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A Review on Integration of Net Zero Energy Building with Smart Grid Energy Piles

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ABSTRACT

The concept of net zero energy building is to develop a structural building which can generate its own required energy and have zero negative effects . The energy will be enough to fulfill all the requirements of the building operations and can save natural quarries . Net zero homes are as beneficial to homeowners as they are to the environment . For example , by curtailing harmful emissions , energy usage , and unnecessary waste , these homes support the future of sustainability while reducing our carbon footprint . This review study represents the current state of knowledge about the thermal and thermo-mechanical behaviors of energy piles . It also investigates the key parameters that effects their design . It is found that thermal efficiency improves significantly by increasing the number of pipes inside the piles and by adding thermally conductive materials to the concrete within acceptable limits . It is concluded that a multi-objective optimization is highly recommended to enhance the dual performance of an energy pile system coupled with a heat pump using the 4E evaluation criteria (energy, energy , economy , and environment) while ensuring the safety of the foundation under thermal cyclic loads Therefore , Net zero is important as it's the best way we can tackle climate change by reducing global warming . This energy will be enough to fulfill all the requirements of the building operations and can save our nature also.

Keywords: ZERO ENERGY, NZEB, LESS ENERGY

1. INTRODUCTION

In order to design and construct a building with less energy consumption and low carbon emission we have to study about the net zero energy building (NZEB) concept. In past 10-20 years, integrating heat exchanger pipes in geo-structure for space cooling and heating of buildings has received increasing attentions . This environmentally friendly technology can be applied to all types of soil-embedded structure such as tunnels , shallow foundation , diaphragm walls, and piles. Energy piles remains the most common application among all of these types geo-structure for the ground heat exchange process. Many study like experimental tests , analytical methods and numerical modeling have been carried out to assess the performance of energy piles . Energy piles remains a complex process due to interaction between the ground and the activated piles . In order to design and construct a building with less energy consumption and low carbon emission we have to study about the net zero energy building (NZEB) concept. In past 10-20 years, integrating heat exchanger pipes in geo-structure for space cooling and heating of buildings has received increasing attentions . This environmentally friendly technology can be applied to all types of soil-embedded structure such as tunnels , shallow foundation , diaphragm walls, and piles. Energy piles remains the most common application among all of these types geo-structure for the ground heat exchange process. Many study like experimental tests , analytical methods and numerical modeling have been carried out to assess the performance of energy piles . Energy piles remains a complex process due to interaction between the ground and the activated piles . Structure.

1.1 Net Zero Energy Building

A zero-energy building is a building with zero net energy consumption . The total amount of energy used by the building on an annual basis is roughly equal to the amount of energy generated on the site through renewable sources . These buildings consequently contribute less overall greenhouse gas to the atmosphere than similar non-zero net energy buildings.

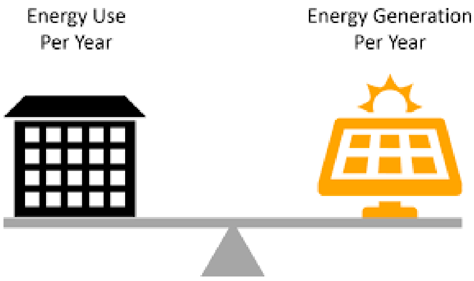


Fig. 1.1 NZEB concept

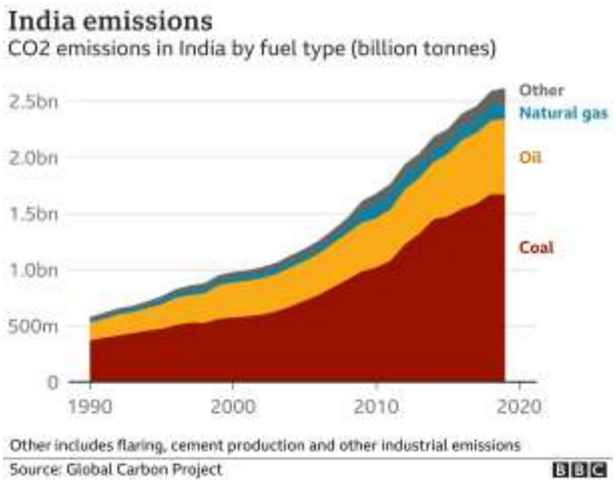
Table 1.1 Net zero energy buildings data of last years

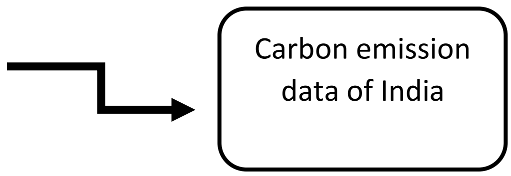
1.2 Carbon Emission

Green house gas emission from human activities strengthen the green house effect , causing climate change . Most is carbon dioxide from burning fossil fuels : coal , oil , and natural gas . The largest emitters include coal in China and large oil and gas companies , many states-owned by OPEC and Russia . Human caused emissions have increased atmospheric carbon dioxide by about 50% over pre – industrial levels . The growing levels of emissions have varied , but it was consistent among all greenhouse gases . Emissions in the 2010s averaged 56 billion tons a year , higher than even before .

