RADIATION PROTECTION IN RADIOTHERAPY

Part 7: Facility design and shielding

PRACTICAL EXERCISE

Objectives of Part 7 - participants should

- Understand the underlying principles for the design of a radiotherapy facility
- Be familiar with the safety requirements for the design of radiotherapy facilities including interlocks, maze design and warning signs.
- Be able to calculate the shielding thickness required for a particular barrier

Part 7: Facility design and shielding

Practical 1: Calculation of shielding requirements for a megavoltage external beam treatment room

Contents + Objective

- Understand the shielding requirements for a high energy megavoltage unit
- Perform calculations using information given in the lecture

What Minimum Equipment is Needed?

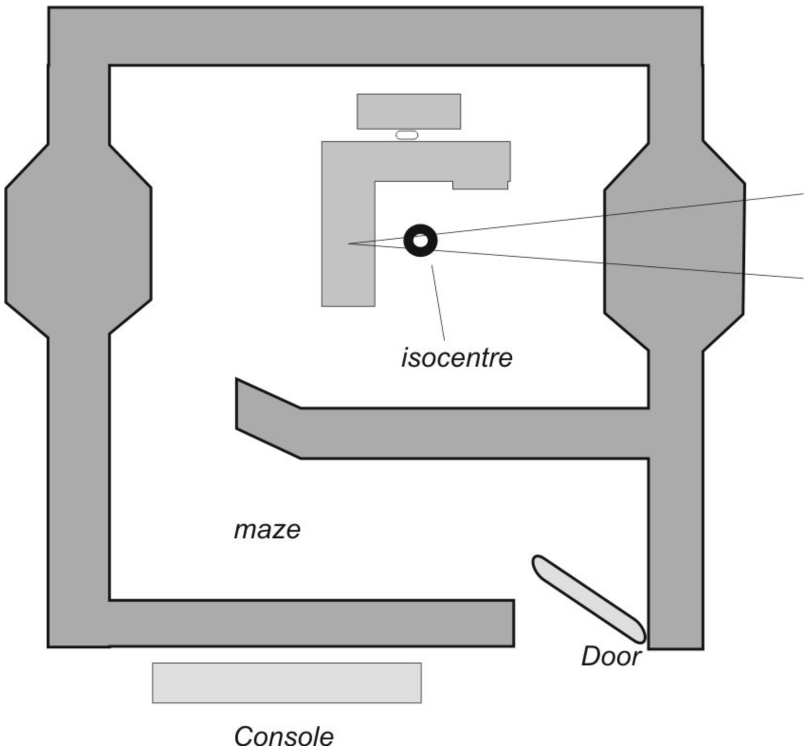
- Paper, pocket calculator
- Whiteboard
- Handout and lecture notes
- (if possible a copy of NCRP report 151 and/or McGinley 1998)

Scenario

- You have been called to assess the shielding requirements for a new linear accelerator. The bunker is shown on the next slide.

