



# Maintenance Techniques for Cracks in Asphalt Layers

M. S. Eisa<sup>1\*</sup>, F. S. Abdelhaleem<sup>1</sup> and V. A. Khater<sup>2</sup>

<sup>1</sup>Department, Faculty of Engineering, Benha University, P.O. 13512, New Benha, Qalubiya Governorate, Egypt.

<sup>2</sup>Department, Higher Institute of Engineering and Technology, Menoufia, Egypt.

## Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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## ABSTRACT

Treating cracks in asphalt pavements is a major stage of each maintenance work for engineers. The goal of any crack cure is to limit the water intrusion into underlying pavement structure layers. Such water infiltrates in to base layers of the pavement and may cause damage to the pavement structure. The previous studies focused on crack repairing materials and methods but not the bonding at the interface joint. In this study, the influence of the repairing materials and depth on the bonding at the interface joint using two repairing materials. Slabs were cast to simulate surface of road. Unlikely, slabs contain cracks in the middle of slab with different depths (35 mm, 50 mm, 70 mm). Consequently, these cracks were repaired with two methods; firstly, repairing them with RC+Sand and secondly, with Sika flex®-1a. The slabs were tested after being repaired to know the best method and depth. It has been concluded that slabs having cracks that have been repaired with RC+Sand increase failure load compared with empty cracks and cracks that have been repaired with Sika flex®-1a. Also, cracks with small depth that have been repaired with Sika flex®-1a increase failure load compared with empty cracks.

**Keywords:** Asphalt pavement; maintenance; cracks; RC+Sand; Sika flex®-1a.

\*Corresponding author: Email: mohamedeisa524@bhit.bu.edu.eg;

## 1. INTRODUCTION

The age of surfacing layer can be determined by measuring the characteristics of fatigue and stress including permanent deformation resulting from traffic loading [1]. The age of pavement can be reduced not only due to Poor asphalt but also causes further issues, for example increased repair, premature failure, increased maintenance costs [2], hazardous conditions for road users and finally, reduced safety. People rely on roads and highways for their livelihoods the movement of goods, the travel from one place to another one, for service, for social and entertainment purposes [3]. Cracks are the main indicative of failure in the pavement structure. In different context fees are introduced for maintenance and repair works [4]. Cracks in the road make people feel uncomfortable when driving, damage the vehicle, and may increase evasive operations that may cause a crash [5]. the behaviors of asphalt binders crack were evaluated under repeated cyclic controlled-stress loadings [6]. However, it was once observed from pavement defects survey that top-down cracks additionally exist extensively in structures of pavement [7-8]. In AASHTO Mechanistic- Empirical Design Guide of Pavement, a preliminary top-down model of cracking had been integrated. It considers excessive tensile strains due to load-related results and has been calibrated to field longitudinal cracking facts [9]. To delay the road ruin, cracks on the surface of the road can be sealed, or the asphalt surface reconstructed [10]. Crack sealing and crack filling are a generally used maintenance action for in-service pavements. The methods are inexpensive, rapid and a well-proven method to lengthen the pavement life, predicated on the use of the proper substances at the proper time using the proper protocols [11].

The Federal Highway Administration (FHWA) defines a pavement preservation software as containing of preventative maintenance, rehabilitation of pavement (structural and non-structural) and routine maintenance activities. FHWA classifies crack sealing as preventative maintenance and crack filling as routine maintenance [12]. In addition, a crack sealing software is defined as a preventative maintenance treatment, not a corrective maintenance measure. FHWA published the strategies presented in Table 1 for the determination of the type of maintenance to be performed. These strategies establish criteria for

when to use crack treatments [13]. Masson [14] accompanied a study regarding usefulness of sealing of pavement cracks. The study stated that crack sealing/filling, if used correctly, is believed to decrease deterioration of pavement by reducing the infiltration of foreign objects into a pavement structure; thus prolonging the age of pavement. The study by Sharaf and Sinha [15] presented that when more crack sealing was performed in the autumn, less patching was required in the winter. According to ASTM D 6690 standards [16], crack sealants are classified into four types (Type I, Type II, Type III, and Type IV) based on their small temperature connected performances. Type I is multiple of maintaining its efficiency in modest climates and Type IV is proper for very cold climate. The goal of this study is to find a new sealants repair materials for cracks.

