7.2 Vibration Induced by Hydro-Blasting

Description:

Hydro-blasting has important advantages over chipping hammer or roto-milling to remove a concrete layer (FM 7.2 Exhibit 1). The water jet pressure that is used is nominally 20,000 psi (FM 7.9 Exhibit 2). The pressure is obtained by means of a plunger positive displacement pump. The water nozzles rotate at 500 rpm. The jet flow rate per nozzle is around 50 gallons per minute.

Damage to concrete may occur if the jet pulsation frequency is equal to a resonant frequency of any part of the containment or bays or sleeves.

Data to be collected and Analyzed:

1. Determine natural frequencies associated with the Mac & Mac and American Hydro hydro-blasting technology (FM 7.2 Exhibit 3, FM 7.2 Exhibit 4, FM 7.2 Exhibit 5, FM 7.2 Exhibit 6, and FM 7.2 Exhibit 7);
2. Measure the natural frequency of the containment building (FM 7.2 Exhibit 8);
3. Review natural frequency as calculated and reported in the FSAR for CR3 (FM 7.2 Exhibit 9);
4. FEA calculation of the natural frequency of the building (FM 7.2 Exhibit 5);
5. FEA calculation of the impulse force from the hydro-blasting machinery (FM 7.2 Exhibit 5);
6. Observation of the crack direction and crack path (FM 7.2 Exhibit 10);
7. Interviews with Progress Energy personnel present during hydro-blasting (FM7.2 Exhibit 11);

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8. Observations of phenomena that may be related to impact from the water jets (FM 7.2 Exhibit 15).

Verified Supporting Evidence:

a. Hydro-blasting pulsation due to the rotation of the injection nozzles is about 8.3Hz (equals 500 rpm). Hydro-blasting pulsation due to the positive displacement pumps is about 8.3Hz (FM 7.2 Exhibit 5). This is close to the resonant frequencies of the wall panels between buttresses of 6.4, 7.5, and 8.4 Hz (FM 7.2 Exhibit 5 page 1 of 11);

b. Frequency measurements on the building show resonant frequencies of 7.3 and 14.96 Hz (FM 7.2 Exhibit 8). They are in the same range as the hydro-blasting frequencies (FM 7.2 Exhibit 5);

c. One witness observed vibrations on containment liner during hydro-blasting (FM 7.2 Exhibit 11);

d. Vibration of the liner resulted in paint spalling on the inside of containment (FM 7.2 Exhibit 12 and FM 7.2 Exhibit 13);

e. Double parallel cracks in the concrete may indicate out-of-plane vibration of hoop sleeves (FM7.2 Exhibit 10). Vibration-induced cracking is associated with reversing of tensile loads and with multiple parallel cracks.

Verified Refuting Evidence:

a. The impulse force resulting from a 17,000psi water jet is not sufficient to excite a structure of the size of the CR3 containment (FM 7.2 Exhibit 5 page 1 of 11). Displacements are under 350 μstrains and tensile stresses under 1 psi;

b. The PII calculation (FM 7.2 Exhibit 5) also agrees with a calculation done by American Hydro (FM 7.2 Exhibit 7). They also conclude that the impulse force from the water jet is minimal;

c. The first time the hydro-blasting equipment was turned on, a mock-up operation was performed. This consisted of a small 8ft wide by 6ft high area to be hydro-blasted about 10 inches deep. There are strong indications that the crack was present very early while this mock-up was being performed (FM 7.2 Exhibit 14). This would indicate that the delamination may have been present before the hydro-blasting operation started;

d. The hydro-blasting power packs are located 400 ft (far) from the reactor opening location (FM 7.2 Exhibit 2) therefore vibrations

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from the pumps themselves cannot impact the containment wall.

Discussion:

The lowest natural frequency reported in the FSAR is 4.4 Hz (FM 7.2 Exhibit 9). This agrees very well with the PII-calculated resonant frequency for swaying of the whole building of 4.43 Hz (FM 7.2 Exhibit 5 page 1 of 11).

Interviews with engineers at Mac & Mac and at American Hydro demonstrated that the two systems are similar. American Hydro has performed eight SGR opening into post-tensioned reactor building containments (seven were performed when we started this investigation and one more was done since at TMI). All were successful, demonstrating that it is possible to hydro-blast the SGR opening.

Additionally, all the literature we found on comparing the various means to perform concrete removal agree that hydro-blasting is the least damaging to the underlying structure.

The multiple "parallel" cracks seen at several locations in the structure can be explained by other mechanisms besides vibration and are not strong evidence that vibration was critical in creating the delamination.

The water pressure is listed at 20,000psi in the Mac & Mac work instruction document. However, it was determined from interviews that the actual pressure was closer to 17,000 psi when operating at CR3.

Near the end of the hydro-blasting when the water jet was impacting close to the liner plate, there are several indications of vibration induced in the liner. It was reported by Progress personnel on the inside of containment (FM 7.2 Exhibit 11) and it was concluded from analysis of cracked features in the concrete outside of containment close to the liner plate (FM 7.2 Exhibit 15). This indicates there was enough force in the water jets to induce radial displacement of the liner plate.

This can be explained because the water at that stage in the hydro-blasting is impacting on a thin (3/8 in) long (25 ft x 27 ft) plate of steel, loosely bonded on the four sides (mostly through mechanical locking due to the plate stiffeners).

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There are three key discoveries leading to our refuting of this failure mode:

1. Although the vibration frequency induced by the hydro-blasting equipment is in the same range as the resonant frequency of the building, the impulse to generate the vibration is small. Note that our calculation on the subject (FM 7.2 Exhibit 5) agrees with the document provided by American Hydro (FM 7.2 Exhibit 7);

2. There are strong photographic indications that the crack was present very early in the hydro-blasting process (FM 7.2 Exhibit 14);

3. The ability of the water jet to vibrate and push the liner plate slightly in the radial direction is compatible with its inability to put a thick section of concrete in vibration;

An important caveat to add is that although the forces generated by the water jet are not sufficient to generate the delamination, it is possible they could have been instrumental in propagating it. Once the crack started in the plane of the tendon sleeves, it is "active" because it is in an area of local tensile stresses. Therefore it can be propagating with minimal forces serving as an "activation energy" force just pushing the local tensile stress above the tensile strength of the concrete.

Conclusion:

Vibration induced by hydro-blasting was not a factor in creating the delamination.
It could have been a factor in the propagation of the delamination.

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TECHNICAL
GUIDELINES

Prepared by the International Concrete Repair Institute September 2004

Guide for the Preparation of Concrete Surfaces for Repair Using Hydrodemolition Methods

Guideline No. 03737

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About ICRI Guidelines

The International Concrete Repair Institute (ICRI) was founded to improve the durability of concrete repair and enhance its value for structure owners. The identification, development, and promotion of the most promising methods and materials is a primary vehicle for accelerating advances in repair technology. Working through a variety of forums, ICRI members have the opportunity to address these issues and to directly contribute to improving the practice of concrete repair.

A principal component of this effort is to make carefully selected information on important repair subjects readily accessible to decision makers. During the past several decades, much has been reported in literature on concrete repair methods and materials as they have been developed and refined. Nevertheless, it has been difficult to find critically reviewed information on the state of the art condensed into easy-to-use formats.

To that end, ICRI guidelines are prepared by sanctioned task groups and approved by the ICRI Technical Activities Committee. Each guideline is designed to address a specific area of practice recognized as essential to the achievement of durable repairs. All ICRI guideline documents are subject to continual review by the membership and may be revised as approved by the Technical Activities Committee.

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Synopsis

This guideline is intended to provide an introduction to hydrodemolition for concrete removal and surface preparation, the benefits and limitations of using hydrodemolition, and an understanding of other aspects to be addressed when incorporating hydrodemolition into a repair project. This guideline provides a description of the equipment, applications, safety procedures, and methods of water control and cleanup.

Keywords

Bond, bonding surface, bruising, chipping hammer, coating, concrete, delamination, deterioration, full depth repair, hand lance, high-pressure water, hydrodemolition, impact removal, mechanical removal, micro-fracture, post-tensioning, rebar, reinforced concrete, reinforcing steel, robot, rotomill, safety, sound concrete, surface preparation, surface profile, surface repair, tendon, vibration, wastewater, and water jet.

Purpose

This guideline is intended to provide owners, design professionals, contractors, and other interested parties with a detailed description of the hydrodemolition process; a list of the benefits and limitations of using hydrodemolition for concrete removal and surface preparation; and an understanding of other aspects to be addressed when incorporating hydrodemolition into a repair project. The guideline provides a description of the equipment, applications, safety procedures, and methods of water control and cleanup. This guideline is not intended as an operating manual for hydrodemolition equipment as that information is specific to each equipment manufacturer.

The scope of this guideline includes the use of hydrodemolition for the removal of deteriorated and sound concrete in preparation for a concrete surface repair. In addition, the use of hydrodemolition for the removal of coatings is discussed.

While the procedures outlined herein have been found to work on many projects, the requirements for each project will vary due to many different factors. Each project should be evaluated individually to ascertain the applicability and cost-effectiveness of the procedures described herein. Other methods of surface preparation are discussed in ICRI Technical Guideline No. 03732, "Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings, and Polymer Overlays."

Introduction

Hydrodemolition is a concrete removal technique which utilizes high-pressure water to remove deteriorated and sound concrete. This process provides an excellent bonding surface for repair material. First developed in Europe in the 1970s, this technology has become widely accepted for concrete removal and surface preparation throughout Europe and North America.

Hydrodemolition can be used for horizontal, vertical, and overhead concrete removals and surface preparation on reinforced and non-reinforced structures. It is effective in removing concrete from around embedded metal elements such as reinforcing steel, expansion joints, anchorages, conduits, shear connectors, and shear studs. Hydrodemolition can be used for localized removals where deterioration is confined to small areas and for large area removals in preparation for a bonded overlay. This technology can also be used to remove existing coatings from concrete.

