European Shotfirer Standard Education For Enhanced Mobility – ESSEEM –
ESSEEM WP 7 Demolition

worked out and giving a lecture by
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\[\sum 1.830\]
1. Types of buildings and constructions

- tall/slim: towers, masts, pylons, smoke stacks
- massive: shelters, fortifications, abutments, walls, bridges, foundations
- steel constructions
- others: houses
- mix of several types: slim and massive
1.1 Distinction between

- tall
- slim

\[ \text{tall} = \text{high (reaching)} \]
\[ \text{slim} = \text{slimness degree} > 3 \]

slimness degree: relation between basic dimension and height
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tall but massive
tall and slim
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massive constructions

air raid shelter at Luebeck

fundaments in a glass factory
2. Methods to blast constructions:

- tilting
- collapsing
- combined tilting – collapsing
- folding
- lowering
- breaking up
- contour and smooth blasting
2.1 tilting

150 m tall chimney
blast level: + 45 m

power station
Lübeck/Germany
2.2 collapse
82 m high skyscraper at Hamburg (D)
structural analysis indispensable
2.3 combined tilting / collapsing
92 m tall sky scraper at Hagen (D)
(system drawing)
structural analysis indispensable
2. 4 folding
300 m tall
smoke stacks
at power station
Boxberg (D)
i structural
analysis indispensable
2.4 lowering

→ should be announced in advance
2.6 breaking up
2.7 contour blasting

contour blasting „window“

smooth blasting
3. Explosives

– commonly used:
  - ammongelite
  - emulsions

– special explosives:
  - linear shaped charges (flexible or rigid)
  - plasticized explosives (e.g. PETN, hexogen, octogen)
  - detonating cord (20 g/m - 100 g/m)
examples of special explosives

„CISALEX“ for contour blasting (France)

linear shaped charges
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linear shaped charges

i follow instructions of manufacturer about cutting force
i correct stand off indispensable
i precise instantaneous initiation absolutely necessary
Initiation systems
– electric detonators
– non electric detonators
– electronic detonators
– (detonating cord)
– combination of systems: e.g.: shock tube and electronic detonators
Stemming
– horizontal drill holes of small diameter
– often short charge column

appropriate materials:
• foam (for installation)
• wet clay
• cartridges filled with sand or water/gel
Stemming
– unsuitable materials
  • hardening materials like mortar
  • materials without sufficient interior friction
  • like drill meal or powder

D attention: stemming must not damage the wires of detonators or shock tube
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stemming with foam
4. Environmental aspects

Prognosis of vibrations
– charges below surface:

\[ v_{\text{max}} = 250 \cdot \frac{L^{2/3}}{R} \]

– charges above surface:

\[ v_{\text{max}} = 100 \cdot \frac{L^{2/3}}{R} \]

\( v_{\text{max}} \) = max. vibration
\( L \) = charge in [kg]
\( R \) = distance [m]
prognosis of vibrations by impact:

\[ v = k \cdot 10 \cdot \frac{m^{1/3} \cdot H^{1/2}}{R^{1.15}} \]

- \( v \) = vibration [mm/s]
- \( k \) = transmission (soil) factor (mostly 2 – 4)
- \( m \) = mass of impact [t]
- \( H \) = height of mass (centre of gravity) [m]
- \( R \) = distance [m]
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reducing of impact: fall bed ( „impact cushion“)
Safety measurements

• active protection
  ➢ geo textiles, felt mats, conveyor belts, blast mats (treads of tires), meshed wire, steel nets, bales of straw (hay, paper, wood wool), sand, soil

• passive protection
  ➢ scaffolding with geo textiles, felt mats, conveyor belts
  ➢ walls from plywood, steel plates, concrete plates
  ➢ containers (empty or filled with rcl material or soil)
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protection against fly of debris: geo textile
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- protection against fly of debris:
  geo textile and mesh wire
protection against fly of debris: geo textile and mesh wire
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Protection against fly of debris
(rubber blast mats form tires)
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protection of neighbourhood by scaffolding and geo textile
Dust suppression by blowing up water filled big bags
5. Basic of structural engineering

- distinction of load-bearing and not load-bearing construction elements
- condition of tilting: centre of gravity must be moved outside the base
- rudimentary knowledge of constructions
 principal of tilting
center of gravity (S) must be
shifted outside of base (S')

\[ \alpha = \text{angle} \]
\[ \alpha' = \text{angle of blast mouth} \]
ideal behaviour = tilting (rotation)  D  break down of the rear pillar

possibilities of behaviour
result: sinking instead of rotating
→ easy method to prevent sinking by a pile of rubble or recycling material
6. Calculation of charges

i. formula:

\[ L = w \cdot a_B \cdot a_R \cdot q \]

- \( L \) = loading in kg
- \( w \) = burden [m]
- \( a_B \) = distance of bore holes [m]
- \( a_R \) = distance of rows [m]
- \( q \) = powder factor [kg/m\(^3\)]
i Definition of „burden“

„burden“ is the shortest distance of the middle of the charge to the next free face (in meter)

