Building in Iceland

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NATIONAL RESEARCH COUNCIL
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DIVISION OF BUILDING RESEARCH

BUILDING IN ICELAND

BY

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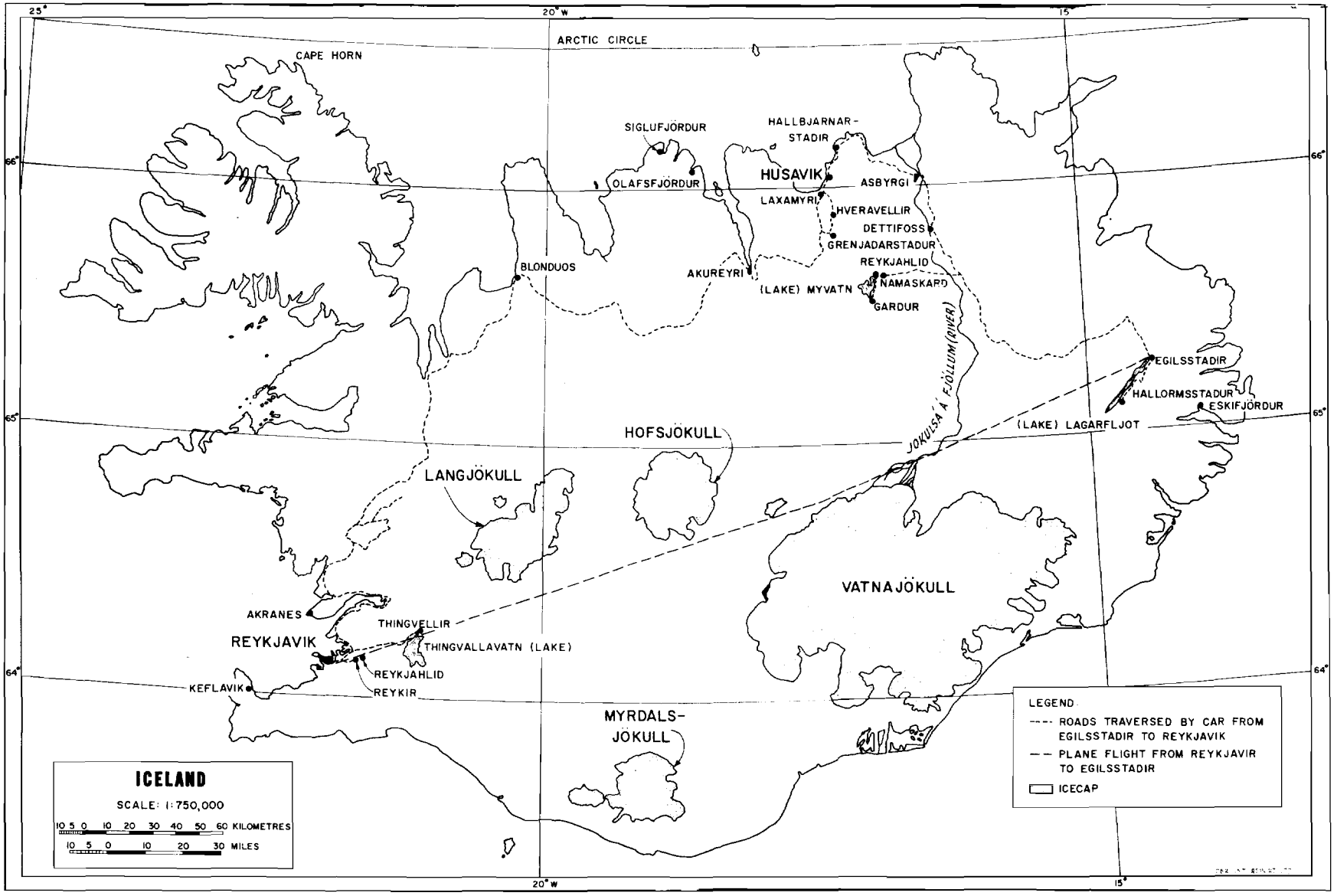

SETTLEMENTS AND NATURAL FEATURES VISITED IN ICELAND

PREFACE

The Division of Building Research has long looked forward to establishing personal contact with building research activities in Iceland. These are conducted by the Icelandic Productivity and Technical Assistance Centre, known as the Technical College Building, in Reykjavik. An opportunity for such a visit arose in the late summer of 1958 on the author's return trip to Canada from Cambridge, England, where he had spent the previous year at the Scott Polar Research Institute. From 30 August to 7 September, 1958, Mr. Brown spent a most profitable week with officials of the Technical College Building and in making a tour of the country.

The information in this report is presented in two parts. The first comprises brief notes on several aspects of the country's geology, climate, history, resources and exports. The second part is a record of information on various aspects of building research in Iceland which was acquired by Mr. Brown during his several discussions with Icelanders engaged in this field.

The author of the report is a Research Officer in the Northern Building Section of the Division of Building Research; his special interest is the distribution of permafrost in Canada. This personal contact has provided a valuable link between building research workers in Iceland and Canada. It is hoped that this report will help in some small way to acquaint Canadians with this interesting and progressive country.

Ottawa
July 1959

R.F. Legget
Director

BUILDING IN ICELAND

by

R.J.E. Brown

INTRODUCTION

From August 30 to September 7, 1958, the writer visited Iceland. During this period, three and a half days were spent in travelling by automobile from the east side of the island to Reykjavik via the north coast. The remaining time was spent in Reykjavik.

This small country, situated in the North Atlantic Ocean just south of the Arctic Circle and in the path of the Gulf Stream, has a cool marine climate similar to parts of Newfoundland and a unique geological framework. Geologically, it is a young country and volcanic forces are now very active. In addition, there are several ice caps in Iceland, including the largest one in Europe. The existence of "fire" and "ice" in combination where active volcanoes are covered by ice produce some unique natural phenomena.

The only resource of any consequence is fish which abound in great numbers near the coast. The Icelanders have a high standard of living but suffer a severe trade deficit because of their almost complete dependence on this one exportable commodity.

In the fall of 1957, the first contact by letter was established between the Division of Building Research and the Isnadatmalastofnun Islands ("Icelandic Productivity and Technical Assistance Centre" - shortened to "Technical College Building") in Reykjavik. This agency is concerned with the establishment of standards in various branches of industry including construction. To follow up this contact, the writer visited Mr. Sveinn Bjornsson and Mr. Jon Brynjolfsson, officials of the Technical College Building to discuss building problems in Iceland. A visit was made also with Mr. Haraldur Asgeirsson, head of the concrete research laboratory of the University Research Institute. In addition, a day was spent in making a general survey of buildings in Reykjavik.

There is no permafrost in Iceland but frost phenomena are prevalent and a useful discussion was held with Dr. Sigurdur Thorarinsson, a geologist, who is the foremost authority on these features in the country. In addition to the kindness of those mentioned above in giving the writer some of their time and information, thanks are due especially to the Honorary Consul General of Canada, Mr. Hallgrimar Hallgrimsson, C.B.E., President and Managing Director of the Icelandic Shell Oil Company, for arranging the tour from Egilsstadir to Reykjavik, and to officials of the Company who were of constant assistance throughout the tour. It was through these arrangements and this assistance that the writer was able to see a great deal of the country, in particular some of the interesting geological features.