Hydrodemolition has been used on the following types of structures:

- Bridge decks and substructures
- Parking structures
- Dams and spillways
- Water treatment facilities
- Tunnels and aqueducts
- Nuclear power plants
- Piers and docks
- Stadiums
- Warehouses
- Retaining walls

The Effects of Mechanical Impact Techniques

Mechanical methods such as chipping hammers, rotomills, scabblers, and scarifiers remove concrete by impacting the surface. These procedures crush (bruise) the surface, fracture and split the coarse aggregate, and create micro-fractures in the substrate (Fig. 1 and 2). As a result, the ability of the fractured substrate to provide a durable

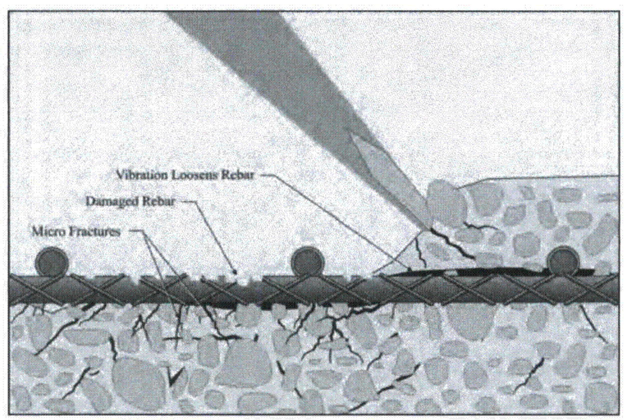

Fig. 1: Damage created by chipping hammer

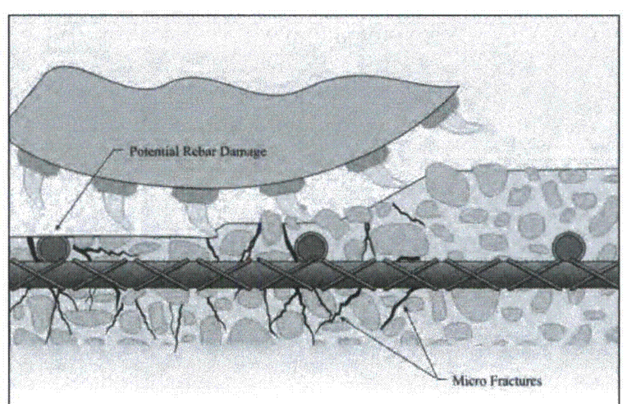

Fig. 2: Damage created by rotomilling

bond with the repair material is compromised, requiring a second step of surface preparation to remove the damaged region.

Furthermore, impact methods may damage the reinforcing steel and embedded items such as conduit, shear studs and connectors, and expansion joint hardware. Impact methods transmit vibrations through the reinforcing steel, which may cause further cracking, delamination, and loss of bond between the reinforcing steel and the existing concrete. Vibration and noise created by the mechanical impact will travel through the structure, disturbing the occupants. During repair of thin slabs and precast tees, chipping hammers may shatter the substrate resulting in unanticipated full depth repairs.

For a discussion on surface bruising and the mechanics of concrete removal by impact methods, refer to ICRI Technical Guideline No. 03732, "Selecting and Specifying Concrete Surface Preparation for Sealers, Coatings and Polymer Overlays."

Hydrodemolition Benefits and Limitations

The benefits of hydrodemolition can be placed into two groups: structural benefits that improve the quality of the repair, and environmental benefits that improve the quality of the work place. Hydrodemolition also has limitations, which need to be considered.

Structural Benefits

- A rough, irregular surface profile is created to provide an excellent mechanical bond for repair materials;
- Surface micro-fracturing (bruising) is eliminated;
- Exposed aggregates are not fractured or split;
- Lower strength and deteriorated concrete is selectively removed;
- Vibration is minimal;
- Reinforcement is cleaned, eliminating the need for a second step of surface preparation; and
- Reinforcing and other embedded metal elements are undamaged.

During concrete removal, the water jet is directed at the surface, causing high-speed erosion of the cement, sand, and aggregate. The water jet does not cut normal weight aggregate which remains intact and embedded as part of the rough, irregular surface profile (Fig. 3). The aggregate interlocks with the repair material to assist in developing a

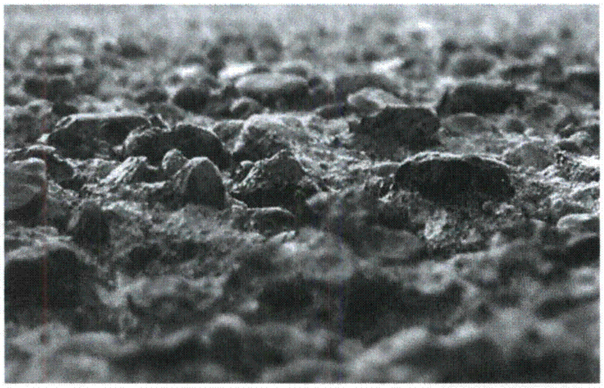

Fig. 3: Surface prepared by hydrodemolition has a rough irregular profile with protruding aggregate and is excellent for creating a mechanical bond

mechanical bond and composite action between the substrate and the repair material.

The rough, irregular surface profile provided by hydrodemolition can result in bond strengths that equal or exceed the tensile strength of the existing concrete. The concrete surface profile can exceed CSP-9 (very rough) as defined in ICRI Technical Guideline No. 03732.

Rotomills and scarifiers remove concrete to a uniform depth and may leave deteriorated concrete below the specified depth. Alternatively, the water jet moves in a consistent pattern over the surface and will remove unsound concrete even if it is below the specified depth.

Since the water jet does not create mechanical impact, vibration is not transmitted into the structure from the hydrodemolition operation. Delamination beyond the repair area caused by vibration of the reinforcing steel is greatly reduced.

During hydrodemolition, sand and cement particles mix with the water jet. The abrasive action of theses particles is usually sufficient to clean uncoated reinforcing bar and embedded metal items without damaging them. Corrosion material is removed from the reinforcing bar and metal items, allowing for easy inspection and identification of cross-sectional area loss. The reinforcing bar is cleaned without any loss of deformations. Cleaning of the entire reinforcing bar, however, will not occur if the reinforcing bar has not been completely exposed during hydrodemolition.

Environmental Benefits

- Minimizes disruptions to users of occupied space by significantly reducing transmitted sound through the structure;
- Increased speed of concrete removal can reduce construction time;
- Minimizes dust; and

- Robotic units reduce labor and minimize injuries as compared to chipping hammers.

Concrete removal by hydrodemolition can take place inside an occupied structure, such as a hotel, apartment building, office building or hospital with minimal noise disruption to the occupants.

Hydrodemolition can quickly remove concrete. As such, project duration can be reduced, minimizing the impact on the users of the structure.

During demolition, cleanup, and final wash down, the concrete debris and repair surface remain wet, minimizing dust in the work area. Since hydrodemolition cleans the reinforcing steel, the need to sandblast is eliminated unless additional concrete removal is required using chipping hammers. As such, silica dust in the work area is reduced, thereby providing a safer work environment.

The use of chipping hammers and other impact methods are labor intensive and physically demanding, which can cause injury to the employee. Robotic hydrodemolition equipment reduces the use of these tools and the possibility of injury.

Limitations

- The hydrodemolition process consumes a significant amount of water (6 to 100 gpm [25 to 380 lpm]). A potable water source must be available. The cost of the water should be considered;
- Wastewater containing sand and cement fines (slurry) must be collected, treated, and returned to the environment. Wastewater disposal may require a permit;
- Projects requiring total demolition can be done faster and more economically with crushers and similar equipment;
- Water can leak through cracks in the concrete and damage occupied space below the repair area. Hydrodemolition should not be used over occupied areas due to the risk of blow-through (unanticipated full-depth removal);
- Repair areas of varying strength will result in non-uniform removal. Areas of high strength may need to be removed using hand lances or chipping hammers;
- The water jet is blocked by reinforcing steel resulting in concrete shadows under the reinforcing bar that may need to be removed using hand lances or chipping hammers;
- Since the water jet of a robotic unit is contained in a metal shroud, some robots are unable to completely remove concrete up to a vertical surface such as a curb, wall or column. The remaining concrete may have to be removed using hand lances or chipping hammers;
- The water jet will remove the sheathing from post-tensioning tendons and may drive water into the tendon;
- The hydrodemolition robot may be too large to access small or confined areas of the structure;
- The water jet can damage coatings on reinforcing steel and other embedded items;
- The water jet can introduce water into electrical system components, especially if embedded in the concrete and already deteriorated or not properly sealed; and
- If cleanup is not properly performed in a timely manner, further surface preparation may be required.

The Hydrodemolition System

The hydrodemolition system consists of a support trailer or vehicle, high-pressure pump(s), a robotic unit to perform the demolition, and high-pressure hoses to connect the pump(s) to the robot. Hand lances are also available to remove concrete in areas inaccessible to the robot.

Support Trailer

Hydrodemolition units are typically transported on 40 to 50 ft trailers (Fig. 4). The robot may be transported on the same trailer or separately on a smaller trailer. The support trailer usually contains a supply of spare parts, tools, maintenance area, fuel and water storage, supply water hoses, and filters. These units are designed to be self-sufficient on the job site with adequate spare parts to perform routine maintenance and repairs.

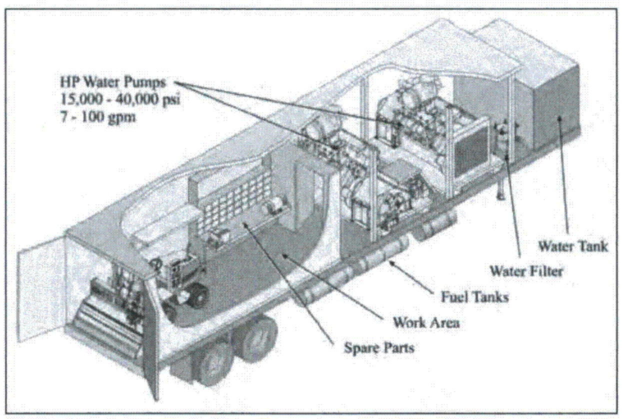

Fig. 4: Hydrodemolition support trailer. A self-contained unit transports pumps, robot, hoses, and spare parts

High Pressure Pumps

The high-pressure pumps used for hydrodemolition are capable of generating pressures from 10,000 psi to 40,000 psi (70 to 275 MPa) with flow rates from 6 to 100 gpm (25 to 380 lpm). The pumps are driven by a diesel or electric motor, typically operating between 100 and 700 horsepower. The engine size will vary based on the flow and pressure rating of the pump. The pumps operate most efficiently at their design pressure and flow. High-pressure hoses connect the pumps to the robot. The pumps may be located a significant distance (500 ft [150 m]) from the actual removal area. However, due to a drop in pressure and flow through the high-pressure hoses, the pumps should be located as close as possible to the removal area, typically within 300 ft (100 m).