### 1.1 Objective of Study

The main objectives of this research are to find the best repairing material to maintain cracks and the effect of using Sika flex®-1a as anew repairing material, best repairing depth of cracks to increase the service life of the road.

## 2. MATERIALS

Materials used in this study are divided into three types: surface materials, subbase materials and repair materials.

### 2.1 Surface Materials

Hot mix asphalt (HMA) mixture that used for this study is a porous mix, with 20% air voids content and composed of optimum bitumen content (5.5%), 55% coarse aggregate, 15% natural sand, 25% crushed sand and 5.0% lime stone dust as a control mineral filler. The gradation of reference mixture lies within the limits of Egyptians standard specifications for binder course [17]. Table 2 presents the Gradation of the used mix.

#### 2.1.1 Aggregate

Crushed dolomite stone obtained from "ATAKA" quarry, Suez governorate was used as coarse aggregate portion in the asphalt concrete mixtures. Table 3 presents the properties of the used aggregate according to the Egyptian specification of asphalt concrete [17].

**Table 1. Guidelines for determining the type of maintenance to be performed**

Crack Density	Average Level of Edge Deterioration (% of crack length)		
	Low (0-25)	Moderate (26-50)	High (51-100)
Low	Do Nothing	Do Nothing or Crack Treatment	Crack Repair
Moderate	Crack Treatment	Crack Treatment	Crack Repair
High	Surface Treatment	Surface Treatment	Rehabilitation

**Table 2. The gradation of the used mix and specification limits**

Sieve size	Gradations of used mix	Specification limits (4C)
1	100	100
3/4"	96.1	80-100
1/2"	83	-
3/8"	67.3	60-80
No. 4	59	48-65
No. 8	40.7	35-50
No. 30	25.3	19-30
No. 50	15.6	23-13
No. 100	11.5	7-15
No. 200	7.5	2-8

**Table 3. Properties of used aggregate**

Test No.	Test	AASHTO Designation No.	Results	Specification limits
1	Los Angeles abrasion (%)	T-96		
	After 100 revolutions		6.5%	≤ 10%
	After washing after 500 revolutions		28%	≤ 40%
2	Water absorption (%)	T-85	2.4%	≤ 5%
3	Bulk specific gravity (g/)	T-85	2.576 cm3	-

**Table 4. Properties of used bitumen**

Test No.	Test	AASHTO Designation No.	Results	Specification limits
1	Penetration, 0.1mm	T-49	64	60-70
2	Softening point, 25 °c	T-53	52	45-55
3	Flash point, 25 °c	T-48	+270	>250
4	Kinematic viscosity, cst	T-201	+345	>320
5	Ductility, cm	T-51	130	≥ 95

### 2.1.2 Bituminous materials

One type of bituminous material (Suez asphalt cement with 60-70 penetration grade) is used through the study. The properties of the used asphalt cement are presented in Table 4.

The table shows that (60-70) penetration grade Suez asphalt cement has acceptable engineering properties for using as a binder according to Egyptian specifications [17]. Table 5 presents the Marshall properties at optimum bitumen content (OBC).

### 2.1.3 Mineral filler

Lime stone dust was used as control mineral filler used in HMA mixture with 2.75 g/cm<sup>3</sup> bulk specific gravity. In Table 6 the gradation of the mineral filler and the specification limits is presented according to Egyptian specifications [17].

## 2.2 Materials of Subbase Layer

### 2.2.1 Aggregate properties

Aggregates that used as sub base material from "ATAKA" quarry, Suez governorate. Table 7

presents the properties of used aggregate according to the Egyptian specification of subbase layer [17].

Table 8 presents the gradation of used aggregate of subbase layer.

## 2.3 Repair Materials

### 2.3.1 RC-70+Sand

Cutback bitumen RC-70 was used with sand to fill crack and repair it. Bulk specific gravity of sand is 2.65 g/. Table 9 represents the specification of cutback bitumen RC-70.

### 2.3.2 Sikaflex®-1a

Table 10 represents the specification of Sikaflex®-1a as another method to repair cracks.

## 2.4 Compaction of Surface Layer

An asphalt slab roller compactor was used to compact all the asphalt samples for the loading tests where slab dimension is 800\*800\*70mm. The compactor applies loads that are equivalent to those of full-scale compaction equipment. Thus, this method can produce asphalt samples that are similar to materials used in actual highway pavements. The compaction process was accomplished using 200 Kg roller to simulate the real compaction process. Fig. 1 shows the roller compactor that has been used in this study.

