BUREAU OF RECLAMATION

Concrete and Rock Core Handling Guide

Concrete and Structural Laboratory & Geotechnical Laboratory and Field Services
Technical Memorandum 8530-2021-03

Technical Service Center
Denver, CO

U.S. Department of the Interior February 2021

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Acknowledgements

The Manuals and Standards Program, Bureau of Reclamation, sponsored this document. Mr. Jack Tousell originally authored a document containing much of this information which was never formally published. Thank you Jack for your dedication and contribution to the industry.

<table>
<tr><td colspan="4">REPORT DOCUMENTATION PAGE</td><td colspan="2">Form Approved
OMB No. 0704-0188</td></tr>
<tr><td colspan="2">T1. REPORT DATE
February 2021</td><td colspan="2">T2. REPORT TYPE</td><td colspan="2">T3. DATES COVERED</td></tr>
<tr><td colspan="4" rowspan="3">T4. TITLE AND SUBTITLE
Concrete and Rock Core Handling Guide</td><td colspan="2">5a. CONTRACT NUMBER</td></tr>
<tr><td colspan="2">5b. GRANT NUMBER</td></tr>
<tr><td colspan="2">5c. PROGRAM ELEMENT NUMBER</td></tr>
<tr><td colspan="4" rowspan="3">6. AUTHOR(S)
Caleb Nickel, P.E.
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(303) 445-2445</td><td colspan="2">5d. PROJECT NUMBER</td></tr>
<tr><td colspan="2">5e. TASK NUMBER</td></tr>
<tr><td colspan="2">5f. WORK UNIT NUMBER
86-68530</td></tr>
<tr><td colspan="4">7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Concrete and Structural Laboratory
Technical Services Center
Bureau of Reclamation</td><td colspan="2">8. PERFORMING ORGANIZATION REPORT NUMBER
8530-2021-03</td></tr>
<tr><td colspan="4" rowspan="2">9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)</td><td colspan="2">10. SPONSOR/MONITOR’S ACRONYM(S)
BOR/USBR: Bureau of Reclamation
DOI: Department of the Interior</td></tr>
<tr><td colspan="2">11. SPONSOR/MONITOR’S REPORT NUMBER(S)</td></tr>
<tr><td colspan="6">12. DISTRIBUTION / AVAILABILITY STATEMENT</td></tr>
<tr><td colspan="6">13. SUPPLEMENTARY NOTES</td></tr>
<tr><td colspan="6">14. ABSTRACT (Maximum 200 words)
This report describes the necessary steps required to handle and transport concrete and rock cores from the jobsite to the destination, which will increase the quality of test specimens and probability of achieving representative test results.</td></tr>
<tr><td colspan="6">15. SUBJECT TERMS
Concrete cores, rock cores, transportation, handling</td></tr>
<tr><td colspan="3">16. SECURITY CLASSIFICATION OF:</td><td rowspan="2">17. LIMITATION OF ABSTRACT
U</td><td rowspan="2">18. NUMBER OF PAGES</td><td>19a. NAME OF RESPONSIBLE PERSON
Caleb Nickel</td></tr>
<tr><td>a. REPORT
U</td><td>b. ABSTRACT
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U</td><td>19b. TELEPHONE NUMBER
303-445-2445</td></tr>
</table>

S Standard Form 298 (Rev. 8/98)
P Prescribed by ANSI Std. 239-18

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Abbreviations and Acronyms

ACI	American Concrete Institute
ASR	alkali-silica reaction
ASTM	ASTM International (formerly American Society for Testing and Materials)
CSL	Concrete and Structural Laboratory
DOI	U.S. Department of the Interior
FER	Field Exploration Request
GLFS	Geotechnical Laboratory and Field Support
ITZ	interfacial transition zone
MB	mechanical breaks
Reclamation	U.S. Bureau of Reclamation
TSC	Technical Service Center
USBR	U.S. Bureau of Reclamation

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Introduction

Rock and concrete samples obtained in the field should be handled in a manner that meets the needs and purpose of the exploration program, site conditions, and the intended mode(s) of transportation. For example, freezing conditions in the winter or direct sunlight and heat in the summer may have detrimental effects on the samples for use in specific tests. Therefore, a plan that is carefully thought out (including technical and common-sense issues) and implemented is needed to handle the samples from the time they are retrieved to when they are delivered to the various users of the samples.

