Demolition of concrete structures

Bringing it down—safely

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The demolition contractor is a specialist in wrecking or destroying buildings safely. With careful planning, he can make the job look easy, and by selecting the right demolition method he also makes the job profitable. Most contractors, even though not demolition specialists, will have to demolish portions of structures as part of their repair and remodeling business. Knowing which method or combination of methods to use for demolition of reinforced or prestressed concrete structures is essential for a safe and profitable job.

Because of the difficulty of estimating the costs of demolition of concrete, the general contractor is usually well-advised to engage the services of a competent demolition contractor when his job requires a significant amount of demolition.

Selection of the best method or methods depends partly on time and money available and on the surrounding environment. The following discussion of methods used is based primarily on my own experience, but I have also relied upon the experience of others and data provided by manufacturers of demolition equipment.

Ball and crane

This is one of the oldest and most commonly used methods for building demolition. A crane uses a wrecking ball, weighing up to 13,500 pounds, which is either dropped onto or swung into the element to be demolished (Figure 1). Concrete members can be broken into small pieces, but secondary cutting of reinforcing may be necessary. The ball and crane method of demolition has certain disadvantages:

• it demands a great deal of skill from the crane operator
• the height of a building that can be demolished is limited by crane size and working room; however, buildings as high as 20 stories have been demolished
• the breakup process can cause considerable dust, vibration and noise which may be objectionable.

The National Association of Demolition Contractors provides guidance for the safe operation of a crane using a wrecking ball. The ball weight should not exceed 50 percent of the safe load of the boom at maximum length or angle of operation, or 25 percent of the nominal breaking strength of the supporting line, whichever is less. The demolition ball should be attached to the load line with a swivel-type connection to prevent twisting of the load line. Taglines may help control the ball during the swinging operation. Smoothness in controlling the swing of the ball is important; missing the target may tip or overload the crane and a wild swing-back may cause the ball to hit the boom.

Dismantling

Selective or complete demolition of concrete structures is possible by cutting elements and then removing them with a crane. The cutting process may be by sawing, water jetting or thermic lance. Because the surface of the cut concrete is smooth and relatively regular, these methods have particular application when the objective is partial demolition, for instance in the creation of openings in walls and slabs. In the case of the lance, however, excessive heat causes some deterioration of the concrete adjacent to the
cut. Whatever the method used, the cutting process isolates a particular element so that it may be lowered to the ground for further breakup or transportation to the dump site.

Most objectives of controlled demolition can be achieved using standard concrete sawing techniques and equipment, including diamond tipped blades to cut reinforcement. Specialized saws may be developed to handle unusual projects (Figure 2). Although sawing produces negligible vibration and dust, it may be noisy and require equipment to supply and clean up the large quantity of water used to cool the saw.

Concrete up to 3 feet thick may be cut with an abrasive water jet. The heart of the abrasive-water-jet cutting system is a small nozzle in which water is pressurized up to 60,000 psi and combined with solid abrasives to create a high-velocity cutting jet. Cutting with a water jet minimizes dust and eliminates vibration and fire hazards. An abrasive and water-catch system is required to clean up during the jetting process.

The water jet can be used not only for cutting straight lines but also contours, a useful feature for cutting access manholes. Straight-line cut rates on the order of 1 inch penetration per minute are possible for reinforced concrete slabs.

A thermic lance is created by packing a seamless mild steel tube with low carbon rods and passing oxygen through the tube. Once the lance is ignited, fusion will take place creating a temperature between 4000 and 7000 degrees F which is capable of burning through concrete up to 12 feet thick. A 2-inch-diameter horizontal hole can be bored in concrete at a typical rate of 2 to 3 inches per minute.

The presence of reinforcing steel is an advantage for thermic demolition, since this provides extra steel that can be oxidized to melt the concrete. Work may also be facilitated by following the path of reinforcement. While this method eliminates vibration and dust problems, it creates other hazards associated with smoke and fire danger.

Whether sawing, jetting or lancing is used to dismantle the structure or its components, each element must be safely lowered to the ground. Lifting hooks or special rigging should be adequately secured to dismantled members. If existing lifting hooks or loops are found to be in good condition then they should be used.

Pneumatic and hydraulic breakers

A common piece of equipment used for demolishing bridge decks, foundations and pavements is a hydraulically or pneumatically operated, boom-mounted breaker. Although small hand-operated breakers are still used, in many cases they have been replaced by machine-mounted breakers capable of delivering 100 to 20,000 foot-pounds of energy at a frequency of 300 to 800 blows per minute (Figure 3). The advantages of a machine-mounted breaker may include a telescoping boom for easy reach and maneuverability, remote control operation and underwater demolition capabilities. Some of the smaller remote-controlled machines can be lifted through window openings and used inside a building to demolish floors and walls.

Productivity can vary greatly depending on hammer size, type of concrete, amount of reinforcing and working conditions. For unreinforced concrete, breakout rates may be as low as 10 cubic yards per 8-hour day. Breakout rates for reinforced concrete (larger hammer required for reinforced versus unreinforced concrete) vary from 13 to 750 cubic yards per 8-hour day. The Dodge Public Works and Cost Guide indicates a productivity of 12 cubic yards per 8-hour day using handheld breakers (jackhammers).

