Sustainable Design Of Chiller Plant Using Green Techniques

K.S. Anandh, Ankesh Kumar, Deepak Goel, Kaisar Khursheed

Abstract: This paper includes a design and analysis of air cooled chiller plant in green buildings to reduce the overall temperature by 5-7 degree Celsius. The objective of the paper is used to design a sustainable mechanism to cool down the building. Chiller plant is a combination of mainly cooling tower and ducting. In this chiller plant air is used as a cooling agent for building. Design of chiller plant is based on difference of specific heat of concrete and air i.e. the cooling agent and Newton's law of cooling. Air cooled chiller plants will help in reducing the consumption of electricity which is used to reduce the temperature of building. This chiller plant is designed for temperature of 40 degree Celsius and G+2 building with a built-up area of 4050m^2. This paper will support the sustainable developments.

Key words: Chiller plant, Temperature, Green techniques, Specific heat, Sustainable, Design, Chennai, India

1.0 INTRODUCTION

Air cooled chiller plants are used in the building to reduce the overall temperature of the building by 5-7 degree Celsius. Existing chiller plants have a high impact on the power consumptions. Air cooled chiller plant is one whose construction ensures a healthiest interior environment and while using less power, land and natural resources. Air cooled chiller plant is a green project which preserve natural resources that are necessary for sustaining the life and become a producer of resources. Building an air cooled chiller plant is just not an assembling of all the elements i.e. cooling tower, suction fan, pipes, ducting etc. but important is to first ensure about the design optimization and impacts of elements. Design of chiller plant is in such a way that it not only treat the building temperature but also provide proper air circulation with respect of all-weather condition.Air cooled chiller plant is an approach towards sustainable development. Sustainable development is a development that meets the needs of the present without compromising the demands of future generations to meet their own needs. Air cooled chiller plants ducts the air from the cooling tower throughout the building space that requires cooling.

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Chiller plant is designed for G+2 Building of total built up area 4050m^2 at Chennai, India with a temperature of 40 degree Celsius. In large complexes and buildings chiller plants are constructed to cool down the indoor temperature, but normally they consume more power and natural resources. To reduce the use of natural resource and power consumption for cool down the indoor atmosphere of the structure air cooled chiller plant will play a vital role. The basic principle on which air cooled chiller plant works effectively is

- The difference between specific heat of concrete and the air.

Table 1
Specific heat at 25°C

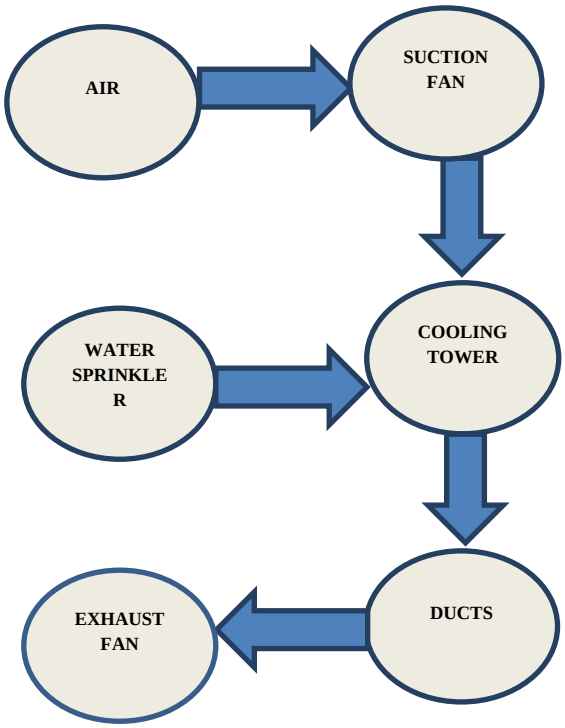
S.No.	Material	Specific heat in J/g°C
1	Concrete	1.020
2	Air	0.880

Specific heat is a measurable quantity of heat energy required to change the temperature of an object by a given amount.

- Newton's law of cooling which states that the rate of change of the temperature of an object is proportional to the difference between its own temperature and the ambient temperature.

2.0 ELEMENTS OF AIR COOLED CHILLER PLANT

Chiller plant is basically an assembling of several elements such as cooling tower, suction fan, water sprinklers, ducting and exhaust fan. For proper functioning of chiller plant all these elements should be properly designed and assembled.



Flow chart 1: Air flow in chiller plant

- **Suction fan**

Suction fan is installed at the top of cooling tower to sucks the atmospheric air that is later going to pass through the cooling tower. High suction pressure in the fan will decrease the density of air. Suction fans are in the position of inclination mainly at 45° to get maximum inlet of air.

