

MEMORANDUM

Fehmarnbelt Fixed Link

Traffic restrictions due to wind on the Fehmarnbelt Bridge

Introduction

23 June 2004 the German and Danish Ministers of Transport signed a Joint Declaration which states that before final selection of the technical solution for the Fixed Link comprehensive studies will be carried out.

One of the studies deals with the issue regarding the influence of strong wind in the Fehmarnbelt area on the traffic in case a bridge solution is selected.

The bridge will be oriented in a north-south direction. The prevailing wind direction is westerly wind. A large open water body to the west of the bridge location exist. Altogether this indicates that the traffic on a bridge across the Fehmarnbelt might be affected by strong wind.

For safety reasons and for the comfort of users of the fixed link it is anticipated that procedures for introducing restrictions on road and railway traffic will be established by the organisation that will be responsible for the operation of a fixed link across the Fehmarnbelt.

Traffic restrictions introduced due to strong winds in the area will influence the accessibility of the bridge crossing. One of the reasons for the political and commercial interests in establishing a fixed link is to improve the accessibility of the crossing of the Fehmarnbelt compared to the ferry service system operating today. Furthermore a reduced accessibility could have an impact on the economy of the project due to short fall of income from the traffic.

For those reasons it has been decided to investigate how often and for how many hours per year traffic restrictions for safety reasons will have to be introduced on the Fehmarnbelt Fixed Link.

On basis of available wind measurements in the region and on basis of known traffic restriction criteria for the Øresund Bridge (similar type of bridge) an estimate of the expected number and duration of restrictions on a fixed link across the Fehmarnbelt Bridge has been calculated. The estimated number and duration of traffic restrictions is compared to other bridges.

1. Traffic restriction criteria

Strong wind can cause traffic accidents for both road and railway traffic. In order to minimize the risk of accidents due to strong wind it has been assumed that a set of criteria for restricting the road and railway traffic as shown in tables 1 and 2 will be introduced by the responsible operator of the Fehmarnbelt Bridge.

The criteria presented in table 1 and 2 for road and railway traffic respectively are identical to the criteria introduced on the Øresund Bridge 1 October 2003.

Light vehicles are defined as caravans, camper trailers and high trucks with no or only light cargo.

Table 1 : Restriction criteria for road traffic

| Vehicle type | The bridge closes when the wind speed is above | The bridge reopens when the wind speed is below |
|-------------------------|--|---|
| Only for light vehicles | 21 m/sec or 17 m/sec ^{a)} | 19 m/sec and 15 m/sec ^{a)} |
| All vehicles | 27 m/sec | 25 m/sec |

a) The wind speed is the speed perpendicular to the bridge direction

Table 2 : Restriction criteria for railway traffic

| Train type | The bridge closes when the wind speed is above | The bridge reopens when the wind speed is below |
|-----------------|--|---|
| Freight train | 27 m/sec | 25 m/sec |
| Passenger train | 34 m/sec | 32 m/sec |

Note: All wind speeds in table 1 and 2 are 10 minute mean speed values.

2. Estimated traffic restrictions on a Fehmarnbelt Bridge

The expected traffic restrictions have been calculated for the Fehmarnbelt Bridge under the assumption that identical restriction criteria are introduced as shown in table 1 and 2.

The calculations are based on wind statistic from German and Danish measurement stations in the Fehmarnbelt area. The results are shown in table 3 and 4.

The calculated number of hours with traffic restrictions for road traffic on the Fehmarnbelt Bridge is presented together with the actual traffic restrictions on the Great Belt Bridge, Øresund Bridge and on the Fehmarnsund Bridge for comparison.

It should be noted that the traffic restriction criteria for the Great Belt and the Fehmarnsund Bridge are not identical to the ones presented in table 1 and 2.

For the Great Belt the criteria are very similar but with slightly lower wind speed limits.

