24.0 CONSTRUCTION CONSIDERATIONS

24.1 Care of Water

Typically, the design, construction, maintenance and removal of temporary measures for the care of water during construction are specified as being the sole responsibility of the contractor, and a separate pay item is included in the contract documents for this work. As a result, the contractor assesses the risks, determines the measures required, and assigns a cost. Where the design and installation of special dewatering techniques (e.g. an extensive wellpoint system) are needed, provisions requiring that such work be performed by a specialist dewatering subcontractor with extensive experience may be included in the specifications.

In some cases, consideration may be given to providing performance requirements within the specifications so that the contractor can better quantify the risk and requirements, and therefore provide better costs. Under this scenario, if the actual conditions exceed the specified performance requirement, additional payments would be made under a change order.

In addition, where specific temporary care of water measures are required, these should be clearly identified, and in some instances designed. Consideration should also be given to including separate pay items for these specific measures.

24.2 Fill Placement

On sloping surfaces, fill placement should begin at the bottom of the slope and proceed in an uphill direction.

Tamped compaction of fill materials within 1 m of structures and within 0.6 m of pipes or other items susceptible to compaction induced damage should be performed using hand-operated equipment such as vibratory plate tampers, jumping jacks or double drum rollers.

For filter and drainage materials, the placement and compaction operations should be specified and carefully monitored to ensure that segregation and particle breakdown is not occurring.

Compaction of fine grained earth materials should be based on a percent of the standard Procter maximum dry density and a percent of optimum moisture content. Compaction requirements for granular materials should be based on the dry density as a percent of the Maximum Index Density determined using a vibratory table in accordance with ASTM D4253-83 (1996).

24.3 Cast-in-Place Concrete

24.3.1 General

In general, information contained in pertinent standards and documents such as CSA A23.1-00, ACI

Manual of Concrete Practice (2000), and USBR Concrete Manuals (1988, 1992) should be considered in determining requirements for the production, delivery, placement, finishing, and curing and protection of cast-in-place concrete for a specific project.

24.3.2 Production and Delivery

In general, it is preferred that a semi-automatic or fully-automatic batch plant be used to produce concrete. The plant should be equipped with an individual storage bin for each mix ingredient (cement, fly ash, fine aggregate, and each size of coarse aggregate).

An onsite batch plant should be required for major projects requiring large volumes of concrete or where there are no suitable facilities located within a close distance to the site that can consistently meet the required discharge times outlined in Section 24.3.3.

For major projects, where significant volumes of mass concrete containing large size coarse aggregate will be used, the need to have a central mixer at the batch plant should be considered as discussed in Section 3.3.5.

Where truck mixers are used to transport concrete, proper maintenance of the fins within the drums is necessary for ensuring that the concrete is discharged without segregation. More frequent inspections of the fins may be required particularly where mass concrete employing large sized aggregate is involved. In addition, ramps may also be needed to facilitate the discharge of mass concrete from the truck mixers.

24.3.3 Placement

It is preferred that the specifications require that the concrete be completely discharged and placed within 90 minutes of mixing the cementitious materials with the water or the aggregates. This time is reduced to 60 minutes when the ambient air temperature exceeds 27°C or under conditions that may cause quick stiffening of the mix.

Where pumping of concrete will be permitted, the specifications should include requirements for the pumping equipment and the mix design. For a concrete mix employing a maximum size of coarse aggregate of between 25 mm to 40 mm, a concrete pump system with a minimum pipeline diameter of 125 mm is normally required. In general, the mortar requirement (cement and sand content) will have to be increased as the diameter of the pipeline decreases. Full-scale field tests should be conducted to verify that the proposed equipment is capable of consistently delivering the concrete with the specified quality requirements.

Placement of concrete in standing water should not be permitted unless required as part of the design. Where underwater placement of concrete is required by design, appropriate tremie placement techniques should be specified.

24.3.4 Finishing

Concrete finishing requirements are normally established based on performance and aesthetic considerations.

As described in USBR (1981), local surface irregularities are typically classified as either abrupt or gradual irregularities. Abrupt irregularities are defined as offsets or fins caused by displaced or misplaced form sheeting, lining, or form sections; defective form lumber; or by improper screeding or trowelling. They also include any isolated irregularity in which the maximum dimension of the irregularity perpendicular to the surface is greater than the maximum dimension of the irregularity in the plane of the surface. Gradual irregularities are defined as bulges or depressions resulting in gradual changes in the concrete surface.

The maximum height and slope (ratio of height to length) of the irregularity is usually measured as deviations from a surface using a 3 m long straight edge or shaped template for curved surfaces.

Examples of typical general finish requirements for unformed concrete surfaces that have ordinarily been specified are provided below.

- Unformed surface permanently concealed by backfill or concrete: level and screed the concrete surface to produce an even uniform surface.

- Permanently exposed unformed surface: level using screeds then use floats to produce a surface that is free of screed marks and uniform in texture.

