

QUARRYING IN ICELAND

LAND OF LIGHT AND DARKNESS

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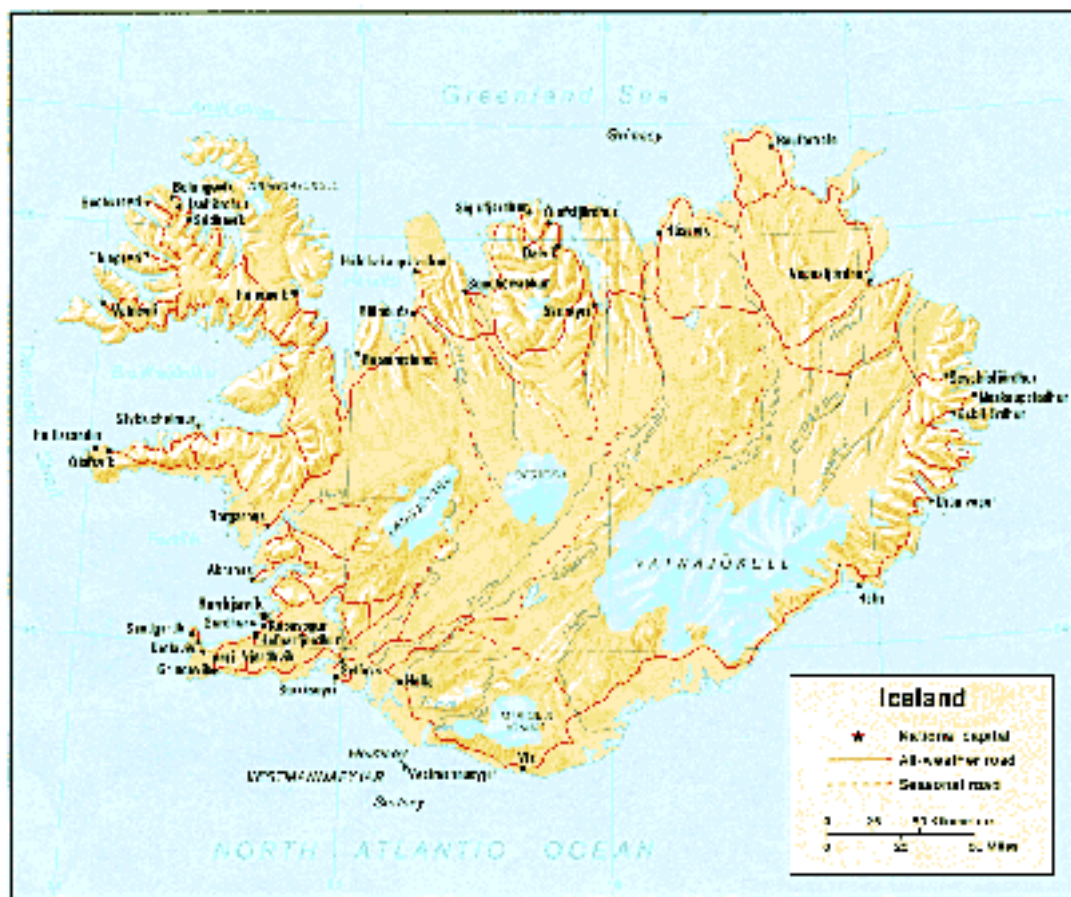


As the proud recipient of the 2003 Goughs Caterpillar Award, presented at the combined, New Zealand Institute of Quarrying Inc / Aggregates and Quarry Association Inc, Conference in Queenstown, New Zealand, I wanted to gain further knowledge and understanding into international quarrying operations. With Iceland being the most isolated country I could think of, not to mention the furthest away, I headed off and found a land where quarrying is different because everything is different.

Location

Iceland lies just beneath the Arctic Circle between Greenland and Norway at 63-66 degrees north and 14-24 west. It covers an area of almost 64,360 square kilometers, which is slightly smaller than the north island of New Zealand at 72,405 square kilometers.

It includes deserts, volcanoes, lava fields, glaciers, grasslands, tundra and coastal icebergs. But in saying this do not think of Iceland as a land of ice. If you think "ice" think Greenland, and likewise if you think "green" think Iceland, strange as this might sound. But even the green is not what you might expect. There's an Icelandic joke that goes "What do you do if you are lost in an Icelandic forest?" Answer: "Stand up". In other words, there are no forests to speak of in Iceland. Vast forests once covered the country but early settlers, which included the Vikings, felled them to build their ships and homes.



Culture

Iceland is perfect for volcanic, glacial, Arctic and terrain research as well as atmospheric and climatic research. Biological and environmental Archaeologists including Anthropologists, who study human origins, find Iceland a wealth of information especially because of its complete and uninterrupted record of settlement with the world's oldest standing parliament, Alþingi, founded in 930 A.D. still in existence at Þingvellir.