## 3. EXPERIMENTAL PROGRAMME

Table 11 presents the experimental program that carried out on slabs to simulate the surface of road.

**Table 5. Marshall properties at optimum bitumen content (OBC)**

Test No.	Test	Results	Specification limits
1	Stability (kg)	1120	900 kg (min)
2	Flow (mm)	3.15	2-4 mm
3	Stiffness (kg/mm)	389	300–500 kg/mm
4	Bulk specific gravity, Gmb (g/)	2.311	–
5	%Air voids in total mix (Va)	4.4	3-5 %

**Table 6. The gradation of mineral filler**

Sieve size Inch	Gradations of used aggregates	Specification limits
No.30	100	100
No.50	100	--
No.100	92	85% (min)
No.200	80	65% (min)

**Table 7. Aggregate properties of subbase layer**

Test No.	Test	AASHTO Designation No	Results	Specification limits
1	Los Angeles abrasion (%)	T-96		
	After 100 revolutions		7%	≤ 10%
	After washing after 500 revolutions		26%	≤ 40%
2	Water absorption (%)	T-85	2.6%	≤ 5%
3	Bulk specific gravity (g/)	T-85	2.576 g/cm <sup>3</sup>	–

**Table 8. Aggregate gradation of subbase layer**

Sieve size	Gradations of used Aggregates
1	100
3/4"	100
1/2"	84
3/8"	71
No. 4	20
No.8	2

**Table 9. The specification of cut back bitumen RC-70**

Property	Min	Max	Test Method
Kinematic viscosity at 60°C (140 °F), cst	70	140	ASTM D2170
Flash point (tag open cup), °C (°F)	—	—	ASTM D3143
<b>Distillate test Distillate, volume percent of total Distillate to 680 °F (360 °C)</b>			
to 374 °F (190 °C)	10	—	ASTM D402
to 437 °F (225 °C)	50	—	ASTM D402
to 500 °F(260 °C)	70	—	ASTM D402
to 600 °F (315 °C)	85	—	ASTM D402
Residue from distillation to 680 °F (360 °C), percent volume by difference	55	—	ASTM D402
<b>Test on Residue from distillation test</b>			
Penetration 77 °F (25 °C) 100g,5s mm	80	120	ASTM D5
Ductility 77 °F (25 °C) 5cm/min cm	100	—	ASTM D113
Solubility in trichloroethylene %	99	—	ASTM D2042
Water, percent volume	—	0.2	ASTM D95

**Table 10. The specification of Sika flex®-1a**

Type	Polyurethane Elastomer
Colour	concrete grey
Density	1.2 - 1.3 kg/l (depending on colour
Movement Capacity	± 35% of the average joint width.
Shore A-Hardness	
DIN 53505	25- 35 (after 28 days at 23°C / 50% r/h
ASTM-D-2240	40 ± 5 (at 21 days)
Curing Rate	Tack-free time 3 to 6 hours
	Tack-free to touch 3 hours
	Final cure 4 to 7 days
<b>Tensile Properties</b>	
Tensile Stress (DIN 52450)	50% elongation at 20 °C = 0.15 - 0.18 N/mm <sup>2</sup>
Tensile Stress (ASTM -D, 412)	100% elongation at 20 °C = 0.2 - 0.3 N/mm <sup>2</sup>
Modulus of Elasticity (ASTM -D, 412)	175 psi (1.21 MPa) at 21 days
Elongation at Break (DIN 52455)	> 400%
ASTM-D, 412	550% at 21 days
Tear Stress (ASTM D-624)	55 b/in at 20°C = 0.1 N/mm

**Table 11. Experimental work**

Name	Dimension (cm)	Depth of crack (cm)	Width of crack (cm)	Length of crack (cm)	Repair Method
C	80×80×7	-	-	-	Without defects
C1	80×80×7	3.5	1	40	-
C2	80×80×7	5	1	40	-
C3	80×80×7	7	1	40	-
C4	80×80×7	3.5	1	40	RC+Sand
C5	80×80×7	5	1	40	RC+Sand
C6	80×80×7	7	1	40	RC+Sand
C7	80×80×7	3.5	1	40	Sikaflex®-1a
C8	80×80×7	5	1	40	Sikaflex®-1a
C9	80×80×7	7	1	40	Sikaflex®-1a



**Fig. 1. Roller compactor**

### 3.1 Description of model

Model contains two layers first layer is surface with size 800mm×800mm×70mm was built from hot mix asphalt. second layer is container with size 1200mm×1200mm×650mm, this container is simulated sub base of road was built from aggregates. subbase used to simulate road layer, fixed and support the surface layer and also to study actual behavior of subbase. Wire layer has distress in the form of crack with dimension 400\*10mm with different depth (350mm, 50mm and 70mm).

