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Behavior of Strengthened R.C Flat Slab with Different Shapes of Openings, with Fiber ReinforcedPolymers

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Abstract: *Several buildings, bridges, tunnels, and marine structures have already been strengthened and repaired in many countries such as Japan, Europe, USA, Canada, and Egypt using fiber reinforced polymers (FRP) [1]. FRP is also used in new structures, especially at bridges.* Carbon Fiber Reinforced Polymers (*CFRP) [2,3] used in special applications including radar stations; structures for magnetic levitation trains, antenna towers, and many n- structural elements. The objective of this research was to investigate the feasibility of strengthening of reinforced concrete flat slab with openings with different sizes using CFRP laminates under uniform distributed load. The study program was used to explore experimentally the effect of opening size on the behavior of CFRP strengthened of flat slabs. Three main groups were used in this Study, 1st group was flat slabs without opening and it's called reference group, 2nd group was flat slabs with opening in columns strips and without strengthened, 3rd group was flat slabs with openingon column strips and strengthened by CFRP. A comparison between ultimate loadsand displacements were done between three groups as well as crack shapes of three groups.*

Keywords:*Flat slabs; opening; strengthen; carbon fiber; polymers.*

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I. Introduction

The main goals of this research effort is to enhance the performance of the reinforced concrete flat slabs with openings externally strengthened with CFRP strips. Recent review of literature[4,5,6,7,8] revealed the need to study the effect of opening size and opening position on the strengthened slabs. Most codes of specifications [9,10,11,12,13] gave requirements to the designer when making opening in flat slabs. Accordingly, the following research steps were undertaken in this research work to fulfill these goals: 1-Exploring experimentally the effect of opening size on the behavior of CFRP strengthened of flat slabs, 2-Study the relation between the ultimate load of flat slabs without opening and that strengthened with CFRP as well as flat slabs without strengthened. 3-Study the relation between displacement of flat slabs strengthened with CFRP, flat slabs without strengthened, and flat slabs without opening.

II. Experimental Program

All experiments were carried out at the concrete research laboratory of the “Faculty of Engineering, FayoumUniversity”. A detailed description of the experimental work introduced in this research

2.1 Materials: The used Materials in the construction and strengthening of the specimens were: aggregates, cement, water, steel reinforcement and CFRP strips.

2.1.1 Aggregates : The coarse aggregate was natural crushed dolomite with maximum nominal size of 15mm. the sand was locally available yellow clean sand and free from impurities.

2.1.2 Cement: The used cement in concrete mix was ordinary cement from Banisewef -Factory, which complies with the Egyptian standard specifications.

2.13 Mixing water : Clean water was used for mixing. A water cement ratio of 0.57 by weight was used.

2.1.4 Reinforcing steel: The used steel reinforcement was mild steel with diameter is 6mm of grade 240/350Mpa. The flat slabs were reinforced by 6Φ6/m in both directions

2.1.5 Concrete Mix : Mix proportion by weight (kg/m3) of fresh concrete isshown in table 1.

Table 1 Shows concrete mix proportion

	Cement	Sand	Gravel	Water
By weight	350	615	1130	200

2.1.6 Carbon Fiber Reinforced Polymers Strips (CFRP strips):CFRP strips used in this Research were MBT-MBRACE S& PLAMINATE (150/2000). The strip was 5cm wide and 1.2 mm thick. The full specifications of the laminates and the adhesive are represented in table2 and 3.

Table 2 Typical Physical Properties MBT – MBRANES& LAMINATE 150/2000

Property	CFRP
Ultimate Tensile Strength:	2700MPa
Modulus of Elasticity:	165GPa min
Thickness:	1.2/1.4 min
Width	50-100 mm
Design strain:	0.06-0.08%
Ultimate strain:	0.014

Table 3 Technical Data/ Typical Properties performance of MBT-MBRACE LAMINTE ADHESIVE

Composition	Two component epoxy-base
Color	Grey
Specific gravity at 20° C	1.80
Glass transitional temperature:	> 65°C
Modulus of elasticity CFRP:	10Gpa
Lap shear strength to CFRP:	>17Mpa
Water absorption:	0.3 Mpa
Tensile strength:	32Mpa
Compressive strength:	>60Mpa
Flexural strength:	>35Mpa
Full cure 25°C	7 days
Bonding, ASTM D4541 • Concrete • Steel	>3.5Mpa(concrete failure) >5Mpa
Pot life at 25°C 40°C	 50 minutes 25 minutes
Cure rate at 25°C 40°C	 5 hours 2 hours
Full cure at 25°C 40°C	 5 days 3 days

III. Description of Studied Slabs

The test Specimens were divided into three groups, the first group, considered as a reference group which consisted of onespecimen without openings named as (SS). The second group consisted of three slabs have different sizes and shapes of openings without strengthing, there were named as (SOR1, SOR2, SOR3) respectively. And the last group consisted of three slabs have the same shapes and sizes of openings as group 2, but they will strengthen with CFRP, there were named as (SOF1, SOF2, SOF3). Table 4 shows a data about tested slabs.Fig.s 1 through 3 show all tested slabs .

