Cracks in Industrial Concrete Floors

This Flooring Technical Note considers the types of cracks specific to concrete industrial floors and the typical causes of non-structural cracks. It does not look at the subject of crazing which is covered separately in *Flooring Technical Note 03 - Surface Crazing*.

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Introduction

This Flooring Technical Note covers the typical causes of non-structural cracks in concrete industrial floors. It should be noted that different crack types are often linked, and some cracks may exhibit characteristics attributed to a number of potential crack inducers. For example, a mid-panel shrinkage crack may be physically connected to a re-entrant corner crack located nearby; this does not necessarily mean that one has affected or created the other.

This flooring technical note does not cover cracking in cold store floors, any floors subject to extreme temperatures or pre-stressed floors, which are rarely used in industrial flooring. The subject of crazing is also not included as this is covered in a separate *ACIFC Flooring Technical Note 03*. Further, more in-depth guidance can be found in The Concrete Society Technical Report 22 – Fourth Edition; *'Non-structural cracks in concrete'*. However, it should be noted that *TR22* is not flooring-specific, and many topics covered are not directly related to internal industrial floors subject to just ambient temperatures.

Commentary

The following types of cracks are specific to concrete industrial floors:

1. Re-entrant corner cracks

Figure 1.

Freshly cast concrete panels shrink towards the centre of the body of concrete, so any intrusions within this panel can provide a potential for restraint, effectively stopping the free movement of the concrete. The threat of cracks emanating from any re-entrant corner, such as walls or columns, can be reduced by good isolation detailing; however, it is common practice to introduce crack control mesh/bars placed at 45 degrees to the re-entrant corner with nominal top cover.

The crack control measures are there to arrest the crack opening and not prevent crack formation. It is the job of isolation detailing and joint positioning to reduce the risk of crack formation at re-entrant corners.

