Strengthening with Shear Collars

Since their development 20 years ago, concrete shear collars have proven to be an effective, versatile method for retrofitting and strengthening existing concrete structures

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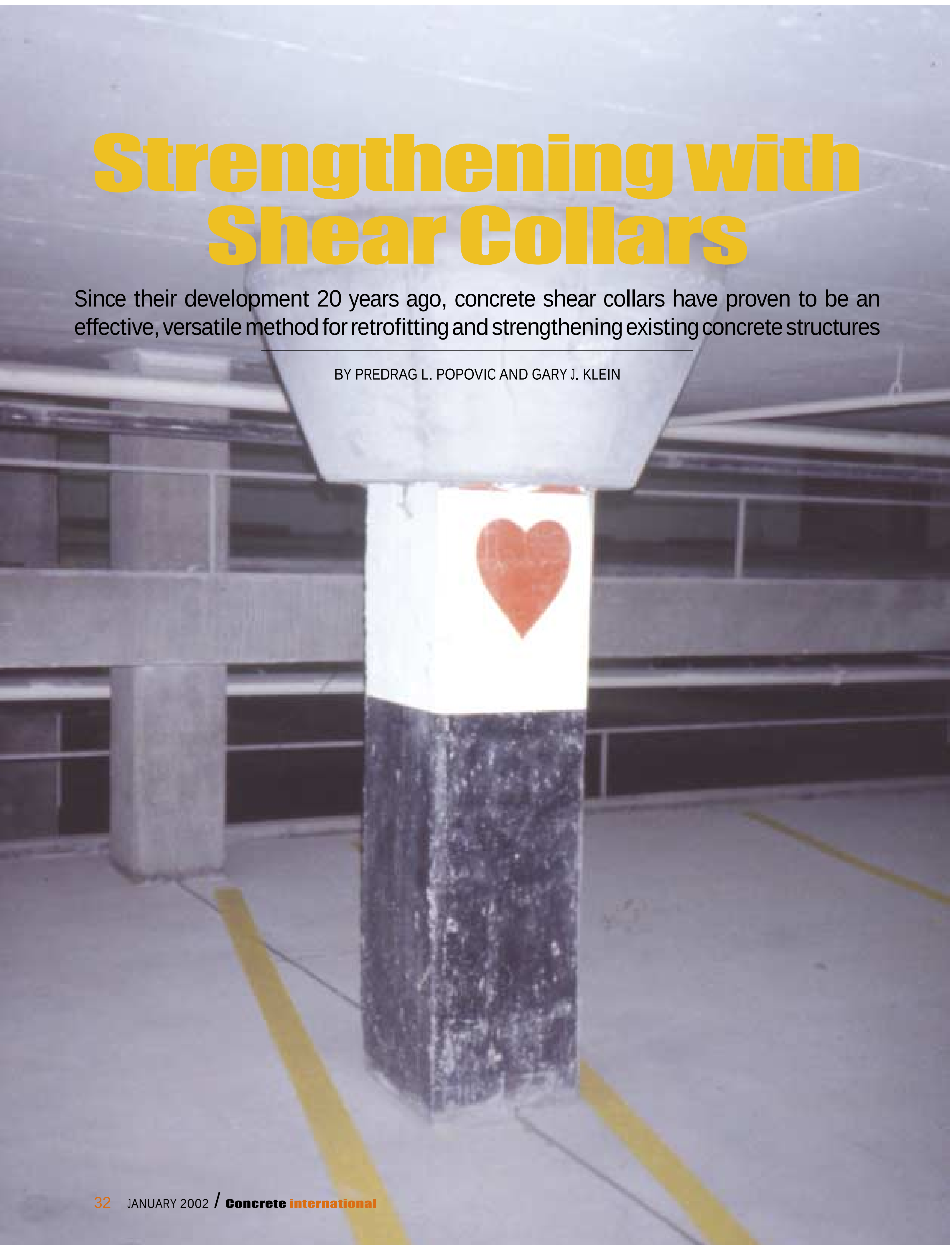

At some point during the life of a concrete structure, retrofitting or strengthening may be required. This need may arise for a number of reasons:

- The type of building occupancy changes, resulting in larger floor loads. Concrete floors also may require strengthening if design or construction errors cause structural deficiencies;
- Deteriorated concrete structures exhibit structural deficiencies resulting from corrosion of reinforcing steel or breakage of prestressing tendon wires;
- Modifications to an existing structure add weight, requiring strengthening of certain parts of the structure. For example, a new concrete overlay used for repair and future protection of a bridge or parking-garage deck imposes an additional load on concrete slab-column or column-footing junctions; and
- Seismic retrofit of existing concrete structures requires strengthening of slab-column junctions, supplemental confinement of column reinforcing, or reinforcing splices to increase ductility.

