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10 **SHOTCRETE**


10.1 **SCOPE OF WORK**

- i) The Specifications described herein under relate to the Work, which includes all labour, materials, plant, equipment and services required for the shotcrete work to be carried out by the Contractor under this Contract.
- ii) The Shotcrete Work shall be performed to the dimensions as shown on the drawings or as otherwise directed by the Project Manager.
- iii) The approval given by the Project Manager to the Contractor's equipment or their operation or of any construction methods shall not relieve the Contractor of his full responsibility for the proper and safe execution of Shotcrete Work or any obligations under this Contract.
- iv) Methods and workmanship in the application of shotcrete shall be in accordance with best modern practice and as specified herein.
- v) Shotcrete shall be placed in layers and to the extent and thickness shown on the drawings or specified herein or as required by the Project Manager.
- vi) Generally, the requirement for shotcrete will be decided by the Project Manager following scaling of rock surfaces exposed by excavation. However, this shall not preclude the possibility of contractor being required to return, to place shotcrete in areas at any time following excavation where the Project Manager considers this to be necessary.

10.2 **DEFINITIONS**

- i) SHOTCRETE is defined as a mixture of cement, aggregate, water and accelerators in correct proportions, with maximum size of aggregate less than 10 mm projected at high velocity from a spray nozzle on to a surface to form a layer of pneumatically applied concrete on that surface. Shotcrete can be either wet or dry mix. It will be used for protection and supporting rock surfaces after excavation, to fill the cavities caused by overbreak or weathering.

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- ii) **DRY-MIX PROCESS:** the cement, aggregates and accelerator batched by weight or volume, are thoroughly mixed dry (with enough moisture to prevent dusting) and fed into a purpose-made machine wherein the mixture is pressurised, metered into a dry air stream and conveyed through hoses or pipes to a nozzle in which water as a spray is introduced to hydrate the mix which is projected without interruption into place.
- iii) **WET-MIX PROCESS:** all materials and water, but without accelerators, are mixed together to produce mortar or concrete. The mixture is then conveyed by positive displacement or compressed air to a nozzle where air, and possibly accelerator, is injected to increase velocity, and projected without interruption into place.
- iv) **LAYER** is a term used for a discrete thickness of shotcrete built up from a number of passes of the nozzle and allowed to set.

10.3 STANDARDS

- i) The Shotcrete materials, production, methods, testing and admixtures shall conform to the latest editions of the following Indian Standards or, where not covered by these Standards, to the equivalent International Standards:

IS: 269	33 grade ordinary Portland cement
IS: 383	Coarse and fine aggregates from natural sources for concrete
IS: 456	Code of practice for plain and reinforced concrete
IS: 516	Method of test for strength of concrete
IS: 1489	Part 1, Portland-pozzolana cement, fly-ash based, Part 2, Portland-pozzolana cement, calcined clay based
IS: 2645	Integral cement waterproofing compounds
IS: 9012	Recommended practice for shotcreting
IS: 9103	Admixtures for concrete


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10.4 **SUBMITTALS**

- i) Within 20 days from the date of issue of the Letter of Acceptance, but before procuring or mobilizing to the Site, the equipment, the Contractor shall submit to the Project Manager, updated and detailed plans and descriptions, of the following:
 - a) Batching and Mixing Equipment: Description and details of the equipment, which the Contractor intends to use to determine and control the quantity of shotcrete ingredients and mixing thereof into uniform mixture.
 - b) Placing Equipment: Full details of the equipment to be used for placement of shotcrete and details of standby equipment.
 - c) Details of methods and equipment which the Contractor proposes to use to control the temperature of aggregates and water during extreme hot and cold weather conditions,
- ii) At least 15 days in advance of any Shotcrete work being carried out on the Site, the Contractor shall submit, to the Project Manager, the following:
 - a) Notification of any admixture and pozzolana, which the Contractor proposes to use, manufacturers thereof and information about the chemical names of the principal ingredients, the effect of under or over dosage and storage requirements on site.
 - b) Description and details of methods which the Contractor proposes to adopt for Shotcreting.
- iii) The Contractor shall at least 30 days before use, submit a detailed program of acceptance tests for steel fibre reinforcement to the Project Manager giving details of the tests to be performed. The tests shall be performed in the presence of the Project Manager.
- iv) The Project Manager reserves the right to require any additional information deemed necessary to be included in the submitted documents.


