critical region. The bolts and baseplate may be cast into a screed to keep them below the finished floor level.

Before deciding to use moment resisting connections at column bases, the designer should carefully consider whether they are necessary for the frame design (for example, they are often needed for 'crane buildings', and tall unbraced buildings). Increased foundation complexity, and therefore increased total cost, is the main consequence of adopting moment resisting bases. When nominally pinned bases are chosen, the holding-down bolt size is normally determined by the moment needed to stabilise the column during erection (although other load conditions should also be considered).

6.1.1 Cast-in bolts

One of the benefits of using sleeved cast-in bolts is that, theoretically at least, the positions of the bolt tips can be adjusted following concreting of the base slab. To facilitate this the bolt sleeves must be of sufficient diameter, and may be conical, as shown in Figure 6.1.

Conical sleeves maximise possible movement at the bolt tip without reducing the area of concrete which provides anchorage. The diameter of the top of the sleeve should be approximately three times that of the bolt. Moving each bolt in its sleeve as the concrete is curing is essential to ensure that the potential adjustment offered by the use of sleeves is not lost.

Several problems can arise in practice when using sleeved bolts, and these may affect the ability of the erector to correctly locate the columns:

- Accurate positioning of bolt groups requires care. A wooden template should be used to align the bolt tips. Complicated steelwork used to anchor the bolts may be difficult to position correctly amongst reinforcing bars. Because the contractor responsible for the foundations has no further direct involvement in the erection of the steel frame once the base **is** poured, the necessary care is often not taken.

- Accurately set-out bolts require care to maintain them in the correct position during concreting.

- Correctly positioned bolts may be bent or damaged after the concreting operation. The practice of heating and bending bolts to bring them back into the desired position should be avoided, since the properties of the steel used for high strength bolts may be adversely affected by the application of heat. To reduce the likelihood of projecting bolts being damaged, a diameter of less than 20 mm should not be used. Threads should be protected against damage.

- In addition to correct alignment, there is a need for a minimum projection of the bolts above the base. The NSSS[6] requires that the level of the base should be within a tolerance of +0 to -30 mm, and the level of the top of the bolt should be within the range +25 mm to -5 mm in order to ensure the necessary projection. If the bolt projection is insufficient, then remedial measures may be required, such as fitting a sleeve over the short bolt and enlarging the hole in the baseplate so that the column can be located over this sleeve. Welding on an extension when bolts are too low should be avoided because of the change in properties of the steel which may take place during heating.

When bolt positions are outside specified tolerances, remedial measures will inevitably involve adapting the column bases. Oversizing the holes in the baseplate, extending the baseplate, or using post fixed anchors may need to be considered.

KEY POINTS - Cast-in bolts

The use of cast-in bolts should give sufficient adjustment on site at the interface between the foundations and the steel frame. However, site work must ensure that:

- bolts are properly located in the specified positions prior to concreting
- bolts are not displaced during concreting
- bolt tips are not damaged following concreting
- bolts project a sufficient distance above the top of concrete
- bolts are free to move within their sleeves.

6.1.2 Bedding material

Having located a column and adjusted its line, level and plumb using the procedures outlined in Section 3.1.6, bedding material must be placed beneath the baseplate. Several different types of bedding material can be used depending on the size of the gap under the plate.

For orthodox bases with a typical 25 mm to 50 mm gap, by far the most common material is non-shrink cementitious grout. This is pre-bagged so that it only requires the addition of water to achieve reliable final properties of the grout. A method statement for placing the grout should be prepared to ensure that the bolt sleeves and void under the baseplate are filled to the expected standard.

Good access aids cleaning out of the sleeves before locating the column, and subsequent placing of the grout. Locating the column base in a recess in the base slab may severely restrict access, although it does provide a good shear key and may be an efficient way of keeping the baseplate detail below finished floor level. Holes should be provided in larger baseplates (more than 700 mm x 700 mm) to allow trapped air to escape, and facilitate placement or inspection of the grout. One hole should be provided for every 0.5 m^2 of plate[15]. If the holes are to be used for placing the bedding material, they should be 100 mm in diameter, otherwise they need only be 50 mm. Packs placed under the baseplate for levelling of the column during erection can be left in place(6), provided this is agreed with the client's representative.

In addition to an increased likelihood of bolt corrosion, a consequence of poor filling of the sleeves may be an inability of the bolts to transfer horizontal loads into the foundations. However, often this is not a problem because friction between the baseplate and grout (under high axial load) is sufficient to resist horizontal loads. No special provisions are required if the shear loads are less than 20% of the axial load[14]. When this is not the case, the bolts are generally designed to resist the shear loads and sound placement of the bedding material is essential. Alternative