ICE BRIDGING IN ALASKA

By Captain Joseph E. Staton and Staff Sergeant Clinton K. Brown II

Soldiers participating in arctic operations must deal with extremely cold temperatures, long periods of darkness, and snow-covered terrain. In these conditions, simple tasks take much longer to accomplish, and new or complex tasks are difficult to complete. Units must be prepared to live, eat, and rest in the open at temperatures far below zero. The environment is unforgiving and mistakes can be costly.

This article provides information from several references and personal observations on reconnaissance of ice bridge sites and construction of ice bridges, which are one means of increasing mobility in severe weather conditions. Under arctic conditions, mobility requires unique considerations.

Cold temperatures and rapidly freezing water are beneficial in ice bridge construction, but they also create problems. Extreme cold takes a toll on soldiers as well as equipment. Since personnel involved in this type of construction are vulnerable to frostbite and hypothermia, tents are a necessity so that soldiers, hoses, and equipment have a place to thaw out.

Ice Crossings

Ice bridges are a viable means of crossing rivers in an arctic environment, because they are inexpensive and field expedient. They free up tactical bridging assets for maneuver operations, do not need to be taken up, and potentially can carry heavy loads. Disadvantages are that they are dependent on weather, are manpower intensive (they must be monitored constantly), take 2 to 8 weeks to build, and are usable only a few months of a year.

In Alaska, the 47th and 23rd Engineer Companies conduct annual training on ice crossings. Near Fort Wainwright, the 47th constructs and maintains several ice bridges that provide land access to large arctic training areas.

Arctic Strike '96

Recently, the 47th participated in Exercise Arctic Strike '96 at Fort Greely. The unit's primary mission was mobility and evaluation of possible crossing and helicopter landing sites. The exercise was a valuable training opportunity to work directly with and provide support to maneuver and aviation elements.

Conditions for building an ice bridge were favorable. Temperatures had been well below zero for more than 60 days, and the frozen rivers provided numerous crossing sites. Most of the exercise was conducted at temperatures ranging from -30 to -57 degrees Fahrenheit. When it warmed up to -20 degrees, the wind increased and the wind chill was at or below -65 degrees. With this chill factor, preservation of personnel—or asset conservation—was more important than the mission.

Reconnaissance

The success of a river-crossing operation depends on the reconnaissance crew's assessment of possible crossing sites. The ice-reconnaissance crew is a squad-sized element consisting of a squad leader, an ice measurer, a recorder, four auger operators, and two soldiers to measure for the next hole.

The crew uses an akio sled to transport the following equipment:

- ❑ Power augers (2)
- ❑ Hand augers (2)
- ❑ Dippers (2)
- ❑ Measuring rod (1)
- ❑ Measuring tape, 100-foot (1)
- ❑ Ice axes (2)
- ❑ Fuel can, 5-gallon (1)
- ❑ Safety rope, 100-foot (1)

Before the reconnaissance begins, the crew establishes security and erects a warming tent. Then it evaluates existing ice conditions to determine the best bridging method to use and the amount of time required to establish a crossing site. Ice uniformity varies along the length of a river or lake, and its thickness depends on snow depth, water current, and springs.

An ideal crossing site meets the following requirements:

- ❑ The river channel is straight at the crossing.
- ❑ The river occupies one main channel and is wide enough to allow a slow current.
- ❑ The bank approaches are gradual (less than three percent).
- ❑ The site is not immediately downstream from creeks or streams or near open bodies of water.
- ❑ The site is near an existing road network.
- ❑ The ice is level.
- ❑ The ice is free of warm springs, sand bars, and deep snow drifts.

