LPG Explosion Damage on The Buildings

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Introduction

What is the LPG?

LPG (Liquefied Petroleum Gas) is flammable mixtures of hydrocarbon gases used as fuel in heating appliances, cooking equipment, and vehicles.

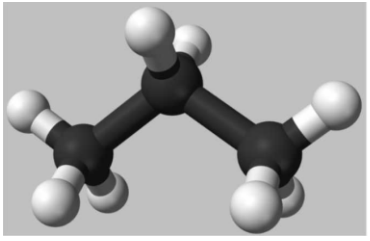
It is prepared by refining petroleum or wet natural gas.

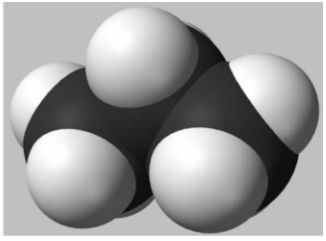
Introduction

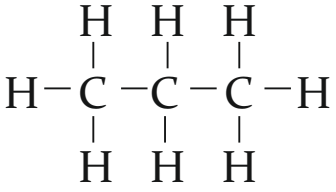
What is the chemical structure?

LPG is a mixture of propane and butane.

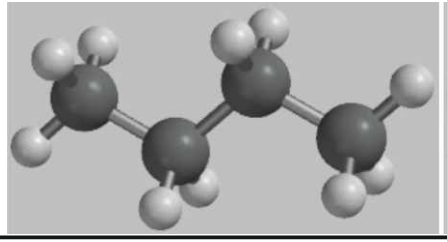
PROPANE (C_3H_8)

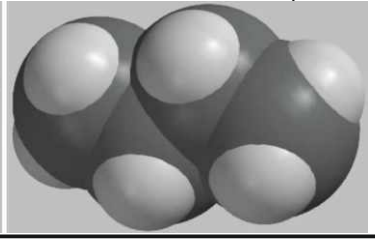


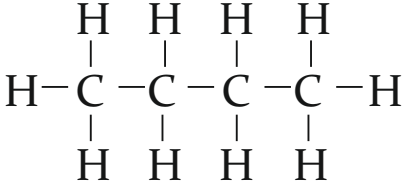




BUTANE (C_4H_{10})







Introduction

Properties of LPG

LPG is a gas at atmospheric pressure and normal ambient temperatures.

It can be liquefied when moderate pressure is applied.

LPG is a colourless in both liquid and gas states. It is odourless.

Ethyl mercaptan is added as an odouriser to it. Thus, leaks can be easily detected.

Introduction

Properties of LPG

When mixed with air, the LPG can burn or explode if it meets a source of ignition.

Introduction

Properties of LPG

LPG is about 2 times heavier than air, so it tends to sink towards the ground.

It can flow for long distances along the ground, and can collect in drains, gullies and cellars.

Introduction

Properties of LPG

Auto ignition of LPG is about 410 degree Celsius (°C). Hence, it will not ignite on its own at normal temperature.

LPG is highly flammable with a lower explosive limit (LEL) of 2% and upper explosive limit (UEL) of 9%, considerably narrower than other common gaseous fuels.

This range of minimum to maximum concentration is termed as Flammable or Explosive range.

Introduction

Properties of LPG

LPG has explosion sensitivity to static electricity.

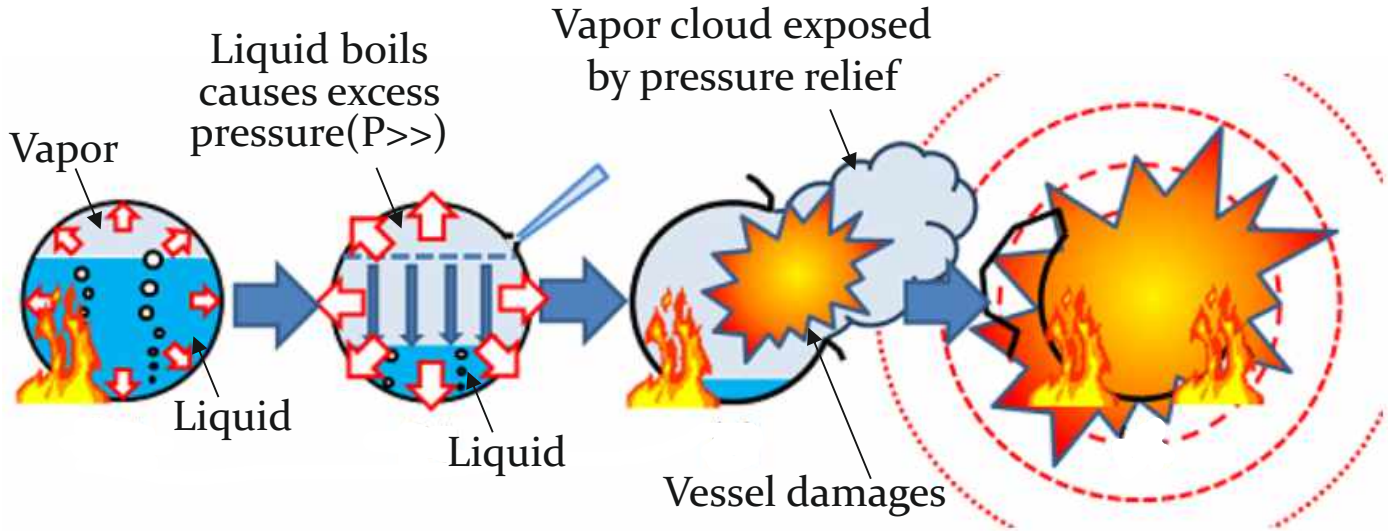
It has a high calorific value of around 11000 kcal/kg.