For large projects, it is typical for detailed instructions to be presented in the Reclamation project-specific Field Exploration Request (FER). The FER outlines size, location and depth of all drill holes, who is responsible for the drilling and extraction of the cores, if the work requires the assistance of the Reclamation Ropes Access Team or Underwater Inspection Team, sample designations, where the sample testing will be performed and what specific tests are required. Sample handling and shipping/transportation instructions should be included. For smaller projects, if a FER is not developed, standard practices should still be employed for sample preservation.

Every project and location have unique characteristics, which means that a sampling plan will need to be developed for each specific investigation which will best fit the site conditions, equipment, weather, material types, intended purpose(s) of samples, and type of transportation from the drill site to both the local storage area and any final destination. General guidelines that can be helpful for developing a sampling and handing plan can be found in the following references:

- U.S. Bureau of Reclamation Concrete Manual, 8th Edition [1]
- U.S. Bureau of Reclamation Earth Manual, 3rd Edition [2]
- U.S. Bureau of Reclamation Geology Manual, 2nd Edition [3]
- Electric Power Research Institute Guidelines for Drilling and Testing Core Samples at Concrete Gravity Dams [4]
- ASTM D420, Standard Guide for Site Characterization for Engineering Design and Construction Purposes [5]***
- ASTM D2113, Standard Practice for Rock Core Drilling and Sampling of Rock for Site Investigation [6]***
- ASTM D4220, Standard Practices for Preserving and Transporting Soil Samples [7]***
- U.S. Army Corps of Engineers Geotechnical Investigations, EM 1110-1-1804 [8]
- ACI 214.4R-10, Guide for Obtaining Cores and Interpreting Compressive Strength Results, American Concrete Institute Guidelines [9]

*** ASTM documents are copyrighted. The Bureau of Reclamation (Reclamation) has a license to download ASTM documents for internal use. ASTM standards can be accessed by creating an account at compass.astm.org with one's @usbr.gov email.

The Concrete and Structural Laboratory Group (CSL) and/or the Geotechnical Laboratory and Field Support Group (GLFS) are available to assist with information or clarification on these documents or assistance with a site-specific sampling and handling plan.

Other good resources are persons involved with previous similar projects, regional Reclamation Geologist and Drill Crew members, local drilling companies or government agencies that may have local experience. Any documentation, especially previous drilling records from the same materials/locations, can have information that is relevant to special needs and concerns which might be required at the project site. This document does not go into detail on drilling practices or the extensive information that is typically presented in a drilling log.

It should be remembered that field investigations can sometimes be dynamic, rather than static. Therefore, the sampling requirements may change as the drilling program progresses or as new ideas or demands come from project team members or inclusion of consultant review board member recommendations.

It is imperative that samples are delivered to the laboratory or testing location in a safe and reliable manner to avoid damaging the samples during transport. Several methods have been used in the past, with varying end results. There are a few common mistakes that cause testing to stray from the original plan. Occasionally, samples are:

- Inadequately labeled
- Packaged in a manner that does not preserve the in-situ moisture content
- Insufficiently protected, leading to physical damage of the samples

The cost of obtaining concrete core samples is often substantial, so it is desirable to receive samples in their best (most accurate) condition to avoid repeated coring efforts at additional cost. Furthermore, samples that arrive damaged or mislabeled could lead to inaccurate data, ultimately affecting subsequent analyses and work planning.

Economic Considerations

One very important consideration is that the cost of a drill hole, or cost per foot to drill a hole, is not necessarily the value of all the potential samples obtained. An extreme example to illustrate this point is a 125-foot-deep hole drilled for the sole purpose of obtaining the shear plane of a landslide for testing (or a foundation-to-concrete interface of a dam). The value of that single sample is the cost to drill the entire length of the hole. Therefore, the curatorial care of that one sample should reflect the value of the sample. Additionally, if the decision is made to ship samples using a common carrier or commercial freight, the risk of loss or damage of priceless samples is often too great. Samples that are less valuable should also be cared for using the proper techniques. Oftentimes there are multiple lower-cost samples available, meaning the success of the operation is not dependent on the quality of one sample. Any approach should consider the highest quality sample possible at the best value to the government.