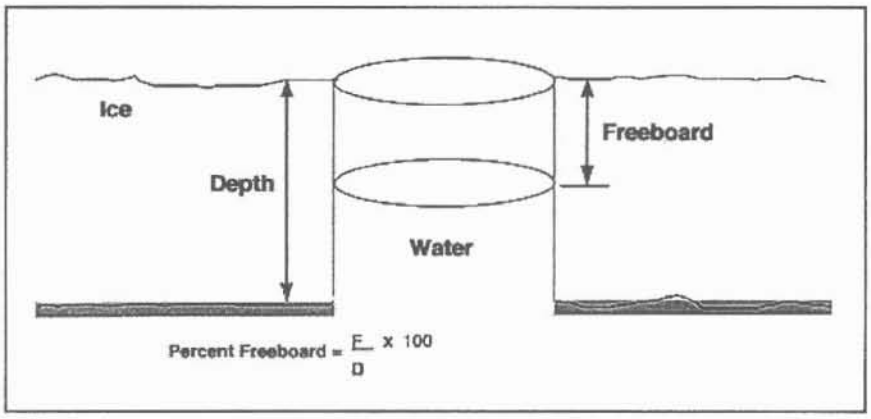


Figure 1 - Freeboard

To perform initial reconnaissance, the crew bores holes in the ice, measures its thickness and freeboard (the amount of ice exposed in the hole above the waterline (Figure 1), and completes an ice bridge profile.

The first hole is bored 20 feet downstream of the proposed centerline and 5 feet from the bank. Test hole distances and layout are shown in Figure 2. During the initial reconnaissance, the crew bores holes completely through the ice to ascertain how it is supported. They determine the bottom conditions and water depth under the ice, plot the borehole depths and the depth to the bottom, and estimate conditions between the holes by connecting the dots with a curve. Their ice bridge reconnaissance report includes:

- ❑ Date of the reconnaissance
- ❑ Individual and unit doing the profile
- ❑ Name of the bridge
- ❑ Horizontal and vertical scales
- ❑ Channel number of the bridge
- ❑ Classification data for that channel and whether the channel is critical or not (refer to the channel with the lowest military load class [MLC])
- ❑ Type of ice on the channel
- ❑ Graph showing ice and water depth and air voids

After the bridge profile is complete, the crew classifies the bridge using the following formulas:

