Appendix 2.21 - GERMANY – Kö-Bogen Tunnel in Düsseldorf

1. SUMMARY – COMPLEX TUNNEL AND UNDERGROUND CAR PARKS

The Kö-Bogen tunnel is a complex tunnel building in the city of Düsseldorf (Germany) with several tunnel tubes that are all connected as shown in Figure 1 and Figure 2. Basically, three tubes over ground streets were conceived and constructed in cut & cover construction method.

The tunnel contains two main tubes "South-North" and "North-South" as well as two side tubes the "South-West" and the "North-West" branches respectively. All tubes are unidirectional. Furthermore, there are three underground car parks namely "Kö-Bogen", "Schauspielhaus" and "Dreischeibenhaus".

The underground car parks "Schauspielhaus" and "Dreischeibenhaus" are accessible over an underground spindle that connects the two car parks with the tunnel shown in Figure 1.

The tunnel is operated by the city of Düsseldorf. The car park "Kö-Bogen" is a public car park and is operated by a private owner. The car park "Dreischeibenhaus" is a privately owned facility used by the employees of the Dreischeibenhaus office building. The car park "Schauspielhaus" is also a public car park operated by a private owner.

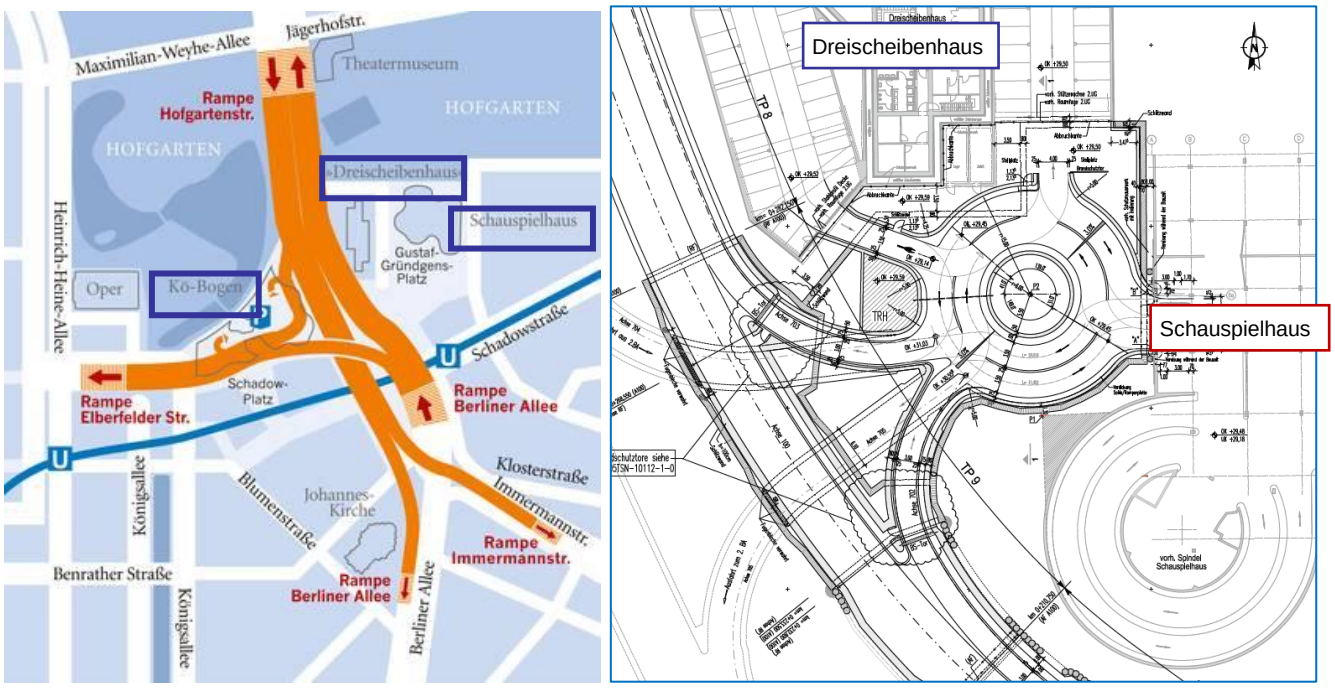

Figure 1 – Kö-Bogen Tunnel geographical location and underground spindle

Figure 2 – Tunnel, underground car park and ramp

The tunnel was built to provide additional space flexibility in the city centre including the creation of a third, new underground car park facility. Also, the water body "Landskrone" was extended and trees planted in place of the old overpass "Tausendfüssler". The whole project was developed in two phases. Figure 3 shows the construction sequence where the "red routes" were part of the first phase and the "blue routes" were part of the second phase.

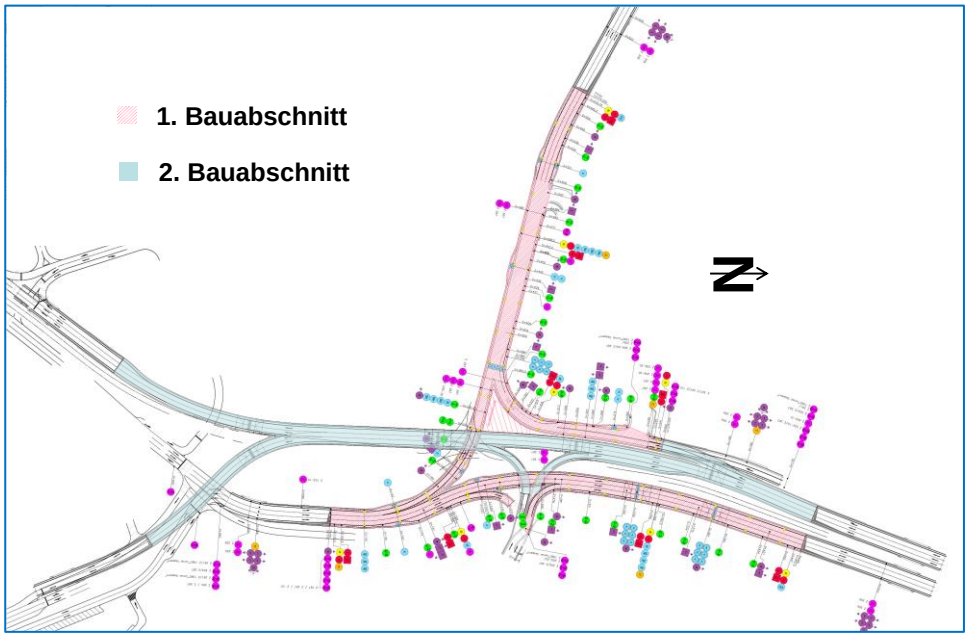

Figure 3 - Overview over the two construction phases

2. MAIN CHARACTERISTICS

2.1 GEOMETRY

- Tunnel length extends from 86 m to 495 m. The full length of all tunnel tubes is 1398 m.
- Gradients of the vertical alignment inside the tunnel raises up to 4 %, while at portals it increases up to 8 %.
- Crossfall remains at an average of 4 %, with a maximum existing grade of 5 %.
- There are 6 ramps to the surface and several underground ramps to access and leave the underground car parks.
- Emergency lanes. Due to tunnel short length of approximately 900 m, there is no provision of emergency lanes in the main tubes. Only the axes 300 and 500 have an emergency lane.
- Height clearance is 4,95 m except the connections to the underground car park.

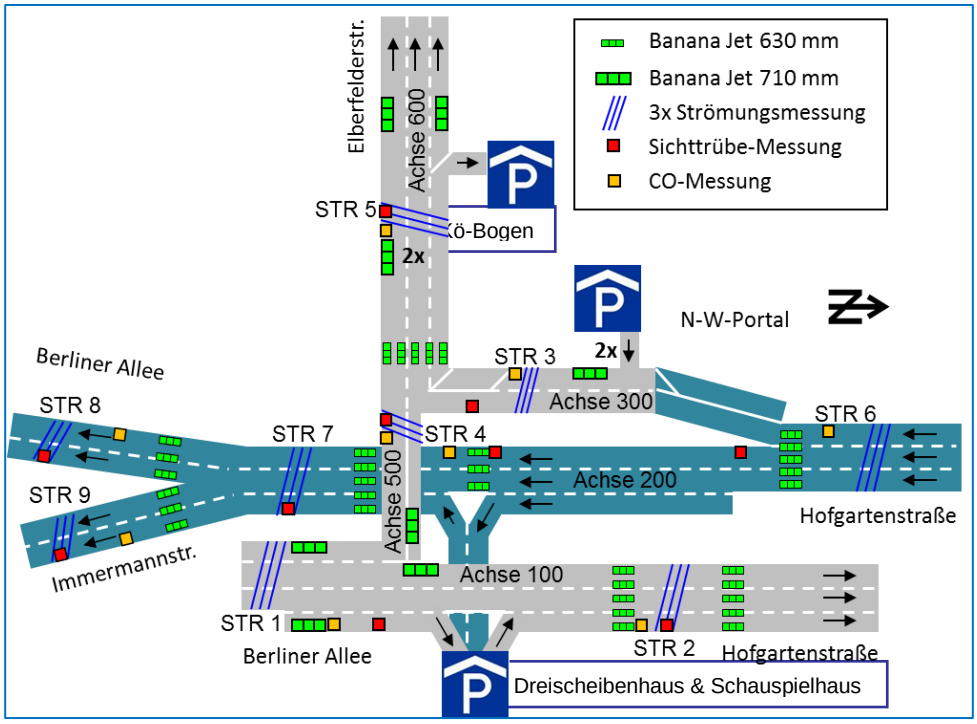

Figure 4 - Location of jet fans and measuring devices

2.2 CROSS SECTION

The tunnel provides for one-way traffic flow with a variable width one to three lanes. Air ventilation fans have been installed in two different ways. Either in niches on the ceiling or in the wall as shown in Figure 4 and Figure 5).

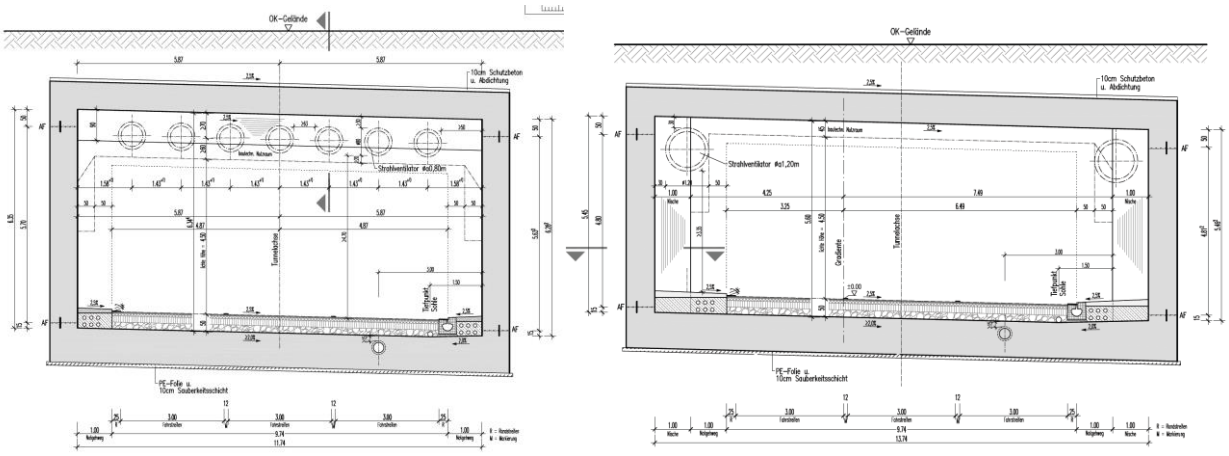

Figure 5 - Cross sections

Due to the complex tunnel system, the following different cross sections are applicable.