The combustion products are carbon monoxite (CO) and carbon dioxite (CO_2).

Introduction

What is the BLEVE?

The BLEVE is Boiling Liquid Expanding Vapor Explosion in LPG



Introduction

What are the result effects of BLEVE?

- Pieces of container can fly off 1000 m or more distance.
- Death from such pieces may occur upto 250 m.
- The diametre of fire ball is about 30 m.
- Severe burn damage occurs about 400 m radius.
- Shock wave can break windows a few kilometer away.
- Flame temperature is as high as 1200 degree Celsius (°C).

Introduction

What is the energy density of LPG?

1 te LPG= 0.42 te TNT

te: mass of fuel

Trinitrotoluene: TNT

One kg of TNT releases 4.184 Megajoules ENERGY!

Introduction

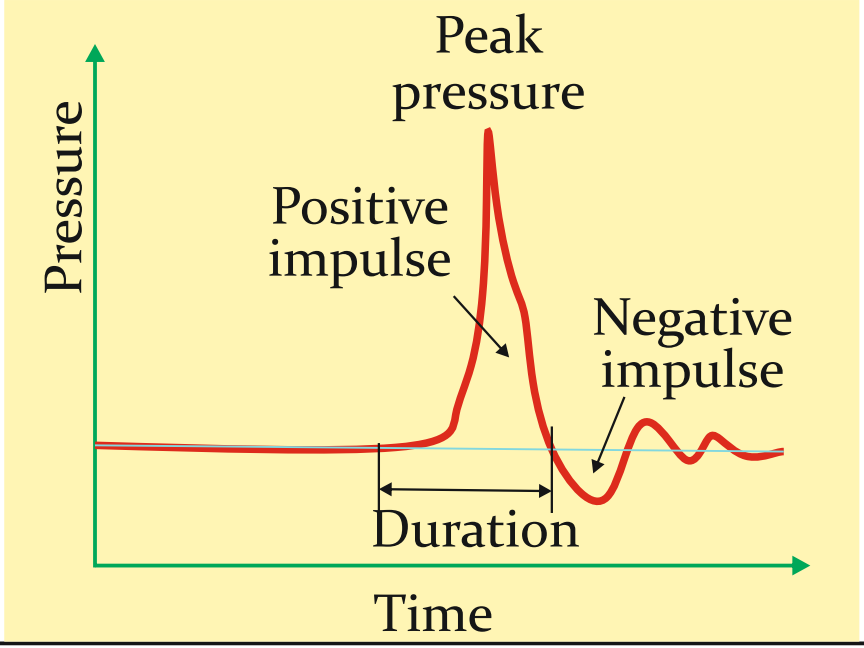
What is the LPG explosion?

In the LPG explosion, combustion of a premixed gas cloud is causing a rapid increase of pressure.

LPG explosion is a very rapid event. LPG explosion creates a dynamic load.

Introduction

How is the variation of the pressure with time during the explosion?



Introduction

In dynamic pressure, the sound waves are also present.

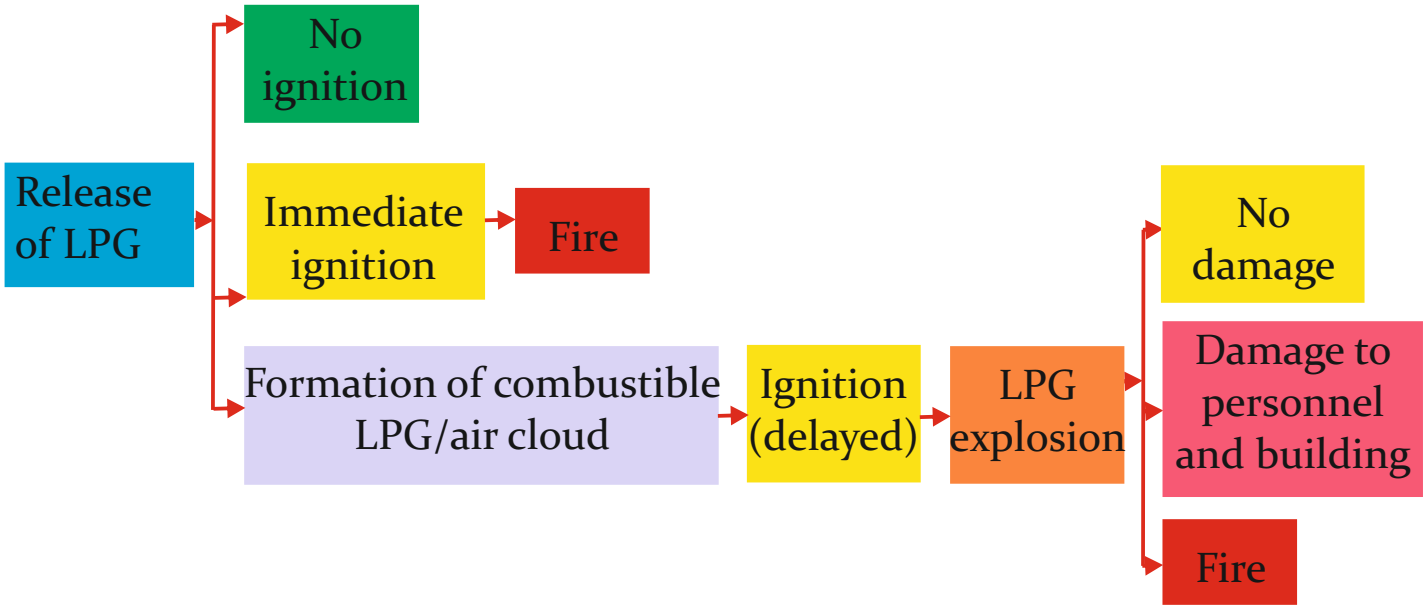
Tertiary blast injury;
injuries due to impact
with another object.

