Waterborne Transportation in Cold Regions
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Outline

- Climate Change and Northern Sea Routes
- Transpolar vs Destinational
- Ice-Breaking vs Ice-Hardened
- Multi-modal facilities
- Barge landings
- Inland waterway systems
- Winter operations
- Problems and solutions
- Example – Gyeong-In Ara System
Why Waterborne Transportation?

Equivalent Units

ONE BARGE
13.4 JUMBO HOPPER CARS

ONE 15-BARGE TOW
TWO 100-CAR TRAINS

58 LARGE SEMIS
870 LARGE SEMIS
Climate Change and Potential Sea Routes

- When will it occur?
- How much will occur?
- How much traffic can we expect?
- Which route?
- What type of ships?

Rotterdam to Yokohama
20,600 km by Suez Canal
8,500 km by NSR
Transpolar

- Shorter transit
- Major ports (Asia, Europe, US)
- Less pirates?

Destinational
Ice Breakers vs Ice Hardened

Vessel Draft
Ice thickness
Power
Need for escort
Ice Breakers USCG Healy and CCG Louis S. St. Laurent
Types of Marine Facilities

Port of Anchorage

multi-modal

Lightering at Red Dog

Typical Western Alaska barge landing
Inland Waterway Systems

- Rivers and Canals
- Hydraulic Structures
- River Ports

The U.S. has 17,000 km of waterways where 1.1 billion tons move annually. Half on Mississippi R. System, 76 locks and dams with ice problems.
Winter navigation on inland waterways

- Common ice problems at locks and dams
- Structural Solutions
- Operational Solutions
Common Ice Problems at Locks

- Ice congestion in the upper lock approach
- Brash ice in the miter gate recess
- Ice on the miter gates
- Ice buildup on lock walls and gate recesses
- Brash ice in the lock chamber
Brash Ice in the Miter Gate Recess

Consequences:

• Gates cannot open fully
• Tow size restrictions, decreased capacity
• Damage to gates and support mechanisms

Solutions:

• Pike poles and ice rakes
• Gate fanning
• High flow bubblers
Ice Buildup on Lock Walls and Gate Recesses

Consequences:
- Gates cannot open fully
- Tow width restrictions, decreased capacity
- Damage to miter gates and support mechanisms

Solutions:
- Chipping
- Steam & hot water
- Electric heaters
- Low-adhesion materials and coatings
Brash ice in the Lock Chamber

Consequences:

• Insufficient space for barges or vessels
• Problems opening lower miter gates
• Difficult to flush ice from upper end of chamber
• Grounded barges at low pool

Solutions

• Ice lockages
• Width restrictions
• Towboat assistance
• Manifolds in upper miter gates
• Reduce ice in upper approach
Icing of Miter Gates

Consequences:
Gates cannot open fully
Tow width restrictions, decreased waterway capacity
Excessive weight on gate and support mechanisms

Solutions:
Chipping
Low-flow ice-suppression bubblers base of gate
Enclose trusswork, apply steam heat to interior
Redesign with skinplate on upstream side of gate
Ice congestion in the upper lock approach

Factors:
- Ice supply
- River discharge
- Wind, Ta, Tw
- Project configuration w.r.t. upstream channel

Consequences:
- Brash ice congestion of lock chamber and miter gate recesses
- Ice in lock-filling intakes, valves
- Delays to navigation

Existing Solutions:
- Ice lockages
- Divert ice to dam gates, around river wall or through drift pass
- Skim ice over submergible lift gates or bulkheads
- Deflect ice with towboats or barges
Clearing Ice from Upper Approach

Skimming ice over bulkheads in aux. Lock on Ohio River

Deflecting ice with high-flow air curtain Soo Locks Physical Model at CRREL

Skimming ice over lift gate at Mel Price Lock on Mississippi River

Widening drift pass at Lock and Dam 25 on Mississippi River
High Flow Bubblers

- Sill curtain
- Gate recess flusher

Electric or diesel
230-300 m³/min compressors
Valve manifolds
Persistent Ice Problems at Locks

Lock Wall Icing

Miter Gate Icing

Brash ice pushed into the lock

Lock wall Icing

Normal lockage time = 45 minutes
Lockage time in heavy ice = 2 to 12 hours
Common Ice Problems at Dams

- Ice in the fore bay
- Passing breakup ice runs and floods surges through the structure
- Gates frozen in
- Icing on the control gates
Tainter Gate Icing

Spray

Leakage
A River Ice Management Plan for the Gyeong-In Ara Waterway
Korea Water Resources Corporation (K-water) funded Hyundai C&I design build Navigable waterway from West Sea at Incheon to Han River at Seoul Flood damage reduction in Gulpo Basin Economic boost through industrial traffic, tourism, culture, leisure $2.1B (USD) project constructed between March 2009 and May 2012 Water quality and ice concerns
18 km navigation channel excavated into natural channel of Gulpo
Incheon Terminal at the West Sea (Industrial port with bulk and container cargo)
   2 sliding lock gates into turning basin
   Control gates maintain water levels
   West Sea tidal range is 10 m
Gimpo Terminal at the Han River
   Industrial port
   Recreational marina
   Conventional miter gate lock to Han River
Recreational features along waterway (bike paths, parks, waterfalls, etc)
Ship traffic intended to include sea-river ships (above), bulk, ferries
Container transport, bulk materials, recreational tourism
20% of width, 15% of area by single vessel at 12.5 km/hr (77 min transit)
2/wk bulk cargo, 2/day container vessels, 14.6/day passenger
Tidal range at the West Sea is almost 10 m (-4.45 to +5.30 m)
Waterway operational level is 2.70 m so periods of flow into the Incheon terminal from the West Sea as well as out of the terminal
Flow reversals throughout the canal
Intended operation always brings 10 m³/s in from Han River (elevation ~4m +/-)
Incheon Terminal
- 2 sliding gate locks
- 4 vertical lift gates to maintain water level in waterway at 2.70m
- Bulk material storage
- Container storage and transfer
- Ferry terminal (Incheon Airport to Seoul)
- Large turning basin

Gimpo Terminal
- Turning basin
- Marina
- Lock with miter gates (multiple)
Cold spell in 2010-2011 allowed measurement of ice thickness in main waterway under construction. Water levels not controlled or at operational levels. Some level fluctuation evident by shore cracking.

Maximum thickness 17.5 cm. Winter temperatures considered very cold by locals. Generally little precipitation during winter.
Potential Ice Problems in the Gyeong-In Ara

Brash ice development from continuous breakage
Increases thickness, friction on vessels,
accumulation in turning basins, blockage at control
gates and locks

Control gate icing
Lock wall and recess icing
River Ice Management Plan

System-wide analysis of the waterway
Account for issues that may arise from winter operation
Three objectives:
  • navigation during periods of ice should be conducted with the highest possible efficiency, approaching that of the non-ice affected season
  • interruptions due to ice impacts should be kept to a minimum and their duration should be as short as possible
  • if a specific ice issue does arise, all technically feasible and reasonable ice-problem solutions will have already been identified and implemented

Addresses problems through a combination of structural and operational solutions
Structural Solutions

Prevent ice from forming or removal from surfaces
- Wall heaters
- Gate seal heaters
- Gate face heaters
- Steam, electrical, coatings

Move ice away from problem areas
- Gate recess flushers
- Line bubblers
- Vertical mixers

Operational Solutions

Convoying, single track, ice prows
- Propeller wash for directing ice
- Ice lockages, pike poles, rakes
- High water level in locks
Unkowns

Included the effects of:
Warm water inflow from Gulpo River (WWTP’s)
Flushing action of tides
Vessel traffic on ice thickness, breakage
Ice accumulation in turning basins
Ice accumulation in locks (ice locakges)
Passage of ice through control gates
Passage of vessels during ice cover
Ice impacts on marina at Gimpo Terminal
Ability to maintain constant levels (especially at Incheon)
Water quality requirements
Operation during summer high rains
The recommended River Ice Management Plan

Plan for first few years
   Learn actual conditions
   Use simple, low-cost management techniques

Develop an ice monitoring program
   Establish key monitoring stations
   Measure ice formation, development, melt

Develop an ice forecasting program
   Use spreadsheet model (temperatures, dates)

Prepare Emergency Response Plan
   High risk, high cost problems

Adapt to actual conditions
   Modify operations and plans as conditions dictate
   Add structural components if necessary
Questions???

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