Icelanders are highly literate and their language is one of the oldest languages in existence and is the purest form of Norse known. There are no surnames amongst the Icelandic people, only last names, the patronymic system, but they rarely call people by their last names and is why the Telephone directory lists people by their first names first. If your father's first name was Peter and your first name was Jack, your name would be Jack Petersson (Jack the son of Peter). Likewise, your sister's last name would be Petersdóttir (Petersdaughter). While this system is not unique, in Iceland this system is required by law in order to protect its culture. Whenever an Icelanders gets married the women do not change their last names and as a result, and because of the small population, they have to make sure they are not too closely linked before they tie the knot. To help them, they plan to type the genetic make-up of the entire Icelandic population into a gene pool, the Genome project, and will be the first country to do so.

Geography

Immense ice fields cover the highest points of Iceland. These fields are the remnants of an ice sheet that once covered the entire island. But there are many places where you might think that you were on the surface of the moon with its rocky, barren, lunar like landscape. In fact, the largest ice field in Europe, the Vatnajökull Glacier (8,400 square km), which would cover the entire Auckland region from Cape Rodney to the Bombay Hills, lies just to the south of the Ódáðahraun (2000 square km) the largest lava bed on earth.



Ódáðahraun. The largest lava bed on earth



Vatnajökull Glacier. The largest ice field in Europe

Lava beds cover some 11% of Iceland and glaciers 12%. Rivers and waterfalls, volcanoes and geysers abound, providing hydroelectric power and hot springs that heat over 90% of homes. Geothermal sources also provide warmth to greenhouses, where fruit such as Icelandic bananas are grown.

Iceland was formed by solidified volcanic eruptions. It is generally very windy, especially on the coast. The interior is a lot harsher and unpredictable, where sudden blizzards and other related cold phenomena could happen throughout the year. Iceland is located on the junction of the Mid-Atlantic ridge. This ridge marks the moving boundary between the North American and Eurasian

(European Continental) Tectonic Plates, which are consistently pulling apart at a rate of two centimeters a year or 25 km per million years, causing, on average, 400 earth tremors a day.

Iceland is one of the few places on earth where an active ridge can be observed above sea level. As a result the oldest rock, flood basalt, is located to the east and west of the island, or to the east and west of the Ridge, accumulating in an area known as the Thulean plateau. This rock is tertiary in age at over 20 million years old and several kilometers thick.

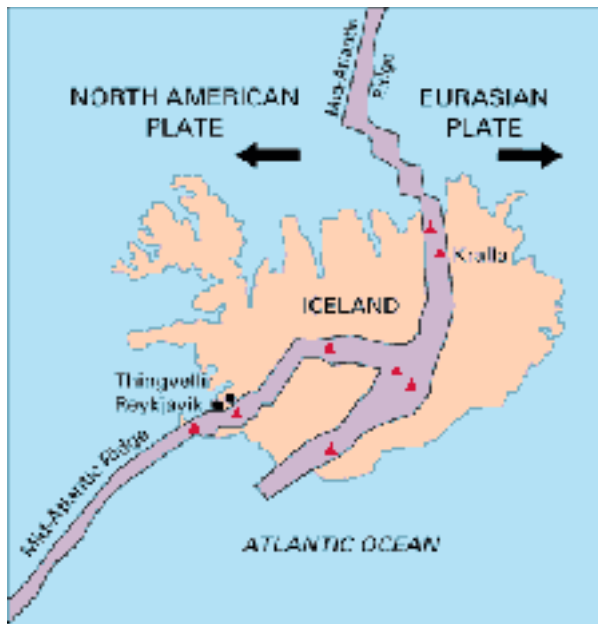


Illustration of how the Mid-Atlantic Ridge divides Iceland and the main volcanoes along it



Dividing of the Continental Plates with the North American Plate on the left and the European on the right

Climate

Due to Iceland's location, it experiences the extension and recession of sunlight hours throughout the year. Depending on where you are on the island - north, south, east or west - summers and winters have varying amounts of daylight hours. During the summer the sky is bright for 24 hours a day and in the north the sun never sets. During winter the opposite is true. As the amount of daylight decreases the Aurora Borealis (northern lights), which is seen all over the island, becomes a welcome and spectacular relief from the darkness.

Four variables interact to create a virtual weather cauldron. These are the Gulf Stream or North Atlantic Drift, the East Greenland Polar Current, Arctic Drift Ice and Latitudinal Influences. Icelanders say that they really never experience weather, just samples of it. There are virtually

only two real seasons in Iceland, which are defined by the amount of daylight hours - darkness (Winter) and light (Summer).

