Cohoe Radio Observatory, Alaska ~ Part 2, Guyed Tower Foundation Construction

Whitham D. Reeve

1. Introduction

In Part 1, I described the radio frequency interference survey performed at Cohoe in summer 2012 [Reeve1]. In Part 2, I describe construction of the foundation for a 60 ft guyed lattice tower (see sidebars) during summer and fall 2013. CRO is located in a rural area about 1 km southwest of where the Kasilof River flows into Cook Inlet and about 125 km southwest of Anchorage (figure 1). Coordinates for the site are 60° 22' 4.93"N, 151° 18' 55.76"W and elevation is approximately 21 m above mean sea level (AMSL). The site is in a rural area.

Figure 1 ~ Aerial imagery of the Cohoe area from an altitude of 5000 m showing CRO in middle (yellow polygon). (Image courtesy of Google earth).

Guyed lattice tower ~ Steel cables (guys) and ground anchors hold a guyed lattice tower upright and respond to wind and ice loads. Guys in sets of three or four extend from the tower to the anchors some distance from the tower base. Guyed towers use much less steel and concrete than self-supporting towers but require much more space.

Units of measure ~ I seldom use non-metric units in my articles but this one is an exception. Metric units are not used in the materials and tools associated with tower construction in the USA at this time. Trade sizes are given in inches (in), feet (ft), pounds (lb), cubic feet (cu ft) and cubic yards (cu yd). Writing with both non-metric and metric units soon becomes quite awkward. To help readers familiar only with metric units, I have provided a conversion table at the end of this article and a link to an online units coverter.

2. Layout

The tower uses a concrete base and three anchors. The location of the base was selected in summer 2012 in the approximate center of an existing clearing near the middle of the property. I determined the anchor locations with reference to the base using a builder's level for the angles and a surveying tape for the distances (figure 2).

Figure 2 ~ Tower layout was done with a builder's level and surveyor's tape while working alone on a nice summer day.

To provide a permanent reference to true north for antenna alignment, I used a latitude-compensated compass to place one anchor directly south of the base. The other anchors were located at 120° intervals (figure 3). Reference stakes were placed to mark the back of the anchor and additional stakes were placed to establish excavation limits. To double-check the stake locations I measured the direct distance between them and found the errors to be less than 4 in, quite adequate for this type of work.

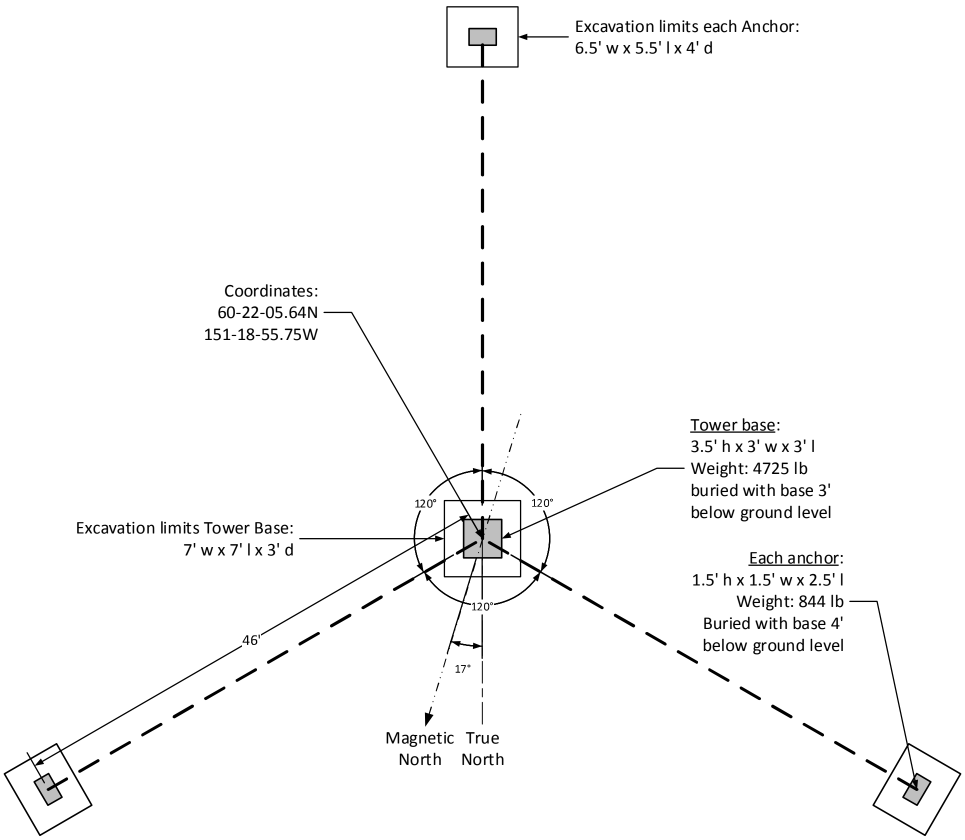

Figure 3 ~ Plan view of anchor and base drawn to scale. One anchor is placed in line with the base and true north azimuth to enable easy antenna alignment. All dimensions are according to specifications provided by the tower manufacturer.