Secondary blast injury;
injuries due to missiles
being propelled by blast force.

Primary blast injury;
injuries due to the
blast wave itself.

Introduction

The chart shows what can happen if combustible LPG or evaporating liquid is released accidentally into the atmosphere.

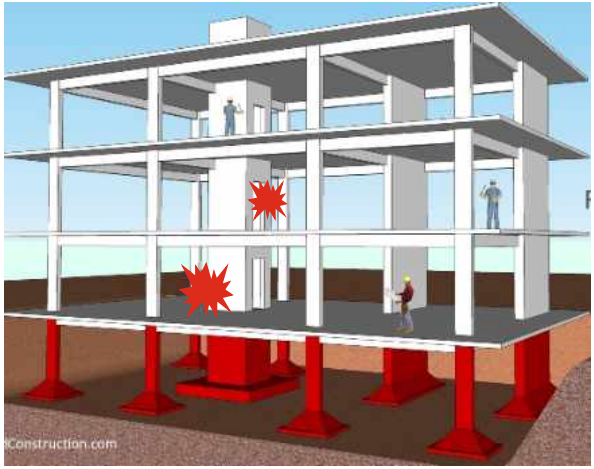


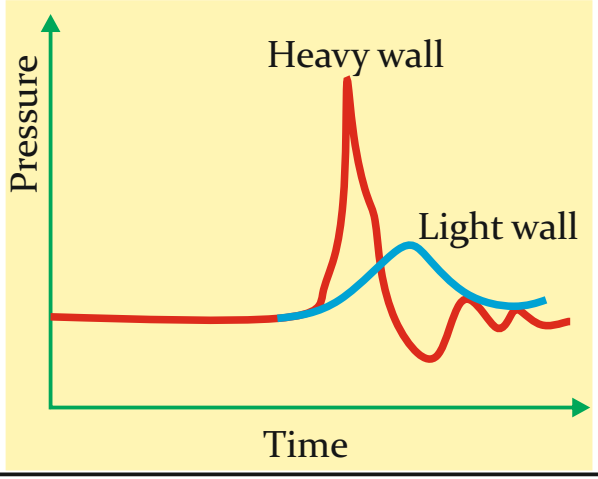
Introduction

Explosion and building safety.

For theLPG explosion safety, the best building has no walls! (Impossible)

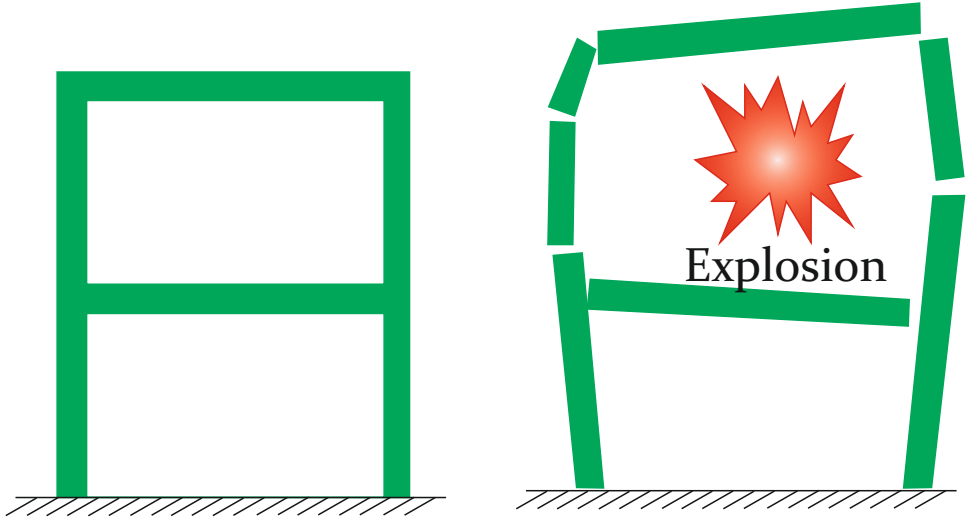
The open areas relieve the pressure if an explosion occurs.





Introduction

Damage in the building in case of an accidental LPG explosion is not a serious problem as long as the building is not collapsing or dangerous fragments are generated within or from the building.



Case Study

In 17 June 2011, at Karakopru town of Sanliurfa in Turkey, a LPG explosion at a petrol station took place and as a result of this explosion 1 person was died and 21 people were seriously wounded.

Case Study

At the location of incident about 200 homes and shops were damaged at various levels, and 20 vehicles were completely destroyed.

All textile materials were burned in the basement of petrol station.