- **Cooling tower**

Cooling tower is a heat absorbing devices similar to the shape of chimney and transfers the absorbed heat to atmosphere. Cooling towers are constructed on the terraces or sometimes on the ground; it depends upon the dimensions and use of cooling tower. Cooling towers vary in dimensions and heights may up to the 100-200 meters. Inlet air from suction pump is allowed to pass through the cooling tower.

- **Water sprinklers**

Water sprinklers are fitted on the top of cooling tower, which sprinkles water in a very little amount. Water is sprinkles just to make air saturated with the water vapours that will reduce the temperature of air and increase the moisture content of the air.

- **Ducts**

Ducts are used to deliver the air and maintain the proper flow of air in the building. Ducts are used to ensure the health of indoor air quality. System of ducts is known as a ductwork. In designing of duct important thing is planning and sizing i.e. based on flow of air quantity. Metals are used in construction of ducts for e.g. galvanized steel. Moving of air from ducts cool down the building and remove odd odours from the building.

- **Exhaust fan**

Exhaust fanis used to control the airflow in the ducts by venting out the air from them. Exhaust fans are integrated with the ducts to ensure the proper flow of air in them. Size of exhaust fan depends on the amount of air is to be vented out in how much time.

3.0 EQUATIONS USED IN DESIGNING OF CHILLER PLANT

In designing mathematical model of chiller plant some scientific equations are used

- **Heat transfer equation**

Heat transfer is a discipline of thermal engineering that concerns the generation, use, conversion, and exchange of thermal energy and heat between physical systems.

$$Q = m \times Cp \times \Delta T$$

Q = Heat
m = Mass of concrete
Cp= Spec. heat at constant pressure
ΔT = Change in temperature

- **Newton's Law of cooling**

Newton's law of cooling, states that the rate of heat loss of a body is proportional to the differencein temperatures between the body and its surroundings.

$$Q/A=h\ (Tw-Tt)$$

Q/A = Heat transfer rate
H = Heat transfer coefficient of air
Tw = Temperature of air
Tt = Temperature of cooled air by water

4.0 MATHEMATICAL MODELING OF CHILLER PLANT

In whole day the temperature of concrete roof slab will be 40 degree Celsius. Desired temperature will be 35 degree Celsius and structure is G+2. Chiller plant is designed based on the climate of Chennai (India).

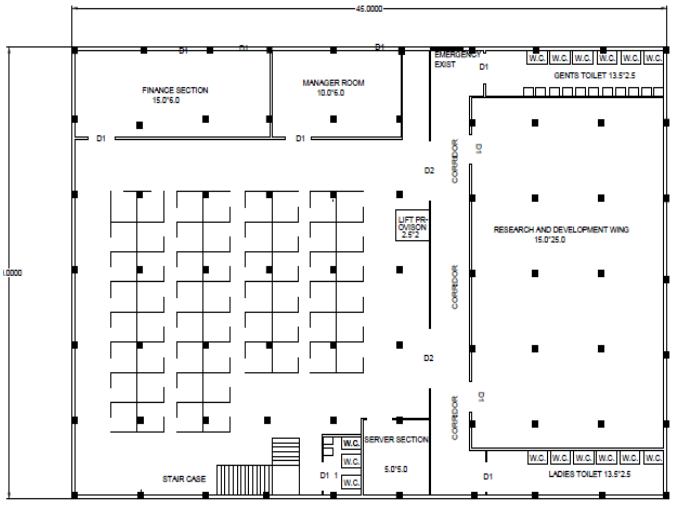


FIGURE 1: PLAN VIEW

Area of slab = 4050 m^2

Overall slab volume = 4050 ×0.30
=1215 m^3

Mass of Concrete in roof slab = Slab volume × Density of Concrete
= V × p
Density of concrete = 2400kg/m^3

Mass of concrete in roof slab = 1215 × 2400
=2916000 kg

Heat required to be removed from roof slab to reduce the temperature by 5degree Celsius

$$Q = m \times Cp \times \Delta T$$

m = Mass of concrete
Cp = specific heat at constant pressure
ΔT = 5 degree Celsius

Q = 2916000 × 0.880 × 5
= 12830400 kJ

We are assuming to cool down the building in 2 hours.
Amount of heat to be removed from building per second
=Q/3600
= 2916000/720000
= 1782 kW

