



INCREASING SHEAR CAPACITY WITHIN EXISTING REINFORCED CONCRETE STRUCTURES—TECHNOTE

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Introduction

Rehabilitation projects often involve the need to increase the load-carrying capacity of members within existing concrete structures that are deficient due to increased load demand associated with change of use, deficiencies in the original design or construction, or deterioration. Such strengthening often includes increasing shear capacity.

Question

What options are available to increase the shear capacity of members within existing reinforced concrete structures?

Answer

The following sections describe various techniques for shear strengthening or reduced shear demands of existing reinforced concrete members such as beams, columns, slabs, and walls. Some considerations in selecting a suitable method are also provided. The shear strengthening measures described are intended for nonseismic applications. For seismic applications, refer to [ACI 369.1](#) and [ASCE 41](#). [ACI 546R](#), [ACI 549.4R](#), [ACI 440.1R](#), [ACI 440.2R](#), and [ACI 437R](#) provide additional information on structural strengthening. All shear strengthening should be performed by or under the guidance of a licensed design professional (LDP) who is familiar with the selected technique and licensed in the jurisdiction where the work is being performed, and in accordance with the evaluation and repair design requirements set forth in the current building code for that jurisdiction. Selected shear strengthening methods should be approved by the applicable authority having jurisdiction.

Considerations for selection of shear strengthening method

The selection of the most suitable shear strengthening method for a given application depends on many factors, including:

- a) *Cause for strengthening* – To select an appropriate shear strengthening method, the cause for strengthening needs to be determined.
- b) *Crack control versus crack prevention* – Most methods will not prevent concrete cracks from forming; rather, they will limit the opening and propagation of shear cracks after crack formation. If crack prevention is important, certain options should be considered, notably section enlargement, supplemental members, and external post-tensioning.
- c) *Strength of the existing member and magnitude of strength increase required* – Depending on the selected strengthening method, limitations exist on the level of strength increase that can be provided. Some methods can produce higher relative strength increases than others.
- d) *Necessity to unload the member before performing the shear strengthening procedure* – If the member is shored and unloaded prior to the procedure, the strengthening system will resist both future (superimposed) and present (dead and sustained superimposed) loads in conjunction with the original member, irrespective of the method being used. However, if the member is not unloaded, external post-tensioning is the only method that will resist both future and present loads. Passive strengthening systems (for example, externally bonded reinforcement) will generally only be able to resist loads applied after strengthening. However, the repairs may be engaged by creep effects over time.
- e) *Possibility of shear reversals* – This is a common situation in continuous structures with variable loading patterns.

f) *Requirement for the shear strengthening system to remain functional throughout the anticipated failure process* – For systems relying on bonded reinforcement or bonded concrete, some form of anchorage will often be necessary to preserve attachment across the shear cracks after initiation of debonding, which needs to be analyzed to ensure the compatibility of deformations.

g) *Size of project* – Some special methods and materials may be less cost-effective on small projects.

h) *In-service conditions* – Methods using adhesives might be unsuitable in high-temperature environments; external steel methods can be vulnerable in corrosive environments; and exposed steel and fiber-reinforced polymer (FRP) methods can impact the fire rating of strengthened members.

i) *In-place concrete strength* – The effectiveness of methods relying on bond to the existing concrete can be significantly limited by low concrete strength.

j) *Dimensional/clearance constraints* – For instance, section enlargement might be limited by the degree to which the enlargement can encroach on surrounding clear space; similarly, the allowable size of the installation equipment or supplemental members might be limited by existing space and surrounding clearance.

k) *Accessibility* – Considerations should be given for both strengthening work and maintenance.

l) *Operational constraints* – Methods requiring longer time for construction might be less desirable if they require building operations to be temporarily shut down.

m) *Aesthetics* – Some methods leave less visible traces than others and, as such, might be preferable to the owner.

n) *Availability* – Consideration should be given for the obtainability of materials, equipment, and qualified contractors.

o) *Cost* – Considerations should be given for initial and life-cycle costs.