Q1 Primary shielding

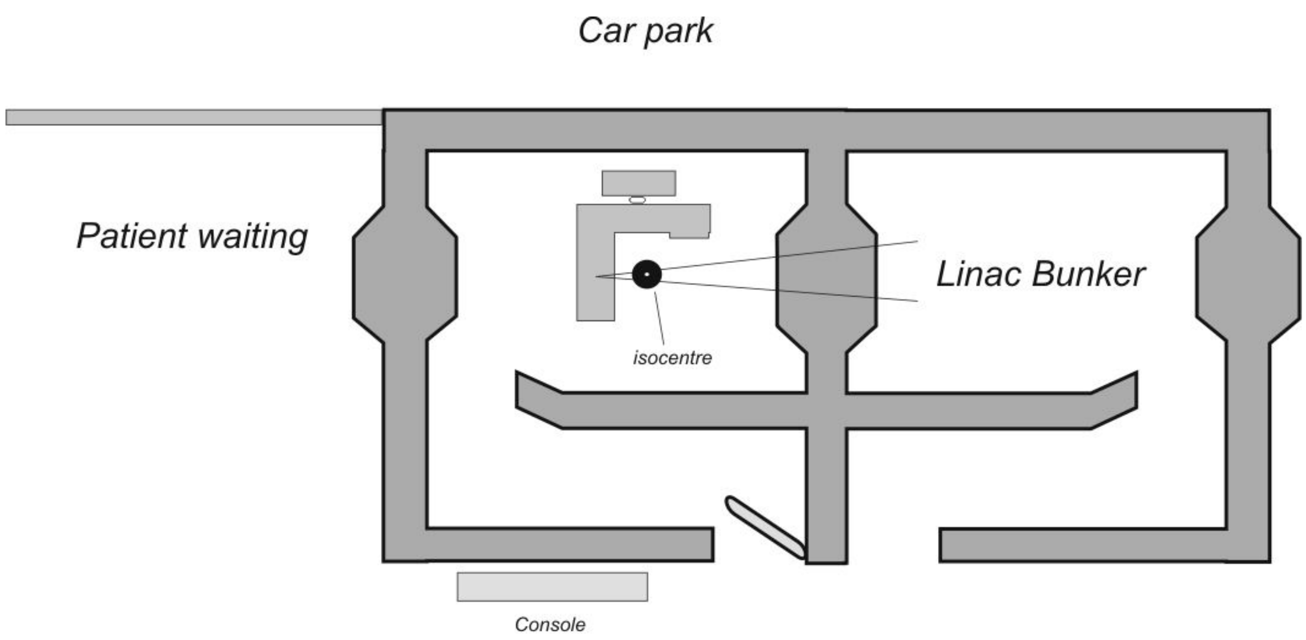
- The bunker shall house a dual energy linear accelerator with 4 and 10MV X Rays and 5 different electron energies
- Except for the door all shielding shall be done using ordinary concrete



Assumptions

Q1

- Workload: 40 patients per day, including a maximum of 10 IMRT patients, 250 treatment days per year