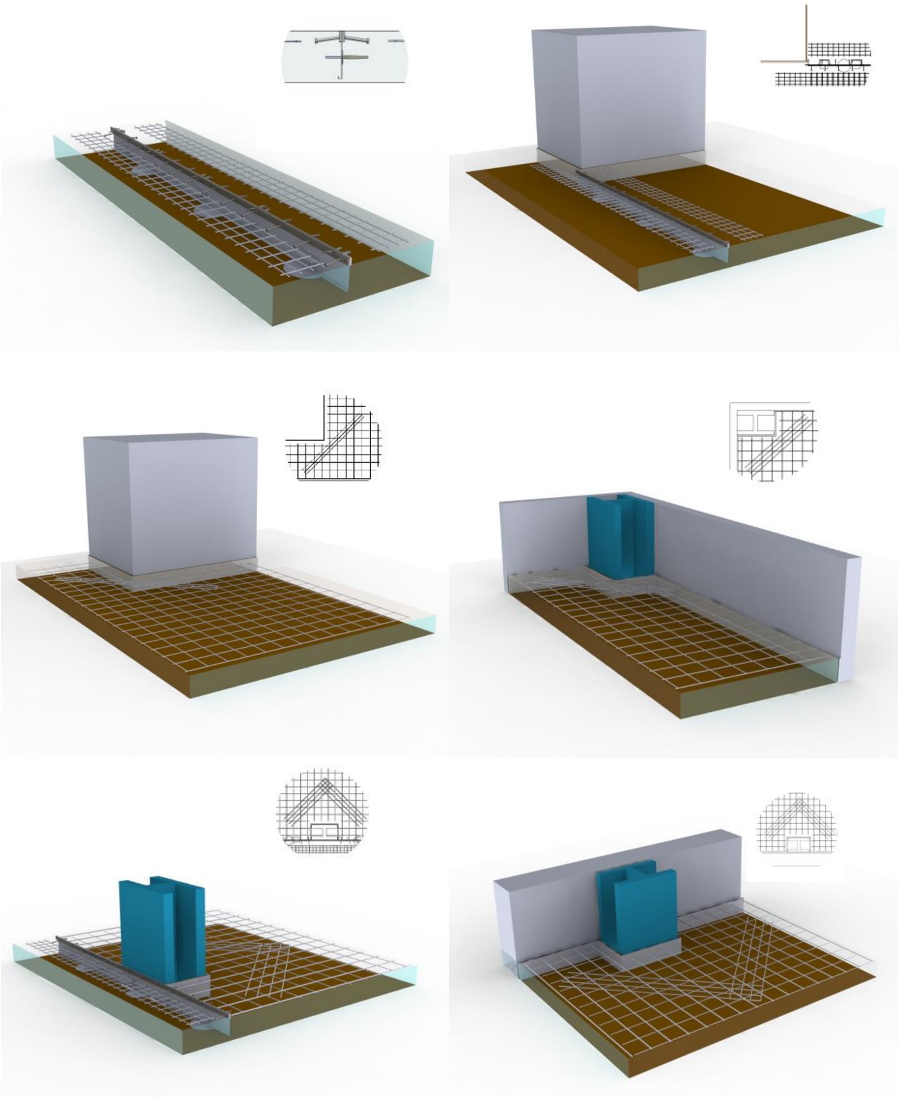

Figure 2. Generic examples of detailing around floor intrusions, such as columns and adjacent office areas

2. Cracks due to rutting of sub-base level

The saying that “your floor is only as good as the ground beneath” is particularly true when considering the levels on which concrete is physically placed. Failure to prepare the final sub-base layer to a satisfactory tolerance can result in crack inducing ‘folds’ being present in the sub-base. These ruts can effectively create localised weak spots in the floor slab where the nominal design depth is not achieved, and also where restraint will be created, hindering uniform concrete shrinkage. For this reason, a heavy roller should be on standby aside the floor construction process if traffic is likely to disturb the already prepared sub-base material. Any plastic sheeting placed beneath the floor should be free of folds, and if the construction process disrupts the placing of this sheet, it is advisable that any laps be taped.

3. Mid-aisle cracks

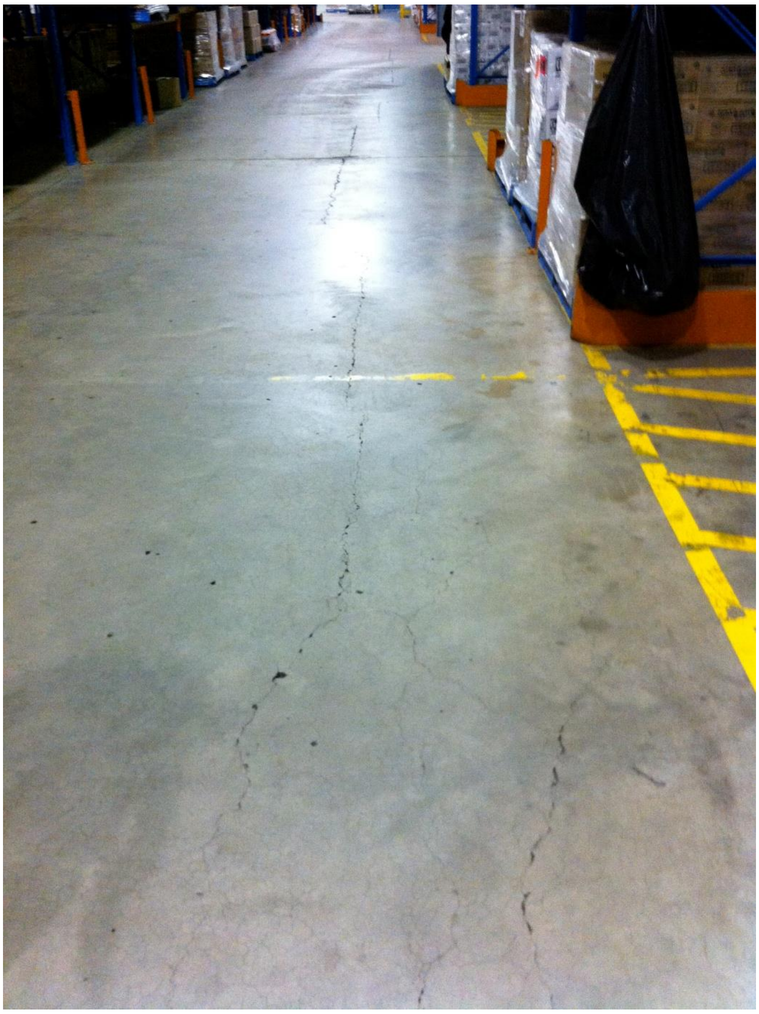

Figure 3.

Mid-aisle cracks are often associated with 'jointless' floors (i.e. large area panels free of saw-cut joints, separated by leave-in-place permanent formwork joints with integral dowelling systems) reinforced with steel fibres, however. Many 'jointed' floors, whether reinforced with steel fabric or fibres with a regular grid of induced saw-cuts, can also exhibit these types of cracks. The main reason for mid-aisle cracks should more often than not be attributed to the early loading of racking systems as opposed to the actual floor type constructed.