- Permanently exposed surface where pedestrian traffic is expected: level by screeding, followed by floating, trowelling, and brooming to produce a dense, uniform, non-slip surface.

- Permanently exposed unformed surface along water passages: level by screeding, followed by floating and applying a steel trowel finish to produce a dense uniform surface, free of blemishes, ripples, and trowel marks.

Examples of typical general finish requirements for formed concrete surfaces that have ordinarily been specified are provided below.

- Formed surface permanently concealed by backfill or concrete: treatment consists of repairing defective concrete, dry packing of tie-rod holes, and correction of surface depressions that are greater than 15 mm in depth.

- Permanently exposed formed surface: repair defective concrete, remove fins, and dry pack tie-rod holes.

- Permanently exposed formed surface along water passages: repair defective concrete; remove fins, dry pack tie-rod holes and excessively large surface voids or cavities.

Information on tolerances for abrupt and gradual irregularities for unformed and formed surfaces that are not exposed to high velocity flows can be found in CSA A23.1-00 and USBR (1981). Where the unformed or formed surface will be subjected to high velocity flow, more stringent finish requirements and/or treatments may be required to prevent cavitation from occurring. Information that can be used to assess the potential for cavitation to occur, and recommendations on flow surface tolerances can be found in USBR (1990 and 1981).

Repair methods for various types of defective or damaged concrete are outlined in Section 24.3.6.

24.3.5 Curing and Protection

Curing and protection measures are required to protect freshly placed concrete from exposure to freezing or large temperature differentials, premature drying, and moisture loss for the period of time necessary to attain the design strength and durability properties of the concrete.

In general, it is preferred that curing of concrete be performed using moist curing techniques applied on a continuous basis for a minimum of 7 consecutive days with an ambient temperature of at least 10°C. For unreinforced massive sections, consideration should be given to extending the curing period to a minimum of 10 consecutive days.

Where conditions are not conducive to moist curing, curing compounds may be considered except where a bond is required with the next concrete pour, or a surface coating. The use of a white-pigmented curing compound should be considered where solar heating is a concern.

Cold weather protection is required when the air temperature is at or below 5°C, or is forecast to fall below 5°C within 24 hours of placing. Heating and hoarding measures including heated enclosures, coverings, insulation or a combination should be required to protect the concrete during the curing period. The specification should require that these facilities be checked on a regular basis to ensure that the hoarding is in place, the heaters are functioning, and the specified temperatures are being maintained. The specifications should also indicate that, where required by regulations, the hoarding structures must be designed by a professional engineer.

24.3.6 Repair of Concrete

Normally, the contractor and the Province's representative should jointly examine all concrete surfaces and clearly mark the defective areas that need to be repaired.

Examples of typical procedures that have been employed to repair defective or damaged areas on recently placed cast-in-place concrete are provided below.

- Repair areas should be clean, sound, and saturated surface dry except where a bonding agent is used that requires a dry surface. Repair methods that will result in a feathered edge must not be used.

- Tie-rod holes, surface voids or other small cavities where lateral restraint is available are filled with dry pack mortar. It is preferred that a fast setting, polymer modified, cementitious mortar be used.

- For small repair areas that are too wide for dry pack filling and that extend no deeper than the far side of the reinforcement, the area is filled under pressure (mortar gun or head box) using a compatible polymerized mortar. Generally this method is not used on water passage surfaces. Alternatively, the following procedure for other repair areas can be used.

- For other repair areas including honeycombed areas, the perimeter is saw cut to a minimum depth of 25 mm, and the defective concrete removed down to sound concrete or to the required depth behind the reinforcing steel, whichever is greater. The required depth behind the reinforcing steel is the greater of 1.5 times the maximum coarse aggregate size of the replacement concrete or 25 mm. In some cases, a high percentage solids epoxy or acrylic bonding agent may be applied to the surface prior to placing the replacement concrete, however particular care is required to ensure that the bonding agent is properly applied, otherwise it can be a detriment.

For water passage surfaces that will be subjected to high velocity flows, and where the abrupt or gradual irregularities marginally exceed the specified tolerances, grinding of the concrete surface may be appropriate. Grinding will reduce the mechanical bond of aggregate particles at or near the surface; consequently, the amount of grinding that will be permitted should be carefully specified. Where the abrupt or gradual irregularities are much greater than the specified tolerances and therefore cannot be properly repaired by grinding, the area should be removed and replaced in the same manner as indicated for honeycombed areas.

The performance of any concrete repair is highly dependent on providing a sound and properly prepared surface, proper application of repair products, and continuous curing and protection. As a result, careful monitoring and inspection is required to ensure that these requirements are achieved.

For existing concrete structures, an evaluation of the strength and durability properties of the existing materials, the exposure and operating conditions, and the extent and cause of the damage should be performed to ascertain the repairs required.

Pertinent information on the repair of concrete is available in USBR Standard Specifications for Repair of Concrete (1996), USACE Evaluation and Repair of Concrete Structures (1995), and the ACI Manual of Concrete Practice (2000).