Robotic Removal Unit–Horizontal Surfaces

The force created by the high-pressure pump(s) is controlled using a robotic removal unit (Fig. 5). The robot is a diesel or electric powered, self-propelled, wheeled or tracked vehicle. It is used to uniformly move and advance the water jet over the surface during concrete removal.

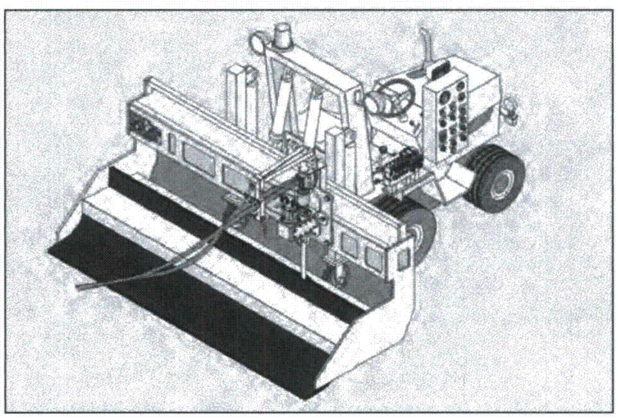

Fig. 5: Typical hydrodemolition robot

The water jet is mounted on a trolley that traverses over the removal area along a cross feed or traverse beam (Fig. 6) perpendicular to the advance of the robot. The water-jet nozzle may either oscillate or rotate (Fig. 7). The oscillating nozzle is angled forward in the direction of the traverse. Rotating nozzles are angled from the center, creating a cone effect while rotating (Fig. 8 and 9).

The nozzle assembly is enclosed within a steel shroud with rubber seals around the perimeter to contain the debris during demolition (Fig. 10).

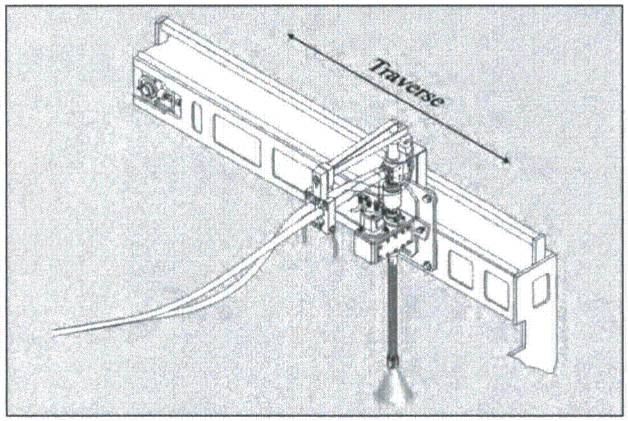

Fig. 6: Nozzle is mounted on a traverse beam

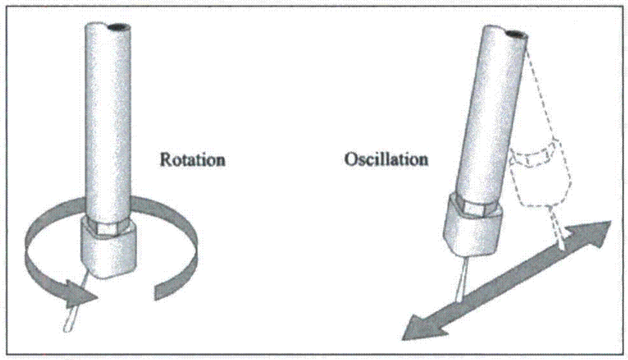

Fig. 7: Rotating or oscillating nozzles

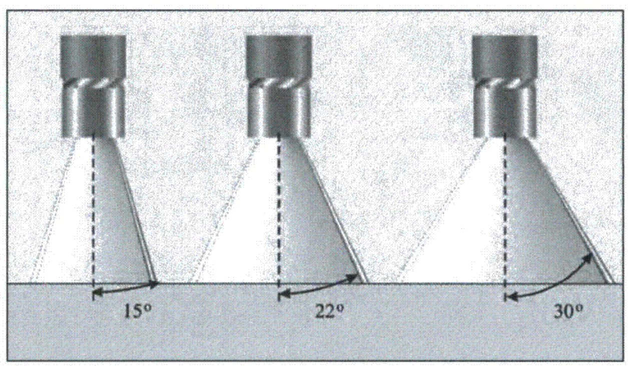

Fig. 8: Rotating nozzles are angled from center

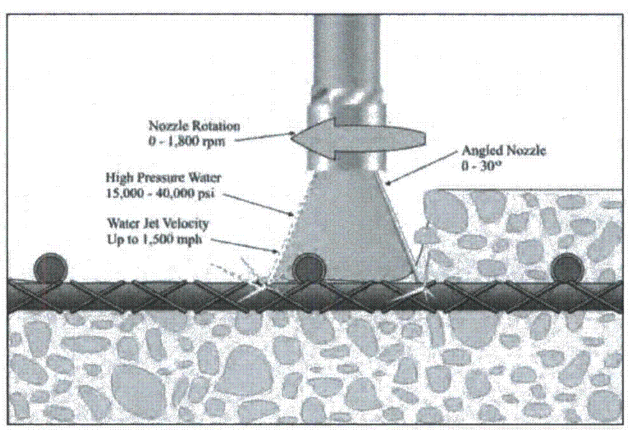

Fig. 9: Rotation of the angled nozzle creates a water cone

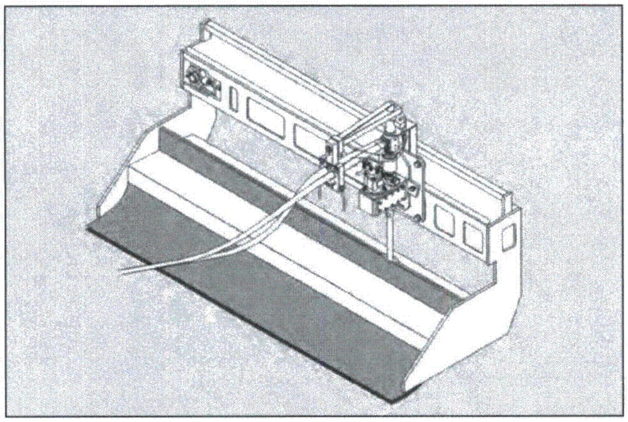

Fig. 10: Nozzle is enclosed within a steel shroud

The rotation/oscillation of the nozzle combined with the traverse and advance of the robot provide a uniform and continuous motion of the water jet over the removal area (Fig. 11). Each of these functions is fully adjustable. The depth of concrete removal is determined by the length of time the water jet is directed at the removal area.

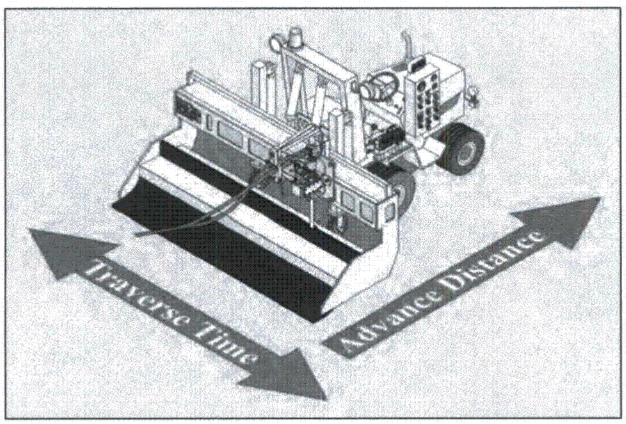

Fig. 11: The water jet traverses back and forth perpendicular to the forward advance of the robot

Adjusting the following parameters will increase or decrease the depth of removal:

a. Total traverse time (time of each traverse × number of traverses); and
b. Distance of the advance.

Once these parameters are set, the robot will reproduce the settings in a programmed sequence to provide consistent removal of the concrete. For example, during deep removal to expose the reinforcing bar 3 to 4 in. (75 to 100 mm), the traverse speed may be 8 seconds (the time required for the water jet to move from one side of the traverse beam to the other) and the water jet may traverse 3 times before the robot advances forward 1 to 2 in. (25 to 50 mm). On the other hand, for light scarification 1/4 to 1/2 in. (6 to 13 mm) or coating removal, the traverse speed may be 3 seconds and the water jet may traverse only one time before the robot advances 2 to 4 in. (50 to 100 mm).

The depth of concrete removal is controlled at the robot. Since the pumps are designed to operate at a specific pressure and flow rate, it is unusual to reduce the pressure (and subsequently the flow rate) to adjust the depth of removal.

Narrow areas may be removed by adjusting sensors that limit the movement of the water jet along the traverse beam. The traverse and advance functions limit the removal to a rectangular area along the advance path of the robot. Because the water jet is contained within a steel shroud, most robots are unable to remove concrete within 3 to 6 in. (75 to 150 mm) of vertical surfaces.

Specialized Robotic Equipment—Vertical and Overhead Surfaces

Various types of robotic equipment are available to perform removals on walls, soffits, substructures, beams, columns, and tunnels. These robots are often built on wheeled or tracked vehicles and have the ability to lift the traverse beam into the vertical or overhead position. The primary functions of traverse and advance are utilized in order to provide uniform concrete removal during vertical and overhead repairs.

As an alternative to the robot, the water jet may also be attached to a frame that allows the jet to move in a two dimensional "X-Y" plane. The X-Y movement of traverse and advance are present in these units to provide uniform concrete removal. The X-Y frames can be lifted and positioned over the removal area using a crane, backhoe, all-terrain forklift or other similar equipment.

