Benefits of Seismic Isolation for LNG Tanks

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Contents

Object of the work

- Questions to be answered about isolation
  - What do we gain
  - How much does it cost
- Conclusions to reach: when does it
  - Start to be reasonable
  - Start to be necessary
  - Situation in between

Parameters to consider

- Relevant parameters
  - SSE acceleration
  - Aspect ratio H/R
  - Type of foundation: slab/piles
  - Spectral shape
  - Storage capacity

Cases studied

- Discussion will centre on:
  - Reference INDEPTH tanks from Huelva
    - 60,000 m^3, H/R = 1.56, surface stab
    - 100,000 m^3, H/R = 1.03, surface stab
  - Typical current projects
    - 160,000 m^3, H/R = 0.96, surface slab
    - 160,000 m^3, H/R = 0.96, pile foundation

Seismic effects on design

- General:
  - Freeboard for sloshing
- On outer tank:
  - Generally none
  - Possibly some rebar in dome
- On inner tank:
  - Increased thickness
  - Anchorage
  - Eventually fatal (thickness, sliding or uplift)

Isolation effects on design...

- General:
  - Sloshing unaffected
- On outer tank:
  - If on piles: generally none, perhaps some rebar savings
  - If on slab: dual slab, thickened slab and pedestals
- On inner tank:
  - Reduce thickness
  - Delay/avoid the need for anchorage
  - Delay global sliding
  - Global uplift is barely affected

...but

- New needs arise:
  - A seismic isolation system
  - Flexible connections for every pipe going into the tank

Other considerations

- A surface slab needs heating
- An isolated tank usually has an elevated base, also possible in non-isolated tanks on piles
- An elevated slab saves:
  - The heating system
  - The energy consumed over the life of the tank

Cost assumptions

- Cost of seismic design: that beyond the cost of designing for 0.0g SSE
- To determine it, assumptions are needed for the cost of:
  - Isolation devices
  - Flexible connections
  - Anchorage
  - Cryogenic steel for inner tank
  - Concrete
  - Energy savings
- Unit costs only partially reliable

Assumed cost (M€) of isolation devices

SSE ZPGA (g´s)	Differential displacement (m)	Tank capacity (10^3 m^3)		
		60	100	160
0.38	0.20	0.48	0.80	1.15
0.76	0.40	0.96	1.62	2.52
1.14	0.60	1.72	2.63	4.46

- Notes:
  - The relation acceler-displ depends strongly on spectral shape
  - Costs are only orientative and depend on standard used

Flexible connections

- Pipes between the tank and the ground:
  - Loading LNG
  - Unloading LNG
  - Vapour recovery
  - Vapour to flare
  - Cooling the tank
  - Firefighting water
  - Nitrogen purge
  - Water, air and instrumentation
- Global cost of connections: 0.3 M€

Anchorage

- Anchor straps are made of cryogenic steel; when needed, a minimum cost of 0.35 M€ has been assumed for a 160,000 m^3 tank
- In the absence of isolation, the cost is estimated to grow to 0.55 M€ when the SSE ZPGA is 0.55g
- Cost is interpolated for other accelerations

Inner tank steel

- The cost of additional 9% Ni steel placed in the tank has been estimated at 5 €/kg
- Thicknesses above 50 mm have been considered unweldable

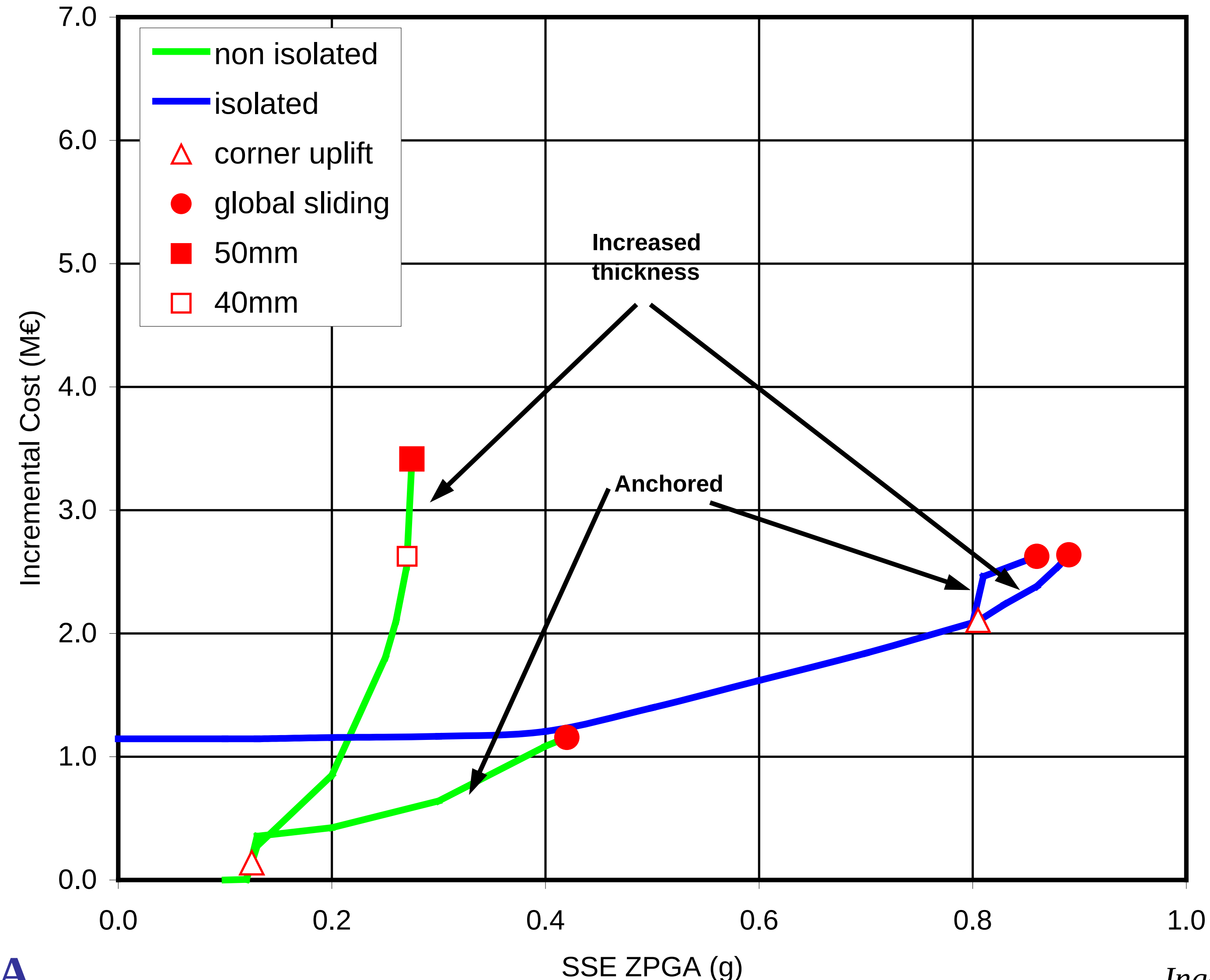
Concrete

- Costs used for concrete include rebars, formwork and supports. The assumptions used are:
  - For surface slab: 300 €/m^3
  - For elevated slab and pedestals: 450 €/m^3

Heating

- The cost assumptions are:
  - Heating system: 1 M€
  - Energy costs, taken as equivalent to 10 years of energy at 0.1 €/kWh: about 1 M€

Cost comparison: 60,000 m^3 Huelva tank



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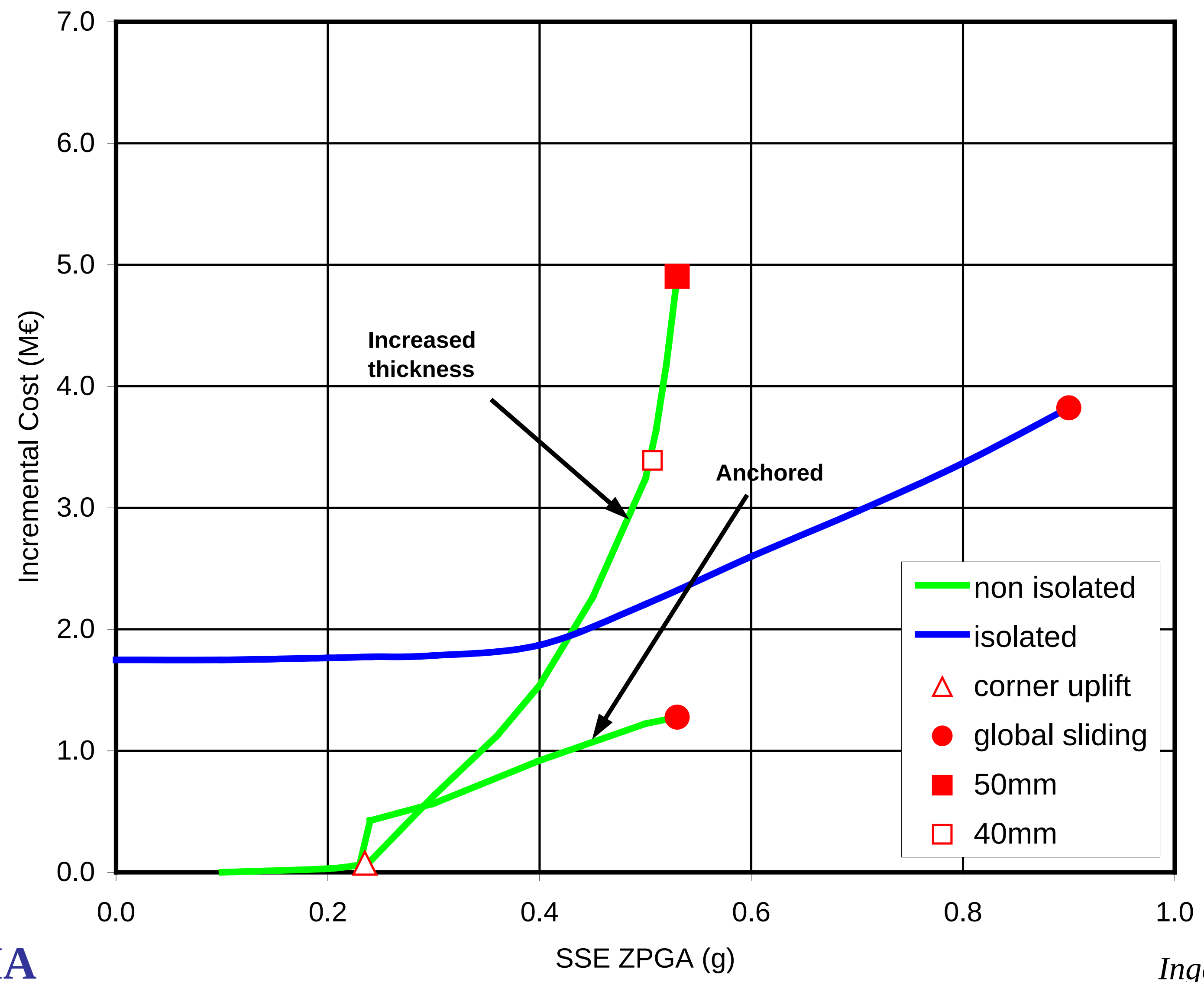
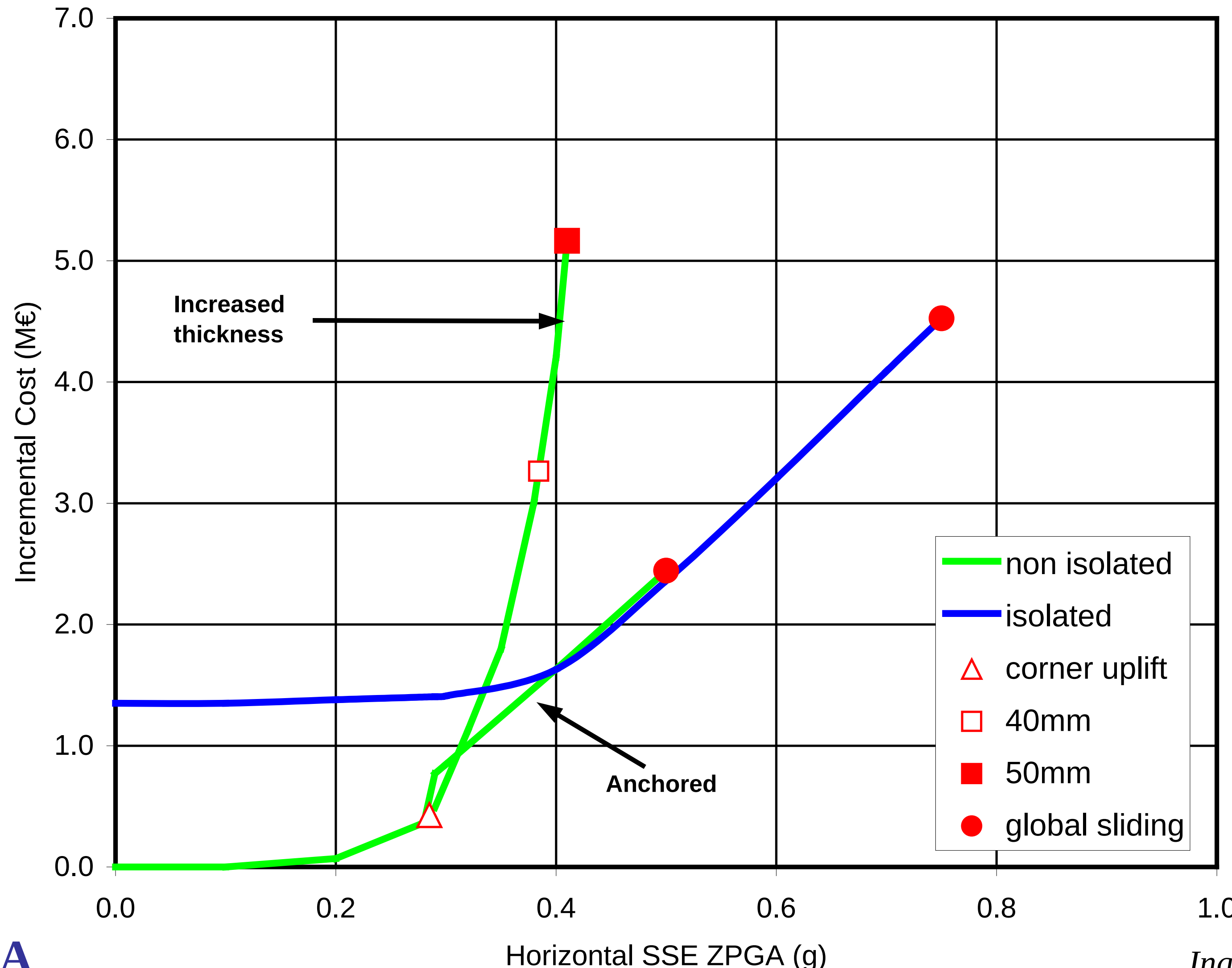
Cost comparison: 100,000 m^3 Huelva tank



Cost comparison: 160,000 m^3 tank on piles



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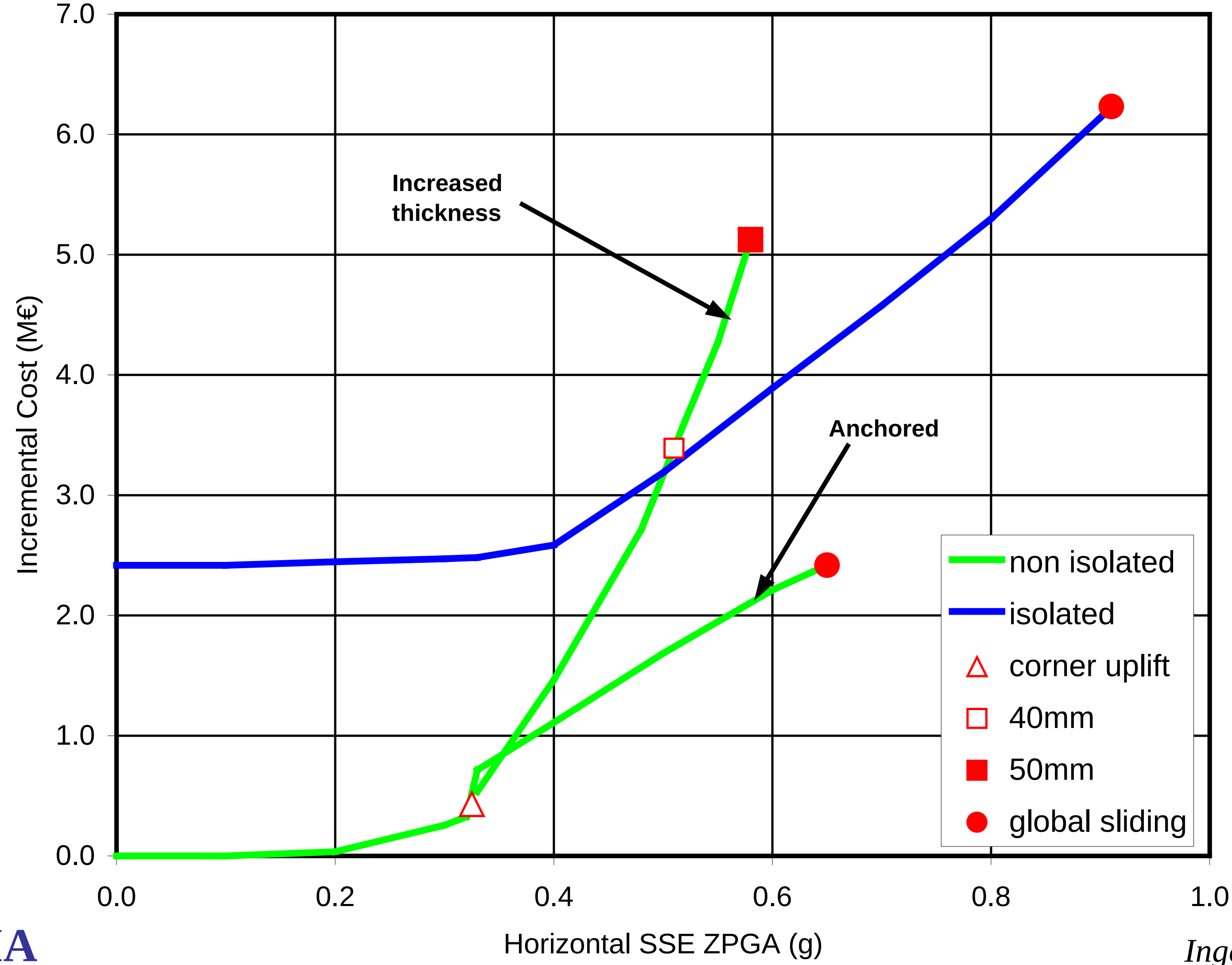
Cost comparison: 160,000 m³ tank on slab



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Conclusions (1)

- For a typical 160,000 m^3 FCAG tank on piles:
  - Isolation is unwarranted if ZPGA < 0.3g
  - Isolation is required if ZPGA > 0.5g
  - For 0.3g < ZPGA < 0.5g, the more reasonable decision is to isolate since the associated additional costs are negligible in that range of accelerations

Conclusions (2)

- For a typical 160,000 m^3 FCAG tank on a slab:
  - Isolation is unwarranted if ZPGA < 0.3g
  - Isolation is required if ZPGA > 0.65g
  - The additional cost of isolation in the intermediate range is fairly constant: about 1.5 M€ or 3% of the cost of the tank
  - Isolation becomes more desirable for the higher accelerations in that intermediate range

Conclusions (3)

- For the INDEPTH reference tanks from Huelva, the conclusions are qualitatively similar, but numbers of course differ:
  - The 60,000 m^3 tank, with H/R = 1.56, requires anchorage after 0.13g and cannot be built without isolation beyond 0.42g; between these limits the extra cost of isolation evolves from 0.8 M€ to nil
  - The 100,000 m^3 tank, with H/R = 1.03, requires anchors after 0.22g and cannot be built without isolation beyond 0.52g; between those limits the extra cost of isolation starts at about 1.4 M€ but settles quickly around 0.9 M€