

Load transfer across cracks and joints

There is a growing demand for in-situ concrete industrial floor slabs throughout the world, largely because of the increase in internal floor space required for warehousing and manufacturing processes. This demand has been coupled with client requirements for extended life expectancies and tighter tolerances in both level and flatness. Although new machinery, such as laser screeds, has helped provide quicker and more accurate concrete placement, the greater size of the pour increases the risk of thermal and hygral movement.

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“Including even small amounts of reinforcement has been shown to provide resistance to degradation and increase serviceability life.”

All concrete slabs must consequently accommodate significant shrinkage throughout their life because, if restricted, additional stresses and cracking will occur. Some form of control to prevent premature degradation is therefore required within the structure. This is commonly achieved by incorporating joints (controlled cracks) to enable the concrete to move at designated locations, leaving the remainder of the slab relatively free of restraint-induced stress. Unfortunately, these areas often become the main cause of failure if incorrectly designed or constructed.

Design

The load transfer mechanism across any crack or joint is essential to the structural capacity of the slab. If this deteriorates for any reason, there is a much greater risk of failure or poor serviceability, including faulting (change in slab level either side of the crack), excessive deflection or further cracking. Knowledge of joint behaviour is therefore essential to enable designers to predict slab response accurately.

Recently, much has been made on the issue of floor flatness and the classification of floors. At present, the floor is surveyed using a relatively lightweight piece of machinery

throughout the slab (including across the joint), and the floor placed into a performance class. However, in most cases it will be the loaded edge situation (i.e. directly next to a crack or joint) that produces the worst-case scenario for floor operators, as the dynamic effect of the vehicle causes the slab edge to cantilever. This generates excessive sway in high vehicles, creating a risk of racking collisions, increased driver fatigue and reduced vehicle life. To overcome this, there has to be a reduction in operational speeds and therefore productivity. As the magnitude of this edge deflection depends heavily on the load transfer of the joint, these areas should be specifically and regularly monitored during flatness surveys using the correct equipment to ensure they conform to a prearranged limit.

Variations in load transfer

Load transfer is constantly changing throughout the life of the joint. High and low temperatures can cause the concrete to expand and shrink respectively, altering crack width. This in turn affects the amount of load transfer, owing to the reduction in effectiveness of aggregate interlock as the crack faces move further apart. This phenomenon is a minor consideration in an internal situation where the floor slab is subjected to fairly uniform temperatures, but can be significant with external concrete.

During its life, a joint will be subjected to many thousands of load cycles. These degrade the crack face, leading to a reduction in load transfer. Research on small-scale specimens at Loughborough University⁽¹⁾ showed that deterioration occurs in four main phases (see Figure 1):

- Phase I: Rapid deterioration throughout the first few hundred cycles caused by mortar degradation.
- Phase II: Little increase in deterioration, with the crack face showing few signs of distress.
- Phase III: Rapid increase in deterioration as the aggregate starts to de-bond from the crack face.
- Phase IV: Failure causing complete face deterioration, resulting in zero load transfer.

The time at which Phase III was reached (signifying the onset of joint failure) varied depending on crack width, crack geometry, load magnitude and quantity/type of reinforcement. However, it was shown that if a differential displacement across the crack/joint of 0.6mm (0.3mm load step on site) was retained, the joint behaved adequately (remaining in Phase II), regardless of other factors.

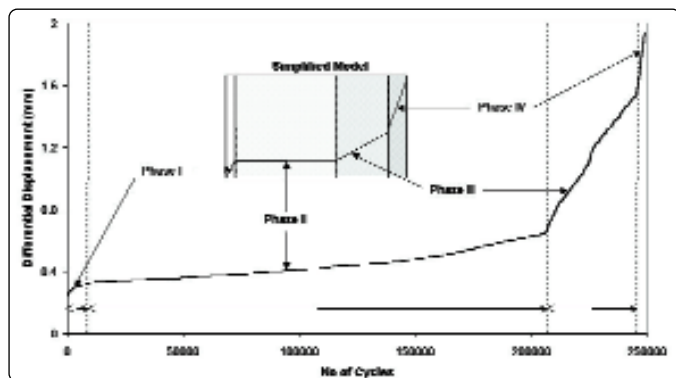


Figure 1: Typical deterioration phases obtained from a laboratory test.