The financial lost in the incident was about one million $.

Case Study

The building mentioned had also a family restaurant. Luckily, the event was not occurred at midday or evening.

There would be a great tragedy if the incident had taken place at these times of the day.

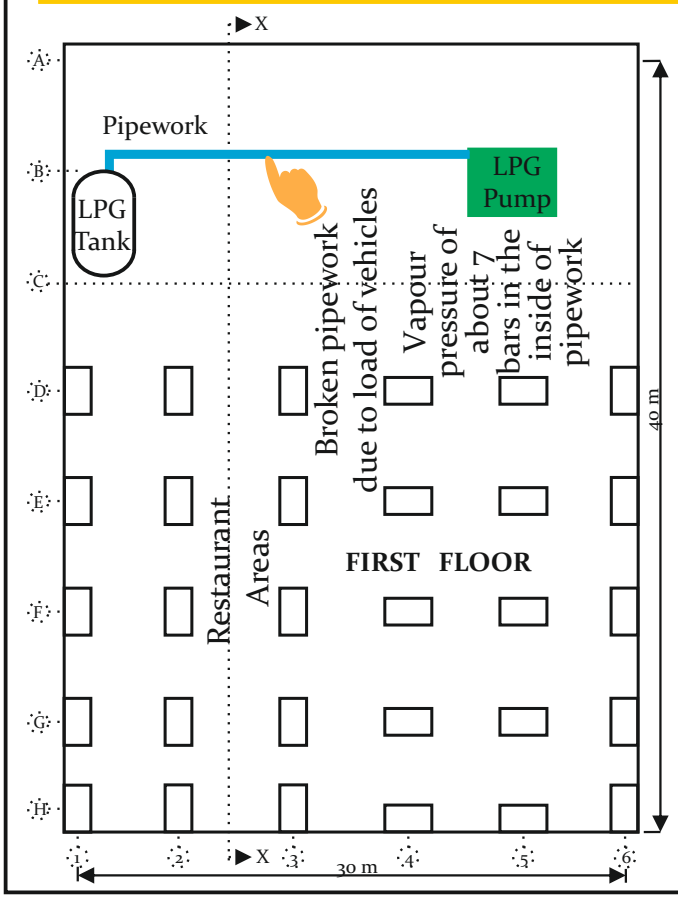
Findings

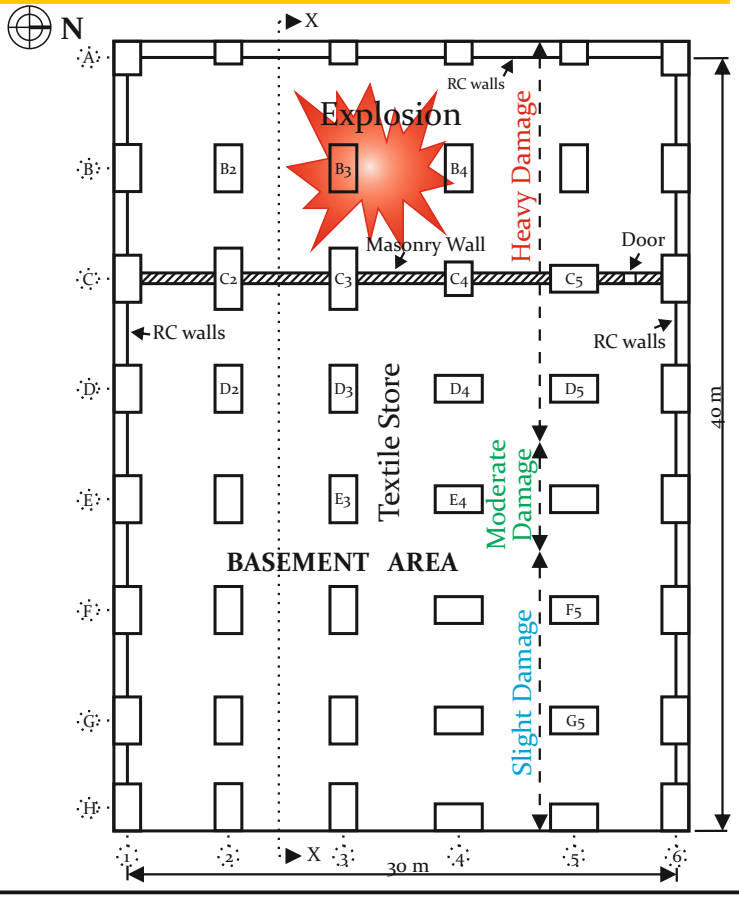
The detailed inspection revealed that the explosion was caused by the ignition of an explosive air that had formed at the basement space of the building due to the leakage of LPG.

Several neighborhood residents expressed that they had smelled the LPG stenching agent before the explosion.

The explanation is that, because the LPG was heavier than air, the smell would probably have been only at the basement.

