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Analysis of Heat Reduction through Roof Using Innovative Insulation Technique

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Abstract: Buildings have a significant and continuously increasing impact on the environment. The power consumption for comfortable housing is ever increasing, which is adding additional burden to the power crisis of the world. The main objective of this project is to reduce the heat transfer through the building roof by providing thermal insulation, thereby reducing the heat load on the building. Moreover, if the building is to be air-conditioned then effective thermal insulation will reduce the power consumption drastically and saves lot of energy consumption. New innovative type of insulation is proposed in this work to reduce the heat transfer through roof structure by using seashells and coconut shells. The coconut shells and seashells layer along with normal tiles will provide very good thermal insulation and it will maintain low roof bottom surface temperature when compared with the normal conventional concrete roof without insulation. Two identical experimental rooms were constructed on the top of the college mechanical engineering department block and were instrumented with thermocouple and RTD along with data logger for obtaining continuous experimental results. The amount of heat reduction provided by the insulated roof structure was calculated using the analytical method. Then the cooling load requirement for air-conditioning and the corresponding energy cost per year was calculated for the new CAD lab of the mechanical engineering department. The result showed the huge energy savings potential for this innovative thermal insulation technique. The electricity savings obtained is around 39.7%.when compared with the conventional concrete roof. This innovative technique for providing thermal insulation to the building is more affordable and comfortable for living.

Keyword: Thermal Insulation, Power Consumption, Cooling Load.

1. RECENT TECHNOLOGY FOR THERMAL INSULATION OF BUILDING

Below there is given a short description of recent technology re thermal building insulation materials and solutions of today. That is the materials and solutions which are, or which are considered to be, the thermal building insulations with the lowest thermal conductivity today.

1.1 Gas-filled panels (GFP)

Close to VIPs, in principle, is the technology of gas-filled panels (GFP), among others. The GFPs has less thermal conductive than air, e.g. argon (Ar), krypton (Kr) and xenon (Xe), instead of a vacuum as in the VIPs. To maintain the low-conductive gas concentration inside the GFPs and avoid air and moisture penetration into the GFPs are crucial to the thermal performance of these panels. Vacuum is a better thermal insulator than the various gases employed in the GFPs. On the other hand, the GFP grid structure does not have to withstand an inner vacuum as the VIPs. Low emissivity surfaces inside the GFPs decreases the radiative heat transfer. Thermal conductivities for prototype GFPs are quite high, e.g. 40* W/m-K, although much lower theoretical values have been calculated. Hence, the GFPs hold many of the VIPs advantages and disadvantages. Nevertheless, the future of GFPs as thermal building insulation may be questioned or even doubtful, as compared to them the VIPs seem to be a better choice both for today and tomorrow [2].

1.2 Aerogels

Aerogels represent a state-of-the-art thermal insulation solution and may be the most promising with the highest potential of them all at the moment. Using carbon black to suppress the radiative transfer, thermal conductivities as low as4* W/m-K may be reached at a pressure of 50 mbar. However, commercially available state-of-the-art aerogels have been reported to have thermal conductivities between 13 and 14* W/m-K at ambient pressure. The production costs of aerogels are still very high. The tensile strength may be increased by incorporation of a carbon fiber matrix. A very interesting aspect with aerogels is that they can be produced as opaque, translucent or transparent materials, thus enabling a wide range of possible building applications. Aerogels have relatively high compression strength but is very fragile due to its very low tensile strength. For aerogels to become a widespread thermal insulation material for opaque applications, the costs have to be lowered substantially [2].

1.3. Phase Change Materials (PCM)

Phase change materials (PCM) are not really thermal insulation materials, but since they are interesting for thermal building applications, they are mentioned within this context. PCMs, change phase from solid state to liquid when heated, thus absorbing energy in the endothermic process. When the ambient temperature drops again, the liquid PCMs will turn into solid state materials again while giving off the earlier absorbed heat in the exothermic process. Such a phase change cycle stabilizes the indoor building temperature and decreases the heating and cooling loads. Various paraffins are typical examples of PCMs, but a low thermal conductivity and a large volume change during phase transition limit their building application [2].