Labeling

When the drill crew removes a section of concrete or rock core from the hole, it is labeled immediately to avoid any confusion (Figure 1). In some cases, it may be prudent to wrap or seal the sample prior to labeling to ensure the in situ moisture content is maintained. More information on preserving moisture content and specimen integrity is presented in the Concrete Cores and Rock Cores sections below.

Core should also have basic information and unique features clearly identified with indelible markings, such as:

- drill hole number
- depth
- orientation
- top and bottom
- date (if applicable)
- rebar or cooling pipes
- other embedded metal
- waterstop
- location of lift lines/construction joint, intact or disbonded (if detectible)
- location of mechanical breaks (MB), man-made or equipment related. Mechanical breaks are typically indicated by two parallel lines drawn perpendicular and crossing the mechanical break and labeled "MB" [6]

Figure 1. Concrete core with core hole location and depth labeled on plastic wrap

Once an individual concrete or rock core samples is labeled, the sample can be prepared for transport with identifiable information also recorded on the shipping container.

The boxes that contain a section of core should also have the project name, drill hole identification and range of depth for the core (Figure 2).

Figure 2. Core boxes labelled with the core hole location and range of depth

Concrete Cores

Concrete coring is conducted on many Reclamation projects to determine mechanical properties and deterioration mechanisms of existing concrete structures. This information may be used in structural analyses, risk analyses, planning for maintenance or repairs, or research. Concrete cores are typically collected for uniaxial compression and elastic properties testing of the concrete mass, direct tension testing of the parent material and/or lift lines, and direct shear testing of parent material and/or lift lines, among other tests. Any change from the in situ moisture content can, and does, affect the test results. Quality of lift line samples are primarily affected by drilling and handling issues. Additionally, samples that have large-diameter aggregates may have weak aggregate-to-paste bonds at the interfacial transition zone (ITZ), which may make the sample vulnerable during handling.

Additional complications can arise due the inherent weight of a concrete sample, with an approximate density of 150 lb/ft^3. Some large diameter concrete samples can weigh hundreds of pounds each. Special techniques may be employed if required to move large-diameter cores (above 6 inches). Mechanical anchors drilled into the concrete samples may be necessary for lifting cores and staging them for transportation (Figure 3).


Figure 3. 18-inch concrete core lifted using anchors

Maintaining Concrete Core Condition and Moisture

Concrete cores need to be handled and stored in the field and any interim storage in a manner agreeable with the site conditions and materials being collected. Preservation of the in situ condition is an important part of the testing program which aims to provide information on the structure in its natural environment. If the core needs to be visually inspected before shipment, re-apply moisture before packing (Figure 4). For example, concrete affected by alkali-silica reaction (ASR) must not be allowed to dry out, nor wet concrete allowed to freeze, or any other exposure that changes the sample properties. This includes any exposure during transport from the drill site. It is easy to forget about cooling or drying effects of the ambient air moving over the boxes while driving. All retrieved core shall be protected from extreme temperature changes and stored in a cool, shaded area until transported. If stored in the sun, cover with shelters to shade boxes and allow air flow. Directly covering boxes with a tarp is not acceptable.


Figure 4. Reapplying moisture and preparing core for shipping

To preserve the in situ moisture content of concrete cores, they are typically wrapped with plastic wrap or sealed in plastic bags (Figure 5). For longer transport or drier conditions, wetted packing material surrounding the concrete samples is also added to ensure the sample moisture can be preserved for days, to weeks, before testing. Concrete samples that have dried can negatively affect test results.


Figure 5. Core sample wrapped with plastic and placed on supports prior to shipping

Shipping Containers

Plastic half rounds can be used to contain samples if agreed to in the FER. Plastic half rounds are made by longitudinally cutting plastic tubes/pipes (Figure 6). Matching halves should be kept paired to assure proper fit. The ends may need to be capped with pipe caps and the sides sealed with an impervious tape if a hermetic seal is required. However, it should be realized that while plastic half rounds can be cheap and adequately protect the sample moisture, they may not provide much physical protection for the samples if the wall thickness is not sufficient, particularly against bending stresses which would be problematic if the core contains intact lift lines that need to be preserved. Plastic half rounds must be labeled with the facility name, drill hole number, and core depth/elevation.