Fig. 2 Show the shape of model.

### 3.2 Description of the Proposed Technology

#### 3.2.1 First stage of this study [Shape of defects]

First stage of this study, slabs were cast to simulate surface of road, one of them without defects (C) and other contain crack by drilling with different depths (35 mm, 50 mm, 70 mm) as shown in Fig. 3.

In the second stage, the crack was filled up with two methods; first one, using cutback bitumen RC-70 with sand and second method using Sikaflex®-1a at different depths. In the third stage, the slabs were tested after filling up to know the best method and depth after repair the crack.

#### 3.2.2 Repair method

Cracks should be filled with emulsion from the bottom to avoid trapped air bubbles in the emulsion, which can weaken it, then fine

aggregate should be applied on the surface [18]. This study used two methods to repair the cracks. Firstly, with cutback bitumen RC-70 with sand and secondly, with Sikaflex®-1a at different depths to identify the best method and depth after repair the crack. Figs. 4 and 5 show the steps of filling up the crack with both methods.

### 3.3 Test Setup

#### 3.3.1 Loading frame

The test was conducted on slab according to the Egyptian code [16]. The test setup consists of rigid steel frame supported on laboratory rigid floor as shown in Fig. 6. The load was applied using a hydraulic jack of 100 t capacity, connected to electrical pump which provides oil pressure. Load was applied and measured using load cell connected to data acquisition system. The reading was recorded and saved in an excel sheet on computer. Load increased linearly until failure. Rigid steel frame is used to distribute a concentrated load at the edge of the contact area (6\*6\*4cm). of crack and slab as shown in Fig. 7. Strain gauges were installed in each specimen to measure the strain during loading at the edge of the contact area of crack and slab.

#### 3.3.2 The properties of used Strain gauges as the follows

Gauge length: 6 mm.  
 Gauge factor:  $2.12 \pm 1 \%$ .  
 Gauge resistance:  $120.3 \pm 5 \Omega$ .  
 Transverse sensitivity:  $0.1 \%$ .

### 3.4 Test Procedures

For each test, the specimen was aligned inside the testing frame and strain gauges were

connected to data acquisition system. During the test, the initiation and propagation of cracks were marked as shown in Fig. 8 after each load increment up to failure in order to understand the behavior of the tested specimens. Crack loads, ultimate failure load and strain were recorded.

#### 4. RESULTS COMPARISON AND DISCUSSION

Different materials were used to repair the cracks such as RC+Sand and Sika flex®-1a at different depths to know which material and depth are the best ones.

##### 4.1 Cracks without Repairing

Fig. 9 shows the relation between max load and max strain without any repairing. It can be observed that slab which has less depth without any repairing has the max load failure like C1.

##### 4.2 Same Repairing Method of Cracks at Different Depth

Fig. 10 shows the relation between max load and strain of cracks that were repaired with RC+Sand. It can be observed that slab C4 has max failure load and low strain compared to another slabs repaired with RC+Sand.

Fig. 11 shows the relation between max load and strain of cracks that were repaired with Sika flex®-1a. It can be observed that slab C7 has max failure load compared to another slabs repaired with Sika flex®-1a.

##### 4.3 Different Method of Patching at Same Depth

Fig. 12 shows the relation between max load and strain of cracks at same depth (35 mm). It can be observed that cracks repaired with RC+Sand have max load failure compared to that repaired with Sika flex®-1a.



