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July 2008

ICEHENGE

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STONEHENGE

ON ICE

THE STORY OF MAKING A FROZEN REPLICA

The idea to build a full scale replica of Stonehenge in ice came at the convergence of two events in the middle of the hottest mid-summer July day in Fairbanks, Alaska. I was the chairman of the 41st annual Alaska Surveying and Mapping Conference (ASMC). Previously the conference had taken place almost exclusively in Alaska's largest city, Anchorage, since its inaugural meeting back in 1966. Only one other time had it been hosted at another Alaska city, the last one being in Fairbanks in 1987. As incoming President of the Alaska Society of Professional Land Surveyors (ASPLS) it was my responsibility to also chair the annual conference in 2007.

What do big city folks think of when Fairbanks comes to mind? Cold and ice: rivers, lakes and ponds of it. Clear ice harvested from Fairbanks-area gravel pits is considered some of the world's best when it comes to carving. Each year carvers from the world over (mainly from similarly situated cold regions like Russia, Mongolia, Sweden, Norway, Poland, Germany, as well as less polar latitudes) converge in Fairbanks to carve large blocks of ice weighing several tons into clear sculptures in the World Ice Art Championship.

The event is sponsored by Ice Alaska as one of the first signs of springtime in Alaska's central interior region. Ice Alaska's frozen Fairbanks festival takes place in March, the same time as our surveying and mapping conference. We contacted Ice Alaska's director, Dick Brickley, on the hottest July day in 2006 to see if there was interest in making a replica of Stonehenge in ice as a draw for visitors. He was excited to have us commission a large carving of such a scale that had not been done by them before. So it was decided over cool raspberry slushies on that hot summer day that a reproduction of Stonehenge in ice would be built.

We had to figure out just what it takes to layout and build a full scale mockup of a megalithic structure. Stonehenge began around 4,500 years ago, constructed from wooden posts, then was upgraded, modified and revised during its long 13-century development. What remains on the Salisbury plains of southern England today is less than half of what was once a large complex of stones, ditches, earthen mounds and causeways linked to a civilization that had no metal tools to work with. The majority of the construction was accomplished by wooden hafted stone and bone implements laid out using knotted leather cords without the

>> By Martin Gutoski, LS

A forklift places one of hundreds of ice blocks harvested in January from the gravel pit pond at Ice Alaska.

A handler maneuvers ice blocks into position for the forklift.

benefit of much else but levers, pulleys and logs to excavate, shape and erect more than 100 monolithic pillars up to 30 feet tall weighing nearly 60 tons.

The builders left behind no plans, so most of the explanations have come from archaeological studies to infer the scenarios for possible methods used to build such an ancient complex. A recent concrete replica of Stonehenge was erected at Maryhill, Washington after World War I, near the Oregon border, but the plans had gone missing since the county took over the operation as a memorial to war dead.

The Internet proved to be equally useless when it comes to anything a surveyor can use for layout, but a few hours at two of our local libraries netted some ancient tomes with descriptions of Stonehenge measurements that proved helpful.

Inigo Jones, Druids & Astronomers

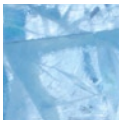
The first measurements were made in 1615 by Inigo Jones, English architect and Surveyor of Works to King Charles I. His findings, however, were not published until 1655, when Inigo's son-in-law compiled the manuscripts to publish them posthumously in Latin, complete with fairly precise dimensional oblique and plan view renderings of what Jones believed was the most likely layout of Stonehenge in its original condition. Jones attributed Stonehenge construction to the early Roman period of England's occupation, some fifteen hundred years earlier.

Others followed in the footsteps of Inigo Jones. In 1640 John Aubrey attributed Stonehenge construction to the Druids and contributed the best measured drawings of the site. The Ordnance Survey of 1867 was the first to use techniques by Royal Army Engineers to generate accurate survey maps of the monuments. Refined measurements did not appear until 1958 when retired professor of engineering Alexander Thom and 20 years later Richard Atkinson in 1978 used modern theodolites to further the precision of the dimensions. Both men were prompted by the assertions of astronomers Gerald Hawkins and Fred Hoyle that Stonehenge was a complex solar and lunar calendar.

High Noon on the Vernal Equinox

So which way should an ice replica of Stonehenge be oriented? The original was set for England's mid-latitude of 51 degrees north at an azimuth of about 24 degrees to catch the summer solstice sunrise. The declination angle of any celestial object varies as a function of the cosine of the azimuth times the cosine of the latitude. Fairbanks, Alaska is at 65 degrees north latitude and 148 degrees west longitude. Summer solstice sunrise happens hardly at all just below the Arctic Circle such that the sun barely skids below the horizon before it pops up a few degrees from true north around local midnight.