General		**2 lanes Axis 100, 200, 400**	
Lane	3,00 m	Lane width	6,62 m
Emergency lane	2,00 m	Height	4,95 m
Sidewalk	1,00 m	Cross section	42,67 m²
1 lane – connection to the underground car park		**3 lanes Axis 100, 200, 300**	
Lane's width	3,50 m	Lane width	9,74 m
Height	2,30 m	Height	4,95 m
Cross section	10,35 m²	Cross section	58,11 m
1 lane with emergency lane Axis 300, 305, 500		**3 lanes with turn lane Axis 100, 200**	
Lane's width	5,50 m	Lane width	9,87 m
Height	4,95 m	Height	4,95 m
Cross section	37,13 m²	Cross section	58,76 m²

2.3 TRAFFIC CONDITIONS

- HGV traffic — allowed, average occurrence: 2,0 %
- Hazardous goods vehicles — prohibited / not allowed
- Buses — allowed
- Bicycles and pedestrians — prohibited / not allowed
- AADT (Annual Average Daily Traffic) — about 30 000 veh/day on the main routes (Figure 6)
- Speed limit — 50 km/h in the overall system and 40 km/h in a limited bend area in the north-west-tunnel
- Detection of traffic jams — traffic loops inside the tunnel with alarm to the operator

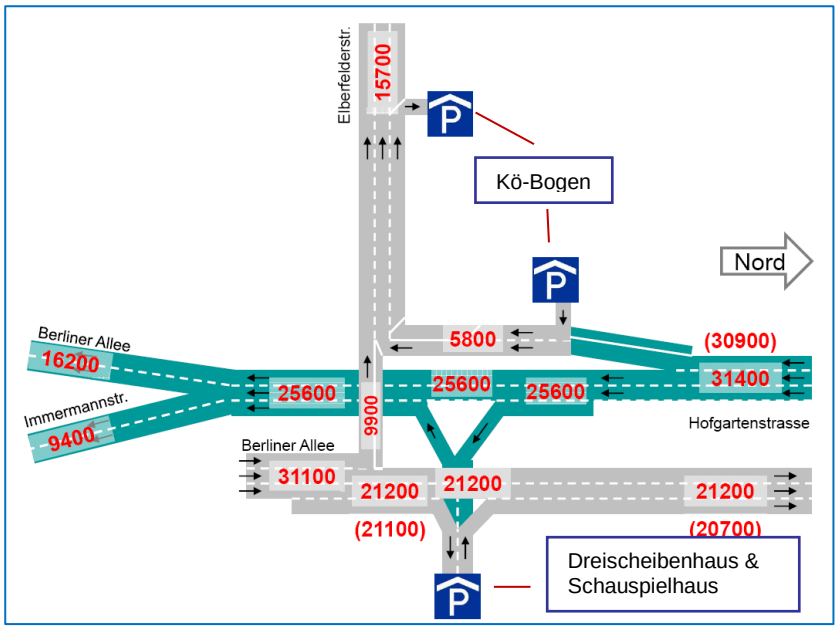

Figure 6- Traffic volume

Risk of traffic jams in any part of the tunnel is not envisaged.

2.4 SIGNALLING

There are no variable signals within the tunnel. Variable signage is only placed at tunnel entries to facilitate the tunnel closure when required.

3. VENTILATION

The tunnel is equipped with a longitudinal ventilation system comprising two different types of jet fans: 10 reversible jet fans with an impeller diameter of 730 mm are installed in niches and on the tunnel walls. Furthermore, additional 34 reversible jet fans with an impeller diameter of 630 mm are equally installed in niches at the ceiling.

Under normal operation, the mechanical ventilation is on "off position" and the tunnel is ventilated by the piston effect of vehicles. If the piston effect is not sufficient, the longitudinal ventilation will start automatically. The use of the ventilation depends on the measured values of visibility and carbon monoxide.

Incident ventilation in case of fire has the following objectives:

- For moving traffic, a wind speed of at least 3 m/s must be reached,
- In case of traffic jam a wind speed of approx. 1,2 m/s should be targeted.

Traffic jams are detected automatically by loops inside the tunnel. In case of fire detection within the tunnel environment, the ventilation starts automatically by default. After the self-rescue phase, the firefighters have the possibility to manage the ventilation manually in order to rescue more people or to fight the fire. The traffic jam detection system is still not operational, and this limits the incident ventilation strategy for traffic jam be used in case of moving traffic. Once the traffic jam detection system becomes fully operational, the incident ventilation will differ for the traffic jams and moving traffic.