Iceland has some unique building problems and also some in common with those in Canada. It is hoped that this brief survey, containing firstly general information, and secondly notes on various aspects of building in Iceland, will to some extent acquaint the reader with this little known but interesting country.

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PART I

GENERAL INFORMATION

1. INTRODUCTION

Iceland is 300 miles long from east to west and 195 miles long from north to south with an area of 40,000 square miles and a fjord-indented coastline of 3,125 miles. It lies approximately between 63° 25' N. and 66° 33' N. and between 13° 30' W. and 24° 30' W. The Arctic Circle is less than 5 miles north of the northernmost point of the mainland.

Most of the interior is uncultivable, consisting of extensive fields of lava, glacial sand and gravel outwash and volcanoes both active and extinct. The average elevation of the interior plateau is 2,100 feet above sea level. The highest elevation is an ice-covered volcano on the south coast, the summit of which is 2,119 metres (approximately 7,000 feet) above sea level. Lowlands containing cultivated area occur in the southwest, west and northeast.

2. GEOLOGY

(a) Volcanic activity

Geologically, Iceland is the youngest country in Europe. It consists mainly of horizontal basaltic lava layers deposited in the Tertiary period. It is intersected from the north to southwest by a broad central zone of submergence containing the most productive volcanic area in the world. There are more than one hundred and fifty volcanoes that have been active in post-glacial time representing nearly every type found on earth. One of these, the lava dome, is found only here and in Hawaii. The one in Iceland is now extinct. There are also cone volcanoes, explosion craters, tephra rings, lava fissures, and crater rows.

More than thirty volcanoes have been active in historical time and one hundred and thirty volcanic eruptions have been recorded. There is an eruption on the average every fifth year. One-tenth of the country has been covered by lava since the Würm Glaciation; two per cent has been covered during historical time. One example of an active volcano is Mt. Hekla in the southwest whose first recorded eruption was in 1104 and has erupted fifteen times since then. The latest was in 1947-1948 lasting with intermittent bursts for thirteen months and producing one cubic kilometre of lava. The eruptions of 1104, 1693, and 1766 caused widespread devastation and subsequent famine because of lava flows and ash deposition.

In 1783, lava issued from a northeast - southwest trending volcanic fissure to the southwest of Vatnajökull Icecap. Approximately 30 to 100 craters, each 30 to 100 metres high, were built. The eruption lasted seven months and lava descended into two river valleys. The total area of land covered by lava was 15 cubic kilometres - enough lava to cover England to a depth of 4 inches. Some farms were destroyed by lava although the ash fall was more devastating. It fell over most of the country, stunting grass and poisoning pasture land so that livestock died. Fifty per cent of the cattle, 76 per cent of the ponies, and 77 per cent of the sheep in Iceland died. Nine thousand people, one-fifth of the total population, died from the resulting famine.

(b) Earthquakes

Earthquakes are frequent although they are confined to a few limited and specific areas. Severe earthquakes have been experienced in only five areas in historical times but these areas have 70 per cent of the population. In 1896, there was a disastrous 'quake which wholly destroyed 17 per cent or 1,309 and damaged 73 per cent or 5,655 of a total of 7,748 buildings in the southern lowlands.

(c) Ice caps

One-eighth of Iceland (11,800 square kilometres) is covered by ice. The largest ice cap is Vatnajökull covering 8,500 square kilometres equalling the total area of all the glaciers in continental Europe. Three other smaller ice caps in the south central part are Hofsjökull, Langjökull, and Myrdalsjökull (Frontispiece).

(d) Glacial bursts

The first type, called "glacilimnogen", is caused by the catastrophic drainage of ice-dammed lakes. Almost every one of the big outlet glaciers of Vatnajökull blocks one or more tributary valleys which are ice free and where water accumulates to form lakes dammed by the ice. The lake level rises until the water can overflow some col or - in case its depth becomes more than nine-tenths of the thickness of the damming ice barrier - the water may lift it and force its way beneath the glacier and overflow the lowland in front of it. One such lake is drained two or three times each year.

The second type, called "volcanogen", is much more disastrous and caused by subglacial volcanic activity. Of the active volcanoes under Vatnajökull, the most famous is Grimsvötn in the centre of the ice cap. Grimsvötn is a depression 35 square

kilometres in area and 500 metres deep. Between eruptions, it is filled with water from ablation and by subglacial volcanic activity. Water is dammed in the same way as in normal ice-dammed lakes. Every ten years the basin is emptied by a violent glacier burst which issues from many tunnels at the ice front. These last about one week and the maximum run-off is 50,000 cubic metres per second which is one thousand times the flow of the Thames River at low tide. These bursts are usually accompanied by violent eruptions in the south part of the basin. The common opinion is that the eruptions are the primary cause of a glacier burst but Thorarinsson (5)* believes that these bursts are not always accompanied by eruptions and it is possible that the drainage of the basin and sudden release of pressure is primary and starts the eruption. This may explain the striking regularity in the length of interval between eruptions of nine to eleven years. The amount of water in each corresponds roughly to the amount of accumulation in the Grimsvötn area in 10 years.

(e) Hot springs and geysers

Associated with volcanic activity are the numerous areas of hot spring activity and geysers. The steam and hot water from many hot springs are being utilized for heating dwellings and greenhouses (Section 17 on Page 16). There are also many water and mud geysers in Iceland. ("Geysir" is an Icelandic word.) The largest water geyser in Iceland is the Great Geysir, 80 miles from Reykjavik which erupts periodically to a height of 160 to 180 feet.

(f) Drainage

There are several large rivers and many small ones having sources in the ice caps and carrying melt water to the sea. These glacial streams carry large volumes of sediment in suspension and are fast flowing. None of them is navigable because of the many waterfalls and long stretches of cataracts and rapids. One of the longest rivers, Jokulsá á Fjöllum flows north from the Vatnajökull to the north coast of Iceland. In its course is Dettifoss, one of the highest waterfalls in the country which is 200 feet high. There are plans to harness it some day for hydro-electric power.

The largest lake in the country is Thingvallavatn, about 9 miles long from north to south by 4 miles wide from east to west. A lava plain extending to the northeast from this lake was the site of the Icelandic parliament for more than 800 years. Another of the larger lakes is Myvatn ("lake of midges") in the northeast. It is surrounded by a lava plain in which the rock surface resembles solidified waves of the sea. There are also volcanic cones and lava pinnacles forming islands in the lake.

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*See References at end of Report.

(g) Frozen ground

It is believed that there is no perennially frozen ground in Iceland at present, although it may have been present during the colder climate prevailing in the nineteenth century. There are, however, a variety of periglacial features such as polygons (3), stone circles and frost mounds, due in part undoubtedly to the close proximity of mean annual temperatures to 32°F and the high number of freeze-thaw cycles. One of the most interesting types of frost mound, or hummock, is the thufa (plural thufur) (Fig. 1). These thufur are covered with vegetation, varying in height from one to two feet and occurring in large concentrations. When such an area is to be cultivated, the mounds are levelled but they re-form after a few years (4).

(The author's visit with Dr. Sigurdur Thorarinsson was the day before he left for Grimsvötn on Vatnajökull to investigate a jokulhlaup (glacier burst). He is well known abroad, particularly in Scandinavia but prefers to stay in Iceland. He is the foremost authority in the geology of Iceland particularly the interaction of glacial and volcanic action. The information he gave the author on frozen ground phenomena in Iceland is all available in the publications listed in the references.)