2. PROPOSED INNOVATIVE INSULATION TECHNIQUE

The major drawbacks of the existing insulation materials are its high cost, difficult to manufacture, installation problems, availability, health problems to humans, etc. So it was always better to look to nature for inspiration and innovation. Roof insulation with naturally available, reliable and eco-friendly materials is one of the viable, dependable and economical option. In this line seashells along with coconut shells are used for insulating the building roof structure. Seashell consists of an outer shell which is a hard, protective outer layer created by the animal itself when it lives in the sea. Empty seashells are often available on beaches and are stacked on the sea beds when the animals die. Especially in South India, they are available in a larger amount. Traditionally seashells are used for making lime powder. Coconuts are used by Indians as an eatable; however, their outer shell is being discarded for burning. The activated carbon produced from coconut shell is considered extremely effective for the removal of impurities. Half-cut coconut shells are used in theater for enhancing sound effects and some dried half shells are used as the bodies for musical instruments.

Fig. 2.1 Proposed Innovative Insulation Technique

These materials can also be used for insulation. It will be more effective and cost beneficial to everyone. Experimental and analytical analysis are done with a model building structure using this innovative idea by making naturally available materials such as seashell and coconut shell. The results are very encouraging to provide an affordable and comfortable building.

3. SOLUTION METHODOLOGY

The amount of heat transferred into building decides the power requirement for the air conditioning. If the infiltration of heat into the building through the roof can be reduced corresponding power consumption for air-conditioning can be reduced and there is a huge saving in electricity cost. Thus the project aims to reduce the amount of heat transferred into the building through the roof. The main focus of the project is to reduce the heat transfer from building a roof by utilizing naturally available, reliable, cost effective materials. In this work seashells and coconut shells are used innovatively for insulation. The roof structure used us for our investigation is described below.

3.1 MODELING OF CONVENTIONAL AND INSULATED ROOF

The roof model used for the analysis is shown in following figures.