Since their development 20 years ago, concrete shear collars have been used successfully for these and many other practical applications where improved load transfer to columns was needed (see "Theory of Shear Collars"). As the following examples illustrate, shear collars are a simple, economical method for correcting existing structural deficiencies, increasing structural capacity for additional loads, facilitating installation of new floors, improving seismic resistance, and simplifying bridge-bearing replacement.

Strengthening slab-column junctions

It's not uncommon for reinforcing in the top of a slab to be placed lower than intended. This can greatly reduce the capacity of the slab to transfer floor loads into the columns (Fig. 1). Improving the punching shear capacity of the slab-column junction may require increasing the slab thickness or the perimeter of the transfer area. Concrete shear collars can increase the perimeter of the load-transfer area of a slab and thus increase the shear capacity of the slab-column junction by several times. This also results in increased slab bending capacity because of span reduction. However, proper design of the circular reinforcing in the collar is essential.

Originally, shear collars used lapped-spliced pairs of reinforcing bars to encircle the column. Recently, mechanically spliced circular ties have been successfully installed. Encircling a column using a single bar is accomplished by rotating it vertically, springing it open, placing it around the column, and mechanically splicing it in the final horizontal position.

Concrete for the shear collar usually is placed from a chute or bucket into a cored hole in the floor slab next to the column. An alternative placement technique of pumping the concrete into the form requires vent holes in the form or slab and may result in more cement and less aggregate in the final concrete mix. To ensure good

Fig. 1: Slab distress due to misplaced reinforcing bars

Fig. 2: Dry packing concrete between poured-in-place collar and slab soffit

Fig. 3: Collar reinforcement in place before form placement

Fig. 4: Installation of shear collars using cardboard forms

contact between the collar and slab soffit, shear collars below slabs are usually installed in two phases.[1] In the first phase, workers leave a space between the top of the collar and the slab soffit when placing the concrete. In the second phase, they dry-pack a stiff mortar into this remaining space (Fig. 2). Another alternative is to pump grout around aggregate preplaced in the form.

Cardboard column forms can be an inexpensive option for forming shear collars, but the collar diameter will be the same for its full height (Fig. 3 and 4). Achieving a sloping collar surface with a variable collar diameter usually requires the use of steel forms (Fig. 5). This results in improved aesthetics and more clearance around the column. Capitals and drop panels installed as retrofits at slab-column junctions are not shear collars because they can't transfer the vertical load to the column by friction unless properly designed circular reinforcing is present. If a flaired capital with plane surfaces is preferred for aesthetic reasons, circular reinforcing steel must be used (Fig. 6).

Strengthening column-footing junctions

Shear collars also can be used to strengthen column-footing junctions when there is an increase in column loads or a deficiency in concrete footings. The concept is the same as in slab-column junction strengthening, except that the loads are acting in opposite direction and the shear collar is installed on top of the concrete footing or pile cap.

An example of this application is the repair of deteriorated concrete stadium stands. The project called for the installation of a latex-modified concrete overlay over the tread-and-riser surfaces to increase their capacity and provide protection. Not only did the overlay increase column loads, the column bases were found to be deteriorated. Installing shear collars on top of the existing footings (Fig. 7) served the dual purpose of repairing the deteriorated column bases and transferring the loads from the columns to the footings, thereby bypassing the deteriorated column areas and increasing the punching shear capacity of the pile caps (Fig. 8).

New floor near midheight of existing columns

To increase the usable space of a building, some building owners will install a new concrete floor in the space between the existing floors or between the basement and the existing first floor. This can be an inexpensive way to increase space, assuming there is

Fig. 5: Reusable steel form for sloping column surface

Fig. 6: Circular reinforcement is needed if a supplemental flaired column capital is to function as a shear collar

Fig. 7: Shear collar reinforces column-footing junction

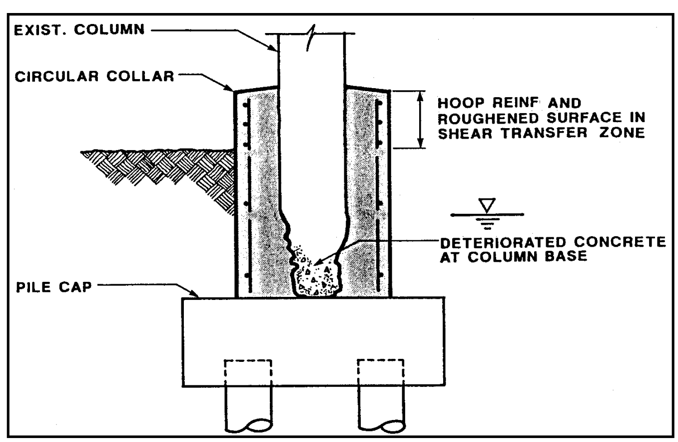

Fig. 8: Cutaway view of a shear collar used for repair of deteriorated column base

Theory of shear collars

Shear collars are circularly reinforced jackets placed around existing columns for strengthening and repair of reinforced-concrete structures (see photo on p. 32). In a search for an alternative to more costly and destructive shear-transfer mechanisms, such as anchored dowels and shear keys, Klein and Gouwens developed the theory for shear-friction load transfer between circularly reinforced collars and columns. Because no reinforcing crosses the potential slip plane, the usual shear-friction mechanism doesn't occur. Instead, the radial compression resulting from tension of the circular confining reinforcement develops the normal force. The reinforcement is tensioned when the collar expands and begins to slip along a roughened surface.

