

# Field test series for development of mitigation barriers and its designs against hydrogen explosion

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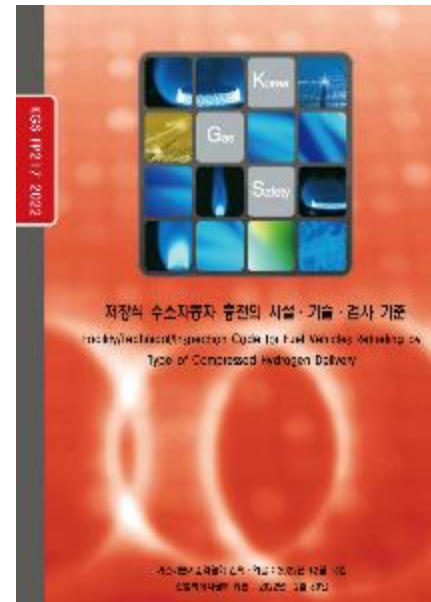
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# Motivations of Project

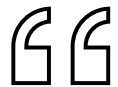
- Explosion of hydrogen tanks in South Korea (2019.5)
  - Consequences are 8 victims (2 fatalities), property loss up to 26.8 M Euros
  - Findings are *no blast mitigation* prepared; and significant *overpressure beyond 30 m*
- National research projects for safety of hydrogen infrastructures (2021.5)
  - One is to find out *safe designs of blast mitigation barrier in HRS*
- Hydrogen Safety Management Roadmap 2.0 (released by MOTIE, 2023.5)
  - To *improve regulations* based on *evidence* including safety distance, mitigation, etc.



Consequences of the incident (2019.5)



## Definition



Wall made of *reinforced concrete higher than 2,000 mm and thicker than 120 mm*, or **structures with comparable strength**



Allowed structures are,

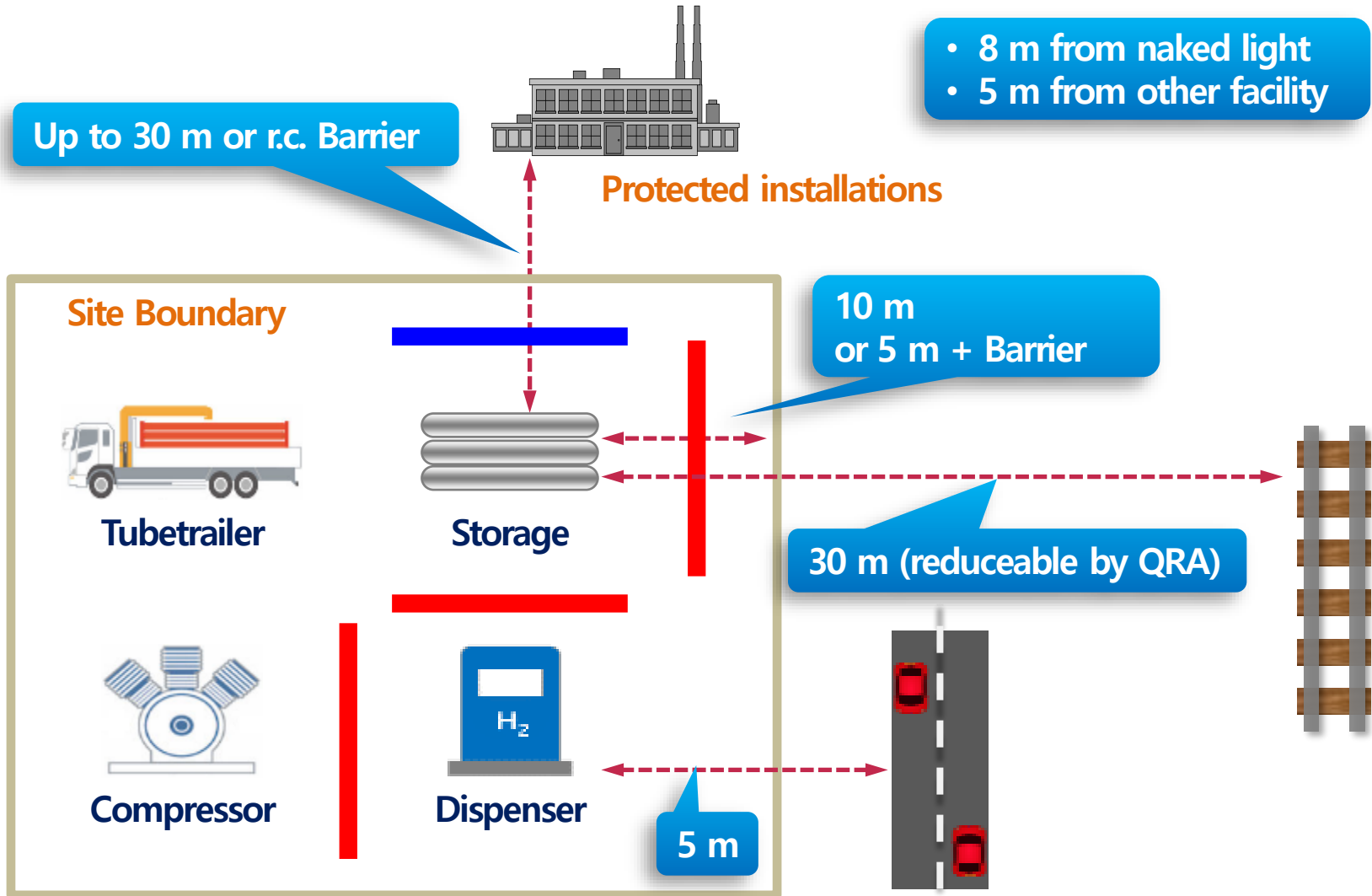
- Steel plates on RC foundation
- Stack of concrete blocks

## Cited by

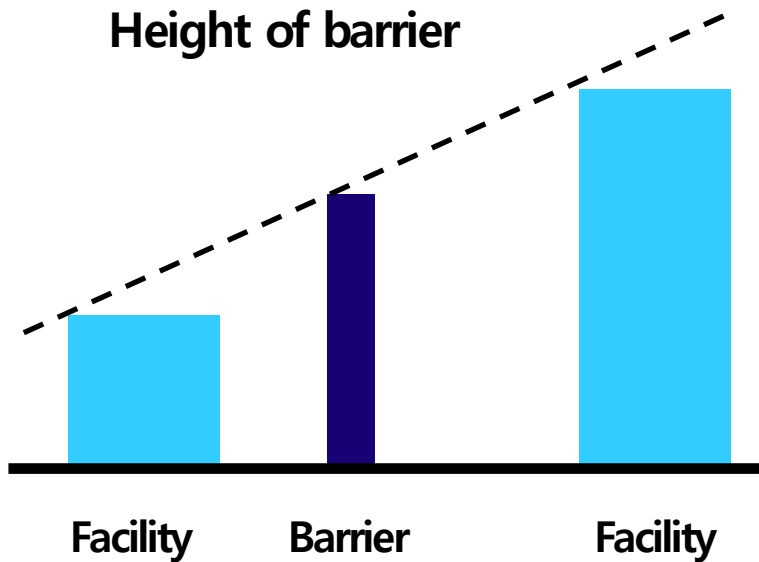
- KGS FP 111: Specified Production of High-pressure Gases
- KGS FP 112: Production of High-pressure Gases
- KGS FP 211: Filling of High-pressure Cylinders and On-board Tanks
- KGS FP 216: Hydrogen Stations (on-site production type)
- KGS FP 217: Hydrogen Stations (off-site production type)

# Mitigation Barriers in KGS Codes

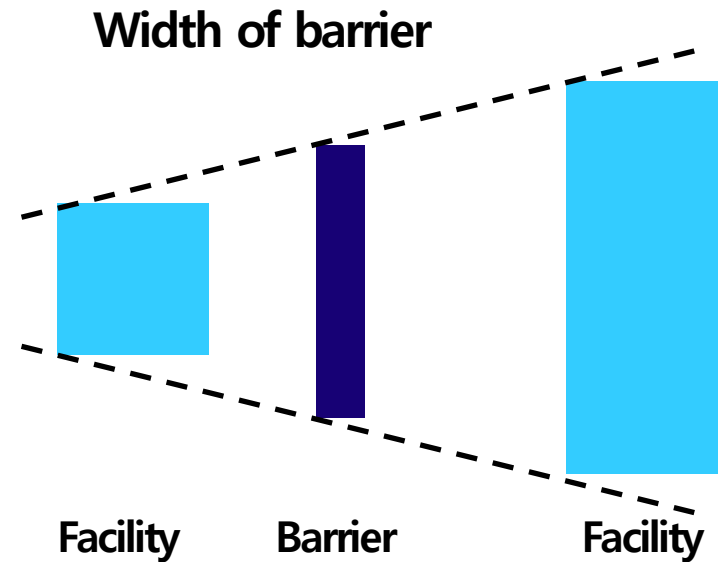
## Layout | Safety Distances and Barriers



## Sizing | Minimum Height and Width



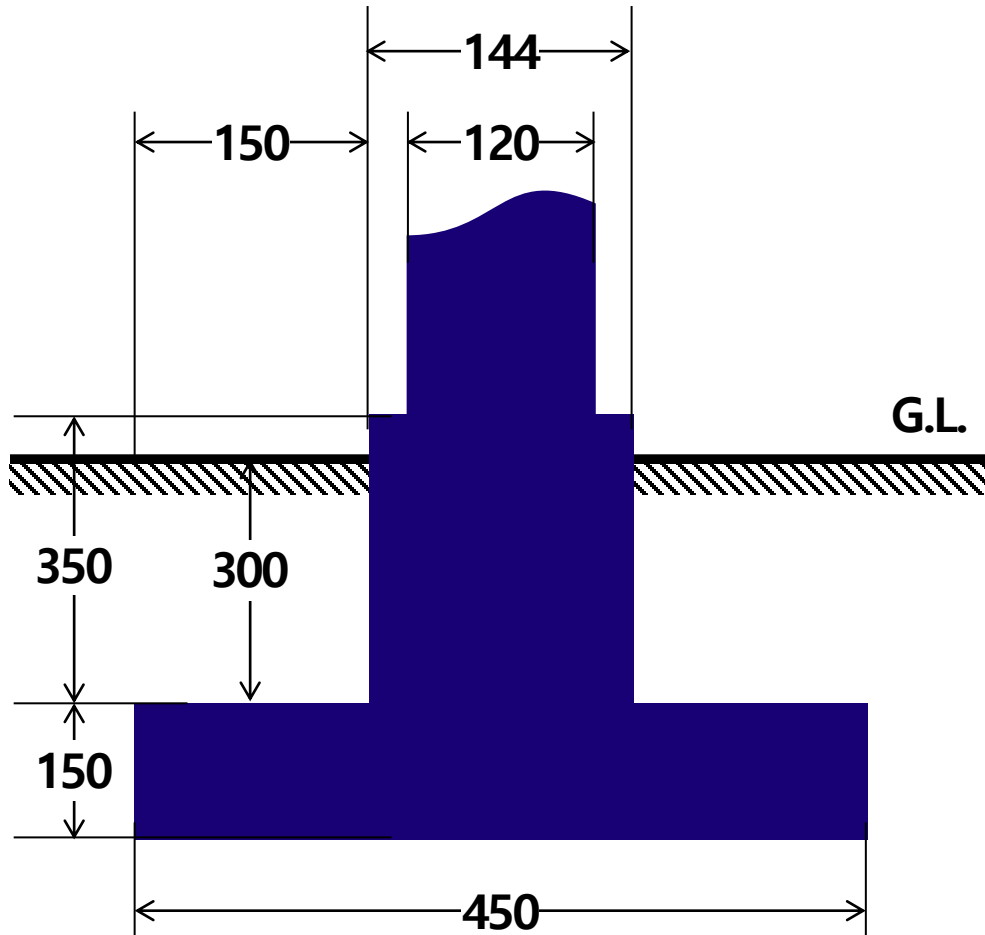
Side View



Top View

**“The barrier should be installed so as to block propagation of risk source in one section into the other sections”**

## Dimensions | Reinforced Concrete Barrier

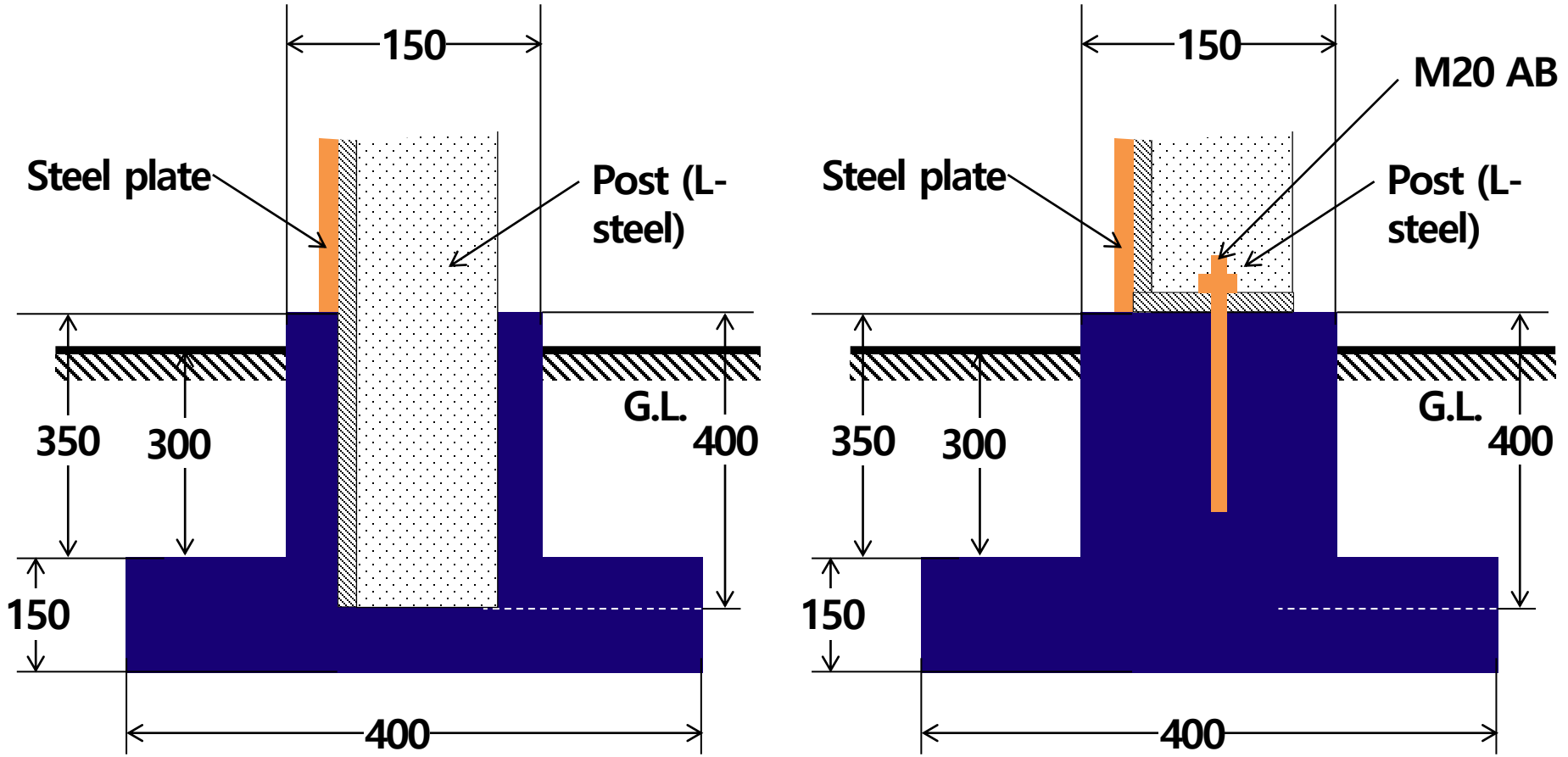


Side View of RC Barrier on Foundation

## Miscellaneous requirements

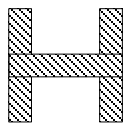
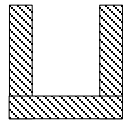
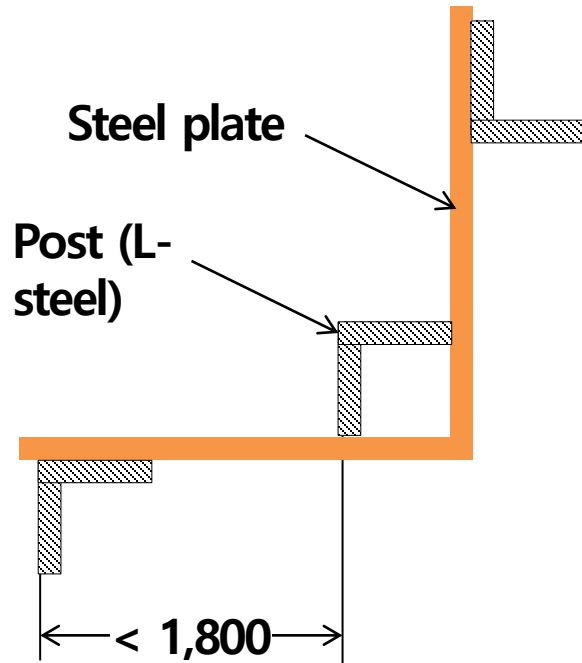
- Monolithic barrier and foundation
- Steel rebars
  - diameter: 9 mm
  - spacing: 400 mm

## Dimensions | Steel Plate Barrier



Side View of Steel Barrier on Foundation

## Dimensions | Steel Plate Barrier



U-, H- Beam are also allowed

## Miscellaneous requirements

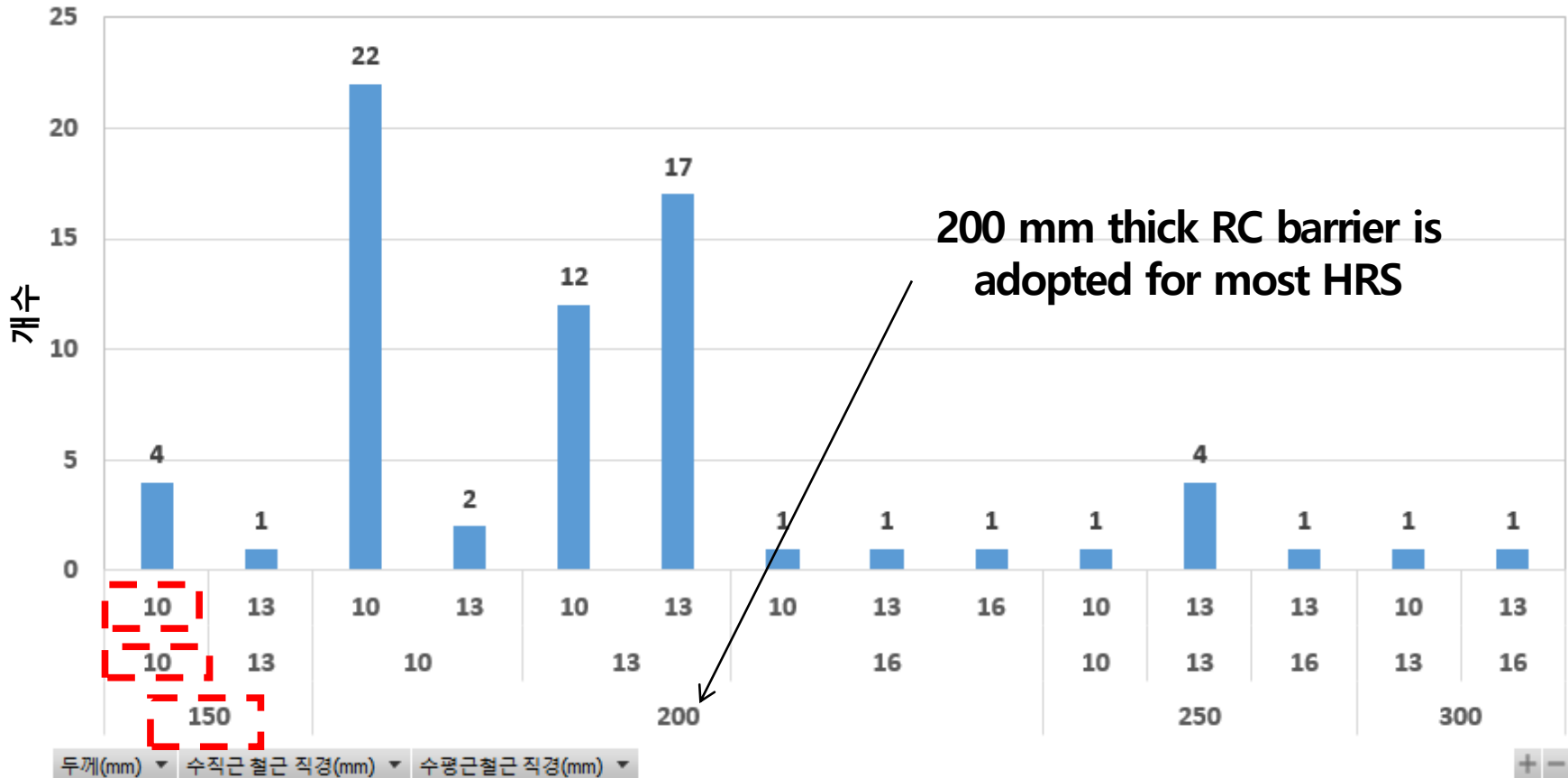
- **Thickness of Plate**
  - 6 mm, or
  - 3.2 mm + Reinforcement with 30-mm angled steel (spacing of 400 mm)
- **Post**
  - 100 x 100 mm

## Top View of Steel Plate Barrier



# Mitigation Barriers Constructed in Korea

## Survey on 69 HRS as of 2021



Statistics for barriers in HRS: wall thicknesses and diameters of rebar

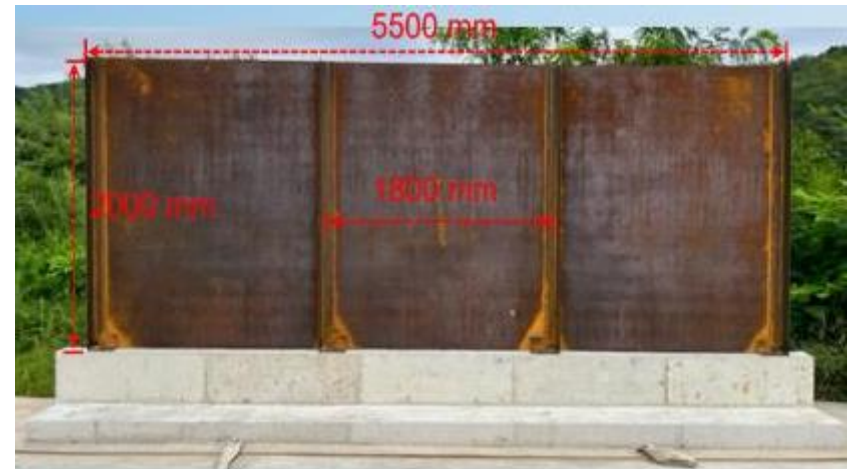
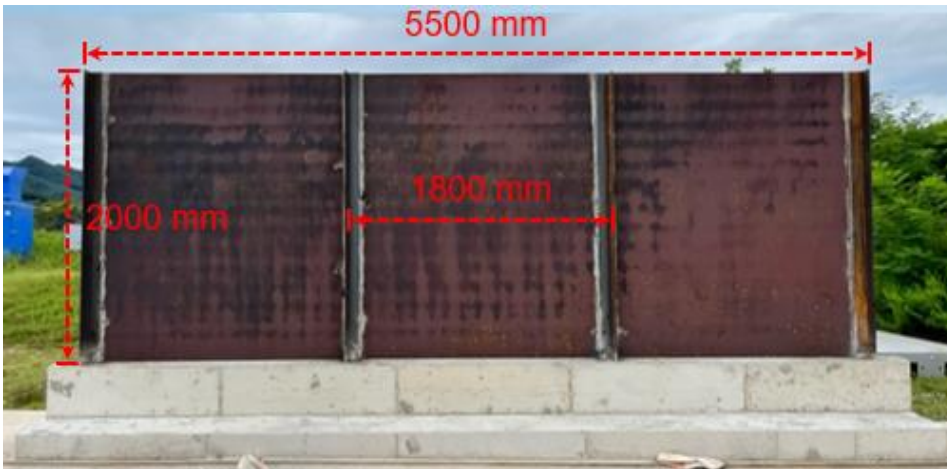
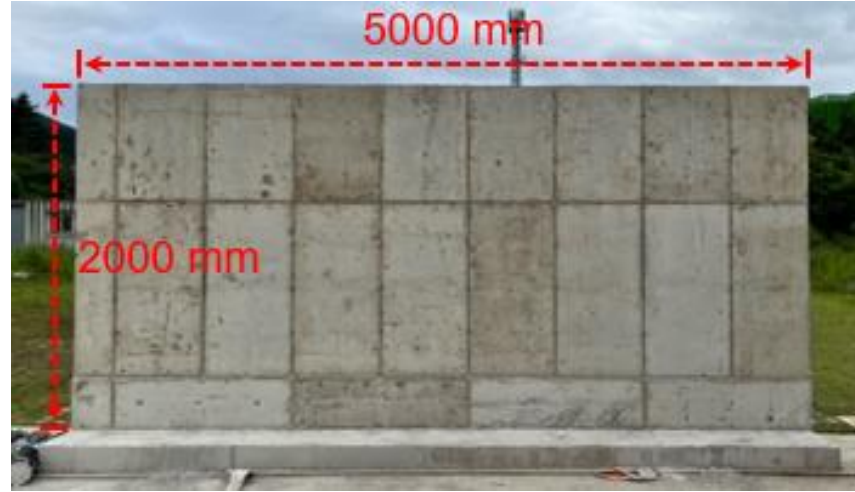
## Objectives

- **Inspection of barriers against explosion of hydrogen**
  - To validate the structural integrity
- **Overpressure measurements**
  - To validate the ability of protection of the barrier
  - To validate the safety distance
  - To compare and find the TNT equivalence

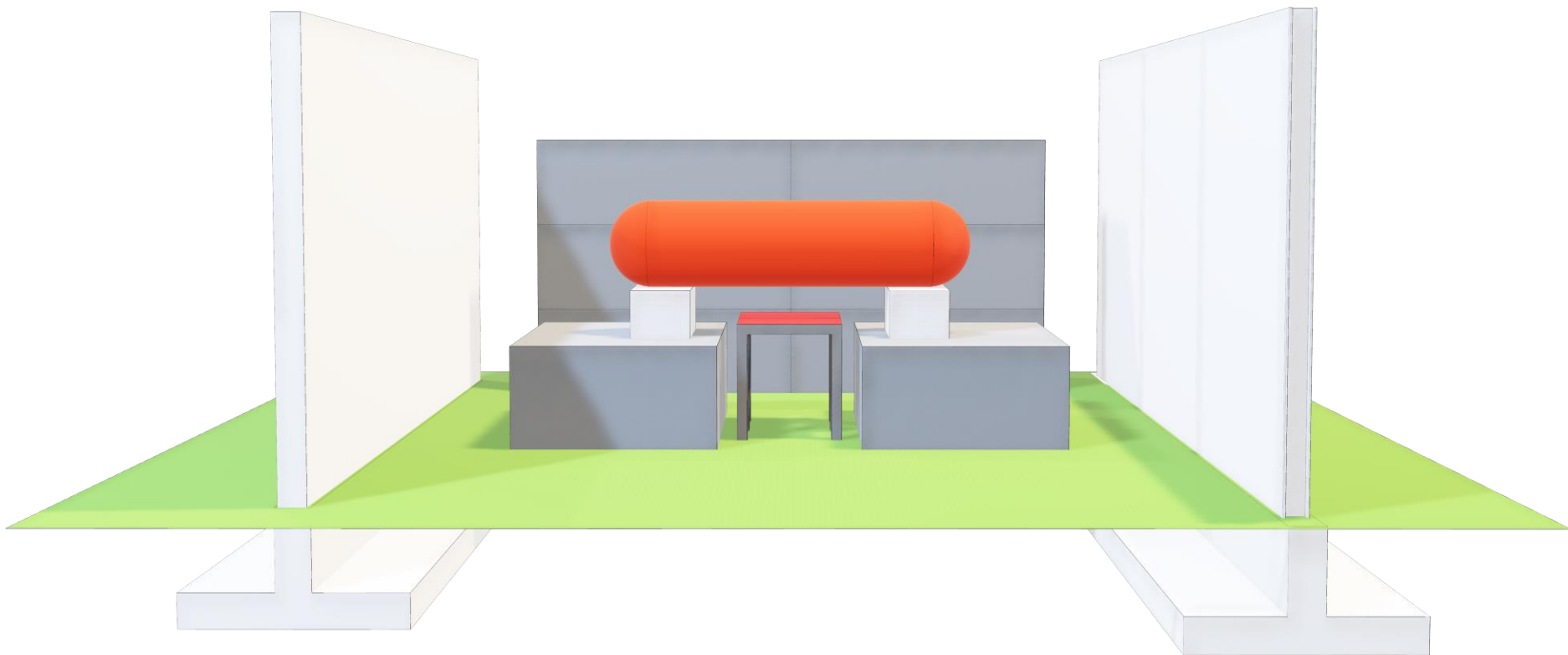
## Planning of Test Series

- **Explosion source: Approx. 7 kg of hydrogen (i.e., 175 L @ 70 MPa)**
  - A type-4 cylinder (TPRD disabled), heated by a planar LPG burner until it blows up
- **Test specimens: 3 types of mitigation barriers with the minimum designs**
  - 1 reinforced concrete barrier, 2 steel-plate barriers(posts are buried in foundation; posts are mounted on foundation with anchor bolts)

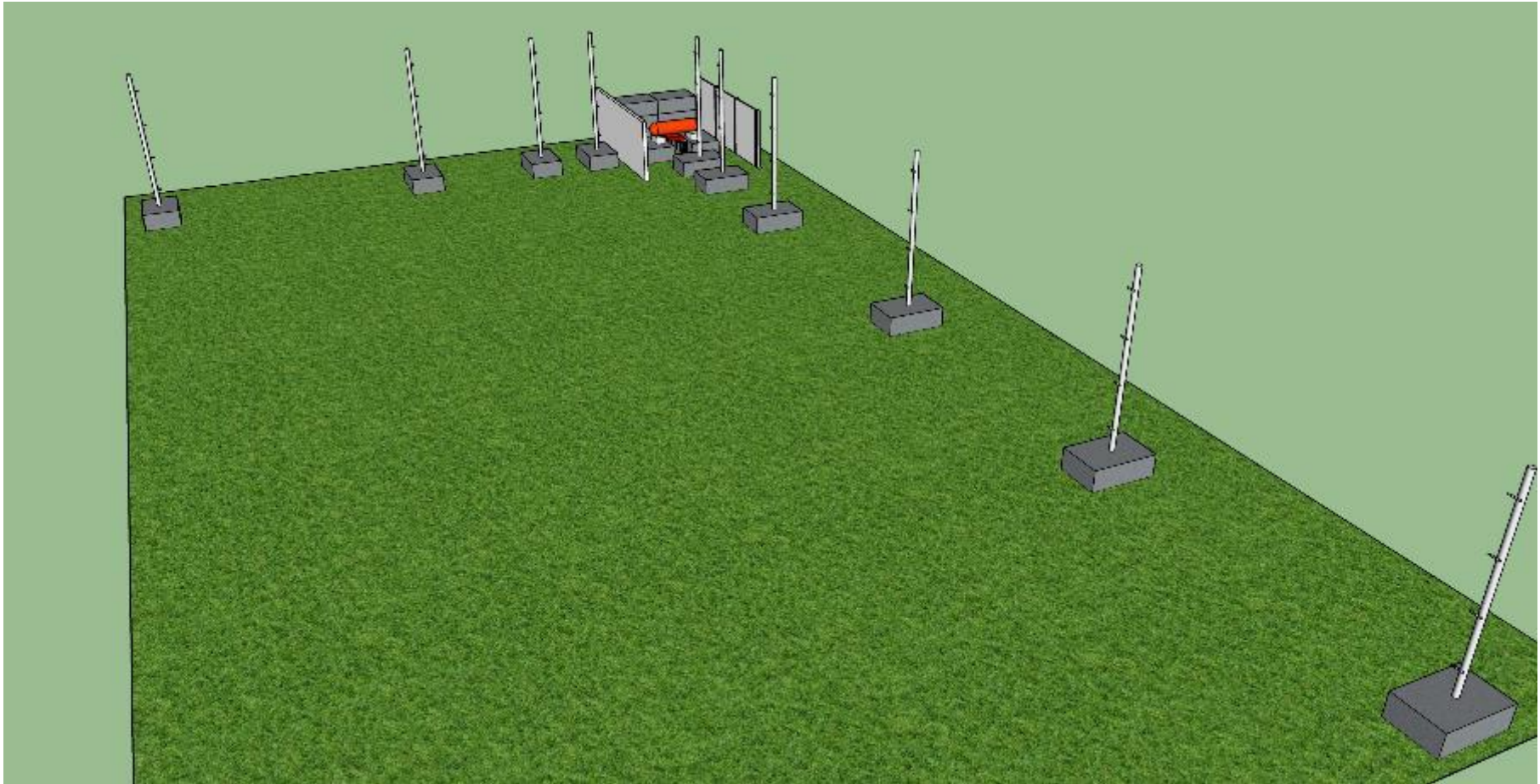
## Preparation of Test Specimens | Mitigation Barriers