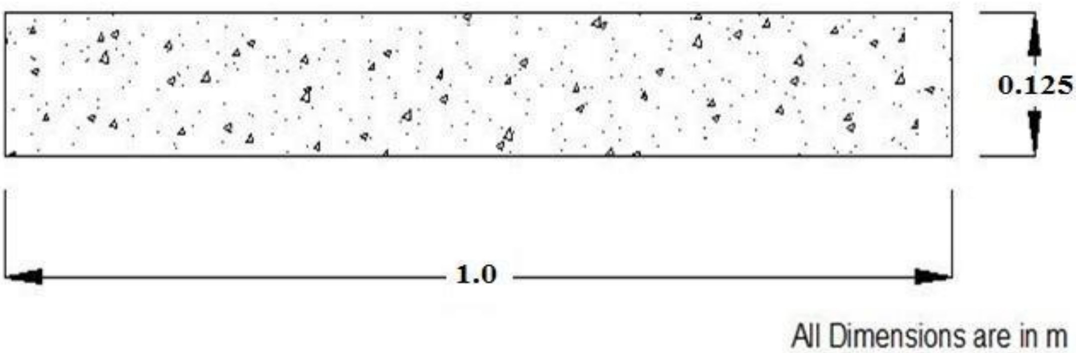


Fig. 3.1 Conventional Reinforced Cement Concrete (RCC) without any insulation

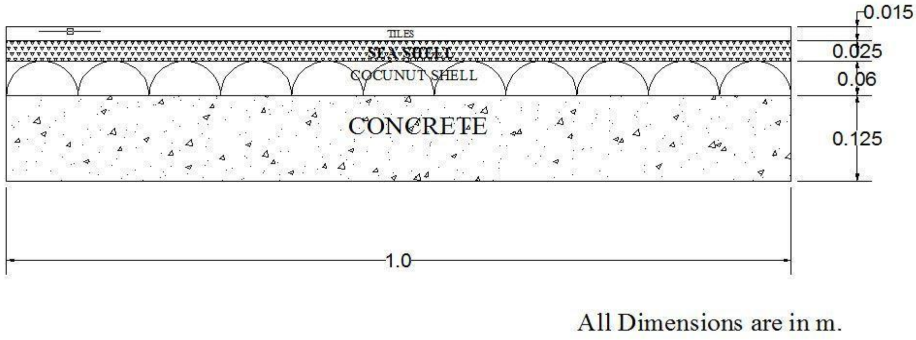


Fig. 3.2 Proposed RCC roof with Seashell and Coconut Shell

3.2 Experimental Rooms

Two rooms having the same dimension, orientation, and the specification was constructed on the top floor of mechanical engineering department as shown in Fig. 6.6.The dimension of the rooms is 1m×1m×1m which is the length, breadth, and height respectively. The roof of these two rooms was constructed using reinforced cement concrete (RCC) by conventional methods. One side of the room is kept open for airflow and it will resemble a door opening of a normal building. The top of one roof and another roof top was kept as such only with a conventional concrete roof (i.e. without insulation). The data logger is connected to a computer installed with eScan9.0 software and the thermocouples are placed at the various nodes of the roof and continuous half-an-hour average temperature values were taken to the computer and logged into the computer hard drive.

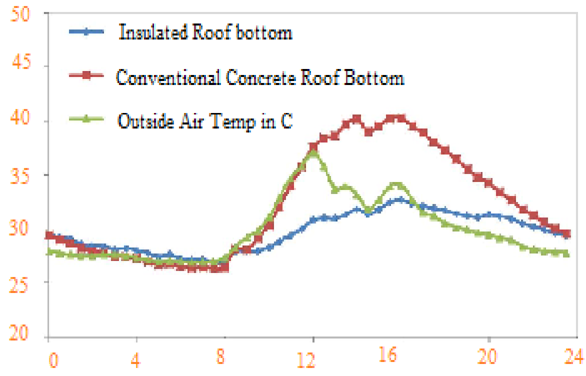
Fig 3.3: Experimental Rooms for analyzing the thermal interference

Fig 3.4: Proposed Innovative Thermal Insulation

3.3 VARIATION OF ROOF BOTTOM SURFACE TEMPERATURE

The temperature measurements were continuously recorded for 3 days and the final day value was analyzed for thermal performance. The following graph explains the variation in concrete roof bottom surface temperature with and without an insulated surface for a period of 3 days.

On Day 1



On Day 2

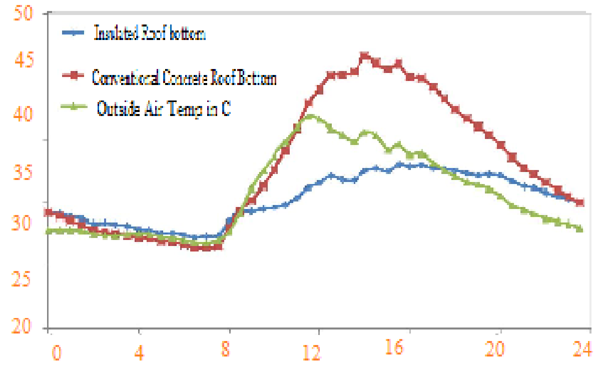
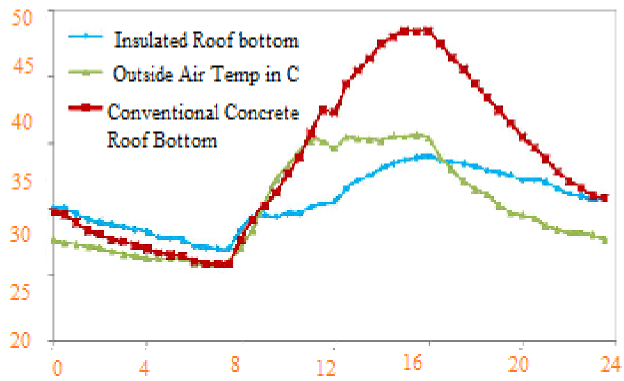


Fig 3.5: Variation of roof bottom surface temperature on day1

Fig 3.6: Variation of roof bottom surface temperature on day2

The maximum temperature on concrete roof bottom without insulation is 40.2 °C at 4 p.m as shown in Fig.3.5.However, the maximum temperature on insulated roof bottom surface is 32.68 °C, recorded at 4 p.m. So, there is a reduction of about 7.52 °C, with this innovative thermal insulation. From Fig. 3.6 the maximum temperature on concrete roof bottom without insulation is 41.56°C recorded at 2 p.m. However the maximum temperature on insulated roof bottom surface is 33.06 °C, recorded at 3.30 p.m. So, there is a reduction of about 8.5°C, with this innovative thermal insulation

On Day 3



The maximum temperature on concrete roof bottom without insulation is 43.42 °C recorded at 3 p.m. However, the maximum temperature on insulated roof bottom is 33.97 °C recorded at 3.3 p.m. So, there is a reduction of about 9.45 °C with this innovative insulation.

