 kWh per apartment is equivalent to 89 years of operational heating and cooling energy consumption.

TABLE 7 – COMPARISON OF OPERATIONAL ENERGY USE TO DCS SAVINGS

ENERGY USE	TYPICAL APARTMENT ONE YEAR
Electricity use of typical apartment unit having insulated façade walls. Option 3 of Table 6	4 470 kwh/yr
Electricity use for heating and cooling[26]	18% x 4 470 kwh/yr = 804.6 kwh/yr
Embodied energy saving by DCS in comparison to conventional frame system – Table 4	72 127 kwh
Equivalent free heating and cooling energy gained by adopting DCS use	72 127 ÷ 804.6 = 89 years
Ratio of operational energy use to embodied energy use for DCS over 50 year building life	4470x50 = 223 500 kwh Op energy 394 215 MJ /3.6 = 109 504 kwh embod energy i.e. ratio of Op to Emb energy is 2 :1
Ratio of operational energy use to embodied energy use for Conventional construction over 50 year building life	223 500 kwh op energy 1 041 562 MJ/3.6 = 289 323 kwh embod energy i.e. ratio of 0.77 : 1
Equivalent free operational energy gained by adopting DCS use	72 127 ÷ 4 470 = 16 years

This paper focuses on only embodied energy of the materials used in construction. Information on how the use of DCS contributes to operational energy savings of buildings is included in another paper, Part 2: Energy Efficiency for Building Operational Use[27].

WHAT DOES CO_2 EMISSION SAVING MEAN TO THE PUBLIC?

Tables 4 and 5 represent the CO_2 emission reductions for the apartment building of this case study. The following comments are important to consider for the positive benefit of DCS to the environment.

- CO_2 emissions represent 74% of Australia's greenhouse emissions (74% x 576 million tonnes), or 427.8 million tonnes.[28, 29]
- CO_2 emissions represent 427.8 million tonnes ÷ 21 862 000 Australian population = 19.5 t-CO_2-e/person per annum.[30]
- Table 4 represents 75.8 t-CO_2-e/per apartment built to accommodate 2.6 persons which is 75.8 ÷ 2.6 = 29.1 t-CO_2-e/person. [30]
- This means that if Australian apartments are built using DCS as the method of construction, the CO_2 emissions saving rate (29.1 t-CO_2-e/person) is greater than the Australian CO_2 emission rate per person (19.5 t-CO_2-e/person) quoted by the authorities. [28 29]

26 18% rate varies depending on the many varying factors. The reader should refer to Energy Australia's web-link given above to see the variation of 18% in between different type and size of buildings. The reader may also refer to the following websites for further information.

http://www.abs.gov.au/AUSSTATS/abs@.nsf/bb8db737e2af84b8ca2571780015701e/850C57021C2D381ECA257320010621A?opendocument AND also:

http://www.environment.gov.au/settlements/energyefficiency/buildings/publications/pubs/energyuse-part1.pdf

27 http://www.dincelconstructionsystem.com/documents/Part%202%20Energy%20Efficiency.pdf

28 http://en.in-en.com/article/News/focus/html/200807167840.html

29 http://www.climatechange.gov.au/inventory/2006/pubs/inventory2006.pdf (page 3 of document)

30 The population of Australia is 21 282 600 and increasing at a rate of 1.6% annually including migration to Australia, that is, 336 000 persons p.a. (31st March 2008, www.abs.gov.au) The Australian average occupancy rate is 2.6 persons per dwelling. If the entire Australian population increase is assumed to be accommodated in apartment units: 336 000 persons ÷ 2.6 persons per dwelling = 129 230 dwellings/year.

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APPENDIX

The Use of Dincel Construction System

Dincel Construction System offers unlimited potential use in any sector as shown in the following table

BUILDING WALLS	Basement, lift-stair shafts, party-corridor-façade walls, residential, office, retail, industrial, warehouses, hospitals, shopping centres. Replacement of conventional precast, tilt-up and masonry block walls.
RETAINING WALLS	Basement walls below permanent water table, earth retaining, mining, erosion control, river embankment protection, sea walls.
STORAGE TANKS	Water (detention, retention, stormwater pits), waste water, sewerage, sludge, petrol, manure, grain and contaminated soil.
SPECIAL USES	Bushfire Prone Areas, mine subsidence areas, sound barriers, prevent the migration of contaminated ground water, construction in acid sulphate soils, bund walls to protect islands against rising ocean levels, protect fresh water lagoons against sea water invasion, reclaimed lands in coastal areas for developments, energy free flood levies to protect township or generate flood free developable lands.

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