Procedures for Setting a CORS Monument

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[*See* attached .pdf file *for the complete document with figures.*]

This document was prepared to assist in constructing a CORS monument according to the recommendations developed by the National Geodetic Survey (NGS). The instructions and drawings depict the establishment of a monument meeting all of the recommended conditions. Adaptation of the recommendations will certainly occur. Contact NGS for assistance and instruction in situations differing from those described herein.

Once a suitable site has been selected, preparations for the construction and setting of the CORS monument can begin. First, acquire and gather together a variety of materials that will be needed to build the monument. Second, locate and make scheduling arrangements with companies to machine components of the antenna mount, check for underground cables at the site, auger the lower pier hole and deliver the concrete. Third, assemble monument components and setting aids prior to pouring the concrete.

Materials

Materials needed for Antenna Mount:

1 - 6-1/2 inch diameter by 1 inch thick Delrin plate
3 - 1 inch diameter by 12 inches long Delrin rods
1 - Off the shelf tribrach adapter
3 - Stainless steel bolts 5/16 in. x 1-1/2 in. x 18 tribrach attachment studs
Make arrangements for machining work of Delrin materials.
A detailed description of the Antenna Mount construction follows.

Materials needed for C-Bar Reinforcement Assembly:

4 - 5/8 inch diameter by 8 ft. long C-Bar rods
1 - 5-1/2 inch inside diameter by 1-2 feet long piece of PVC pipe
32 - Plastic Cable Ties to construct C-Bar reinforcement assembly
A detailed description of the C-Bar assembly construction follows.

Materials and tools needed for setting monument:

1 - Assembled Antenna Mount
1 - Assembled C-Bar Reinforcement Assembly

1 - 12 inch diameter by 5 foot tall Sonotube form
8 - 8 foot long 2 x 4 lumber
6 - 1-2 ft long 1 inch x 1 inch wooden stakes
1 - Box of 3 inch dry wall screws
1 - Box of 1 inch dry wall screws
Saws, hammer, cordless drill, trowels, one or two 3 ft. step ladders, shovels and hoe.

Materials for finishing the monument after curing:

Hydraulic cement to seal joint between upper and lower piers
Concrete filler cement to fill any holes on surface of upper pier
White concrete sealer to paint monument.

Scheduling Services

Take the Antenna Mount materials and construction instructions to a machine shop. Be sure they can do the work and deliver the mount prior to setting the monument.

Contact a company, such as, “Miss Utilities”, to check the site for the location of underground cables, phone lines and water pipes prior to auguring hole.

Although it may be possible to auger the hole and pour the concrete in the same day, it is probably better to schedule the auguring on one day and pouring the concrete the next day or later. Contact a company to auger monument hole and schedule time of work. Types of companies that may have an 18 to 24 inch auger are electric power companies, state departments of transportation, well drillers, and highway engineering construction companies.

Contact a concrete delivery company and order cement type Portland A3, air entrained, with an aggregate size of 3/4 to 1½ inches and schedule delivery. Explain to the concrete company that your are setting a stepped tiered pier and want to pour the entire upper and lower piers in one pouring. The slump of the concrete should be for a dry mix so that the concrete will not leak out from under the upper pier form when poured. Be sure to carefully compute or have concrete company compute the amount of concrete you will need. Get an extra ½ - 1 yard to be sure you will have enough to finish the monument in one pouring.

Make arrangements to pickup, from an equipment rental company, a concrete vibrator to settle concrete when pouring. Be sure that this item will be available at the same time as the concrete delivery.

CONSTRUCTION OF THE RECOMMENDED CORS ANTENNA MOUNT

Recommended Antenna Mount

A custom-made antenna mount consisting of a tribrach adapter mounted on a Delrin base. The antenna mount base, which must be custom-machined, consists of three notched Delrin legs (recommended dimensions are 1 in (2.54 cm) diameter and 12 in (0.3 m) long) that are threaded into the underside of a circular Delrin platform (recommended dimensions are 6 in (0.15 m) diameter and 1 in (2.54 cm) thick). To allow for the antenna attachment, and its orientation to north, a standard, commercially-available tribrach adapter is attached to the Delrin platform. To attach the tribrach adapter to the platform, the standard tribrach studs (feet) are replaced with threaded studs that are screwed into the top of the Delrin platform. The tribrach adapter is secured to the studs with set screws. A locking screw secures the tribrach adapter plug once the antenna is oriented to true north.

