# Case study: Widening an existing bridge structure Challenges and solutions

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***Abstract** - This paper is a study that summarizes, the procedure used to increase the capacity of an existing concrete bridge in the UAE. Traffic congestion is a severe problem in modern life. Severe congestion can negatively impact the country's economy, environment, and the health of road commuters. The increase in trip duration due to traffic congestion will result in consuming more fuel which results in a higher cost of trip and more emissions which affect both the economy and the environment. Moreover, the road commuter will be traveling for a long time which can affect their sleeping hours and mental health. Constructing more roads, and bridges and encouraging people to use public transport are some of the measures taken to reduce traffic congestion. To evaluate the effectiveness of an existing highway, certain parameters such as traffic quantity, type of vehicles in the traffic stream, speed of traffic stream, and the density of traffic stream will be measured and assessed to determine the need for increasing the road capacity.*

*This paper considers the structural part and challenges faced during the process of widening an existing bridge structure. The existing bridge under consideration is composed of two spans with a length of 33.10 m of each span, two abutments with pot bearing connection, a single monolithic pier, asphaltic plug expansion joint at abutments, voided post-tensioned concrete slab with concrete barriers. The decision was taken to widen the existing bridge to relieve the aggravated traffic jam problem. The development of residential areas nearby resulted in increasing the volume of traffic exceeding the existing road capacity. The new development proposal involves the construction of a completely new bridge with 4 lanes and the widening of the existing bridge. The final output is two bridges with 4 lanes in each direction.*

## 1. Introduction

Bridges have been used ages ago as a tool to overcome obstacles such as rivers and deep valleys, Romans Engineers used the arch system and stones to build many bridges that still stand up to date such as the Pons Fabricius bridge. The industrial revolution in the last century resulted in increasing the number of personal and commercial vehicles around the world. The increasing of vehicles around the world where associated with the construction of new roads and bridges to cope with the increase in traffic volume. It is important to note that the availability of good infrastructure such as roads is important for attracting investments in different sectors because it facilitates the transportation of goods and people. Roads and bridges are a vital part of the infrastructure. This paper will focus on the widening of existing bridges and the following topic will be discussed in this paper:

- Condition survey of the existing bridge
- Challenges faced during the extension of the existing bridge
- Stitching of existing and new bridges.
- Protecting bridge deck from harmful chemicals
- Strengthening of existing piers

This paper studies the process of widening an existing bridge and all the constrain faced during the construction stage and the implemented solutions for each constrain. The constraints faced in this case study are not identical for every project and they can differ for different projects but learned lessons can be useful and applicable sometimes. The widening of the existing bridge was performed by constructing a new bridge with a width of 8.5 m, then part of the existing structure was demolished and the new and old structures connected to form a new bridge with a width of 20.80 m. The existing and new bridges were made from post-tensioned voided concrete slabs, the bridge deck casted at the site then stressing is performed once the concrete attains sufficient strength. Replacing existing bridge bearings, stitching work, adjusting levels in old and new structures, and matching expansion joint gaps were the main challenges encountered during the construction process.

## 2. Condition survey

It is important to precisely assess the condition of the existing structure. Assessment is important to determine the feasibility of keeping and widening old structures. It is wise and economical to demolish old severely damaged structures where the repair cost will be high and the life span of repaired structure will be less than the new structure. Thus, a comprehensive condition survey has been performed at an early stage of the project for the Existing bridge to determine the structure condition and the integrity of the structure.

Conducting detailed condition survey performed in stages. Initially, a thorough visual inspection of structure conducted for the structure to observe any possible damage. The visual inspection should be carried out by a competent and experienced inspector for better results. Found defects must be recorded appropriately, Records of defects at inspection report must contain the location of the defect and a clear description of the defect. Moreover, photos shall be taken of each defect. In case of defects, a deeper investigation can be performed to determine the extent and severity of the defect by involving non-destructive testing or by acquiring samples by coring or any other methods. Defects in concrete structures can be cracks, concrete delamination, concrete spalling, reinforcement corrosion, damaged bearing, damaged expansion joint, etc. The condition survey of the existing bridge structure under investigation found no severe defects and the structure was deemed to be in good condition and can operate safely.

## 3. Challenges faced during construction

Various challenges were encountered during the construction stage. Some of these problems have been defined and predicted during the design stage of the project such as the difference in level between the existing bridge and the new bridge, but others arise during the construction stage such as damaged and cracked concrete of the existing bridge exposed after asphalt removal and absence of approach slab for existing bridge. the following sections provide a glimpse of each challenge and the best methods used to overcome it and complete the construction without reducing the quality or contradicting project specifications.