Figure 6. Plastic half rounds to secure cores in the field

The preferred container for storage and shipping is a wooden core box (Figure 7) assembled using screws (not nailed), with an interior plastic liner (polyethylene sheeting) and wetted sawdust, burlap, or terry cloth towels. The plastic liner provides a short-term hermetic barrier around the wetted packing material surrounding the concrete samples, which are also wrapped in clear plastic wrap (Figure 8).

Figure 7. Containers used to transport 6-inch diameter samples

Figure 8. Wrapped with plastic on rolling jig, loaded into box with plastic and dampened wood shavings

The wetted packing material provides an additional barrier that cushions and preserves the moisture and integrity of the sample until it reaches the laboratory. Boxes can come in all shapes and sizes based on the diameter of core, job location, length of core, and storage limitations and are typically constructed by the drill crew responsible for extracting the samples. Core boxes may need internal dividers or supports. This includes taking any necessary steps to seal and brace the sample appropriately for transport. Reclamation's drill crews have experience fabricating core boxes for a variety of core sizes and conditions. CSL group also has empty concrete core boxes and half rounds which can be sent to the site.

Straps, ropes, or forklift inserts make lifting the core box and sample more convenient (Figure 9). Adding 4x4 blocking under the heavy boxes will allow either a forklift or pallet jack to be used, whereas 2x4 blocking may not provide the necessary clearance for the forks.

Figure 9. Handles and straps are helpful when moving boxes and sections of core

Another option is to transport the samples vertically, if there is ample protection between samples and they are not able to shift during transportation (Figure 10 and Figure 11). Core box spacers, for filling in unused space, can be made of wood but a durable foam material which can be written on with an indelible marker is preferable.

The shipping container must be labeled with the facility name, drill hole number and elevation/depth of the core run(s) contained. A copy of the drill log(s) should also be included in/on the shipping container. A sheet protector with the open-end taped shut is sufficient to prevent the paper from absorbing moisture from the core and/or wetted sawdust.

Figure 10. Large diameter concrete samples in a shipping container

Figure 11. Shipping containers placed on pallets for forklift transport (left) or stacked (right)

Rock Cores

Rock mass strength and deformation characteristics are influenced by the nature of both the intact rock and the discontinuities. As such, careful sampling, preservation, and shipment of all obtained materials is critical for any field investigation. Discontinuities may include faults, factures, joints which may contain clay or other weak infillings. The thickness, durability, degree of weathering, and mineralogy of any shear zone, or infilling (both primary and secondary) of discontinuities will require professional judgment at the drill site if the preservation of the test samples is to be selective. Furthermore, potentially weak zones should not be allowed to separate or move in a way that would disrupt or lose the material in the test zone. Any loss of weak samples leads to testing only the stronger materials and results in biased test results. Care needs to be taken to preserve all samples including soft and hard intact rock and discontinuities.

Maintaining Rock Core Condition

Rock may or may not be stable under atmospheric conditions; air slaking of shale and other argillaceous materials is common and needs to be accounted for in the sample preservation program. Figure 12 shows a shale sample that has air slaked under laboratory climate conditions.

Figure 12. Air-slaked shale

Where materials may slake, select samples should be preserved using a layer of plastic wrap, overlain by aluminum foil and then a paraffin wax. Index cards with the sample interval (drill hole, depth, an orientation arrow) can be included in the wax layer such that the specimen is clearly labeled. A similar waxing procedure should be used for weak zones or other discontinuities to preserve the shear surface and in situ water content. Figure 13 shows waxed samples shipped to the lab in a plastic box.

Figure 13. Waxed samples shipped to the laboratory in a plastic box

While rocks like granite may be less sensitive to curatorial care, it is still not unusual to hit zones that have been weathered to the point of being very fragile.

