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Numerical analysis of temperature distribution across the cross section of a concrete dam during early ages

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***Abstract:* -** In mass concrete dams, heat generated by the hydration of cement produces high temperature which cannot quickly dissipate. The surface of the dam cools faster than the interior body. This causes a temperature gradient between the cooled surface and the hot interior mass. Such a difference will result in a thermal gradient that is likely to generate undesirable thermal stresses which may cause cracks at the exterior surface. So, thermal stress analysis should be performed for mass concrete dams to provide a basis to minimize and control the occurrence of thermal cracking. This paper presents thermal analysis on Perunthenaruvi dam during its early age using Finite Element Software ANSYS 10.0. Parametric study of the Perunthenaruvi dam is conducted by varying the parameters thermal conductivity, specific heat, lift height, initial temperature

***Keywords:* -** *Keywords: thermal gradient; thermal conductivity; specific heat; lift height; initial temperature; hydration*

I. INTRODUCTION

Mass concrete is used in structures like dams, pavements, piers, in which the blocks are huge and the concrete serves its purpose by virtue of its weight, durability and impermeability. Although concrete used for massive structures like dams have little cement content, the temperature produced by cement hydration becomes extremely high if not controlled. This is because the heat generated by hydration of cement builds up faster and the outside layers can lose heat easily to atmosphere compared to the interior part. The variation in temperature over the cross section can produce stresses in concrete structures of the same order of magnitude as the dead or live loads.

Present study is focused on the thermal analysis. A coupled thermal-structural analysis for a 60 m high RCC Tannur Dam in Jordan was carried out using both a two- and a three-dimensional finite-element model using ANSYS (Malkawi et al.2003a, b) and concluded that detailed thermal stress analysis should be performed for large RCC dams to provide a basis to minimize and control the occurrence of thermal cracking. Xiaoyun and Baolong [1] presented a study on the lining temperature field for the crack control of tunnel linig using ANSYS and concluded that cracks can be controlled by pouring concrete in different section, mixing amount of fly ash and controlling mold temperature. Cervera et al. [2] presented a study on the numerical procedure for the simulation of construction process of RCC dams. It takes into account the relevant features of behaviour of concrete at early ages and concluded that FE model can be applied to perform parametric studies in order to establish the effect of some major variables of the construction process that may have an influence in the temperature distribution and evolution: the placing temperature, the starting date, and the placing speed. Cervera et al. [2] also presented a study on the numerical procedure for the simulation of construction process of RCC dams taking into account behaviour of concrete at early ages, such as hydration, aging, creep and damage and concluded that it is able to predict the evolution in time of the thermally induced tensile stresses that develop due to hydration heat released during the construction and the subsequent cooling process; this allows one to assess the risk of occurrence of tensile damage either at short or long term. Zhang et al. [4] presented a study on merge concreting and crack control analysis of mass-concrete base slab of nuclear power plant and concluded that with FE model, accurate temperature distribution was obtained from the comparisons with the field observations and is possible to decrease the expensive and time consuming field measurements in the future and improve the accuracy of temperature distribution. A thermo-mechanical model based on the framework of finite element techniques was presented involving the consideration of phenomena such as the heat production induced by the cement hydration, the evolving properties of concrete during hydration and early-age creep and it was concluded that it is enough to do 2D thermal analysis since the results obtained in 2D were comparable with that of 3D [5].

Our present study is limited to the thermal analysis study of Perunthenaruvi dam in Kerala during its early age using Finite Element Software ANSYS 10.0. Parametric study of the Perunthenaruvi dam is conducted by varying the parameters thermal conductivity, specific heat, lift height and initial temperature.

II. GENERAL DETAILS OF THE DAM

The Perunthenaruvi Dam is a RCC dam in the India. It is a small hydro-electric power project in Pathanamthitta district in Kerala. It is a concrete gravity dam, approximately 12 m high. The Dam is constructed of high paste content RCC, placed in 300 mm thick layers with a facing made of grout enriched roller compacted concrete. The concrete is designed to have a very low air void content and to achieve maximum strength and density with minimum permeability and with a good bond between layers. The upstream face of the dam is vertical. The stepped downstream face has a slope of 0.7H: 1V. This profile has been adopted to reduce vertical stresses by a more distributed loading, and to achieve higher compressive stresses at the upstream heel due to the vertical loading, thus reducing tensile stresses at the location under seismic loading. The dam is a straight structure 250 m long at the crest. The overflow section is 140m long and non-overflow section is 110m long. The cross section of Perunthenaruvi dam is shown in Fig. 1, The material properties such as density, thermal conductivity, and other thermal properties are given in Table 1.In this study, the heat of hydration was simulated as a ramp input, as shown in Fig. 2.

