SIGNIFICANCE OF SOLAR RADIATION ON CONCRETE WATER RETAINING STRUCTURES

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Declaration

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Abstract

According to the codes of practice for design of concrete structures, the effect of solar radiation has to be given due consideration. However, it is not specifically incorporated in the structural design. Often providing expansion or sliding joints is the common practice to accommodate the effect of solar radiation. The need to provide reinforcement bars at tensile stress regions where thermal stresses may develop within the design life of the structure is currently an undocumented fact.

Therefore the main aim of this research was to investigate the significance of solar radiation effect on concrete water retaining structures and to highlight the occurrence of high stress zones that need attention. The investigation was performed using a finite element model with gathered solar radiation data. The model was simulated with probable thermal properties of concrete and environmental conditions including solar heat flux, to identify the governing parameters.

In order to process large amounts of data and for economic reasons, a finite element method of analysis using ANSYS software was considered. This provided the robustness and contributed to focus on the sensitivity of the parameters under investigation. Further, several simplified models were verified with numerical calculations and compared with the finite element model. Characteristic points on stress response curve from the finite element analysis were compared with the numerical results. Comparisons were made with respect to the accuracy and reliability of using the finite element model for the analysis.

Based on the verified modeling approach, a typical underground water tank was investigated for sliding and fixed roof slab to wall connectivity. The temperature variation and corresponding stress variations were obtained.

It was found that significantly high tensile stresses are developed at the soffit level of the roof slab near the column heads, where normally only compressive stresses are expected. This occurs for both fixed and sliding roof slab-to-wall connections. Also at the mid spans, as the top surface of the roof slab was being compressed due to thermal expansion, the bottom surface was not being compressed due to the comparatively low temperature than the top surface (i.e. the temperature gradient). Therefore the bottom fibers developed tensile stresses, which was significantly more than the tensile stress due to selfweight only.

It is conclusive that the solar radiation is significant on concrete water retaining structures and the use of sliding or fixity conditions between the roof slab and wall is not effective in minimizing the tensile stresses due to solar heat gain;

Keywords: solar radiation, stresses in concrete, transient thermal analysis, element overlay, ANSYS

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List of Abbreviations (Nomenclature)

3D	three dimensional
A	cross sectional area
AM1.5	Air Mass number = 1.5 atmosphere thickness, corresponding to a solar zenith angle of z=48.2°.
c	specific heat capacity, J/kg/K
DOF	Degrees of freedom
FEM	Finite element model
FEA	Finite element analysis
HFLUX, q	Solar Heat Flux, (W/m^2)
h	convective heat transfer coefficient, W/m^2/K
h_w	convective heat transfer coefficient, W/m^2/K
k	thermal conductivity, W/m/K
I_h	Solar radiation on horizontal surface , W/m^2
L	Length, heat flow path length of interest
Q	rate of heat transfer (W)
q	Surface flux (power per unit area)
T	temperature, K or °C
T_{max}	maximum shade air temperature with an annual probability of being exceeded of 0.02
T_{air}	air temperature
T_s	surface temperature
ΔT	Temperature difference, (°C, K)
t	time (s)
ρ	mass density, kg/m^3
ρc	specific heat