Construction of the recommended antenna mount should be easily accomplished by any experienced machinist. The following drawings were made to identify the various components of the antenna mount and to describe the measurements, modifications and machining made to each component before assembly.

The antenna mount consists of four major components: tribrach adapter, tribrach adapter mounting studs, Delrin plate or platform, and the Delrin legs.

1. Tribrach Adapter

The tribrach adapter component is a standard adapter used in surveying to attach targets and GPS antennas to the top of tripods. It is precision made to clamp into a standard tribrach which is used for centering and leveling the target or antenna. The location of the feet or studs to which the adapter clamps into the tribrach have been standardized to allow the use of the adapter with tribrachs of various manufacturers. Construction of the antenna mount requires the precise location of three mounting studs in the top of the Delrin plate in order to attach the tribrach adapter. No modification, other than the removal of the standard feet, of the tribrach adapter is required. If the studs a located correctly, the holes in the bottom of the adapter should fit snugly over them. The set screws that held the original feet can now be tightened to secure the adapter to the studs.

2. Tribrach Adapter Mounting Studs

The tribrach adapter mounting studs consist of modified stainless steel bolts that are threaded into tapped holes in the top of the Delrin plate. The bolts required are 1-1/2 inch long by 5/16 inch diameter with 18 threads per inch. Modifications required are the removal of the bolt heads, machining a notch for the set screw, and cutting a screw driver slot in the top. The studs must be precisely positioned on the top side of the Delrin plate to exactly fit into the holes in the bottom of the tribrach adapter.

3. Delrin Plate or Platform

The Delrin plate is a 6 inch diameter by 1 inch thick plate or disk used to provide support for and an attachment point for the tribrach adapter and connect solidly to the top of the upper concrete pier. The Delrin comes in a variety of shapes, sizes and thickness. The Delrin used for the support plate is constructed from a piece of flat 1-inch thick material rough-cut into a disk about 6-1/2 inches in diameter. The initial modification is to smooth the rough-cut edge in a lathe to about a 6-inch diameter. This dimension does not need to be an exact 6 inches, but should be clean enough to allow measurement of the location points for the tribrach adapter mounting studs on the top of the plate. A good machinist should know how best to do these measurements. Location of the mounting points of the legs on the bottom of the plate is not as critical as the studs, but they should be located at a distance from the edge of the plate sufficient to obtain the greatest strength of the threaded joint. Although the drawings recommend using 3/4 in. x 10 threads to attach the legs, ½ in. x 13 in. could also be used.

4. Delrin Legs

The three antenna mount legs provide the attachment points of the mount to the top of the upper concrete pier. They are constructed from 1-inch diameter by 1-foot long Delrin rods. The top of the legs are turned to a diameter that allows 3/4 inch diameter by 10 threads per inch threads to be die-cut to a length of a 7/8 inch. Complementary holes are drilled and tapped on the bottom of the Delrin plate. At the other end of each leg, a 1- inch tapered point is turned. The points make it easier to push the antenna mount into the wet concrete. Finally, three 1-inch notches are cut to a depth of 1/8 inch or a diameter of 3/4 inch. The notches provide places for the concrete to grip and hold the antenna mount in place.

Availability of Materials

Availability of the materials for the antenna mount should be quite good. The tribrach adapter is an off-the-shelf surveying item and is sold by about all surveying supply companies and original manufacturers. The stainless steel mounting stud bolts should be readily available from a variety of supply houses. The Delrin acetal resin material used for the antenna mounting plate and legs can be obtained from any good plastic products company and comes in a variety of shapes and sizes.

Construction of the Antenna Mount

Order all of the materials needed for the antenna mount. For one antenna mount you should have the following:

1 - Tribrach Adapter
1 - Delrin plate rough-cut to a diameter 6-1/2 inches
3 - Stainless steel bolts, 1-1/2 in. x 5/16 in. x 18
3 - Delrin rods, 5/8 inch diameter x 12 inches long

Take all these materials and this document to a machine shop. Hopefully, the machinist will be able to tell you if he can do the work and give you a cost estimate for the construction based on this information.

Remember, the goals of the recommended antenna mount design were to minimize the amount of metal near the antenna and fix the antenna to the upper pier without creating any resonance cavities beneath the antenna.

