REMR TECHNICAL NOTE CS-MR-9.2

SPECIALIZED REPAIR TECHNIQUE: REPAIR OF STRUCTURES DAMAGED BY CAVITATION-EROSION

PURPOSE: To provide information on the causes of cavitation-erosion damage to concrete and guidance on corrective actions and selection of repair materials.

PROBLEM: Cavitation-erosion is the result of relatively complex flow characteristics of water over concrete surfaces. There is little evidence to show that water flowing over concrete surfaces at velocities less than 40 fps causes cavitation damage to concrete. However, when flow is fast enough (greater than 40 fps) and there is a surface irregularity, the flowing water may separate from the concrete surface. In areas of separation from the concrete, vapor bubbles develop because of the lowered vapor pressure in the region. As these bubbles are carried downstream, they soon reach areas of normal pressure. There the bubbles collapse with an almost instantaneous reduction in volume. This collapse, or implosion, creates a shock wave which, upon reaching a concrete surface induces very high stresses over a small area. The repeated collapse of vapor bubbles on or near the concrete surface causes pitting.

CONCRETE DAMAGE: Concrete spillways and outlet works of many high dams have been severely damaged by cavitation. Concrete that has been damaged is severely pitted and extremely rough. As the damage progresses, the roughness of the damaged area may induce additional cavitation.

HYDRAULIC CONSIDERATIONS: Even the strongest materials cannot withstand the forces of cavitation indefinitely. Therefore, proper hydraulic design and the use of aeration to reduce or eliminate the parameters that trigger cavitation are extremely important (Ref a). Since these topics are beyond the scope of this technical note, hydraulic engineers and appropriate design manuals should be consulted for further guidance.

REPAIR MATERIALS: While proper material selection can increase the cavitation resistance of concrete, the only totally effective solution is to reduce or eliminate the causes of cavitation. However, it is recognized that in cases of existing structures in need of repair, the reduction or elimination of cavitation may be difficult and costly. The next best solution is to replace the damaged concrete with more cavitation-resistant materials. Cavitation resistance of concrete can be increased by use of a properly designed low water-cement ratio, high-strength concrete. The use of no larger than 1-1/2-in. nominal maximum size aggregate is beneficial. Furthermore, methods which reduce the unit water content of the mixture, such as use of a water-reducing admixture, can also be beneficial. Vital to increased cavitation resistance are hard, dense aggregate particles and good aggregate-to-mortar bond.

Cavitation-damaged areas have been successfully repaired using steel-fiber concrete and polymer concrete (Ref b). Some coatings, such as neoprene and

and polyurethane coatings, have been found to reduce cavitation damage to concrete; however, since near-perfect adhesion to the concrete is critical, the use of coatings is not common. Once a tear or a chip in the coating occurs, the entire coating is soon peeled off.

CONSTRUCTION PRACTICES: Construction practices are of paramount importance when hydraulic surfaces may be exposed to high-velocity flow, particularly if aeration devices are not incorporated in design. Such surfaces must be as smooth as can be practically obtained. Accordingly, the good construction practices as given in Engineer Manual 1110-2-2000 (Ref c) should be maintained whether the construction is new or a repair. Formed and unformed surfaces should be carefully checked during each construction operation to confirm that they are within specified tolerances as given in EM 1110-2-2000. More restrictive tolerances on hydraulic surfaces should be avoided since they become highly expensive to construct and often impractical to achieve despite the use of modern equipment and good construction practices. Where possible, transverse joints in concrete conduits and chutes should be minimized. These joints are generally in a location where the greatest problem exists in maintaining a continuously smooth hydraulic surface. One construction technique which has proven satisfactory in placement of reasonably smooth hydraulic surfaces is the traveling slipform screed. This technique can be applied to tunnel inverts and to spillway chut slabs. Information on the slipform screed can be found in Ref d. Since surface hardness improves cavitation resistance, proper curing of these surfaces is essential.

REFERENCES:

a. Erosion resistance of concrete in hyraulic structures. ACI Committee 210. In: ACI Manual of Concrete Practice, Part 1, American Concrete Institute, Detroit, MI, 1985. ACI 21OR-55.

b. Cavitation resistance of some special concretes. D. L. lioughton, 0. E. Bor-e, J. A. Paxton. In: Journal of the American Concrete Institute, Vol 75, No. 12, American Concrete Institute, Detroit, MI, 1978, pp 664-667.

c. Standard practice for concrete. US Army Corps of Engineers, Washington, DC, Sep 1985. Engineer Manual 1110-2-2000.

d. Formwork for concrete. M. K. Hurd. American Concrete Institute, Detroit, MI, 1979. Special Publication 4, 4th ed.