Shipping Containers

The preferred storage container for rock samples is wooden core boxes (see the Reclamation Geology Manual [3] for more information). However, there are steel core boxes (Figure 2) that are currently cost effective, depending on steel and wood prices, that might be preferred if termites or other environmental issues could be detrimental to the wooden core boxes. Corrugated or plastic-coated cardboard boxes, while much cheaper, are not acceptable if they do not meet the needs of the exploration and testing program. Any cost savings from the boxes will be exponentially offset by any loss of critical samples needed for the investigation. The content of the core boxes must be marked on the end and top of the core boxes as shown in the Reclamation Geology Manual. This facilitates locating and handling of the core boxes when they are stacked and on pallets.

The dimensions of the core boxes will depend on many factors. The length of the core boxes will depend on such things as core barrel length and any need to minimize core breaks needed to fit the sample in the boxes, the size of the pallet for shipping, and any confined spaces where the boxes need to be handled. The number of sample channels is primarily determined by the total weight to be handled. Hinges and hooks are shown in the Reclamation Geology Manual, however while functional in some ways, they are a hindrance and are therefore not recommended. Screws are preferred for assembling the boxes. The lids should be screwed down on the box when filled and logging completed. This will minimize any sample loss due to any accidental dropping, such as during handling at the drill site.

The box design needs to be such that the samples do not support any weight that bears from stacking the sample boxes, for example the dividers contact the lid and not the sample. This is especially important if the samples, and in particular the samples that will be tested, are weak, which is another draw back in the corrugated box design because the samples are required to withstand the weight and any gyrations of boxes stacked on top. This can and does damage samples by splitting and crushing forces. Furthermore, any savings in using the corrugated boxes is diminished by the increase in storage costs at the Denver Laboratories since the storage costs are per box and they cannot be stack up as high to reduce storage costs too.

The width and height of the sample channels also must be planned so there is no excessive side motion to damage the sample during shipping, or not so tight that the sample is damaged while removing them from the box. Sample channels should be rigid, firmly attached along the entire length, and higher than the samples to help support the lid if necessary (Figure 14).

Figure 14. Close-up of a core box

Also, box dimensions will need to include provisions for any additional sample protection used (such as wax coatings or plastic half rounds) which change the diameter. Core box spacers for the end of core runs, core loss zones, filling unused space, and where samples were removed in the core boxes can be made of wood or foam. Long lengths of durable foam, precut to fit the width and height of the sample channel in the core boxes, can be stored at the drill site and easily cut to length with a pocket knife, or saw, to fill in the entire space required.

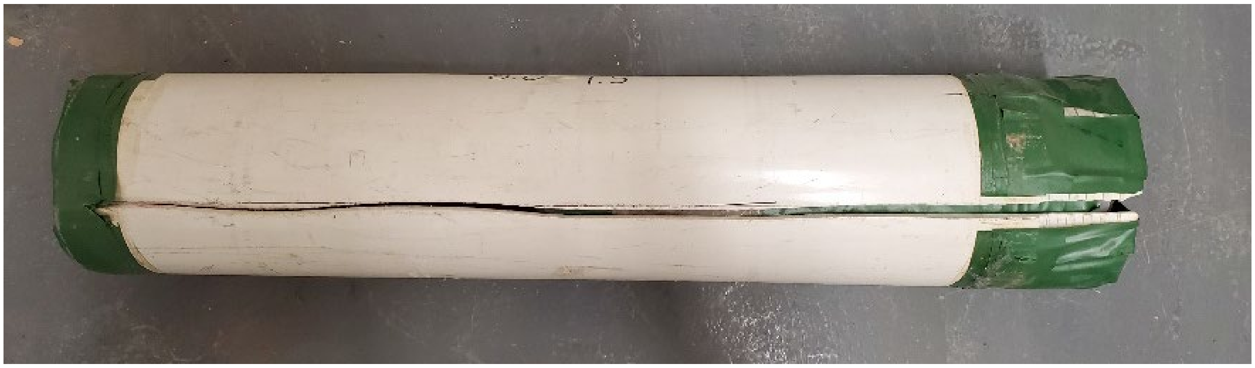

Figure 15. Plastic half-round containing core

Half rounds can be constructed by splitting plastic tubing longitudinally and cut to the correct sample length (Figure 15). Use of plastic half rounds minimizes sample disturbance when removing the core from the core barrel (See basic method in Reclamation Geology Manual). Any excess space at the end of the tube can be filled to prevent axial spreading of the sample during handling, especially when there are weak discontinuities. The plastic tubing comes in various materials diameters, and wall thicknesses. Therefore, tubing can be obtained that, when split, will fit the core within acceptable tolerances. The width of the cut should not be overlooked when determining the type of tubing to order. Also, unless the cuts are perfect, the matching half rounds should be kept paired to assure proper fit. Clear plastic half rounds and end caps for cores are also available from the TSC laboratory. A list of alternative sources can be provided, if needed.