Hand Lance

Hand lances operate at pressures of 10,000 to 40,000 psi (70 to 275 MPa) while delivering approximately 2 to 12 gpm (8 to 45 lpm) of water. Hand lances are not as fast or as precise for concrete removal as a programmed robot and are slower than chipping hammers. Hand lances are effective in performing light scarification and coating removals. It should be noted that the water jets on hand lances may not be shrouded, increasing the risk of debris becoming airborne. Hand lances can be used for removal of:

- Concrete shadows below reinforcing bar;
- Concrete adjacent to walls, columns, curbs, and in tight and confined areas not accessible to the robotic equipment; and
- Coatings.

Safety

Hydrodemolition involves the use of potentially dangerous specialized equipment. At all times, the manufacturer's instructions for the safe operation of the equipment and personal protective equipment should be followed, as well as all local, state, and federal regulations. Hydrodemolition units should be supervised and operated by qualified personnel certified by the equipment manufacturer.

Hydrodemolition employs high-velocity water jets to demolish concrete and perform surface preparation. Even though the water jet is shrouded on robotic units, debris can be propelled from beneath the shroud with sufficient velocity to cause serious injury. Serious injury or death can also occur if struck by the water jet. Hand lances are typically not shrouded and care must be exercised to avoid injury when using these tools.

Workers, equipment operators, and any individuals entering the work area are required to wear hard hats, safety glasses, hearing protection, safety shoes, gloves, long pants and long-sleeve shirts, and must be trained in the proper use of personal protective equipment. When using a hand lance, the operator should wear a full-face shield, rain suit, and metatarsal and shin guards. Additional protective clothing may also be required for use with hand lances. Everyone involved with the hydrodemolition operation should receive specific training outlining the dangers associated with the use of high-pressure water.

Prior to starting demolition, an inspection of the area should be performed including the area under the work area. All barricades, partitions, shielding, and shoring must be installed and warning signs posted to prevent unauthorized entry into the work area. The area below the work area must be closed off and clearly marked "Danger— Do Not Enter." Electrical conduits or other electrical equipment in the work area should be deenergized to avoid electrical shock.

Special precautions are required for post-tensioned structures as referred to in the section "Considerations for Hydrodemolition Use."

Hydrodemolition Applications

Scarification

Scarification is performed to remove the surface concrete and provide a rough profile (Fig. 12 and 13). Scarification is often used in preparation for

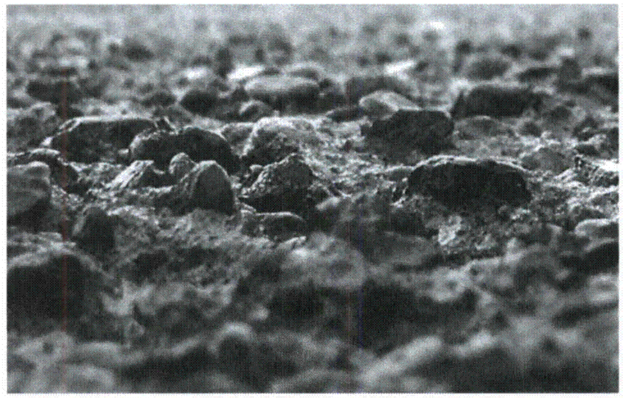

Fig. 12: Scarified surface with 1 in. aggregate

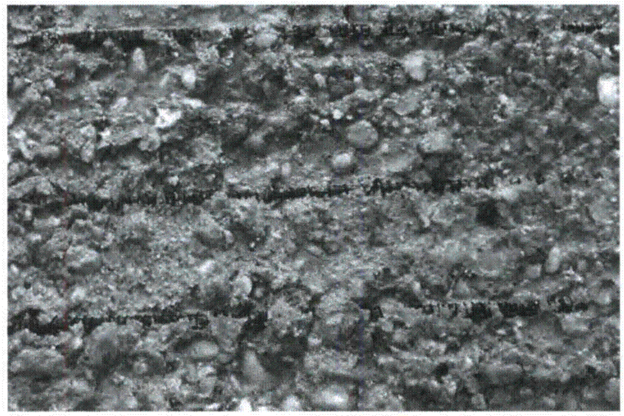

Fig. 13: Scarified surface with 3/4 in. aggregate

a concrete overlay. If the surface was previously rotomilled, the minimum removal depth using hydrodemolition should equal the size of the coarse aggregate to remove all concrete micro fractures and damaged or crushed aggregate.

Scarification may not remove all unsound concrete due to the rapid rate at which the water jet moves over the surface. It may be necessary to resurvey the scarified surface and identify delaminated or deteriorated areas for further removal.

Partial Depth Removal

Partial depth removal is commonly required if chloride contamination has reached the top mat of reinforcing steel or deterioration, delamination or spalling occurs within the top mat of reinforcing steel. Partial depth concrete removal can expose the top mat of reinforcing steel and provide clearance, typically a minimum of 3/4 in. (19 mm), below the bottom reinforcing bar of the top mat (Fig. 14 and 15). Determining the reinforcing bar size and concrete cover are critical to determine the required removal depth.

Concrete removal using hand lances or chipping hammers may be required to remove shadows under the reinforcing bar, previously repaired areas

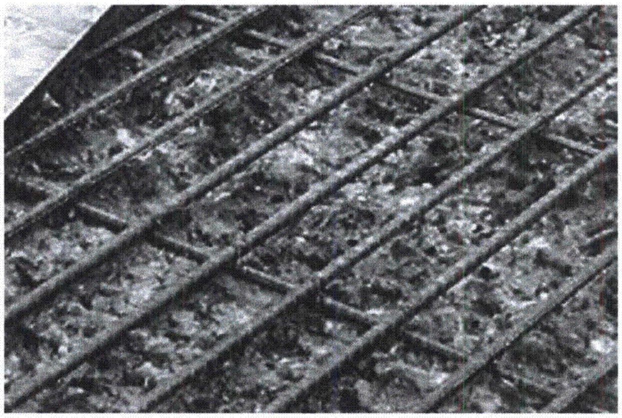

Fig. 14: Partial depth removal

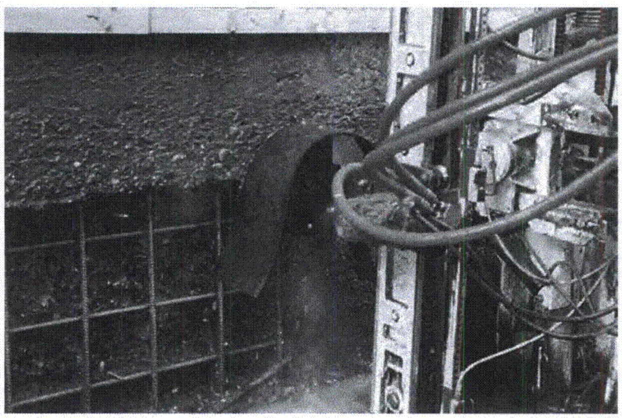

Fig. 15: Partial depth removal on a retaining wall

or high areas resulting from variations in the strength of the concrete. In addition, concrete removal may be necessary adjacent to vertical surfaces such as curbs, walls and columns. Saw cutting of the perimeter of the repair area, if required, should be performed after hydro-demolition to prevent damage to the saw cut. This will require additional concrete removal along the repair perimeter with hand lances or chipping hammers. If the saw cut is made first, the area outside the saw cut should be protected using a steel plate. The steel plate will allow the water jet to slightly over run the saw cut without damaging the surface outside the saw cut while completely removing the concrete within the repair area.

Full Depth Removal

Hydrodemolition can be used for full depth removal where delamination has occurred in the lower mat of reinforcing or chloride contamination exists throughout the entire thickness of the slab. Full depth removal can be performed along expansion joints and other areas where there is a high concentration of reinforcing steel that may be damaged if conventional removal methods are used. Other structural elements such as shear connectors, shear studs, and steel beam flanges can be exposed without damage.

During full depth removal, the removal rate slows as the depth increases because the water jet stream dissipates as it moves away from the nozzle and the water jet must push more water and debris from its path prior to contacting the surface to be removed.

Full depth removal is often necessary on waffle or pan joist slab systems (Fig. 16).

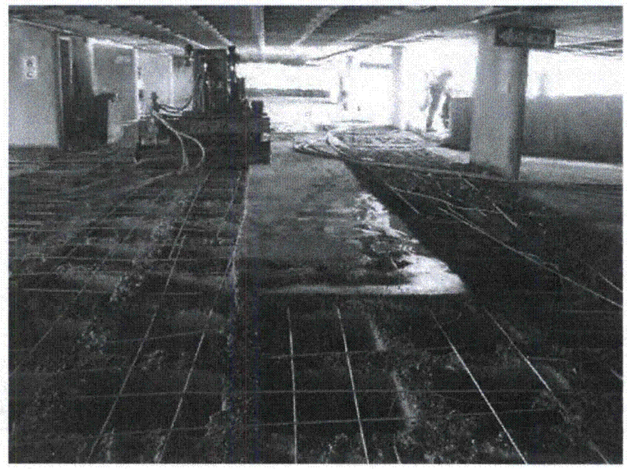

Fig. 16: Full depth removal—waffle slab

Coating Removal

Hydrodemolition can be used for the removal of epoxy, urethane, hot applied membrane, and other coatings from concrete surfaces (Fig. 17). When performing coating removal, a multiple jet nozzle is used. The multiple jets allow the water to penetrate the coating without damaging the concrete. However, if the concrete below the coating is deteriorated, it may be removed along with the coating.

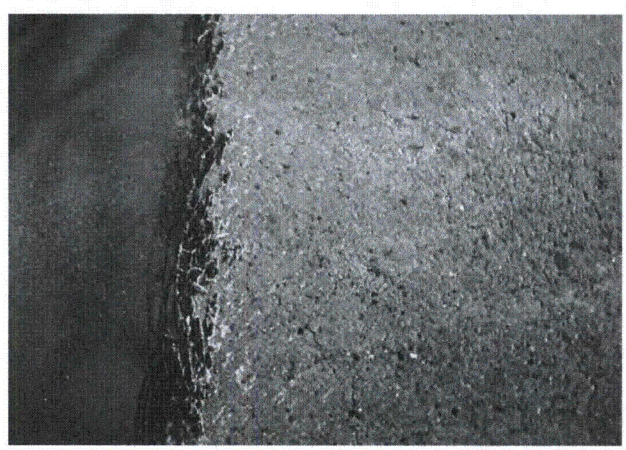

Fig. 17: Coating removal using a spinning, multi-nozzle spray head

The Hydrodemolition Process

Concrete removal by hydrodemolition is impacted by the following factors:

- Size and density of the aggregate;
- Concrete strength;
- Uniformity of concrete strength;
- Extent of cracking;
- Deterioration and delamination;
- Surface hardeners;
- Previous repairs with dissimilar strength material; and
- Size and spacing of reinforcing steel or other embedded items.