Findings


X
A
B
C
D
E
F
G
H
Pipework
LPG Tank
LPG Pump
Broken pipework due to load of vehicles
Vapour pressure of about 7 bars in the inside of pipework
Restaurant Areas
FIRST FLOOR
40 m
1
2
X
3
30 m
4
5
6


N
X
A
B
C
D
E
F
G
H
RC walls
Explosion
Heavy Damage
B2
B3
B4
Masonry Wall
Door
C2
C3
C4
C5
RC walls
RC walls
D2
D3
D4
D5
Textile Store
Moderate Damage
E3
E4
BASEMENT AREA
F5
Slight Damage
G5
40 m
1
2
X
3
30 m
4
5
6

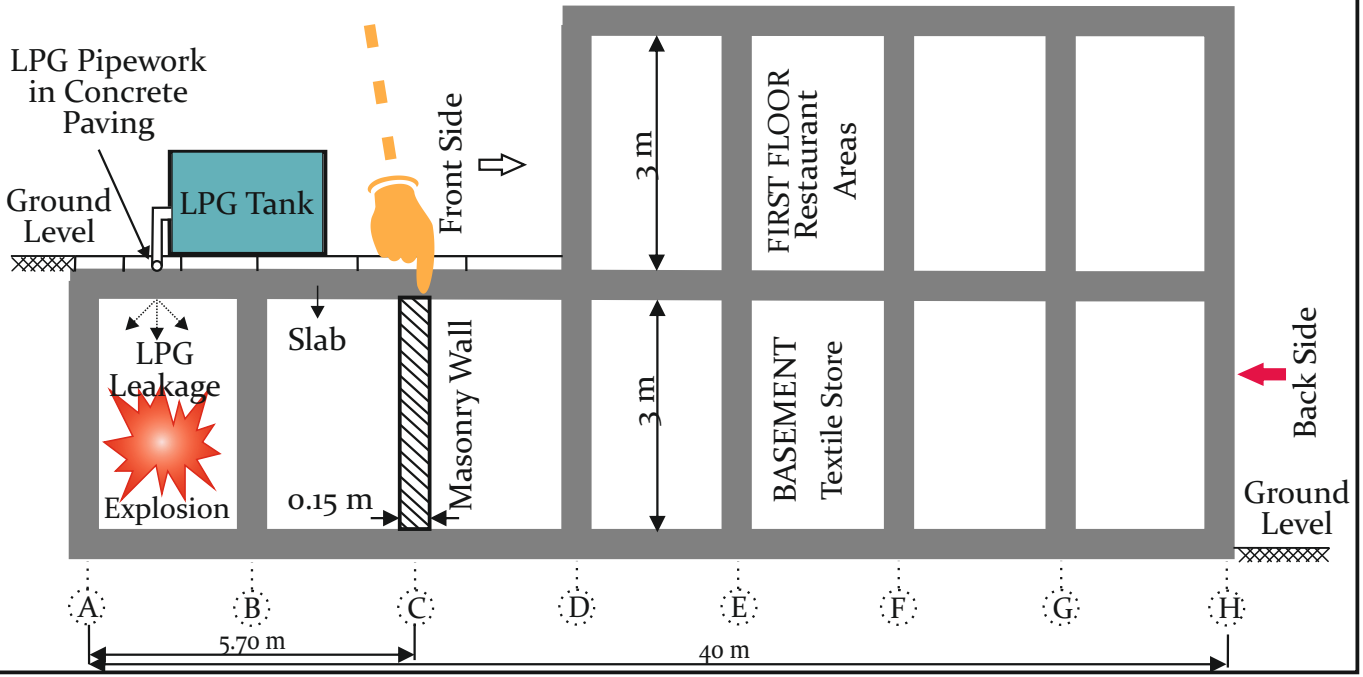
Findings


market
ofis
Just above the begining
point of explosion
at the basement
Front Side


Back Side

Findings

The basement had a masonry partition wall but not it in original project of building. It was reported that the door in partition wall had been closed. Thus, the higher concentration of LPG was accumulated in this confined space.



Findings

The direct cause of the explosion was the escape of LPG from the fractured underground pipe in the concrete paving on the basement slab under the effect of continual loads of vehicles.

The failure of the pipe caused a significant leak of LPG into the basement.

Then, the accumulation of this LPG in there constituted an explosive mixture of air.

The basement space had no mechanical ventilation.

Findings

What was the effect of partition wall in the explosion?

The partition walls should be lightweight and designed to open quickly in case of explosion.

The 10 kg/m^2 wall is opened quickly (Light). Best!

The 30-50 kg/m^2 is not opened easily but some reduction in the duration of the explosion pressure (Heavy). Not so bad!

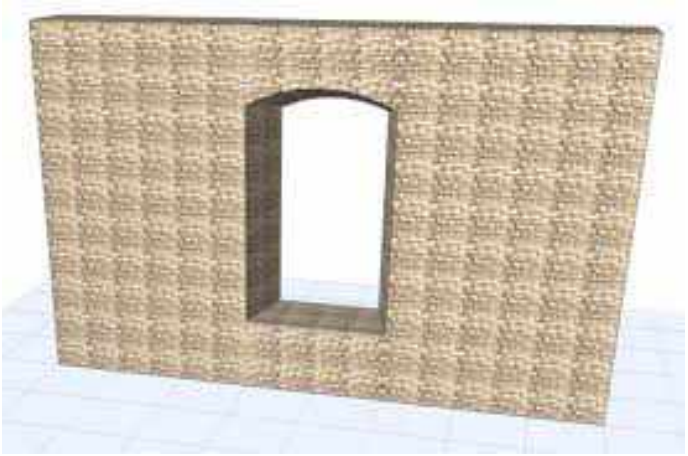
The 100 kg/m^2 wall is not opened easily (Too heavy). Bad!