Electricity generation and transport are major emitters , the largest single source being coal-fired power stations with 20% of GHG . Deforestation and other changes in land use also emit carbon dioxide and methane emissions is agriculture , closely followed by gas venting and fugitive emissions from the fossil-fuel industry . The largest agricultural methane source is livestock . Agricultural soil emit nitrous oxide partly due to fertilizers . Similarly , fluorinated gases from refrigerants play an outsized role in total human emissions .

At current emission rates averaging 6 and ½ tones per person per year , before 2030 temperature may have increased by 1.5 degree Celsius over pre-industrial levels , which is the limit for the G7 countries and inspirational limit of the Paris Agreement





1.3 Energy piles

Energy piles are relatively a new technology that have dual function as heat transferring and load bearing . In some cases for storage of energy (from warm to cold periods) and for heating and cooling of buildings energy piles can be used . The ground source heat pump heat exchange tubes are embedded in the pile foundations of traditional buildings to provide heat exchange and cooling for the upper building space . It can take full use of the larger thermal conductivity of concrete as compared to traditional ground source heat pump systems and the contact area with the surrounding soil to improve heat exchange efficiency and save underground space resources .

Energy pile typically contains approx 60-80 meters of geothermal heat hoses . As opposed to traditional , horizontal solutions , where geothermal heat hoses are placed approx 1.5 meters below the ground surface , the heat from the energy piles is collected vertically through the layers of the subsoil from 1 meter and down to 18 meters below ground .

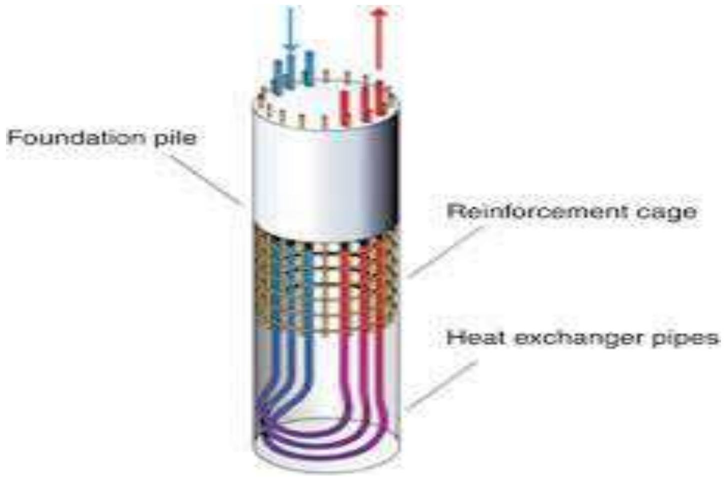


Fig 1.3 Energy piles

Construction sequence of energy piles

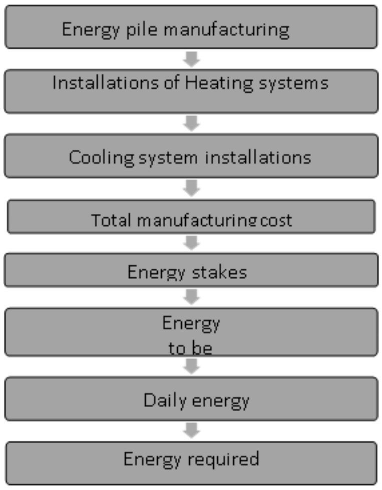
The installation functioning takes place over an annual cycle :

1. **In winter**
   1. When the water is colder than the soil , heat is removed from the circulating fluid .
   2. Rendering of higher temperature to the heating is done .
2. **In summer**
   1. Conversely , when the water is warmer than the soil , heat is dissipated into the soil for cooling .
3. **During screwing-in phase**
   1. A soil displacing screw head inserts the guide tube to the correct design depth .
4. **During screwing-out phase**
   1. As the auger is simultaneously withdrawn while rotating concrete is pumped into the borehole through the hollow central tube of the auger .
5. **Fitting phase**
   1. The reinforcement , fitted with integrated heat exchangers in collector pipes , is then placed into the concreted pile .
   2. A heat exchange fluid (usually simply clear water) circulates in an u-shaped pipe loop located between the piles and a heat pump and is heated or cooled by surrounding soil .