Antenna Mount Drawings

The first drawing is an overview of the antenna mount depicting each of the components, the required modifications to them, and an exploded view of the antenna mount showing each component. It is followed by a one page drawing showing the Tribrach Adapter in great detail. Next is a one page drawing showing construction of the tribrach attachment studs. The next two pages (Delrin Plate - Part 1 and Delrin Plate - Part 2) depict the modifications to the Delrin plate. The last drawing shows the modifications to the Delrin rods needed to create the antenna mount legs.

CONSTRUCTION OF THE C-BAR REINFORCEMENT ASSEMBLY

Materials required for one C-Bar reinforcement assembly:

- 4 - 5/8 inch diameter by 8 foot long C-Bar rods
- 4 - 5-1/2 inch inside diameter by ½ inch width PVC rings
- 32 - Plastic Cable Ties (medium duty 3/8 inch wide and 14-1/2 inches long)

WARNING: ALWAYS WEAR GLOVES WHEN HANDLING C-BAR RODS. FIBERS WILL PENETRATE SKIN!

Construction of the C-Bar reinforcement assembly is very straight forward. The only component requiring some prior work is the PVC rings. If a power hack saw is available, it will make short work of this. Take about a two foot long piece of 5-1/2 inch inside diameter PVC pipe and from one end make marks at ½ inch intervals. Place the PVC in the power hack saw and at each mark cut a half inch width ring. You will need four rings for each reinforcement assembly. The following drawing "COMPONENTS AND CONSTRUCTION OF C-BAR REINFORCEMENT ASSEMBLY" depicts and describes the construction of the reinforcement assembly.

NOTE: If CORS monument setting requires that a shallow lower pier is set due to hitting bedrock, it may be necessary to shorten the length of the C-Bar rods. The C-Bar rods can be cut, but it is necessary to SEAL the ENDS where they are cut. If this is the case, order some sealing material from the C-Bar company. It is called EPDM Rubber Spray Coating.

PREPARING SONOTUBE FORM AND SUPPORT BRACES

NOTE: The step numbers stated in the following text refer to the step numbers depicted in the drawings interspersed in the text.

Materials List

1 - 12 inch diameter by 5 foot Sonotube form
1 - Short piece of Sonotube, a foot or less tall
10 - 8 foot two by fours (2x4)
6 - 1-1/2 foot by 2x2 or 1x2 inch stakes
Box - 3-1/2 inch dry wall screws
Box - 1 inch dry wall screws

Tools

1 - Cordless Drill
1 - Hand saw or table saw
1 - Tape measure
1 - Square
1 - Protractor

The following Steps, 1 - 5, can be done prior to going to the monument site.

STEP 1 - Measure and cut Sonotube form to a length of 5 ft. keeping the ends as square as possible. Sonotube usually comes in 12 foot lengths. If this is the case, cut it into two 6 foot pieces, then cut each piece to the needed 5 foot length. Use a carpenters square or a tape measure to mark where the cut off line will be on the form. The will keep the ends square. Keep one of the short pieces cut off. This will be used when pouring the concrete to make a indentation in the wet cement for positioning the Sonotube form for the upper pier.

STEP 2 - Cut 6 pieces of 2x4 to a length of about 30 inches. On one end of each of the 30 inch pieces, cut the end to an angle of 60 degrees along the narrow dimension.

STEP 3 - Set the Sonotube upright on a flat surface. Place 3 of the 30 in. pieces around the Sonotube form with the narrow width down. Butt the angled ends against the inside of the adjacent pieces. Adjust the pieces so that the inside surface touch the Sonotube and the angled ends are still in contact with its adjacent piece. The none angled ends of the pieces should project beyond the point where the angled end makes contact.

Starting at one of the intersections where the angled end meets the inside of it adjacent piece, drill two pilot holes from the outside piece into the adjacent angled end and then connect using two 3-1/2 inch drywall screws. Move to the next intersection and while keeping the pieces snug against the side of the Sonotube form, again drill two pilot holes and secure the pieces with two 3-1/2 in. drywall screws. Do the same for the last intersection, while holding the pieces tight against the Sonotube. All 3 of the pieces should now be connected and snug against the Sonotube.

If the CORS monument is being set on flat terrain, then move the assemble bracket up the Sonotube so that about an inch of the Sonotube projects below the bottom edge of the three sides of the bracket.

Without moving the bracket, lay the Sonotube on its side so that access can be made to the inside of the tube. From inside the Sonotube, at the point where the inside of the bracket pieces touch the Sonotube, secure the Sonotube to each piece using one or two of the 1 inch drywall screws. This will be the upper support bracket.