## Test Plan | Barriers & Heated Hydrogen Cylinder



## Test Plan | Overpressure Measurements



## Preparations





## Consequence | Health of barriers



**Summary:** a hole created; many horizontal closed cracks found; wall tilted out; debris (> 1 kg) found even in 30 m; overpressure measurements beyond barrier failed

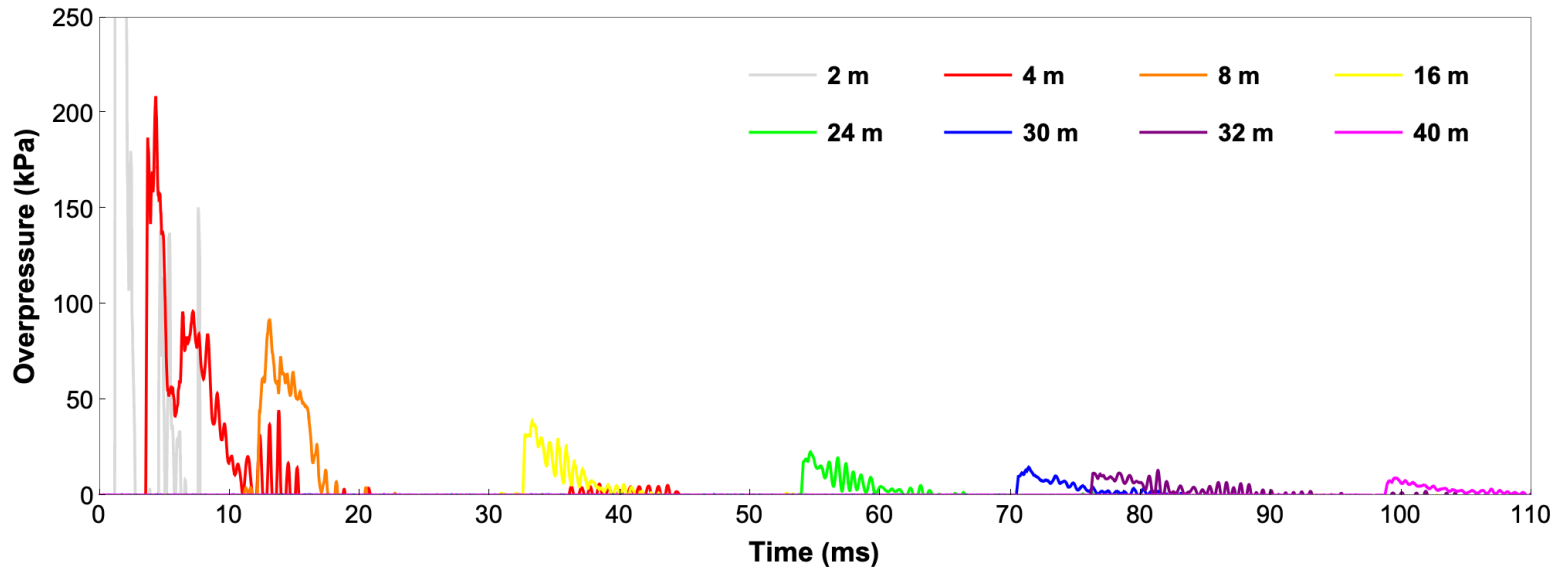


## Consequence | Health of barriers

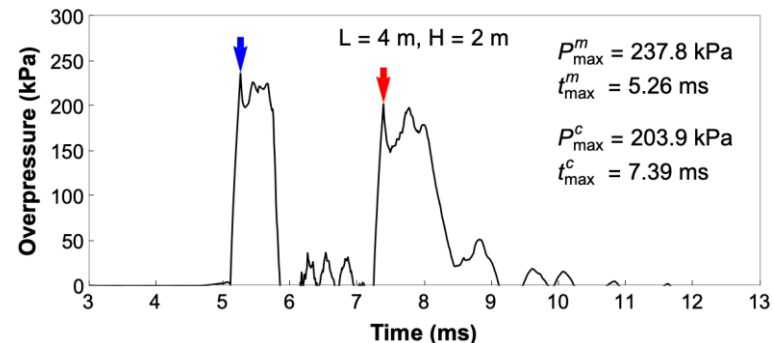
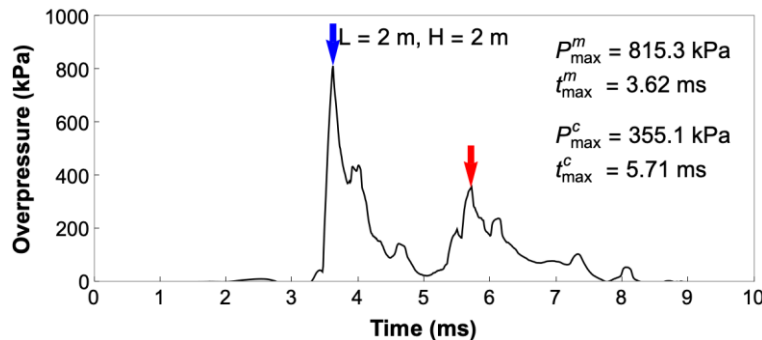


