5 DISCUSSION AND CONCLUSIONS

The basic premise of the proposed method is the extrapolation of concrete beam behaviour to slab problems. The cracked and creep behaviour of beams is applied with slight modification to a plate or slab. Since slabs are subjected to biaxial stress states, the assumption that biaxial behaviour is equivalent to the superposition of two uniaxial solutions is an obvious simplification.

The error introduced by the simplification is of dubious importance when the inaccurate prediction models for the calculation of creep and shrinkage influences are taken into account. The equivalent frame approach will produce conservative estimates of long term deflection as slabs exhibit higher flexural stiffness due to torsional interaction.

This assumption has been the basis of many a simplified method in the past and the proposed method merely applies it to the finite element method.

5.1 Elastic deflections

Figures 4.2 through 4.5 demonstrate that the Mindlin element compares very well with classical solutions for simply supported plates. As expected, some divergence occurs at smaller plate thicknesses due to numerical issues. Since practical span to depth ratios of concrete slabs are rarely large, the Mindlin formulation yields elastic results of acceptable accuracy for this class of problems (span to depth ratios less than 32).

5.2 Cracked deflections

Polak's effective slab stiffness method produces acceptable results for both uniaxial and biaxial moment conditions as illustrated by figures 4.10 and 4.11. Although the Bilinear and Branson's method yield very similar results in the finite element analysis of slab SM1, the bilinear method performs poorly with low reinforcement ratios.

Authors such as Park and Gamble (2000) have objected to the use of Branson's method in slab problems due to the fact that this entirely empirical equation was developed for beams. They argue that slab steel ratios are often orders of magnitude smaller than those of beams and it follows that the tension stiffening effect in slabs would be far lower than predicted by Branson's equation.

Based on the findings of this dissertation, Branson's effective moment of inertia is preferred over the bilinear method for use in a finite element analysis.

5.3 Creep deflection

The proposed method of incorporating creep effects into a finite element analysis compares well with the experimental results of Haddad's beam and Neville's simple analysis. Branson's method again yields results superior to the bilinear method as far as the influence of cracking on creep deflections is concerned.

The proposed method has much to recommend it:

- The influence of reinforcement on creep is taken into account.
- Movement of the neutral axis due to cracking is incorporated.
- Only two parameters are required to quantify the creep strains of the material.

The creep method developed in this dissertation compares favourably with the concrete frame tested at the Cardington facility when constant loading is assumed. As mentioned in the previous section, some work is required to accommodate varying load histories.

5.4 Shrinkage deflection

As with creep, very little data is available on the shrinkage behaviour of flat slabs and the same procedure used for beams was implemented, based on the single free shrinkage parameter. The proposed method compares very well with Haddad's beam. It should be noted that the proposed method to include shrinkage deflection in the analysis fails with clamped beams or plates since rotation, and not only axial deformation, is prevented in these cases. Further analytical work is required to apply a complete shrinkage analysis to models with clamped boundary conditions.

5.5 Recommendations and Suggestions

The applicability of Polak's method using Branson's effective moment of inertia has been well demonstrated, although the boundary conditions for flat slabs do raise some concerns as to its use in the serviceability design of these structures.

Further work could include different plate formulations and more rigorous methods of estimating the magnitudes of the reduction factors for cracking and creep. Specifically the average moment for use in Branson's equation and the influence of both cracking and creep on the shear characteristics of flat slabs. Varying, and especially decreasing, load histories need to be considered in greater detail as few practical slabs are subjected to lifetime constant loading.

A point raised by one of the research groups at Cardington, was that with slender slabs dynamic effects also impact the magnitude of long-term deflections. Further work in this aspect would make the method widely applicable.