In this damaged building, the calculated weight of masonry partition wall was about 115 kg/m^2. So bad!

Findings

An open wall (wall with windows) is normally the best solution from an explosion point of view.

If a large part of the wall is open, the natural ventilation is good and explosive cloud formation is less likely.



Findings

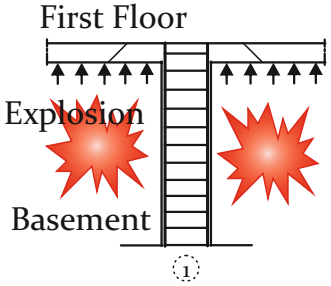
Damage levels and general descriptions in RC buildings

Slight	No significant spalling or cracking in concrete. No buckled/fractured reinforcement. No significant residual displacement in members. Damage requires no more than cosmetic repair. No structural repairs are necessary. For nonstructural elements this would include spackling partition cracks, picking up spilled contents, putting back fallen ceiling tiles, and righting equipment. Building performs its function. Building is reusable following an explosion. Only minor repairs needed. Very little risk to occupants because of building damage.
Moderate	Building is not reusable following an explosion. Building performs its function. Spalling or cracking occurs in concrete. No buckled/ fractured reinforcement. No significant residual displacement in members. Repairable structural damage has occurred. The existing elements can be repaired in place, without substantial demolition or replacement of elements. For nonstructural elements, this would include minor replacement of damaged partitions, ceilings, contents, or equipment. Major repairs needed close to or exceeding replacement cost. Risk of some injury to some occupants caused by building damage.
Heavy	Building blast resistance is impaired. High risk of severe (to incipient collapse) injury to occupants caused by building damage. Boundary longitudinal reinforcement is buckled/fractured or concrete within core of boundary regions (not just cover concrete) is heavily damaged. Cracking becomes concentrated at one or more cracks. Damage is so extensive that repair of elements is either not feasible or requires major demolition or replacement. For nonstructural elements, this would include major or complete replacement of damaged partitions, ceilings, contents, or equipment.

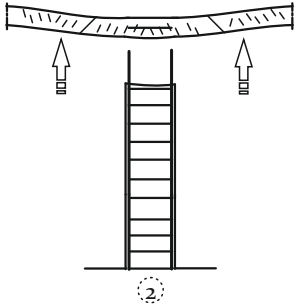
Findings

B2 column damage mechanism (heavy damage)

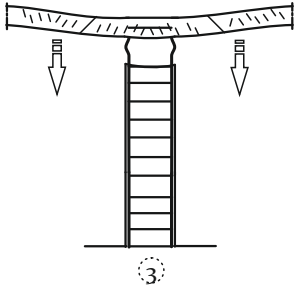
The slip length of longitudinal bars at the column top was about 100 cm. This showed explicitly that the ceiling in this point was lifted higher than 100 cm.



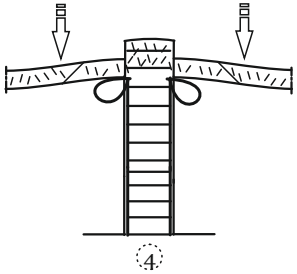
Explosive pressure



Unseating of beam-slab system from the column head and slipping of lap bars



Falling of slab and buckling of lap bars

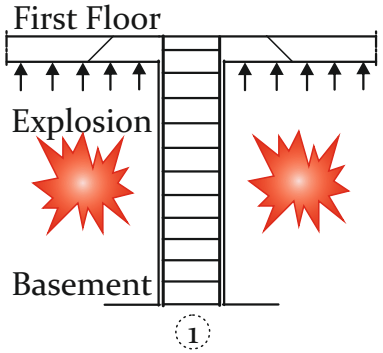


Completely buckled bars

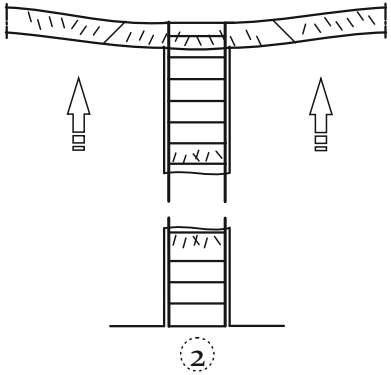
Findings

B3 column damage mechanism (heavy damage)

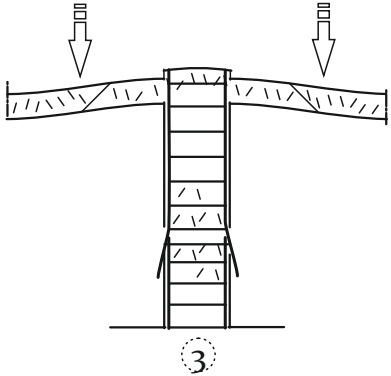
All the longitudinal bars in the column B3 were completely fractured, due to the consequence of the upward movement of the RC beam-slab system with the effect of strong explosion.



Explosive pressure



Fracture of column under the big axial tension caused by explosive pressure



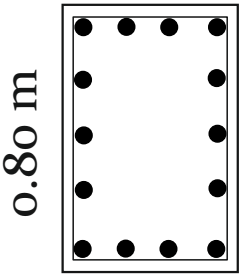
Falling of slab and fractured up part of the column

Findings

What is the value of force applied to B3 column during explosion?