In sound concrete, the variation in the depth of removal will generally equal the size of the coarse aggregate (Fig. 18). For example, if the coarse aggregate is 1 in. (25 mm), $D = 1$ in. (25 mm) and the specified depth of removal is 2 in. (50 mm), the range of removal will be 2 in. (50mm) ± $D/2$ (1/2 in. or 13 mm), or 1-1/2 in. (38 mm) to 2-1/2 in. (63 mm).

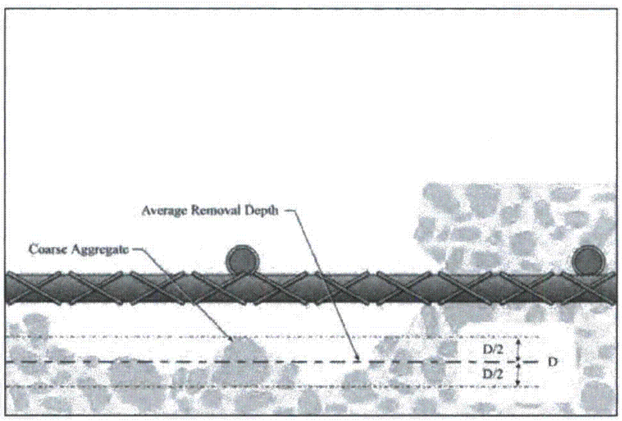

Fig. 18: The depth of removal depends on the size of the course aggregate

During hydrodemolition, a high-pressure water jet is uniformly moved over the surface and, provided the concrete is sound and the strength does not change significantly, the removal depth will remain consistent. Depth variations occur when the concrete strength changes, cracking or delamination is present, the concrete is deteriorated or the surface has been previously repaired using a different type and strength of material. In comparison, rotomilling or dry-milling equipment can be set to a specific depth and the milling drum will mill the surface to that depth regardless of any variations in the concrete strength, quality or level of deterioration.

If the strength of the concrete increases or a high-strength repair area is encountered during hydrodemolition, the removal depth will decrease (Fig. 19). The decrease in depth may not be immediately detected by the operator, resulting in an area of shallow removal (Fig. 20). To obtain the required depth in higher strength concrete, the total traverse time is increased and the advance of the robot is decreased. If the high-strength repair area is large enough, it may be possible to set up the hydrodemolition robot over the area and remove to the specified depth. This

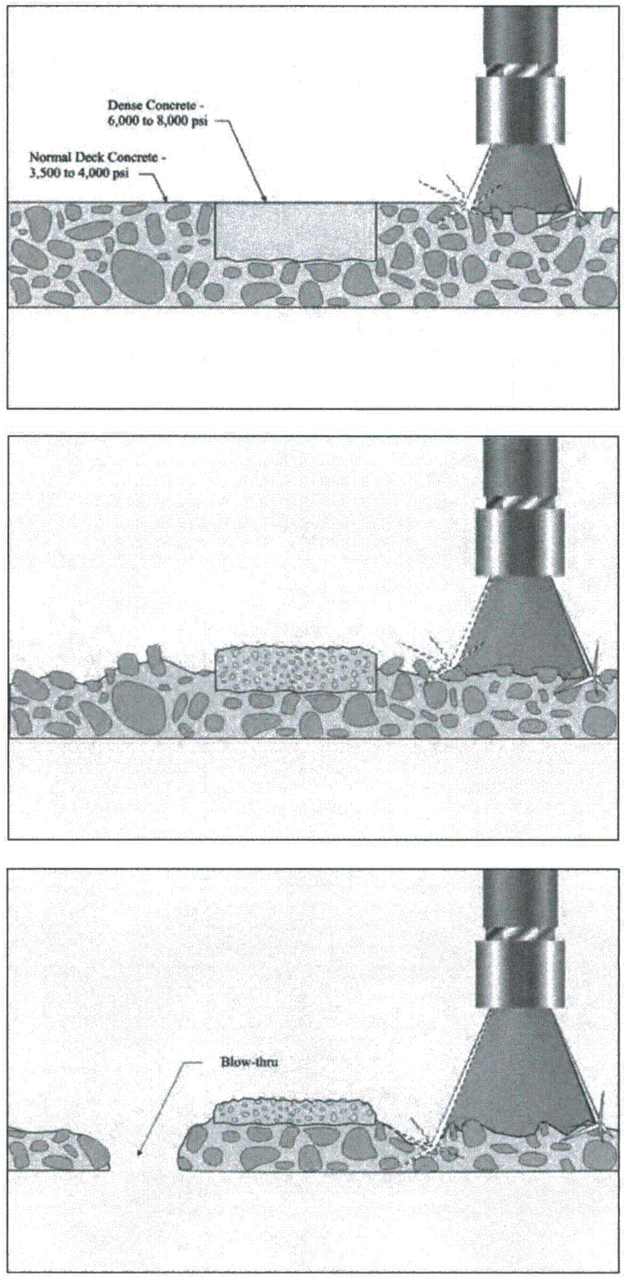

Fig. 19: High-strength concrete is removed at a slower rate than normal concrete, which can result in a non-uniform removal

Fig. 20: High-strength repair area within the hydro-demolition area

procedure can be problematic for two reasons. First, if the water jet overruns the high-strength repair area, it may result in a blow-through or full depth removal at the perimeter of the high-strength repair area. Second, since the water jet must be slowed significantly, it may cause excessive removal below the high-strength area once it is removed and the softer base concrete is exposed. For these reasons, it is often preferable to use chipping hammers in high-strength repair areas.

The opposite effect is encountered if the concrete strength decreases or there is cracking, deterioration or delaminations (Fig. 21). Concrete that is deteriorated, low strength or delaminated is removed faster than the surrounding sound concrete by the water jet. For example, if the average removal depth is 2 in. (50 mm) and there is a delamination that is 2 in. (50 mm) deep, the actual removal within the delaminated area could be 3 to 4 in. (75 to 100 mm) deep. For this reason, removal in an area that is seriously deteriorated and delaminated may not be consistent.

This effect is often described as "selective removal of deteriorated concrete." While the water jet is traversing and advancing uniformly over the surface, it is removing unsound, delaminated, deteriorated, cracked, and low strength concrete selectively below the specified removal depth.

Selective removal is not without limitations. For example, if the robot is traversing and advancing rapidly as during scarification, it may not remove deeper delaminations.

Size and spacing of the reinforcing steel will also influence the removal depth. The reinforcing steel blocks the water jet and shields the concrete below, creating concrete "shadows" (Fig. 22 and 23). Removal of concrete shadows becomes more difficult as the reinforcing bar size increases and

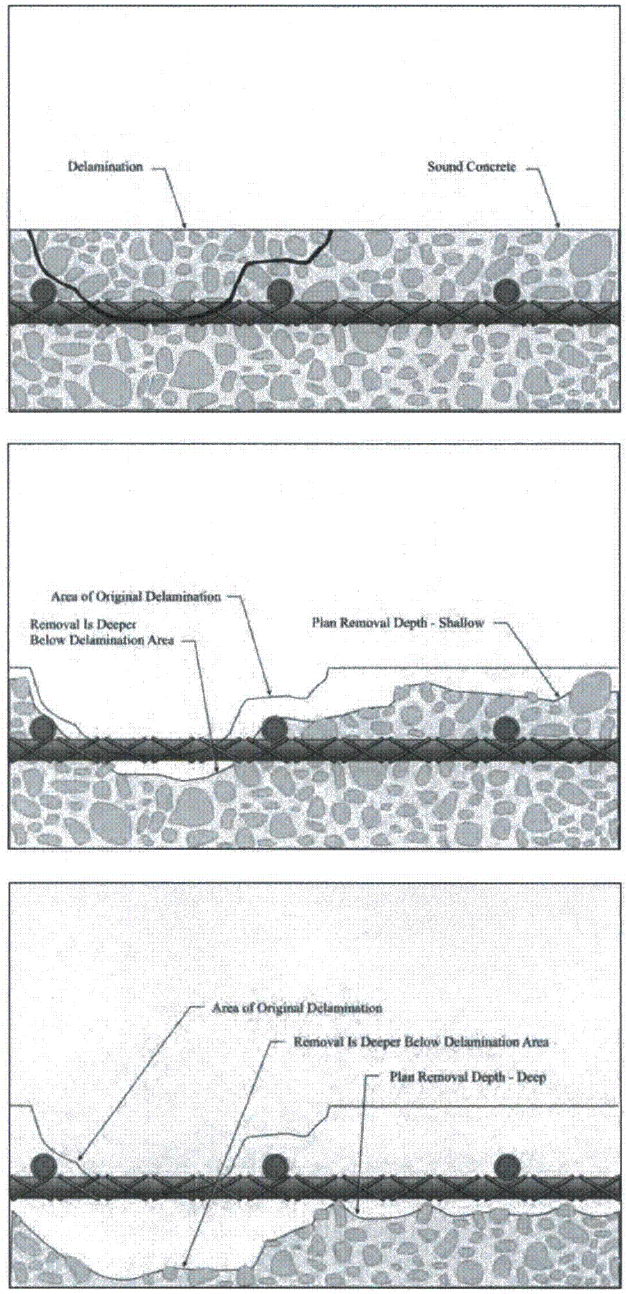

Fig. 21: Delaminated or deteriorated concrete is removed at a faster rate leading to non-uniform removal

is most difficult at reinforcing bar intersections. Increasing the specified depth of removal will minimize the amount of shadowing.