Clear plastic half rounds coupled with good quality specimen photos should be used for sensitive materials to reduce the potential for handling disturbance. Opaque plastic half rounds are acceptable too, but extensive photographs are required. Photos should be taken of the sample in the split tube when the first half is taken off and then a second photograph taken of the other side of the sample after the sample is transferred to the first half of the plastic split tubing. Similarly, for non-split tube samplers the photo should be taken when it first removed from the barrel and in a half round and, if possible, a picture of the other side taken as well.

While the plastic half rounds are very good for protecting the specimens, a layer of clear, thin plastic still needs to be placed around the core samples. This is especially important for clayey materials that may adhere to the inside of the plastic half round and lead to serious damage to the specimen when the half round is removed later for specimen prepping. Note the method shown in the Reclamation Geology Manual of only protecting a soft zone in plastic does not prevent losing moisture out the ends of the sample and should not be used. Furthermore, it is very important that only a single layer of plastic be used with a slight overlap. This is easily accomplished with a tube sample barrel, as shown in the Reclamation Geology Manual, and having the plastic sheeting precut. Other sample tubes can still be used, and the sample protected if the core is slid out of the tube onto a plastic half round that already has a sheet of plastic laying in it. It is important to keep the entire sample in compression as much as possible to keep any weak zones from falling apart. The objective of either method is come up with steps that minimize the disturbance of the core. Wrapping multiple layers of plastic around the sample may not be desired if it results in extra effort to remove which results in specimen damage. Furthermore, any core boxes where plastic half rounds are used must have allowances for the thickness of the plastic half rounds and/or end caps.

Major preservation effort of only selected geologic features and/or materials, and not the rest of the samples, may be done if agreed upon by the FER team. These can be left in the main core boxes or removed and placed in separate core boxes to simplify boxing of the samples. As mentioned in the references, any removal of select samples should be clearly marked in the boxes with a spacer the same length of the sample and all necessary information on what, when, why, and where on the core sample alternate location. It is preferred that all samples be sent back to the laboratory for viewing.

With regards to rock cores, other handling techniques may be needed if there are thick lithologic layers, or discontinuity infilling that are fragile or more soil like. This is especially important if any of those geologic zones might be tested. Reclamation's Earth and Geology Manual and ASTM Standard D4220 [7] are good references for soil like materials.

Transportation

For concrete and rock samples extracted from Reclamation projects, it is preferred that they remain in the custody of Reclamation staff during transit. The best practice is for samples to go directly from the exploration site to the testing laboratory to minimize sample handling and delegate the responsibility of the samples to one person [8]. If drill crew, CSL, or GFSL staff are available to drive the samples from the project to the testing laboratory, that is preferred. If the decision is made to ship samples using a common carrier or commercial freight, the risk of loss or damage of priceless samples is often too great. However, for a very large program this may be unavoidable.

Figure 16. Large diameter concrete core boxes secured to a trailer (note straps being added closest to cab)

When determining factors involved in the transportation of concrete or rock cores, it is important to consider the following:

- Diameter of core
- Length of individual sections
- Total length of core to transport

These considerations will control the selection of an appropriate vehicle and the proper equipment. If the quantity of material is a high enough, a semi and trailer may be an option (Figure 16). Core boxes need to be handled, transported, and stored in the field and any interim storage in a manner agreeable with the weather and materials being collected. While the core boxes discussed above are intentionally protective of the samples, any transport of the boxes from the drill site may also require that the boxes be tied down in the vehicle. This is especially true if, for example, the transport of the boxes from the drill site involves a rough and/or unpaved road.