$$W = MLC\ (wheeled) = \frac{(T^2)CS}{25}$$

and

$$A = MLC\ (tracked) = \frac{(T^2)CS}{20}$$

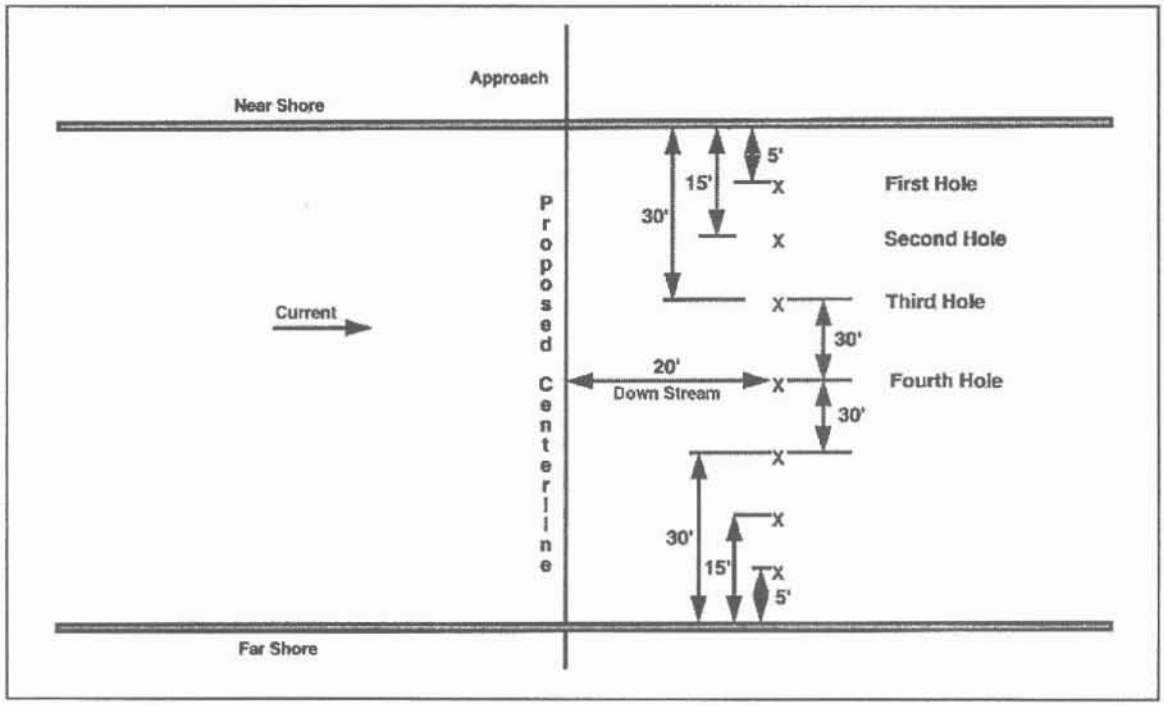


Figure 2 - Test Hole Layout

Note: To provide a safety factor, round down to the next whole number.

Where: T = ice thickness, in inches
C = color factor (Table 1)
S = strength factor (Table 2)

Table 1. Determining Color Factor of Ice

Ice Color	Factor (C)
Clear (transparent or black)	1.0
Semiclear (both transparent and black and white layers)	0.9
White (snow mixed with ice)	0.8
Discolored (stained yellow or brown)	0.7

Table 2. Determining Strength Factor of Ice

Ice Condition	Ambient Temperature	Factor (S)
Solid	Remained at or below freezing for the previous week	1.0
Solid	Above freezing during the day, below freezing at night	0.9
Solid	Water is running on the surface from runnoff or overflow	0.8
Not solid	Water or air pockets are found between layers	0.7
Has air under it	Ice is not supported by water (freeboard is <90 percent)	0.6

The reconnaissance crew determines the classification of each channel in the river based on the thinnest ice thickness found. The critical channel is the one that limits the entire class of the bridge and/or has the lowest MLC. If the ice is frozen to the bottom of the channel, it is classified as unlimited. The classification is also unlimited if 2 inches or less of water is under the ice, because the load on the bridge would flex the ice to the bottom of the channel.

A quick reference card (issued by the U.S. Army Cold Regions Research Engineering Laboratory [USACRREL]) provides information to quickly evaluate possible crossing sites (Figure 3, page 36 and Table 3, page 37). Note the distances between vehicles when using this card. The color and strength factors can be used with the card to further define the ice.

Landing Zones

When evaluating possible helicopter landing zones (LZs), consider the following:

- ❑ Helicopter spacing on ice is the same as that for vehicles (150 feet); however, helicopters must land harder on ice than usual (1.2 to 1.3 times the force of gravity) so the wheels will set down more firmly on the surface and avoid sliding.
- ❑ When evaluating lakes as LZs, bore the first four holes as if it were an ice bridge (Figure 2, page 34), then space the holes 100 feet apart.
- ❑ The MLC of static loads on the ice must be doubled (for example, a fully loaded CH-47 weighs 49,000 pounds, giving MLC 42 for ice LZs).
- ❑ When parking on ice, bore a hole 20 feet from the vehicle. If water flows out of the hole onto the ice, move to another location immediately.

Strengthening Natural Ice

If the strength of existing ice meets traffic requirements, the only necessary steps for building an ice bridge are to compact the snow layer to 2 inches, improve the approaches, and mark the centerline. If conditions do not meet the required specifications, two options are available: use standard Army bridge construction or strengthen the ice.

Ice forms naturally from the bottom of an ice sheet when the temperature is cold enough. Ice and snow are insulators and control the natural formation of ice—the thicker the layer of insulation, the slower the ice growth. The ice formation process can be speeded up by flooding the surface of existing ice where it is exposed to the air and not insulated. An ice bridge should be at least 150 feet wide to allow for ice strengthening along the entire section of the ice sheet carrying vehicular loads.

A flooding crew consists of a supervisor, a warming tent guard, an equipment operator, one to three pump operators, and a hose handler.