3. CLIMATE

(a) General

Climatically, Iceland is a land of paradox. It lies near the polar regions so it is never hot but it lies in the path of the Gulf Stream so it is never cold. The mean monthly air temperature for July is about 50°F and for January, about 30°F. At the same latitude in Canada, the mean monthly air temperature for July is also about 50°F but in January it varies from -10°F to -30°F.

(b) Ocean currents and temperatures

The island is situated at the confluence of two ocean currents. Because of a submarine ridge extending between Scotland and Iceland, a branch of the North Atlantic Drift (the continuation of the Gulf Stream) is deflected westward and flows along the south and west coasts of Iceland. Sea temperatures off the south coast average 43°F. The harbours on these coasts are ice free throughout the year. At Cape Horn in the northwest this current, because of its higher salinity, is submerged under the East Icelandic Polar Current (a branch of the East Greenland Current) which flows east along the north coast and southward along the east coast. This current carries drift ice. Sea temperatures off the east coast average 38°F.

(c) Drift ice

From 1600 to 1900, years of severe drift ice were more frequent than during the first three or four centuries of settlement. The last fifty years have been the most free of ice since 1550. The last thirty years are probably the longest practically ice-free period since the beginning of settlement.

(d) Weather

Prevailing wind direction is from the southeast. The weather varies depending on the strength of the high pressure system over Greenland. If this is strong, the depressions are forced to the south bringing southeast winds and mild wet weather to the southern parts of the country. If the high over Greenland is weak, then the depressions move further north resulting in clear weather over the south and cool wet weather in the north. At Reykjavik, the mean annual temperature is 39°F and the mean January temperature is 31°F. The mean annual precipitation at Reykjavik is 50 inches; the amount of this that falls as snow varies from year to year. Thunderstorms are rare.

(e) Conclusion

Years of severe climate mean adversity for Iceland because the country is so near to the northern limit of what a white civilized people can endure while maintaining high cultural standards.

4. HISTORY

(a) Outline

Iceland was settled and colonized from 874 to 930 A.D. partly by Norwegians and partly by people from the northern parts of the British Isles. A republic or commonwealth was established in 930 when a Central Parliament (Althing) was established at Thingvellir. The republic ended in 1263, when a Treaty of Union was made with the Crown of Norway.

Norway and Iceland became united to Denmark in 1389. Iceland had only provincial autonomy, although it maintained that it accepted supremacy of the Danish king but not the Danish government. A constitutional struggle ensued which lasted until 1874.

In 1874, Iceland was granted a constitution by the King of Denmark by which the people were allowed a small voice in their own affairs. This constitution was a compromise and did not work

well. Some bills that were passed by the Althing were vetoed in Copenhagen. In 1903 a new constitution provided a Danish minister for Iceland, solely occupied with Icelandic affairs and residing in Reykjavik.

In 1918 the long struggle for constitutional freedom came to an end with the Act of Union which was passed by the parliaments of both countries acknowledging Iceland to be a sovereign state united to Denmark by one king. Denmark managed Iceland's foreign affairs. The Act of Union provided that after 1940, either party could request negotiation regarding Iceland's future and should no agreement be concluded within three years then either parliament could, by a two-third majority, resolve the Act to be cancelled subject to confirmation by a three-quarter majority in a plebiscite. Denmark was under occupation so no negotiation could be entertained and Iceland adopted a temporary regency because its monarch in Denmark could not exercise his powers. On June 17, 1944, a plebiscite was taken and the independent Republic of Iceland was declared. In November, 1946, Iceland joined the United Nations.

(b) Thingvellir

Thingvellir means "The Plain of Parliament" and has been closely linked over the centuries with the national life. The Althing, the oldest existing parliament in the world assembled from 930 to 1798 at Thingvellir in the open air. It moved to Reykjavik in 1798.

The site is a lava plain about 5 miles wide and about 25 miles long extending north from Thingvallavatn, the largest lake in Iceland, 30 miles northeast of Reykjavik. The plain is enclosed by mountains and volcanic peaks. There are many rifts and faults in the lava covering the plain. Extending along the west side of the plain is a sheer north - south trending fault scarp of columnar basalt lava called "Almannagja". Below the scarp and separated from it by a narrow gorge through which the road proceeds, is the down-dropped portion below the fault which has been eroded into a range of low rounded hills. One of these knobs, called the "Lögberg", has a commanding view of the plain. From here, the law speaker proclaimed all existing laws and important declarations.

The Althing convened every summer in the open air. Several thousand people from all parts of the country came for the session. For legislative purposes, it acted through a committee of 144 men. Besides being a legislative assembly, the Althing also possessed judicial powers and all important matters

that could not be settled by local authorities in the country were brought before this general meeting. The Althing, as a court of appeal, acted through four courts. Skirmishes and even full-scale battles were fought here when riotous chiefs would not abide by the verdict of the courts.

The session lasted about two weeks. The plain was studded with tents because all visitors had to camp but the more powerful leaders had their so-called "budirs" (booths) built of turf and stone. Many of the ruins of these booths are still in evidence. Present buildings at Thingvellir include a small church, parsonage, and hotel.

(c) Catastrophes

Iceland has been affected by many natural catastrophes during its history. A few of the more important ones are listed below to show how much the people are under the influence of the unusual natural conditions:

1300	Mt. Hekla erupted - violent earthquakes, cattle diseases, epidemics and famines
1301	Epidemics
1311	Volcanic eruption
1341	Mt. Hekla erupted
1389	Mt. Hekla erupted
1402	Black Death - two-thirds of total population perished
1618	Volcanic eruptions and earthquakes
1619	Volcanic eruptions
1625	Volcanic eruptions
1636	Mt. Hekla erupted - ashes carried to Scotland and Norway
1660	Mt. Katla erupted
1693	Mt. Hekla erupted
1707	Smallpox killed one-third of total population
1729	Öraefajökull erupted

1732	Earthquakes
1755	Mt. Katla erupted
1757	9,000 died of starvation and disease
1766	Mt. Hekla erupted
1783	Skaptarjökull erupted devastating meadows so that cattle died of starvation and people of famine
1875	Volcanic eruptions.

5. CONSTITUTION

Iceland is a republic in which legislative powers are vested in the Parliament (Althing). Executive power is exercised by the president under the advice of the ministers who are responsible to the Althing. Justice is administered by the judiciary and the highest court of appeal is the Supreme Court in Reykjavik. There is therefore a three-fold division of power similar to that in the United States, i.e. executive, legislative, and judicial.

The President of Iceland is elected every four years. Asgeir Asgeirsson, the second president of the republic proclaimed in 1944, now holds this office. He needs only a majority not a plurality and appoints the ministers. There is no vice-president. If the president dies, his power is delegated to three men jointly: the prime minister, speaker of the Althing, and president of the supreme court.

The ministers vary in number from two to six. There must be at least two. The minister who forms the government is the prime minister. The Althing is elected every four years. There is universal suffrage and fifty-two members are elected to the two houses of the Althing. One-third of these members sit in the upper house. The Supreme Court consists of five judges appointed by the Minister of Justice.

6. POPULATION

The present population of Iceland is between 150,000 and 160,000 which is twice the number of one hundred years ago. The population of Reykjavik is now nearly 60,000 compared to 300 in 1801. Twenty-eight per cent of the total population of Iceland

support themselves by agriculture, 25 per cent are employed in industry, 25 per cent in fishing, 20 per cent in commerce, and communications, etc. Nearly two-thirds of the population live on the coast. In 1951, the birth rate was 26/1,000 and the death rate 7.8/1,000. In 1940, there were 27,000 people of Icelandic origin living in North America.

