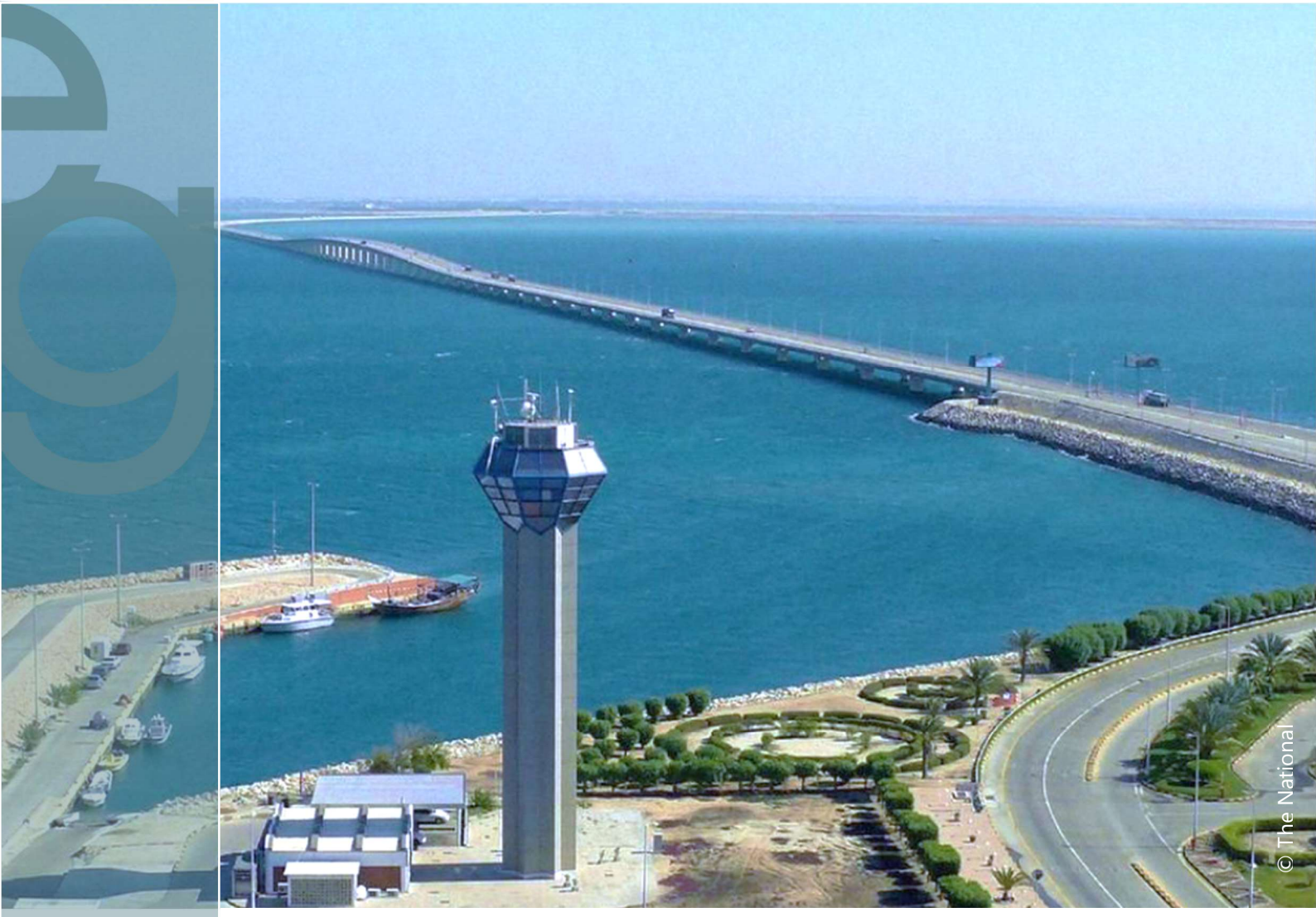
KING FAHD CAUSEWAY ASSESSMENT

Bridge Condition Index

08 August 2024

المؤسسة العامة لجسر الملك فهد
King Fahd Causeway Authority



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1 INTRODUCTION

1.1 General

The King Fahad Causeway Authority (KFCA) launched a tender for a condition and life assessment of all the bridges this because the bridge is reaching its mid-life, and it is of economic and social interest for KFCA to evaluate and possibly extend the remaining life of the bridge.