The type of pump used to flood the ice depends on the temperature and the pumps available. Submergible, electric pumps are best. They do not freeze up as easily since the water and ice are in equilibrium at or near 32 degrees. The 47th and 23rd Engineer Companies use surface-operated pumps (typhoon pumps manufactured by Wayjax, NSN 4320-00-Z27-5852). These pumps have gas engines that tend to freeze up every 20 to 30 minutes, requiring that they be rotated through the warming tent. Other pumps, such as chain-belt and Gorman-Rupp pumps (both with free-standing, gas-operated engines) may be used as long as the hoses can withstand sub-zero temperatures. The pneumatic tool and compressor outfit (250 cubic feet per minute [CFM] trailer) comes with sump pumps that continue to run below

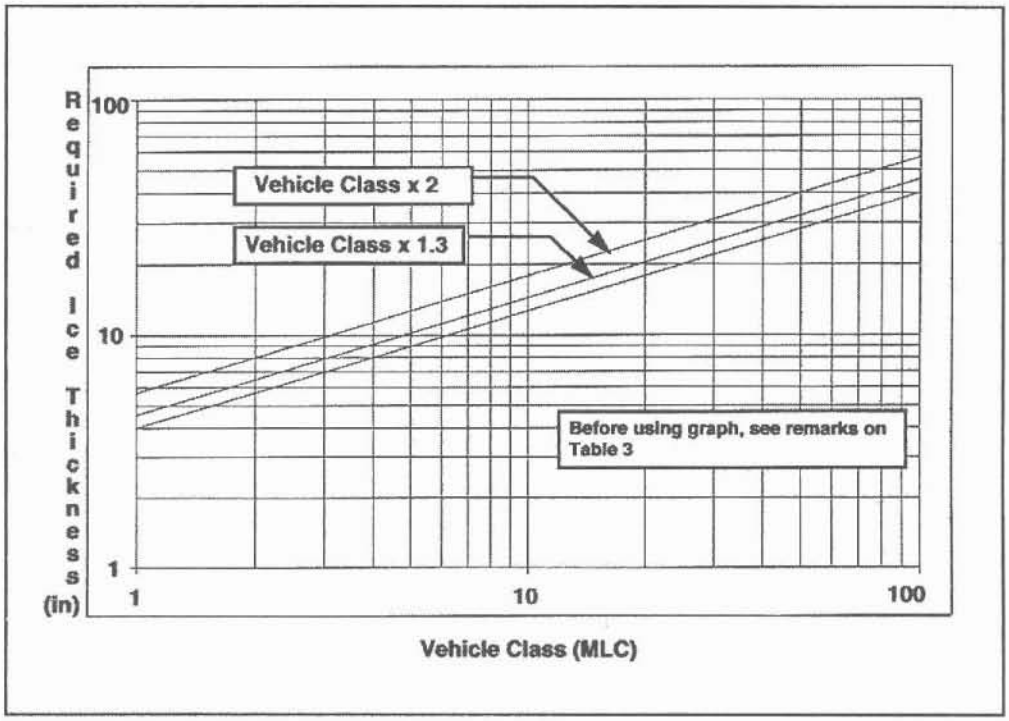


Figure 3 - Quick Reference Graph

the surface. The compressor hoses on the surface are exposed to sub-zero temperatures (down to -60 degrees). A concern is that the 1 1/2-inch hose, which operates at 100 to 200 CFM, may break and injure a soldier. However, arctic hoses that stay flexible to -60 degrees may be purchased locally.

If the snow layer is deep, pumping water on it may cause voids in the ice. Much of the snow must be removed by a crew consisting of a supervisor and equipment operators as necessary (for the SEE tractor, grader, bucket loader, snow blower, or shovel).

The snow removal crew must avoid pushing the snow into berms along the sides of the bridge area for two reasons. First, moving heavy snow from one area and concentrating it on the sides causes the ice to form into a crown in the center of the roadway. Then water applied to the center of the bridge will drain to the sides, failing to strengthen the roadway of the bridge. The crown also may develop an air pocket and become unsupported (freeboard less than 90 percent, which will not permit safe passage of vehicles). Second, ice will not form on the bottom of the ice sheet near the snow berm. This leads to thin ice along the edges, which can cause the bridge to fail (Figure 4 and Figure 5, page 38).