It is very important to have ample padding for the samples. During transportation, the samples can shift if the walls of the container are not rigid. This can be prevented by securing the interior and exterior walls of the shipping container and providing additional padding when needed. Boxes shall be placed on a 1-inch thick dense Styrofoam (or similar material) mat when stacked or placed on truck beds to prevent excess vibration or shock to the samples. Additionally, it can never hurt to be especially cautious in all aspects of concrete and rock core transportation, as accidents can occur. If an accident does occur, loss can be minimized by properly securing the cargo (Figure 17).

Figure 17. Straps properly securing boxes during transportation

Boxes seen in Figure 2 and Figure 9 were transported back to the CSL in Denver via standard heavy duty pickup truck and trailer. Due to the weight of the samples, a vehicle with the proper payload and towing capacity was required. Trailer capacities are also important to consider. All vehicles and trailers should be inspected periodically during the trip for ensure they are working properly. If the boxes are stored in a location where shifting is possible, ratchet straps (or equivalent) will be necessary. Do not use duct tape. It is not strong enough to prevent boxes from shifting (Figure 18).

Figure 18. Duct tape used to "strap" sample containers enables shifting

If available, a truck with a topper or the use of an enclosed trailer will protect the samples from potential changes in moisture caused by a high rate of flowing air, exposure to precipitation during transport, or freezing. For maximum winter protection, a box truck may be utilized (Figure 19).

Figure 19. Core boxes secured in enclosed trailer for winter transport (note cross bracing)

To the extent possible, pick-up trucks with an open or flatbed carrying heavy samples should be equipped with a headache rack or cab guard to protect the passengers in the cab from cargo in the bed. Passenger vehicles are not recommended for transporting concrete or rock samples. Samples can become projectiles in a crash and can seriously or fatally injure the vehicle occupants.

Handling in the Laboratory

The goal of the sample preservation and shipping program should be to get the samples back to the laboratory in a condition representative of their in situ condition for layout, as shown in Figure 20.

Figure 20. Rock core box layout in Denver Laboratory

Figure 21. Concrete core box layout in Denver Laboratory

When boxes of core arrive to the CSL or GLFS, they are laid out for examination and sample selection, cut to size and tested for a number of desired properties (Figure 21). Once received in the laboratory and unboxed, samples will need to be cared for to preserve moisture and move about the laboratory as they are saw cut, capped, strain gaged and tested. All of these steps will require attention to detail to ensure the safety of the samples and the staff performing the sample preparation and testing. Note that some large diameter samples can weigh hundreds of pounds each (one 18-inch core after it has been cut to a length of 36-inches weighs around 800 lbs).

Rock core generally can be left in the core boxes and displayed on sawhorses or tables to allow for ergonomically viewing at a good working height.

Small diameter (6-inch or less) concrete cores are removed from the containers and placed on wetted terry cloth, which is laid out on wooden (half-moon shaped) core supports that prevent the core from rolling, supported by foldable sawhorses (Figure 22). The wetted terry cloth is then wrapped around the core and covered with a large sheet of plastic. Staff will document the as-received condition of samples and select samples for appropriate tests based on visual observations, also photographing the dampened sections of core on all sides (Figure 23). If not being tested or prepared for testing, cores are to be properly covered and kept in a location where the relative humidity is 50%, to avoid moisture loss. Larger diameter core is generally handled in the same manner, except that is kept on the floor and refrained from rolling using wedges. It is not advisable to place larger diameter core on tables or sawhorses because of the danger to staff if they should fall.

