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Influence of transient strain on fire resistance of RC elements

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1 Material Models

Stress strain numerical model :

Total strain of concrete : $\varepsilon_{mc} = \varepsilon_{th}(T) + \varepsilon_{\sigma}(\sigma, T) + \varepsilon_{cr}(\sigma_0, T, t) + \varepsilon_{tr}(\sigma_0, T)$

Mechanical strain of concrete : $\varepsilon_{\sigma} = \varepsilon_{mc} - \varepsilon_{th}(T) - \varepsilon_{cr}(\sigma_0, T, t) - \varepsilon_{tr}(\sigma_0, T)$

Total strain of steel bars: $\varepsilon_{s,m} = \varepsilon_{s,th}(T) + \varepsilon_{s,\sigma}(\sigma, T) + \varepsilon_{s,cr}(\sigma, T, t)$

After we get the mechanical strains of each unit of concrete and steel bars, we can get the stress of each unit $\sigma_c(T_{i,j}, \varepsilon_c)$, $\sigma_s(T_{i,j}, \varepsilon_s)$ **by stress-strain relationship that is given by Jin Tao (for SCC concrete).**

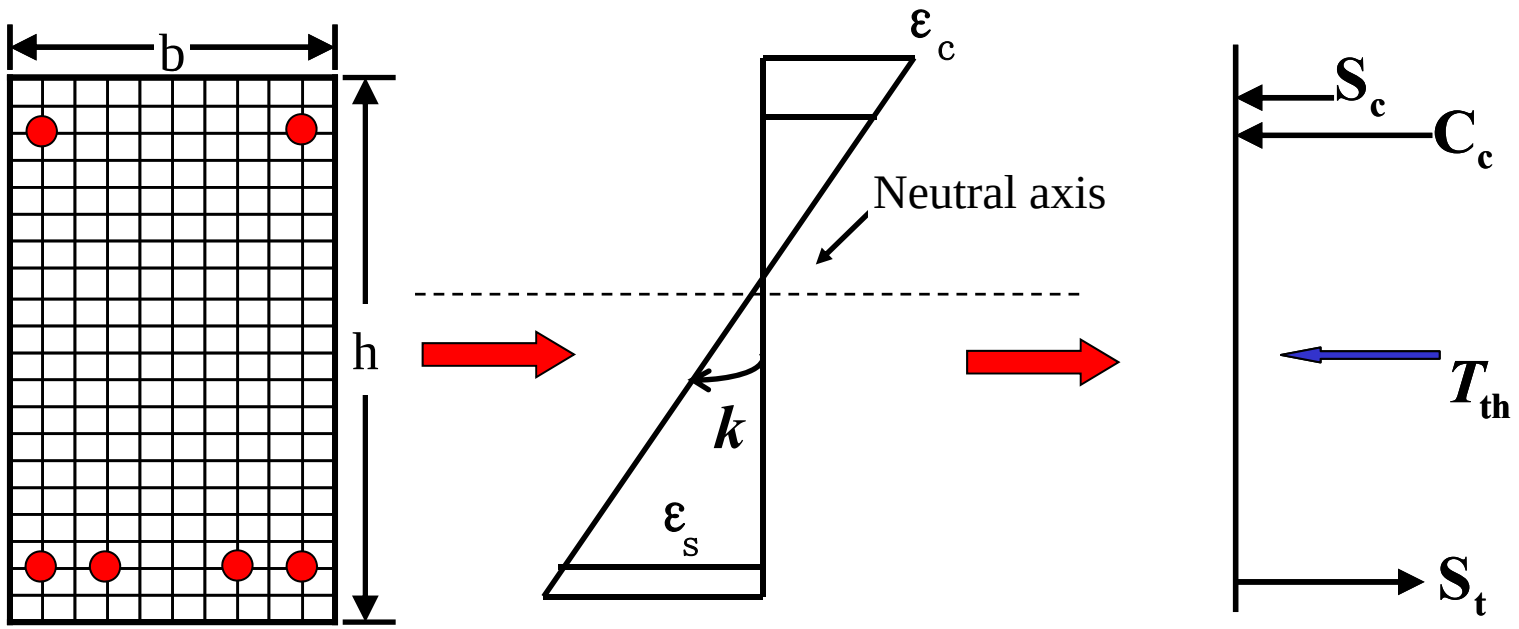
2 Section analysis

Assumptions :

(1) Plane section will stay plane.

(2) The temperature field is analyzed under ISO-834 fire curve.