Pointing the water jet under the reinforcing bar can reduce concrete shadows. This can be accomplished by using a rotating or oscillating nozzle (refer to Fig. 7-9). Rotating nozzles are typically angled 10° and 30° from center. The nozzle rotates between 100 and 1800 rpm, creating a demolition cone that will undercut both the transverse and parallel reinforcing bar provided the specified removal depth is greater than the

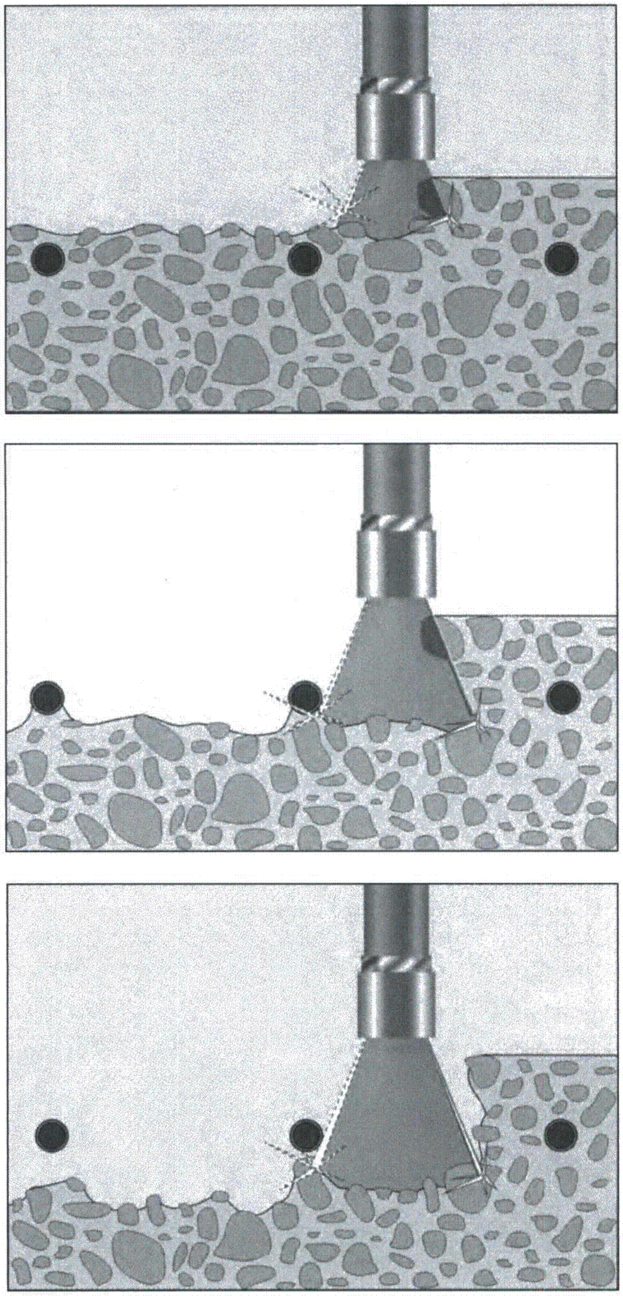

Fig. 22: Reinforcing steel blocks the water jet leaving a concrete "shadow" under the reinforcing. Increasing the removal depth will decrease the amount of shadowing

depth of the reinforcing bar. Similarly, the oscillating nozzle moves from side to side as it traverses, directing the water jet at an angle to the surface, cutting under the reinforcing bar. The nozzle is angled forward as it traverses left, and at the end of the traverse, flips to face forward as it traverses right. To minimize concrete shadows, the required depth of removal should be at least 3/4 in. (19 mm) below a #5 reinforcing bar. Larger reinforcing bars will require a greater removal depth to minimize shadowing. While this additional

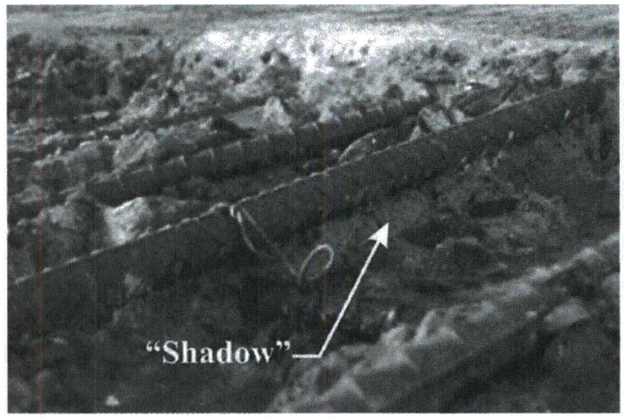

Fig. 23: "Shadow" under the rebar (note tie wire undamaged and in excellent condition)

removal may result in the removal of sound concrete, it will minimize the need for concrete removal under the reinforcing bar with chipping hammers or hand lances.

Considerations for Hydrodemolition Use

Issues that should be considered when evaluating the use of hydrodemolition for a repair project include:

Limited quantity of repair: Mobilization and set up of the hydrodemolition equipment can be expensive. If there are only minor repairs or a limited quantity of repairs, the mobilization cost may make the process uneconomical.

Increase in repair quantity: The traverse and advance function of the hydrodemolition robot results in removal areas that are rectangular. The removal areas may have to be "squared up" in order for the hydrodemolition equipment to efficiently remove the concrete. "Squaring up" the repair areas may lead to an increase in the removal quantity and the cost of the project.

Reinforcing bar size and concrete cover: Partial-depth removal normally requires clearance below the bottom reinforcing bar of the top mat of reinforcing. The size and quantity of the reinforcing bar and the concrete cover over the reinforcing bar should be determined in order to specify the correct removal depth to achieve the required clearance.

Potential for full-depth blow-throughs: Hydrodemolition of severely deteriorated structures may result in full-depth blow-throughs. Blow-throughs may take place where full depth slab cracks occur, especially if deterioration is evident on the slab underside. Shielding may be required to protect the area below from damage. Shoring below the blow-through may be damaged or destroyed. When the water jet is in the open air, as will happen when the water jet blows through the deck, it is extremely noisy (may exceed 130 db) and dangerous. Sound resistant partitions should be installed to contain the noise within the structure if blow-throughs are expected.

Extent of previous repairs: Repair materials may have a different compressive strength than the original concrete. Since the hydrodemolition jet is set to move at a uniform rate, the presence of dissimilar strengths of material will result in a variation in the depth of removal. Higher strength areas may require further concrete removals using chipping hammers or hand lances to achieve the specified depth of removal. Lower strength areas may result in deeper removals and possibly full-depth blow-throughs.

Occupied areas adjacent to or under the repair area: Occupied spaces such as stores or offices may occur in the structure. It may not be practical to perform hydrodemolition adjacent to or over these areas. Water from the hydrodemolition may leak to the occupied level below. As such, the repair area should be protected to prevent water from entering the occupied area.

Shoring requirements: During structural repairs, concrete may be removed from around the top reinforcing. An analysis of the structural capacity of the remaining slab section should be made by a qualified engineer to determine if shoring will be required. The weight of the hydrodemolition robot should be considered when determining shoring requirements.

Equipment location: The hydrodemolition equipment is transported on a trailer. If possible, the pumps should be located within 300 ft of the repair area. A suitable location next to the structure must be selected. Pump units that are powered by diesels engines should not be located next to the air intake of adjacent buildings. In congested metropolitan areas, the pumps may be removed from the trailer and placed within the structure. Diesel powered pumps will need to be located close to an exhaust shaft and the exhaust from the pumps piped to this location. A fuel tank will also have to be placed in the pump area and provisions made to fill the tank as required. Although electric pumps may be used inside the structure eliminating the fueling and exhaust concerns, they have a substantial power requirement and will need an electrical service installed. Due to the weight of the pumps, they may need to be placed on the slab on ground or in a shored area of the structure. Temporary shoring may be needed to move the pumps into the structure.

Available water sources: Pumps used for hydrodemolition require a steady supply of clean water at a sufficient volume to perform the work. Generally, local municipal water is used for hydrodemolition. Sources close to the work area, such as a nearby fire hydrant or water line feeding the structure, should be adequate. Specific water requirements will vary, depending on the hydrodemolition unit used for the project and the method of cleanup. Cleanup performed using a fire hose operating at 100 to 200 gpm (380 lpm to 760 lpm) will use substantially more water than an 8000 to 10,000-psi (55 to 70 MPa) water blaster operating at 8 to 12 gpm (30 to 45 lpm). In remote areas, water can be drawn from wells, fresh water lakes, rivers, or streams. This water must be pre-filtered to remove any suspended solids to avoid damage to the high-pressure pumps. Recycled water has been used for hydrodemolition, however, it can add substantially to the cost of the project due to collection and filtration of the water and the added wear to the equipment caused by dissolved minerals in the recycled water. When available, potable water is used. Water may have to be trucked into remote locations.

Post-tensioned structures: The use of hydrodemolition on post-tensioned structures has potentially severe risks and must be carefully evaluated to maintain a safe working environment, maintain structural integrity, and to preserve the long-term durability of the structure. Sudden release of anchorages can result in dangerous explosive energy and flying debris capable of causing damage to equipment and serious injury or death to workers. Tendons should be de-tensioned prior to removing concrete from around anchorages to prevent the sudden release of the anchorages and loss of pre-stress forces. The loss of pre-stress forces may result in the loss of structural integrity and result in the need for shoring. Careful evaluation must also be exercised when removing concrete around post-tensioning tendons. Removal of concrete around tendons can result in a change of tendon profile, which may also result in the loss of prestressing force and structural integrity.

The wires or strands of post-tensioning tendons are usually undamaged during hydrodemolition, however the sheathing and protective grease will be removed from unbonded tendons. In bonded post-tensioning tendons, the water jet may penetrate the duct and remove the grout inside. In either case, the hydrodemolition water may enter the tendon at the edge of the repair area and can be driven into the tendon outside the work area. Water remaining in the tendon can cause future corrosion affecting the long-term durability of the post-tensioning system. Each tendon must be carefully examined and any water that has entered the tendon removed. Both the grease and the protective sheathing must be restored.

It may not be possible to remove moisture that has entered the post-tensioning system during the hydrodemolition process. In addition, verification of the presence of moisture is difficult and may not be possible. Refer to ICRI Technical Guideline No. 03736, "Guide for the Evaluation of Unbonded Post-Tensioned Concrete Structures," for suggested procedures to detect water in post-tensioning tendons. Long term monitoring for future corrosion may also be prudent.