2. METHODOLOGY AND EXPERIMENTATIONS

Introduction:

Energy Piles represents a sustainable geo-energy solution with significant environmental and economic advantages . They combine structural components of the buildings with ground source heat technologies which can be used for heating and cooling applications . In residential area , office , commercial buildings since they are a combination of ground structures needed for stability and energy source which results in an additional low costs . Therefore we have to focused both their experimental and numerical work to enhance the understanding of the behavior of thermal piles under significant temperature changes . Due to the fact that implementation of underground geo structure is currently in its beginnings in some European countries , further research in that area is crucial to have a clear understanding on the performance of such structure and their impact on the overlaying building and the surrounding



Energy Pile Heat-Exchanger function : The energy piles also called heat exchanger piles because these are equipped with individual or several pipe circuits in order to enable exchange of heat with the surrounding soil .The function of energy piles is dual .

1) The first function consists of transferring load from a construction into the bearing layer .

2) The second function is the use as heat exchanger with the soil .

Energy piles are installed either using soil displacements techniques or soil excavation systems .

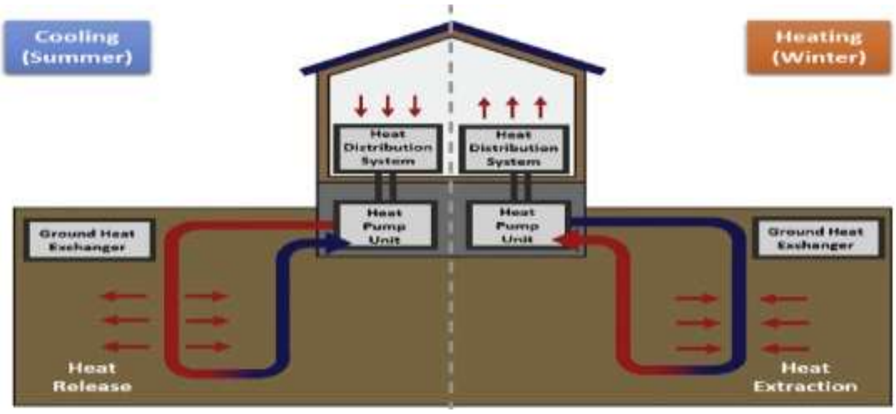


fig. 1.4 Energy pile heat exchanger

3. OBSERVATIONS AND RESULTS

1) Temperature changes effects: The global climate is undergoing major upheavals , posing a serious risk of premature obsolescence for the current nZEB. In study it is seen that urban heat island phenomenon is more accentuated in the area closer to the city center . The following conclusions are below:

1) The respective rises of 3.4 dc and 3.9 dc by 2050

2) Peak electricity demands is especially worrisome since it is usually covered by low efficiency power plants , yet it is strongly associated with typical nZEB . In fact , while air conditioning is only a fraction of all building energy uses , it is the primary driver of peak electricity demand . Efficiently curbing the air conditioning needs by targeting a resilient nZEB design will be key in the future .

3) By 2050 , not only temperature rise , but a 19.7% increase in global solar irradiance on the horizontal plane is also to be expected during the summer months , thus triggering higher solar gains .

The increase in the solar irradiance does not apply an increase in the solar contributions inside the building because the national nZEB regulation foresees the use of mobile shading devices for the whole summer period . These system appear rather effective , since the increase in the solar gains is negligible in summer , but becomes evident in winter .

It was demonstrated that the comfort implications of the pronounced excursion and large variations in daily temperature will be marginal and with greater influence on northwest rather than southeast oriented thermal zones , likely owing to the effect of the combination of higher temperatures and higher solar irradiation in leveling out the daily swings .