Table4 Dimensions and Details of tsted Specimens strengthened

Specimen	Slab Dimension (mm)	Slab Reinforcement mesh top and bottom	Strip dimensions	Opening Dimensions(mm)
SS	1700× 1700×100	6Φ6/m	--	NA
SORI	1700× 1700×100	6 Φ 6/m	--	200×200
SOR2	1700× 1700×100	6 Φ 6/m	--	300× 200
SOR3	1700× 1700×100	6 Φ 6/m	--	400× 200
SOFI	1700× 1700×100	6 Φ 6/m	1.2× 50×1200	200×200
SOF2	1700× 1700×100	6 Φ 6/m	1.2× 50×1300	300× 200
SOF3	1700× 1700×100	6 Φ 6/m	1.2× 50×1400	400× 200

Fig. 1 Reference flat slab slab

(a)

(b)

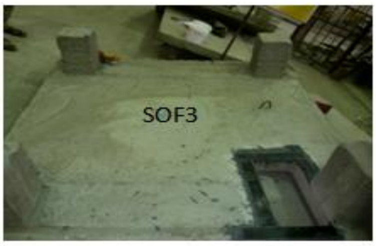
Fig. 2 a- flat slab with opening 200x200 mm
b- flat slab with opening 200x300 mm c- flat slab with opening 200x400 mm

(c)

(a)

(b)

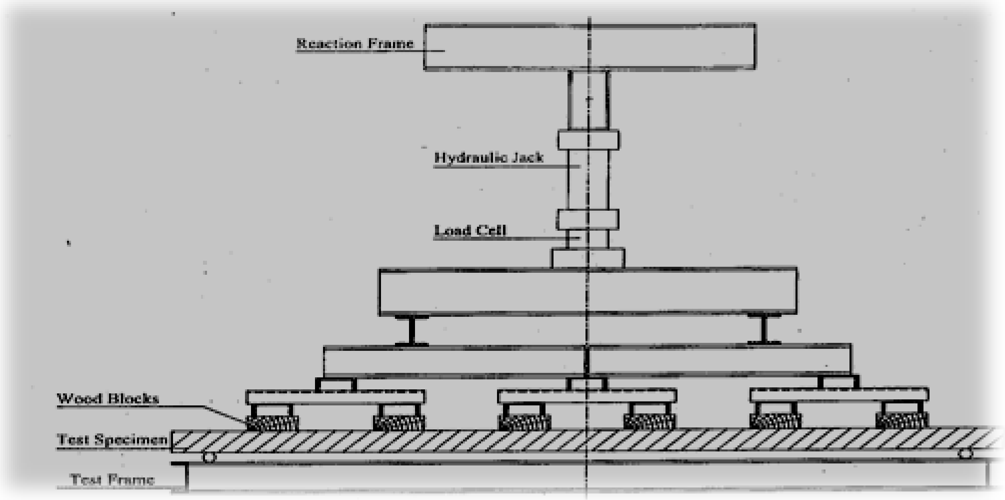
Fig. 3 a- flat slab with opening 200x200 mm and strengthen by CFRP.
b- flat slab with opening 200x300 mm and strengthen by CFRP.
c- flat slab with opening 200x400 mm and strengthen by CFRP.