Because the climate is very volatile and inconstant, the averages do not reflect the weather year by year. This comes about by looking at the extremes. There may be warm weather in winter and cold weather in summer. Because of these conditions, industries, that require working outside, such as quarrying, are hazardous. Lifestyles even culture must be carefully adapted. This is especially true in light of the aforementioned volcanic and earthquake activity, as well as the now emerging threat of global warming, as immense glacial dams melt and burst, releasing millions of tons of ice and water that destroy everything in their path.

Quarrying

As one can expect, quarrying in this environment presents many challenges. In winter, where temperatures can plummet as low as minus 30 degrees Celsius, workers are covered in furs to keep out the bitter cold and use water from geothermal bores for all necessities. With a population of only 280,000, Iceland has a remarkably large number of quarries. There are 3000 quarries registered by the Iceland Public Roads Administration (PRA), with 65% (1950) of these being in constant use. Of these quarries, 90% (2700) are owned privately, then sell or lease to larger companies, which in turn supply aggregate for the PRA. This all is done with a strong community focus that is not only beneficial to the quarry operator but the local population as well.

When you compare this to a country like New Zealand, where the population is over 4 million with 1300 registered quarries and 700 of these active, you can clearly see Iceland has one of the largest number of quarries per capita in the world.

With much of the good natural sand and gravel been used, lava, scoria and pillow lava is increasingly being utilized. Approximately 10 million cubic meters of aggregate was produced in 2004 with 75% (7.5 million) going towards roading. This figure equates to around 53 tons per person per year, which is a significant amount especially when you compare this figure to New Zealand where around 6 to 8 tons per person per year is used.

These figures do not include the aggregate required for the Kárahnjúkar Hydroelectric Project as they have obtained their own supply, independent of the PRA.

Before 2002 there was no association of aggregate producers in Iceland and as a result it is difficult to get an accurate record of aggregate produced or sold before then. Because of this, the total amount of resource is not exactly known but it is obvious that Iceland's aggregate reserves are extensive.

Import and Export

Remarkably, Iceland still imports aggregate from Norway and this is increasing. 22,500 cubic meters of Granite and Quartzite used for bituminous pavements was imported from Norway in 1995, and in the year 2000 that figure was up to 60,000 cubic meters.

This is because, predominately, the Icelandic basalt is weak and vesicular with the only major exceptions being the basalt that has been exposed to extreme weathering, thus leaving only the hardest of rock behind while eroding the rest.

Iceland exports pumice, mainly to the German market. Recently this figure has been around the 100,000 cubic meters per annum down from 400,000 10 years ago.

Trolls

Roading in a country where people believe in trolls is not straightforward. Roading contractors will reroute roads or put bends in straight roads only to respect the "hidden people" living there. This may sound familiar to New Zealanders, where belief in Taniwha is not unusual. But trolls are taken extremely seriously in Iceland, so much so that when the main contractor building the Kárahnjúkar hydroelectric project in the eastern highlands found out that there were believed to be man-eating trolls in the area, they contemplated suing the Icelandic government for withholding vital information in the contract.



Icelandic road – straight until they reach the home of trolls

Quality Control

While Iceland is a geologically young volcanic island, containing mainly basaltic rock types, the aggregate that is used in roads and other constructions do meet roading specification. The largest concrete producer in Iceland, HeidelbergCement, has sea-dredged aggregates from the bottom of a bay near the capital Reykjavik since 1960. This aggregate is of glacial origin, produced by the action of glaciers, rivers and waves that selectively remove soft materials formed at the end of the last glacial period when the sea was lower than present.

Due to the Iceland's freeze-thaw cycles, freeze-thaw durability is very important. However, most quarries do not have a standardized quality control system but simply operate to their customer requirements. This is because the resources around the country are very different in both physical and chemical properties. During the past 20 years a classification system based on rock type (petrological classification) has been developed with the aggregates divided into three subclasses based on their level of porosity. While this system differs from international standards, it has been developed to into consideration the level of porosity in relation to strength, fragmentation, wear resistance and abrasion.

Such a system is lacking for concrete and as a result aggregates used in concrete is based on experience rather than actual test results. While the European standard EN 206 is active in Iceland, the only requirement for concrete aggregate is that they have to be able to withstand alkali-silica reactions. Icelandic aggregate is generally silica deficient and as a result cement is of high alkali and until 1979, when silica fume was blended into the cement, alkali aggregate reactivity caused extensive damage throughout the country, particularly in concrete homes, with the rock types of andesite, dacite and rhyolite the most reactive.



Iceland's columnar jointed (column) basalt

Largest Quarry - Hydroelectric Project

At present the largest Quarry in Iceland is centered on the 1 Billion U.S. dollar Kárahnjúkar Hydroelectric Project, where approximately 20 million cubic meters of aggregate is required, for the construction of 5 dams, 3 reservoirs and 16 tunnels, to harness enough hydro power to supply the Aluminum Smelter being built in Reyðarfjörður. The construction of these dams have posed their own problems, and none more challenging than the climatic conditions one has to work under, especially with a six-month winter (darkness) and a six-month summer (light) to contend with.