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10.5 **MATERIALS**

- i) Shotcrete shall be composed of cement, aggregates, water and approved admixtures as specified herein.
- ii) Cement shall be ordinary portland cement or portland pozzolana cement conforming to the requirements of relevant Standards or as specified on the drawings.
- iii) Aggregates shall conform to the requirements of relevant Indian Standards.
- iv) Aggregates shall be furnished by the Contractor from a source accepted by the Project Manager, but acceptance of source by the Project Manager shall not be considered as constituting the acceptance of all aggregates to be taken from that source or grading of aggregates to be in conformance with Contract.
- v) Air used for spraying shotcrete shall be clean and free of oil.
- vi) Accelerating and Super Plasticiser admixtures shall be used to develop quick set and high early strength, as approved by the Project Manager, conforming to the requirements of relevant standards and in accordance with the manufacture's recommendations.
- vii) All admixtures shall be stored in accordance with the manufacturer's recommendations.
- viii) The shotcrete shall be reinforced with wire mesh or steel fibres, as shown in the drawings or as instructed by the Project Manager.
- ix) Fibres shall be deformed steel fibres produced from mild steel or cold drawn wire and shall be un-galvanised.
- x) Fibres shall be stored in dry sealed containers until ready for use and shall be free from corrosion, oil, grease, chlorides and deleterious materials which may reduce the efficiency of mixing or spraying processes, or which may reduce the bond between the fibres and the sprayed concrete.
- xi) Fibre type shall be selected on the basis of compliance with EFNARC (European Specification for Sprayed Concrete, 1996) energy absorption test and on the basis of ease of use in the batching, mixing and spraying

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processes proposed, as demonstrated by site trials to the approval of the Project Manager. Fibres which tend to form fibre balls during batching and mixing shall not be used.

10.6 MIX DESIGN AND PROPORTIONING

10.6.1 SHOTCRETE

- i) The type/class of shotcrete to be used in a particular location shall be as per drawings and as directed by the Project Manager.
- ii) The mix proportions of Cement, aggregates and permitted admixtures in each class shall be determined by Contractor and shall be subject to the approval of the Project Manager. The mixes shall be such as to permit placement without excessive rebound and segregation.
- iii) The admixtures shall have proven compatibility with the cement brand and type so as to ensure initial and final setting time as 3 to 12 minutes respectively. The Contractor shall supply, to the Project Manager, all the necessary test results and reports to confirm compatibility.
- iv) The water content of the mixes shall be limited to prevent sloughing. The water-cement ratio of fresh shotcrete in place shall be between 0.32 and 0.45.
- v) The Mixes shall be such that aggregate gradation and cement content after placing are as those obtained from samples taken from test panels produced from approved trial mixes. All constituents shall be uniformly dispersed throughout the mix.
- vi) The proportion of admixture shall vary between 2% to 7% of the weight of cement or as determined by testing prior to any shotcrete work.
- vii) Proportioning of aggregate and cement shall only be carried out by weigh batching.
- viii) The shotcrete shall meet the following compressive strength requirements or as shown on the drawings:
 - a) 4.5 N/mm² after 8 hours,

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- b) 12.5 N/mm² after 72 hours,
- c) 25.0 N/mm² after 28 days.
- ix) The Compressive strength after 7 days shall be 70% of the specified strength of 28 days.
- x) Moisture content of the combined aggregate at the time of mixing with cement shall not exceed 6% (six percent) by weight of the oven dry aggregate.
- xi) Mixed material shall be used within 90 minutes after adding cement.
- xii) The accelerating admixture, if in dry state, shall be added immediately after depositing the materials in placing equipment and shall be accurately proportioned and thoroughly mixed with other ingredients. If in liquid form, the admixture shall be accurately proportioned into the water supply at the application nozzle.
- xiii) Mix proportions shall be varied, when required by the Project Manager, to obtain required strength of shotcrete, to maintain rebound to the minimum and to meet other requirements of the Contract. The Contractor shall notify to the Project Manager of all variations to the mixes.

