Fig. 5.2—Shooting through welded-wire mesh cut and bent to follow contours or repair.

Intersecting reinforcing bars should be rigidly tied to one another and to their anchors with 16 gauge (1.3 mm) or heavier tie wire and adequately supported to minimize vibration during shotcrete placement. Vibrations in the reinforcing steel can cause sagging of plastic shotcrete, create voids, and reduce in-place strengths. Large knots of tie wire should be avoided to minimize the formation of sand pockets and voids. Loose mill scale and rust and oil or other coatings that can reduce the bond of the shotcrete to the reinforcement should be removed.

5.4.3 *Steel mesh reinforcement*—The mesh should be cut to proper size and carefully bent to closely follow the contours of the areas to receive shotcrete (Fig. 5.2).

The reinforcing mesh should be securely tied with 16 gauge (1.3 mm) or heavier tie wire to preset anchors or reinforcing bars. Large knots of tie wire should be avoided to minimize the formation of sand pockets and voids. When sheets of mesh intersect, they should be lapped at least 1.5 spaces in both directions and be securely fastened. In no case should the wires be spaced less than 2 in. (50 mm) apart (Section 5.4.2). When more than one layer of mesh is required, the first layer may be covered with shotcrete before placing the second layer. Some type of anchor or tie should extend to the second layer. Unless the design dictates otherwise, the sheet of mesh should be placed in the center of the shotcrete layer.

5.5—Anchors

Special devices are used in shotcrete work to anchor, support, or space the reinforcement. Some of the factors involved in determining the type, size, and spacing of these devices are: the type of application; its design; the shotcrete thickness; the nature of the original surface; and the type, weight, and geometry of the reinforcement. The maximum recommended spacing of anchors for most applications is 36 in. (900 mm) on-centers-both-ways for horizontal surfaces, 24 in. (600 mm) on-centers-both-ways for vertical and inclined surfaces, and 18 in. (450 mm) on-centers-both-ways for overhead surfaces. If special conditions exist, the design of the anchor spacing and size should be checked for sufficiency in pullout and shear. Anchors or spacers for reinforcement should be located to provide sufficient clearance around the reinforcement, permit proper cover, and complete encasement with sound shotcrete. Special bowtie connectors are sometimes used with fiber-reinforced shotcretes to provide mechanical connection to the anchors.

5.5.1 *Anchoring to steel*—Reinforcement can be attached to steel surfaces using mechanical clips, blank nuts welded to the steel, stud-welded devices, slab bolsters, or self-tapping screws; by direct attachment; or by any manner that does not compromise the integrity of the structural member. Clips and bolsters are only used to directly attach mesh to steel. Studs or nuts can be used to attach reinforcing bars or mesh. Drilling holes through structural members to facilitate the anchoring of reinforcement should be avoided. Consult the structural engineer before drilling into structural members or before welding reinforcing steel.

5.5.2 *Anchoring to concrete, masonry, or rock*—Reinforcement can be attached to concrete, masonry, and rock surfaces using expansion anchor bolts, steel dowels, self-drilling fasteners, and expansion shields. The choice depends to a large degree on the application, type of specified reinforcement, position of work, number and size of anchors, and cost. The manufacturer's recommendations for size, depth of hole, and safe-working loads in shear and pullout should be explicitly followed.

Expansion anchor bolts are the most commonly used concrete anchors. They are available straight and threaded with a nut at the exposed end or without threads with a hooked or L-shaped exposed end. Both styles have some type of expanding sleeve or wedge on the embedded end to provide positive locking action in a predrilled hole. These anchors come in variable lengths so they can be adapted to shotcrete from 1-1/2 to 6 in. (40 to 150 mm) thick.

Self-drilling fasteners and expansion shields may be used and are useful for 6 in. (150 mm) and thicker layers, up nonuniform shotcrete sections, and where multiple layers of reinforcement are specified.

Steel dowels or reinforcing bars are used in structural shotcrete applications when sections are 6 in. (150 mm) or thicker, and heavy cages of reinforcing bars have to be supported and anchored. They are also used for anchoring shotcrete to rock. They should be set sufficiently deep to meet pullout criteria and installed using a nonshrink cementitious grout, epoxy, or polyester resin.

5.5.3 *Anchoring to wood*—Reinforcement may be attached to wood surfaces using individual bar chairs, slab bolsters (continuous chairs), or nails. They should be positioned to provide proper cover and encasement by the shotcrete. Bolster legs should be trimmed off when they are adjacent or parallel to reinforcement. If the wood surface is a removable form, nails should not be used and the chairs and bolsters should be plastic-tipped to eliminate rust on the formed surface. Reinforcing bars or individual wires in mesh should not coincide with the longitudinal wire of a slab bolster (Fig. 5.3).

5.6—Alignment control

Alignment control is necessary to establish line and grade in shotcrete construction and to ensure that proper and uniform

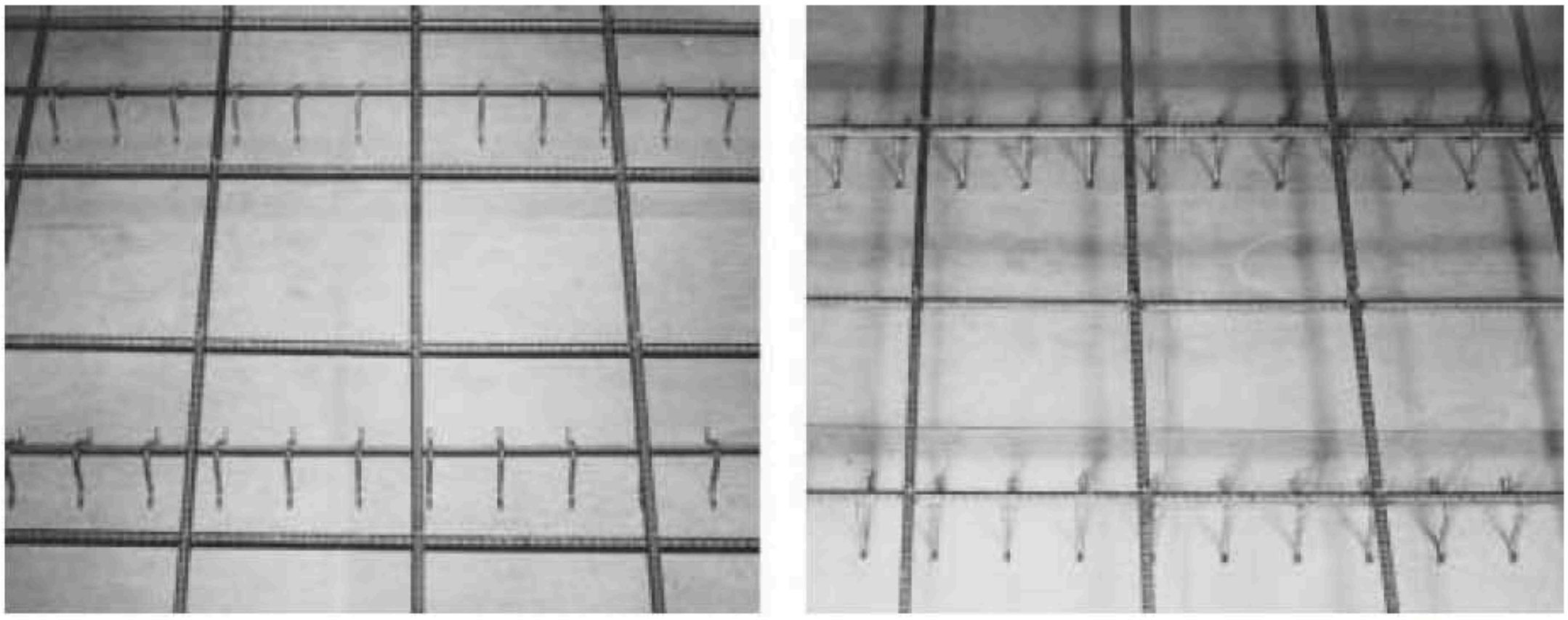

Fig. 5.3—Positioning slab bolsters. Correct (left) and incorrect (right) method for placing continuous chairs or slab bolsters. (To avoid sand pockets, the bolster wire should not be adjacent or parallel to a wire mesh.)

material thickness and cover are maintained. Alignment control is accomplished by the use of ground wires, guide strips, depth gauges, depth probes, or conventional forms.

5.6.1 *Ground wires*—Ground wires consist of 18 or 20 gauge (1 or 0.8 mm) high-strength steel wire, called "music" or "piano" wire that can be combined with a device that places the wire under suitable tension (not all situations require a tensioning device). Ground wires are the most convenient means to establish line and grade when forms are used to shoot against. Wires may be used individually to establish corners, while several parallel wires in combination may be spaced 2 to 3 ft (0.6 to 0.9 m) apart to provide screed guides for flat areas (Fig. 5.4). For work with tight tolerances, space the ground wires 12 to 18 in. (300 to 450 mm) apart.

5.6.2 *Guide strips*—Guide strips consist of wood lath usually no larger than 1 x 2 in. (25 x 50 mm) connected by crosspieces at 2 to 3 ft (600 to 900 mm) intervals. Guide strips serve as an excellent method of alignment control in both repair and new shotcrete construction. Chamfered edges are readily attained using a chamfer strip at the corner of the guide strips.

5.6.3 *Depth gauges*—Depth gauges are small metal or plastic markers attached to or installed perpendicularly in the substrate or backup material at convenient intervals and heights. Depth gauges provide a preset guide to the thickness of the shotcrete and are positioned approximately 3/4 in. (20 mm) below the finish coat of shotcrete. They are normally left in place, provided they do not affect the integrity of the application (Fig. 5.5). Any gauge that is normal to the surface and is tied to the reinforcement will provide a conduit for moisture and allow subsequent corrosion. Gauges that are tied to reinforcement should be cut back 3/4 in. (20 mm) to prevent a moisture conduit.

5.6.4 *Depth probes*—Depth probes are used in situations where there is greater latitude in the finish tolerance requirements. They are usually made of 12 to 14 gauge (2.1 to 1.6 mm) steel, and marked with the specified shotcrete

Fig. 5.4—Shooting concrete using ground wires as a guide to bring materials to line and grade.

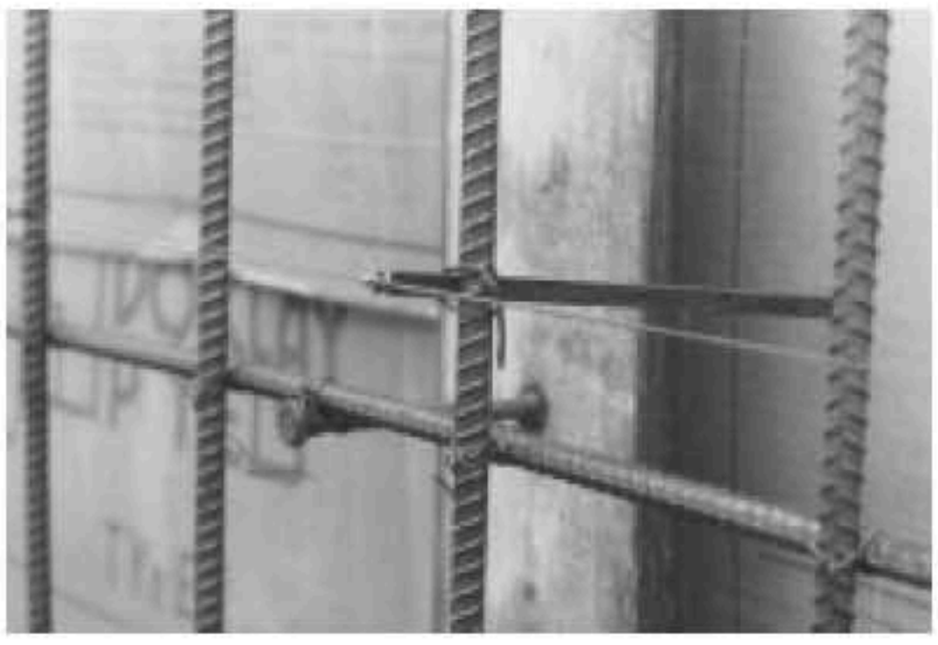

Fig. 5.5—Ground wire attached to depth gauge, which is tied to reinforcing steel and will be left in place.

thickness. Probes are inserted into the shotcrete until the substrate is reached, indicating the depth of shotcrete. Probes should only be used if puncture holes can be tolerated.

5.6.5 *Formwork*—The use of conventional forms in shotcrete work is the exception rather than the rule. Conventional forms may prevent adequate escape of air, resulting in the formation of