Temperature of air to be supplied from cooling chimney is 35 degree Celsius Heat flux to be removed per second (Newton's law of cooling)

$$Q/A = h\,(Tw - Tt)$$

h = Heat transfer coefficient
Tw = Temperature of Air
Tt = Temperature of cooled air by water

Q/A= 300(40-30)
= 3 kJ/m^2

Heat can be removed from whole building in one second is 1782 kW. Calculation of mass flow rate of air

$Q = m_0 \times Cp \times \Delta T$
m_0 = Mass of air
1782 = m_0 × 1.005 × 5
m_0 = 354.82g

Density of Air at 40 degree Celsius is 1.218 kg/m^3
Volume of air required = 291.11 m^3
Air to be supplied on each floor = 291.11/3
= 97.09 m^3

- **Design of Duct**

Thickness of each duct is ratio of Air to be supplied on each floor to the roof surface area.
Thickness of each duct = 97.03/1050
= 0.09 m

- **Design of Cooling Tower**

Shape of tower = Cuboid
Overall length (l) = 5.8m
Overall Breadth (b) =5.8m
Inner length (l0) = 5 m
Inner breadth (b0) = 5m

Volume = Inner length × Inner breadth × Height
291.11 = 5 ×5×h
Height = 12m
Slanting Height = 2m
Total Height = 14m

5.0 3D MODEL OF CHILLER PLANT

Three dimensional models that will display the image of the structure that it will appear to be physically look. Three dimensional structures include length, breadth and height. Three dimensional structures help in further analysis and simulation work on structure. 3D model of chiller plant is created in ANSYS workbench 14.5 using static structural module.

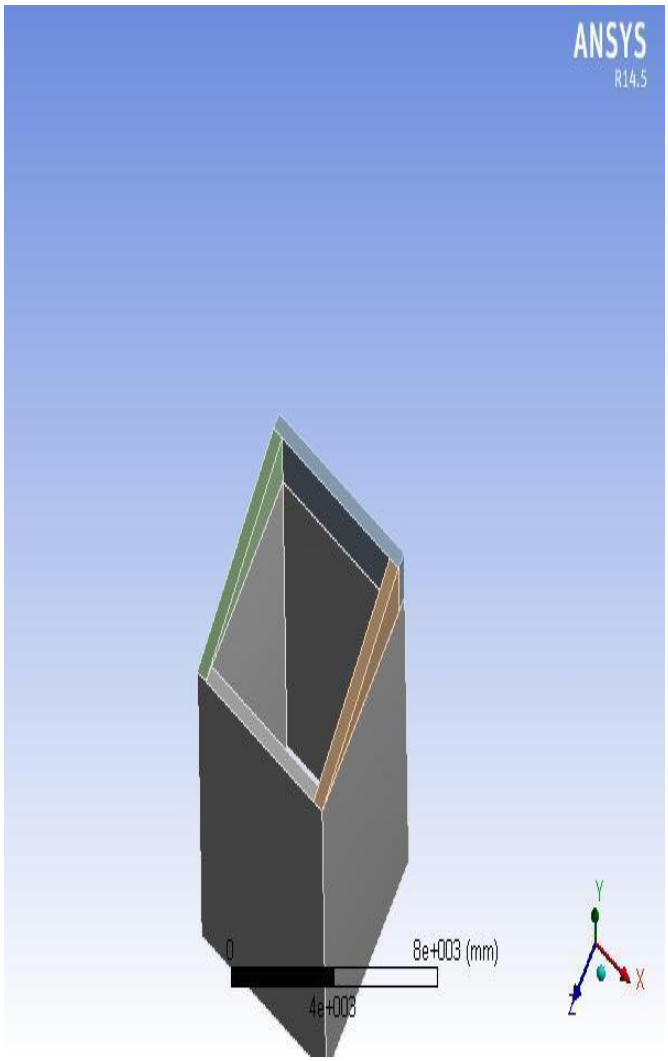


FIGURE 2: 3D MODEL OF CHILLER PLANT

6.0 ANALYSIS OF CHILLER PLANT

Analysis is the process of breaking a complex topic or substance into smaller parts to gain a better understanding of it. Analysis work is done on ANSYS workbench 14.5. Linear static structure is done on the structure. Linear static analysis that is simply providing results on stresses or deformations. Thickness of the concrete wall is 400mm. Structure is taken as fixed at the base and material property is defined as concrete.