**Summary:** both walls pulled out from foundations and flew away approx. 25 m; foundations destroyed; welded part in post cut out; no crack found on walls; a small hole created without flying debris

## Consequence | Overpressure propagations & analysis

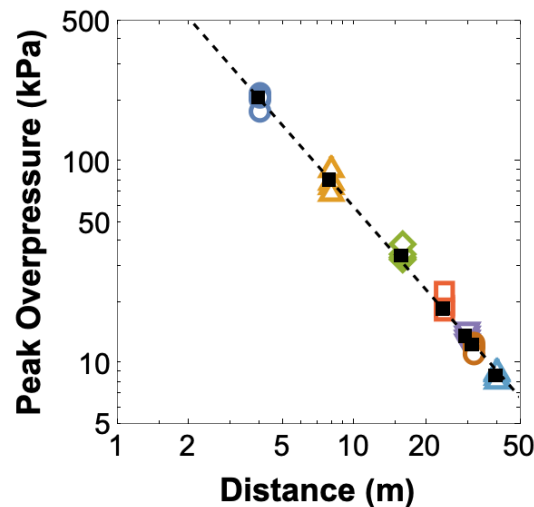
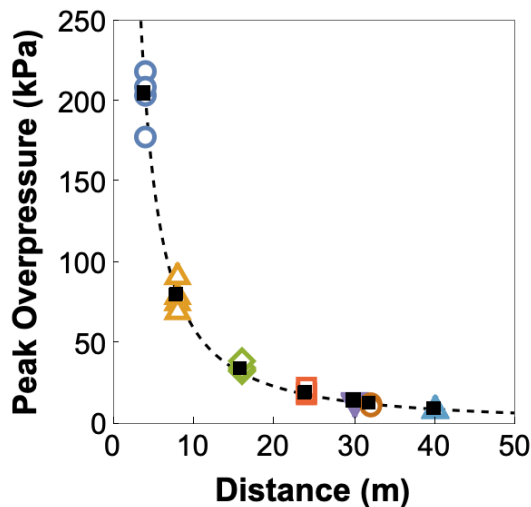
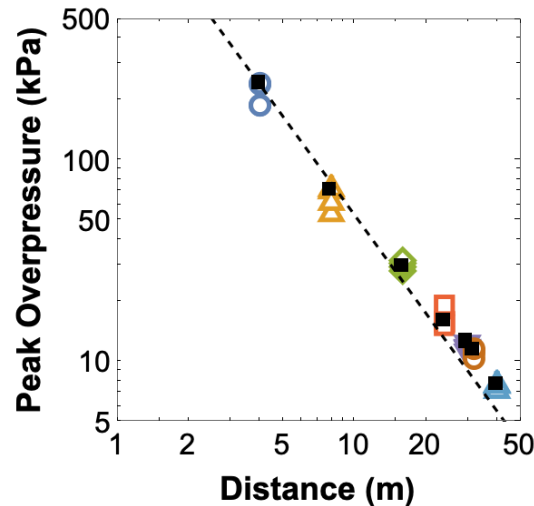
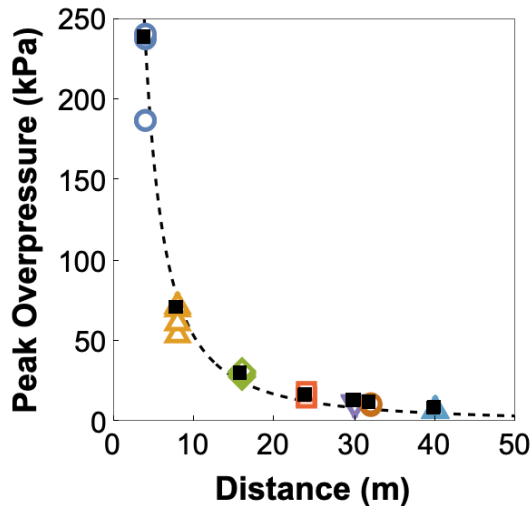


### Example of overpressure readings in different distances at 2 m from ground



Overpressure profiles:  $P^m$  mechanical explosion;  $P^c$  chemical explosion

## Consequence | Overpressure propagations & analysis



## Miscellaneous requirements

- Peak overpressures by both mechanical and chemical explosions are in exponential decrease to distance
- At 30 m, human may survive, but building is in question

- **Explosion tests of compressed hydrogen were conducted with mitigation barrier**
  - **Approx. 7 kg of hydrogen in 175 L @ 70 MPa was forcefully heated**
- **Structures of all types of specimens were seriously damaged**
  - **Thicker reinforced concrete barrier should be tested**
  - **Improvement is necessary to hold posts of steel-plate barrier firmly to foundation**
  - **No debris implies that steel plate barrier may provide better protection**
- **The results of overpressure measurements**
  - **The overpressure data are still under investigation, therefore the consequence cannot be asserted yet**
  - **Exponential decay in peak overpressure were seen, and the safety distance of 30 m may be good for human, but in question for building**
  - **In the future, for computing TNT equivalence, overpressure measurements at the same locations will be conducted when different masses of TNT are exploded**



**Thank you very much  
for your attention.**

For further questions, email me at [ksbears@kgs.or.kr](mailto:ksbears@kgs.or.kr)