10.6.2 STEEL FIBRE REINFORCEMENT

- i) The Contractor may use the fibre of his choice, subject to approval of the Project Manager. The Contractor shall perform tests to establish the actual dose of steel fibre and submit the results of his proposed mix to the Project Manager for approval.
- ii) Steel fibre reinforced shotcrete shall have a minimum fibre content of 30 kg/m³ in the place and shall conform to EFNARC (European Specification for Sprayed Concrete, 1996) energy absorption class b (700 Joule at 25 mm deflection on a standard 600 mm x 600 mm x 100 mm plate test for hand spraying and 1000 mm x 1000 mm x 100 mm plate test for robot spraying).

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10.7 TESTING FOR SHOTCRETE QUALITY

10.7.1 SHOTCRETE

- i) For the purpose of approving mix design, the Contractor shall prepare not less than three test panels for each mix for testing by Project Manager initially at least 42 days before any shotcreting work is started. For any subsequent change in additive or equipment the Project Manager may order fresh testing. All tests shall be done as per IS: 516 and IS: 9012. The Contractor shall furnish all plant, materials and assistance necessary and carry out all work to obtain representative tests panels of shotcrete.
- ii) For the purpose of routine quality control, the number of panels to be supplied shall generally consist of 3 for every 250 m³ of shotcrete to be placed. The sets of three panels for mix design approval and for routine quality control shall consist of one shot downward onto a horizontal surface, one shot onto an inclined or vertical surface and one shot overhead onto a horizontal surface.
- iii) Test panels shall be obtained by securely attaching an approved 1 m² by 80 mm deep timber box with a rigid base to an area of rock similar to that to be shotcreted or an approved alternative surface arrangement, wetting the box and applying shotcrete to the area contained by the box in the manner specified herein and using the same mixing and placing equipment to be used for the works. All panels shall be of a minimum thickness of 80 mm, and shall be made in the presence of Project Manager. The panels shall be left undisturbed at the point of placement until the final set has taken place. Test panels and specimens shall be transported by the Contractor to the site laboratory immediately after final set has taken place, not sooner than two hours and not later than eight hours after manufacture, and in such a manner as to prevent them from being damaged in any way.
- iv) The crushing strength of the shotcrete shall be determined by testing 75 mm cubes drawn from the test panels immediately before testing and shall be capped and tested in accordance with IS: 456. Cube test results will be statistically analysed in accordance with the recommendations of IS: 516. In

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the event that test specimens fail to meet the specified requirements, the Project Manager may order the Contractor to take in place 80 mm diameter core specimens of placed shotcrete associated with such specimens. If tests performed on cored specimens indicate that the shotcrete fails to meet the specified requirements, then Contractor shall carry out such remedial works as Project Manager may require, including placement of additional shotcrete, and if deemed necessary repair and/or removal and replacement of shotcrete.

10.7.2 STEEL FIBRE REINFORCEMENT


- i) The strength of steel fibre reinforced shotcrete shall be checked in accordance with the EFNARC (European Specification for Sprayed Concrete, 1996) energy absorption class b (700 Joule at 25 mm deflection on a standard 600 mm x 600 mm x 100 mm/1000 mm x 1000 mm x 100 mm plate test. The approval of the mix proportions shall be based on a minimum of 5 panels per mix.
- ii) For every 250 m³ of shotcrete placed 3 cores of dimensions to be fixed by the Project Manager shall be taken and tested to confirm that in the place fibre content is consistent with that of the plate tests used to determine the mix proportions. If in the place fibre content falls below the tested value the Contractor shall increase the dosage of fibres to ensure that the required content in place is reached.