Figure 22. Laboratory storage of cores received from the field

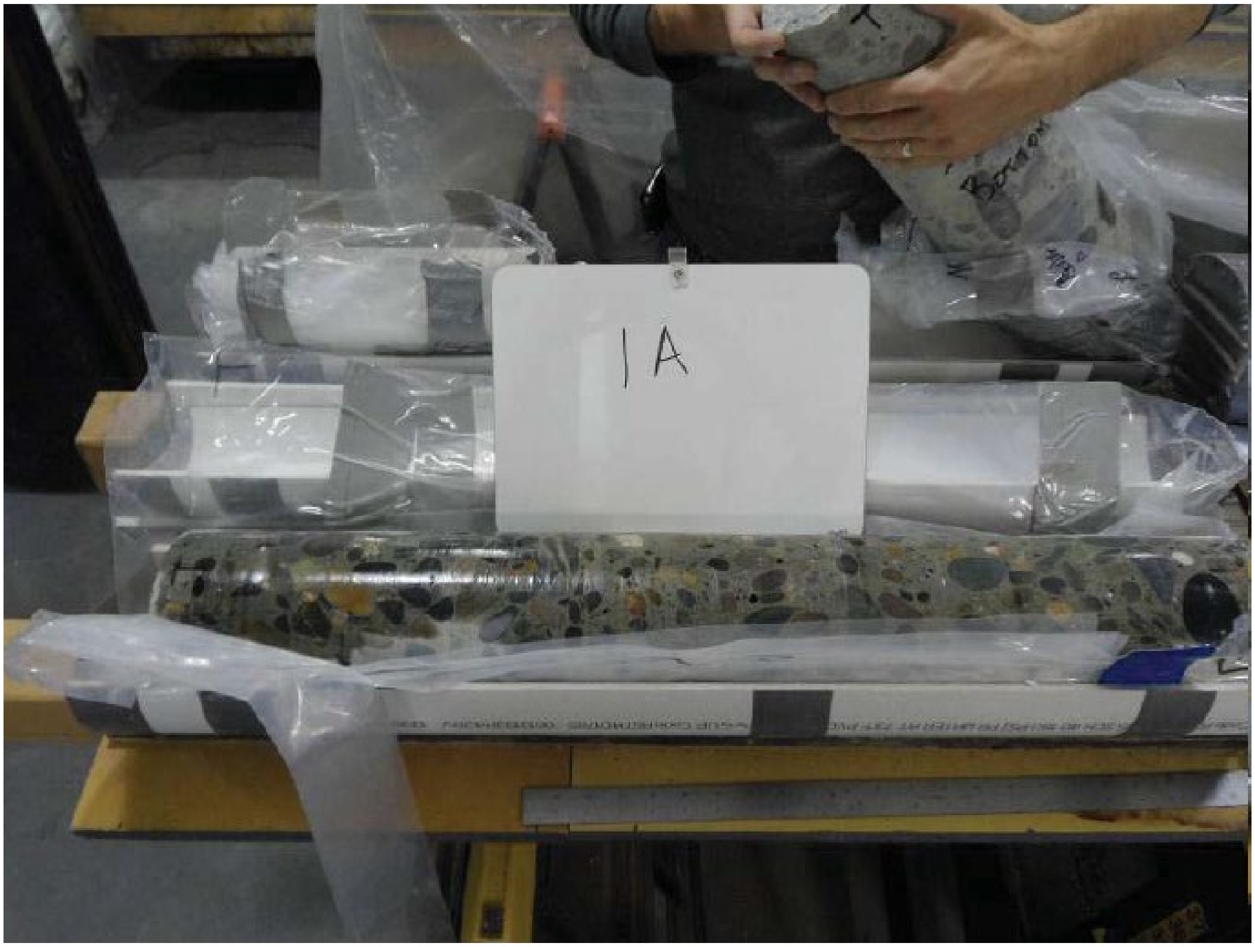

Figure 23. Laboratory storage and documentation of cores received from the field

There are many different methods of moving samples throughout the laboratory, depending on the task or test. In most scenarios, samples can be hand-carried about the, lab but a forklift is required for large-diameter concrete samples. Figure 24 shows an 18-inch concrete sample being placed on a fresh bed of hydrostone to create a level, consistent test surface. Figure 25 shows a forklift clamping attachment used to transport test specimens. Because of the different tasks and the fact that samples can vary in diameter and shape, there are numerous clamping attachments available to fit the need (Figure 26). When saw-cutting large diameter samples, it is necessary to lay the core down. This requires rolling the specimen with extreme caution. Blocks and other restraints should always be used (Figure 27).

For additional technical details on concrete or rock curatorial requirements please contact the TSC's Concrete and Structural Laboratory or Geotechnical Laboratory and Field Services Group.

Figure 24. Placing an 18- inch diameter core under the 5-million-pound press for compression testing

Figure 25. Core clamp with forklift attachment, used for transporting large diameter samples

Figure 26. Core grabber with two chains and chain vise grip clamps for forklift

Figure 27. Rolling core horizontally to a pallet with forklift and wedges

References

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