Fig. 2. The shape of model



Fig. 3. Shape of defects



**Fig. 4. Steps of filling up of crack with cutback bitumen RC-70 with sand**



**Fig. 5. Steps of filling up of crack with Sikaflex®-1a**



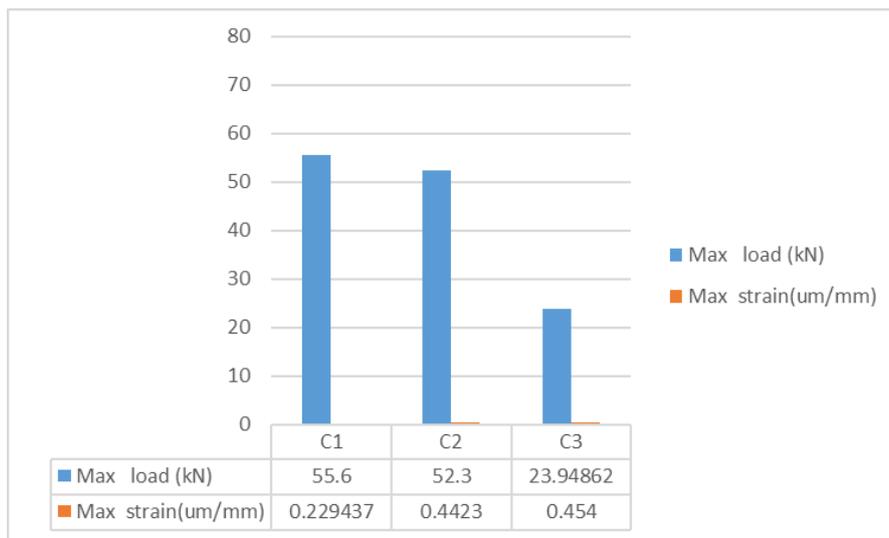
**Fig. 6. Rigid steel frame**



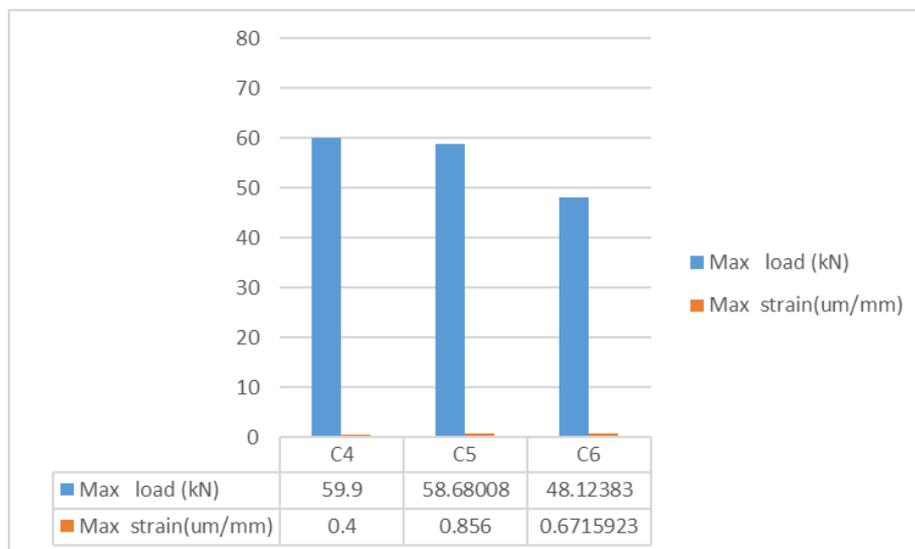
**Fig. 7. Location of a concentrated load of rigid steel frame**



**Fig. 8. Marked cracks after loading**



**Fig. 9. Max load - Max strain comparison without any**



**Fig. 10. Max load - Max strain comparison of cracks that repaired with RC+Sand RC**

Fig. 13 shows the relation between max load and strain of cracks at same depth (50 mm). It can be observed that cracks that were repaired with RC+Sand have max load failure compared to that repaired with Sika flex®-1a

RC+Sand with low depth have max failure load and those repaired with Sikaflex®-1a with high depth have max failure load.