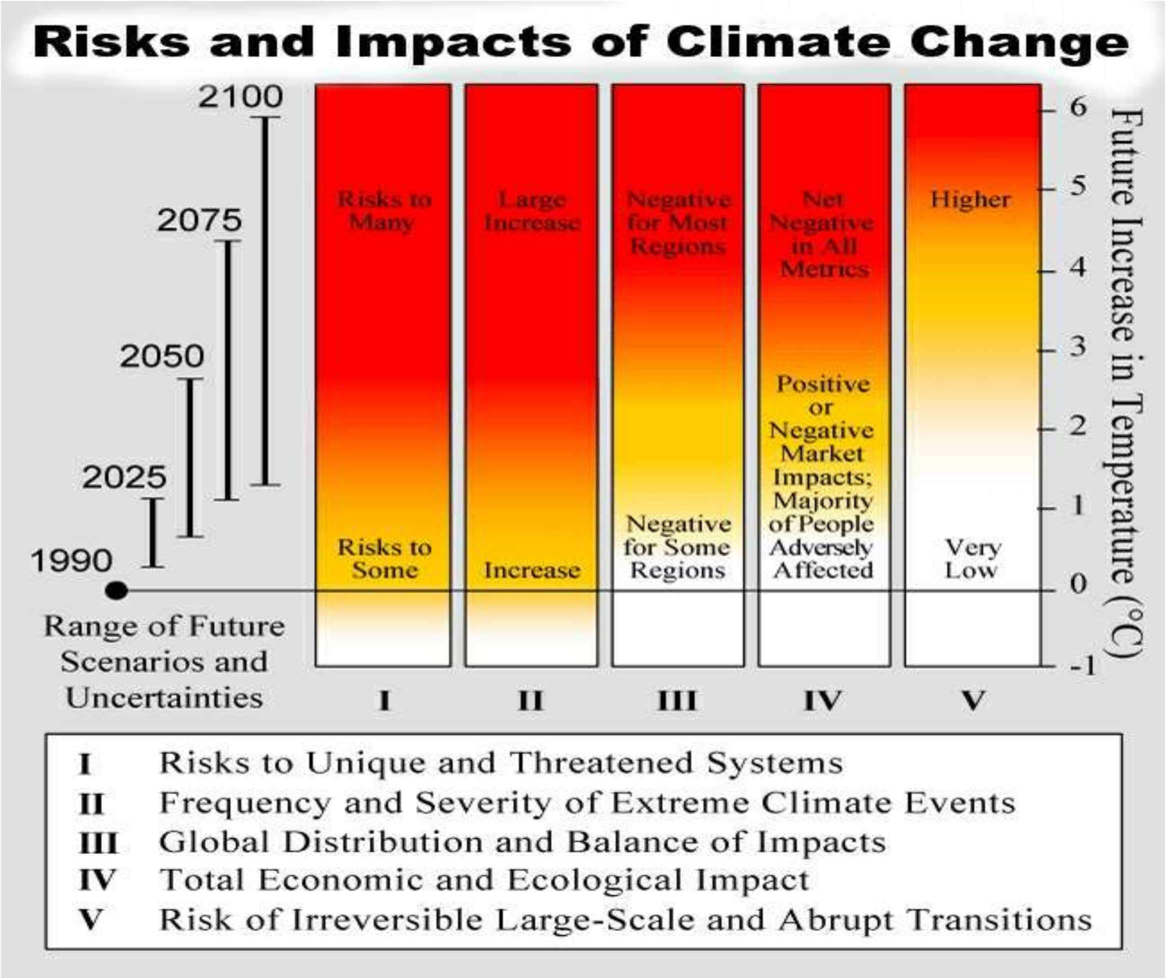


Fig.1.5 Temperature changes effects in upcoming years

2) **Heat exchange capacity** : For heat exchangers , heat transfer per unit temperature difference and heat capacity is defined by effectiveness of heat exchanger and capacity ratio of hot and cold streams . Effectiveness of heat exchanger decreases as capacity ratio increases .

Heat exchange capacity = Effectiveness of heat exchanger / Capacity of hot and cold streams

-Heat transfer performance of heat pipe exchanger affected by many factors :

1) such as the opening temperature of the heat pipe
2) the rate of fluid filled
3) the physical nature of liquid refrigerant
4) the work temperature of the tube
5) angle of the tube
6) tube spacing
7) tube length increment
8) hot and cold fluid flow and wind speed .

All of these parameters changes the heat pipe heat exchanger performance according to their values .