Conduit and embedded metal items: Embedded aluminum and steel conduit will not be damaged by hydrodemolition if they are in good condition. However, deteriorated portions of aluminum and steel conduit will be damaged and water will enter the conduit system. PVC conduit will be damaged during hydrodemolition. As a safety precaution, all conduits should be deenergized during demolition. Other metal items within the removal area such as shear connectors, shear studs, and anchorages will not be damaged by hydrodemolition.

Noise limitations: Hydrodemolition does not produce sound that is transmitted through a structure, however, the noise from the hydrodemolition unit in the work area is sufficiently loud to be objectionable to the public. Furthermore, noise can be excessive during full-depth repairs or blow-throughs. Sound reducing partition walls that separate the public from the work area may be required. Acoustical studies indicate that the sound waves created by hydrodemolition are low frequency and are best controlled using dense material such as sheet rock or concrete board. There are a variety of sound deadening materials supplied by various vendors that have proven effective in controlling noise. Partition walls should be protected from moisture. If properly sealed at the base, a water resistant sound reducing partition wall will also assist in containing the water within the work area.

Protection of lighting, sprinklers, and other services: Light fixtures, fire protection systems, and other services may be damaged by airborne debris from the hydrodemolition or clean up operation. If full depth removal or blow-throughs are anticipated, light fixtures may need to be removed and stored and temporary lighting installed. Sprinkler heads may need to be protected. Mist and high humidity in the work area could damage electrical panels and other services. Items remaining in the work area should be protected.

Temperature: When the temperature falls below freezing, the structure must be heated or the hydrodemolition stopped to prevent water from freezing in the work area.

Test Area

A test area should be designated to establish the operating parameters and to demonstrate that the equipment, personnel, and methods of operation are capable of producing satisfactory concrete removal results. The test should include sound and deteriorated concrete areas, each a minimum of 50 ft^2 (5 m^2). First the robot is set to remove sound concrete to the specified depth. Once the operating parameters have been determined, the equipment is moved to the deteriorated area and a second test is performed using the same operating parameters. If satisfactory results are achieved, the quality and depth of removal will become the standard for the project. If hand lances are to be used to perform concrete removals, they should also be demonstrated to show satisfactory results.

It is noted that the hydrodemolition robot will move the water jet over the surface in a constant motion and if the concrete is of uniform strength, the removal depth will be consistent. However, since concrete is seldom uniform, there will be variations in the removal depth on the project. Other factors affecting the removal depth include the extent and depth of deterioration, the size and quantity of reinforcing bar, the concrete cover over the reinforcing bar, and the presence of surface hardeners. As the equipment is used, nozzles will wear, changing the force created by the water jet. As such, the hydrodemolition equipment operator must monitor the depth and quality of removal and adjust the parameters of the robot to provide consistent removal throughout the project.

Wastewater Control

Controlling the wastewater has often been viewed as one of the more difficult tasks associated with the use of hydrodemolition. However, with preplanning and proper installation of a wastewater control system, the water can be properly managed (Fig. 24). Hydrodemolition wastewater should be

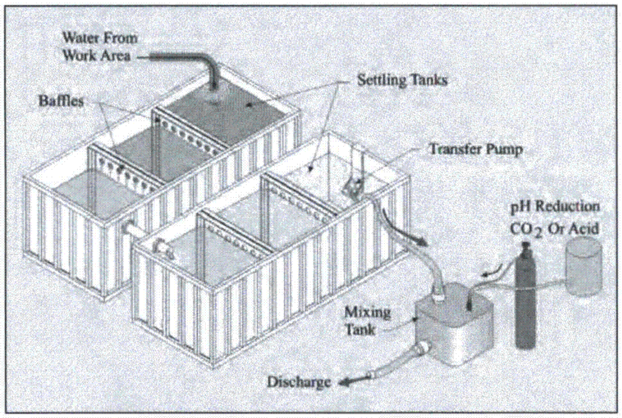

Fig. 24: Typical wastewater handling system

discharged to the storm or sanitary sewer or to the ground for absorption and/or evaporation under permit from the controlling authority. Discharge into an existing storm or sanitary line may occur in the structure or to a nearby storm or sanitary line accessed through a manhole. A 4-in. (100 mm) connection should be adequate. Wastewater may not be discharged directly to a wetland, stream, river or lake.

Hydrodemolition wastewater contains suspended particles and typically has a pH of 11 to 12.5. The wastewater is initially placed in settling tanks or ponds to reduce the suspended solids. The particles are heavy and settle out quickly as the water is allowed to stand. This can also be accomplished by allowing the water to pass through a series of berms that are lined with filter fabric or hay bales.

The controlling authorities for discharge have varying requirements for the level of suspended solids and the range of pH for discharge into their system. Typically the water should be clear and the pH range between 5 and 10. Ponding the water will clarify it, however, the pH of the wastewater may have to be reduced prior to discharge. This can be accomplished by the introduction of acid, CO_2 or other pH reducing materials into the wastewater. Adding flocculants can assist in reducing suspended solids. A location for settling ponds or tanks and pH reducing equipment should be determined.

The cost to discharge wastewater ranges from the cost of a discharge permit to charges for the actual water consumed and discharged. The cost of water consumed is generally that of commercial water usage within the community. The controlling authority may require monitoring and testing of the wastewater. Local ordinance requirements must be reviewed and met prior to discharge, including the obtaining of proper permits.

Water containment and collection systems will vary depending on the structure. Where possible, it is best to take advantage of gravity to move the water to the treatment area. In many structures, the slab on ground can be used to collect and treat the water. The water may be allowed to flow through the structure to the lowest level or through the existing drains, which have been disconnected just below the underside of the first supported level. All slab-on-ground drains should be plugged and water should not be allowed to enter the drainage system prior to treatment. Once the water is clear and the pH adjusted, it can be pumped directly to the discharge point. Additional treatment capacity may be necessary if rainwater cannot be separated from the wastewater.

Floor slabs and decks are commonly crowned or sloped to provide drainage. Since water will run to the low area, a simple method of water control involves the use of hay bales or aggregate dams, which can be set up along curb lines or the perimeter of the work area. As the water ponds in front of the hay bales or aggregate dams, the suspended solids will settle out. In areas where the drains are plugged, the water is forced to pass through the hay bales or aggregate dams. Retention ponds can be built at the end of the structure and the water directed or pumped to these ponds. Settling tanks can also be used and the water pumped from the structure to the tanks.

Debris Cleanup and Disposal

Hydrodemolition debris consists of wet sand, aggregate, chips or chunks of concrete, and slurry water. Slurry contains cement particles and ranges from muddy water to a thick paste. Removal of the debris should occur as soon as possible to prevent the debris from solidifying and adhering to the surface, making cleanup more difficult.

Tools used for cleanup include: fire hoses, pressure washers, compressed air, sweepers, skid steer loaders, vacuum trucks, and manual labor.

The types of cleanup will vary based on the type of removal performed as follows:

1. *Above the reinforcing bar*—any removal depth above the top reinforcing bar of the top mat of reinforcing and the reinforcing bar remains supported by the concrete;
2. *Below the reinforcing bar*—any removal depth below the top mat of reinforcing bar in which the top reinforcing bar mat becomes unsupported by the original concrete; and

3. *Full-depth* removal.

During *above the reinforcing bar* clean up, equipment such as skid steer loaders, sweepers, and vacuum trucks may be driven over the surface to assist with the cleanup (providing they meet the weight requirements of the structure). The debris can be swept, pressure washed or air blown into piles where it is picked up by a loader. A vacuum truck may be used to vacuum the debris from the surface. In all cases, the surface must be pressure washed to remove any remaining cement slurry.

If the removal is *below the reinforcing bar* and the reinforcing bar is unsupported, it is difficult and possibly unsafe to drive equipment into the removal area. The debris can be removed by washing with a fire hose (large water consumption), pressure washing or blowing it onto the adjacent original surface where it can be picked up with a loader. A pressure washer operating at 8000 to 10,000 psi (55 to 70 MPa) and 8 to 12 gpm (30 to 45 lpm) is effective. Vacuuming has proven very effective in removing debris from around the reinforcing steel, however, the surface will require pressure washing to remove the cement slurry and paste.

During *full-depth removal*, the debris simply falls to the floor below where it can be picked up with a loader.

The debris, which consists of wet sand, aggregate, chips or chunks of concrete, and slurry is placed in dumpsters or hauled away in trucks and may be recycled or placed in a landfill in accordance with the requirements of the controlling authority.

Removal Depth Measurements

Following hydrodemolition, the surface profile is very rough and three depth measurements are possible (Fig. 25):

1. Minimum removal—original surface to the shallowest removal point.
2. Maximum removal—original surface to the deepest removal point.
3. Average depth of removal—The difference between the minimum and maximum removal at the same location.

Measuring the depth of removal can be accomplished using:

1. A straight-edge placed on the original surface;
2. A string-line pulled over the removal area; and
3. A surveyor's level.

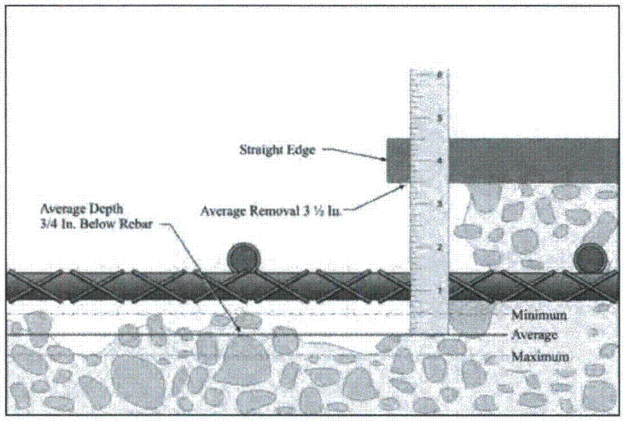

Fig: 25: Measuring depth of removal using a straight edge

The most common practice of measuring the depth of removal is to place a straightedge on top of the original surface and extend it over the removal area. Measurements are taken from the bottom of the straightedge to determine the depth of removal. This quick and simple technique can only be used during the removal process and is not applicable for final measurements in large removal areas.

A string line may be pulled over the removal area and measurements taken below the string. However, this method could provide incorrect results if slopes or crowns occur in the original surface. Surveying equipment may be used and is very accurate; however, to account for slopes, pitches and crowns in the original surface, a detailed survey must be made of the original surface prior to removal and measurements taken at the same locations after removal for comparison and determination of the actual removal depth.

