product option

LUSAS
Finite Element Analysis

Heat of Hydration

LUSAS Civil & Structural and LUSAS Bridge products permit modelling the heat of hydration of concrete for a variety of cement types. Effects due to the addition of fly ash and ground granulated blast furnace slag can also be included. When the Heat of Hydration option is used in conjunction with Nonlinear, Dynamic, and Thermal software options the heat of concrete hydration can be computed during a thermo-mechanical coupled analysis and the temperatures and degree of hydration can be read in to the mechanical analysis. Currently the mechanical properties of the concrete can only be defined as a function of temperature.

In detail

The Heat of Hydration facility allows for 2D/3D modelling of coupled thermal-mechanical behaviour of concrete due to its curing, and can also allow for inclusion of formwork and other materials that might act as insulators. The analysis results in thermally induced strains that can be used to calculate crack widths and crack patterns. Heat of Hydration analysis can be undertaken on mass or reinforced concrete with detailed geometric modelling of reinforcement within the concrete section being possible. The user has full control over the ambient and casting temperatures at the start of the analysis and can also allow for fluctuations in temperature. The internal inclusions of artificial cooling or heating can be done at discrete locations in a 2D analysis or along pipe lines in a 3D analysis.

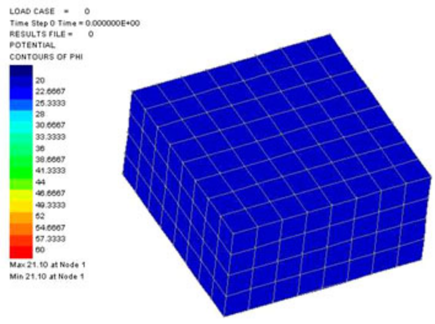
Results from LUSAS have been validated against academic research and also against a third party heat of hydration program.

Cement types

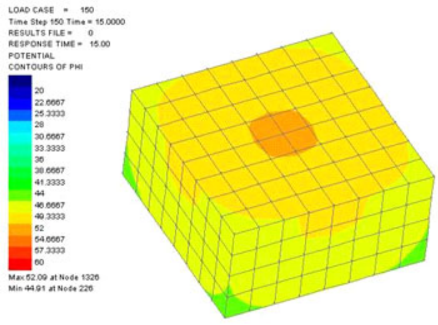
The concrete heat of hydration facility caters for cement types I, II, III and V. Effects due to use of fly ash and ground granulated blast furnace slag can also be taken into account. Although the mechanical properties of concrete cannot be directly linked to the degree of hydration, it is possible to define concrete properties that are appropriate for the time when the greatest temperature differential occurs. Typically this occurs between 24 and 48 hours so mechanical properties appropriate for this time interval could be specified to assess any possibility of cracking. The chemical composition for any cement type can be defined should the need arise.

Heat of hydration example:Test cube

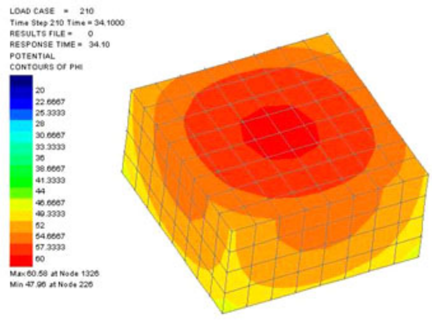
This quality assurance test case, whilst simplistic, illustrates the benefit of using the facility. A cube of concrete is modelled with an 8x8x8 mesh of HF8/HX8 elements and the concrete curing process is simulated. Temperatures due to the heat of hydration can be obtained by examining the hourly timestep results. From these it can be seen that the greatest temperature differential occurs at 34 hours. A structural analysis using a concrete cracking model based upon mechanical properties for this time interval is then carried out and cracks can be observed when differential expansion is enough to cause principal stresses that lead to material failure. In this example the external thermal boundary conditions were chosen to emphasize the heat gradient across the concrete block, and in the structural analysis the block is free to expand unrestrained.



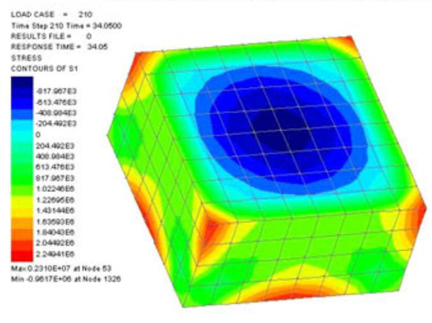
Initial temperatures, mid-section through block



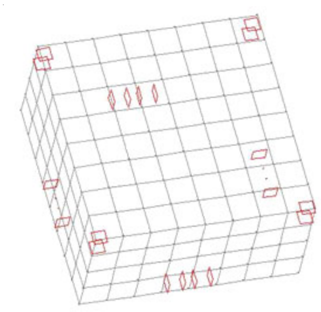
Temperatures after 15 hrs, mid-section through block



