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Concrete strains under transient thermal conditions: A state-of-the-art review

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ABSTRACT

Extensive research has been carried out over the past four decades on the behaviour of mechanically loaded concrete under transient thermal conditions. The purpose of this paper is to provide a concise review of the existing experimental and analytical works with a strong focus on the load-induced thermal strain (LITS) component. In order to eliminate ambiguities in definitions, the existing terms used to describe the strain components that develop in concrete under a transient thermal regime are compared and a clear definition of LITS and its components is given. The analysis of the existing experimental work shows that LITS is: a strain occurring only during first heating of loaded concrete to a given temperature; significantly influenced by the moisture flux in the temperature range 100-250 °C; and independent of aggregate type for temperatures up to about 400 °C. Examination of the existing multiaxial test data demonstrates that LITS is the result of markedly confinement-dependent phenomenon and that experiments on concrete subjected to triaxial compression and transient temperatures above 250 °C are needed. In the light of the experimental evidence, for temperatures up to about 400 °C LITS seems to be mainly due to chemical reactions and microstructural changes taking place in the cement paste, such as dehydration, drying and rearrangement of the water molecules within the cement paste. By contrast, for higher temperatures, thermomechanical damage due to thermal incompatibility between cement paste and aggregates is believed to contribute significantly to the development of LITS. Moreover, the necessity for modelling explicitly the LITS component in the case of Heating-Cooling (HC) cycles is discussed. Finally, a review of the main existing uniaxial and multiaxial explicit LITS models is given, and the advantages and drawbacks of each model are outlined.

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Review article





Nomenclature

a, b, c	polynomial coefficients	E _{ela}	elastic strain
Ε	Young's modulus of elasticity of material	E _{ela.0}	elastic strain at ambient temperature
<i>k</i> tr	transient strain coefficient	E _{heat}	strain developed during the heating phase of a load-
Т	temperature		then-heat test
\overline{T}	normalized temperature	Е _{іј}	components of the total strain tensor
V_a	volume fraction of aggregates	Elits	load-induced thermal strain
α	thermal expansion coefficient expressing the ratio be-	\mathcal{E}_{lits^*}	load-induced thermal strain without increment in the
	tween the increment in free thermal strain and the		elastic strain
	increment in temperature	\mathcal{E}_m	mechanical strain
α_T	thermal expansion coefficient expressing the slope of	ε_{sh}	shrinkage strain
	the free thermal strain curve	ε_{th}	thermal expansion strain
β	load-induced thermal strain function for multiaxial	E _{tot}	total strain
	models	ε_u	ultimate strain
C_m	triaxiality coefficient for multiaxial models	ε_{ts}	transient strain
$\Delta \varepsilon_{ela}$	increment in the elastic strain	ε_{ttc}	transient thermal creep strain
δ_{ij}	Kronecker symbol	ε_{σ}	instantaneous stress-related strain
3	strain	v	Poisson's ratio
£0,3	load induced thermal strain for load $\sigma_i/\sigma_{u0} = 3$	v _{lits}	load-induced thermal strain Poisson's ratio
E _{cr}	creep strain	σ	stress
E _{cra}	smeared crack strain	σ_i	initial compressive stress before heating
E _{CT*}	creep strain plus transient strain	σ_{u0}	compressive strength
E _{dcr}	drying creep strain		

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1. Introduction

Experimental evidence shows that mechanically loaded concrete specimens exhibit a significant quasi-instantaneous load-induced thermal strain, usually referred to as LITS, upon virgin heating. Accurate understanding and modelling of this phenomenon is crucial for a reliable assessment of the effects of thermal loads on concrete structures, particularly if a certain level of performance is required in the case of accidental loads such as fire. This is the case for nuclear structures, such as prestressed concrete pressure vessels (PCPVs). For example, the recent Fukushima accident, where reactors overheated due to a failure of the power station cooling system, clearly highlights the importance of considering a wide range of possible accidental conditions in designing and assessing nuclear structures. Moreover, other applications in civil engineering occur whenever concrete is loaded in compression under transient Download English Version:

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