7. EDUCATION

Education is compulsory from 7 to 15 years of age. Schools in Iceland include primary, secondary, agricultural, technical and grammar schools at Reykjavik and Akureyri. There is a university with five faculties at Reykjavik. These are theology, medicine, law and economics, philosophy and philology, and engineering.

8. RELIGION

The Evangelical Lutheran Church is the state church with a bishop presiding over twenty deaneries and a number of clerical livings. Religion is free and there are two independent Lutheran congregations and three other confessions represented.

9. HYGIENE

There are about fifty government-appointed district physicians augmented by one hundred and twenty medical practitioners. There are small district hospitals in the provinces and special hospitals in Reykjavik and Akureyri including the State Hospital, sanatorium for tuberculosis, mental hospitals, etc.

The tuberculosis sanatorium is in Reykir, twelve miles from Reykjavik, and has one hundred and thirty patients. The corporation to operate the hospital is organized and financed by the patients and shows a slight profit each year. One-third of the patients are chronically ill and are there permanently or until they are sent to old people's homes. The remaining two-thirds are there for six months to two years and begin working three to six hours per day. The main rehabilitation training is in plastic, wood working and sewing and the products are sold on the open market in competition with other manufacturing concerns. The professional staff includes a doctor and two nurses. There are five to six deaths per year from tuberculosis. Iceland used to have the highest death rate from this disease in Europe but now has one of the lowest. Every person is required to be X-rayed once each year.

10. COMMUNICATIONS

There are about 3,000 miles of roads in Iceland and no railroads. In 1948, there were over 10,000 automobiles in the country. Every community on the island has telephone service.

11. RESOURCES AND EXPORTS

(a) Fishing

By far the most important economic resource of Iceland is fish. An indication of how important this resource is to the country can be obtained from a comparison of the deep sea fish catch per person of total population by three maritime countries - England 20 kilos per person, Denmark 25 kilos per person and Iceland 3,245 (one kilo equals 2.2 pounds).

Fish abound in large numbers on the continental shelf off the coast where the cold East Greenland Current and the warm North Atlantic Drift converge. The main drawback is the storminess of the sea because of the absence of offshore islands. The main species are cod and herring.

The development of fishing was responsible for the growth of Reykjavik into the largest city in the country. It is separated by a lava plain from the most flourishing farm land in Iceland. The introduction of the larger steam trawlers in 1930 resulted in a sizable increase in the catch per person of population and the continued growth of Reykjavik. Siglufjördur, on the north coast became the centre of the herring fishery. Herring oil and herring meal are produced there. The main drawback is the unevenness of the catch which is caused in part by climatic fluctuations.

(b) Agriculture

Although fishing constitutes almost the total export, there are nearly twice as many people engaged in farming. In 1890, 90 per cent of the population was on the land and today it is still 30 per cent as compared to 16 per cent in fishing. There are estimated to be 1.8 million hectares (a hectare equals 2.2 acres approximately) of arable land on volcanic loessial soils. There are now about 40,000 farms on the coast and in river valleys and about 48,000 hectares are under cultivation. Soil erosion is a major problem.

The chief crop is grass and two to three crops can be raised each year. Livestock includes sheep, cattle and ponies. Sheep are the most numerous and there are now about 800,000 in the country. Iceland is self-sufficient in mutton and has a surplus. There is enough fresh milk to satisfy the home consumption but it is difficult to market. Therefore, much of it is made into cheese.

Horticulture is increasing with the use of greenhouses heated by steam from the numerous hot springs. There are now about 600 potato gardens in the vicinity of Reykjavik but imports of this vegetable are still required.

Because of the continual movement of rural people to the cities, agriculture is heavily subsidized by the State in the form of low tax rates, and cheap telephone and bus service. There is a government research station and experimental farm near Reykjavik where specially selected strains of barley, oats, and summer rye are being grown. One major factor in the growing importance of agriculture is the improvement in the natural conditions. Since 1875 there have been no large-scale volcanic eruptions and no subsequent large-scale economic losses. Since 1896, only two earthquakes have done material damage.

(c) Forestry

When the first settlers arrived in Iceland there were several forested areas. Over the centuries these were depleted because wood was used for building and fuel. Today there is only a total of about 250 acres of birch forests scattered through the lowlands and on mountain sides. There are also a few conifers. Sheep are the chief enemy because they nip off the young saplings. Driftwood and peat are used for fuel.

There are at present four government tree nurseries under the Forestry Department. The largest is at Hallormsstadur (Frontispiece) in a river valley inland from the east coast. It was begun in 1905 with seeds and seedlings of birch, spruce, and larch from Canada, Norway, and Siberia. The tallest trees are 30 feet high with trunks 5 inches in diameter. The preserve is fenced off to protect it from sheep. Another is in Asbyrgi (Frontispiece), a horseshoe-shaped depression with sheer rock walls which is believed to be either a tectonic depression or a former course of the river, Jokulsá á Fjöllum. The entrance is fenced off to protect the trees from sheep.

(d) Exports

Fish and fish products constitute almost all the exports from Iceland. These include iced fresh fish, quick-frozen cod fillets and salted cod, herring meal and oil. Mutton, sheepskins, and wool constitute the meagre agricultural exports.

Some interesting projects in developing other resources for export are underway in Iceland. One of these is the collection of diatomaceous earth from the bottom of Lake Myvatn. It is pumped through a pipe into a collecting basin where it is drained and allowed to dry over the summer. It is then used as a flocculating agent in fertilizer. Vast deposits both in lake bottoms and off the sea coast have been discovered and it is hoped that this will become an exportable commodity.

Although there are now several hydro plants in operation, there is much water power that is still unharnessed. There are plans to utilize this power both for aluminum refining and the manufacture of heavy water.

(e) Co-operatives

Iceland has one of the most highly developed groups of co-operative societies in the world. The first co-operative was formed in the 1880's and there are now 55 in the country. Akureyri, the second largest settlement in Iceland has the highest development. There are co-operative textile mills, shoe factory, glove and bag factory, white tile factory, margerine factory, soap and dental cream factory, coffee roasting plant and freezing plants.

(f) Conclusion

Because of her extreme paucity of natural resources, Iceland must import everything she needs except fish and some farm products. The chief difficulty is that the unstable winter cod fishing and the uncertain herring catches in summer have to be relied on so much to obtain a sufficient balance of export against all the manufactured and consumer goods which have to be imported.

PART II

BUILDING IN ICELAND

12. ICELANDIC PRODUCTIVITY AND TECHNICAL ASSISTANCE CENTRE

This government agency is located in Reykjavik (Fig. 2); its purpose is to promote progress in Icelandic industry and to introduce improved techniques in industry (2). There is, however, little actual building research being conducted in Iceland, although testing of various materials is being carried out. The agency in Canada most similar to this centre in Iceland is the Canadian Government Specifications Board. In Iceland there is only one committee at present doing technical standardization work. This deals with concrete and works in close co-operation with the other Scandinavian countries (1). The Productivity Centre has started a technical library of periodicals and books.