The number of bars: 14
The diameter of bars: 18 mm

B3 column



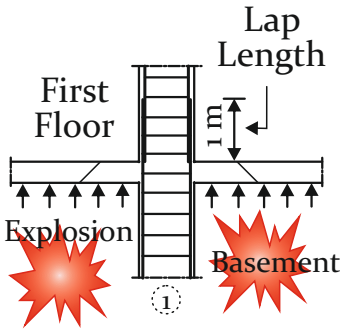
$$P_{\text{ultimate}} = A_{\text{st}}\sigma_{\text{st,ultimate}} = 14 \times \frac{\pi \times 18^2}{4} \times 500 = 1.781 \times 10^6 \text{ N}$$

The force applied on the column B3
due to blast pressure
is
about 178 **TON**!

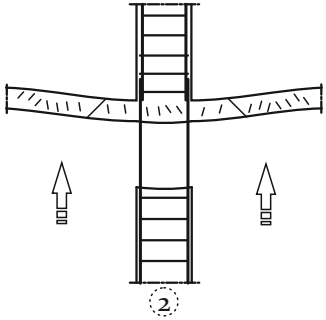
Findings

D2 column damage mechanism (heavy damage)

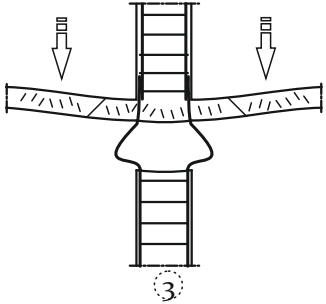
The longitudinal bars in the column D2 slipped along the lap length, while beam-slab system had lifted above. Excessive buckling in lap bars took place under the effect of falling down of the beam-slab system with the decay of explosive pressure.



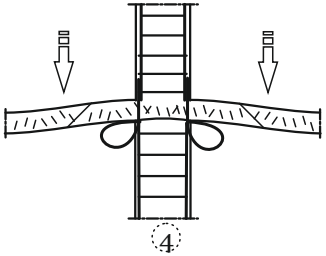
Explosive pressure



Partial slipping of lap bars with the effect of explosive pressure

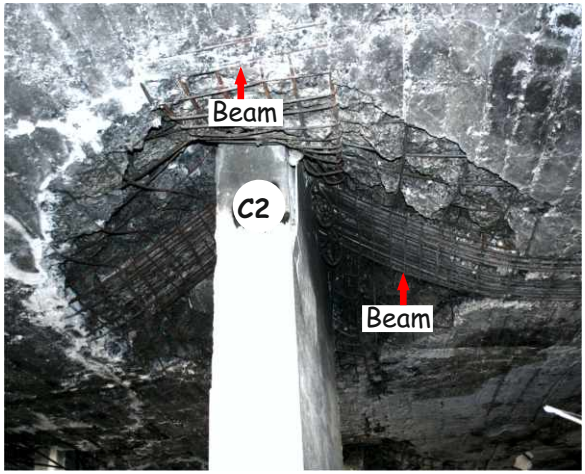


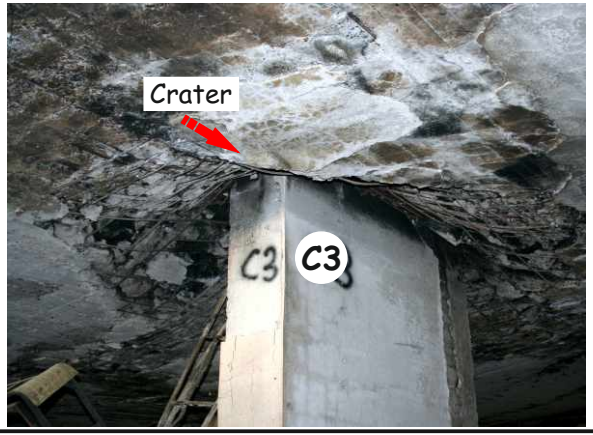
Buckling of lap bars with the effect of falling down slab

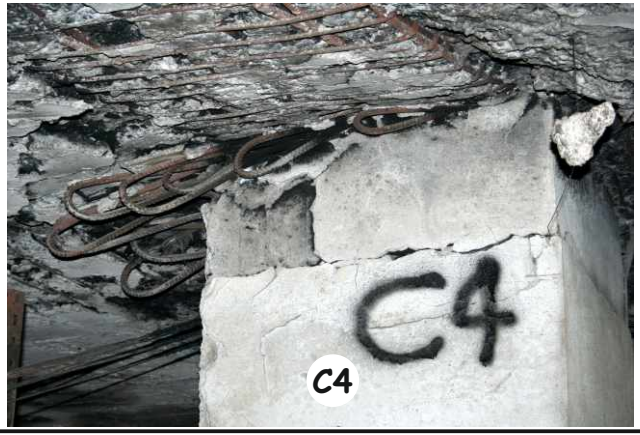


Completely buckled state of lap bars at the column head

Findings



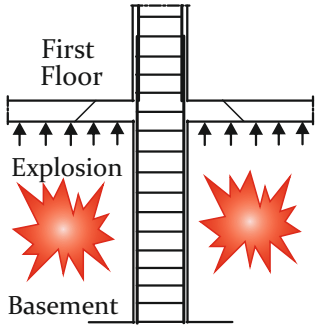




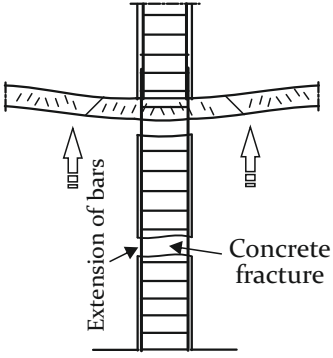
Findings

D3 column damage mechanism (heavy damage)