3. Excavation

The tower manufacturer's drawings specified 48 in depth from ground level to the bottom of the anchors and 36 in for the base. It would have been possible to hand-dig all four holes but I chose to hire an excavator (figure 4). This made it easy to oversize the holes for working space. The digging required about 2 h from the time the excavator arrived and was unloaded from the trailer until it was reloaded and ready to leave. The charges for this work included 1 h mobilization and travel time in each direction from and back to the operator's office in the city of Sterling about 30 mi away.

The soils are typical for the area – approximately 6 in of peat, 12 to 18 in of red clay, and hard-pan sand and gravel below the clay to an unknown depth (most likely at least 20 ft). The rocks found in the gravel layer mostly were pebble size, and the gravel layer was very difficult to dig with a hand-shovel (validating my decision to hire an excavator). The excavator easily moved tree stumps and root masses out of the way, something that is very difficult and time consuming to do by hand.

4. Wood forms and reinforcing steel for concrete

In Anchorage, I prebuilt a set of wood forms for the base and anchors from dimensional lumber and plywood, and I obtained the reinforcing steel (rebar) cut to order from a local supplier (figure 5). It was much easier for me to transport and handle the prebuilt forms than the uncut wood. Each form consisted of four walls screwed together in the shape of an open box with no top or bottom. After hauling the forms to the site, I leveled the bottom of the holes and reassembled them at their exact location.

The rebar was tied to shape a cage and placed in each form. To ensure the rebar was surrounded by a minimum of 3 in concrete at the bottom of the forms, I used bricks that I cut into 3 in lengths to raise the cage height above the open floor of the forms. Setting and leveling the forms and tying the rebar cages required a couple days including 1/2 day travel each direction.

Figure 4 ~ Upper-left and -right: The excavator eliminated a lot of hard, back-breaking work. It was well equipped with a large bucket, claw on the bucket for grabbing and moving trees and roots and a blade at the front for scraping peat. I asked the operator to pile the different soils separately so I could later backfill with the same soil at depth. Lower-left and -right: Base and anchor locations ready for the concrete forms. The intact layout stakes seen in each corner attest to the operator's accurate digging skills. The three soil layers are clearly visible in these images, in order peat, clay, and gravel.

Figure 5 ~ Upper-left: The pre-built wood forms were easy to assemble in-place with screws to hold the four sides together. Upper-right: Reinforcing steel was cut to length by a supplier in Anchorage. Lower-left: The base form has been placed and leveled. The H-frame at top is a template that holds the tower base plate in position while the concrete cures; fixed wood blocks hold the H-frame in alignment. The reinforcing steel has not yet been placed. Lower-right: One of the anchor forms with the reinforcing steel in-place. The anchor rod projects up and out of the form to the left of the image. The lower end of the anchor rod has a hook to increase its pull-out resistance. The hole for each anchor is 4 ft deep.

5. Concrete pour

Having mixed a lot of concrete with a wheelbarrow, hoe and shovel when I was younger, my first choice was to have premixed concrete delivered to the site by ready-mix truck. However, the site is wooded and the surface soil too soft for such a truck. A concrete pump truck would have been too expensive considering the small amount of concrete to be poured, only 44 cu ft or 1.6 cu yd. Therefore, I decided to mix the concrete myself. I worked alone for about one-half of the concrete mixing and pouring. I knew this would require several days and figured it would be cheaper to buy a small cement mixer and then sell it afterward than rent a mixer for that time period. I purchased a 0.5 hp electric mixer for US$285 and then sold it a week after finishing the pour to an area resident for US$200. The mixer had a 5 cu ft drum and could safely hold about 2 cu ft of mix. Electricity is supplied to the site by a rural electric cooperative. I used heavy-duty extension cords and had no trouble with the mixer.

Figure 6 ~ A total of 118 out of 130 bags of concrete/aggregate mix, delivered on wood pallets, were used in the tower base and anchors.

I purchased 130 bags of bagged multi-purpose concrete mix (3/8 in aggregate), 60 lb each, from a lumber yard about 20 mi away. The bags were delivered on pallets (figure 6) for a charge of US$55. The delivery crew brought a crane-truck along with the flatbed truck and was able to place the pallets within about 125 ft of the tower base. I then used a small garden wheelbarrow I found on-site to move two bags at a time to each location.