### 3.1 Replacing existing bridge bearings

Pot bearings were used for the existing bridge, and two bearings were used at each abutment, the used bearings are guided and free bearings. The bearings are a structural device that is used to transfer the loads from the bridge superstructure into the bridge substructure (abutments and piers) and it is used to accommodate bridge movement and rotation. The main causes of bridge movement and rotation are shrinkage, creep, thermal effects, traffic loads, post-tensioning, construction tolerances, and others. Monolithic bridges are constructed with no bearing which restrain the bridge movement and generate stresses. the bearings will relieve the bridge movements through translation movement in both directions and rotation, relieving bridge movement will reduce the stresses on the bridge structure and improve structure durability and integrity. A wide range of bearings are used around the world such as steel bearings, elastomeric bearings, pot bearings, spherical bearings, friction pendulum bearings, etc.

The existing bridge bearings were replaced for the following reasons:

- The existing pot bearing age exceeds 25 years whereas the service life of pot bearings is 25 years.
- The sliding material (PTFE) of bearings is severely deformed as shown in Figure no:01
- The capacity of the existing bearing is insufficient to accommodate the expected increase in load and movement due to bridge widening.

*Figure 1*

The replacement of bearings was performed by lifting the existing bridge by 10 mm. Hydraulic jacks were used to gradually lift the bridge for the required duration to replace the existing bearing with new bearings. A few obstacles were encountered during the process of replacing bearings, the main obstacle was the clashing of bearing sole and masonry plate shear suds with existing reinforcement. To overcome this issue, existing reinforcements were cut and new dowels were planted in the bridge soffit and abutment seat as shown in Figure no:02.

*Figure 2*

The planting of rebar dowels was performed with the use of epoxy materials. The process involves drilling a hole with a specific diameter and depth then epoxy material is poured into the hole and finally, the rebar is inserted into the hole. Successful planting of dowels requires paying attention to some details and strictly following the material manufacturer's recommendations. For example, drilled hole diameter and depth should as specified in the epoxy material data sheet. Also, appropriate cleaning of the drilled hole is important to ensure proper bonding between the rebar dowel and concrete.

Afterward, placing the bearing in the correct position was easy and quick. it is very important to place the bearing at the correct position to allow for smooth transferring of bridge movement and avoid stressing of bearing. Therefore, the axis of bearing and orientation should not deviate from the design. The gap below and above the bearing masonry and sole plate was filled with appropriate grout material. The grout material should possess sufficient flow-ability to fill the gap between the bearing and the concrete with forming voids. Also, grout material should produce sufficient strength (not less than concrete strength) to transfer the stress efficiently. Pressurized pumping was used to fill the gap between the bearing sole plate and the bridge soffit.

*Figure 3*

### 3.2 Concrete defects found at the existing bridge after pavement removal (cracks, rusted reinforcement, disintegrated concrete)

Some defects were not identified during the condition survey due to traffic above the bridge. few defects were identified after diverting the traffic. The overlaid asphalt above the bridge deck and ramps were removed and an enormous number of cracks were found at the existing concrete top slab. Fortunately, the cracks were narrow and shallow and don't threaten the structure's integrity or stability. However, the presence of cracks is not preferable and sealing of these cracks is very important to prevent the ingress of harmful chemicals. The ingress of chemicals can result in unwanted subsequences such as corrosion of reinforcement, disintegration, and spalling of concrete. The repairing of cracks method involves the following steps:

- Determine the location of cracks.
- Determining the size and depth of cracks.
- For non-structural cracks which shallow and narrow in size, the crack is chipped preferably into a V shape notch to allow proper filling and bonding of repair materials with the concrete surface.
- Before filling the cracks, the chipped area should be cleaned from dust and any debris to ensure proper bonding between repair material and concrete

After chipping After Filling with Repair material

*Figure 4*

The removal of the existing expansion joint unveils serious defects as shown in Figure no:05, existing reinforcements were rusted and concrete disintegrated at the expansion joint. the primary cause of these defects could be the use of a non-watertight expansion joint which results in damaging the concrete and reinforcement around the expansion joint. The damaged area is determined by the sounding test. A hammer was used to determine the location of the delaminated concrete. The repair of this type of defect involves removing damaged concrete, replacing rusted reinforcement, and casting concrete. In order, to prevent the occurrence of similar defects in the future, a watertight expansion joint is used to drain the water away from the structure.