Temperatures after 34 hrs, mid-section through block



Maximum principal stresses at 34 hrs



Crack planes at 34 hrs

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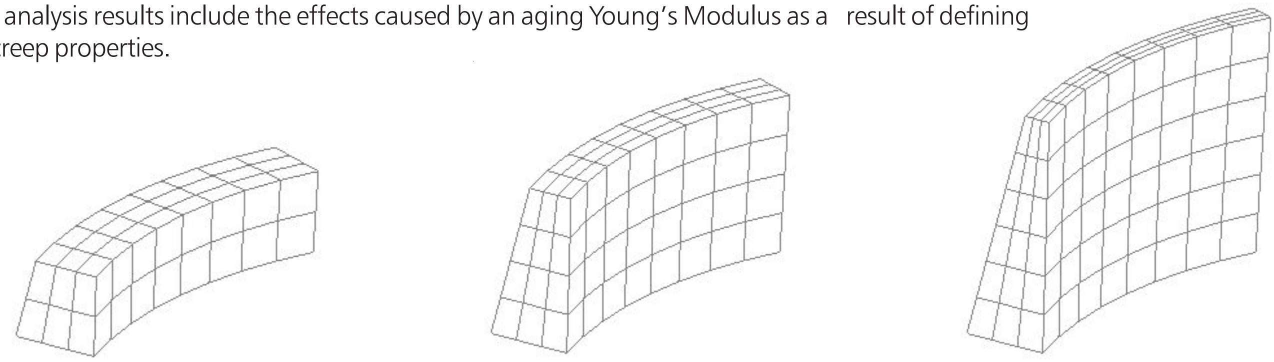
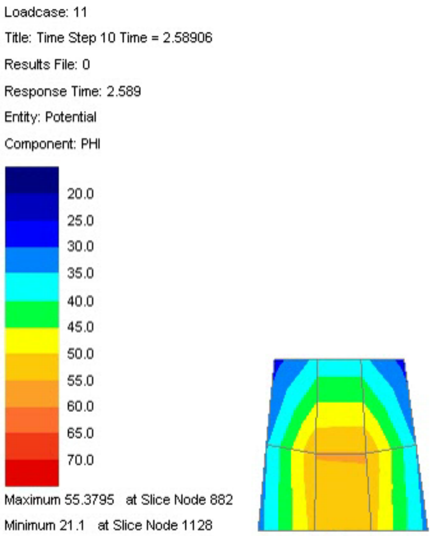
Typical application example: Dam construction

Heat of hydration analysis and a semi-coupled structural analysis is carried out on a simple testcase model of a dam that is constructed in three stages. Results for the heat of hydration analysis are plotted on section slices through the model. Structural analysis results include the effects caused by an aging Young's Modulus as a result of defining concrete creep properties.

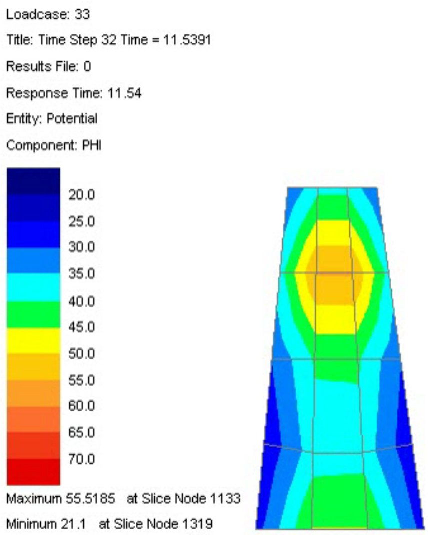


Simple testcase to model three stage dam construction

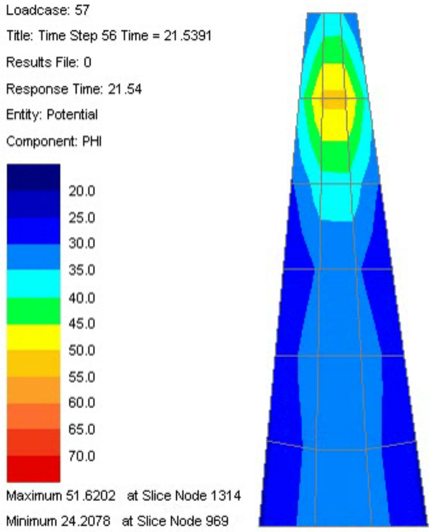
Heat of Hydration analysis



Maximum temperature differential in first casting stage

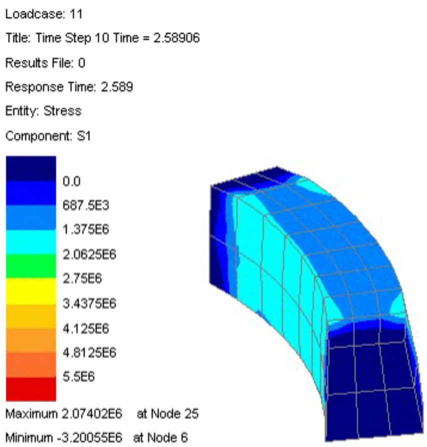


Maximum temperature differential in second casting stage

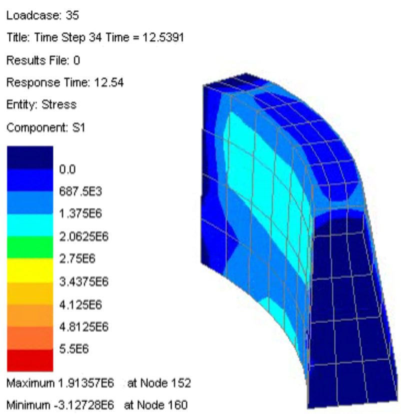


Maximum temperature differential in third casting stage

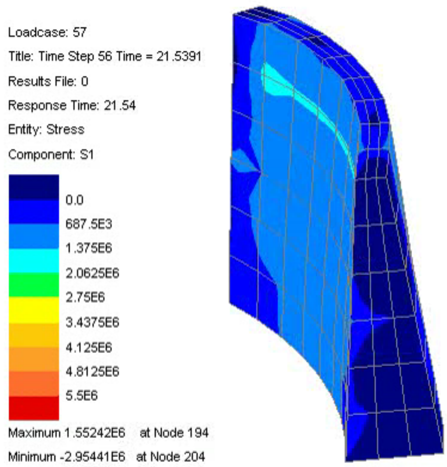
Semi-Coupled thermal /structural analysis



Maximum surface stress in first casting stage



Maximum surface stress in second casting stage



Maximum surface stress in third casting stage

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