(3) The thermal restraint axial force is same along the span of the element



3 Balance equations

$$T_{th} = C + S_c + S_t \begin{cases} C = \sum_{i=1}^{n}\sum_{k=0}^{r}\sigma_1(T_{i,j},\varepsilon_\sigma) = \Delta b\Delta h \times \left[\sum_{i=1}^{n}\sigma_1(T_{i,j},\varepsilon_\sigma)\times\theta + \sum_{i=1}^{n}\sum_{k=1}^{r}\sigma_1(T_{i,j},\varepsilon_\sigma)\right] \\ S_c = \sum_{i=1}^{n}\sum_{j=1}^{m-r-\theta}\sigma_2(T_{i,j},\varepsilon_\sigma) = \Delta b\Delta h \times \left[\sum_{i=1}^{n}\sigma_2(T_{i,j},\varepsilon_\sigma)\times(1-\theta) + \sum_{i=1}^{n}\sum_{j=1}^{m-r-1}\sigma_2(T_{i,j},\varepsilon_\sigma)\right] \\ S_R = \sum_{i=1}^{n_s} A_{si}\sigma_s \end{cases} \quad (1)$$

$$M = C_c(y_c - \alpha_s) + S_c(y_{sc} - \alpha_s) + T_{th}(y_{th} - \alpha_s) \quad (2)$$