Table No. 3.1: Temperature and Heat Flux variations for day1

Time of the Day	Convectional Concrete Roof bottom Surface Temp (°C)	Insulated Roof bottom Surface Temp (°C)	Room Temp (°C)	ΔT Without insulation (°C)	ΔT With insulation (°C)	Heat Flux without insulation W/m2	Heat Flux with insulation W/m2
9	28.07	27.93	23	5.07	4.93	50.7	49.3
10	30.3	28.23	23	7.3	5.23	73	52.3
11	34.01	29.39	23	11.01	6.39	110.7	63.7
12	37.54	30.77	23	14.54	7.77	145.4	77.7
13	38.63	30.93	23	15.63	7.93	156.3	79.3
14	40.1	31.81	23	17.1	8.81	171	88.1
15	39.52	31.76	23	16.52	8.76	165.2	87.6
16	40.2	32.68	23	17.2	9.68	172	96.8
17	38.9	32.12	23	15.9	9.12	159	91.2
18	37.27	31.71	23	14.27	8.71	142.7	87.1
19	35.49	31.19	23	12.49	8.19	124.9	81.9
20	34.23	31.29	23	11.23	8.29	112.3	82.9
21	32.67	30.88	23	9.67	7.88	96.7	78.8
Total heat flux entering the room during 12 hours W-hr/m^2						3281.3	1963.1

Table No. 3.2: Temperature and Heat Flux variations for day2

Time of the Day	Convectional Concrete Roof bottom Surface Temp (^{0}C)	Insulated Roof bottom Surface Temp (^{0}C)	Room Temp (^{0}C)	ΔT Without insulation (^{0}C)	ΔT With insulation (^{0}C)	Heat Flux without insulation W/m2	Heat Flux with insulation W/m2
9	30.17	29.28	23	7.17	6.28	71.7	62.8
10	32.63	29.56	23	9.63	6.56	96.3	65.6
11	35.58	30.39	23	12.85	7.39	128.5	73.9
12	39	31.52	23	16	8.52	160	85.2
13	40.15	31.77	23	17.15	8.77	171.5	87.7
14	41.56	32.47	23	18.56	9.47	185.6	94.7
15	40.6	32.46	23	17.6	9.46	176	94.6
16	39.94	32.86	23	16.94	9.86	169.4	98.6
17	39.11	32.75	23	16.11	9.75	161.1	97.5
18	37.37	32.53	23	14.37	9.53	143.7	95.3
19	35.98	32.14	23	12.98	9.14	129.8	91.4
20	34.53	32.11	23	11.53	9.11	115.3	91.1
21	32.74	31.25	23	9.74	8.25	97.4	82.5
Total heat flux entering the room during 12 hours W-hr/m^2						3541.9	2179.6

Table No. 3.3: Temperature and Heat Flux variations for day3

Time of the Day	Convectional Concrete Roof bottom Surface Temp (^{0}C)	Insulated Roof bottom Surface Temp (^{0}C)	Room Temp (^{0}C)	ΔT Without insulation (^{0}C)	ΔT With insulation (^{0}C)	Heat Flux without insulation W/m2	Heat Flux with insulation W/m2
9	30.22	29.47	23	7.22	6.47	72.2	64.7
10	32.62	29.6	23	9.62	6.6	96.2	66
11	35.7	30.1	23	12.7	7.1	127	71
12	37.24	30.53	23	14.24	7.53	142.4	75.3
13	40.41	32.1	23	17.41	9.1	174.1	91
14	42.41	33.02	23	19.41	10.02	194.1	100.2
15	43.42	33.68	23	20.42	10.68	204.2	106.8
16	43.41	33.97	23	20.41	10.97	204.1	109.7
17	41.47	33.51	23	18.47	10.51	184.7	105.1
18	39.43	33.18	23	16.43	10.18	164.3	101.8
19	37.39	32.72	23	14.39	9.72	143.9	97.2
20	35.39	32.15	23	12.39	9.15	123.9	91.5
21	33.73	31.95	23	10.73	8.95	107.3	89.5
Total heat flux entering the room during 12 hours W-hr/m^2						3797.1	2261.3