Orienting a model of Stonehenge here would mean spinning it around such that it almost becomes a compass pointing due north. Ice here doesn't survive much beyond April, so by the time Icehenge could point to summer solstice sunrise it would be a shimmering puddle of water reflecting the midnight sun. Since the ice festival in Fairbanks was to occur during the spring equinox, it made more sense to have Icehenge point to the one harbinger



Top left Chinese carvers position the two-ton blocks of ice to assemble the columns.

Top right A boom crane lifts the capstones into place.

Modern tools like metal scaffolding and a long reach forklift sped up the construction process, resulting in a finished product in just 11 days.

to the end of winter for Alaska: the high noon sun on the vernal equinox.

Tim Sprout (ASPLS President-Elect) and I worked to produce a CAD drawing based on the best available dimensions, to lay out the outside ring of 30 blocks that make up the Sarsen Circle, the 60 smaller Bluestones inside that ring, and the nine largest stones that form the five trilithons in a horseshoe for the inner arc. (A *trilithon*– a Greek term that means "having three stones"–is a structure built from two vertical stones that support a horizontal or lintel stone across the top.)

Layout at 20 Below

The Ice Alaska team gets two ice harvests from the nearby gravel pit pond per season. The first harvest yields 18-inch blocks that are sold to local businesses for commercial carvings in January. The second harvest yields 4 x 6 x 3-foot blocks that are used for big carvings by the competitive exhibitors in mid-February.

Daylight lasts less than three hours a few weeks after winter solstice, and temperatures can drop to 30 below zero when twilight wanes. We began to lay out nails in a skating pond on a dark, 20-below "day" in January.

The dimensions of Stonehenge are really rather modest by today's megalithic standards. The outer stones of the Sarsen Circle plinths are hardly much more than a modern hundred-foot diameter cul-de-sac. The concentric inner rings and horseshoe-shaped arrangements occupy a spread of 25 feet between the highest Trilithons, and an arced open ellipse of 19 gravestone-shaped tapered slabs face outward in an opening about 20 feet wide.

May I Borrow Your Cubit Tape?

Because the published dimensions were in English feet and inch units of measure, and ours were reduced to decimal feet for survey layout with a total station, the original unit of measure used by the ancient builders of Stonehenge was inferred from the rocks themselves. The proportions of the largest inner stones, the five trilithons (each more than 20 feet tall with a 15.5-foot capstone) and outside Sarsen Circle (a complete 100-foot diameter circle of 30 13-foot tall upright stones capped with curved lintels mortised together) all seemed to be dimensioned with some common unit of measure that was standard throughout.

When the numbers all got crunched by archaeologists *cum* surveyors-in-training, they determined the unit appeared to be an ancient cubit–a unit traditionally applied by masons to stone cutting throughout the ancient world by measuring the length from one's elbow to the end of the middle finger laid out flat. Taking into account that ancient people were smaller than today, the ancient cubit was approximately 20.47 to 20.39 inches, or about 1.7 feet by our current standard of measure.

A very interesting ratio was observed when this derived unit was applied to the outer Sarsen circle of Stonehenge. There were 57 cubits in the circumference of the 96'-10" perimeter stones inside diameter. Splitting this into half-cubit units made the ancient foot about 10.2 inches or 0.85 survey feet. This relationship prevailed in the proportions of the openings between the stone plinths, depth to width of the cut stones and spacing between them. This also led some researchers to conclude that the ancient masons had a knowledge of the relationship of pi to circular measurements to determine how to equally lay out the 30 outer stones for a full circle.

A Pentagon in a Hexagon

There are two ways to break a circle into 12-degree segments if you don't have a compass or modern tool. One way is to bust it up into segments of equal lengths by knowing the chord or arc length. Another way is to inscribe a pentagon in a hexagon. The subtended arc between the two inscribed figures interior angles to their chords is 60 degrees for the hexagon minus the 72-degree pentagon to yield the 12-degree difference.

When I tried this method without a CAD program, I had to resort to my old geometry textbooks to remember how to inscribe a pentagon in a circle using mechanical drafting techniques. Hexagons are simply the radius of the circle applied to the circumference to break it into six equal units. Pentagons made me break out the old compass to strike arcs, bisect lines, erect perpendiculars and lay out the five sides inside the hex. That was a long lost geometry lesson for a CAD-driven surveyor dependent on menu choices available from a computer program for inscribing objects.