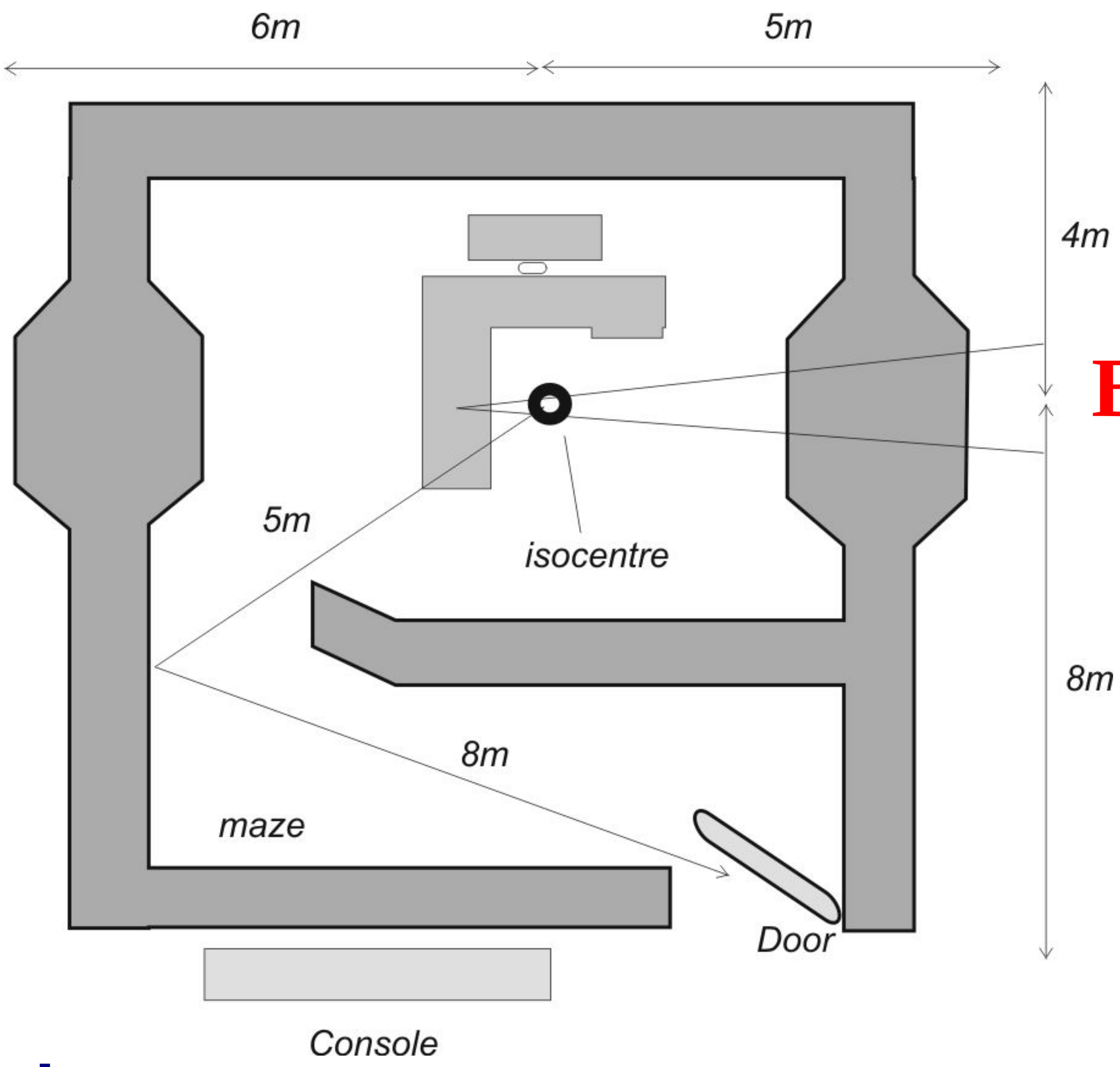


Groundfloor - no rooms underneath

Area above bunker storage - only accessible when linac is turned off

Q1

Location **A**



B

Need dimensions

Location **C** above

Workload for primary shielding

- Assume T = 2.5Gy at isocentre
- Assume 50 patients treated per day (conservative estimate) on 250 working days per year

W = 50 x 250 x 2.5 = 31250 Gy per year

- Allow for other uses such as physics, blood irradiation, total : 40000Gy per year at isocentre for primary beam
- As no statement was made about the energy to be used, assume 10MV

Attenuation A required for primary beam shielding

Common assumptions for all locations

- Linac 10MV
- d_{ref} = 1m (FAD = 1m)
- W = 40000Gy/year
- $TVL_{concrete}$=40cm

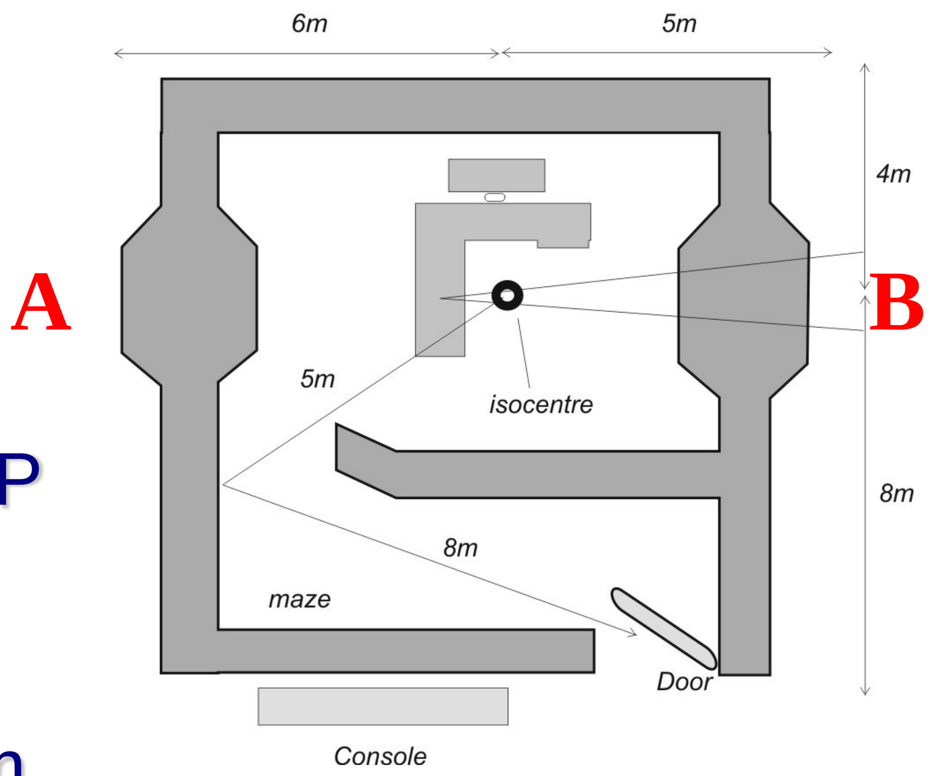
Assumptions depending on the location to be shielded

