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ANALYSIS OF REINFORCED CONCRETE CHIMNEYS UNDER THE EFFECT OF TEMPERATURE CHANGE WITH FINITE ELEMENT METHOD

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ABSTRACT
In this research, the behavior of a reinforced concrete chimney was studied under the effect of temperature changes, and a reinforced concrete chimney was designed with a height of 25 meters and modeled by the SAP2000 program. The chimney was exposed to three different temperatures (250°C, 500°C, and 750°C) and the behavior of this chimney was studied and the values were observed without heat and under the effect of each temperature. The values of moments, forces, maximum potentials, and displacements under each temperature were compared. And we take the value of the maximum principal shear V_{max}, maximum principal moment M_{max}, the maximum principal stress S_{max} and the displacements U1, U2 and U3. The results showed a significant increase in the value of the moments, stresses, and shears when the temperature increased, and showed the amount of deformation and displacement that occurred with increasing temperatures.

Keywords: Reinforced concrete chimney, Shear and stress, Moment, Displacement, Temperature effect.

I. INTRODUCTION

Chimneys are the installation responsible for evacuating smoke and toxic gases to the upper atmosphere. This chimney must be as vertical or nearly vertical as possible so that the gases can flow comfortably and smoothly through it and the air within is sucked in. in the case referred to as the chimney effect. Chimneys are found in factories, ships, power plants, etc. Although the height of the chimney affects the chimney's ability to evacuate gases to the outside atmosphere through the chimney effect, the role of this height in reducing pollution is by dispersing pollutants into Altitudes higher than the atmosphere [2],[3],[13],[14],[15],[16]. A sufficiently high chimney can allow it Partial or total self-treatment of hazardous chemicals released into the atmosphere before these pollutants reach the ground [5]. Temperature is a measure of how hot or cold a system is. Unlike heat, the temperature is a property of a system that describes its state. One of the important properties of components is their resistance to high temperatures. However, this feature is not taken into account at the design stage of the building, only in special buildings, factories, thermal power plants, high-temperature chimneys, [1], etc.in these structures. Exposing a normal structure to high temperatures is not considered very important. However, industrial development brings with it increased energy consumption, and excessive energy consumption poses a risk of fire. Since the influence of fire is one of the most important high-temperature factors for structural elements, high-temperature conditions must be considered for each structure [4],[5].

II. MATERIAL AND METHOD

A. Effect of The Behavior of Reinforced Concrete at High And Very Low Temperatures

Concrete is (in general) affected volumetrically and dimensionally by heat, and the coefficient of linear expansion of one degree for each degree of temperature at which the material expands with increasing temperature is relative to 0.01 mm (1/100.000) per concrete type Freezing has a significant effect on the concrete because large internal forces are exerted on the concrete as a result of the freezing of water in cavities. Expansion, which can cause the concrete to crack, and with the repetition of this phenomenon, the water absorption of the concrete increases, increasing the freezing effect, which accelerates the damage to the concrete and increases its permeability, and increases the likelihood of the iron bars rusting and adhesion decrease[7],[8],[9].If other reinforced concrete members and a reinforced concrete element are partially exposed to heat, that is one side is more exposed than the other, there will be relative movement between the layers of material and forces will act on the element. And it may tear, and stretching and contracting movements may occur at the site [11].

B. Description of Concrete Chimney Model

First, the concrete chimney was designed and modeled using the SAP2000 program. The height of the chimney is 25 meters. The diameter of the upper part is 0.5 and the lower part is 1.5 meters, and the thickness of the chimney wall is 0.1 meters. Once modeled, it was analyzed before exposure to three temperatures and after exposure to three different temperatures. In this study, examined each model and compare it to the next model.

Mass and Weight of Material:

- Weight per Unit Volume = 23.5631 kN/m^3

  Mechanical Properties of Material:
- Modulus of Elasticity: E= $3*10^4$ kN/m^2
- Poison's Ratio: U= 0.2
-

III. RESULT AND DISCUSSION

A. Concrete Chimney Analysis without Temperature Effect

The reinforced concrete chimney was analyzed using the finite element method with SAP2000. The model below shows the finite element analysis of the reinforced concrete chimney without the effect of temperatures. 3D View of displacement without temperature is given in fig. 1.