*Figure 5*

### 3.3 Absence of approach slab for the existing bridge

The primary function of the approach slab is to provide a smooth transition between the roadway and the bridge deck. in other words, it is a transition between flexible pavement (road) and rigid pavement (bridge deck), the presence of an approach slab will reduce the cracks in pavement at the joining point between the roadway and bridge deck. The approach slab is constructed at a slope steeper than the roadway slop so it will gradually reduce the differential settlement and prevent the formation of cracks in the pavement as shown in Figure no:06.

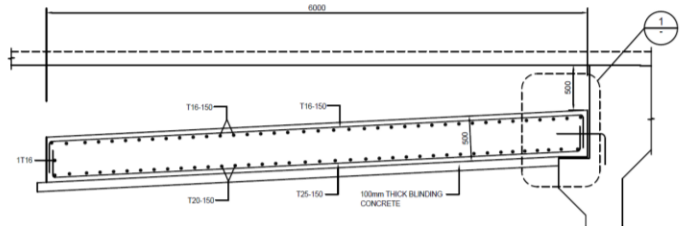



*Figure 6*

The site verification shows the absence of an approach slab for the existing bridge. Therefore, Engineers decide to construct a new approach slab at both ends of the bridge. Constructing a new approach slab for the existing bridge will reduce the differential settlement and prevent the formation of cracks in the pavement.

*Figure 7*

### 3.4 The difference in level between the new bridge and the existing bridge

The new structure was designed with a cross-slope of 2% for efficient draining of stormwater, while the existing bridge cross-slope is almost 0%. Therefore, the cross-slope of existing and new bridges as one unit will not be uniform.

Therefore, leveling screed concrete was used to produce a uniform cross-slope over the whole bridge deck. Figure no:08 shows the difference in cross-slope between the new and old structures and the leveling concrete screed.

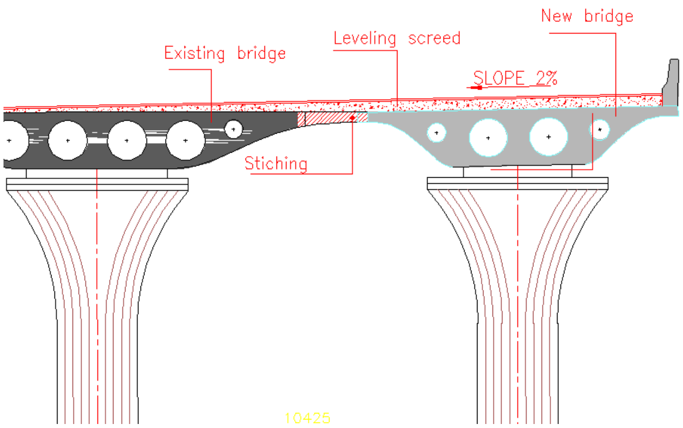



*Figure 8*

The thickness of leveling screed will vary and it will not be the same over the bridge deck. The thickness of the screed at any point will be the difference between the final road level, the level of deck concrete top level, and the thickness of road surfacing such as asphalt and deck waterproofing. It is important to cure casted concrete screed properly for a sufficient time to prevent the formation of shrinkage cracks.

### 3.5 Protecting bridge deck from chemicals and weather

Protecting existing and new concrete structures from chemicals will increase the structure's durability and reduce the defects during the service life of structures. Therefore, the outer surface of the existing bridge is repainted. Also, the bridge deck is protected with waterproofing to prevent the penetration of chemicals carried by stormwater. Spray waterproofing was used to seal the deck surface below the pavement asphalt. Two layers of spray waterproofing were applied with a total thickness of 4 mm.

*Figure 9*

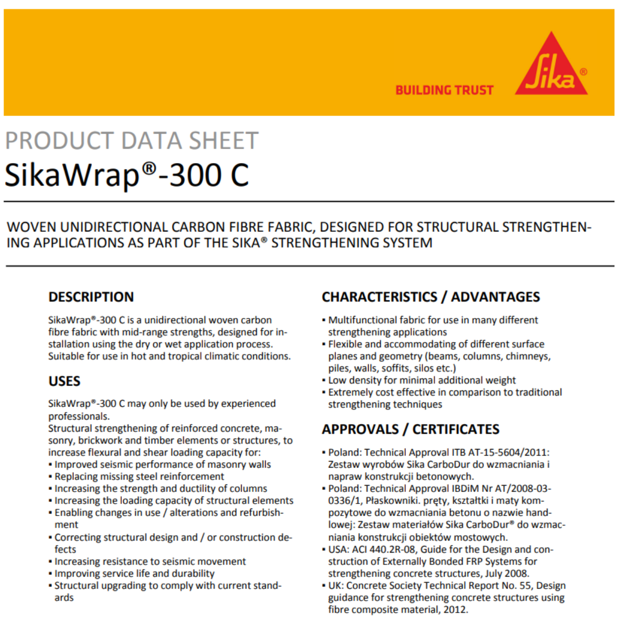
Applied waterproofing should be tested for pull-off, thickness, and integrity test. The performing of these tests is very important to ensure the compliance of waterproofing with requirements and that the material will function properly and appropriately protect the concrete surface. The pull-off test is important to test the adhesion between waterproofing and concrete, while the integrity test will determine the location of defect and discontinuity.