The main dam, Kárahnjúkar, will be the highest dam in Europe at 190 meters high, 600 meters thick at its base, and 730 meters wide, it will require 8.7 million cubic meters of rock to fill it at a specification of GAP 400. It will be lined with concrete with a 32-degree angle from its outside base to the top to accommodate the massive forces imposed on it during the long winter months.



***The Dimmugljufur (Dark) canyon that will be dammed.
Note the plane which clearly illustrates the canyons size***

Aggregate Supply

With the rock for the dam being quarried from the surrounding area that will eventually be flooded by the 57 square km Háslón reservoir, supply is not a problem. However, the aggregate in the winter months has to be heated and thawed in huge warming sheds before being used for concrete and gap production. Frozen ice-covered aggregate cannot be used directly in dam construction because it would lead to major stability problems in the summer months, as the ice melts. This is, where practicable, also the case when stripping overburden. As the earth is uncovered it exposes vast areas of permafrost (permanently frozen subsoil) that is left exposed over the summer months to thaw out as much as possible before removing it at the first onset of winter.



Kárahnjúkar site

Safety Record

The construction of this project has had added difficulties, in 2004, the lost time injury rate was at an average of 3 a day, 90 a month, with already one fatality. Amongst any work force this is totally unacceptable but with a work force of only 1300 this figure is unbelievable. While there has been some speculation regarding the man eating trolls, that are believed to be in the area, it

is mainly put down to the fact, that the climate is so harsh and unforgiving, that boredom and depression take hold which results in low concentration levels. The main contractor, Italian company Impregilo, employs mainly Chinese and Italian labour who are not used to the extreme conditions. As a result the turn over of staff is very high, as much as 50% leaving after only 6 months, which means recruitment, and retraining issues are another major problem that contribute to the high lost time injuries. Amongst the Icelandic workforce the lost time figure is much lower and in some cases zero.

While Iceland's economy is very stable, because of its climate and isolated location it is generally an expensive place to live or work. Where a kilo of chicken breast can cost as much as \$25.00 U.S. dollars a kilo eliminating safety issues can also be expensive. As such, the temptation to downgrade safety concerns due to financial constraints, especially by outside companies, is very real.

This is a clear example of what can happen when companies are required to self regulate without direct control from the government. While I do not suggest this is the norm I do however believe that one should not be surprised when a situation like this occurs, for whatever reason.

Environmental

Because of Iceland's unique landscape, environmental damage is itself unique. The reservoir, which will be created by damming two of the three main rivers flowing from Europe's largest glacier, will not only severely restrict the grazing ground of the Icelandic Reindeer, but also destroy approximately 500 nesting spots of the pink-footed Icelandic goose while endangering several types of mosses and lichens. Some plant life, such as the Lambgras, being unique to this area.



Icelandic Reindeer around the Kárahnjúkar area



Lambgras

With this amount of disturbance, it is obvious why a huge amount of opposition to this project has occurred. Organizations such as the Icelandic Conservation Association are publicly calling for the project to be stopped. But the projection that this project will help the economy grow by 8% and bring the unemployment rate down from 3% to 1% makes any abandonment extremely unlikely.

Natural Energy

A benefit to come from Iceland's climatic and environmental situation is the island's tremendous resources of energy, which seem to hold the island in a primordial state of fire and ice. As Iceland has no oil reserves, Icelanders have taken advantage of their huge natural resources of natural raw energy, and since the 1990's have led the way in geothermal and hydroelectric industries. With the development of hydrogen fuel cells, their ambition now is to become the first country in the world that is not dependent on oil. This hydrogen initiative would include all heavy machinery used in the extractive industry.

In Conclusion

Iceland is a young volcanic island containing mainly basaltic rock, the extraction of which is exceptional because of:

- The very high aggregate production in tons per capita/year
- Number of quarry sites
- Unique environmental issues
- Hazardous and challenging climatic conditions

Iceland has some unique quarry practices that are very different to New Zealand, and while New Zealanders may grab for a Swandri when it gets cold and Icelanders a seal fur, they clearly embrace this uniqueness, and perhaps more importantly than that, are clearly proud to do so.

About two years ago a Dutch study concluded that the Icelanders were the "happiest people on earth"-at least that is what most Icelanders like to report. And it is not too far from the truth: Icelanders were deemed to be the happiest, most contented and optimistic nation of all studied. Thus it came as a bit of a blow when another study, made public last June, reported that the Icelanders were the greatest consumers of anti-depressants of all the Nordic nations.

A contradiction in terms? Perhaps. Perhaps not. One thing is for sure, though: contradictions are what one repeatedly comes up against when attempting to dissect the national psyche of the Icelanders.

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Thank you (**Takk**)

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