Table No. 3.4: Comparison of Heat Flux on 3 Days

Day	Total heat flux entering the room per day (without Insulation – W/m^2 – day)	Total heat flux entering the room per day (with Insulation – W/m^2 – day)	Reduction of heat flux (%)
Day 1	3281.3	1963.1	40.17
Day 2	3541.9	2179.6	38.46
Day 3	3797.1	2261.3	40.45

Average Heat flux entering the room per day,

Without insulation = 3540.1 W/m^2-day

With insulation = 2134.67 W/m^2-day

Average Reduction of Heat flux entering into the room= 39.69 %.

Thus we found out that we get 39.69 % reduction of heat flux entering the room by adopting our proposed roof insulation. It directly reflects the corresponding savings in the electricity used to maintain at 23 °C.

3.4 COOLING LOAD ESTIMATION

The total quantity of heat to be removed from the space to be conditioned to the desired temperature by using air conditioning equipment is known as the cooling load. The objective of this project work is to reduce the cooling load on the air-conditioning system thereby reduces the power consumption and the cost associated with it. For this analysis, the new CAD lab on the top floor of the mechanical department is considered.

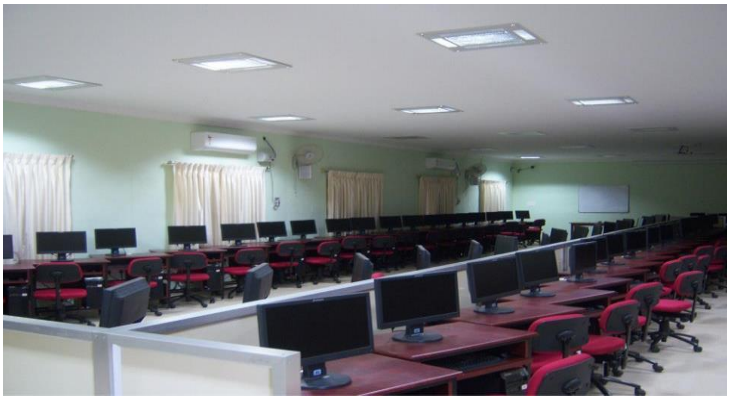


Fig. 3.5 inside view of new CAD lab of mechanical engineering department, MIT

Table No: 3.5 Specifications of the new CAD lab of Mechanical Engineering Department, MIT

Description	Dimension & Unit
Length of the lab	21 m
Breadth of the lab	9.9 m
Top surface area of the lab	207 m^2
Conditioned temperature of the lab	23°C
Working hours per day	12 Hrs
Cost of Electricity cost /unit	Rs. 8
Assumed COP for split A/C	3
No. of working days per year	250 days

3.4 POWER AND COST SAVINGS

For conventional reinforced concrete roof (RCC) without insulation:
Average heat flux entering the room per day per unit surface area = 3540.1 W-hr/m^2-12 hrs
Roof surface area of the lab = 207.9 m^2
the quantity of Heat entering through roof = 3540.1×207.9= 735.98 kW-hr/day (No. working hours per day is 12)
COP = [Cooling Effect / Power Consumption]
Cooling effect required = the amount of heat entering the room
Power Consumption =735.98/3 = 245.32 kW-hr /day.
Cost of Electricity /day= Units consumed per day × Cost/unit = 245.32×8 = Rs.1962.63/day
Cost of Electricity /year= Units consumed per year × Cost/unit = 245.32×250×8
(No. of working days per year is 250 days) = Rs.490,657.86/year
For conventional reinforced concrete roof (RCC) with innovative thermal insulation to the roof:
Average heat flux entering into the room per day per unit surface area =2134.67 W-hr/m2-12 hrs
Roof surface area of the lab = 207.9 m2
The quantity of heat entering the lab through roof =443.79 kW-hr/day (No. working hours per day is 12)
Power Consumption =443.79/3= 147.932 kW-hr /day.
Cost of Electricity /day= Units consumed per day × Cost/unit = 147.932×8= Rs.1183.461/day
Cost of Electricity /year = 147.932×250×8 = Rs.295,865.26/year (No. of working days per year is 250 days)
Cost of electricity savings /year = Rs.490,657- Rs.295,865 = Rs 194,792

