software option

LUSAS
Finite Element Analysis

Heat of Hydration

The Heat of Hydration software option allows for 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 used with the Nonlinear, Dynamic, and Thermal software options the heat of concrete hydration can be computed during a thermo-mechanical coupled analysis, with the temperatures and degree of hydration used by a structural analysis to determine a range of time and age-dependent effects.

In summary

LUSAS has long been known for its advanced analysis capabilities, with a concrete cracking and crushing material model developed over many years in collaboration with top researchers in the field. Using the time-dependent creep and shrinkage concrete material model allows for better assessment of existing concrete structures and better predictions for concrete placed quickly or adjacent to existing material.

For early age concrete, hygro-thermal analyses allow the determination of heat of hydration across a body of concrete, taking into account the availability of water for the exothermic reaction with time, based on the concrete mix, shape, exposed faces, insulated surfaces, environmental conditions etc. This avoids the use of "typical" heat generation curves, although these can still be drawn upon for comparison purposes.

When a hygro-thermal analysis is coupled with a structural or "mechanical" analysis, the cracking, crushing, creep and shrinkage capabilities of LUSAS can be employed. This allows the determination of time- and age-dependent deformations, stresses, crack-widths and more, working to - and beyond the scope of - international Codes of Practice.

In detail

The Heat of Hydration software option 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.

Heat of hydration example

In the simplistic example shown right, 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 the half-model results 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.

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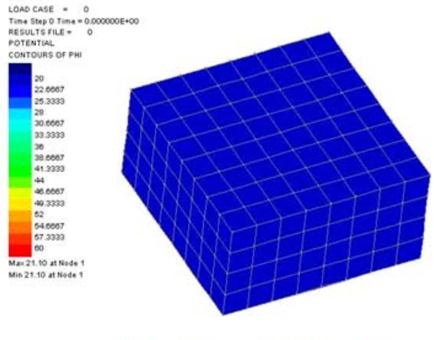
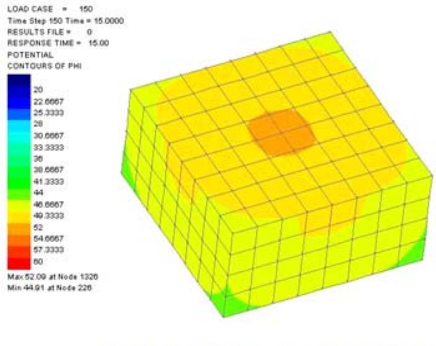
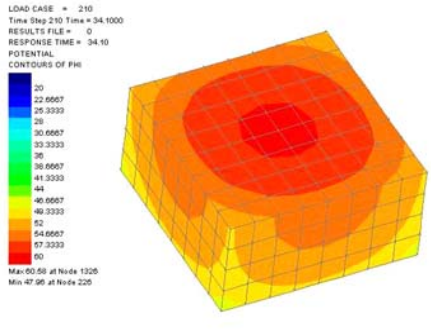


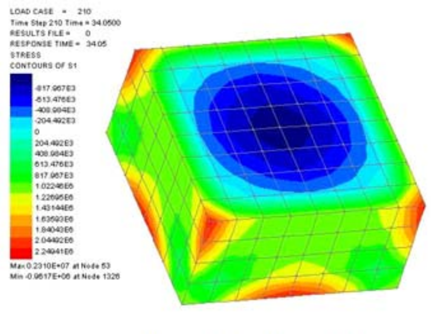
Initial temperatures, mid-section through block



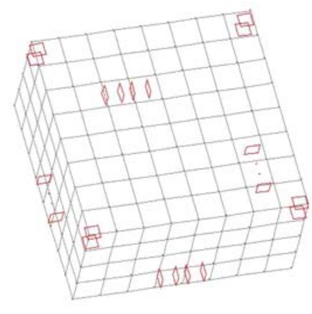
Temperatures after 15 hrs, mid-section through block



Temperatures after 34 hrs, mid-section through block



Maximum principal stresses at 34 hrs



Crack planes at 34 hrs

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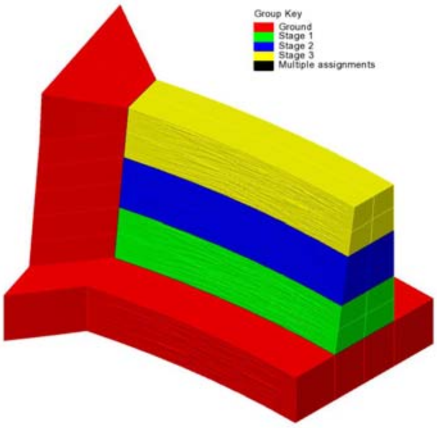
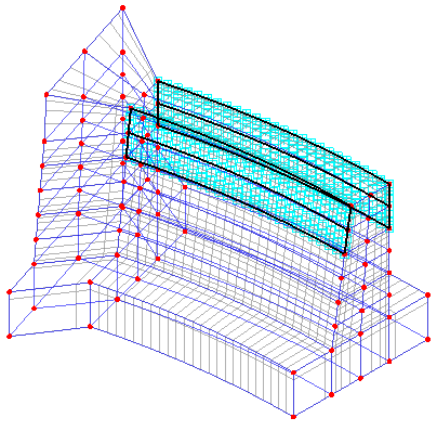
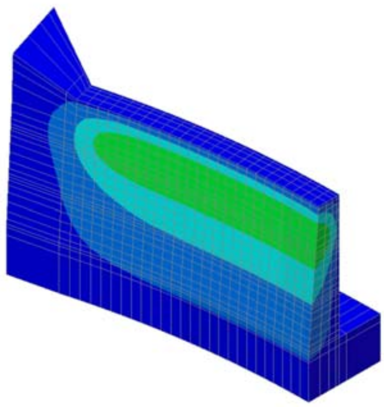
Hygro-thermal analysis of a dam