Machine-mounted breakers are usually noisy, generate dust and vibration and may be restricted in areas of limited work space. To keep vibrations at a safe level, one Corps of Engineers office places a 150 foot-pound limit on the hammer energy

Figure 2. A special 72-inch-diameter saw was manufactured to dismantle the 33-inch-thick beams of this cantilevered skywalk. Each dismantled segment weighs 7 tons.

Figure 3. A boom-mounted remote-controlled hydraulic breaker reduces the slab section prior to lifting with a crane. The slab section has been sawn free on two sides while it rested on shoring.
allowed for concrete removal on its locks and dams.

Pressure bursting

This method of demolition can be classified into two categories, mechanical and chemical bursting. Pressure bursting with mechanical tools is fairly inexpensive, quiet, and doesn't cause vibration; but the drilling of holes for the insertion of the splitter does produce noise and vibration. This can be overcome by coring the holes with a diamond-tipped coring machine, but at far greater cost.

Mechanical bursting is done with a hand-held splitting machine that operates on hydraulic pressure provided by a small motor. The splitting end of the device is a steel wedge or plug positioned between two hard metal shims called feathers. Holes ranging from 1 to 2 inches in diameter are drilled into the concrete. The wedge is inserted into the hole and the subsequent hydraulic pressure forces the wedge against the two feathers.

Forces as high as 410 tons can be exerted against the feathers, which expand and force the concrete to split. Controlling the crack direction and the movement of the demolished mass may be difficult using mechanical bursting tools. Additionally, when reinforced concrete is being split, it is almost always necessary to utilize a hydraulic or pneumatic breaker, either hand-held or machine-mounted to expose the reinforcing bars for cutting. Figure 4 shows how to use a splitter to break a reinforced concrete wall.

Although they are more costly, chemicals may be preferred for pressure bursting. An expansive agent when correctly mixed will undergo a large increase in volume over a period of time. By placing the expansive slurry into boreholes that are located in a predetermined pattern, concrete can be split in a controlled manner for removal (Figure 5). Within 10 to 20 hours, cracks are generated by an expansive pressure that can exceed 4300 psi.

The chemical agent is formulated to be used at a certain temperature; any deviation from this temperature will reduce the expected expansive pressure. Freezing the chemical agent will greatly reduce its effectiveness.

Explosives

Blasting methods employ rapidly expanding gases confined within a series of boreholes to produce controlled fractures which provide for easy concrete removal. In general, blasting methods are efficient means of removing large volumes of distressed or deteriorated concrete. But, due to dangers inherent in handling and usage, blasting is considered most dangerous and requires more stringent controls than any other methods of demolition.

For the demolition of concrete structures it is usual to drill holes at a predetermined angle into the concrete to be removed. The holes are then charged with an explosive which is electrically detonated. Empirical judgment based on the skill and experience of the operator is the basis for blasting design. Recent advances in blasting design include the utilization of recognized formulas and calculations which determine the position, angle and depth of the borehole, as well as the size of the charge.

A simpler but far less effective method of blasting is to lay the explosive charge on the element to be demolished and cover it with sandbags. Another method, particularly useful for containers, is to fill the structure with water and detonate an explosive charge which has been suspended at the center. The water transmits shock waves to the surrounding walls. Shaped charges for the directional cutting of elements are also available.

Explosives are versatile and have great flexibility in terms of work output. However, excessive ground vibration may damage adjacent structures and air blast may cause superficial damage such as window breakage elsewhere. The National Association of Demolition Contractors states that the use of explosives to demolish entire buildings or portions thereof shall not be permitted unless there is sufficient clear space in all directions equal to 75 percent of the height of the building being demolished.
demolished. Precautions should be taken to stop flying debris and in all circumstances strict site control must be maintained to ensure the safety of workers and the general public.

Safety checklist

Whatever the demolition method chosen, or the size of the job, safety is of prime importance. Following are some key factors to consider.

Services. Gas, water, electricity and other services to the structure must be properly capped where necessary. Electricity or other lines needed to aid demolition must be of approved heavy-duty construction and must be kept adequately protected along a known path.

Access. All movements of people within the structure should be along designated routes, that is, through agreed doorways and stairways, or along specially constructed walkways with fixed ladders. Removal of debris should also follow an agreed route. All other openings, horizontal and vertical, should be blocked off completely to avoid danger from falling material. Even openings needed for debris removal should be blocked when not in use.

Loadings. Demolition may seriously change loadings from those for which the structure was originally designed. Any wall or floor that will be required to carry the excess weight of stored material, or which will be subject to undue pressure from waste, must be adequately shored to withstand the extra loading. At no time should debris be allowed to accumulate to a weight greater than a floor can carry. High impact loads from falling debris can be another source of unsafe loading. In general, no area of wall or slab greater than 10 square feet should be allowed to fall on any floor at one time. The lower walls of a building within which waste is allowed to pile up are particularly susceptible to the effects of a destructive loading for which they were not designed. Wind loadings must also be considered. Under no circumstances should walls be left standing overnight if they are not plumb and strong enough to resist toppling by wind pressure. If wall stability is questionable, demolition should continue down to the nearest structural cross member, or temporary shoring should be erected. In general, no section of wall more than one story high should be left standing unsupported at any time unless it was specifically designed to stand higher.