Egis is leading an international team of experts carrying out the assessment of the King Fahd Causeway including developing inspection, maintenance, and repair works. The project has a scheduled duration of 12 months.

The purpose of this document is to provide method statement for the bridge scoring of the King Fahd Causeway. The bridge scoring will lead to the calculation of the Bridge Condition Index.

1.2 The King Fahd Causeway

The King Fahd Causeway (KFC) is a 25 km long series of bridges and causeways connecting the Kingdom of Saudi Arabia (KSA) and Bahrain, in the Persian Gulf.

Specifically, the King Fahd Causeway is composed of 5 bridges and 7 embankments. There are also 3 flyovers, 2 flyovers are on the Middle Island and the third flyover is the Al Azeziya flyover located after the toll gate on embankment N° 1.

The King Fahd Causeway was built between 1981 and 1986.

The structure consists of 2 carriageways, each carrying 2 traffic lanes and an emergency lane. The KFC is tolled and is managed by the King Fahd Causeway Authority, a company jointly owned by the KSA and Bahrain.

The embankment N° 4 is a global artificial Island, the Middle Island which corresponds to the border between Bahrain and KSA.

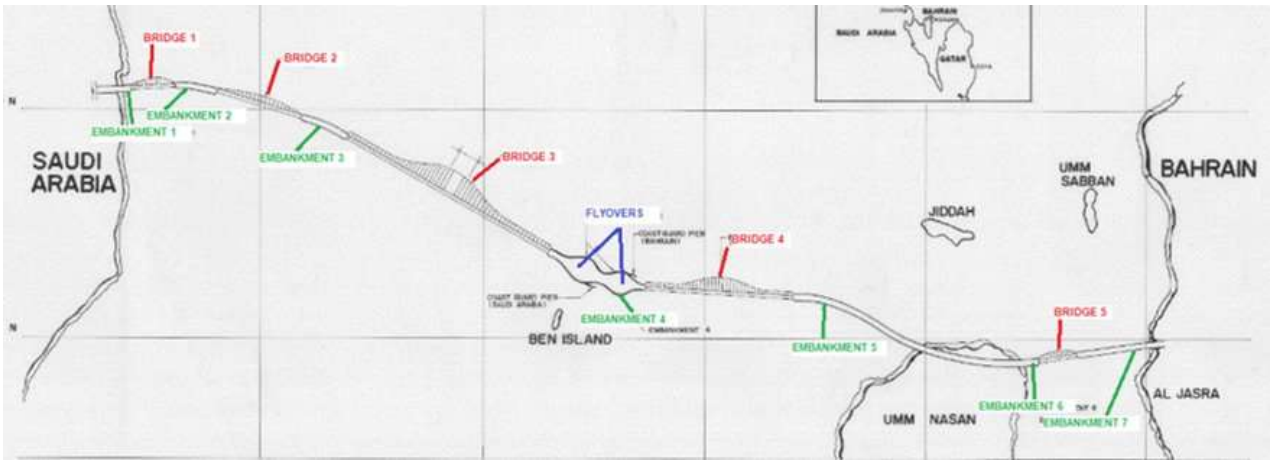

FIGURE 1 : LAYOUT OF THE KING FAHD CAUSEWAY.

2 THE BRIDGE CONDITION INDEX (BCI)

2.1 Germany's BCI

The Germany's BCI is one of the methods that uses the worst-conditioned approach. It is driven by bridge component condition data that capture the severity and extent of identified forms of deterioration. The approach captures information about the critical defects in bridge components. Not all damage is factored into the calculation of overall BCI. The condition rating of the whole structure corresponds to the state of the worst conditioned components. The component in the worst condition is related to the individual damage with the worst rating based on its severity and frequency of occurrence among other components of the structure. The number of components contributing to the index and the type of rating system adopted may be different from one country to the other.