III. TRANSIENT THERMAL ANALYSIS

The dam was modeled as a two-dimensional transient heat transfer model using a birth and death procedure to simulate the real construction process of dam. The PLANE77 element type with one degree of freedom for temperature at each node was used for the analysis. This is a higher-order element that has eight nodes, is suitable for simulating irregular shapes, and is applicable to the study of a two-dimensional steady-state or transient thermal analysis. The finite element mesh of the dam is shown in Fig. 3. From the transient thermal analysis, considering 81 combinations of the 4 parameters namely: placing temperature, lift, thermal conductivity and specific heat: A Lift of 1m, Initial Temperature of 15°C, Specific heat of 1170 J/kg °C and Thermal conductivity of 3.5 J/s m °C gives the minimal maximum temperature. So, taking these values, the influence of all the 4 parameters is studied and the optimum value is found out. Influence of Initial Temperature/Placing Temperature and its optimum value: From Fig. 4, it is evident that Line1 and Line 2 is almost a straight line. So, an initial temp of around 25°C (in between 15 and 25°C) is found to be optimum for reducing the maximum temperature. Influence of Lift Thickness and its optimum value: The slope of the line1 is 50° and line 2 is 4°. The difference in maximum temperature value is more in the case of lift in between 1 and 1.5m from Fig. 5. So, lift in between 1 and 1.5m is found to be optimum. Influence of Thermal Conductivity and its optimum value: The slope of line 1 is 6° and line 2 is 22°. (Line2 is steep).

Fig.1 Cross Section of Perunthenaruvi Dam

Table 1 Material Properties

Properties	Value
Density	2400 kg/m^3
Placement temperature	15, 25 & 40 °C
Foundation Rock temperature	28 °C
Heat generation of RCC	309 J/g at 28 days
Specific Heat	800,950 & 1170 J/kg°C
Thermal conductivity	1.5,2.5 & 3.5 J/sm°C
Film convection coefficient	15 J/sm^2