Table No: 3.2 Energy and Cost of Electricity savings

Roof of the Lab	Average Heat Flux / Day W/m^2	Cost of the Electricity / Year in Rupees	Power Consumption Kw-Hr/Day	Cost Saving / Year in Rupees	% of Cost Savings / Year
With Out Insulation	3540.1	490,657	245.32	-	-
With Insulation	2134.67	295,865	147.23	194,792	39.7%

Thus, by adopting this new innovative roof insulation on top of the mechanical engineering department CAD lab the cost of electricity per year is reduced when compared with the conventional concrete roof. The power consumption and cost of electricity for both conventional reinforced concrete roof and reinforced concrete roof with insulation are shown in Table in 3.2.

CONCLUSION

'Go green to save the earth,' that's the motto of this project work. That is, to reduce the energy consumption of a building and to make it affordable and sustainable. New innovative thermal insulation using naturally available material was provided above the conventional RCC roof to reduce the major portion of heat gain in an air-conditioned space. The heat reduction analysis for this innovative constructional material was carried out to quantify the energy and cost saving achieved through this project. The following are the major findings of this project work. By adopting this new innovative thermal insulation technique, average heat flux entering the room is reduced by 39.69% compared to the conventional concrete roof. By adopting this new innovative thermal insulation technique, the energy consumption is reduced by 39.7% compared to conventional concrete roof in CAD lab taken for case study in this project work By adopting this new innovative thermal insulation technique, cost of electricity is reduced by 39.7% compared to conventional concrete roof in CAD lab studied for this project work. Thus this new innovative insulation technique provides very good thermal insulation and makes huge savings in electricity cost. By adopting this innovative technique the building can be made more affordable and comfortable for living.

REFERENCES

[1] Ahmad Okeil (2010), "A holistic approach to energy efficient building forms", Energy and Buildings, Vol. 42 pp. 1437–1444.
[2] Bjørn Petter and Jelle (2010), "Traditional, state-of-the-art and future thermal building insulation materials and solutions – Properties, Requirements and Possibilities". Energy and Buildings, Vol. 43 pp. 2549–2563.
[3] Chau C.K., Tse M.S., and Chung K.Y. (2010), "A choice experiment to estimate the effect of green experience on preferences and willingness-to-pay for green buildings", Building and Environment, Vol.45 pp. 2553-2561.
[4] Castleton H.F., Stovin V., Beck S.B.M. and Davison J.B. (2010)" Green roofs; building energy savings and the potential for retrofit", Energy and Buildings, Vol. 42 pp. 1582– 1591.
[5] Gupta J.K., Khurmi R.S. (2002) "A textbook of Refrigeration and Air Conditioning", pp.527-571.
[6] Jerry Yudelson (2007) "GREEN BUILDING A To Z Understanding the Language of Green Building", pp. 3-70.
[7] Michael Bauer, Peter Mösle and Michael Schwarz "Green Building-Guide Book for sustainable architecture", pp.11-90
[8] Sami A. Al-Sanea (2002) "Thermal performance of building roof elements", Building and Environment, Vol. 37, pp. 665 – 675.
[9]Tahir Ayata, Paulo Cesar Tabares-Velasco and Jelena Srebric (2011), "An investigation of sensible heat fluxes at a green roof in a laboratory setup", Building and Environment, Vol.461 pp.851-1856.
[10]Vijaykumar K.C.K., Srinivasan P.S.S and Dhandaphani S. (2010) "An investigation on a performance of hollow clay tile (HCT) laid reinforced cement concrete (RCC) roof for tropical summer climates", Energy and Buildings, Vol.39 pp. 886–892.
[11] Warren L. Paul and Peter Taylor A. (2010), "A comparison of occupant comfort and Satisfaction between a greenbuilding and a conventional building", Building Environment, Vol.43 pp.1858-1870.
[12]William S. Janna (1986) "Engineering Heat Transfer", PWS Engineering, Bolton.
[13]Zhai X.Q., Wang. R.Z, Dai Y.J., Wu J.Y., Xu Y.X.and MaSolar Q. (2007), "Integrated energy system for a green building", Energy and Buildings, Vol. 39, pp. 985–993.
[14]http://en.wikipedia.org/wiki/Green_building.