The German BCI uses a hierarchical approach to assess the overall health of a structure. At the lowest level, an index is assigned to each individual damage identified. The next level involves calculating a condition index for predefined groups of structural components (i.e., piers, bearings, etc.) followed by a final level that computes the overall BCI.

2.1.1 The Damage Ratings

Each instance of damage detected during inspection is rated on a five-level scale in terms of its effect on the bridge's structural stability (**Table 1**), traffic safety (**Table 2**), and the bridge's durability (**Table 3**). The overall damage degree score is obtained from the highest score of any category of any damage recorded on the bridge.

The extent of damage is not quantified by measured length or area. It is described qualitatively as either small, medium, or large. From this information, a decimal condition index (**Table 4**) ranging from 1.0 (very good condition) to 4.0 (insufficient condition) is assigned for each damage.

Assessment	Description	Applus Rating System
0	Defects have no effect on structural stability of elements or overall structure.	7
1	Defects affect stability of structure elements but not the overall structure.	6
2	Defects affect stability of structure elements and have little effect on stability of overall structure.	5
3	The effect of defects on stability of structural elements and the overall structure is beyond permissible tolerance.	4
4	The structural stability of structural elements and the structure itself no longer exists.	3

TABLE 1 : DAMAGE RATINGS FOR STRUCTURAL STABILITY.

Assessment	Description	Applus Rating System
0	Defects have no effect on traffic safety.	7
1	Defects affect traffic safety only slightly.	6
2	Defects may impair traffic safety.	5
3	Defects affect traffic safety.	4
4	Traffic safety is no longer given due to defects.	3

TABLE 2 : DAMAGE RATINGS FOR TRAFFIC SAFETY.

Assessment	Description	Applus Rating System
0	Defects have no effect on durability.	7
1	Defects affect durability of structure elements but not the durability of the overall structure.	6
2	Defects affect durability of the structure elements and, in the long term, can affect the overall structure.	5
3	Defects affect durability of the structure elements and, in the medium term, can affect the overall structure.	4
4	The durability of both the structure element and the overall structure is no longer given due to the defects.	3

TABLE 3 : DAMAGE RATINGS FOR DURABILITY.

Condition Rating	Description	Condition (Optional)
1.0 – 1.4	• Very good structural condition. • The stability, traffic safety, and durability of the structure is assured.	Very Good
1.5 – 1.9	• Good structure condition. • Stability and safety of structure is assured. • Durability might be impaired slightly in the long term.	Good
2.0 – 2.4	• Temporarily satisfactory structural condition. • Stability and safety of structure is assured. • The durability of the structure might be impaired considerably in the long term.	Fair
2.5 – 2.9	• Unsatisfactory structural condition. • Stability of structure is assured. • Traffic safety can be impaired. • The durability of the structure might be impaired considerably in the long term.	Fair
3.0 – 3.4	• Critical structural condition. • Traffic safety is affected. • Structure is not durable. • Immediate repair is needed.	Poor
3.5 – 4.0	• Inadequate structural condition. • Traffic safety is not adequate. • Structure is not durable. • Immediate repair or rehabilitation is needed.	Very Poor

TABLE 4 : DAMAGE CONDITION RATINGS.

2.1.2 Calculating German BCI

The overall condition of the bridge corresponds to the rating of the worst component rather than the aggregate component conditions. The bridge condition of the King Fahd Causeway will be calculated using the German BCI.

2.1.2.1 The Bridges of King Fahd Causeway

There are 5 bridges and 3 Flyovers of the King Fahd Causeway as follows:

- Bridge B1 – KSA side
- Bridge B2 – KSA side
- Bridge B3 – KSA side
- Bridge B4 – Bahrain side
- Bridge B5 – Bahrain side
- Ramp 06 Flyover – KSA Side
- Ramp 09 Flyover – KSA Side
- Aziziya Flyover – KSA Side

The calculation of the bridge BCI will be done with each bridge and Flyover.