Photo by John Bolds

Tim Sprout holds the tape while I check the distance to one of the uprights placed for the inner horseshoe.

The largest trilithon grew cloudy as the April sun expanded the bubbles trapped in the ice.

Kneel, Drill, Freeze!

The area we selected for Icehenge was a 75 by 140-foot oval skating pond. The pond was flooded with two inches of water to make the surface level. Except for the cupping caused by the ice heaving around the perimeter of the pond, it was relatively flat for the majority of the layout. Since the pond was narrower than the 100-foot diameter outer ring of the Sarsen Circle, we concentrated on the large horseshoes of the trilithons,

Photo by Tula Belton

Illuminated on the night of the vernal equinox, Icehenge exhibits a mystical beauty.

Bluestone inner circle of 60 six-foot tall slabs, and the innermost horseshoe of the 19 gravestone-shaped uprights.

We had to clip the outer Sarsen Circle to fit within the pond limits to just two arcs of five base blocks at opposite ends. Tim and I took a five-gallon plastic bucket filled with water, inverted it when it was frozen, cemented it with more water to weld it to the pond, and put a nail in the upside down bucket for our radius point. Initial layout was done by a Leica TC-600R for the 12-degree arcs of the Sarsen Circle bases with a Spencer logger's tape pulled from the nailed bucket for the radius points. We used a battery-powered drill with an eighth-inch bit to auger a hole and freeze back 10-penny nails with colored plastic whiskers attached. We could get two dozen nails per hour per gallon of water per battery charge before our knees, equipment and water jug froze up.

After the control nails were frozen in, we laid out the outer limits of each base block with a notched stick and froze-in

The ASPLS logo was etched in ice at the entrance to conference.

colored flag utility wire locator stakes to show the carvers where to place the blocks. We completed the layout on three weekends by mid-February just as the Chinese carvers started to lay the two-ton base blocks on our marks.

Surveyors Say They Need More Ice

We had laid out points for a dozen of the thirty blocks for the two segments of the outer Sarsen Circle, two dozen of the 60 Bluestone inner rings, all of the five trilithons, and all 19 for the two inner horseshoes. The trilithons were the biggest ones capping at more than 20 feet tall. Each ice block was stacked with the four-foot side for the vertical, laid out six feet long on the horizontal, with the three-foot ice thickness for the depth. Each block was equivalent to 500 gallons of water. Unlike the original construction 4,000 years ago, we had the benefit of long reach forklifts, boom trucks, chainsaws, and steel tools to move, stack and shape the blocks into their final form. The original Stonehenge took more than 1,100 years to complete using Neolithic technology, Maryhill

Photo by Tula Belton

Above Stacked 20 feet tall, sunset illuminates the ice blocks.

Left Two of the five trilithons stand behind smaller uprights that define the inner horseshoe.

Below A portion of historic Stonehenge today.

took 11 years to build following World War I using concrete, and Icehenge was built in 11 days out of water.

We used more than 100 blocks of ice to complete our full-scale model, even though it only survived for a month before the spring sun took its toll. Ice Alaska was open for the month of March 2007, which happened to be much colder than normal for the festival. Because of the cold weather, the sun did not get a chance to boil the entrapped air bubbles out of the clear blue ice until well after the event closed. Ice Alaska harvests more than a thousand blocks of ice for the annual show and stores the unused raw ones under sawdust and tarps to be used for next year. We had depleted their stash so much that they had to steal surplus blocks from other carvers that were held as backups in case of breakage.

Photograph © Ade Rowbotham www.aderowbotham.com

Ice Age Meltdown

Our surveying conference was held in conjunction with the kick-off for the International Polar Year (IPY) at the University of Alaska Fairbanks (UAF). The IPY began in March 2007 as an intense two-year research campaign focusing on circumpolar regions. UAF contributed substantially to co-sponsor the ASMC as part of the IPY initiative being heralded in by global warming studies at the tip of the iceberg. Melting ice in the form of permafrost, sea and lake ice was a significant topic for erosion and climate studies reflected in historical surveys of shorelines as a measure of that change and its effect on infrastructure investments.

Our Icehenge represented an investment of nearly two weeks of six-person crews working ten-hour days. This work was all reduced to a 48,500 gallon pond of water – six inches deep – when the summer solstice sun once again returned the water to its liquid state.

Martin Gutoski is a senior platting officer for the Fairbanks North Star Borough, and holds a master's degree in anthropology. He has been surveying since 1966, and professionally since 1988.

Except where noted, all photos by Martin Gutoski.