*Figure 10*

### 3.6 Strengthening of existing piers

The condition survey found the exiting pier to be in good condition without serious defects such as cracks, concrete spalling, or other serious defects. However, the engineer decided to improve the strength of the existing pier. The method proposed by the engineer to strengthen the existing pier is the use of CFRP sheets (carbon fiber reinforced fiber polymer). SikaWrap – 300C is an example of the CFRP sheets. The SikaWrap – 300C uses as described in the product data-sheet:

- Improved seismic performance of masonry walls
- Replacing missing steel reinforcement
- Increasing the strength and ductility of columns
- Increasing the loading capacity of structural elements.
- Correcting structural design or construction defects.
- Increasing resistance to seismic movement
- Improving service life and durability Structural upgrading to comply with current standards



BUILDING TRUST

PRODUCT DATA SHEET

SikaWrap®-300 C

WOVEN UNIDIRECTIONAL CARBON FIBRE FABRIC, DESIGNED FOR STRUCTURAL STRENGTHENING APPLICATIONS AS PART OF THE SIKA® STRENGTHENING SYSTEM

DESCRIPTION

SikaWrap®-300 C is a unidirectional woven carbon fibre fabric with mid-range strengths, designed for installation using the dry or wet application process. Suitable for use in hot and tropical climatic conditions.

USES

SikaWrap®-300 C may only be used by experienced professionals.
Structural strengthening of reinforced concrete, masonry, brickwork and timber elements or structures, to increase flexural and shear loading capacity for:
- Improved seismic performance of masonry walls
- Replacing missing steel reinforcement
- Increasing the strength and ductility of columns
- Increasing the loading capacity of structural elements
- Enabling changes in use / alterations and refurbishment
- Correcting structural design and / or construction defects
- Increasing resistance to seismic movement
- Improving service life and durability
- Structural upgrading to comply with current standards

CHARACTERISTICS / ADVANTAGES

- Multifunctional fabric for use in many different strengthening applications
- Flexible and accommodating of different surface planes and geometry (beams, columns, chimneys, piles, walls, soffits, silos etc.)
- Low density for minimal additional weight
- Extremely cost effective in comparison to traditional strengthening techniques

APPROVALS / CERTIFICATES

- Poland: Technical Approval ITB AT-15-5604/2011: Zestaw wyrobów Sika CarboDur do wzmacniania i napraw konstrukcji betonowych.
- Poland: Technical Approval IBDiM Nr AT/2008-03-0336/1, Płaskowniki. pręty, kształtki i maty kompozytowe do wzmacniania betonu o nazwie handlowej: Zestaw materiałów Sika CarboDur® do wzmacniania konstrukcji obiektów mostowych.
- USA: ACI 440.2R-08, Guide for the Design and construction of Externally Bonded FRP Systems for strengthening concrete structures, July 2008.
- UK: Concrete Society Technical Report No. 55, Design guidance for strengthening concrete structures using fibre composite material, 2012.

*Figure 11*

The surface of the concrete should be checked and prepared before installing the CFRP. The concrete should be free from honeycombs, cracks, and any defects, all defects should be repaired. Also, a pullout test shall be conducted for the old structure to measure the tensile strength of the concrete surface and to ensure it is as per manufacturer requirements. If the tensile strength of concrete is lesser than the required, then the tensile strength of the concrete surface shall be increased by applying epoxy. The concrete surface shall be grinded to remove the loose layer of concrete and ensure proper bonding between concrete and CFRP. The second stage involves, preparing the CFRP sheets for installation. The CFRP sheets should be prepared to the required size and the location of CFRP sheets should be determined and marked. Then, the adhesive material will be mixed and applied to the concrete surface and the CFRP sheets will be fixed on the adhesive properly.