4. FACILITIES AND OPERATIONAL EQUIPMENT

❑ Video control

Fixed cameras are installed in the tunnel, at every 60 m spacing. At the portals, movable cameras are in use. In order to receive a fast-operational monitoring, all cameras are equipped with an automatic picture evaluation.

❑ Emergency Exits

Beside the portals, emergency exits into the escape stairs near the tunnel control centre are built. This is aimed to ensure that the emergency exits are within a spacing of less than 300 m (Figure 7).

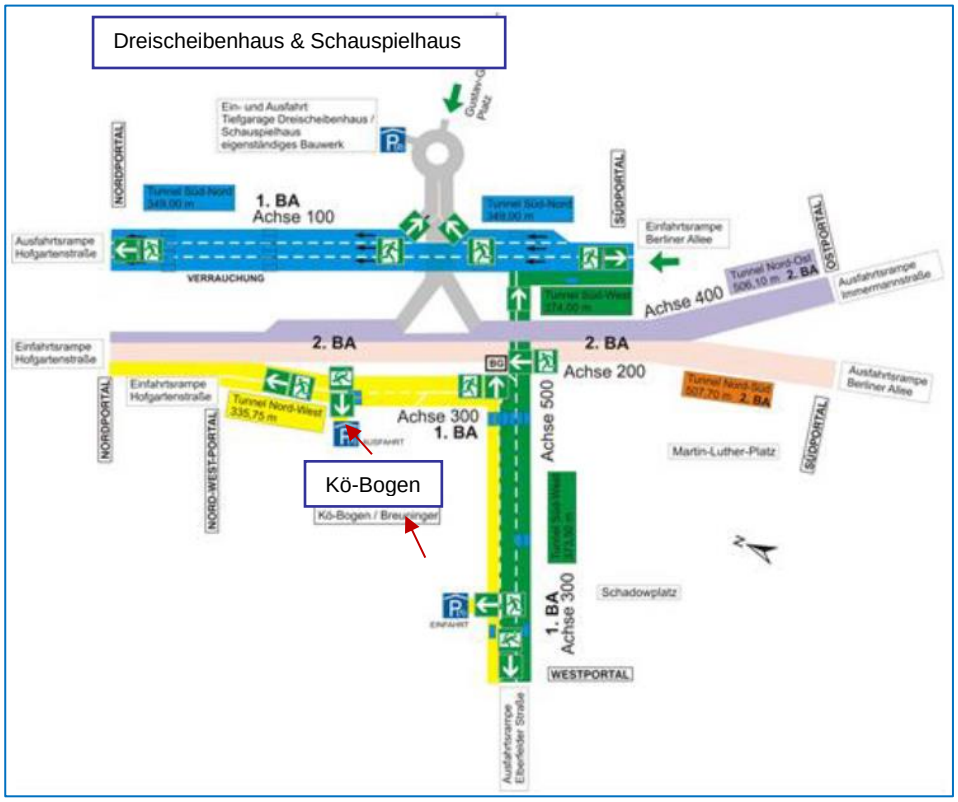

Figure 7 - Emergency exits – Overview

❑ Fire doors

Between the tunnel and the underground car park, fire doors are installed. In case of a fire, the fire doors will be closed to ensure that two separate ventilation sections, the tunnel and the underground car park, are obtained.

❑ Sound pollution

The jet fans are fitted with noise attenuators.

5. MANAGEMENT AND ORGANISATION

Knowing that the four constructions Dreischeibenhaus, Libeskindgebäude (above Kö-Bogen car park), underground spindle and the tunnel itself are connected, their interfaces in case of incidents have to be managed. Each construction has its own fire alarm control centre. If there is an alarm in one of these constructions, it will automatically be transferred to the alarm central of the other buildings in line with the following protocol.

Localisation of the alarm	Action
Alarm in tunnel	transferred to Dreischeibenhaus, Libeskindgebäude and spindle
Alarm in Dreischeibenhaus	technical notification to spindle
Alarm in Libeskindgebäude	technical notification to tunnel
Alarm in spindle	transferred to Dreischeibenhaus

The reset of the fire alarm is done manually.