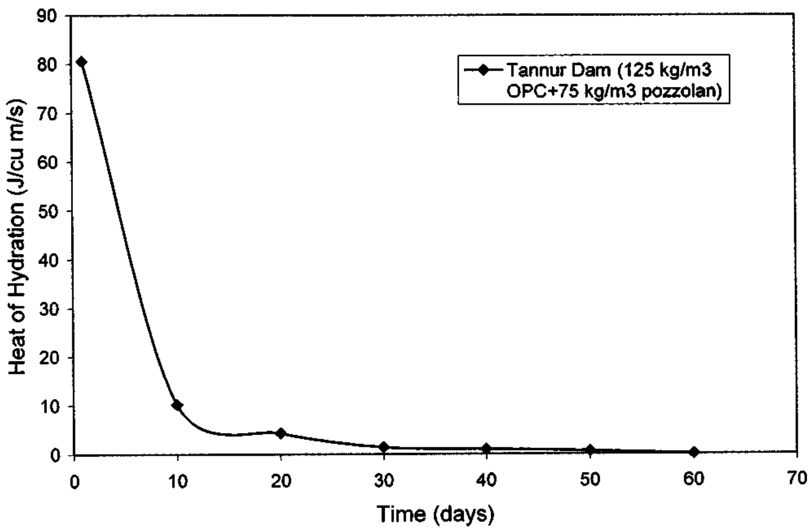

Fig.2 Heat of Hydration

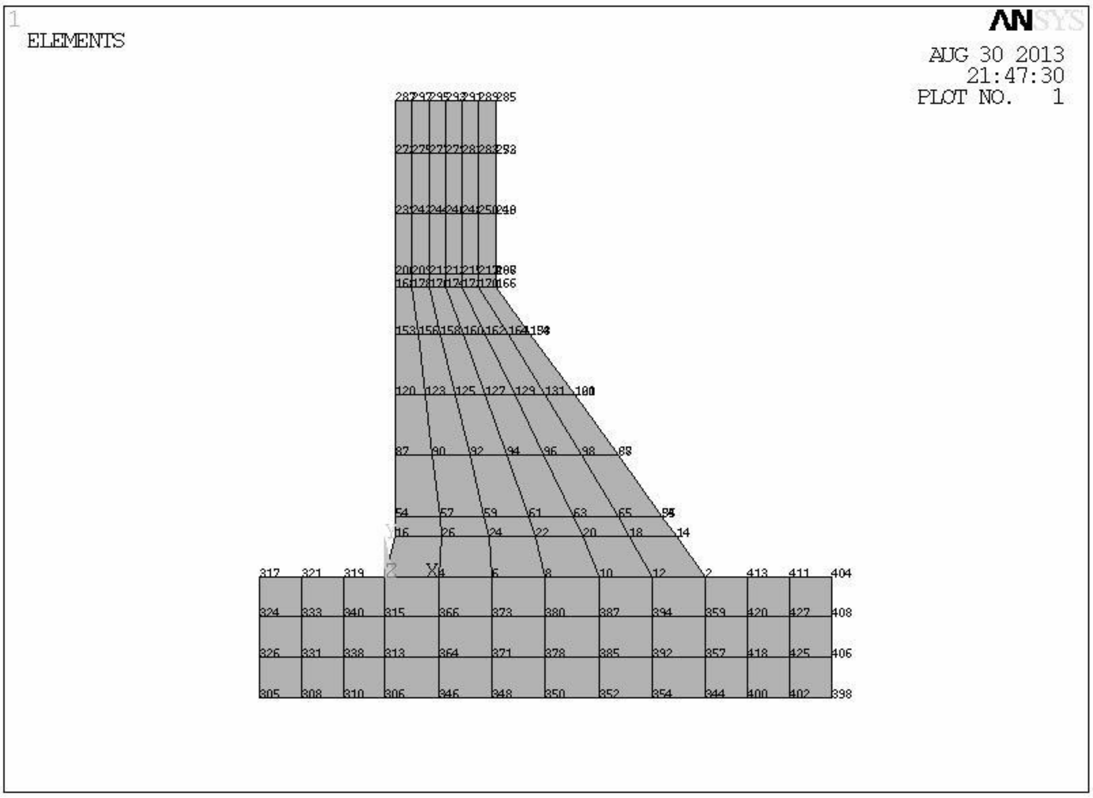

Fig.3 Finite Element Mesh of Perunthenaruvi Dam

From Fig. 6, it can be concluded that thermal conductivity value, k in between 2.5 and 3.5 J/s m °C is found to be optimum, since the temperature difference is maximum in this interval.