- Usefactor U
- Occupancy T
- distance d
- Design constraint P

$$A = WUT\,(d_{ref}/d)^2 \,/\, P$$

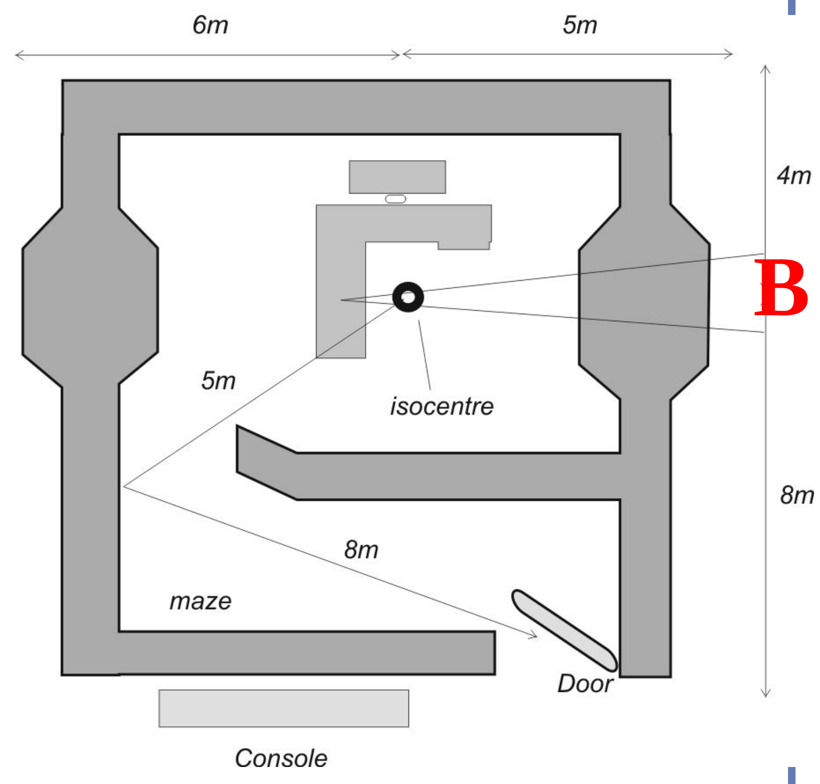
Lateral beams: U = 0.25

- Location A, patient waiting: d=6m, P=0.3mSv/year T=0.25 averaged over a year
- A = WUT $(d_{ref}/d)^2$ / P
  A = 232,000
- For concrete approximately 2.2m



Lateral beams: U = 0.25

- Location B, other bunker: d=5m,
  - For patients: P=0.3mSv/y T=0.05 averaged over a year
  - For staff: P=20mSv/y, T=1
- $A = WUT\,(d_{ref}/d)^2 / P$
  $A = 67{,}000$
- For concrete approximately 1.9m



Beam pointing up and down

- Pointing down: U=1 but T=0 - therefore, no shielding is required
- Pointing up: U=0.25, T in the room directly above = 0, however, there could be rooms even higher in the building. While distance may reduce the dose, there could be shielding requirements *e.g.* for an office on top of the storage area.

How much change would there be to the shielding requirements if 4MV instead of 10MV were used for all treatments?

Q2

Q2

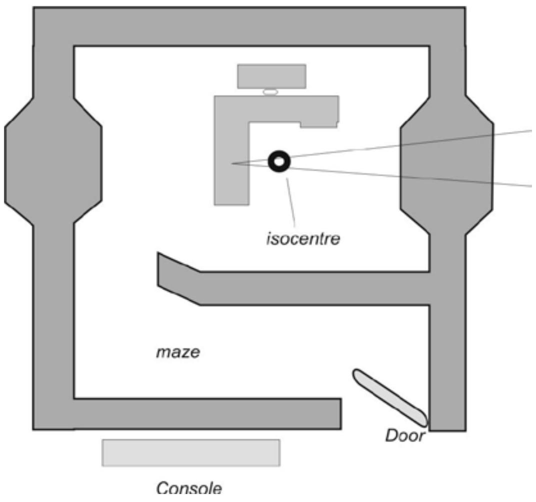
Answer

Q2

- The difference in TVL between 10MV (40cm) and 4MV (30cm) photon beams is 10cm. For the approximately 5 TVL of material required, the shielding could be reduced by approximately 50cm if one can ensure only 4MV is used for treatment.

Q1 Secondary shielding

- Leakage and scatter
- Workload for scatter similar to primary (40,000Gy/year)
- Workload for leakage higher (10x for IMRT patients)
- $W_{conventional} = 40 \times 2.5 \times 250 = 25000$Gy/y
- $W_{IMRT} = 10 \times 25 \times 250 = 125{,}000$Gy
- $W_{total} = 160{,}000$Gy



Quick reality check

- 160,000 Gy/year @ isocentre includes physics work.
- It means that every day about 640Gy are delivered. At a typical dose rate of 4Gy per minute this means the beam is on for 1.6 hours every day
- This can be verified by checking beam on time...

Attenuation A required for leakage secondary beam shielding

Common assumptions for all locations

- Linac 10MV
- d_{ref} = 1m (FAD = 1m)
- W = 160000Gy/year
- $TVL_{concrete}$=45cm
- Usefactor = 1
- Leakage factor 0.002

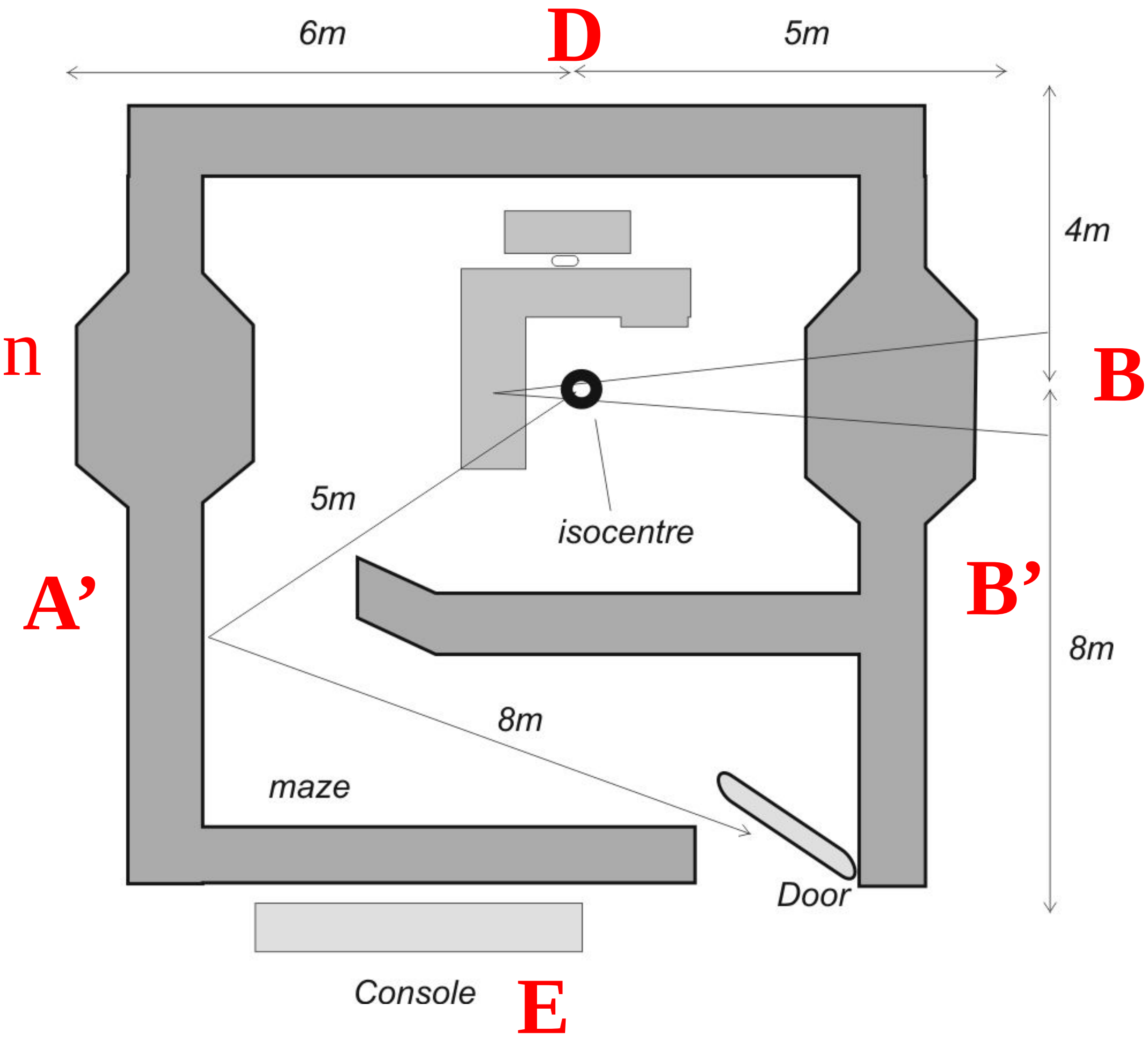
Assumptions depending on the location to be shielded

- Occupancy T
- distance d
- Design constraint P

$$A = L\,WT\,(d_{ref}/d)^2 / P$$

Q3

Location
A



Location **C** above bunker

Attenuation A required

- Location A' patient waiting: T=0.25, d=6m, P=0.3mSv
- Location B' bunker: T=0.05, d=5m, P=0.3mSv
- Location D parking: T=0.25, d=4m, P=0.3mSv
- Location E control: T=1, d=8m, P=0.3mSv

Rem : occupancy factors changed in NCRP 151

Attenuation A required

- Location A’ patient waiting: T=0.25, d=6m, P=0.3mSv - A = 7400
- Location B’ bunker: T=0.05, d=5m, P=0.3mSv - A = 2200
- Location D parking: T=0.25, d=4m, P=0.3mSv - A = 16700
- Location E control: T=1, d=8m, P=0.3mSv -   A = 16700

Rem : occupancy factors changed in NCRP 151

Scatter

- More complicated calculation including
  - the area of the beam at the scattering surface. In practice this is usually assumed to be 400cm^2 at the patient
  - the angle of the scattered radiation
- In the present case, scatter can be conservatively approximated by being similar to leakage

Q3

Location

A = 2.2

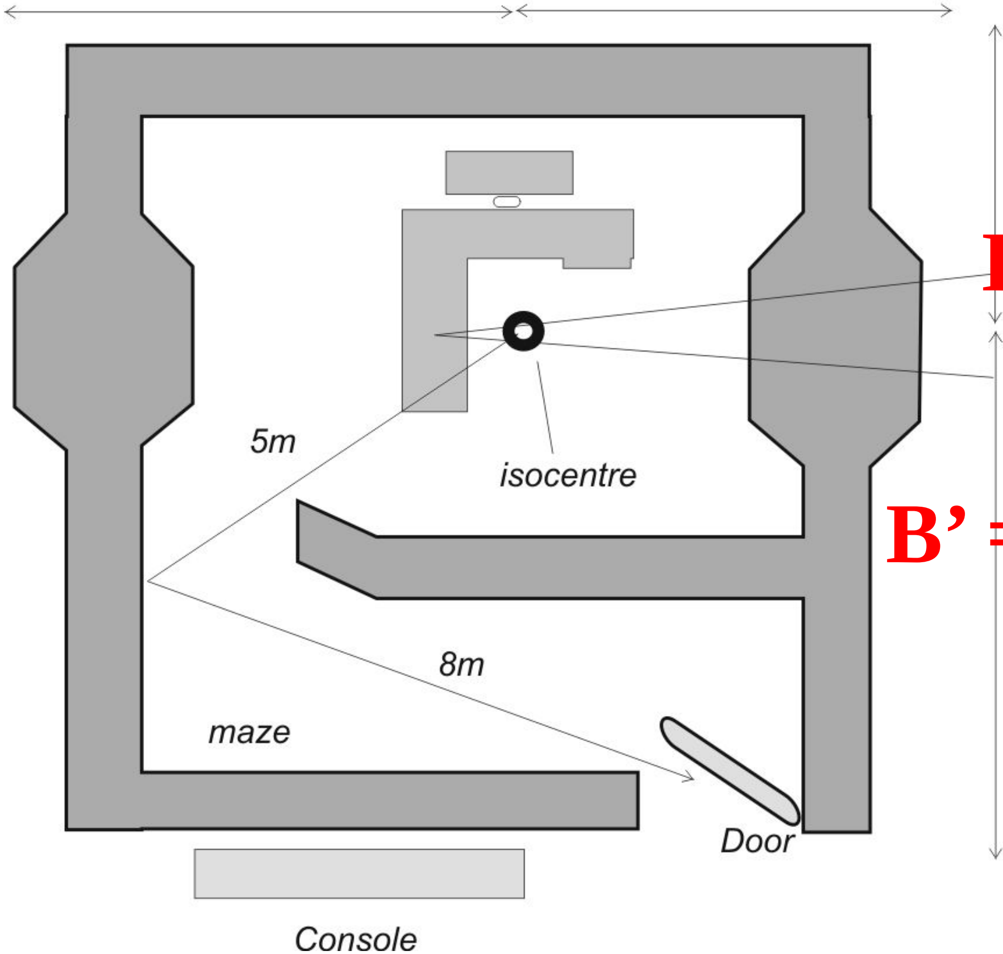
A’ = 1.7

D = 1.8

B = 1.9

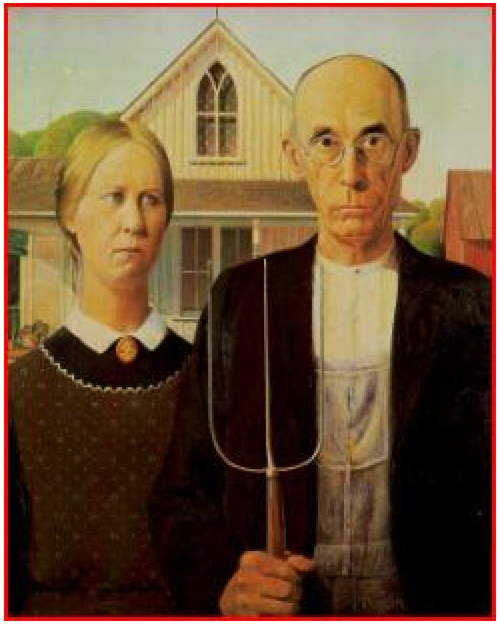
B’ = 1.3

E = 1.8



Resulting concrete thickness in meter

Questions?



Let’s get started...