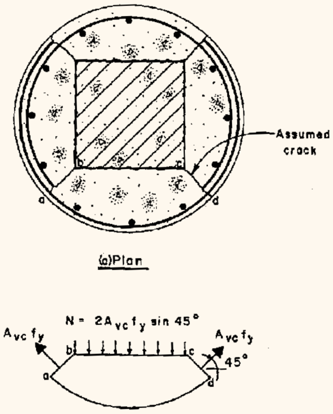

Fig. 1: Normal force development for a square column

Figure 1 illustrates the normal force developed by circular reinforcement around a square column. The total normal force depends on the column shape. Because dowel action, which normally contributes to shear strength, is not a factor, the effective friction coefficient is somewhat less than usual. Accordingly, the equation for determining shear strength of a circularly reinforced collar is:

$$V_n = C_n A_{vc} f_y \mu_c$$

where C_n is a normal force constant that varies with column shape, A_{vc} is the area of circular reinforcement, f_y is the yield strength of the circular bars, and μ_c is the reduced friction coefficient applicable to concrete collars.

Based on theoretical study and limited load testing, Klein and Gouwens made the following discoveries about shear-collar design:

- For normalweight concrete, the friction coefficient for circularly reinforced collars, μ_c, is:

$$\mu_c = \frac{700}{v_u}$$

  where v_u is the ultimate shear stress in psi. Alternately, a constant μ_c equal to 0.7 may be considered, which is more consistent with the shear friction provisions in ACI 318-99;
- The normal force constant, C_n, is as follows:

Column Shape	C_n
Square	5.64
Rectangular (a x b)	$4(a + b)/\sqrt{a^2 + b^2}$
Round	2π or 6.28

- The column surface should be roughened and cleaned, and the average amplitude should be at least three to four times the calculated separation between the column and collar at yield;
- The collar reinforcement should be fully developed and located at or near the outside face; and
- Unless shear-transfer strength is verified by load test, the collar height should be at least 80% of the column width, and the distance from the load application point to the face of the column should not exceed 40% of the collar height or one-half of the collar thickness.

Reference

Klein, G. J., and Gouwens, A. J., "Repair of Columns Using Collars with Circular Reinforcement," *Concrete International*, V. 6, No. 7, July 1984, pp. 23-31.

Fig. 9: Shear collar supporting a steel truss for supplemental floor framing

Fig. 10: Eccentrically loaded shear collar

Fig. 11: A shear collar confines column reinforcing for seismic retrofit

Fig. 12: Shear collar on top of a bridge pier provides a jacking surface for bearing replacement

enough height to accommodate the additional floor. Installing concrete shear collars around the existing columns near midheight (Fig. 9) can support supplemental floor framing without reducing floor area.[2] If shear collars are loaded from one side only (Fig. 10), their design must account for this eccentricity.

Seismic strengthening

Concrete shear collars have been used to increase the capacity and ductility of slab-column junctions in existing structures located in seismic zones. They also have been used to seismically retrofit a parking garage by providing supplemental confinement of column reinforcing at column-footing junctions (Fig. 11). In this instance, the retrofit required cutting several dowels projecting from the footing into the column in order to define a hinge location for a future earthquake. For this hinge to form and act as designed, the existing column reinforcing had to be confined. Installing concrete shear collars was the most economical method to provide the required confinement.

Surface for replacement of bridge-pier bearings

An interesting application of concrete shear collars involved using them as a jacking surface for the replacement of bridge-girder bearings. The project required jacking each bridge girder from the top of a single-column pier. Installing a permanent shear collar at the top of the column provided additional area to facilitate jacking (Fig. 12). For this application, an external steel jacket served as the circular reinforcement. By placing the jacks at the top of the pier next to the existing girder bearings, workers were able to lift the girders to remove the existing bearings and install the new ones. The permanent shear collars will also simplify future replacement of girder bearings when required. Due to the unusual nature of this application, the shear-transfer strength was tested using a half-scale model (see cover photo).

References

1. Popovic, P. L., and Klein, G. J., "Shear Collars Save a Parking Garage Slab," *Concrete Construction*, Oct. 1988, pp. 924-928.

2. Popovic, P. L., and Reed, R. C., "Support Options for Floor-Strengthening Framing," *Concrete Repair Digest*, Feb.-Mar. 1992, pp. 4-8.

Selected for reader interest by the editors.

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