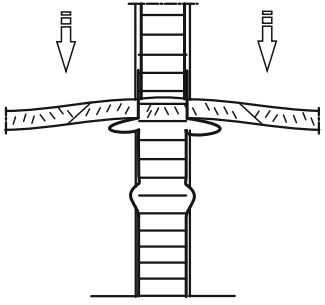
Column D3 was divided into two parts by fracture of concrete and, firstly elongation and then buckling of longitudinal bars at nearly mid-point of the column. In the column, besides mid-height, at the column top, buckling of longitudinal bars were observed.



1 Explosive pressure



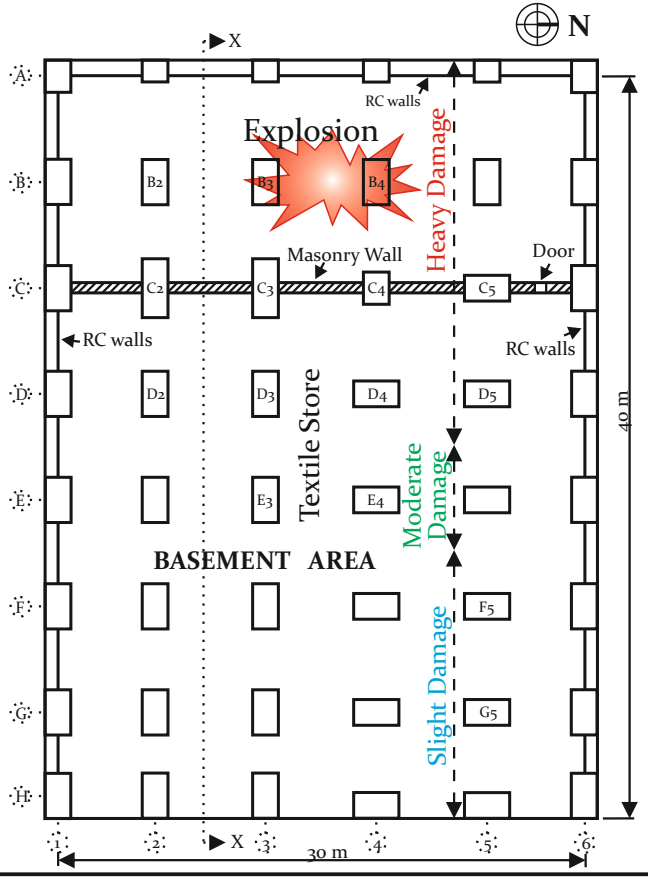
2 Extension of longitudinal bars due to the upward effect of explosion overpressure



3 Prominent buckled states of bars with the slammingdown slab system

Findings

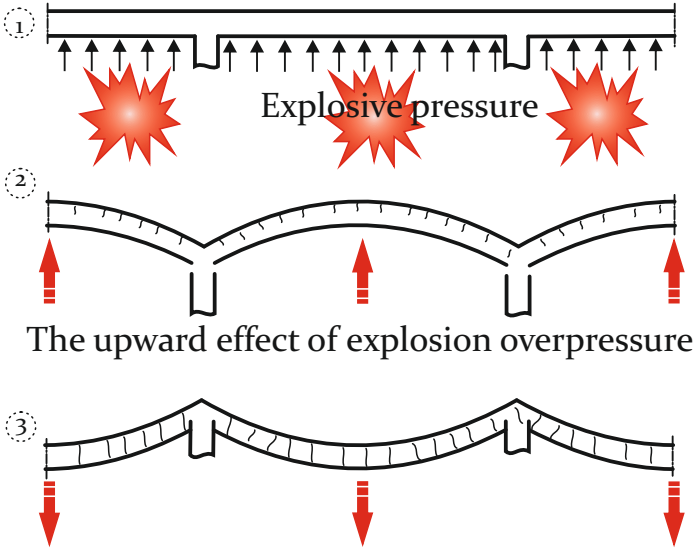
Slightly damaged columns far from the explosion starting point!



Findings

Damage in beam-slab system (heavy damage)

Like a carpet!



This upward load requires that the beam-slab system would be reinforced to resist loads opposing the effects of gravity.

This building was only designed for dead and live load, not for explosive pressures.

Findings

An interesting damage in an apartment nearby the gas station!

Suggestions

- The potential consequences of LPG leaking can be very high, although considered the risk of a release of liquid LPG to be low.
- The leakage of LPG into an unventilated space is very dangerous.
- Therefore, users and suppliers must adhere to the highest possible standards when storing and handling LPG.

Suggestions

- The severity of LPG explosion on building depend strongly on the venting arrangements.
- Small changes in the buildings can change the explosion pressure significantly. It is therefore important to understand the mechanisms of pressure build-up.
- Based on this knowledge, it is often possible to suggest changes in the layout that affects the explosion behavior significantly and hence improve overall safety.

Suggestions

For the safety;

- Existing fire hazard,
- Suitable means of escape,
- Fire fighting equipment and provisions.

should be taken in the consideration.

Thank you for your attention

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