13. CONCRETE RESEARCH

A discussion was held with Mr. Haraldur Asgeirsson, Department of Industrial Testing and Research, University Research Institute, Reykjavik. The following points emerged from our talk. Up to the present, the main emphasis of building research in Iceland has been in concrete. The biggest problem is in the selection of aggregate. Often the sand that must be used is of the wrong sort, usually too acid (volcanic origin) resulting in crumbling and failure of the concrete. Frost deterioration is also a serious problem.

The amount of concrete used per capita is the highest in the world - 555 kilos (one kilo equals 2.2 pounds) per capita in 1956 compared with 320 for the USA and 223 for England. Iceland is not happy about this situation because it reflects the country's almost complete dependence on this building material to the neglect of others (1).

Unlike the situation in most countries, labour is the big expense constituting two-thirds of the total cost of building. All the concrete used in Iceland is now of local manufacture using local materials. In August 1958, Iceland's first cement plant was opened at Akranes, about 40 miles from Reykjavik. The plant should have been located nearer Reykjavik but factors other than economic influenced the location. It is still almost as economical to import such materials as cement despite the import tariffs.

Asgeirsson uses standard American and German concrete testing equipment and has a staff of five technicians. He is experimenting with two types of aggregate: 1) volcanic glass (palaconite), which is found around Reykjavik but does not measure up to ASTM standards; and 2) basaltic sand, which is found in other parts of Iceland. Because of the two different types of aggregate, it is difficult to produce a standard for concrete. There are many experiments being conducted on foam plastic and lightweight concrete.

Frost deterioration of concrete is a serious problem because the mean annual temperature in Reykjavik is 31°F and there are as many as one hundred freeze-thaw cycles per annum. The mild and moist climate is suitable, however, for curing concrete. Asgeirsson produced some concrete samples from a hydro dam where there were areas of poor aggregate and a high number of freeze-thaw cycles. The concrete was poorly bound and crumbled.

The main design for eaves in concrete houses is shown in Fig. 13A. Moisture migrates through the concrete towards the eaves causing cracking and spalling both in the overhang and the concrete wall.

14. BUILDING DESIGN

Iceland has a variable climate with the possibility of frost, rain, thaw, snow and hot sun in rapid order. As a result, rain penetration and masonry deterioration are serious problems. The strong winds often cause rain to penetrate through to the point where sills and curtains are wet.

Although there have been no serious earthquakes in recent years, they are taken into account in design because they can happen at any time. Reinforced concrete has been the most commonly used material in Reykjavik since 1915 and is now being used in their tremendous building program, giving the city a characteristically integrated appearance. As the old houses and shops of wood and corrugated iron are cleared away, concrete ones will replace them.

Among the first of the new public buildings to be erected in the present "new era of building" were the National Theatre started in 1928 and the National University completed in 1940. These represented the beginning of an autochthonous Icelandic architecture.

The Theatre (Fig. 3) is of reinforced concrete designed by the State Architect, the late Prof. G. Samuelsson, who was experimenting with this material. The design incorporates a necessary and usually awkward gridiron as part of a strong functional design. The auditorium seats 700 and is without windows but is surrounded by well lighted corridors and cloak rooms. It has a revolving stage.

The lobby is finished in polished spar found only in Iceland and rapidly becoming unobtainable; it reflects and refracts light and lends itself to hard surfaces and sharp detail.

The University (Fig. 4) has a concrete exterior and dolerite is used inside. This native grey stone is cut into squares for the floor of the entrance hall. Expanses of glass brick are used in the many windowed wings. There is a large square skylight of double Iceland spar. The convocation room is finished in white birch.

Four other buildings that are built along the same severe lines are the Gardur Hotel, the National Museum of Natural History, the Seaman's School and the City Hospital.

15. HOUSE DESIGN

Typical of the evolution in house design and materials in Iceland is the pattern of development in Husavik, a settlement on the north coast (Frontispiece). Prior to 1920, the houses were exclusively frame (Fig. 5). During the 1920's, it was the practice to place corrugated iron siding over wood (Fig. 6). Concrete was used almost exclusively after 1930 (Fig. 7). Foundation walls are generally ten inches thick and the superstructure walls eight inches. An example of a typical wall section of a house built of wood and corrugated iron is shown in Fig. 13B, and a typical section of a house built of concrete is shown in Fig. 13C.

Corrugated iron is used almost exclusively as roofing material; asphalt shingles and tiles are rarely used (Figs. 6 and 7). The roofs are always painted to prevent salt corrosion of the metal. Paint used outside on roofs and walls is subject to severe blistering and chipping resulting in the need for a new coat every few years. Paint is often used now rather than stucco on wall exteriors. Wallpaper is scarce and the interior walls are usually painted. Vapour barriers are not used in houses because of lack of experience with them and also their high cost. The claim was made, however, that there is little trouble with condensation.

Many windows are used and they are large, with every advantage being taken of the southern exposure. Windows are located mostly on the south and east sides of houses and apartments. Most windows are neither sash nor casement but are built solidly into the wall with only one movable pane which can be loosened for ventilation. Another interesting innovation in windows can be seen in Fig. 8, which shows a row of slanting windows and a window in the roof.

Many new apartment buildings are built in rows on the diagonal to present two sides to the south (Fig. 9). Most houses in Iceland have basements. For any basementless building founded on a flat slab, the soil is excavated to a depth of a few feet and crushed volcanic scoria is used as backfill.

At Grenjadarstadur (Frontispiece) in the north, is the site of one of the few remaining old Icelandic farms. This particular farm is one hundred years old. The roof has five peaks (to simulate the mountain peaks). Each of the five sections is separated by a wall of lava blocks with peat insulation. The various rooms are connected by dark passages. Farm houses are built of concrete now but old sheep barns of turf and stones are still being used. Soil is piled up on the north sides of these buildings to provide extra protection against the wind.

16. BUILDING SERVICES

(a) Heating

Fifty per cent of the buildings in Reykjavik are heated with hot water from the thermal springs at Reykir located 12 miles from the city. The remaining buildings use oil which must be imported and is very expensive. Eventually, the entire City of Reykjavik will be heated with hot water. Peat is still used for fuel in some rural areas.

(b) Insulation

The present regulation is that heat loss must not exceed 1.0 cal/m^2/sec but this was considered too lenient for wall panels. It is hoped that this amount can be reduced to 0.7.

Insulation materials include cork, pumice and rock wool. Foam plastic is being introduced as an insulating material. There is a factory in Iceland which manufactures insulating slabs of pumice stone to line the inside of concrete houses. Unlike American cinder blocks, pumice cannot be used in exterior construction.

(c) Sewage

There are no treatment plants in Iceland. Even in Reykjavik the raw effluent is dumped into the sea.

17. UTILIZATION OF HOT SPRINGS

Reykjavik has a municipally-owned hot water distribution system for heating a large number of its buildings, utilizing the hot springs occurring at Reykir and Reykjahlid (Frontispiece),

villages about 11 and 12 and a half miles from Reykjavik respectively. In 1930, a small hot-water distribution plant was built two miles from Reykjavik. This was used to heat the State Hospital, a large public school, a swimming pool and between forty and fifty houses. It is still in use but is overshadowed by a larger one begun in 1939 and completed in 1943. In the early 1930's, the city bought the rights to all the thermal springs within ten miles for 150,000 kronur (present rate of exchange is 16 kronur = $1.00 but the 1930 exchange is not known).