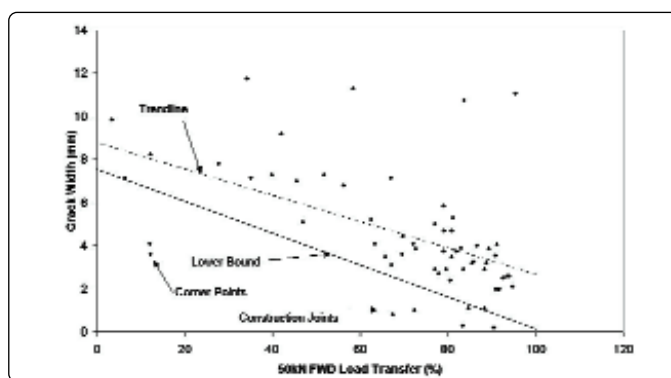
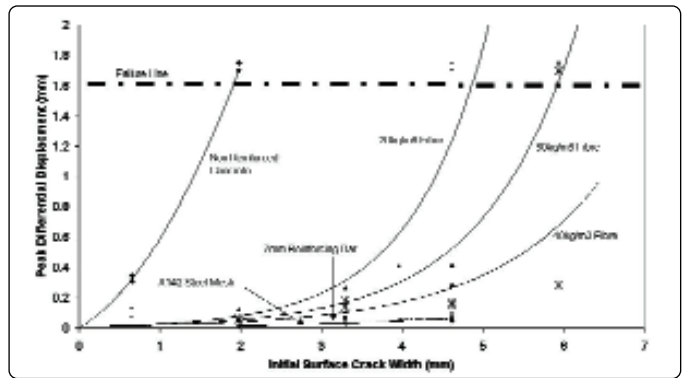
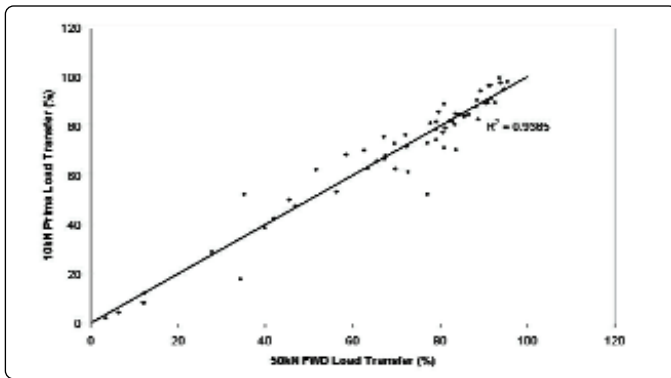


Figure 2: Relationship between crack width and load transfer.



Monitoring/assessment

At present, it is uncommon for cracks and joints in slabs to be regularly monitored. They will only normally be examined if a problem has been found, or if the joint or crack width is seen to be problematic. Such assessment is inadequate because these problems will usually only be associated with Phase III or IV deterioration, i.e. in imminent failure. Arnold⁽²⁾ found crack width to be a poor indicator of joint/crack performance, owing to the variation in deterioration levels that different areas of floor slab may experience (see Figure 2). In some circumstances, surface crack widths >7mm were found to contain over 80% load transfer, whereas narrower widths were less effective.

Equipment commonly employed for assessing road pavements can be used to obtain a physical value of load transfer. The Falling Weight Deflectometer (FWD) contains a series of geophones, which measure deflections under an applied dynamic load. The geophones can be placed either side of the joint or crack and enable a ratio of load transfer to be determined. With Very Narrow Aisles (VNA), a smaller device called the Prima dynamic plate can provide a similar type of assessment (comparisons between the FWD and Prima have shown good correlation (see Figure 3). If load transfer is monitored regularly throughout slab life, the transition into Phase III behaviour, along with localised areas of poor joint performance, can be identified. These areas can then be repaired as necessary, without time-consuming and expensive additional warehouse downtime following complete failure.

Reinforcement

Research at Loughborough University examined the effect of a variety of reinforcement types and quantities on the rate of load-transfer deterioration using small-scale laboratory testing⁽³⁾. The results showed specimens containing 20–40kg/m³ fibre and A142 steel fabric deteriorated much less than non-reinforced specimens (see Figure 4). However, only fibre quantities greater than 40kg/m³ could provide a similar amount of resistance to those containing steel fabric. Aspect ratio of the fibre (length/diameter) was also found to be highly influential, as those containing the highest ratios, thereby having the greatest number of bridging points across the crack, provided the most resistance to displacement and deterioration.

Concluding remarks

Failure of joints and cracks has long been known to be one of the main causes of distress in concrete slabs on grade. The load transfer across the crack must be retained if the slab is to function as expected and retain a long and usable life. To ensure cracks and joints maintain acceptable load transfer, regular monitoring is essential. Repairs can then be undertaken at the appropriate time, preventing the onset of failure. Including even small amounts of reinforcement has been shown to provide resistance to degradation and

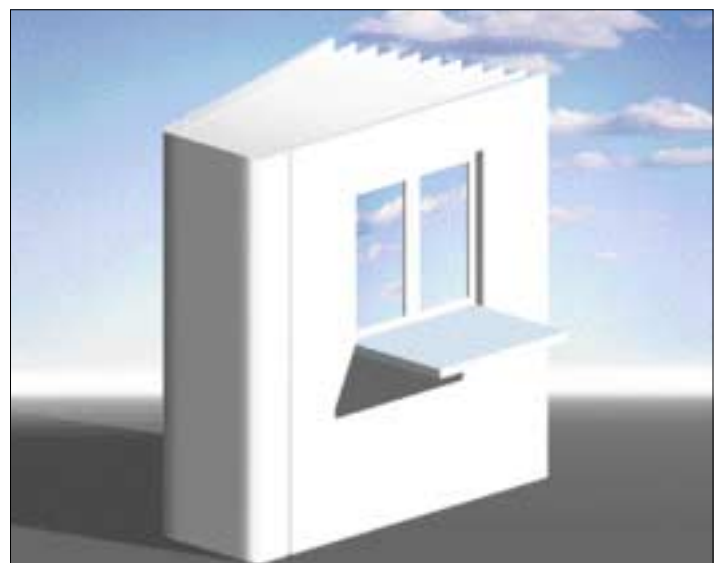
increase serviceability life. Some form of joint reinforcement, alongside regular monitoring, should therefore be recommended in all concrete slab specifications to enhance the long-term effectiveness.

Figure 3 left: Comparison between FWD and Prima.

Figure 4: Comparison of reinforcement types and quantities.

References:

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