The degree of composite action—that is, the level of load-sharing effectiveness between the shear strengthening system and the existing concrete member, should be evaluated and considered in the strengthening design, detailing, and application. The effectiveness of the selected shear strengthening method should be evaluated on a case-by-case basis using a combination of means such as structural analysis; field tests (for example, pulloff tests); and, if judged necessary by the licensed design professional (LDP), in-place load tests.

Inventory of shear strengthening methods

1. Section enlargement

Shear strengthening of an existing concrete member can be accomplished by enlarging the section with concrete or specialty repair mortar in the intended area (Fig. 1).



Fig. 1—Section enlargement of joist.

Common examples include increasing the section size of beams and walls, using jackets or collars on columns (Fig. 2 and 3), and infilling between ribs of ribbed slabs.

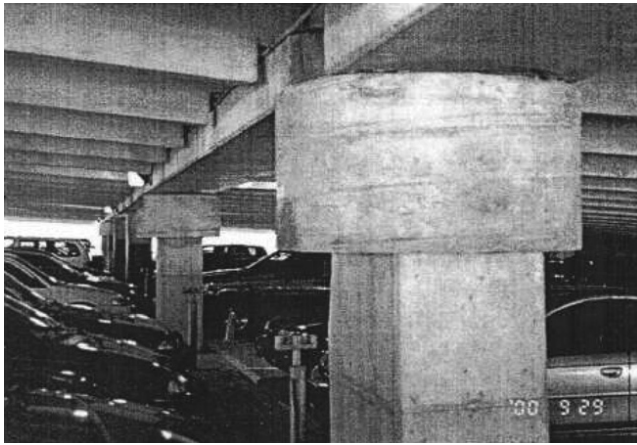


Fig. 2—Completed section enlargement of columns with collars.



Fig. 3—Section enlargement of column with collar.

Composite behavior between new and existing material is provided through bond, a shear transfer mechanism at the interface, or both (Alkhrdaji and Thomas 2002). The LDP should consider removal of any deteriorated concrete that is present; however, if deteriorated concrete cannot be removed, the LDP needs to consider the presence of the deteriorated material in the section enlargement design. In addition, this method requires that the existing concrete and reinforcing steel surfaces are prepared to receive the new material. Guidelines for surface preparation are provided in ACI 546R. The increased dead load associated with additional material needs to be considered during analysis.

2. Internal reinforcement with dowels

This method involves installation of additional steel reinforcement (dowels) across already formed or potential crack planes within an existing concrete member. The dowels are installed within holes drilled either vertically (more frequently) or at an angle normal to the shear crack plane (Fig. 4), and are bonded to the concrete using materials such as grout or epoxy adhesive.

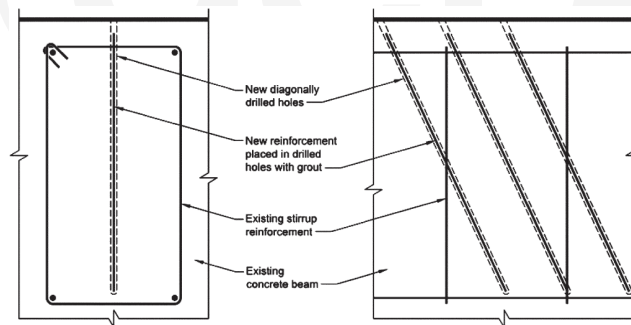


Fig. 4—Internal reinforcement of member with dowels drilled at angle normal to shear crack plane.

The dowels may be deformed reinforcement, smooth or threaded steel, stainless steel bars, carbon fiber reinforcement, or bolts (ACI 546R). If possible, plates, headed bars, or nuts should be used at the ends of the dowels to provide anchorage and maximize their effectiveness. The strengthening procedure uses commonly available equipment. Nevertheless, nondestructive testing should be performed to avoid cutting or damaging existing embedded reinforcing bars or conduits during the drilling operation (ACI 546R). The method may not be applicable in the case of a heavily-reinforced concrete member or where there is limited space around the member.

3. External reinforcement with supplemental steel or FRP members

Surface-attached external reinforcement

This method involves attachment of supplemental steel members (for example, plates, channels, or angles) or precured FRP members (plates or strips) to the surface of an existing concrete member to increase its shear capacity (Fig. 5).