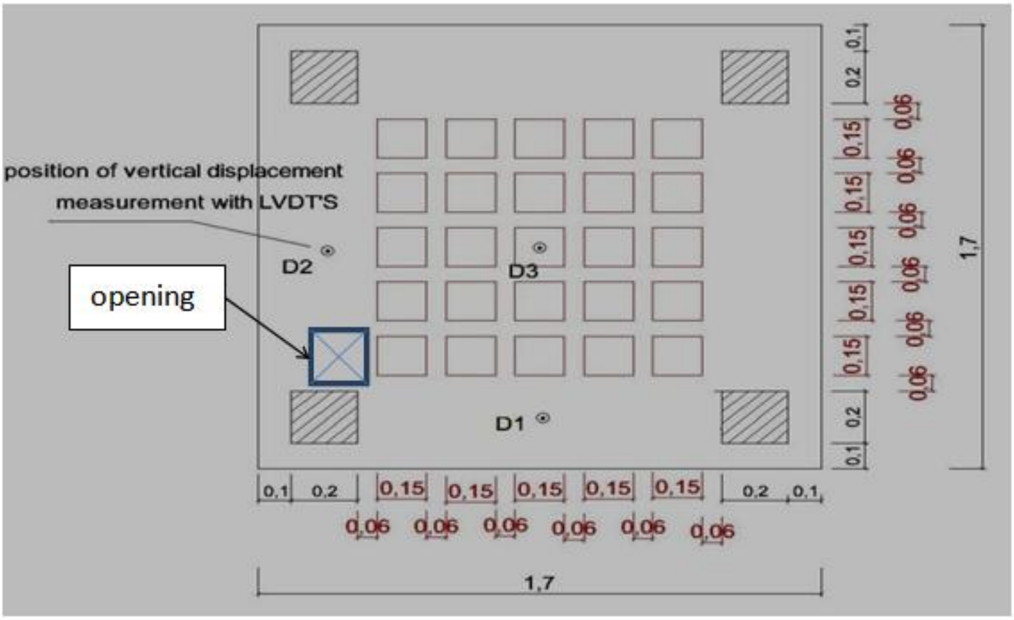
(c)

IV. Test Setup

The slabs were placed on the supporting frame consisting of four channels 26 rested on frame consist of B.F.I.B 60. A steel rod of diameter 22mm was fixed to the top surface of the channel. To obtain uniform distributed load, the load was applied through a single hydraulic jack to a system of steel channels arranged in a pyramid shape. The base of these steel channels arrangement was resting on an arrangement of wooden blocks so as to assure a uniformity of load applied to the specimen as shown in Figs. 4 (a,b).



(a)



(b)

Fig. 4 (a,b) Details of setup for distributed load and the tested points

4.1 Instrumentation: The loading system was attached to the data acquisition system by load sensor connected with the hydraulic jack. The deflection readings were recorded using linear variable differential transducers (LVDT’S) connected to the data acquisition system.

4.2 Deflection Measurements: The deflections were measured using LVDT's connected to the data acquisition system. Fig.4(b) shows the position of vertical displacement measurements with LVDT's for slabs named D1, D2 and D3. The stroke of LVDT used in the test was +/- 100 mm with 0.1 sensitively. The sensor was mounted on handling unit, which was located on the ground under the center of the slab (D3), center of column strip with opening (D2) and center of column strip without opening (D1) as shown in Fig. 4 (b).

V. Test procedure

At the beginning of each slab test, the specimen were supported on four corner columns in the loaded frame and tested using a hydraulic jack, and the LVDT's were adjusted in their positions and they were attached to the data acquisition system. The initial reading of LVDT'S was recorded just before loading the specimen was loaded as shown in Fig. 5. load deflection was recorded for each load increments. The overall behavior of each specimen was also observing the crack pattern and propagation over the loading time.

5.1 Measurement: The well-known Lab View graphical computer program language is used to monitor the load, the measurements of the deflections. The output data is stored in spreadsheet file, and is also presented graphically step by step on the PC monitor during the test. The bottom face (tension side) was observed and the cracks were marked after a completion of test.

Fig. 5 Loading frame, control machine and computer parts.

VI. Experimental Results

5.2 Load Deflection Results: In Specimen SS, at ultimate load of 15.09 ton, the maximum deflection recorded at points D1, D2 and D3 were equal to 3.35 mm, 3.35 mm and 4.575mm respectively. In specimen SOR1, at ultimate load of 12.143 ton, the maximum deflection recorded at points D1, D2 and D3 were equal to 12 mm, 15mm, and 11.8 mm respectively. In specimen SOR2, at ultimate load of 11.60 ton, the maximum deflection recorded at points D1, D2 and D3 were equal to 22 mm, 32.5mm, and 25 mm respectively. In specimen SOR3, at ultimate load of 10.30 ton, the maximum deflection recorded at points D1, D2 and D3 were equal to 18.25 mm, 26 mm, and 28.2 mm respectively.In Specimen SOF1, at ultimate load of 16.25 ton, the maximum deflection recorded at points D1, D2 and D3 were equal to 17 mm, 20.3 mm, and 23.3 mm respectively.. In specimen SOF2, at ultimate load of 14.30 ton, the maximum deflection recorded at points D1, D2 and D3 were equal to 33.25 mm, 38 mm, and 44.2 mm respectively. In specimen SOF3, at ultimate load of 13.40 ton, the maximum deflection recorded at points D1, D2 and D3 were equal to 16 mm, and 18 mm respectively 16.9 mm respectively. . Load-Deflection for different points D1, D2 and D3 are shown in table 5 while table 6shows the crack , ultimate loads and maximum deflection for the tested slabs at point D3.

