Concrete

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The crack widths predicted by the different codes have been calculated for a range of varying parameters: Varying tension reinforcementstress(Figure 9) Varying cover (Figure 10) Varying bar spacing with constant reinforcement area and stress. (Figure 1 1) Varying bar spacing with constant reinforcement area and maximum stress to AS 3600. Figure 12) BBS 5400 results have been plotted using a Ms / MGM ratio of 0. 1 and 1. All results have used long term values where available. Larger versions of these graphs may be found on the Powering presentation associated with this paper. The following observations can be made from the graph results: The BBS 5400 results using the two different load ratios gave substantially different results, with the higher ratio giving increased crack widths. The BBS 8110 results were either approximately centrally placed between the two BBS 5400 results, or close to the lower values.

The Recoded 2 results were usually reasonably close to the mean of the other results. The CUBE-Flip-1990 results were consistently the lowest for high steel stresses and high concrete cover values. Results with varying spacing were close to Recoded 2 results. The IAC 318 results were consistently the highest, being close to and slightly higher than the upper bound BBS 5400 values. All crack widths increased approximately linearly with increasing steel stress Crack widths increased with increasing cover, with Recoded 2 reaching a constant value at 70 mm cover, and the CUBE-PIP code at 35 mm cover.

The other codes continued to increase more than linearly up to 100 mm cover. All codes predicted increasing crack width with increasing bar spacing and constant reinforcement area steel stress. Figure 9: Varying tension reinforcement stress Figure 10: Varying cover Figure 11: Varying bar spacing with constant reinforcement area and stress Figure 12: Varying bar spacing with constant reinforcement area and maximum stress to AS 3600.

When the steel stress was adjusted to the maximum allowable under AS 3600 (I. E. Reduced for increasing bar spacing and increasing bar diameter) the predicted crack widths were reasonably uniform in the spacing range 50 to 200 mm, then tended to reduce with greater spacing. DEFLECTION The main differences in approach to the calculation of deflections are summarized low: Australian and American codes are based on the Brannon equation, using a uniform average effective stiffness value.

Australian codes allow for loss of tension stiffening through a reduction of the cracking moment related to the free concrete shrinkage. Allowance for shrinkage curvature in the Australian codes is simplified and will underestimate curvature in symmetrically reinforced sections. British codes allow only a low tension value for cracked sections, which is further reduced for long term deflections European codes adopt an intermediate approach for cracked sections, tit an allowance for loss of tension stiffening.

British and European code provisions for shrinkage curvature are essentially the same Effective stiffness, calculated according to AS 3600, Recoded 2, BBS 5400, and BBS 8110, and with no tension stiffening, is plotted against bending moment for the same concrete section used in the crack width analysis. Figure 13 shows results with no shrinkage, and Figure 14 with a shrinkage of 300 Microscopic. RESEARCH ABOUT THE METHODS USED IN DIFFERENCE CONCRETE STANDARDS AS 3600 limits the maximum reinforcement stress under serviceability loads to a axiom value dependent on either the bar diameter or the bar spacing, whichever gives the greater stress.

AS 5100 has the same limits, with an additional requirement to check for lower limits under permanent loads for elements in exposure classifications 82, C or U. Recoded 2 limits stresses in essentially the same way, except that the limits are presented as maximum bar spacing or diameter for a specified stress, rather than vice versa. The Recoded 2 limits are related to 3 different values of nominal crack width, 0. 2 mm, 0. 3 mm or 0. 4 mm, under pseudo-static loading. The applicable crack Edith depends on the exposure classification and type of member.

Code Provisions for Crack Width Limits As well as stress limits, Recoded 2 has detailed provisions for the calculation of design crack widths, which are summarized below: The basic formula for crack width: crack spacing x (mean steel strain - mean concrete strain) makes no allowance for variation in crack width between the level of the reinforcement and the surface of the concrete, however the crack spacing is mainly related to the cover depth, and the crack width is directly proportional to crack spacing, so the depth of cover has a significant effect on crack widths.

The expression for Seems - ECMA limits the effect of tension stiffening to 40% of the steel strain. For long term effects the tension stiffening coefficient is reduced by 1/3, from 0. 6 to 0. 4. The British concrete design codes specify a design crack width at the surface of the concrete as follows: The basic approach is similar to Recoded 2, except that the crack width is projected from the reinforcement level to the concrete surface. The main differences between BBS 5400 and BBS 8110 are: BBS 5400 includes a factor to reduce the effect of tension stiffening, depending on the ratio of live load moment to dead load moment (Ms / MGM).

The effect of this is to reduce tension stiffening effects to zero for a load ratio of 1 or greater. The tension stiffening coefficients are differently formulated. The IAC requirements are based on stress limits derived from the Surgery-Lutz equation: The IAC 318 equation makes no allowance for tension stiffening, and predicts crack width at the upper bound of those studied in this paper. Results are usually similar to those from the BBS 5400 equation using a Ms / MGM ratio of 1 .

AS 3600, AS 5100, and IAC 318 AS 3600 and AS 5100 provisions for " simplified" calculation of deflections are identical other than a typographical error in AS 5100), and are both based on the " Brannon" equation, which is also used in IAC 318. The equation in IAC 318 is differently formulated, but will give identical results for the same cracking moment and section stiffness values. The AS 3600 version of the equation is shown below: left is calculated for the maximum moment section, and applied along the full length of the member being analyses.

The calculation of the cracking moment in the Australian codes (but not IAC 318) includes an allowance for the shrinkage induced tensile stress in the unchecked section, which contributes to loss of tension stiffening: AS 3600 and AS 5100 provide a factor KC , applied to the calculated deflection, to account for the additional deflection due creep and shrinkage: KC = [2- 1.

2(ASS / East)] Note that for a symmetrically reinforced section KC reduces to the minimum value of 0. , being the effect of creep deflection alone. 6. 4. 2 OBSESS, BBS 8110 Deflections in BBS 5400 and BBS 8110 are calculated from integration of section curvatures. The cracking moment and curvature of cracked sections allows for a short term concrete tensile stress of 1 Amp, reducing to 0. 5 Amp in the long term. Shrinkage curvatures in BBS 8110 are determined from the free shrinkage strain, and the first moment of area of the reinforcement about the cracked or unchecked section, as appropriate.

BBS 5400 uses a similar approach, but tabulates factors based on the compression and tension reinforcement ratios. 6. 4. 3 Recoded 2 and CUBE-PIP 1990 (MAC 90) The European codes also provide for calculation of deflections by integration of section curvatures, but provide a different expression for the stiffness of cracked sections: Shrinkage curvatures are assessed using a similar method to that given in BBS 8110: