

Underwater Bubble Jetting Effects on Infrastructure Infrastructure Protection Vulnerability Analysis and Mitigation

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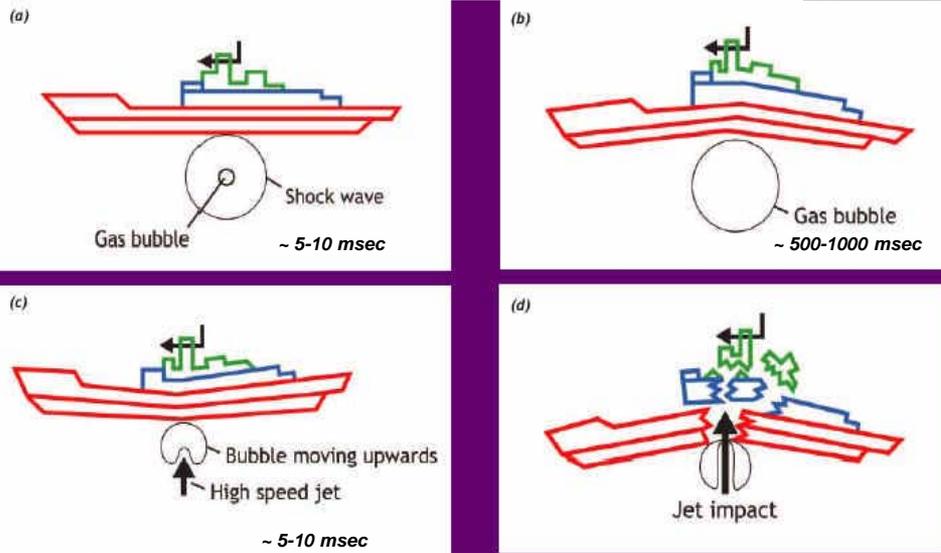
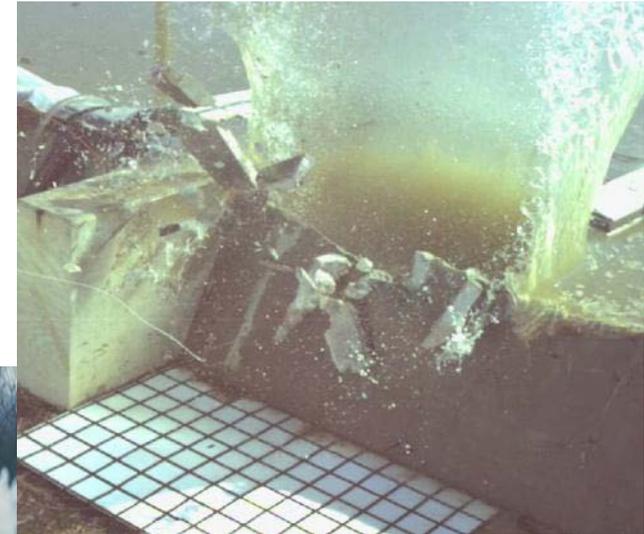
Contributors

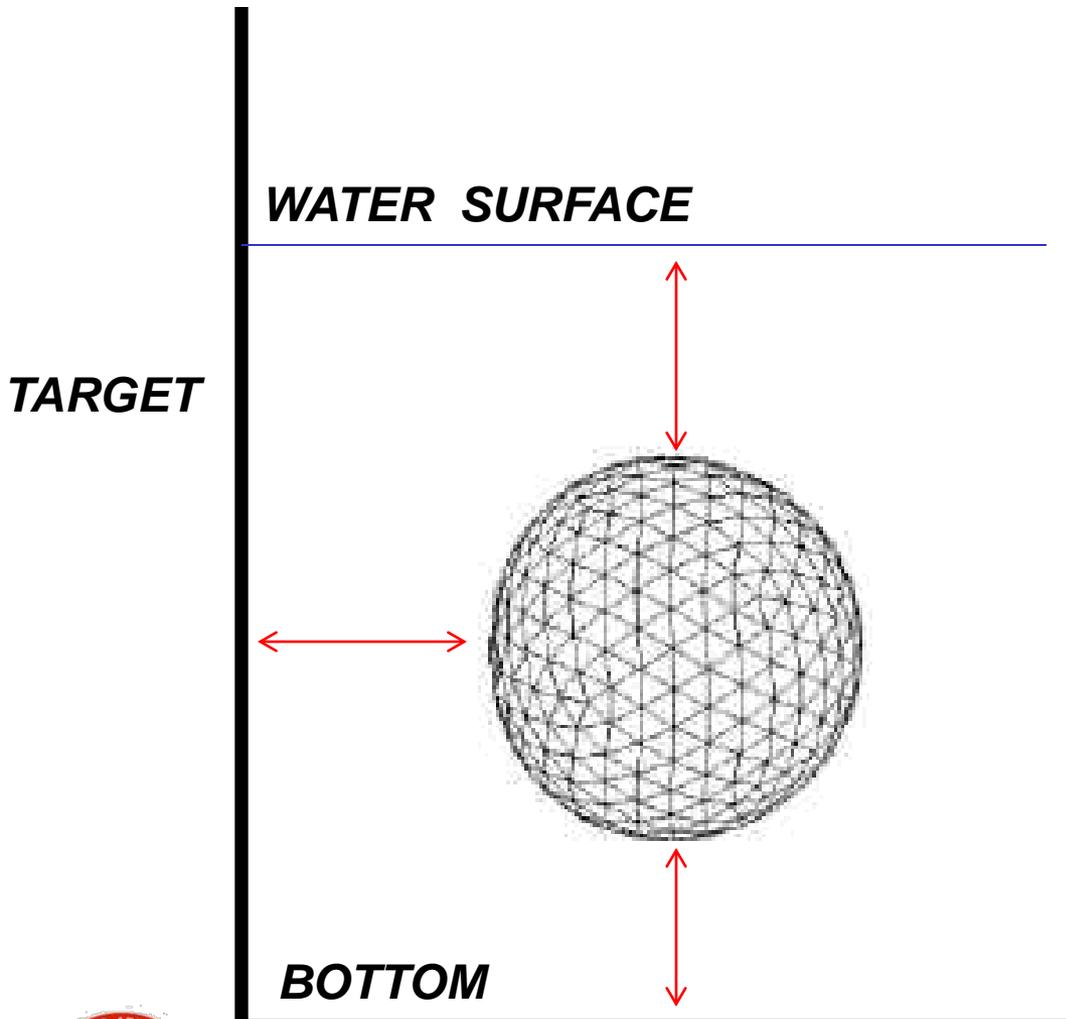
- ERDC: Response of dam structures, Computational effort, Combined Testing, Engineering Model development and implementation
- Navy
 - Naval Surface Warfare Center/Indian Head Division: Computational efforts, performance of small scale tests, lead group and Small-scale Test Site
 - Dynaflo, Inc.: Performance of Spark Gap Tests, determination of bubble parameters





Objective: Determine effects of Bubble Jetting loads from an Underwater Explosion (UNDEX)



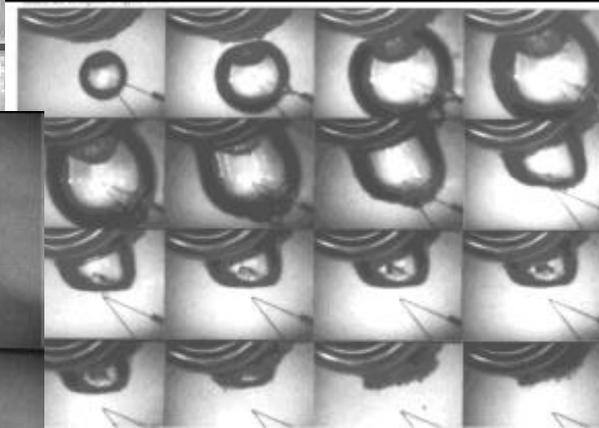
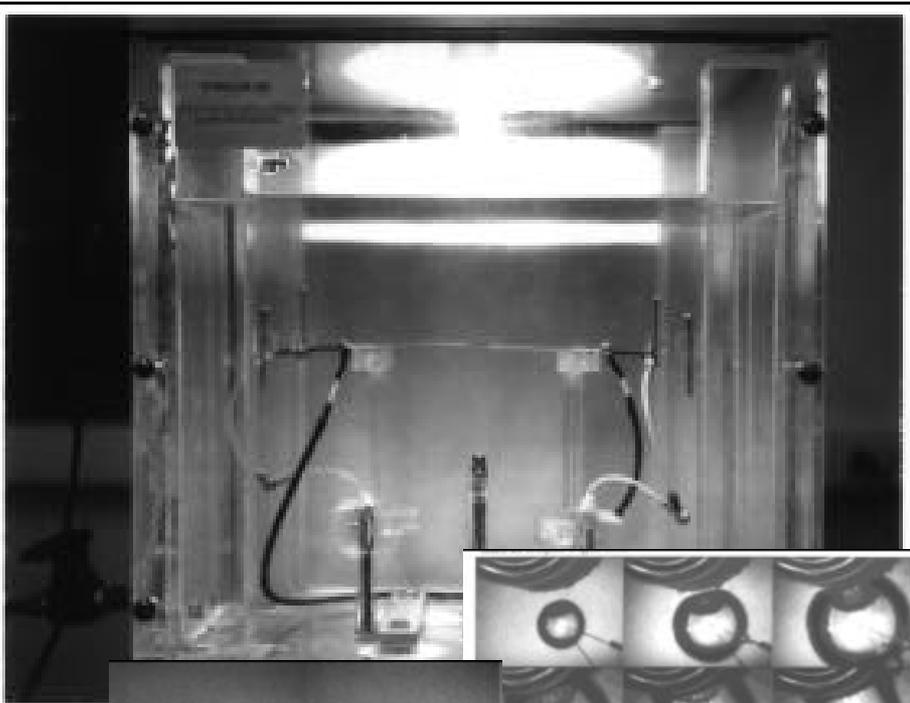


- Where does explosion need to be to cause jetting to occur?
- What is the loading generated by the jetting?
- What is the response of the structure?
- Historically, the problem of a vertical target has not been extensively quantified

Experimental Series

	Bubble Dynamics (Visual)	Scale	Scaled?	Pressure Data	Structural Response?
Spark Bubble Tests	✓	Very small	Yes	~	No
Carderock Pond UNDEX Tests	✓	Small	No	✓	No
ERDC Small Scale Tests	✓	Small	No	No	✓
ERDC Pond UNDEX Tests	No	Medium	No	✓	✓
ERDC Mitigation Tests	Yes	Small	No	✓	✓

Spark Gap Bubble Tests



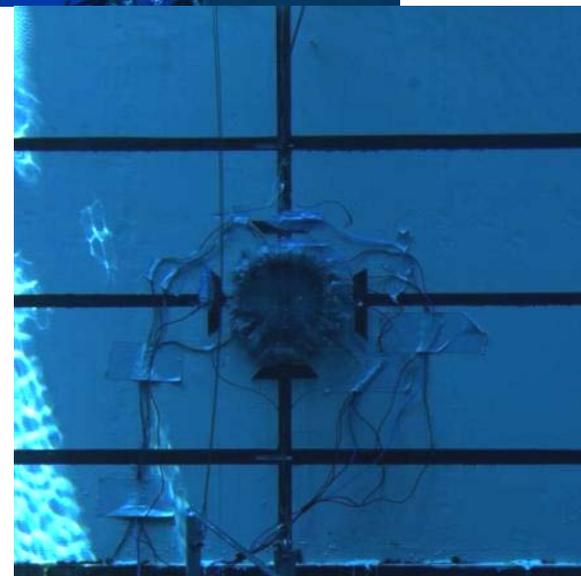
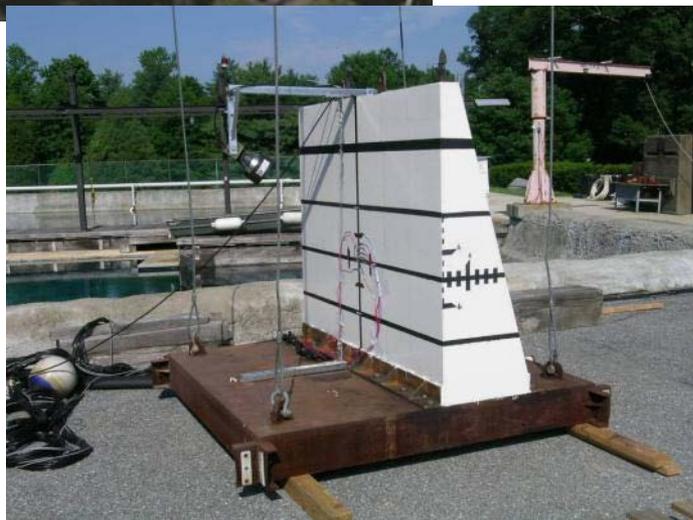
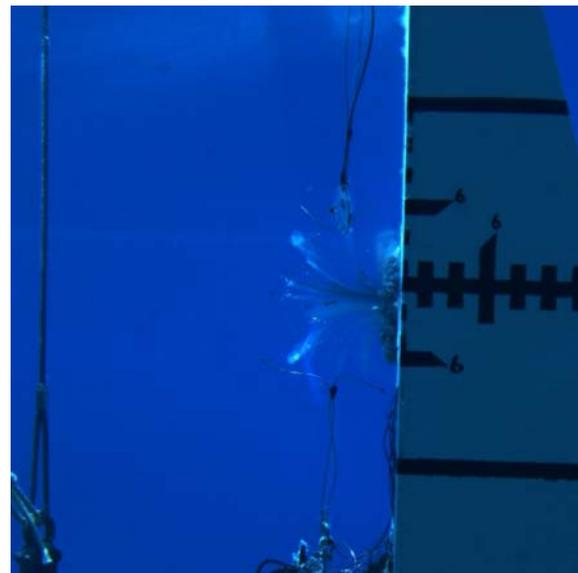
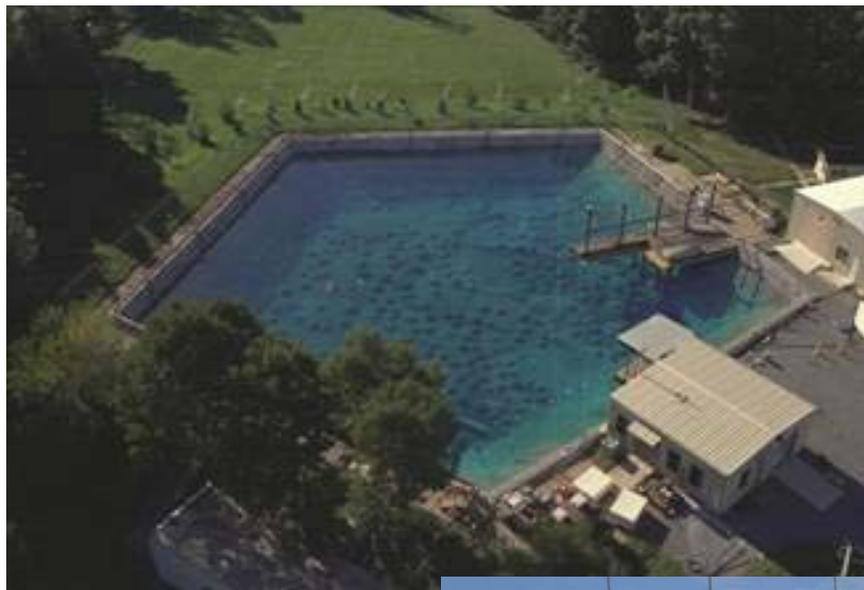
- Georges Chahine at DynaFlow
- Laboratory scale models of UNDEX bubble dynamics
- Shock loading is not modeled
- Gravity equivalent induced through depressurization of “atmosphere”
- Long history of use by the Navy
- Clear visualization of phenomenon
- Relatively simple to perform
- Parametric studies can be greatly supplemented
- Limited study of vertical targets and shallow water effects

Small-Scale UNDEX Tests

- **Objective: to provide actual UNDEX test data for bubble dynamics and surface pressure loads**
- **To be conducted in NSWC/Carderock test pond – existing facility**
- **UNDEX event next to “rigid” plate**
- **Record free field and surface pressure measurements and high speed underwater photography**
- **Design small scale test conditions to replicate findings of the jet parameter study**
- **Provide validation data for BEM and DYSMAS analyses**



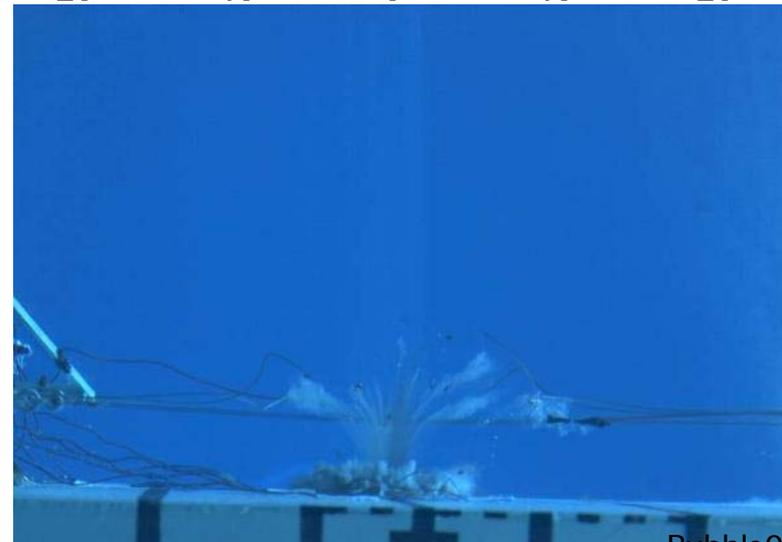
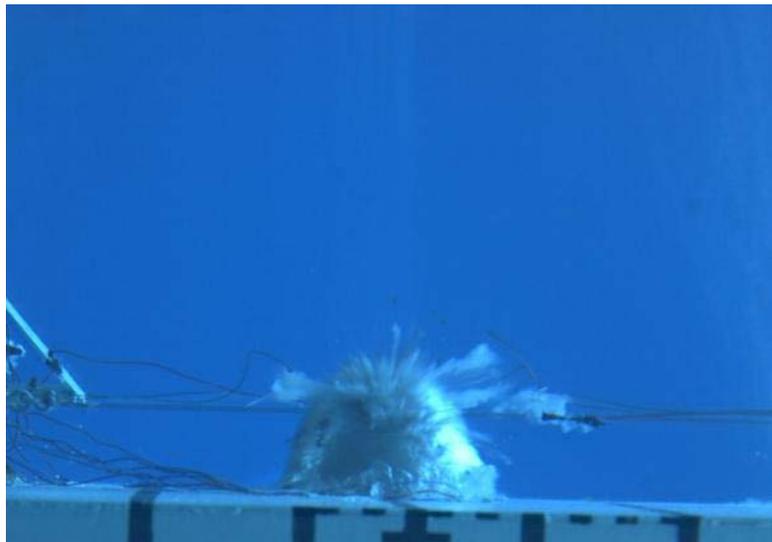
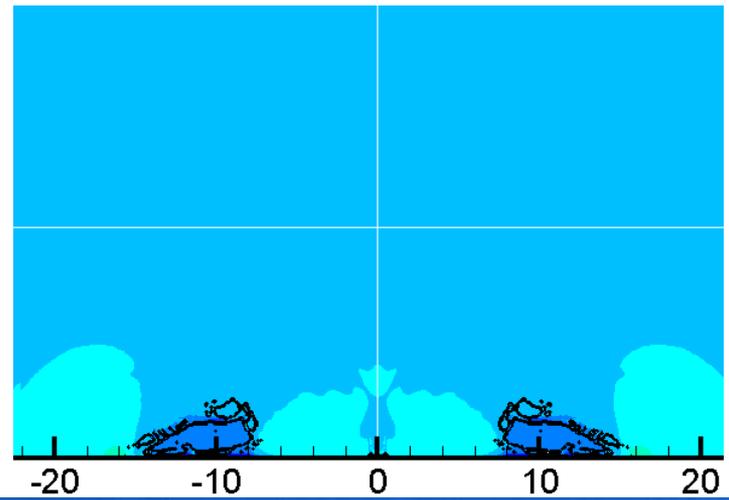
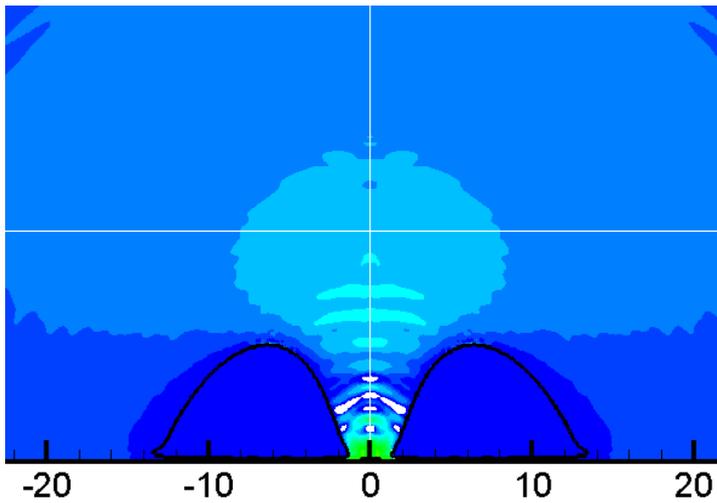
NSWC/Carderock Test Series: Results



- 135' /side
- water depth ~25'
- observation viewport in side



Carderock Test Series: Results

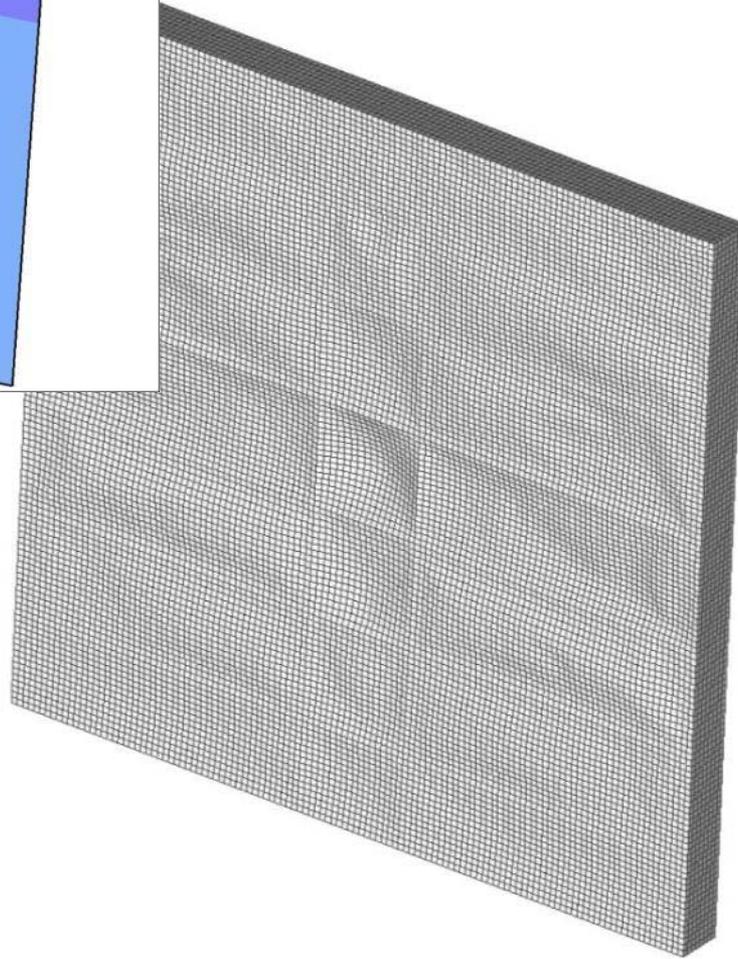
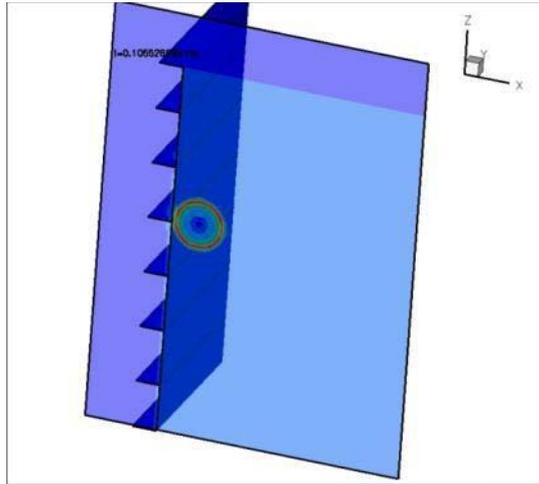


Bubble09.wmv

Larger Scale Test

- **Performed at ERDC basin**
- **Use bubble jet to inflict damage to a steel structure**
- **Approximately 10' Gate-like steel structure**
- **Will not be a “Scaled” Test**
- **Provides invaluable validation data for entire bubble jetting and structural response process**

Larger Scale Test

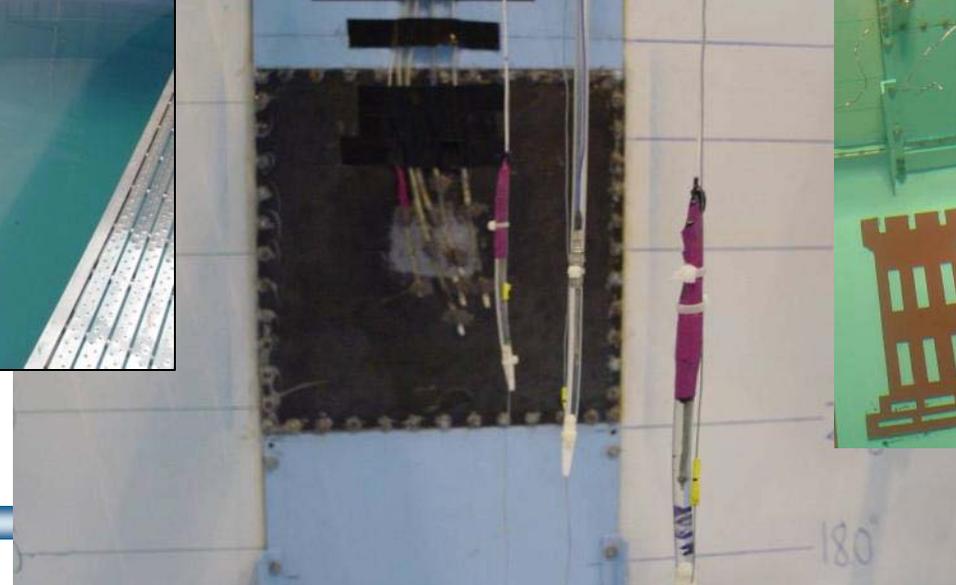
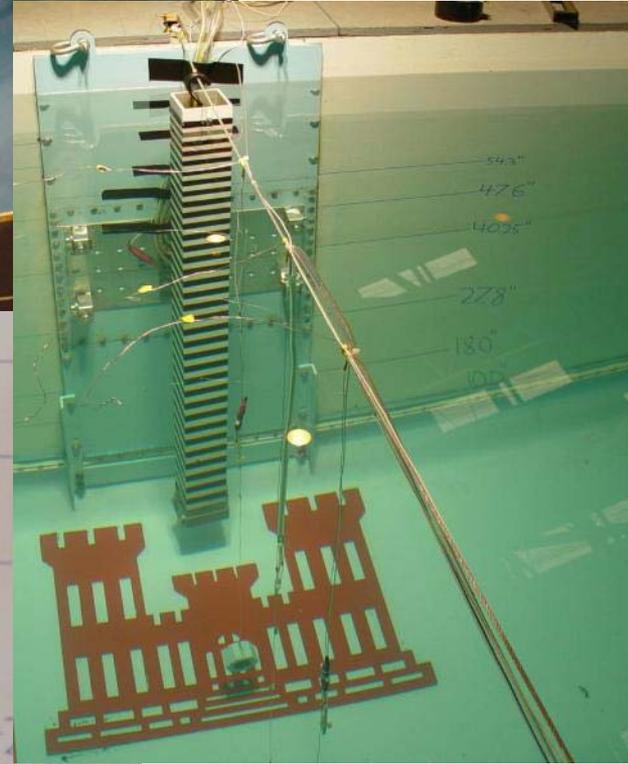
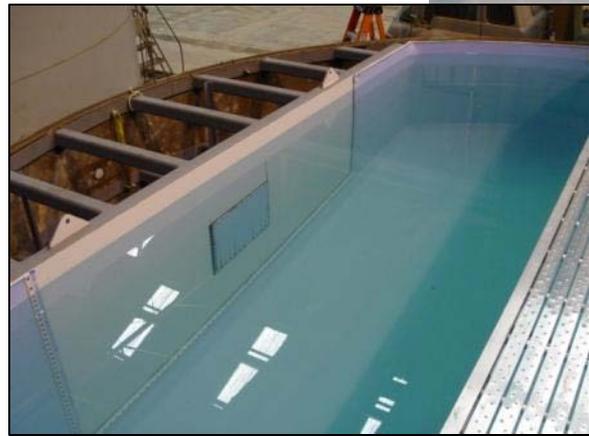
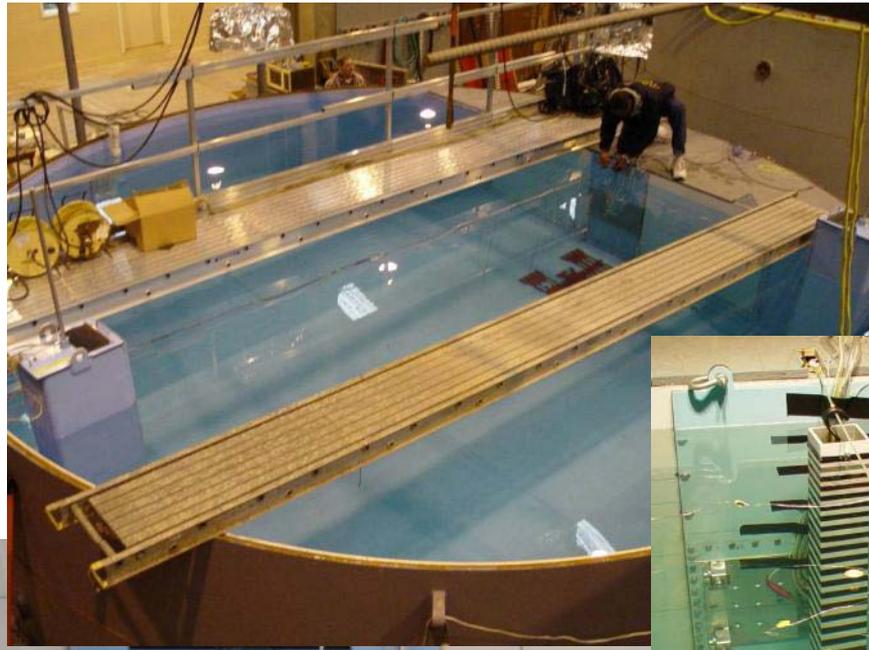


Current Mitigation Test Series

- **Performed at ERDC**
- **Pond constructed inside for ease of use**
- **Including:**
 - Air gap structure
 - Bubble screens
 - Air filled tubes
 - Water jets/Flow
 - Solid bars
- **Vary Detonation Depth – observe effect of surrounding surfaces**
- **Phenomenological Bubble Tests with DetaSheet**
- **Limited tests against concrete panels**