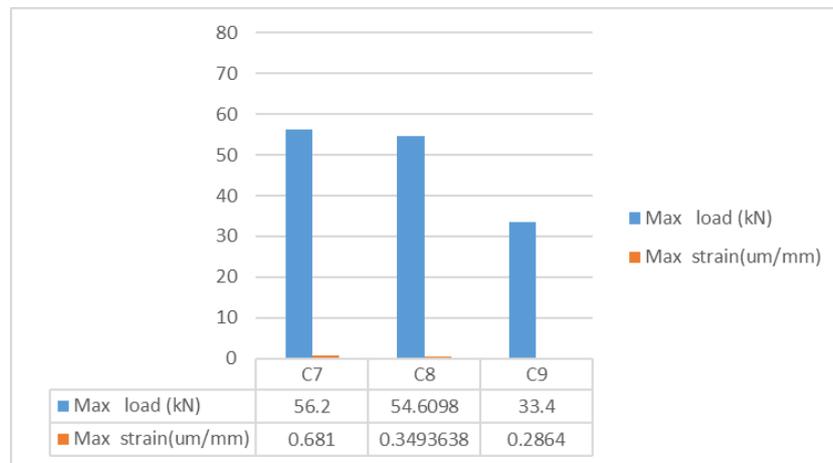
Fig. 14 shows the relation between max load and strain of cracks at same depth (70 mm). It can be observed that cracks repaired with RC+Sand have max load failure compared to that repaired with Sika flex®-1a.

**Table 12. Comparison between Max Load and Max strain results**

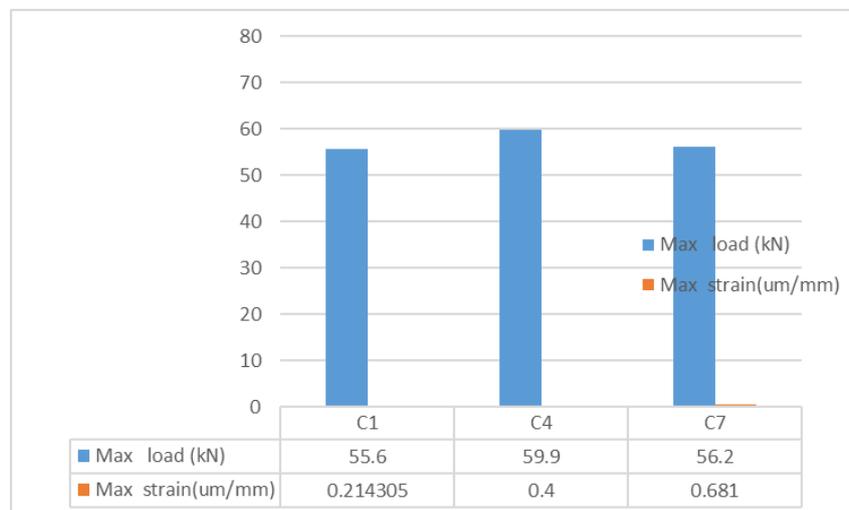
Sample	Max load (KN)	Max strain (um/mm)
C1	54.334	0.214305
C2	52.3	0.4423
C3	23.94862	0.454
C4	59.9	0.4
C5	58.68008	0.856
C6	48.12383	0.671592
C7	56.2	0.681
C8	54.6098	0.349364
C9	33.4	0.2864

**4.4 Laboratory Max Load and Analysis Max load**

Comparison of maximum values of load and max strain of the nine tested specimens are presented in Table 12 and Fig. 15. It can be observed that specimens that repaired with



**Fig. 11. Max load - Max strain comparison of cracks that repaired with Sika flex®-1a**



**Fig. 12. Max load - Max strain comparison of cracks at same depth (35 mm)**

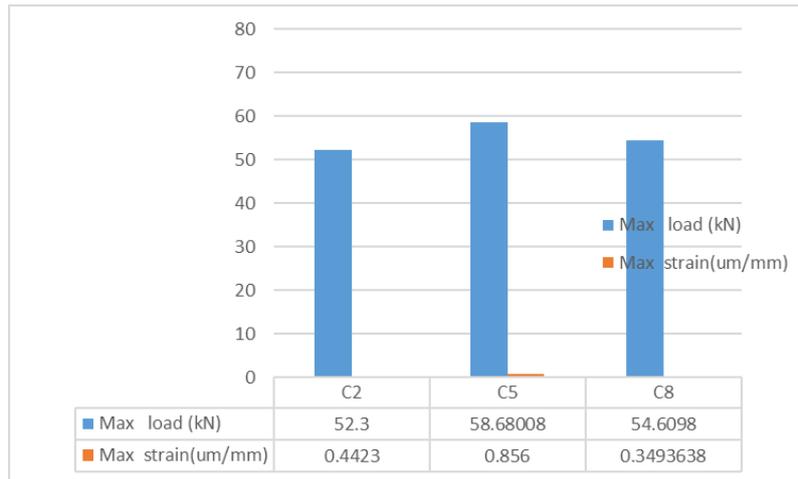


Fig. 13. Max load - Max strain comparison of cracks at same depth (50 mm)