The crew removes the snow on the surface until the layer can be compacted to 2 inches or less. Then they flood for the first lift (layer). The flooding depth depends on the available equipment and the air temperature. Normally, one 2-inch lift can be completed in each 24-hour period. Under extremely cold temperatures, more than one layer may be applied per day. Once the first lift is completely frozen, successive lifts can be placed until the bridge reaches the desired classification. To avoid water pockets between the layers, each lift must be completely frozen before the next lift is added. The time required for the water to freeze depends on the air temperature, wind speed, and floodwater depth. As the ice thickens, the bridge takes on a dish shape because the heavy section of ice causes the water to pool naturally (Figure 6, page 38).

Bridge Maintenance

Ice bridges require daily maintenance, because river ice thickness can change daily. The thickness also varies throughout the winter and in different locations on the river. Thickness of river ice depends on the current strength and temperature variations (air and water). The critical ice channel depth must be checked and the bridge capacity reclassified daily. Constant travel over the same path may cause the ice to become thin in that area.

If temperatures rise above freezing, all channels of the bridge must be checked. During the daily check, look for changes in the color of the ice and strength factor requirements. Compact new snow to 2 inches or less and flood or remove the excess. If temperatures remain below freezing, check all of the channels every 3 days. If any of the channels must be strengthened, traffic cannot cross until the lift has frozen completely. When the ice bridge is thick enough to support the heaviest crossing vehicle, spread and pack 1 to 2 inches of snow over the roadway to provide traction and a wearing surface.

Table 3. Field Guide Quick Reference Card

Vehicle Class (wheeled or tracked)	Required Ice Thickness (inches = $4\sqrt{\text{veh class}}$) (in)	(cm)	Distance Between Vehicles (about 100 x thickness [in cm]) (ft)	(m)
200 lbs	2	5	17	5
1	4	11	34	11
2	6	15	48	15
3	7	18	58	18
4	8	21	67	21
5	9	23	75	23
10	13	33	106	33
15	16	40	130	40
20	18	46	149	46
25	20	51	167	51
30	22	56	183	56
35	24	61	198	61
40	26	65	211	65
50	29	72	236	72
60	31	79	260	79
70	34	85	280	85
80	36	91	300	91

Before using table, see remarks below:

1. If the air temperature has been above freezing for more than 6 of the past 24 hours, multiply the vehicle class by 1.3 to obtain the required ice thickness. If the air temperature stays above freezing for 2 hours or more, the ice starts to lose strength, and the table no longer represents safe conditions. A rapid and unusually large temperature drop causes the ice to become brittle, and travel may not be safe for a period of 24 hours.
2. For the distance required between two vehicles of different classes, use the distance required for the higher class.
3. If you plan to park for extended periods, multiply the vehicle class by 2 to obtain the required ice thickness and maintain at least the original distance requirements. Drill a hole through the ice near the vehicle and move if the ice begins to flood.
4. The ice must have water support. Be very careful close to shore. Very often the water level will drop after freeze-up. When this happens, the ice close to the shore may no longer have water support.
5. Cracks are either dry or wet. If dry, they do not penetrate ice cover and can be ignored. If wet, multiply the vehicle class by 2 to obtain the required ice thickness and try to drive straight across the cracks (avoid going parallel to wet cracks).

During construction, cracks will appear everywhere in the ice bridge and loud snaps may be heard. The noises are caused by the thermal expansion and contraction of the entire ice mass and do not indicate failure of the bridge itself. Many cracks are caused by sudden changes in temperature. These are usually dry and do not weaken the bridge. They can be flooded and refrozen if desired. If a vehicle crosses that is classified at or above the bridge load class, wet cracks may form. They will refreeze, strengthening the bridge. If the temperature is below freezing, harmless cracks perpendicular to the flow of traffic will be visible.

If the bridge banks have a slope greater than 3 percent, use snow to reduce the slope. Pump water on a snow pile to make wet, heavy snow, which is good for construction. The snow pack will freeze and the 1- to 2-inch snow cover acts as a wearing surface.