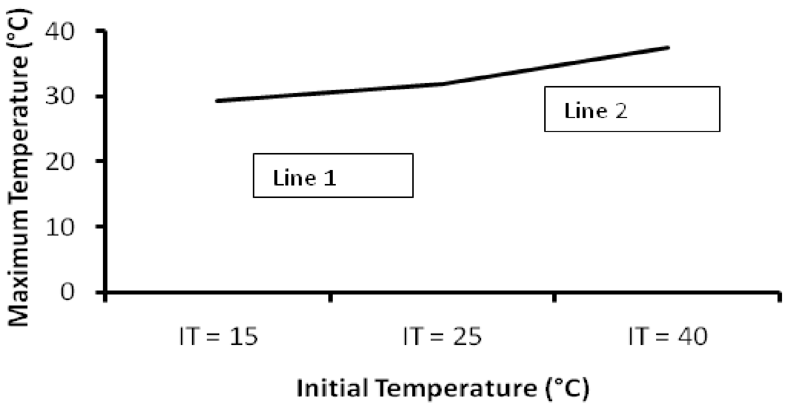

Fig.4 Maximum temperature Vs Initial temperature

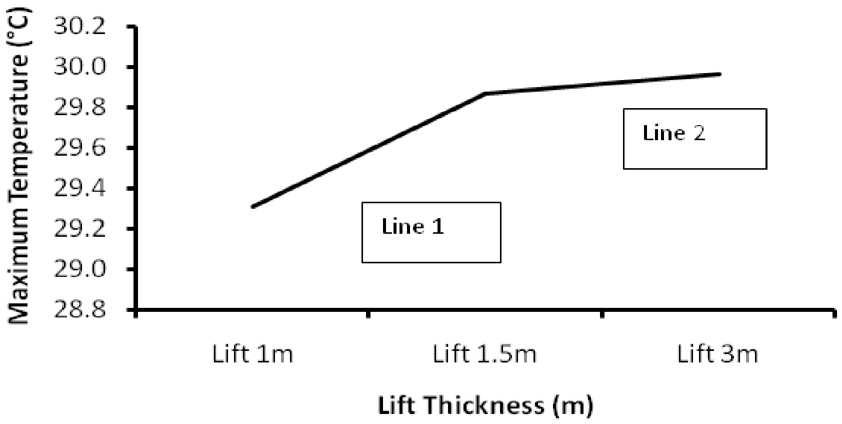

Fig.5 Maximum temperature Vs Lift Thickness

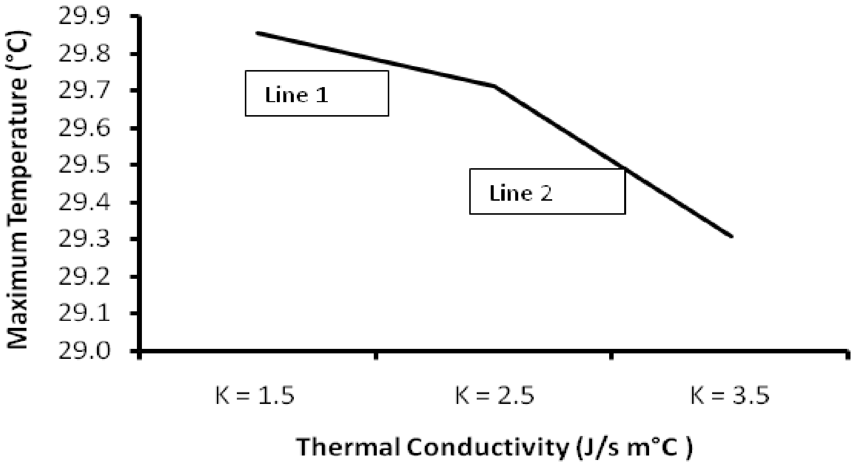

Fig.6 Maximum temperature Vs Thermal Conductivity

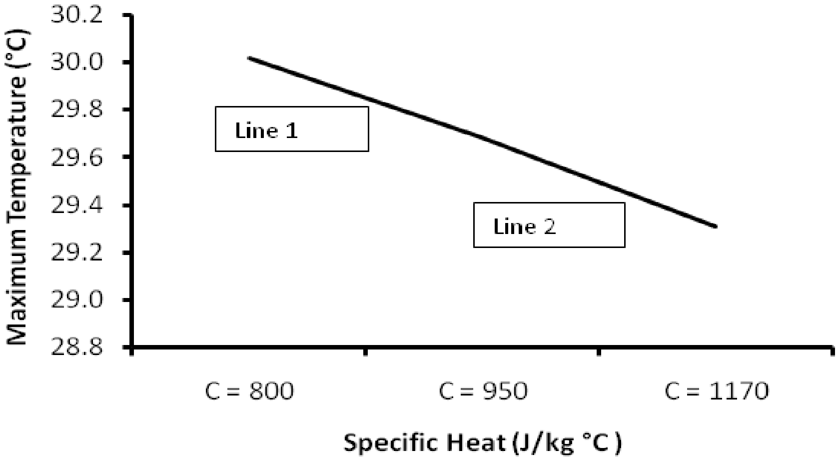

Fig.7 Maximum temperature Vs Specific Heat

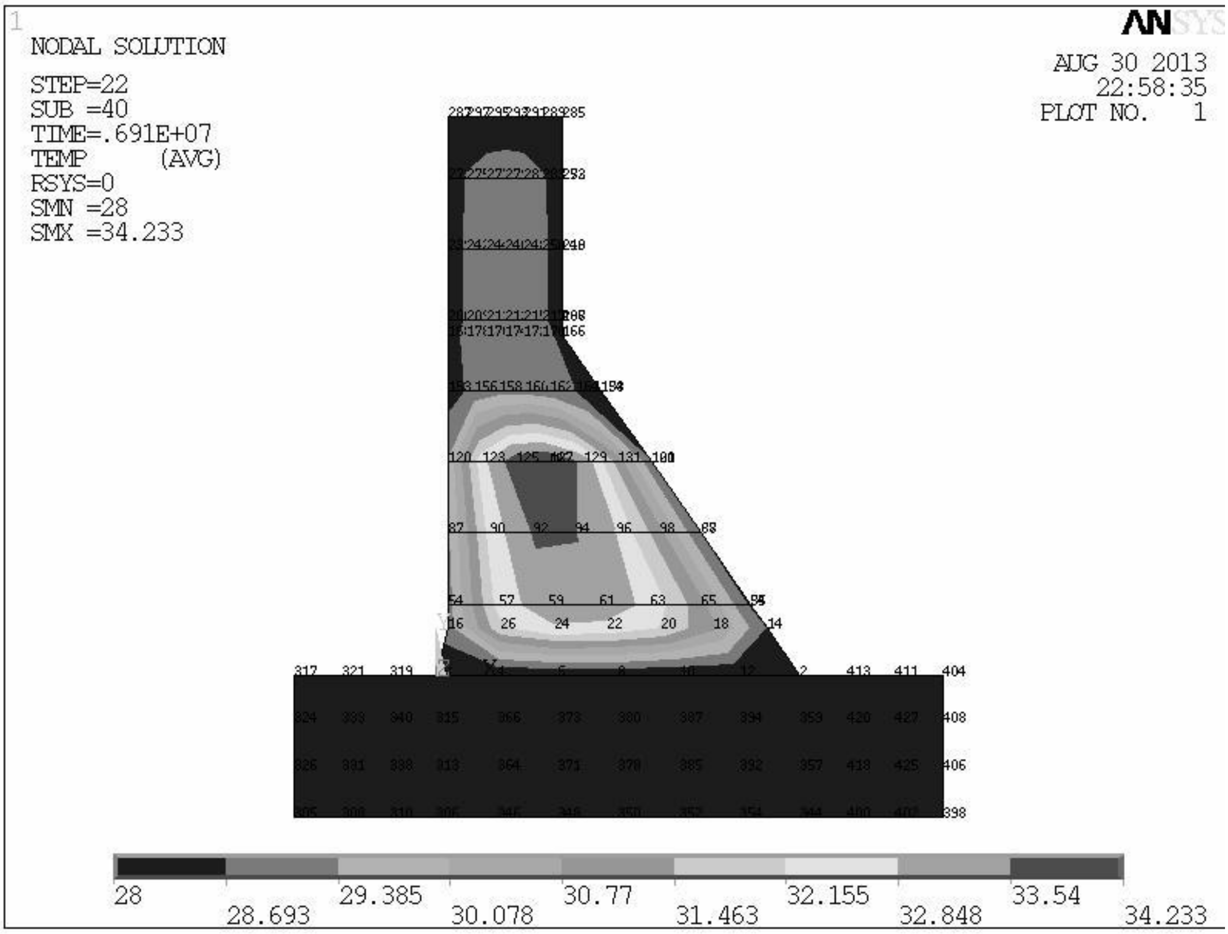

Fig.8 Temperature distribution for C=950 J/kg °C, IT=25 °C, Lift =1.5m and k= 3.5 J/s m °C

Influence of Specific Heat and its optimum value: From Fig. 7, Line1 and Line2 is almost a straight line and so, Specific heat of around 950 J/kg °C (in between 950 and 1170 J/kg °C) is found to be optimum for reducing the maximum temperature across the cross section of the dam. Temperature Profile across the Cross Section of the Dam: Fig. 8 shows the temperature distribution across the cross section of perunthenaruvi dam for a lift of 1.5m with specific heat (C) of 950 J/kg °C, thermal conductivity (K) of 3.5 J/s m °C and an Initial temperature (IT) of 25 °C.

IV. CONCLUSIONS

This work presents transient thermal analysis of Perunthenaruvi Dam, in Kerala. Parametric studies are performed in order to establish the effect of some major variables of the construction process that may have an influence in the temperature