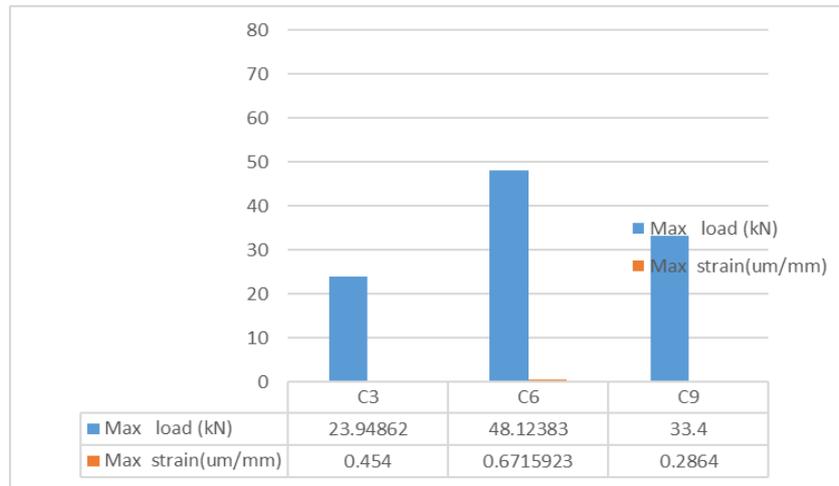


Fig. 14. Max load - Max strain comparison of cracks at same depth (70 mm)

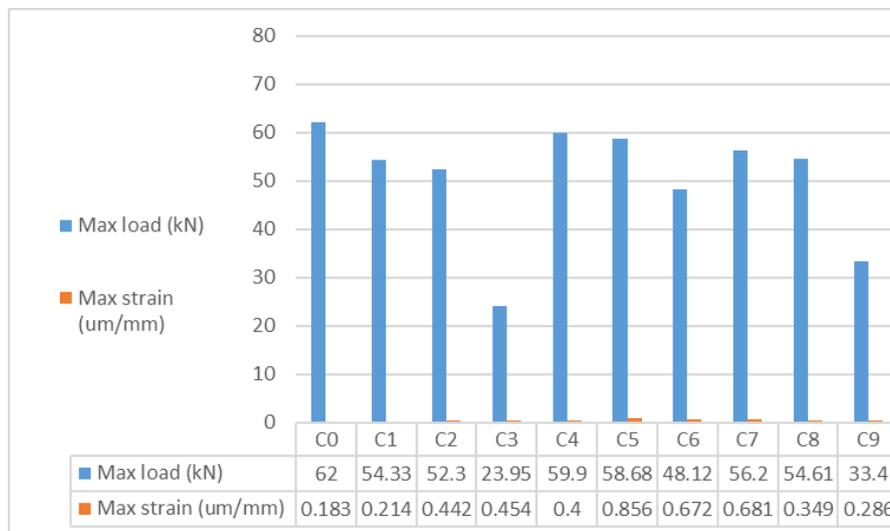


Fig. 15. Max load comparison of the nineteen tested specimens

## 5. CONCLUSIONS

In this study, the load failure at the joint interface of repaired cracks using RC+Sand and Sika flex®-1a was investigated at different conditions of repairing material and depth using a rigid steel frame to study the stress strain behavior. The results showed that the effect repairing material on its progress is more important than its depth. The use of Sika flex®-1a slightly increased the bonding at joint interface for cracks. Regarding the RC+Sand, increasing the repairing depth increased the bonding at the interface joint better results than Sika flex®-1a -repaired ones. Crack with depth 70 mm that have been repaired with RC+Sand increase failure load by value 50.24% with respect to cracks without repairing with depth 70 mm but Cracks with depth 70mm that have been repaired with Sika flex®-1a increase failure load by value 28.30% with respect to cracks without repairing with depth 70 mm.

## 6. RECOMMENDATIONS FOR FURTHER RESEARCH

Based on the conclusions above, the following recommendations can be made:

- Various crack sealants are on the market at several prices. However, no consistent standard is available to estimate crack sealants for crack repair. Therefore, a standard method to estimate crack sealants should be founding.
- Future research will focus primarily on improving the performance of crack sealants.

## DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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