Structural members. When demolishing a structure from the top down, no supports at a lower level should be cut or removed until demolition at the upper level is complete. Particular care should be exercised in removing load-bearing beams and columns which tie into party walls. When beams and columns are cut they should always be well secured with wire rope or chains. If a large amount of debris is expected it may be desirable to increase the volume of ground-floor space into which waste can be dumped.

Worker protection. Workers must always stand on a firm base while carrying out demolition. Free ends of cut members may be needed as work platforms and must therefore be shored.

Other hazards. All glass and combustible material should be removed from a structure before demolition begins. Removal of asbestos and polychlorinated biphenyls (PCBs) must be done in accordance with regulations set by the Occupational Safety and Health Act (OSHA) and the Environmental Protection Agency (EPA). Each of these materials can be extremely dangerous to workers.

Demolition of Prestressed Concrete

Demolishing prestressed concrete structures can be more difficult than demolishing reinforced concrete because of the energy stored in the prestressing tendons. Prestressing tendons are like stretched rubber bands, with energy stored in the stretching process. The release of the stored energy in a rubber band causes it to sail through the air. Likewise, the release of stored energy in a prestressing tendon may cause it to sail through the air—as a dangerous missile—threatening the lives of workers. While a rubber band carries only small forces, a prestressing tendon commonly transmits forces in excess of 125,000 pounds.

Methods of prestressing

Two basic methods of prestressing are in use:

- Pre-tensioning, in which the steel is tensioned before the concrete is cast, transfers the prestressing force to the concrete by bond.

- Post-tensioning, in which the tendons are tensioned after the concrete has been cast and allowed to harden, transfers the prestressing force by means of end anchors.

Pre-tensioning is used primarily for factory-made units. These may be subsequently post-tensioned on site with additional tendons. Generally post-tensioning is applied to cast-in-place concrete in which ducts are formed within the members. The tendons are inserted in these ducts and then stressed and permanently anchored.

Post-tensioned tendons can be bonded or unbonded. After the tendon is inserted into the duct, the space between the tendon and duct may be grouted for the full length of the member. This grouting bonds the tendon to the duct.
and the surrounding concrete, hence the name bonded. Tendons for which the duct is filled with grease (to prevent corrosion) rather than grout are considered unbonded.

Demolition of prestressed pre-tensioned structures
The total demolition of a prestressed pre-tensioned structure is no more difficult than the demolition of a cast-in-place reinforced concrete structure. Prestressed pre-tensioned members are usually designed to resist applied loading in only one direction. Because of this, the members will fail rather easily if a force can be applied in an opposite or lateral direction.

The partial demolition of a prestressed pre-tensioned structure requires more care than a similar operation on a cast-in-place structure. More attention must be given to proper placement of adequate shoring, careful rigging and lifting, and the avoidance of impact loads to the structure below. Pre-tensioned slabs and beams, or smaller dismantled portions, may be lifted and lowered to the ground as complete units (Photo A). Generally, any necessary shoring and subsequent lifting should be from points near the ends of the units.

Demolition of prestressed post-tensioned structures
The total demolition of a prestressed post-tensioned structure presents a very different problem, particularly if the tendons are unbonded. As this is a relatively new type of construction, few post-tensioned buildings have been demolished. Safe, uneventful demolition of relatively low structures using a crane and a ball has been accomplished where there is adequate surrounding work space. However, the majority of experienced contractors and engineers familiar with the problems and potential dangers of post-tensioned structures suggest that they be dismantled a floor at a time. This is true whether the structure is of cast-in-place concrete with subsequent post-tensioning, or of precast, prestressed members which were also post-tensioned.

Disassembly or from-the-top-down demolition requires a large amount of shoring which must be installed along the entire length of the members, unless intermediate tendon anchors were installed during construction. Once shored, the slab and beams can be detensioned—in reverse order in which they were tensioned. Then the slabs and beams can be demolished using those methods previously described, with the exception of the ball-and-crane method.

Partial demolition of post-tensioned structures
The partial demolition of an unbonded post-tensioned structure can be very complicated and hazardous. If “as-built” drawings are not available, this operation can be even more complex. The original structure drawings are used as a guide for the proper placement of shoring under each member. After the shoring is in place, the tendon and reinforcing bars are located using magnetic detection devices. Once this is done, careful drilling, chipping or sawing may be used to expose the pre-tensioning tendons (Photo B). Then a hydraulic tensioning device is used to detension the tendon, releasing its force and allowing the concrete member to rest on the shoring.

The concrete can then be broken with either hand-held or machine-mounted breakers, or once completely severed, reduced to a size which may be lifted and lowered. Because the concrete may contain no reinforcing steel, or only top reinforcing, the section must be rigged such that it can be lifted and lowered without causing the concrete section to rupture from its own dead weight.

Careful planning by competent persons experienced in post-tensioning is essential before attempting partial demolition of post-tensioned structures.