STEP 4 - Stand the Sonotube upright again with the just attached bracket at the top and repeat the assembly described in Step 3 above for the bracket at the bottom. This will be the lower support bracket.

STEP 5 - Cut 3 pieces of 2x4 to a length of about two feet. These pieces will be called the lower adjusting brackets. With the Sonotube sitting in an upright position, overlap the end of one of the adjusting brackets on the outside of and about 4 or 5 inches from the extended end of one of the corners of the lower support bracket. At about the middle of the overlap section, drill a pilot hole and drive a single 3-1/2 in. drywall screw just tight enough to allow the adjusting bracket to pivot. Do the same for the other 2 corners of the lower support bracket. The adjusting brackets provide the means to plumb and raise or lower the sonotube form at the CORS monument site.

AUGURING THE HOLE AND POURING THE CONCRETE

The following Steps, 6 - 29, are done at the monument setting site.

STEP 6 - Auger the hole for the lower pier. Measure the depth of the hole as the digging progresses. Don't drill it more than 10 feet or more concrete will be required. After the hole is done, remeasure its depth and diameter and compute the volume to determine if more concrete will be needed. If so, advise the concrete company.

STEP 7 - After the hole is augured, clear away the dirt left around It. Be careful not to let any dirt fall back into the hole.

STEP 8 - Begin pouring concrete. Every two feet of pour, insert the vibrator to settle the concrete and remove air bubbles. Don't leave the vibrator in the concrete very long or it will cause the aggregate to settle and the water to separate (15 to 30 seconds at time).

STEP 9 - Continue pouring and vibrating. Measure the level of the concrete below the surface of the ground. When the height below the ground reaches 4 feet or a little more, stop pouring. Place the C-Bar Reinforcement Rod Assembly into the hole and center it as close as possible. Measure the height of the top of the C-bar Assembly above the ground. It should be 4 feet or less. Anywhere from 3 feet 5 inches to 3 feet 10 inches will be good. If necessary, move the assembly up or down in the concrete. Be sure to keep it centered. Use two people to hold the assembly.

STEP 10 - Continue pouring and vibrating the concrete. Use a 2 to 3 foot carpenters level to check the plumb of the C-Bar Assembly. It is important to keep the assembly as plumb as possible so it will stay centered in the upper pier when it is poured. Do not allow the concrete to push the assemble sideways.

STEP 11 - Continue pouring and vibrating the concrete and keeping the C-Bar Assembly in position until the concrete is at the surface of the ground. Check the plumb and the height above the ground of

the C-Bar Assembly. The assembly should be still centered, plumb and 3 ½ to 4 feet above the ground.

STEP 12 - Place the short piece of 12 inch Sonotube over the C-Bar Assembly and gently set it on the top of the wet concrete. Center the C-Bar Assembly in the center of the Sonotube circle by moving the Sonotube around. Once centered, press the Sonotube into the wet cement enough to leave a visible indentation. Remove the short piece of Sonotube.

STEP 13 - Carefully lift the 5 foot Sonotube form with brackets up and over the C-Bar Assembly. Set it down so that the bottom perimeter of the form sets into the indentation made in Step 12 and the bottom support bracket and adjusting brackets support it by sitting on the ground surface. Using a step ladder, look down into the form to determine if the C-Bar Assembly is reasonably centered.

STEP 14 - At about the middle of each of the adjusting brackets, drive a support stake solidly into the ground.

STEP 15 - Use one or two 2-3 foot carpenters levels to plumb the Sonotube form. Use a step ladder to look down into the form and see that the C-Bar Assembly is still centered in the form. Adjust the form if necessary. The bottom of the form should be just touching or slightly imbedded into the wet concrete of the base pier. If the form is at the correct height, plumb and the C-Bar centered, drive a 3 ½ inch drywall screw near the one where the adjusting bracket pivots to fix the bracket in place. Do this at all three adjusting brackets. Check the plumb and centering again. If all is ok, then drive two 3 ½ inch drywall screws through each of the adjusting brackets and into each of the support stakes. The form should now stay securely in place.

STEP 16 - Place the end of an 8 foot 2x4 at each of the extended ends of the upper support bracket and attach by driving a 3 ½ inch drywall screw. The other ends of the 8 foot 2x4s can just sit on the ground. Near the ends of each of the 8 foot 2x4s touching the ground drive a support stake.