2.1.2.2 The King Fahd Causeway Bridge Components

The bridge BCI is calculated based on the scoring of the bridge components. The King Fahd Causeway Bridge Components are as follows:

- Piers/ Piles
- Pier Heads/ Crossbeams
- Foundations
- Bearings
- Box Girder End Blocks
- Box Girder Typical Section
- Box Girder Diaphragms
- Longitudinal PT
- Transverse PT
- Expansion Joints
- Continuity Slabs (Normal Joint)
- Roadway Wearing Surface
- Edge Beams
- Safety Barriers
- Lighting Posts
- Signage Posts
- Gangway
- Abutment

2.1.2.3 The Damage Index

Step 1

The first step of the process is to evaluate each component of the bridge (see Section 2.1.2.2). Each component is surveyed for damage or deterioration. For each individual occurrence of damage, an index (Zi) is calculated based on its effect on 3 categories as traffic safety, stability, and durability (see **Table 1 to Table 3**). The overall damage degree score is obtained from the highest score of these 3 categories.

Step 2

The condition index is supplemented with the extent of the identified damage (Δ1) and assigned a value (**Table 5**). Each component may have 1 or more defects to evaluate, i.e. pier may have cracking and spalling (see **Figure 2**). For anyone's discretion, the damage extent may be related to the importance level of the component. The final damage index is the sum of the overall damage degree score in step 1 plus the Δ1 value.

Damage Extent	Δ1 Value
Small	-0.1
Medium	0.0
Large	+0.1

TABLE 5 : IDENTIFIED DAMAGE VALUES.

Each component group (CG) consists of damage ratings for each individual occurrence (**Figure 2**).

$$CG = \{ Z_1, Z_2, Z_3, \ldots\ldots, Z_N \}$$

FIGURE 2 : EQUATION. COMPONENT GROUP.

Next, a component group condition index is calculated.

2.1.2.4 Component Group – Level Condition Index

Step 3

The index at the component group level is equivalent to the maximum ratings assigned to damage at the subcomponent level. The number of occurrences of the damage identified within the component group (Δ2) is accounted for in calculating the component group condition index (Z_{CG_i}) (**Figure 3**).

$$Z_{CG\_i} = \max\{ Z_i \} + \Delta 2$$

FIGURE 3 : EQUATION. COMPONENT GROUP CONDITION INDEX.

For a substructure component group, Δ2 is assigned a value according to **Table 6**.

Number of Damage Occurrences (n)	Δ2 Value
n < 5	-0.1
5 ≤ n ≥ 15	0.0
N > 15	+0.1

TABLE 6 : VALUES OF Δ2 FOR SUBSTRUCTURE COMPONENT GROUPS.

For all other components groups, Δ2 is assigned a value according to **Table 7**.

Number of Damage Occurrences (n)	Δ2 Value
n < 3	-0.1
3 ≤ n ≥ 5	0.0
N > 5	+0.1

TABLE 7 : VALUES OF Δ2 FOR OTHER COMPONENT GROUPS.

2.1.2.5 Structure – Level Index

Step 4

The overall bridge condition index (Z_{ges}) (**Figure 4**) corresponds to the maximum rating at the component group level, taking into consideration the extent of damage to other component groups. The extent of damage to other component groups (Δ3) is assigned a value based on the number of damaged component groups (**Table 8**).

$$Z_{ges} = \max\{ Z_{CG} \} + \Delta 3$$

FIGURE 4 : EQUATION. GERMAN BCI.

Number of Damage Component Groups	Δ3 Value
1 to 3	-0.1
4 to 5	0.0
More than 5	+0.1

TABLE 8 : VALUES OF Δ3.

3 REFERENCES

1. Synthesis of National and International Methodologies Used for Bridge Indices, Publication No. FHWA-HRT-15-081, May 2016.
2. The German Approach to Bridge Management, Peter Haardt, Federal Highway Institute (BASt), Germany.

4 APPENDIX – GERMANY'S BCI

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