Table 5 Maximum load and deflection of the tested slabs

Specimen	Opening Location	Ultimate Load (ton)	Maximum Deflection at D1 (mm)	Maximum Deflection at D2 (mm)	Maximum Deflection at D3 (mm)
SS	ne	15.09t	3.35	3.35	4.575
SOR1	Column strip	12.143t	12	15	11.8
SOR2	Column strip	11.6	22	32.5	25
SOR3	Column strip	10.3	18.25	26	28.2
SOF1	Column strip	16.25	17	20.3	22.3
SOF2	Column strip	14.3	33.25	38	44.2
SOF3	Column strip	13.4	16	18	16.9

Table 6 Cracking loads , ultimate loads and maximum deflection of the tested slabs

Specimen	Slab Thickness (mm)	Opening Size (mm)	Cracking Load (ton)	Ultimate Load (ton)	Maximum Deflection at D3 (mm)
SS	100	…………..	4.2t	15.09t	4.575
SOR1	100	200× 200	2.4t	12.143t	11.8
SOR2	100	200× 300	2.1t	11.6	25
SOR3	100	200× 400	1.7t	10.3	28.2
SOF1	100	200× 200	4t	16.25	22.3
SOF2	100	200× 300	3.7t	14.3	44.2
SOF3	100	200× 400	3.2t	13.4	16.9

Fig.s through 6to 8 show load-deflection curves comparison between tests slabs(SS, SOR1, SOF1),(SS, SOR2, and SOF2) and (SS, SOR3, SOF3) respectively for point D3.

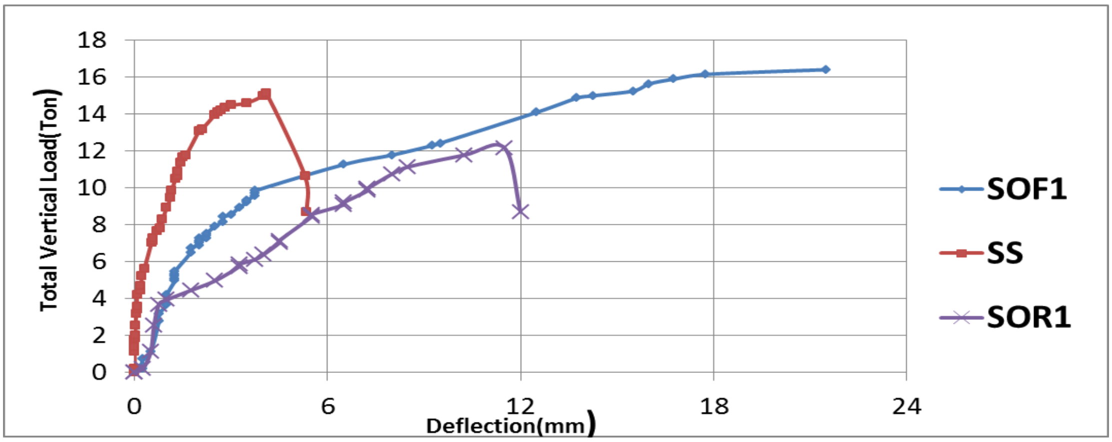


Fig.6 Load-Deflection Curves Comparison of load/middle span deflection for slabs with opening (200× 200)mmin Column strip with respect to reference slab(ss) at D3