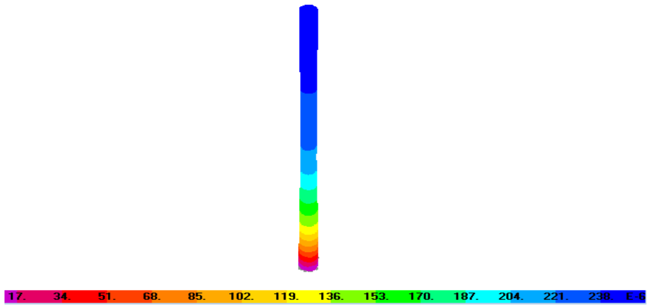

Fig.1. 3D View of displacement without temperature

For the maximum principal shear V_{max}, maximum principal moment M_{max}, the maximum principal stress S_{max} and the displacements U_1, U_2 and U_3. Found these values that will be displayed in the table 1 below:

TABLE I. THE VALUES OF MOMENT, STRESS, SHEAR AND DISPLACEMENTS

U_1 (m)	**U_2(m)**	**U_3(m)**	**S_{max} (kN/m²)**	**V_{max} (kN/m)**	**M_{max} (kN-m/m)**
$2.032*10^{-6}$	$-7.39*10^{-7}$	$-2.54*10^{-4}$	Max 4.672	Max 0.003	Max 0.017
			Min -1.511	Min 0.002	Min -0.04

B. Concrete Chimney Analysis with Temperature Effect

The reinforced concrete chimney was designed and modeled using the SAP2000 program, analyzed by the finite element method, given three different temperatures, and the values were monitored and in each model.

Below given in figures (fig.2., fig.3., fig.4.) the model under a temperature of 250°C, 500°C, and 750°C.

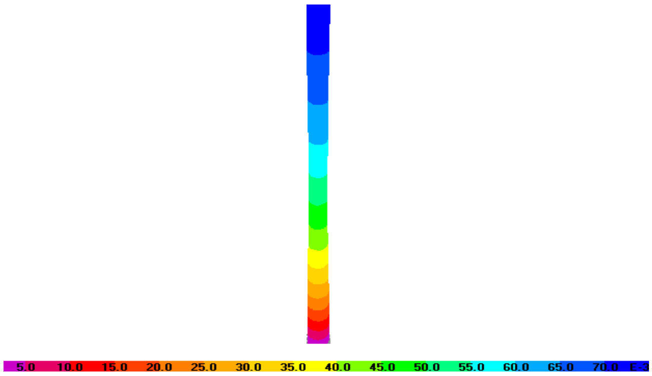

Fig.2. 3D View of displacement with 250 °C

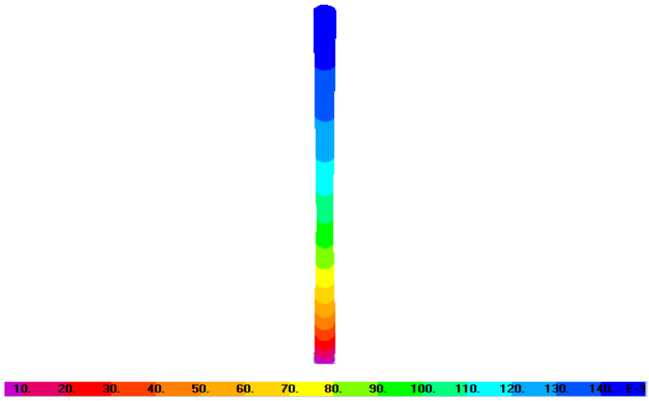

Fig.3. 3D View of displacement with 500 °C

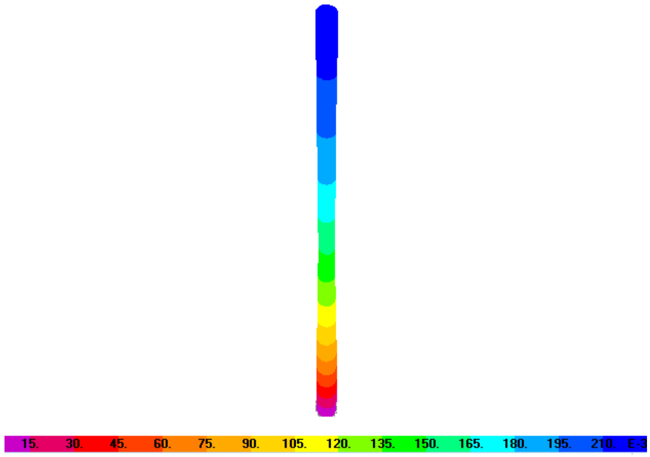

Fig.4. 3D View of displacement with 750 °C

The displacements U1, U2 ve U3 table are given table 2.