STEP 17 - Check the plumb and centering of the Sonotube form again. If all is good, drive a second 3 ½ inch drywall screw near the ones in the extended ends of the upper support bracket. Next, drive two 3 ½ inch drywall screws through the 8 foot 2x4s and into the just driven support stakes. The Sonotube form should now be plumb, fixed very rigidly in place and ready for the rest of the concrete to be poured.

STEP 18 - To pour the concrete into the Sonotube form, get a couple of short step ladders or boxes high enough to allow viewing down into the form. Slowly shovel or hoe the wet concrete into the form. Make sure the C-Bar Reinforcement Assembly stays centered. The concrete may tend to push it to one side. After pouring a foot or so, tamp the concrete with a stick to settle it in around the C-Bar assembly. **!!! WARNING !!! BY NO MEANS USE THE VIBRATOR TO SETTLE THE CONCRETE IN THE SONOTUBE FORM AS IT COULD POSSIBLE EXPLODE THE FORM.**

STEP 19 - Continue pouring and tamping the concrete and keeping the C-Bar assembly centered.

STEP 20 - Continue pouring and tamping the concrete until the Sonotube form is full to the top. Use a trowel to clean up and smooth the wet concrete. The pier is now ready for the installation of the antenna mount.

STEP 21 - Attaching Antenna Mount to Upper Pier - Place the antenna mount as close to the center of the top of pier as possible and press the legs into the wet cement. Wiggle the mount to work it in until the bottom of the Delrin plate touches the cement (See Drawing - Step 21 Figures A, B, C). Use a small stick to tamp the cement around the legs. Once the mount is at the surface of the cement, use a stick or hand of a trowel to gently tap the top of the Delrin plate to remove air bubbles from beneath it and settle it into the wet cement. Keep tapping around the plate until it is imbedded no more than ½ inch (See Drawing - Step 21 D).

STEP 22 - Leveling the Antenna Mount - It is important the antenna mount be leveled before the concrete cures. Remove the adapter plug (See Drawing - Step 22 A) and place a carpenters level across the center of the tribrach adapter (See Drawing - Step 22 B). While observing the bubble on the level, rotate the level 30 degrees or so (See Drawing - Step 22 C) to determine in what direction the tribrach adapter is misleveled. With the level sitting on the tribrach adapter, gently tap the top of the Delrin plate (See Drawing - Step 22 D) with the handle of the trowel until the level bubble is centered. Rotate the level around again to be sure the tribrach adapter is level in all directions (See Drawing - Step 22 F).

STEP 23 - Use the trowel to smooth the top of the wet concrete. If possible, try to slope the concrete to the outer edge of the pier so that water will run off and away from the adapter. Be very careful not to disturb the antenna mount. When done smoothing, check the level of the tribrach adapter again to be sure it was not moved.

STEP 24 - Marking True North Direction - Carefully set a compass on the tribrach adapter and orient it to true north allowing for local declination. Make a arrow in the wet concrete or stick a small bolt in the concrete to mark the direction to true north.

STEP 25 - Place a plastic bag over the top of the upper pier and tape it to the Sonotube form. This will protect the wet concrete from rain and birds, etc. while the concrete is curing. Be very careful not to disturb the antenna mount and move it out of level. This completes the initial setting of the recommended CORS monument. The following steps are to be done after the concrete has cured for 3 to 7 days.

STEP 26 - After a period of 3 to 7 days, remove the Sonotube form from the upper pier. The form is designed to peel in spiral. It has a spiral tear line along which it can be torn. Start at the top where the spiral groove begins and start pulling the form away from the concrete. The ease with which the form comes off seems to depend on whether the form got wet during the curing time. It may come of easy in some place and stick in others.

STEP 27 - After the concrete has cured a while, observe the line where the concrete meets the antenna mount Delrin base plate. If any separation should occur, seal the joint with RTV silicone to prevent any water from getting in. The prototype CORS monument set at the NGS Instrument and Methodologies Branch in Corbin, VA. showed no sign of separation after more than month of curing. So this may not be a problem, but is worth checking.

STEP 28 - After the concrete has cured for a week or two, seal the joint between the upper and lower piers with concrete hydraulic cement. This will prevent any water from penetrating, freezing and possibly cracking the monument.

STEP 29 - After the concrete has cured for a couple of weeks or more, patch any holes left on the surface of the upper pier with patching cement and paint the monument with a good quality concrete sealing paint. Use a white color which may reflect radiant heat and help stabilize the thermal expansion.

This completes the establishment of the NGS recommended CORS monument. Attaching the GPS antenna and running the cables to the receiver are not addressed in this guide.

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