Table 2
Structure dimensions

S.No.	Description	Dimension(mm)
1	Length	5800
2	Breadth	5800
3	Height	14000

Analysis is done on the 3D model of the structure to get the results for

- Total deformation of the structure at the time of flow of air in the structure.
- Strain energy i.e. strain energy is the energy stored by a system undergoing deformation. When the load is removed, strain energy is gradually released as the system returns to its original shape.
- Equivalent elastic strain
- Equivalent stress
- Total Deformation

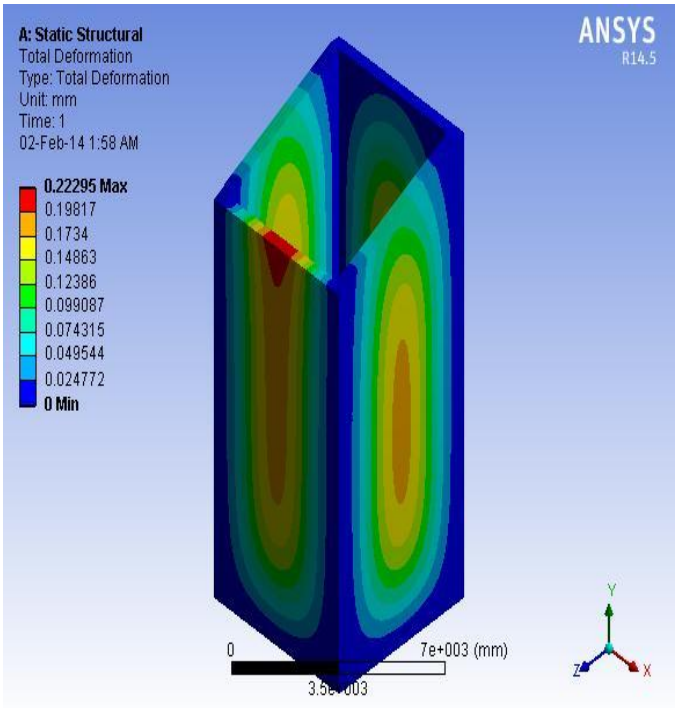


FIGURE 3: TOTAL DEFORMATION ANALYSIS

- Strain Energy

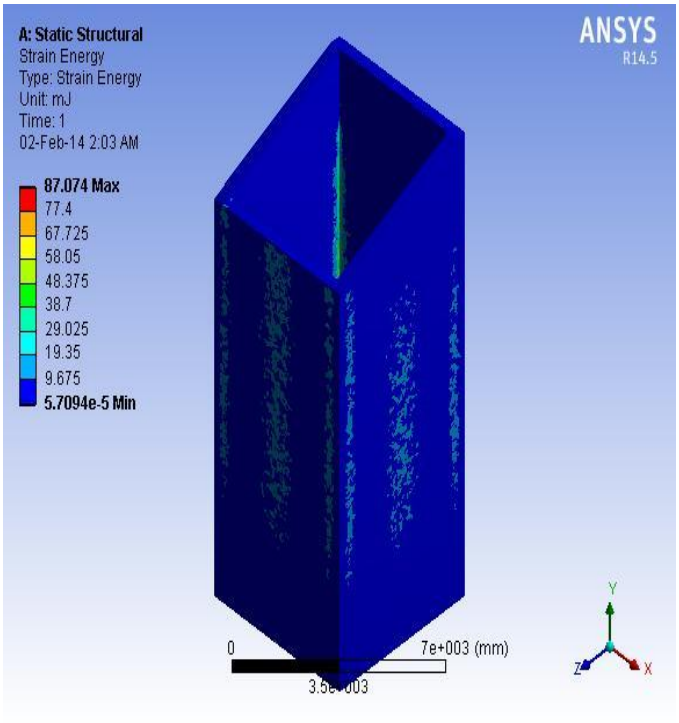


FIGURE 4: STRAIN ENERGY ANALYSIS

- Equivalent Elastic Strain

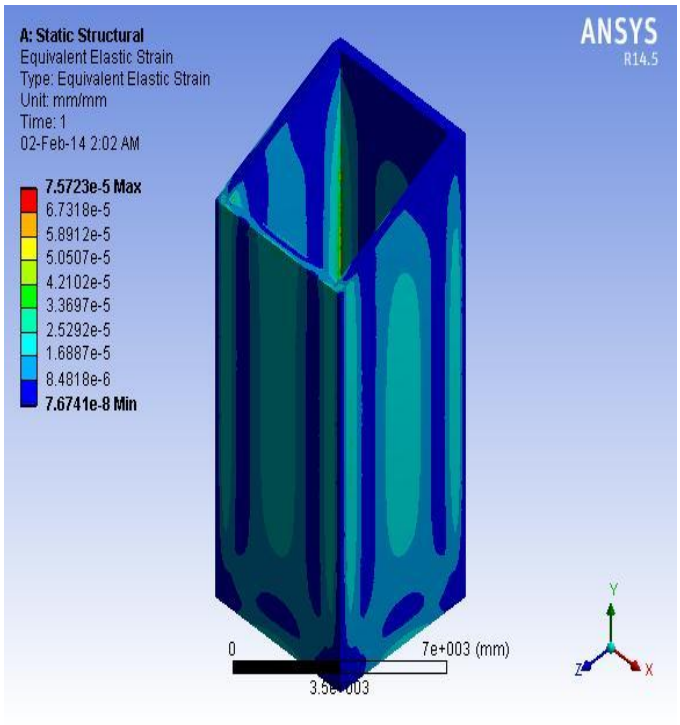


FIGURE 5: EQUIVALENT ELASTIC STRAIN ANALYSIS

- Equivalent Stress

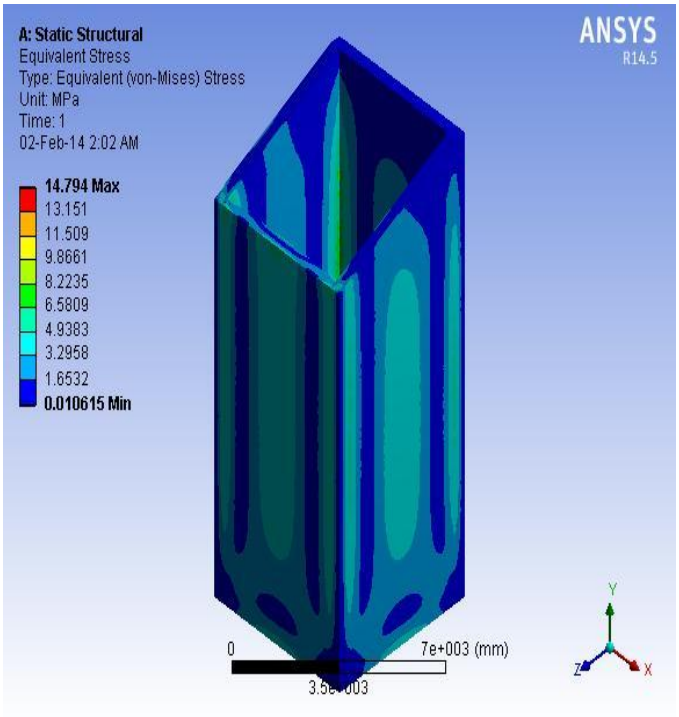


FIGURE 6: EQUIVALENT STRESS ANALYSIS

7.0 ESSENTIAL CHARACTERISTICS OF EFFICIENT CHILLER PLANT

Mainly there are three characteristics of an efficient chiller plant. Without overcoming in any one of these areas we can't design an efficient chiller plant. For designing an efficient chiller plant we have to focus on all these areas. Neglecting any of these areas will not design an efficient chiller plant.

- **An efficient design concept**

Concept of designing chiller plant should be selective based on the climatic conditions of that area i.e. chiller plant will anticipate the overcoming operational demands. Chiller plant should be design to reduce the temperature in the range of 5-10 degree Celsius. For example design of ducting and cooling tower is based on the overall temperature of that area.

- **Efficient components**

Chiller plant components like suction fan, cooling tower, and motors should all be selected for stand-alone as well as systemic efficiency. For example include premium efficiency pumps and delivering fan, suction fan, ducting, cooling tower, water sprinklers motors and that have high efficiency at anticipated operating conditions.

- **Proper installation**

A chiller plant having the above two criteria can also waste a lot of electricity and can't be able to provide the comfort to occupants of building, if it is not properly installed. For example if ducting is not sealed properly chilled air will leak from it.

8.0 CONCLUSION

This study of design and analysis helps in constructing an air based chiller plants in the buildings. Chiller plant design with green techniques plays an important role towards the sustainable development. Chiller plant uses natural resource i.e. air to cool down the building. It will play a major role to overcome global problem i.e. global warming. Global warming a gradual increase in the overall temperature of the earth's atmosphere generally attributed to the greenhouse effect caused by increased levels of carbon dioxide, CFCs, and other pollutants. These type of air cooled chiller plants will minimize the use of air conditioners in the buildings especially in the commercial complexes and reduce the uses of greenhouse gases used in air conditioners and CFCs. This design and analysis of chiller plant is towards the sustainable development of chiller plant using green techniques.

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