Furthermore the Great Belt criteria includes meteorological forecasts and measured gust across the bridge

The criteria used on the Fehmarnsund Bridge differ too and are less differentiated.

Data regarding actual traffic restrictions is available since 1984 for the Fehmarnsund Bridge, since 1998 for the Great Belt Bridge and since October 2003 for the Øresund Bridge.

Table 3 : Estimated and actual traffic restrictions per year for road traffic

| Vehicle type | Fehmarnbelt Bridge (Estimated) | Great Belt Bridge (June 1998 to December 2003) | Øresund Bridge (October 2003 to December 2004) | Fehmarnsund Bridge ^{b)} (1984 to 2002) |
|---------------------|-------------------------------------|---|---|--|
| Only light vehicles | 170 hours 24 hours ^{a)} | 130 hours | 100 hours | 200 hours |
| All vehicles | 12 hours | 9 hours | 7 hours | - |

a) The number of hours with traffic restrictions can be reduced by introducing a wind screen on the bridge.

b) On the Fehmarnsund Bridge the elevation of the traffic is lower than on the other bridges and therefore the traffic is less exposed to wind compared with the other bridges.

In general the train traffic is less affected by strong wind and for that reason the wind speed limits for introducing restrictions are higher.

In table 4 the results of the calculations of the expected number of hours per year where introduction of restriction can be expected for goods trains respectively passenger trains are shown.

Table 4 : Estimated traffic restrictions per year for railway traffic

| Train type | Fehmarnbelt Bridge |
|------------------|--------------------|
| Freight trains | 12 hours |
| Passenger trains | Less than 5 hours |

Since the opening of the Øresund Bridge in July 2000 the bridge has only been closed for 6 hours (January 2005) for passenger trains due to strong wind. The Great Belt railway link consist of a bored tunnel and of a low bridge and therefore the railway traffic is less exposed to wind compared to the Øresund Bridge.

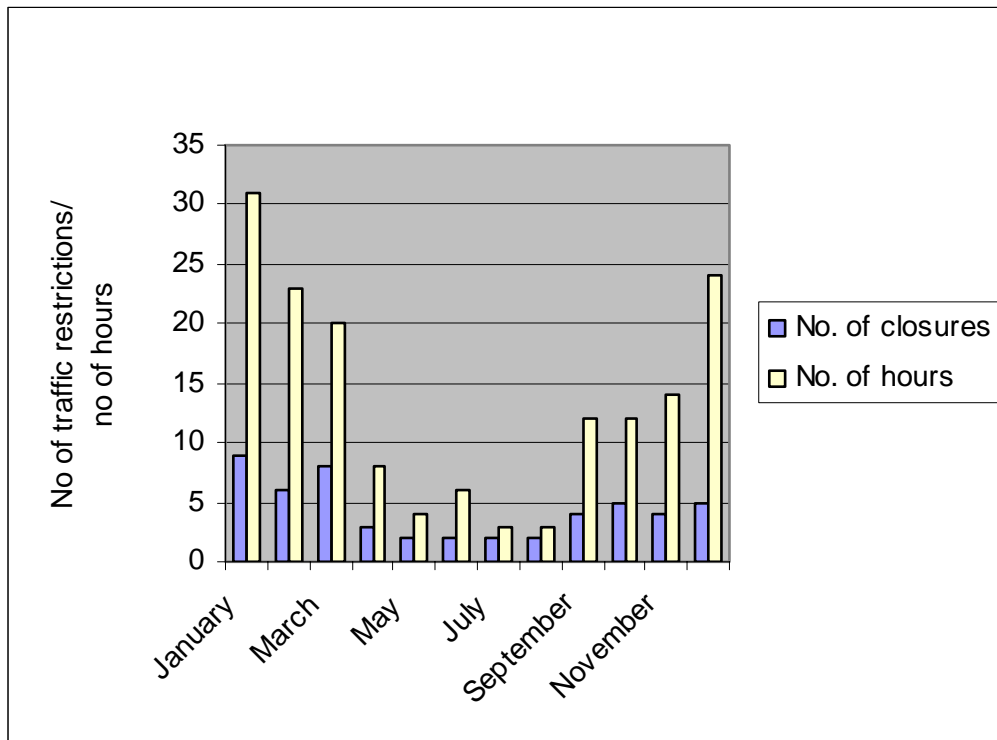
In general traffic restrictions are expected to occur more often on a Fehmarnbelt Bridge than on the Great Belt Bridge and on the Øresund Bridge due to