### 3.7 Expansion joint gap and construction

Elastomeric expansion joint was used to bridge the expansion gap and accommodate the movement of existing and new structures. The elastomeric expansion joint system is composed of a waterproofing membrane, bolts, and the joint. The joint is made from neoprene rubber reinforced with steel plates. The performance of the expansion joint will depend on two factors, the expansion joint itself and the method used for installing the expansion joint. Proper installation of expansion joints will ensure a long service life with less maintenance. The engineer should consider the following points to ensure the proper installation of the expansion joint:

1. Joint gap to be equal or lesser than joint capacity to prevent premature wearing of joint
2. Joint top surface to be slightly below with asphalt surface, elevated joint above the asphalt may suffer premature wearing.
3. Installation of waterproofing membrane to drain excess water and avoid damaging concrete in the proximity of joint
4. Periodic cleaning of joint slots to allow joint movement without restrain
5. Maintain the thickness of leveling mortar within the allowable limit as per the material manufacturer's recommendation
6. Ensuring that the toque of bolts and nuts as recommended by the expansion joint manufacturer
7. Ensuring that the bolts of the expansion joint are installed inside hard and reinforced concrete

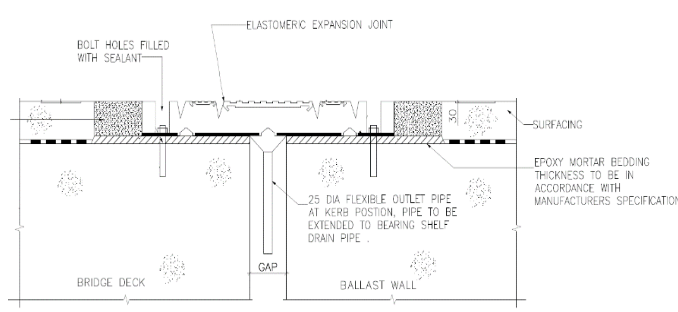



*Figure 12*

The problem faced during the installation expansion joint is the leveling screed used to adjust the difference in level between existing and new structures. The thickness of leveling screed at some locations was almost 35 cm, installing the bolts in leveling screed is not recommended because the screed is weak and there is a high possibility that it will break due to dynamic loads generated by passing vehicles. Therefore, a reinforced concrete upstand was constructed at the location of the expansion joint to allow the installation of expansion bolts inside the hard substrate which prevent early damage to the expansion joint. Moreover, the constructed upstand ensures a uniform and aligned gap along the existing and new structures.


*Figure 13*

### 3.8 Stitching works of the new structure with the old structure

Stitching new and old structures was a challenging job because it involves breaking a portion of the old structure. Precautions were taken during the process to prevent damaging the old bridge. Also, to prevent the falling of concrete pieces into the live road. The old bridge is crossing a main highway. Therefore, the following measures were implemented to prevent harming road users:

1. Construction of a platform with safety mesh below the stitching area to prevent the falling of concrete into the road.
2. Preventing the accumulation of concrete waste at the constructed platform.
3. Using small equipment for breaking concrete.
4. Working at night when traffic volume is low

The implementation of these precautions prevented the falling of concrete into the live road and eliminated any hazard associated with the stitching process. Another concern was to prevent damaging the existing bridge deck during the breaking. To prevent damaging the existing bridge deck, a small breaking equipment (electrical compressor) was used to break the stitching portion. Also, the boundary of the stitching zone has been observed during the breaking process to identify any possible concrete defect formed during the breaking such as cracks.

*Figure 14*

The casting of the stitching area should not be done immediately after the construction of the new structure. Casting the stitching area immediately may result in the formation of cracks due to differential deformation between the old bridge and the new bridge. we should note that the new structure will undergo a higher deflection due to concrete shrinkage and creep.

Another important point is the traffic on the existing bridge, traffic should be stopped and diverted during the concreting of the stitching area. in case, it is not possible to divert the traffic, then concrete should be cast when the traffic volume is low.

## 5. Conclusion

The widening of an existing bridge is performed to ease the traffic jam by increasing the bridge width and the number of existing lanes. The existing structure should be checked by specialists to determine the condition of the existing structure. If the structure is severely damaged and the needed repair is expensive. Then, the demolition of the old structure and building a new structure is more feasible. However, if the condition survey report shows no serious defects in the old structure, then widening the existing structure will be more economical.

The engineer responsible for designing the new structure should carefully consider the existing structure. Producing a good design for a new structure with fewer mistakes should be associated with reading the As-built drawings of the existing structure, site verification of the location of the existing structure foundation, site verification of the alignment of the existing structure, etc. Despite this, some problems may arise during construction and all parties should cooperate to find reasonable solutions complies with project standards and design requirements. The above-listed challenges are examples of problems that may be faced during the widening of existing bridges and they may vary for other projects.

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