Prefabricated steel free contraction joints in concrete floor slabs

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The Concrete Society recently published the third edition of The Concrete Society recently pub-Technical Report 34 *Concrete industrial ground floors: A guide to design and construction*[1]. Section 8.1 of TR34 stresses the importance of the design and construction of joints, most especially formed free contraction joints, which it states are less durable than sawn induced joints if unprotected. Poorly performing formed joints have proved to be the main flooring problem for building occupiers. Section 8.5 of BS 8204-2: 2002 *Screeds, bases and in-situ floorings. Concrete wearing surfaces. Code of practice*[2] requires that metal armouring should considered for all free contraction joints heavy-duty situations, while section 8.9 TR34 also comments on joint armouring.

The other main function of prefabricated joints for floor slabs is load transfer. The report reminds designers that the slab will have to be designed for a free edge/corner load condition if load transfer not provided across a joint (and some joints now open very wide). The significance of these precision-engineered joints discussed in this article, together with the need for buildability.

Joint efficiency – movement

Restraint of movement in a slab is a major cause of cracking. The function of a free contraction joint is to allow shrinkage movement to take place easily. Figure 8.2 of TR34 illustrates available options, all of which allow normal shrinkage movement. However, ordinary round dowels do not allow movement in two directions, increasing the risk of cracking at corners, and misalignment, which is a major factor leading to restraint and cracking. For many years, round dowels installed through predrilled holes in timber formwork, were used. To improve this method, two back-to-back 10 x 50mm steel sections were fixed at the top of the timber to provide joint arris armouring.

Although this method worked, difficulty was always experienced with the removal of the timber formwork and any misalignment of the dowels restricted the joint from opening. It did not permit two-directional movement of the slab. This is essential to avoid cracking, particularly at individual slab corners. Later developments incorporated square dowels with rectangular sleeves to permit two-directional joint movement. In the case of main floor slab joints, a system providing two-directional movement is essential.

For various reasons, including the increased use of jointless slabs reinforced with steel fibres, free contraction joints open wider than previously. Thus, the designer is recommended to provide clear information on the load transfer values at, for example, 10mm or 20mm joint opening for every joint.

Well-engineered, prefabricated, steel free contraction joints now open and close much more freely than sawn induced joints. Joints are now available with pre-compressed foam inserts that will accommodate large movement and exclude debris from the joint without the need for relatively unaccommodating mastic.

Joint efficiency – load transfer

As mentioned, today's free contraction joints are opening much wider than historically considered normal. Joint widths of 25mm are not uncommon. Ground-bearing slabs with sawn joints that show no increase in width are also found, with all joint opening taking place at the formed joint (see Figure 1). The designer must make sure the joint provides the required load transfer at the 10mm or 20mm joint opening expected. The performance in this respect will depend on the shape and design of the load-transfer system in the joint. Figures 2 and 3 show the Alpha trapezoidal plate dowel and Diamond plate dowel which provided the highest load transfer capability of any dowel system when tested at the Queensland University of Technology[3]. Joint performance will also depend on the precision of manufacture: for example, with joints based on interlocking profiles there will generally be a slack fit at the mating faces. Providing load transfer would therefore be detrimental, with deflection between adjacent slabs resulting in arris breakdown. Testing at Queensland University, Australia, has demonstrated that concrete strength around and immediately adjacent to the dowel to resist concrete burstout is the

Figure 1. Joint opened to 25mm.

Figure 2: Alpha dowel with trapezoidal plate, which provides good load transfer at wider joint openings and should be preferred for jointless slabs.

Figure 3. Diamond dowel with diamond dowel plate.

limiting factor, especially in thinner slabs. With joint slabs based on continuous load-transfer mechanisms, planes of weakness are created.

Joint types based on discrete transfer plates do not suffer from this continuous effect and can rely on the full depth of the concrete on either side of the dowel (see Figure 4).

Joint efficiency – arris protection

BS 8204-2: 2002 requires arris edge armouring in heavy-duty situations. The types of prefabricated joint generally available are based on 5mm or 10mm steel section thickness in double strips. It is generally accepted that 10mm steel sections provide better service than 5mm. For efficient arris protection, it is also necessary to make sure the joint is precision-manufactured, minimising any difference in level from one side to the other. The contractor must also take care to trowel the finished floor level with the top of the steel profile, not a few millimeters higher (see Figure 5).