- The north-south orientation of the Fehmarnbelt Bridge compared to east west direction of the Great Belt Bridge and the Øresund Bridge
- A slightly higher elevation of the road traffic on the Fehmarnbelt Bridge (max 80 m) compared to the Great Belt East Bridge (max 75) and the Øresund Bridge (max 65 m)
- A difference in wind climate because the Fehmarnbelt Bridge will have a large area of open water to the west of the bridge.

3. Seasonal distribution of the traffic restrictions

The seasonal distribution of the traffic restrictions for light vehicles is shown in figure 1 where it is seen that the number of restrictions is lowest in the summer months and highest in the winter months.

Figure 1: Mean monthly distribution of closures for light vehicles



4. Mitigating measure - Wind screens

Wind screens might be installed to protect light traffic from strong cross wind. Wind screens can be provided either over the entire bridge length or partly around pylons where the wind screens will smooth the transition for light traffic.

A wind screen can reduce the wind speed with 50 to 75 %. A reduction of 50 % of the wind speed will reduce the number of hours with traffic restrictions for light vehicles from 170 hours to 24 hours.

5. Users perception

For the users of the bridge traffic restrictions due to strong wind will naturally be seen as annoyance. On the other hand the calculated number of hours where traffic restrictions are expected to be introduced is quite low and most of them occur in the winter months where traffic intensity is low. Furthermore users of the bridge normally appreciate that the restrictions are introduced for the safety of the users themselves.

6. Financial implication

Traffic restrictions due to strong wind will only have a marginal influence on the number of vehicles and trains which pass the bridge. The restrictions will therefore only have a marginal effect of the toll revenue from the passing traffic. If a storm situation in the area will result in a total closure of the bridge it will normally be forecasted by the bridge operator responsible for introducing restrictions. By use of "public traffic information systems" the users will be advised well in advance.

A significant part of the light vehicles will be camper trailers and caravans. These will based on the experience from Øresund and Storebælt constitute app. 2% of the total traffic. The major part of these are expected to cross the fixed link in the summer period (May - September), where the number of restrictions due to strong wind has been calculated to in average 12 closures of a duration of less than 3 hours.

Restrictions for this category of light vehicles will in other words be introduced in approx. 2 % of the time. On basis of the calculation of the number of restrictions and the duration hereof it can roughly be estimated that the loss of revenue would be less than 0,05% provided that the travellers would cancel their planned crossing. This will of course not be the case as most travellers will accept to wait until the restriction has been cancelled."

Normally alternative modes of traffic and bridges in the region will in such a situation also be affected. A loss of revenue will therefore be limited because the users have no alternative to a postponement of their travel.

In most of cases where traffic restrictions are introduced the duration will be less than 3 hours and the duration will often be forecasted well in advance. The users of the bridge will have to wait until the restrictions can be cancelled. Normally the users will accept this because there will be no alternative available as other bridges or ferry services will also be affected.

Wind screens can reduce the number of hours with traffic restrictions and thereby reduce the "loss" of revenue due to strong wind.

The cost involved for having the entire length of the bridge equipped with wind screens have been estimated to an amount in the range of 15 to 50 million Euros depending on the technical and esthetical solution for the wind screens.

7. References

Traffic restriction due to strong wind on the Fehmarnbelt Bridge,
Risø National Laboratory , Roskilde, Denmark and Deutscher Wetterdienst, Hamburg,
Germany, June, 2005.