The holes drilled at Reykir numbered 46, at Reykjahlid 25 and nearer to Reykjavik 29. The average depth of the borings is 1,000 ft and the deepest is 2,500 ft, varying from 4 to 9 in. in diameter. The average temperature of the water in the holes is 190°F, varying from 180°F to 210°F. The total yield of water from the 71 holes in the Reykir-Reykjahlid area is about 5,280 imperial gallons per minute.

The water flows from the borings under its own pressure and is piped to pumping stations at Reykir and Reykjahlid. The water from the Reykjahlid pumping station is sent through a 10-in. pipe over a ridge to Reykir where the water from both areas is gathered. The Reykjahlid station which has two electrical pumping units, is partly automatic and partly remote controlled from the main pumping station at Reykir. This station has three electric pumping units. Each pump has a 300-hp motor and delivers 1,980 imperial gallons per minute. There is also a reserve power station at Reykir equipped with a 1,050-hp diesel engine and a 860-KVA generator.

The hot water is pumped from Reykir west to Reykjavik through two 14-in. steel pipes in a concrete duct. The pipes are lagged and covered with pitch and packed in moss and soil (Fig. 10). There are double expansion joints every 1,335 ft to allow for temperature changes and three stations where one pipe can be cut off for repairs leaving the other to carry water. This pipeline delivers water at the rate of 4,620 imperial gallons per minute to eight concrete storage tanks standing on a hill at the edge of the city. This is augmented by local borings delivering water at the rate of 800 imperial gallons per minute. The aggregate volume of the tanks is 2,184,000 imperial gallons which is about one-quarter of the maximum daily consumption. The function of these tanks is to equalize the pressure throughout the city and the flow throughout the day.

The location of the tanks above the city permits gravity flow to the street-mains and house connections. In case of maximum consumption, a booster pumping station built in the line can be utilized to increase the pressure by two atmospheres. This pumping station, which is situated just below the tanks is automatically controlled by a manometer in the city.

The thirty miles of street-mains vary from 1 to 18 in. in diameter. The total length of the house connections is about twenty miles and these pipes vary from 3/4 to 2 1/2 in. in diameter. The mineral content of the water is so low that it is piped directly into the heating systems of the houses. There it cools and leaves the houses through the drainage pipes. Some of the water is used for washing and bathing, etc.

All the pipes are well insulated to maintain high water temperatures. The main line from the storage tanks is in a concrete duct above ground and insulated with special turf mats. The street-mains are laid three ft below the ground surface in concrete ducts which are insulated with porous lava slag. Glass-wool is used for the house connections.

The degree of cooling of the temperature of the water from source to consumer varies throughout the year. During the winter, the temperature drop from the Reykir pumping station to the storage tanks is only about 5°F. From the tanks to the furthest house in the city, the cooling is somewhat more because of the lower velocity and volume. Nevertheless, the temperature of the water in the houses is 167°F to 175°F and higher. Sixty thousand tons of coal, which would have to be imported, are saved per year by using water from the hot springs, as well as making Reykjavik a smokeless city.

When the system was first installed, it heated 84 per cent of the city buildings. The city has grown so quickly that the percentage has dropped considerably but it is being enlarged continually. Four thousand houses are now heated by the system and three hundred new houses will be connected to it in 1959.

Reykjavik has the oldest and largest district hot water heating system in Iceland. There are four others in the country now with plans for additional ones where there is subsurface thermal activity.

At Hveravellir, (meaning "place of hot springs"), in the north of Iceland, there are geysers, one of which erupts two or three times per day. Two farms in the district use the boiling water for heating (Fig. 11). There is a plan to pipe it ten miles northward to Husavik and the farms along the route of the proposed pipeline will also use it. There are several greenhouses at Hveravellir in which cabbages, tomatoes, cucumbers and grapes are grown. Iceland grows enough greenhouse tomatoes to satisfy her own needs. In the south, oranges, bananas and coffee are grown in greenhouses on an experimental basis.

At Hveragerdi, twenty-nine miles from Reykjavik, there are acres of greenhouses in which various sorts of vegetables and fruits are grown. Recent drilling here has released a steam which drives turbo-generators producing electricity.

18. BUILDING CODES AND TOWN PLANNING IN REYKJAVIK

There is no national building code in Iceland but each municipality, including Reykjavik, has its own regulations. The building laws in Reykjavik are strict. Each plan must be checked by the Building Committee with regard to appearance, height, and distance from the street, in relation to the town planning scheme. The drawings must be passed by the City Engineer and a building inspector must supervise construction. The site of Reykjavik is restricted on the landward side by another municipality which has a different code. The planned amalgamation will produce the problem of obtaining uniformity.

Iceland was the first Scandinavian country to adopt precise legislation for town planning and its execution. The act was passed in 1921. One clause of the zoning by-law states that no wooden buildings are allowed within the city limits, although there are no restrictions outside the city.

The built-up area in Reykjavik has increased threefold since 1945. As the population increases the green areas within the city limits will be built up. The present airport will be abandoned because it is too near the city. There is a plan to build another airport near the city but many people insist that the city should use Keflavik, the NATO air base thirty-one miles away. In this event, the road to Reykjavik would have to be paved.

In Reykjavik, housing is very critical. Although new apartments are going up very quickly, the demand still far exceeds the supply. As in Sweden, many people own their own apartments. Figure 9 shows an apartment building that is typical in design to many that have been erected in recent years. In 1958, construction was begun on a new type of apartment building, or vertical multiple housing unit (Fig. 12). These units are built with gliding moulds and work is done twenty-four hours per day. In May and June of 1958, one such structure was erected at the rate of twelve stories in seventeen days. Much criticism has been levelled against these "skyscrapers" (so called because they are the highest buildings in the country) because they interrupt the skyline. They do appear to be the answer, however, to the critical shortage of accommodation, as the population of Reykjavik is growing at a rapid rate.

The Icelandic Productivity and Technical Assistance Centre reports that 35 per cent of Iceland's total budget is used in construction - a very high figure of which the Icelanders are not proud. An average house in Reykjavik costs from $8,500 to $14,000. A five-room apartment costs about $11,000 to buy. The cost of building is high, averaging 1,000 kronur per cubic metre (about $60.00 under the present official rate of exchange). All steel, wood, glass, plumbing and lighting fixtures must be imported.

The following combination of circumstances will give the City of Reykjavik peculiar characteristics: a cultural background unbroken for over one thousand years; almost no architectural tradition or landmarks to influence modern ideas; climatic and seismic conditions necessitating buildings of great strength; the eventual heating of all Reykjavik by hot water making it absolutely smokeless.

19. BUILDING PRACTICE

In 1944, one-third of all compulsorily insured industrial work in Iceland was in connection with construction undertakings and house building (6). A little more than one-third of this was absorbed by the building trade and various handicrafts connected with building or the repair of houses, such as masonry work, painting, fitting of pipes, and electrical installations. These trades were of little importance until towns and villages began to arise, but since the close of the nineteenth century, their growth has been strong and steady. However, much more labour is absorbed by other kinds of work, especially road and street construction, laying of water works, the hot water supply of Reykjavik, and construction of harbours and piers.

There is an Industrial Council in every town composed of elected representatives for various industries to look after the interests of local trades and be their spokesman when needed. In 1932 "The Federation of Icelandic Artisans" was created, having a membership of all those who are engaged in trades and industries. The work of the Federation is to promote Icelandic industrial enterprise and trade, to represent them and the members there, and be the leader and guiding spirit in industrial matters of the nation. For this purpose, the representatives for various trades and industries meet together every two years.