Early liaison between client and contractor(s) is advisable if storage systems are to be (a) installed, and (b) loaded quickly after floor construction, to gauge whether excessive cracking may be likely. The rapid shrinkage expected in concrete during its first few weeks cannot really be reduced effectively, although it can be minimised by using concrete mixes with lower cement contents whilst still maintaining the compressive strength required for the floor slab to carry the intended loadings.

However, the positioning of joints in certain locations can be the key to minimising the occurrence of these types of cracks. It should be noted by the client that a joint is essentially a planned crack. Whilst seeing a crack is not desirable, these can often stay tighter than saw-cut induced contraction joints. A non-structural crack of this type is simply a sign of the concrete doing what it does when it shrinks; the occurrence of a crack is not always the fault of the contractor or designer, and if the crack only propagates within specified tolerances, no repair is required.

4. Mid-panel cracking

Figure 4.

This can be caused by a number of things, including the positioning of joints at too large a centre; this is easy to diagnose with hindsight, but not always obvious until cracking has actually occurred. It should be noted, however, that mid-panel cracking is probably more desirable than having dominant joints; the phenomena of one induced joint accumulating all of the shrinkage intended for a series of joints. For this reason, solutions with minimal joints and a slightly higher risk of cracking can still be the best solution.

5. Cracking due to retrospective floor intrusions

Many buildings are designed to give clients future flexibility, for example, to accommodate the possibility of a mezzanine system being erected, or different machinery being used in a production area, etc. As such, retrospective drilling to allow the connection of baseplates to a slab can have a detrimental effect, but only aesthetically if it has actually been designed for these new loadings.

Whilst many changes of use are carried out years after construction of a building, any that are implemented early, certainly within two years of the floor being cast, can be a potential form of crack inducement. These details are extremely difficult to cater for at the original design stage due to the unpredictability of future (often unknown) client requirements, therefore any cracks formed which are deemed excessive should be repaired by the client to maintain the integrity of the floor.

6. Changes in slab depth, tapers etc.

Where different slab depths are required in the same building due to changes in localised floor usage (or differing ground conditions), it is good practice to separate the floor areas using a suitably located joint. Failure to do so, and hence casting the two slab depths using a tapered sub-base level, can create a localised weakness due to restraint, and hence a high risk of unwanted cracking. If the two areas must be cast in the same pass for some reason, additional traditional reinforcement should be utilised locally at the position of change in slab depth.

Cracks in Piled Floors

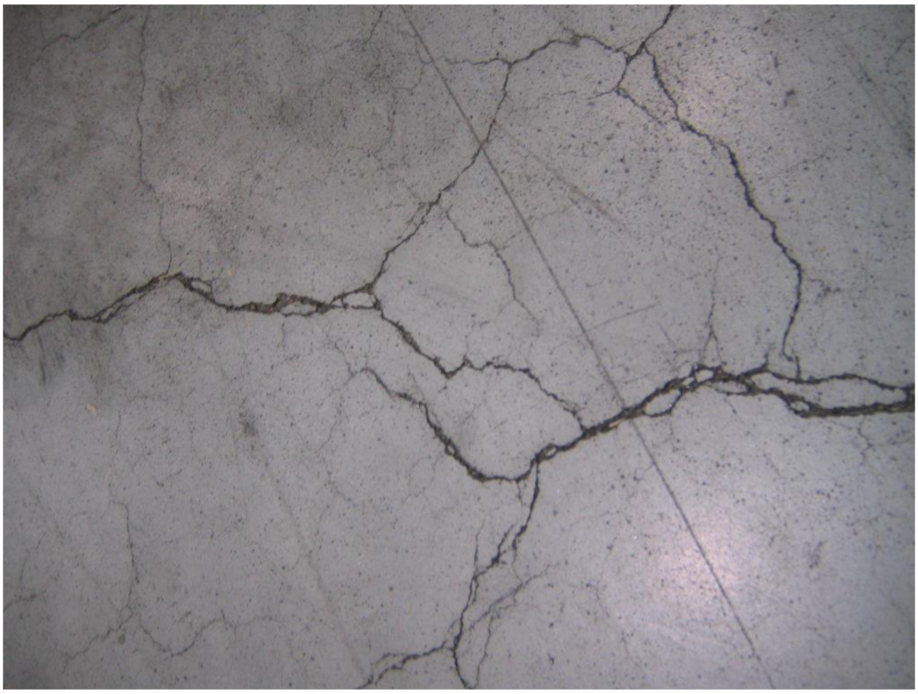

Figure 5.