10.8 RESOURCES FOR SHOTCRETING

10.8.1 EQUIPMENT

- i) Only modern, properly operating mixing, delivery, and placing equipment approved by the Project Manager shall be used for the performance of the work.
- ii) The compressor shall provide a supply of air adequate to maintain sufficient nozzle velocity for all parts of the work while simultaneously operating a blowpipe for clearing away rebound when required.

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- iii) The delivery equipment shall be a pneumatic feed type or, for the wet-mix process, positive displacement type. The equipment shall be capable of delivering a continuous smooth stream of uniformly mixed material at the proper velocity from the discharge nozzle at all heights of the work.
- iv) The delivery equipment shall be thoroughly cleaned at the end of each shift. Equipment parts, especially the nozzle liner and water ring, shall be regularly inspected and replaced as required.
- v) The discharge nozzle, for the dry-mix process, shall be equipped with a manually operated water injection system (water ring) for directing an even distribution of water to the aggregate- cement mixture. The water valve shall be capable of ready adjustment to vary the quantity of water and shall be convenient for the nozzleman.
- vi) Water pressure shall be maintained at a uniform level which shall be at least 1 bar above operating pressure and sufficient to ensure adequate hydration at all times.
- vii) The nozzle shall be capable of delivering a conical uniform discharge stream. Distortion of this stream shall be remedied by examination of the nozzle and any malfunction rectified by replacement of defective parts before further work is carried out.

10.8.2 PROFICIENCY OF WORKMEN

- i) Nozzlemen shall have previous experience in the application of coarse aggregate shotcrete or shall work under the immediate supervision of a foreman or instructor with such experience. Each crew shall demonstrate, when required by the Project Manager acceptable proficiency in the application of shotcrete to vertical and overhead test panels before beginning production work.
- ii) Acceptable shotcrete shall consist of a dense uniform concrete without major rebound inclusions and without discernible weakness of bond between layers. The nozzlemen shall shoot Shotcrete with a uniform consistency and at the wettest consistency short of the sag point. The

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nozzle shall be held at a predetermined distance and position so that the stream of flowing materials shall impinge as nearly as possible at right angles to the surface to be covered. The inclusion of rebound or aggregate pockets will not be permitted in the finished work. Rebound shall be removed and disposed off as specified herein.

10.9 EXECUTION

10.9.1 SURFACE PREPARATION

- i) When shotcrete is to be applied to excavated surfaces immediately after blasting, the surfaces shall be prepared by a minimum of scaling, followed by washing with clean water. All surfaces shall be wet, clean and free of rebound, at the time of application of shotcrete. For all other shotcrete application, the surfaces to be treated shall be thoroughly sluiced with air and water jet or cleaned by other means approved by the Project Manager to remove all traces of dirt, mud, debris, oil, loose particles, rebound or loose rock and any other deleterious matter. The surfaces shall be kept moist until shotcrete is applied.
- ii) Where water flows from the rock against which shotcrete is to be placed and when water cannot be sealed off by shotcreting alone, the water shall be excluded from the area by caulking or diverted by pipes, pans or other approved means in such a manner that the shotcrete will be unaffected by action of the water through percolation, by hydrostatic pressure or erosion.
- iii) A layer of shotcrete which is to be covered by a succeeding layer shall first be allowed to take its initial set and shall have all litanies, loose materials, dirt or other deleterious material and rebound removed by brooming, sluicing or other means acceptable to Project Manager.
- iv) Shotcrete surfaces shall be kept moist until the succeeding layer of shotcrete is applied or the curing requirements have been observed.
- v) At any time during surface preparation the Project Manager may order that contractor apply shotcrete to isolated areas before proceeding with surface preparation.