There is a iteration between Tth, k, ε_{i0} ,while there is only one equation

4 Results

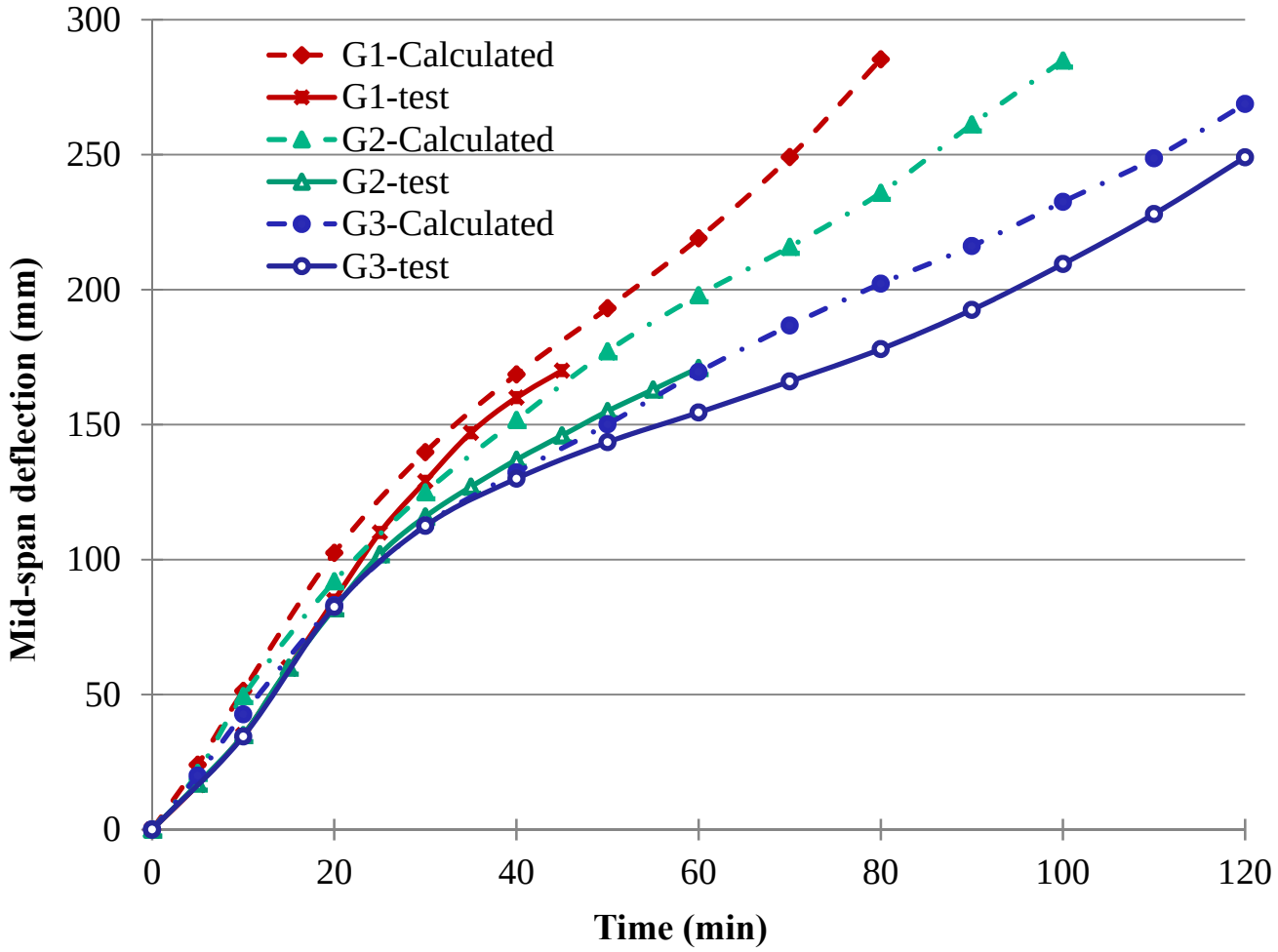


Fig.1 Mid-span deflections of G1, G2 and G3

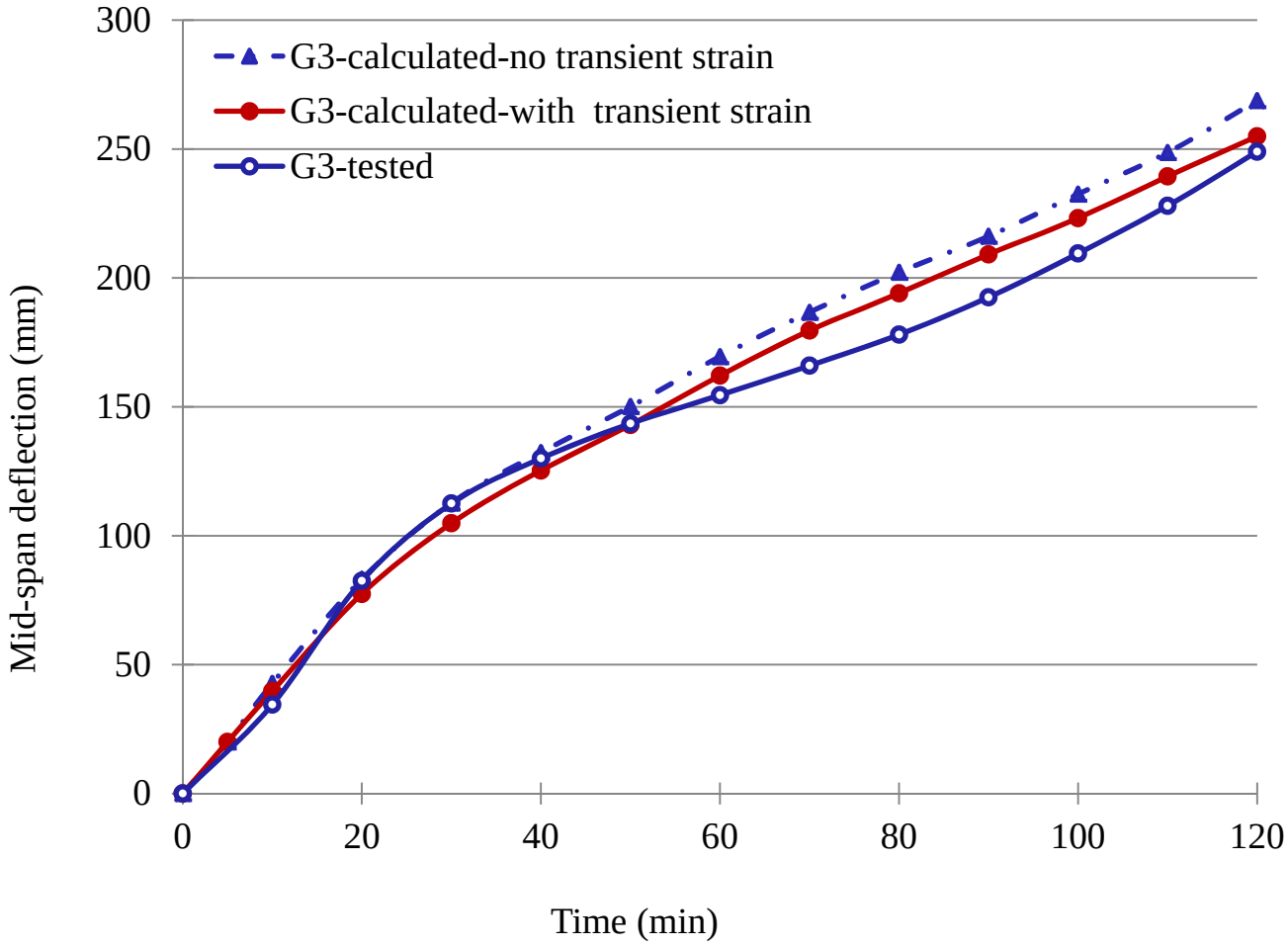


Fig.2 Mid-span deflections of G3 with and without transient strain

5 Conclusions

1) G1 and G2 failed after 60 min heating in the test, and G3 last until 2hrs. As the slabs are heated from the tensile side, the ultimate bearing capacity of the elements is decided by steel bars, so the thickness of the concrete cover is essential for the fire-resistance of the structures.
2) The numerical results and the test results are very close and have similar trend. After 30 min, the numerical results are higher than the tested ones, but the differences are acceptable.
3) Fig.2 indicates that the calculation became more accurate when transient strain is considered. Without it, the deflections will be overestimated. However, for slabs this influence is small and can be neglect in the future design.