TABLE II. THE VALUES OF THE DISPLACEMENTS UNDER THE EFFECT OF EACH TEMPERATURE

Displacements / Temperature	U_1 (m)	U_2(m)	U_3(m)
250°C	$2.316*10^{-3}$	$-0.843*10^{-3}$	$0.74*10^{-4}$
500°C	$4.63*10^{-3}$	$-1.685*10^{-3}$	$1.48*10^{-4}$
750°C	$6.943*10^{-3}$	$-2.527*10^{-3}$	$2.23*10^{-4}$

The stress, moment and shear table are given table 3.

TABLE III. THE VALUES OF THE STRESS, MOMENT AND SHEAR UNDER THE EFFECT OF EACH TEMPERATURE

Temperature	**S_{max} (kN/m^2)**	**V_{max} (kN/m)**	**M_{max} (kN-m/m)**
250°C	Max 29221.12	Max 3.406	Max 19.548
	Min 9653.6	Min 1.864	Min -3.987
500°C	Max 58458.5	Max 6.808	Max 39.080
	Min 19436.7	Min 3.726	Min -7.970
750°C	Max 87749.82	Max 10.211	Max 58.610
	Min 29220.3	Min 5.59	Min -11.954

On displacement: Found that when the chimney is exposed to a high temperature of 250°C, the displacement value increases significantly and this affects several factors during the operation of the chimney, including the occurrence of cracks and the weakness of the concrete, leading to significant heat losses. And when the temperature values increase, the displacements also increase and the damage of the chimney increases.Moment, shear, and stress: Found that when the chimney was subjected to high temperatures, this resulted in an increase in the values of moments, shear and forces, and as know when these values increase, decreases the life of the concrete decreases and the performance of the chimney decreases over time. Based on these results, design the chimney in such a way that have taken into account the economic aspect, so that the fireplace is safe and economical at the same time. And don't have to do regular maintenance after a short time.

IV. CONCLUSIONS

With the increase in temperature, very serious increases in maximum stresses (S_{max}) were observed for every 250 °C degree increase. These increases were found to be approximately 100% from 250 °C degrees to 500 °C degrees, and about 50% from 500 °C degrees to 750 °C degrees. In addition, extremely large increases were observed between the initial state and the heated state.

With the increase in temperature, very serious increases in maximum shear (V_{max}) were observed for every 250 °C degree increase. These increases were found to be approximately 100% from 250 °C degrees to 500 °C degrees, and about 50% from 500 °C degrees to 750 °C degrees. In addition, extremely large increases were observed between the initial state and the heated state.

With the increase in temperature, very serious increases in maximum moment (M_{max}) were observed for every 250 °C degree increase. These increases were found to be approximately 100% from 250 °C degrees to 500 °C degrees, and about 50% from 500 °C degrees to 750 °C degrees. In addition, extremely large increases were observed between the initial state and the heated state.

With the increase in temperature, there is an increase of approximately 100% in the displacements from 250 °C to 500 °C degrees, and an increase of approximately 50% percent from 500 °C to 750 °C degrees. Especially in U_1 and U_2, extremely large differences were observed with the effect of temperature. Depending on the geometry and structure, the difference in temperature effect in U_3 is quite low compared to other directions and change of direction was observed. This is thought to be caused by the extremely large differences in the U_1 and U_2 directions.

In this study, the destructive effects of the temperature effect on a reinforced concrete chimney are clearly demonstrated. It has been revealed that the internal forces and displacements in the reinforced concrete chimney have increased excessively. It should be noted that this effect may increase or decrease depending on the selected model. The results in this study were obtained according to the model in this study.

In the light of all these findings, it is thought that the temperature effect in reinforced concrete chimneys is very important and should be taken into account. In addition, methods and materials that will reduce the temperature effect should be used in the designs of reinforced concrete chimneys.

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