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10.9.2 MIXING AND PLACING

- i) Shotcrete materials shall be accurately weigh-batched before mixing. Aggregates shall be thoroughly mixed without the addition of water before being deposited in the placing equipment. Cement shall be added not more than 1-1/2 hours before application. Mixes, which are not applied within 1-1/2 hours of adding cement, shall be discarded. Rapid-hardening additive shall be accurately proportioned.
- ii) Shotcrete shall not be applied to any surface without the permission of the Project Manager. Should the Contractor consider that any surface requires shotcreting urgently, he shall immediately inform the Project Manager..
- iii) In general, the maximum thickness of shotcrete in any one layer shall be such as to prevent sagging. The maximum thickness of shotcrete applied in any single spraying at any location shall not be more than 50 mm. The minimum thickness of shotcrete in any one layer at any location shall be 25 mm.
- iv) The Project Manager will examine rock faces following blasting and scaling. On the basis of such examination, the Project Manager may require immediate shotcreting of surfaces, in which case shotcrete shall be applied within 4 hours of blasting and before drilling the next round. Where very poor rock conditions are anticipated the Project Manager may require that shotcrete equipment be available before blasting so that shotcrete can be applied with the minimum of delay.
- v) Shotcrete, other than that placed immediately after blasting, shall not be placed in any area until all blasting within 20 m of the area has been completed, unless otherwise approved by Project Manager.
- vi) Shotcrete above ground shall not be carried out when, in the opinion of the Project Manager, shotcrete cannot be placed effectively because of adverse weather conditions, unless adequate cover is provided over the working area until the shotcrete has been cured sufficiently to prevent damage.
- vii) The Contractor shall develop operating procedures and operations to the satisfaction of the Project Manager to give:

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<div> <div> a) minimum rebound, b) no inclusion of rebound in the finished shotcrete, c) as smooth a finished surface as possible, d) no hollow areas in the shotcrete, e) a minimum of shrinkage cracks, f) good adherence of the shotcrete of rock or other surface. </div> <div> viii) The flow of the material at the nozzle shall be continuous and uniform and the rate of application over any given area shall be uniform. Slags, sand spots, wet areas or other defects shall be cut out and corrected as specified herein. </div> <div> ix) At the start of shotcreting operations in any area, contractor shall, in close co-operation with the Project Manager and as part of the initial placement, establish procedures for the application of shotcrete, which will produce the best quality product with the minimum of rebound. Such establishment of procedures shall be as required by the Project Manager and shall include minor variations in mixes, variations to acceptable finishes, thicknesses and nozzle discharge quantities on a unit area of rock or length of tunnel. The quantities of shotcrete to be discharged at the nozzle shall be determined on the basis of the average thickness of shotcrete shown on the drawings or as required by the Project Manager and taking due account of rebound. Once procedures for the placement of shotcrete are established, subsequent work shall be carried out accordingly. </div> <div> x) When required by the Project Manager, the thickness of a layer in any area shall be checked by either probing immediately after the shotcrete has been applied, by placing pins of known lengths in the rock before shotcreting or by any other means approved by the Project Manager. </div> <div> xi) In shotcreting vertical or steeply inclined surfaces, other than roofs of underground cavities, application shall begin at the lowest point and the shotcrete layer shall be built up in horizontal trips until the entire surface is covered. </div> </div>		
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- xii) The edges of shotcrete areas against which no further shotcrete is to be placed and where required by the Project Manager shall be formed to clean, regular lines and slopes.
- xiii) Where drain holes have been drilled and instruments have been installed into rock on which shotcrete is to be placed, contractor shall take all necessary precautions to prevent such holes from being plugged or instruments from being damaged.
- xiv) When shotcrete is to be performed near existing structures, the Contractor shall ensure that no damage results to the structure and shall protect the surface of structures before shotcreting.
- xv) Application of shotcrete in any area shall be considered complete when the shotcrete has been built up to the specified thickness. The thickness of shotcrete specified on Drawings shall be the minimum thickness measured anywhere in the treated area, with the exception of protrusion of rock whose dimensions in plan are less than the thickness of the shotcrete specified, in which case the minimum cover shall be 30 mm.
- xvi) Where shotcrete is placed over wire mesh and supporting bolts, it shall be covered with shotcrete to a depth of at least 30 mm. Where rock bolt extensions are to be added to existing rock bolts, the exposed ends of the rock bolt threads shall be suitably protected before shotcreting.
- xvii) Particular attention shall be paid to construction joints in the shotcrete, which are subject to approval by the Project Manager. Joints shall be formed by overlapping layers of shotcrete.