( The free faces can also be generated by rows with earlier detonations )

examples: wall of a chimney: half of the thickness

slab of a bridge: half of the thickness
7.1 Concrete example: motorway bridge
length: 31.80 m  width: 7.50 m  thickness: 1.05 m
material: reinforced concrete
mass: slab: ~ 250 m³  abutments: 2 x ~ 63 m³
middle pillar: ~ 42 m³  total: 418 m³
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slab:
drilling pattern: 0.83 m x 0.83 m
(random holes have a distance of 0.61 m from random)

number of holes: 357
depth of holes: 0.72 m (~ 2/3 of slab thickness)
diameter of holes: 38 mm
drill rig: hydraulic machine
drilling pattern   top view
slab: horizontal cross sections
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slab:
calculation of charges:

– powder factor: 0.500 kg/m³
– burden: \( \frac{1}{2} \) slab = 0.525 m
– spacing: 0.83m x 0.83 m
– (random holes: 0.61 m x 0.83 m

\[ L = 1.05 \text{m} \times 0.83 \text{ m} \times 0.83 \text{ m} \times 0.5 \text{ kg/m}^3 = 0.362 \text{ kg} \]
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charges of slab: random holes:

\[ L = 1.05 \text{m} \times 0.61 \text{m} \times 0.83 \text{m} \times 500 \text{kg/m}^3 = 0.266 \text{ kg} \]

loaded charges: 0.4 kg = 1 cartridge Ø 30 mm x 380 mm
and 0.25 kg = 1 cartridge Ø 25 mm x 380 mm

total:

\[ 84 \times 0.250 \text{ kg} = 21 \text{ kg} \]
\[ 273 \times 0.400 \text{ kg} = 109.2 \text{ kg} \]

\[ \Sigma = 130.2 \text{ kg} \]
Initiation:
shock tube detonators and detonating 5 g/m delay 1 – 20 (25 ms)
initiation starting in the middle of the bridge abutments: with delay 1
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abutments
dimensions:
thickness under slab: 1.40 m
lower parts: 1.9 m – 3.30 m
height: 4.50 m
length: 7.00 m

drilling: inclination of 9°
distance of holes: 1.00 m
depth of holes: 4.5 m + 1.06 m
additional holes in the spur;
wings already demolished
Calculation of charges

Principle:

Volume x powder factor = charge

Powder factor for cast concrete:

0.300 kg/m³

deck loading with detonating cord
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middle pillar:
length: \(~ 9.0 \text{ m}\)
drilling:
vertical holes in
one row of \(5.6 \text{ m}\)
depth
distance of holes:
\(0.83 \text{ m}\)
middle pillar:

loading scheme

deck loading

powder factor: 0.300 kg/m³
load per hole: 2.500 kg
total: 15.000 kg

detonating cord: 12 g/m
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the blast
7.2 smokestacks

material: 

- brickwork (up to 140) 
- (reinforced) concrete
- cavity blocks
- mixed: lower part: concrete
  upper part: brick work

commonness

- frequent
- becoming more frequent
- seldom
- sometimes
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Blasting methods: i  structural analysis necessary
  tilting  folding  collaps
importance of „windows“:
- give clarity about material
  (hidden rings of steel or/and concrete)
- limit destruction of bearing back wall
- reveal soot / dust
- determine precise tilting direction

preferred shape:
  triangle (trapeze)
peculiarities:

brick work smoke stacks:
  - soot
  - smoke outlets
  - reinforcement rings (inside of the brick work
  - steel rings outside
  - reinforced walls
  - steel tubes inside
  - double walls (second wall inside for smoke)
study of premature collapse and later tilting

220 m tall smoke stack of a refinery
peculiarities of concrete smoke stacks:

- big problem:

D weaknees of thin walls can lead to a premature collapse

- solution: installation of a steel hinge
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Di premature collapse
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premature collapse and deviation of fall direction due to lacking structural analysis
drilling of smoke stacks:

normally from outside

D when from Inside:
consider the growing
distance
of the holes
smoke stacks: calculation of charges

powder factor:
brick work:  0.600 - 0.800 kg/m³

reinforced concrete:  up to 1.500 kg/m³

rule of thumb: better more than less
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- to consider

D length of fall:
reinforced concrete smokestacks can „grow“ up to 25 % of their length

debris can fly far away by angle acceleration

lateral expansion movement backwards
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8. Frequent mistakes/misfires

8.1 D misjudgement of structure
    behaviour of collapse
    insufficient knowledge about structure/reinforcement

8.2 D initiation
    wrong sequence of delays
    lack of current (only electric detonators)

8.3 D wrong drilling
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collapse of rear columns

failure of connection of the connection of the two parts of the building
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D misjudgement of structure - no support of rear columns
insufficient knowledge and wrong judgement of reinforcement
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D explosion of soot / chemical dust
D damaged wire, danger of misfire because of loss of current

reinforcement bars as “razor blades” can damage wires
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wrong drill pattern  distance of holes to large
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References:

NOBEL-Hefte, Troisdorf
J. Lippok: Bauwerkssprengungen, Berlin 2006
J. Lippok + D. Korth: Abbrucharbeiten, Köln 2007

Own sources and pictures and experiences