distribution: the placing temperature, the lift thickness, the thermal conductivity and the specific heat. An initial temp of around 25°C, lift in between 1 and 1.5m, thermal conductivity value in between 2.5 and 3.5 J/s m °C and specific heat of around 950 J/kg °C are found to be optimum for reducing the maximum temperature across the cross section of the Perunthenaruvi dam.

REFERENCES

[1] J. Xiaoyun, L. Baolong (2011),"Simulation of temperature field on massive concrete", 2011 Third International Conference on Measuring Technology and Mechatronics Automation, 261-264.

[2] M. Cervera, J Oliver., and T. Prato (2000), "Simulation of construction of RCC dams-I :Temperature and aging", Journal of Structural Engineering, Sep.2000,1053-1061.

[3] M. Cervera, J. Oliver, T. Prato (2000),"Simulation of construction of RCC dams- II: Stress and damage", Journal of Structural Engineering, Sep.2000,1062-1069.

[4] Z. Zhang, X Zhang., X Wang., T. Zhang and X. Zhang (2011), "Merge Concreting and Crack Control Analysis of Mass-concrete Base Slab of Nuclear Power Plant", Applied Mechanics and Materials, 94-96, 2107-2110.

[5] R. Faria, M. Azenha, J.A. Figueiras (2006), "Modelling of concrete at early ages: Application to an externally restrained slab", Science Direct Cement & Concrete Composites, 28, 572–585.