In Iceland there are co-operative building societies to which the State Building Fund grants loans for construction to their members. Loans are granted on first and second mortgages and may add to 85 per cent of the total value of the building under special circumstances; they are redeemable in 42 years with amortization and interest at 4 per cent. The first block of houses under this act was built near Reykjavik in 1932 and the number has increased steadily since then.

20. ROADS

Iceland has the highest mileage of roads per capita of the Scandinavian countries. So much of the annual allotment for roads is used for maintenance that none remains for paving. The equipment used is poor and limited, being mainly second hand from the NATO

base at Keflavik. There are few spare parts. The main streets of Reykjavik and Akureyri are paved but the side streets and the roads between towns are unpaved. Gravel, consisting of volcanic material such as pumice, ash, breccias, tuffs and scorias, is used as grade.

Frost damage to roads is severe; frost penetrates to depths varying from 50 to 100 centimetres during the winter. In the spring, the roads are unusable. Some break-up of the pavement occurs in Reykjavik and Akureyri. Rain and traffic are also causes of deterioration.

Since 1940, there has been an extensive bridge-building program. A new concrete suspension bridge was built in 1944 across one of the larger rivers in Iceland. The concrete anchoring piers of this bridge show some cracking and spalling from frost action.

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Fig. 1 "Thufur" or frost hummocks one to two feet high with grass cover near Blondous.

Fig. 2 The Icelandic Productivity and Technical Assistance Centre.

Fig. 3 Front entrance of the National Theatre, Reykjavik.

Fig. 4 Main building of the University of Iceland, Reykjavik.

Fig. 5 Frame house with stone-block foundation built before 1920 in Husavik.

Fig. 6 Frame house with corrugated iron siding and roof built in the 1920's in Husavik.

Fig. 7 New concrete house, with corrugated iron roof, in Husavik.

Fig. 8 Row of slanting windows above a restaurant in Reykjavik.

Fig. 9 A new apartment building in Reykjavik with individual wings built diagonally so that two sides will face south.

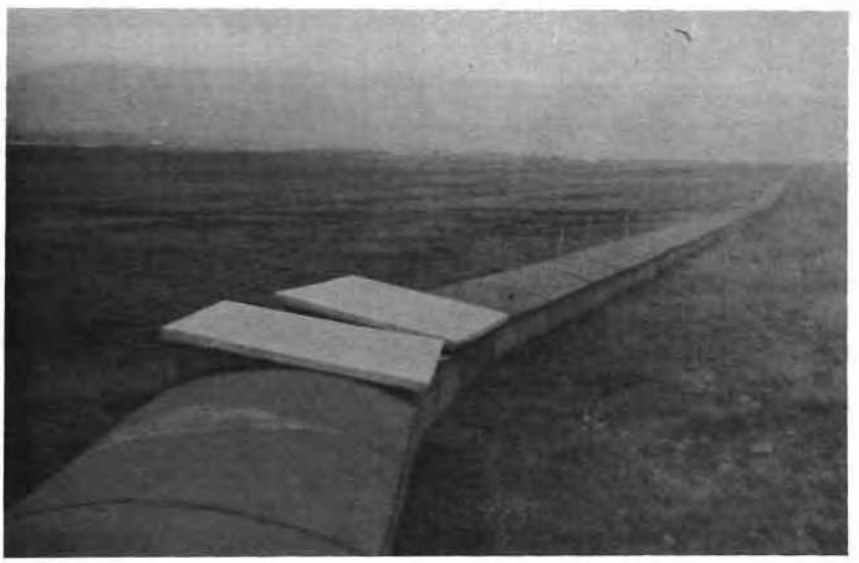


Fig. 10 Concrete duct carrying hot water from Reykir to Reykjavik (note expansion joints in the foreground).

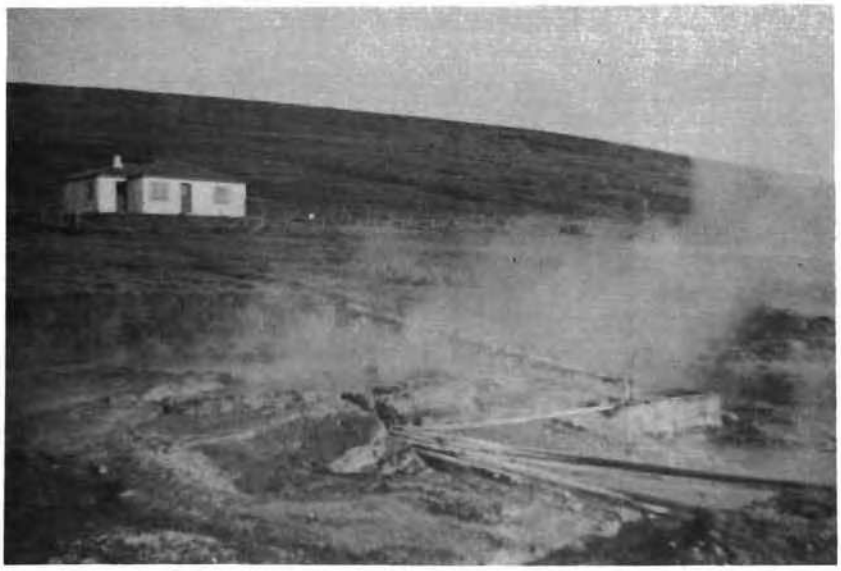
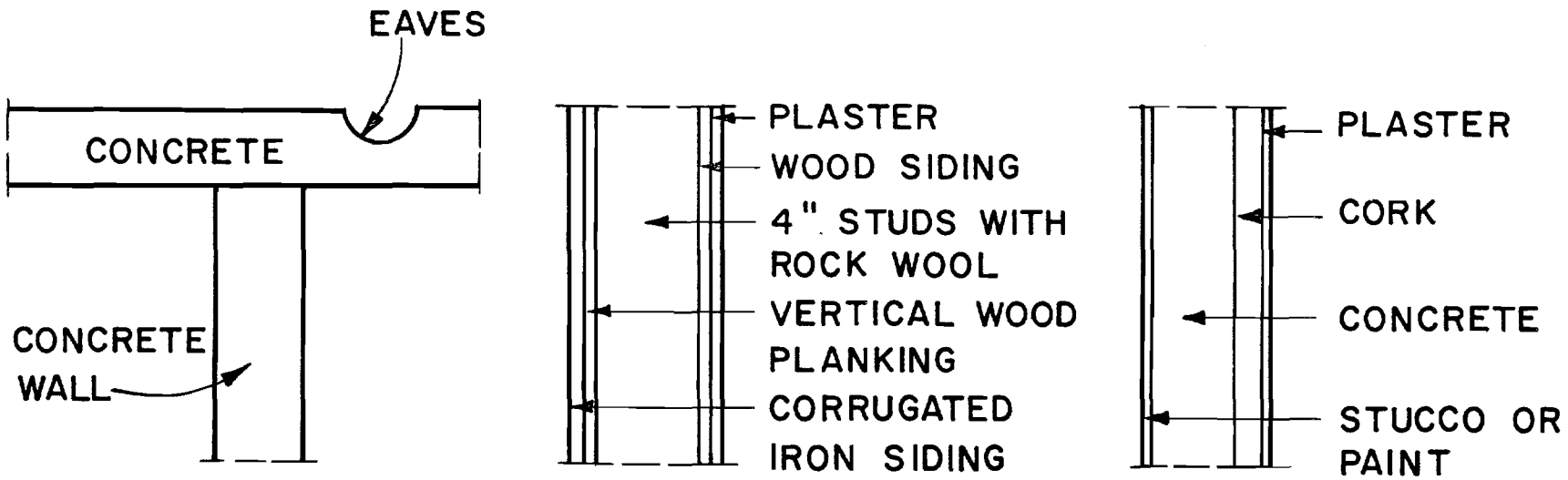


Fig. 11 Thermal springs at Hveravellir being utilized to heat farm houses and greenhouses.