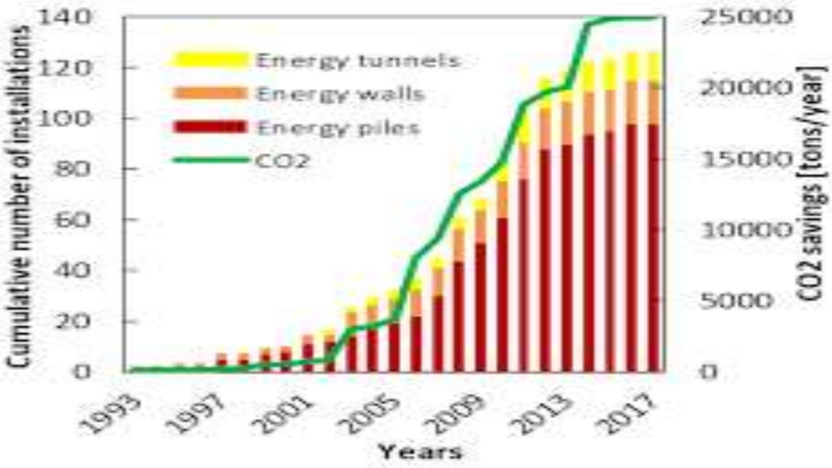


Fig.1.21 Heat exchange capacity last years data

Years	CO2 savings [tones/year]	Cumulative no of installation
1993	1000	20
1997	5000	40
2001	10000	60
2005	15000	80
2009	20000	100
2013	25000	120
2017	30000	140

Table 1.16 Heat exchange capacity last years data

3) **Efficiency of heat transfer** :

The heat exchanger efficiency is defined as the ratio of the heat transferred in the actual heat exchanger to the heat that would be transferred in the ideal heat exchanger . The concept of heat exchanger efficiency provides a new way for the design and analysis of heat exchangers and heat exchanger networks .

Calculation: 1) the efficiency of a device, such as pile can be calculated as

Efficiency = useful energy out / total energy in (for a decimal frequency)

or

efficiency = (useful energy out /total energy in) * 100 (for percentage frequency)

It is not possible to have an efficiency greater than 1 or an efficiency percentage greater than 100%

This would mean that more energy is being transferred than is being supplied , which would mean that energy is being created . This would break the law of conservation of energy .

Table 1.17 efficiency of heat transfer

Description	Value
Emitted /Supplied output at 0/35°C	5.9/1.3 kW
Emitted /Supplied output at 0/50°C	5.4/1.7 kW
Minimum flow heating medium	0.14 l/s
Nominal flow heating medium	0.20 l/s
Superheat	3 °C
Subcooling	4 °C
Refrigerant R407C mass flow rate	0.02 kg/s
Evaporating temperature (dew point)	-1 °C
Condensing temperature (dew point)	58.9 °C
Evaporating pressure	4.5 bar
Condensing pressure	24.7 bar

4) **Effect on Economy , Environment , Energy , Energy , and Geo-structure** :

On economy : It was found that energy pile GSHP systems are the most cost-effective method for space heating and cooling, with an annual gain ranging between $600 and $2,900 compared to all other efficient HVAC alternatives depending on the reference system. These economic benefits could easily translate into millions when using energy pile GSHP systems in Greenfield developments to accommodate the growing urban population. The better financial feasibility of energy pile GSHP systems is contributed by the reduction in drilling cost and the high energy efficiency of GSHP systems. However, other intangible benefits of energy pile GSHP systems are not factored into the analysis, such as reduced greenhouse gas emissions. In addition, the cost associated with GSHP systems is still relatively high. Thus, with wide adoption of energy pile GSHP systems, especially in regions where soft or collapsible soils exist, the capital cost of energy pile GSHP systems would be further reduced, resulting in further financial benefits .

On Environment : In the past few decades, energy piles have proved to be innovative and environmentally friendly structural elements that function as heat exchangers providing energy to the overlaying structure. Different examples and existing research studies are presented in this paper, providing general information obtained in the previous work. Although this technology has been recently applied in various countries, there are still important knowledge gaps on the consequences of the application of such technology because of the potential risks that might arise due to unforeseen induced cyclic thermal stresses making construction companies reluctant to apply energy piles in daily practice. Potential issues and knowledge gaps related to thermal, hydraulic and mechanical behavior of soil and the soil pile interaction are pointed out which, if further investigated, could help to better understand the long term behavior of such systems .

4. CONCLUSIONS AND FUTURE

Conclusions:

From this study on the energy piles used in the Net zero energy buildings the conclusions find out are given below :

1. The operation of energy piles affects their ultimate and serviceability limit states .
2. Heating cause an increase in shaft resistance , while cooling cause a reduction in shaft resistance resulting in an extra pile settlement.
3. The change of shaft resistance was found to be linear with respect to temperature variation .
4. Contrast to the exiting framework , the neutral plane of an energy pile is not located at the mid depth of the pile .
5. When a replacement floating energy under working load was subjected to heating and cooling cycles , ratcheting pile settlement but at a reduced rate is observed , irrespective of soil type .
6. The serviceability limit states of energy piles have to be carefully designed for, and is a major challenge that has to be solved before more countries are willing to adopt energy piles.
7. Although, benefits of energy piles towards the environment have been widely demonstrated, no existing theory and constitutive soil models can capture the observed ratcheting pile settlement accurately. Hence there are still some countries which are reluctant to use energy piles.

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