10.9.3 REBOUND

- i) Rebound shall be kept to a minimum and continuously monitored. Rebound shall be removed and disposed off before any adjacent area is shotcreted. Rebound shall not be reused. Special care shall be taken that rebound does not build up at the junction of walls and floors both in underground and surface structures.

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- ii) The Contractor shall make every effort to keep rebound to a maximum of 10%. If in the opinion of Project Manager, rebound is excessive, he may require contractor to revise the mix design for shotcrete or its application procedures or take such other measures, necessary to reduce rebound to a reasonable level.

10.9.4 CURING

- i) During shotcreting the tunnel entrances shall be sealed by suitable curtains to minimise the through draft.
- ii) Suitable screening of the nozzle and of the application surface shall be provided during periods of windy or draughty conditions.
- iii) Freshly placed shotcrete shall be protected from rain or water until the surface is of sufficient hardness to prevent damage.
- iv) When dry specks first appear at the surface of any shotcrete layer, it shall be wetted with a water jet at least once in every 4 hours or otherwise cured to the satisfaction of the Project Manager for a minimum period of 7 days. If water jets are used the shotcrete shall not be allowed to dry out. Membrane curing shall not be used when a further layer of shotcrete or other bonded finish is to be applied. Membrane curing shall not be used without the permission of the Project Manager.
- v) Shotcrete used as rock support in underground excavation, which will be covered with structural concrete later, will not require any curing when the ambient relative humidity is above 85%. In underground excavations with lower humidity and in surface excavations the shotcrete shall be water cured.
- vi) Should another, special surface texture be required, a different working process shall be used by applying flash coat or a layer of mortar reworked and finished to the desired texture.

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10.9.5 REPAIR OF SHOTCRETE

- i) Before a succeeding layer of shotcrete is placed, the preceding layer shall be checked for hollow zones.
- ii) The Contractor shall repair all hollow zones, sandy, cracked or spalled areas and any other areas where the shotcrete is faulty, by removing the shotcrete to a sound area of rock or shotcrete, carrying out surface preparation as specified herein and replacing that area to the satisfaction of the Project Manager.

10.9.6 TOLERANCES


- i) For shotcrete on natural surfaces or surfaces with an undefined shape, the average thickness shall be within 10% of the specified nominal thickness.
- ii) The thickness over the individual protruding rock pieces may not be less than two-thirds (2/3) of the specified nominal thickness.

10.10 MEASUREMENT AND PAYMENT

10.10.1 GENERAL

- i) The payment area for shotcrete in underground excavation works is defined as the projection of irregular area covered by shotcrete on to the excavation pay-line (i.e. B-line perimeter multiplied by length along the underground opening).
- ii) Payment will be made at the Unit Price per cubic meter entered in the Bill of Quantities, which shall include the entire cost of, but not be limited to, the following,:
 - a) All labour, plant and materials,
 - b) Storage, batching and mixing of all materials, water supply, preparation and cleaning of surfaces,
 - c) Placing of gauges for control of layer's thickness,
 - d) Placing of shotcrete including rebound,

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- e) Temporary protection, curing and testing,
- f) All activities related with performance of material testing.
- iii) Payment for shotcrete will be independent of the location of application.
- iv) The in-situ volume of shotcrete placed in underground works shall be deducted from the volume of structural concrete lining and backfill concrete behind steel lining to be measured for payment as stipulated in the Chapter "Concrete".
- v) Shotcrete placed by the Contractor in excess of thickness shown on the Construction Drawings or as specified by Project Manager will not be measured for payment.

10.10.2 EXCLUSIONS

No payment shall be made for the following items:

- a) Removing the defective shotcrete, carrying out surface preparation and re-shotcreting the area where the shotcrete has been found to be faulty by the Project Manager,
- b) Any replacement or repair of shotcrete damaged by blasting carried out by the contractor,
- c) Taking out of cores from the finished shotcrete and filling the core holes with dry pack mortar.

End of Chapter

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