Fig. 12 An apartment building in Reykjavik built with gliding moulds.



A

DESIGN FOR EAVES IN CONCRETE HOUSE

B

WALL SECTION OF HOUSE BUILT OF WOOD AND CORRUGATED IRON

C

WALL SECTION OF HOUSE BUILT OF CONCRETE

FIGURE 13 TYPICAL HOUSE SECTIONS

APPENDIX A

CONTACTS

1. Isnadatmalastofnun Islands ("Icelandic Productivity and Technical Assistance Centre" - shortened to "Technical College Building"), Reykjavik.

(a) Mr. Sveinn Björnsson, Managing Director, civil engineer, undergraduate training at University of Iceland, graduate work at Illinois Institute of Technology, Chicago.

(b) Mr. Jon Brynjolfsson, mechanical engineer, training at University of Copenhagen. One of six members on Building Council in Iceland, he represents the Technical College Building.

(c) Mr. Loftur Loftsson, chemical engineer, training at McGill University and M.I.T., directs technical assistance work to industry.

(d) Mr. Gudmundur H. Gardarsson, economist, training at University of Iceland and Kiel University, Germany, office manager concerned with retail distribution of building materials.

2. Department of Industrial Testing and Research, University Research Institute, Reykjavik.

(a) Mr. Haraldur Asgeirsson, civil engineer, graduate of University of Illinois, head of the concrete research laboratory.

3. Icelandic Shell Oil Company

(a) Mr. H.F. Hallgrimsson, Director

(b) Mr. Isak Sigurgeirsson, Public Relations Officer

(c) Mr. I.F. Hallgrimsson, Eastern Representative (resident in Eskifjördur)

4. Department of Geology and Geography, Museum of Natural History, Reykjavik.

(a) Dr. Sigurdur Thorarinsson, glacial and volcanic geologist, secretary of Iceland Glaciological Society.

5. Department of Highways, Maintenance Division, Reykjavik.

(a) Brother-in-law of Mr. Björnsson, mechanical engineer just returned to Reykjavik from Worcester Polytechnical Institute, Massachusetts.

6. District Heating System, Reykjavik.

(a) Mr. Helgi Sigurdsson, Director

APPENDIX B

ITINERARY

Saturday, 30 August 1958

The writer left Glasgow at 8:45 p.m., British Summer Time on Icelandair, and arrived in Reykjavik at 10:45 p.m., Iceland time (which is one hour behind British time). At the airport to meet him were Mr. Sveinn Björnsson, Managing Director, Isnadat-malastofnun Islands (Icelandic Productivity and Technical Assistance Centre) and Mr. Isak Sigurgeirsson, Public Relations Officer, Icelandic Shell Oil Company and representing the President and Managing Director of the same company, Mr. H.F. Hallgrimsson (the latter is also the Honorary Canadian Consul General in Reykjavik).

Accommodation was provided at the Gardur Hotel in Reykjavik; this building is actually a university residence for men and women which is used as a hotel for tourists from 4 June to 29 September.

Sunday, 31 August 1958

The morning was spent walking around Reykjavik looking at the following sites: the National Bank, Telegraph and Telephone Exchange, House of Althing (Parliament), Lutheran Cathedral (Domkirch), Statue of Ingolfur Arnarsson who was the first colonist in Iceland in 874 A.D., National Library and Archives, and the National Theatre.

In the afternoon, a visit was made by bus to Thingvellir ("Plain of Parliament"), 31 miles from Reykjavik (See Section 4 (b)).

Monday, 1 September 1958

At 10:00 a.m., Mr. Sveinn Björnsson called for the writer at the Gardur Hotel and took him to his office. The morning was spent discussing building in Iceland, meeting the staff, and in discussion with one of his officers, Mr. Jon Brynjolfsson.

The early part of the afternoon was spent in writing up notes. At 5:35 p.m., the writer left Reykjavik by plane for Egilsstadir, 250 miles to the northeast and arrived at 7:05 p.m. (Frontispiece). Mr. I.F. Hallgrimsson, Eastern Representative of the Icelandic Shell Oil Company met him and they drove along the east shore of Lagarfljot (lake) to the Government Forest Experimental Station at Hallormsstadur (See Section 11 (c)).

Tuesday, 2 September 1958

At 9:30 a.m., the writer left Egilsstadir by taxi, crossing the longest bridge in the country (300 metres) to the north end of Lagarfljot and arrived at Reykjahlid on Lake Myvatn at 1:45 p.m. (Frontispiece). Mr. Sigurgeirsson and his wife met him and in the afternoon they drove along the east shore of Lake Myvatn to Gardur to see various lava and volcanic formations. Accommodation was provided for that night at the hotel in Rekjahlid.

Wednesday, 3 September 1958

The entire day was spent driving with the Sigurgeirssons to Akureyri (Frontispiece), stopping to see the following sights: Dettifoss Waterfall (See Section 2 (f)), Asbyrgi (See Section 11 (c)), Hallbjarnarstadir (unconsolidated Pliocene deposits containing layers of marine shells), Husavik (fishing port and herring plant), Hveravellir (See Section 17), Laxamyri (hydro power dam - see Section 11 (d)), Grenjadarstadur (an old Icelandic farm - see Section 14). Overnight accommodation was provided at a hotel in Akureyri.

Thursday, 4 September 1958

In the morning, a visit was paid to Akureyri to see the outdoor heated swimming pool, public gardens and the new Lutheran church. The remainder of the day was spent in driving back to Reykjavik (Frontispiece).

Friday, 5 September 1958

Mr. Brynjolfsson called at the hotel and took the writer to meet Mr. Asgeirsson. The morning and lunchtime were spent discussing problems of concrete in Iceland and the writer was shown through Mr. Asgeirsson's laboratories (See Section 13).

At 2:00 p.m., Mr. Brynjolfsson took the writer to meet Dr. Thorarinsson with whom an hour was spent discussing frozen ground phenomena and other geological features in Iceland (See Section 2 (g)).

At 4:00 p.m., Mrs. Björnsson drove the writer and Mr. Brynjolfsson to Reykir to visit the Tuberculosis Rehabilitation Sanitorium (See Section 11) and the pumping station which pumps hot water from hot springs to Reykjavik (See Section 17).

In the evening, the Bjoranssons entertained at their home where the writer met Mr. Bjoransson's brother-in-law, a mechanical engineer with the Highways Department; various highway problems in Iceland were discussed (See Section 20).

Saturday, 6 September 1958

The morning was spent sightseeing in Reykjavik. In the afternoon, the writer made a walking tour to inspect the various building developments in Reykjavik, taking notes and photographs.

Sunday, 7 September 1958

The writer left Reykjavik at 6:30 a.m., Iceland time and arrived at New York at 7:30, Eastern Daylight Time.