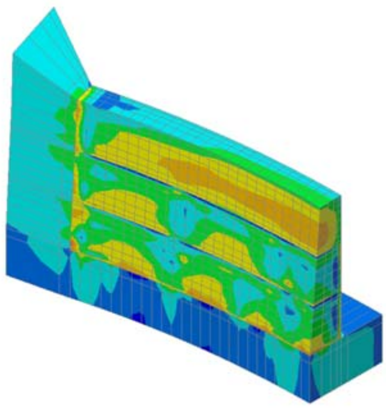
For the staged construction of a dam, the effects that formwork and environmental conditions have on the curing concrete can be examined:



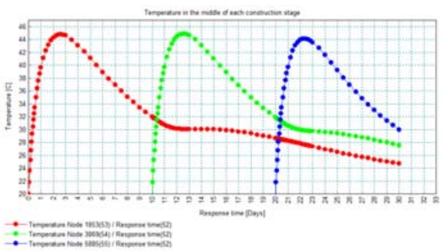


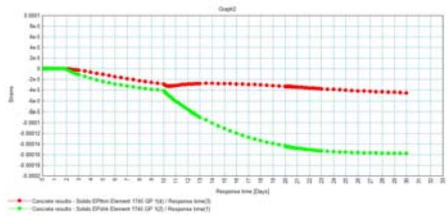
The temperatures and stresses for each time step for each construction stage can be obtained:



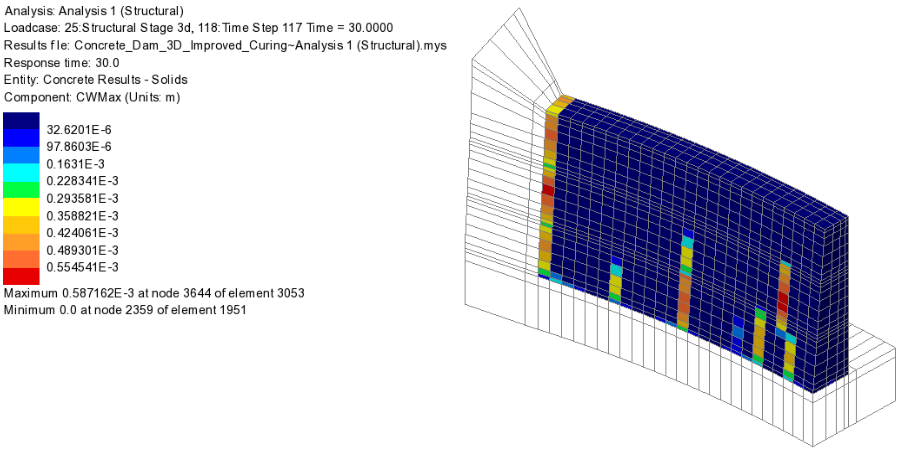


Graphs of results such as the changing of concrete temperature over time, shrinkage and thermal strains, or water distribution, and more can be generated:



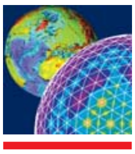


And calculated crack widths for each time step in each construction stage, externally and internally (as shown here) can be visualised:



Heat of hydration analysis

- Model heat of hydration based on the availability of water, in preference to "typical" curves.
- Evaluate any shape, any concrete mix, any environmental conditions (varying with time).
- Cement types I, II, III, V or user-defined chemical composition are available. Include PFA and/or GGBS.
- Model the time (hydration) dependent behaviour of concrete from time of casting to old age.
- Take into account the time dependent environmental conditions when the concrete cures, such as daily cycles of temperature and humidity, to the desired degree of detail.
- Model the effect the formwork (and environment) has on the heat and moisture transfer to and from the concrete
- Predict the internal heat generated as the concrete cures so that any excessive temperature gradients that might cause the concrete to crack can be identified.
- Compute the amount of shrinkage in the concrete as it cures via the migration of moisture and the degree of saturation.
- Take into account the creep strains that occur during cure as the concrete is stressed. ion) dependent behaviour of concrete from time of casting to old age.
- Model the evolution of properties E, fc, and ft.
- Predict failure when the concrete is fully (or partially) cured, and if the mesh is fine enough, obtain estimates of crack widths.



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