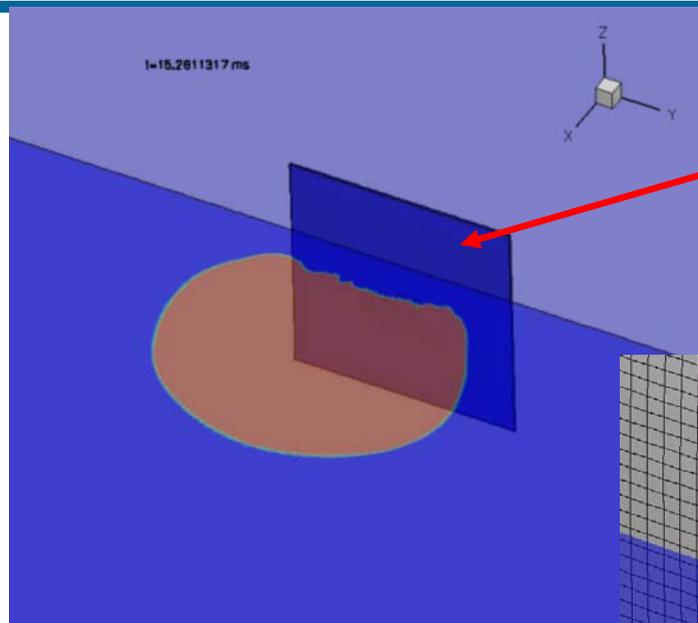
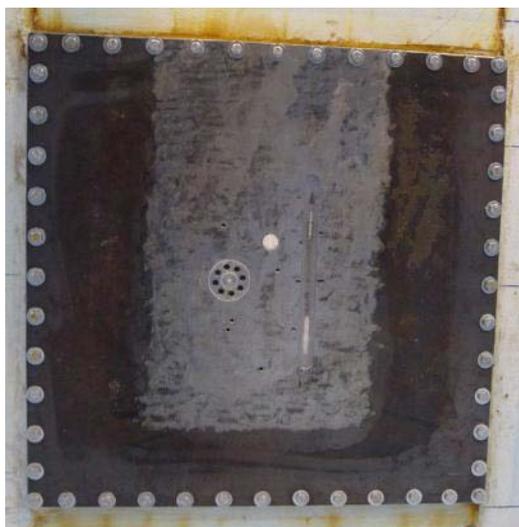


Mitigation Bubble Jetting Experiments

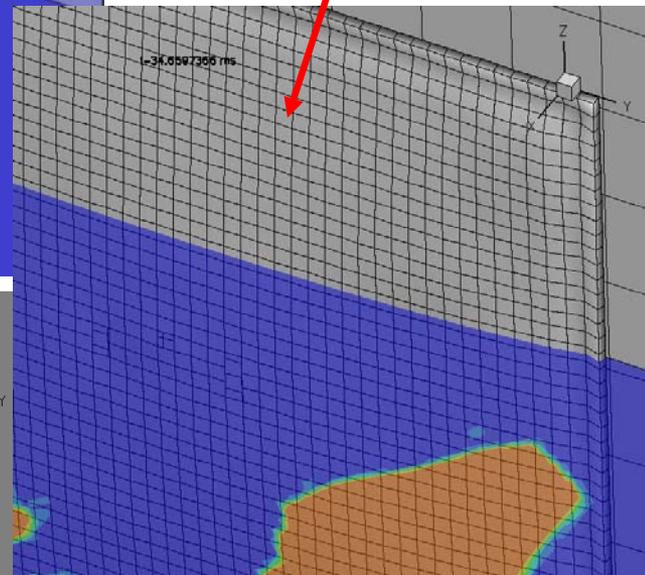


Numerical Mitigation Concepts

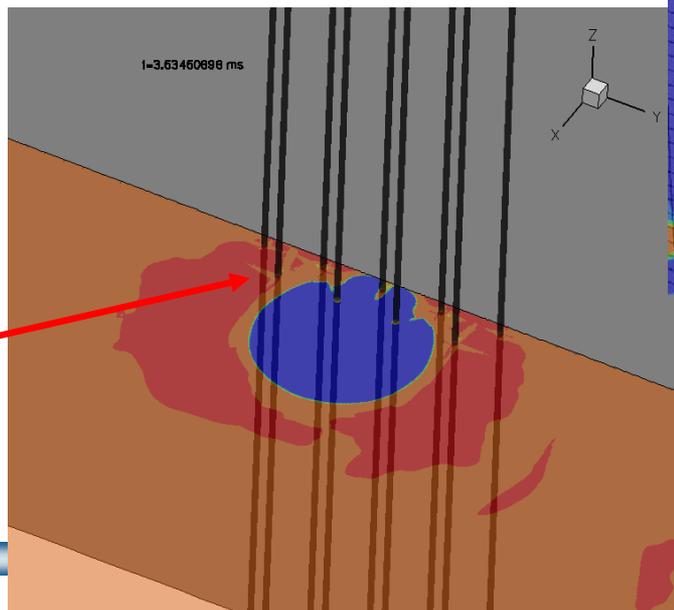
**Mitigation schemes
attempting to
interfere with Jet
load on structure**



Air Filled Box



Solid Pipes



Summary

- Investigating Bubble Jetting effect on vertical structures in shallow water
- Testing at various scales to study:
 - Effect of parameters on jet
 - Loading from the jet
 - Structural response
- Corresponding Numerical Simulations
- *Mitigation Concepts against Jetting*
- *Future: Concrete Structures*