Air voids normally occur near river shores because the water recedes after the initial freeze. Ice that is not supported by water is very weak. Breaking the ice sheet and setting it back on the water will greatly increase the strength of the ice. Use a wrecking ball and crane to break the ice, or load it with enough wet snow to cause it to break. Boring holes in the ice will also help. If the ice sheet does not break up, try another location. Push dirt or snow over the ice to the supported area of the bridge, especially near the banks, or use planks to move the load to the supported ice.

Crossing an Ice Bridge

Mark ice bridges like any other river crossing as shown in FM 90-13. Place signs near the bridge to inform drivers of safety precautions. Place a marker 150 feet from each shore to determine the proper vehicle spacing on the bridge.

Before vehicles are allowed to cross, drivers must be aware of the following safety precautions:

- ❑ Bridge classification is for one-way traffic only.
- ❑ Avoid crossing if the vehicle classification exceeds the limits of the bridge.
- ❑ Passengers need not dismount or open doors during a crossing.
- ❑ Stop vehicles before driving onto the ice bridge to reduce the impact.
- ❑ Space vehicles at least 150 feet apart.
- ❑ Maximum speed on the bridge is 10 mph. Keep vehicles in the lowest gear possible. Driving too fast may create a wave ahead of the vehicle and cause the bridge to fail.
- ❑ Avoid stopping on the bridge. A sudden application of brakes increases the weight pressure of a vehicle, especially in the front wheels.