Because a piled floor is designed to actually be suspended between piles, it should be noted that floors of this type could be deemed as structures, not just floors. For this reason, cracking exhibited in a piled floor should not automatically be deemed 'non-structural', and further investigation may be needed to deduce the importance of the crack, and a suitable remedial action. Similarly though, the principles of shrinkage cracks exhibited in ground bearing slabs still apply to floor on piles.

Cracks can often occur in floors on piles due to the slab being restrained by the piles beneath, particularly when small precast piles are used (and less so with large pile caps or formed flared heads). Even through slab self-weight, cracks can occur in the top surface due to this type of restraint; the amount of imposed load is not always critical in influencing this type of restraint.

Any physical tie between pile and floor will result in the slab cracking. If every pile is tied into the slab, a two-way grid of cracks which mirrors the pile locations beneath can be expected. For this reason, the design should be based around the top-of-pile level being at the underside of slab soffit level (i.e. no intrusion into the slab). A negative tolerance on the pile level has less of an impact and should be allowed (to approximately 25mm below the underside of the slab level), but piles located too far down can also create unwanted slab thickening locally, which will also result in crack formation.

The most common failure mode of floor on piles is due to hogging moments over piles (punching shear, and even less so, sagging moments between piles, are very rarely identified as the worst case during the floor design process). Cracks occurring over pile locations do not immediately indicate floor failure, as most reinforcement concepts and design methodologies use reinforcement which adds post-crack strength; in other words, the reinforcement doesn't work until an initial yield is created, so some cracks are expected, and indeed *needed* for the reinforcement to become active. For further information refer to TR34 4th edition.

7. Parallel cracks aside joint locations

When using traditional dowels (round or square) in daywork construction joints, these must be positioned accurately and remain in place, straight and true, both in plan (the view from above) and in section (when viewed head-on). Dowels which are misaligned in either plane can restrain joint movement, creating cracks parallel to the joint position. A simple remedy to 'dowel-lock' is to use a leave-in-place steel formwork joint, with an integral but non-continuous dowelling system.

8. Cracks in Floors on Composite Steel Decking

As most floors on composite steel decking are often cast when cladding is not in place, prevailing winds can cause increased rates of concrete drying during the casting operation.

There is a significant risk of cracking in all composite slabs due to restrained drying shrinkage and bending, and these factors cannot be eliminated. As the deck profile has peaks and troughs at regular centres, concrete is not free to move when it contracts, causing restraint and subsequent tension in the top surface of the slab; this can produce a series of parallel cracks which follow the direction of span. Bending is prevalent when decking is un-propped at construction stage, and the movement of secondary beams under load can cause hogging effects over these deck support positions. The presence of shear connectors can also produce cracks because of the local stress concentrations these cause.

It should also be noted that, as free water from the concrete mix can only leave the concrete through the slab's top surface, the hydration process of cement in decking concrete is often increased at the surface compared to some ground floors cast on sub-base, for example.

Any cracks in floors on composite steel decking should be closely monitored by the client to assess movement over time.

Summary

In summary, shrinkage related cracks will not form unless there is some type of restraint; however, cracks will form when the tensile stress exceeds the tensile strength of the concrete.

Once a crack has been identified as being non-structural in nature, the client should only consider having it repaired if the practical floor usage (i.e. forklift truck movements etc.) is compromised. Early repair of non-structural cracks may be unwise as further concrete shrinkage over time may result in failure of an early repair; a second (or more) round of repairs will undoubtedly disrupt the building usage for a further period, so ideally one repair should be sought, not several.

Further Reading

The Concrete Society, *Non-Structural Cracks in Concrete,* Technical Report 22 (4th Edition, 2010)

The Concrete Society, *Cracking in composite/corrugated metal decking floor slabs,* Concrete Advice No. 13 (July 2003)

The Concrete Society, *Concrete Industrial Ground Floors; A guide to design and construction,* Technical Report 34 (4th Edition, 2013)

The Concrete Society, *Composite concrete slabs on steel decking; guidance on construction and associated design considerations,* Good Concrete Guide 5 (2008)

ACIFC, *Steel Fibre Reinforced Concrete Industrial Ground Floors; An Introductory Guide,* 1999

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