Summary

Effective concrete removal and proper surface preparation are key elements to a successful repair project. A surface prepared using hydrodemolition is rough, irregular, and is excellent in creating a mechanical bond with the repair material. Hydrodemolition eliminates micro-fractures and damage to reinforcing steel, minimizes transmitted noise and dust, and cleans the reinforcing steel.

The use of hydrodemolition may not be appropriate for every structure and a careful review of the benefits and limitations of the process relative to each structure should be undertaken. Proper safety procedures must be observed at all times when using hydrodemolition.

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PROGRESS ENERGY SERVICE COMPANY, LLC
CRYSTAL RIVER THREE (CR3) NUCLEAR PLANT
CRYSTAL RIVER, FLORIDA

HYDRODEMOLITION WORK PLAN

PROJECT

Create a temporary opening in the CTMT wall removing all concrete using high pressure Hydrodemolition technology.

HYDRODEMOLITION EQUIPMENT

2 – 2000HP diesel pumping unit power packs. Each power pack contains 3 high pressure pumping units delivering 50 gpm @ 20,000 psi per pump to a Hydrodemolition nozzle mounted on the Hydrodemolition concrete removal track.

HYDRODEMOLITION CONCRETE REMOVAL TRACK

Stationed on access platform at temporary opening location. Track frame mounted on CTMT wall exterior outline of concrete to be removed 28' wide x 24' high.
Frame has two Hydrodemolition concrete manipulators mounted side by side, each covering 14' wide x 24' high
Each manipulator contains three Hydrodemolition nozzles. Each nozzle is connected to a high pressure pump in the power pack.

HYDRODEMOLITION PROCESS

Each manipulator passes over the surface removing concrete as it travels width wise one pass then index up 2 inches repeating the process until it reaches the top of the track (24' level). To prevent over cutting steel stops are installed at the 24' level.

When rebar is exposed manipulator is locked in place above the top (24') level while crews remove the rebar below. (Approx. 12 hours)
When rebar is removed Hydrodemolition resumes until Tendons are exposed. When tendons are exposed manipulators are locked in place above the top (24') level while crews remove and plug the tendons below. (Approx. 12 hours)

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When tendons are removed Hydrodemolition resumes until Liner plate is completely exposed.

When Liner plate is completely exposed Manipulators are locked in place until clear access is available to dismantle Frame.

RUBBLE CONTROL

As Hydrodemolition is in progress the water and concrete rubble will fall down to the platform into a chute running down to rubble and wastewater containers located on the ground.

To prevent rubble from escaping the immediate area a screen hoarding will be erected around the Hydrodemolition track.

HYDRODEMOLITION EQUIPMENT STAGING

2 active Hydrodemolition power packs to be setup approx. 400' from reactor opening location.

Three hoses will run from each power pack to the Hydrodemolition Track. =
2 – power packs = 6 hoses supplying two 3 nozzle manipulators mounted on the Hydrodemolition track.
1 backup power pack ready to operate less high pressure hoses will be staged also.

WATER CONTROL

Wastewater will be pumped from bins at the CTMT to wastewater treatment location in the staging area approx.400' away.
Discharged waste water will be:

- 6.0-9.0 PH
- Total suspended solids, 30ppm
- Oil in water, daily maximum of 18.4 ppm with a monthly average below 13.8 ppm
- List of all fluids, lubricants will be submitted for approval

ACTIVITIES

MAC & MAC HYDRODEMOLITION SERVICES INC.

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- 6 months prior to commencing Hydrodemolition submit superintendent name for security clearance

- 2-3 months (to be determined) prior to commencing Hydrodemolition Mac & Mac superintendent arrives onsite

- 2 -3 months prior to commencing Hydrodemolition submit crew names for security clearance

- 3 weeks prior to commencing Hydrodemolition crew arrives for Security, Fitness-For-Duty, Health Physics, Badging, Setup equipment,

- 3 weeks prior to commencing Hydrodemolition, Hydrodemolition power packs, tracks, manipulators/robots, all accessories and supplies arrive on site.

- 3 weeks prior to commencing Hydrodemolition all wastewater equipment, tanks, pumps arrive on site

- 3 weeks prior to commencing Hydrodemolition all vacuum truck units arrive on site

THIRD WEEK BEFORE COMMENCING HYDRODEMOLITION

- Crew clearance completed (4 days)
- Stage Hydrodemolition power packs in Staging area approx. 400' from CTMT
- Stage and Assemble wastewater treatment facility in Staging area approx. 400' from CTMT

SECOND WEEK BEFORE COMMENCING HYDRODEMOLITION

- Run High Pressure lines to CTMT location
- Run Wastewater lines from CTMT to Staging area approx. 400' from CTMT
- Run fresh water line from source to Hydrodemolition power packs in staging area approx. 400' from CTMT
- Install trash pump at containment bin to pump water to treatment facility approx. 400' from CTMT
- Install piping from treatment center to settling pond
- Build berm around equipment in staging area

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State of Washington Contractor License #MACMAHS996NB
State of California Contractor License #800844

ASSEMBLE HYDRODEMOLITION TOWER

- Assemble Tower on the ground outside of compound – small (60 ton) crane required for 3 days and a 8,000lb forklift
- Lift Assembled Tower onto chipping platform – crane required
- Bolt Tower Guide Legs onto chipping platform
- Run all hydraulic (water soluble oil), electrical, and pressure lines from Power Pack located outside of compound to Tower. (run lines under fence)
- Hookup high pressure hoses, hydraulic and electrical lines to Hydrodemolition manipulators (Manipulators are attached to the track. Track is attached to Tower)
- Place 125 ft. manlift in position
- Mount Hydrodemolition Control box in 125 ft. manlift bucket (Operator/Technician location / station)
- Test High pressure lines, electrical and hydraulic lines and controls
- Place 8' x 20' (2-8x10) sheets of steel on platform against reactor wall for testing system
- Test: Tower / Track system, High pressure system, hydraulic and electrical controls

ONE WEEK BEFORE COMMENCING HYDRODEMOLITION

- Complete projects (if any) not completed in week 2
- Fine tune all equipment
- Standby ready to begin Hydrodemolition 3 days prior to commencement date and time.

HYDRODEMOLITION COMMENCED

• Cutting Concrete removing 13% (13% of total)	4 Hours
• Remove rebar	12 Hours by others
• Cutting Concrete removing 17% (30% of total)	6 Hours
• Remove and plug tendons	12 Hours by others
• Cutting Concrete removing 23% (53% of total)	8 Hours
• Cutting Concrete removing 24% (77% of total)	8 Hours
• Cutting Concrete removing 13% (90% of total)	4 Hours
• Cutting Concrete removing 10% (100% of total)	4 Hours

MAC & MAC HYDRODEMOLITION SERVICES INC.

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- Cutting concrete perimeter clean up allowance 8 hours
- Hydrodemolition Equipment Demob 2 Days
- Water Treatment Demob 4 Days

At all times Mac & Mac's project superintendent will keep Progress Energy representatives aware of our project progress and status.

10/28/2009 Interview Dave McNeill on phone

Present: Dave McNeill (Mac&Mac, Vancouver), Craig Miller, Chong Chiu, Patrick Berbon

Hydrolazing uses high-pressure pumps (triplex) with plungers (3 cylinders per pump).

Have X-Y machine on the platform.

Using 6 pressure pumps (1 pump per nozzle).

17,000-17,500 psi water pressure.

Flow rate 40-45 gallons/minute/nozzle.

Running 2 x 3 nozzles at the same time (3 nozzles per head, 2 heads).

Nozzle rotates at 500 rpm and projects water at a 5 degrees angle around the axis of rotation. Spin rate can be adjusted from 250 to 1,000 rpm. Was fixed at 500 rpm here.

Cut about 4 feet wide per head (total width of cut about 8' per pass).

Travels 1 ft/s along the beam, then move up 1.5 in, travels back 1 ft/s.

Each pass cuts 1in to 1.5in deep.

Nozzles are 7 inches apart.

Water is taken from Progress large holding tank. It is pumped up from the tank and filtered to 1 micron. It is recovered and re-filtered at the end (not recycled, dumped in settling pond after use).

Supply water is usually around 60 F. it was 85 F in this case. The pumping added an additional 25 F so that the water exited the nozzle around 110 F.

Mac&Mac works on many bridge decks. First nuclear project for the company.

Their in-house calculations for 17,000 psi, 500 rpm rotation, 40 gal/min water, 1ft/s travel, shows a force on the wall of 100 psi.

Nozzle is 1/8 inch.

First nozzle is 2-4 in from the wall, second nozzle is 3-5 in, third nozzle is 4-6 in (nozzles are in same plane, but distance increases as material is removed by each nozzle).

Takes approximately 35 min for one pass.

Pump is diesel powered (1,800 rpm), runs at 500 rpm.

Pistons are 1.5 in diameter, and move back-and-forth at 500 rpm.

10/29/2009 Interview Bob Nettinger at American Hydro

Present: Chong Chiu, Dan Fiorello (Exelon), Partha Ghosal (Southern Company), Patrick Berbon

Bob Nettinger is with American Hydro. They are a competitor company to Mac & Mac, who performed the hydro-blasting for the CR3 containment.

They have done 7 post-tensioned containments.

They use 6 HP pumps, 2 robots.

Rotating jets lead to a better cut.

20,000 psi water, 150 gal/min/nozzle.

Use a plunger pump.

Wayne Younger (also works at American Hydro) would know the numbers for vibration and rpm.

Tower is 50ft high, can move on the platform, 4-wheel vehicle, 6ft wide cut top to bottom and back, 25ft from the wall.

1.5 inches deep cut per nozzle.

Nozzle is 6 inches from the wall.

They use nozzle extensions to get closer to the wall as they hydro-blast.

Use potable water as input into the pumps.

They are starting at TMI on Sunday, 11/1. John Piazza, structural engineer, senior design engineer on SG replacement at TMI.

Wayne Younger and Bob Nettinger called back later. They require PII to sign a NDA before giving additional information. It seems there is a lawsuit going on between American Hydro and Mac & Mac.