Even with an electric cement mixer, concrete work is no afternoon duck hunt (figure 7). However, after the bags and water were dumped into the mixer drum, it was ready to pour in only a few minutes. I used an on-site water source and carefully measured the correct amount of water for each bag (2 qt), mixing 2 or 3 bags at a time for the anchors and 4 bags at a time for the base. I seldom had to adjust the water ratio.

Figure 7 ~ "The Glamor of Radio Astronomy" (caption provided by Richard Flagg). The author is shown working the concrete mix prior to pouring into the trough and from there into the base form. The mixer was remarkably stable even though it does not look that way on its tripod legs.

I used 17 bags in each anchor and 67 bags in the base, for a total of 118. Although the bagged concrete vendor's datasheet said each bag would mix approximately 0.5 cu. ft, I found it closer to 0.4 cu. ft. I had anticipated this and over-purchased by 25% (which turned out to be another good decision). I sold the remaining 12 bags for only a few dollars less than I paid for them to the same person who bought the mixer, so there was virtually no money or material wasted.

The anchors were too deep to use a trough (concrete chute) from the mixer to the forms, so I had to use a 5 gal bucket to transfer the mixed concrete (figure 8). I could put about 60 lb of mixed concrete in the bucket, so each anchor required 17 trips in and out of the hole. However, I was able to use a trough on the base pour, making that work much more efficient. My daughter helped me with the base, and we mixed and poured the 67 bags in one day. After the base form was filled, I placed and leveled the template I made for the tower base plate. When each location was completed, I covered it with a clear plastic sheet to prevent moisture loss while the concrete cured. The concrete was allowed to cure for 7 days and the wood forms were then removed, which required only a few minutes each (figure 9).

Figure 8 ~ Left: The cement mixer was placed at each anchor next to the hole, and a 5 gal bucket was used to transfer about 60 lb of mixed concrete at a time. After filling the bucket it was placed on the edge of the hole, lifted down into the hole and poured into the form. Right: At the base, I built a trough from pine boards and used it to guide the concrete from the mixer. This way, four bags could be mixed and poured in just a few minutes. The base form is shown about 2/3 full. The rods seen pocking up through the wet concrete were used to remove air-bubbles and left in-place when finished.

Figure 9 ~ Wood forms have been removed and holes are ready for backfill. Left: The base was poured with a 1 in chamfer around the top, something not seen on many small tower bases. This view also shows the tower base plate bolted in position. The base weighs about 4725 lb. Right: One of the anchors ready for burial. Each anchor weighs about 844 lb.

Figure 10 ~ Holes were backfilled using the native soil and the "Armstrong Method". The base is ready to accept the first tower section.

6. Backfill

The holes were backfilled by hand, the gravely/sandy mixture placed first followed by the clay (figure 10). No load was placed on the concrete for 2 weeks. In total we moved about 650 cu ft (24 cu yd) of backfill. Surprisingly, even with the volume of the concrete, the loose soil did not completely fill the holes, leaving about 4 to 6 in of open depth at the surface. These will be filled in summer 2014 with gravel from a nearby barrow pit.

7. Costs (USD)

Excavation	$815
Lumber	$100
Reinforcing steel, bricks, tie wire	$90
Bagged concrete mix, 118 bags	$870
Cement mixer	$85
Travel to/from site (gasoline)	$150
Labor	$0
Total	$2105

8. Next step

Part 2 described construction of the tower foundation. The tower material was delivered to the site in 2012 consisting of six 10 ft lattice tower sections, guying material, anchor and grounding hardware, anti-climb panels and climbing safety cable (figure 11). After the concrete base and anchors cured I erected the tower itself, and this activity will be described in Part 3 of this series.

Figure 11 ~ Tower sections resting on the crate material in which they were shipped.

9. Units of measure conversion

Many unit converters can be found online, for example: http://www.digitaldutch.com/unitconverter/volume.htm, but for convenience conversions of the non-metric units used in this article are shown below.

Convert from	To	Multiply by
inches (in)	millimeter (mm)	25.4
feet (ft)	meter (m)	0.305
pound (lb)	kilogram (kg)	0.454
cubic feet (cu ft)	cubic meter (m^3)	0.028
cubic yard (cu yd)	cubic meter (m^3)	0.765
gallon (gal)	liter (l)	3.8
mile (mi)	kilometer (km)	1.6
horsepower (hp)	kilowatt (kw)	0.746

10. References:

[Reeve1] Reeve, W., Radio Frequency Interference Survey at Cohoe Radio Observatory, Alaska, Radio Astronomy, Society of Amateur Radio Astronomers, September-October 2013.

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