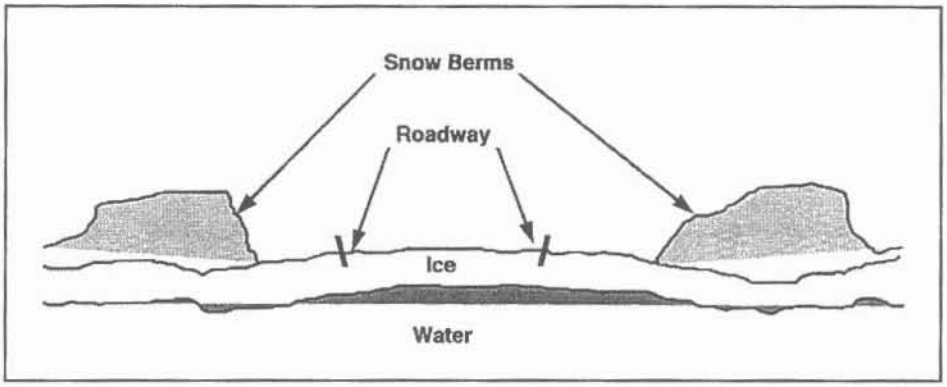


Figure 4 - Cross Section of Bridge and Berms

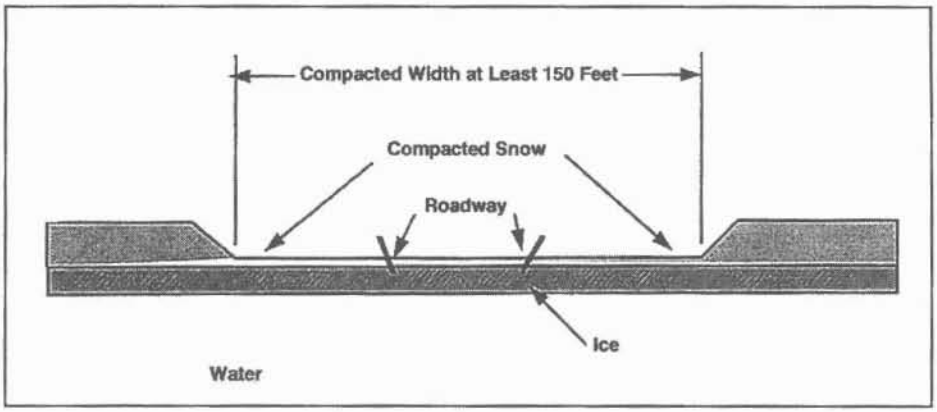


Figure 5 - Cross Section of Snow Compaction

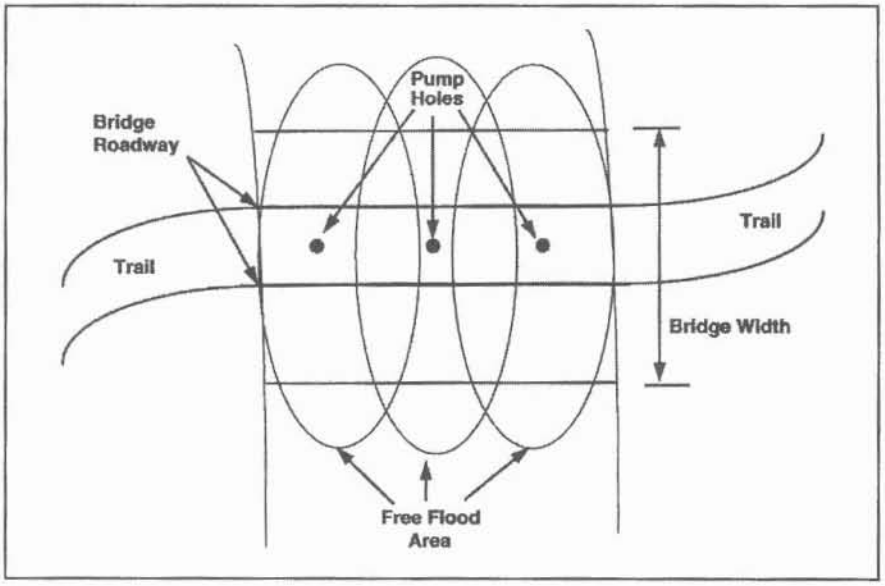


Figure 6 - Location of Pump Holes for Flooding the Bridge

- If parking on the ice is unavoidable, double the vehicle classification and bore a hole 20 feet from the vehicle. If water surges out of the hole and floods the ice, move the vehicle immediately.

Prepare a recovery plan for vehicles that break down on the ice bridge. During recovery, vehicles should not exceed the 150-foot spacing requirement unless the combined load is less than the bridge classification. If the combined load exceeds the classification, chose another recovery method. If the ice fails, a team must be prepared to react quickly. A slow response could allow ice to form around the vehicle, requiring demolitions to free it. The first vehicle at or near the maximum bridge classification should have a tow cable connected to the pintle and thrown on top of the vehicle to aid in recovery.

Conclusion

Engineers must be prepared to deploy anywhere in the world and to provide expertise in many areas. In cold environments, the battlefield may require that they build ice bridges to gain access to critical regions. Ice can enhance maneuverability for both vehicular and air mobile traffic. A thorough knowledge of ice bridging allows engineers to overcome one of the major problems faced in cold-weather operations.

References

1. 6th Infantry Division (L) Pamphlet 350-11, *Squad Leader's Guide for Constructing Ice Bridges*, October 1986.
2. USACRREL Report 76-29, *Failure of an Ice Bridge*, August 1976.
3. USACRREL Report 85-18, *Snow in the Construction of Ice Bridges*, October 1985.
4. USACRREL Report 93-12, *On Winter Warfare*, June 1993.
5. Technical Manual 5-349, *Arctic Construction*, 19 February 1962.
6. Field Manual 90-13, *River Crossing Operations*, 30 September 1992.

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Engineer Problem

Using the information provided in the above article, test your knowledge by completing the following exercise.

Situation: Your company is deployed to a remote cold-weather region. The task force commander directs a reconnaissance of a possible ice bridge crossing site. The platoon you task to perform the reconnaissance provides the following report:

- ❑ Critical ice thickness = 43 inches
- ❑ Water depth below the ice = 60 inches
- ❑ Type of ice = Semiclear with dry cracks
- ❑ Temperatures have been below freezing for at least a week
- ❑ Freeboard = 25 percent
- ❑ Width of river = 600 feet
- ❑ Critical channel width = 335 feet

Use the equations on page 37 to determine the following:

1. Determine the military load classifications (MLCs) of the bridge for wheeled and tracked vehicles.
2. Determine how long it takes to increase the strength of the bridge to safely cross an M1A1 tank if temperatures remain below zero.

Engineer Solution is on page 47.