Buildability

There are many designs of prefabricated armoured free contraction joints: most look good on paper yet cannot be built to a suitable accuracy. Traditional back-to-back steel angles are top-heavy, hotrolled angles being manufactured to unsatisfactory tolerances for general use in high-tolerance main floor slabs, such as in warehouses. Slightly misaligned, 100mm of combined flange showing in the finished floor would have a detrimental effect on heavily loaded fast-moving motorised pallet trucks, the small hard wheels quickly causing rapid deterioration of the joint and necessitating premature truck maintenance.

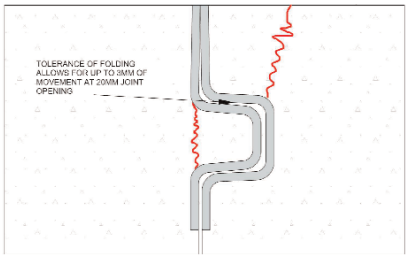

Figure 4: Continuous load transfer joints may provide insufficient load transfer values.

Installation method

There are three main installation methods. They may be installed by fixing (usually welding) to pins driven into the sub-base, may sit directly on the sub-base on their own purpose-designed feet, or may be fixed to timber formwork. One advantage of fixing to pins is that the alignment does not depend on sub-base flatness and casting both sides on the same day is straightforward. However, the pins left in the slab will represent some constraint to subsequent movement and steadiness will rely on sub-base quality.

Joints are often installed directly on the sub-base on proprietary feet, and need to provide a solid fixing. The feet can be leave-in-place (allows for casting both sides on the same day) or reusable. Both types have their own level-adjustment system. However, the sub-base at the joint location must be properly rolled and compacted because, if the sub-base slopes, so will the joint. Such an installation is most effective in main slab areas but, where the sub-base falls away (e.g. at doorways), installation using the pin fixing method may be more appropriate (see Figure 6).

Prefabricated systems are more efficient to install and timber formwork does not give the option of casting both sides on the same day. For deep slabs, prefabricated systems may require some additional timber support to achieve maximum stability. Good specialist concrete floor slab contractors will be familiar with these practical aspects and be able to reassure the designers that the selected joint will be built to the necessary standards.

Figure 5: A 10mm section AlphaJoint in a busy transport warehouse. Note how the floor slab contractor has finished the concrete to the correct level and not buried the steel profiles.

Concluding remarks

Good joint design is essential to good floor performance. Any engineer designing a floor should understand that neglecting the efficiency of joint arris armouring and load transfer will lead to client dissatisfaction. The installed cost of a proper functioning joint system is around £20–30 per metre (£0.60/m^2 on a 15,000m^2 floor), compared with more than £100 per metre for repair, not taking into account disruption cost. Good joint design makes sense. ■

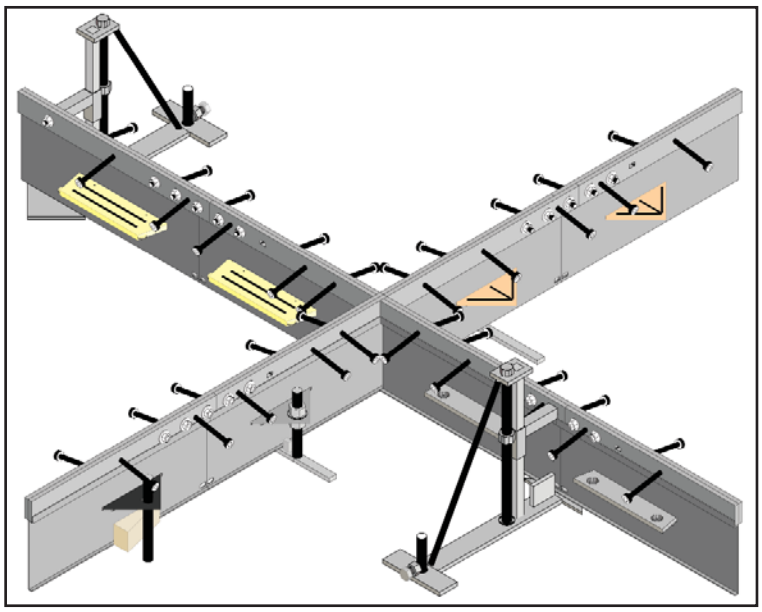

Figure 6. The AlphaJoint.

References:

1. THE CONCRETE SOCIETY. Technical Report 34: Concrete industrial ground floors – a guide to design and construction, The Society, Crowthorne, 2003, 146pp.
2. BRITISH STANDARDS INSTITUTION. BS 8204-2: 2002 Screeds, bases and in-situ floorings. Concrete wearing surfaces. Code of practice, 40pp.
3. QUEENSLAND UNIVERSITY OF TECHNOLOGY. Jointing systems in concrete structures – testing of dowel systems, 2002, 25pp.