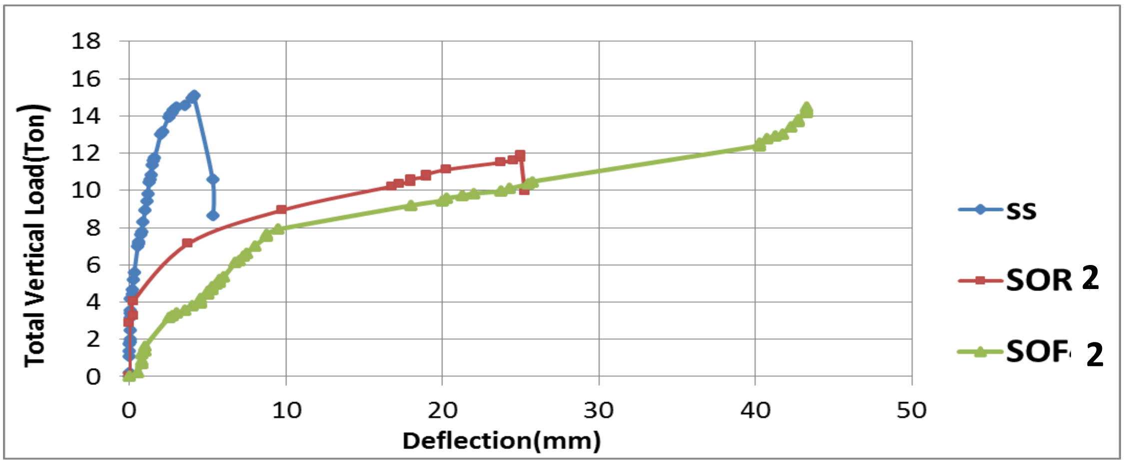


Fig.7 Load-Deflection Curves Comparison of load/middle span deflection for slabs with opening (300× 200)mmin Column strip with respect to reference slab(ss) at D3

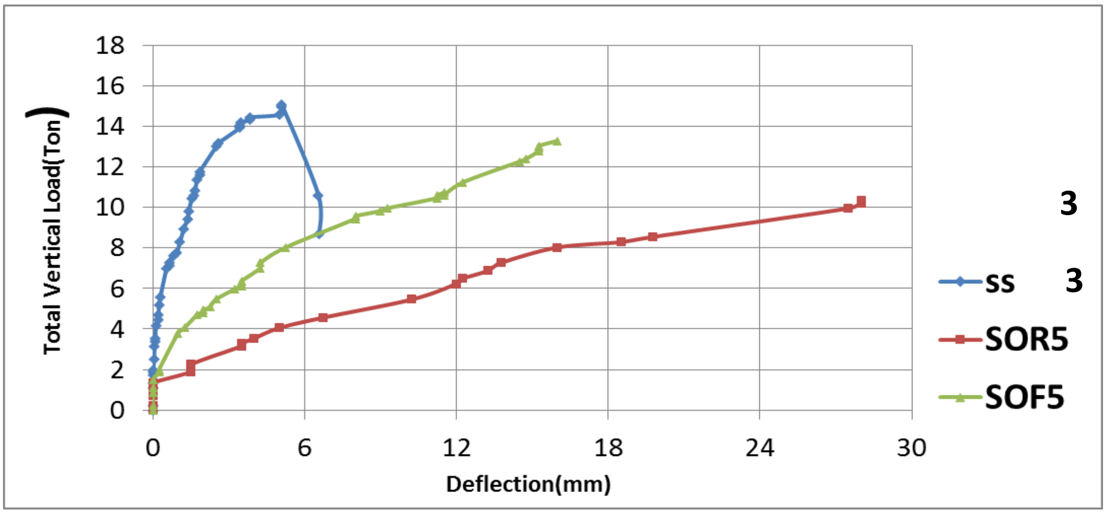


Fig. 8 Load-Deflection Curves Comparison of load/middle span deflection for slabs with opening (400× 200)mmin Column strip with respect to reference slab(ss) at D3

5.3 Cracking pattern and mode of failure: Fge.9 through Fig.11 show the cracking pattern at the lowers surfaces of specimens SS, SOR1, SOR2, SOR3, SOF1, SOF2 and SOF3, respectively, after the completion of the tests. In specimen SS crack pattern observed around the supporting columns while for specimens SOR1 through SOR3 it was observed that the cracks turned around the ends of opening.In specimens SOF1through SOF3, it was observed that the cracks turned around the ends of the CFRP strips ends. The CFRP strip divides the slab into multi separate zones. The cracks were discontinuous between zones. At the four corners zones the cracks were diagonal and extended from the edges of CFRP strip to the corners of the slab.

Fig.9 Crack pattern of Specimen SS

(a)

(b)

Fig.s 10 a- Crack pattern of Specimen SOA1
b- Crack pattern of Specimen SOA2 c- Crack pattern of Specimen SOA3

(c)

(a)

(b)

Fig.s 11a- Crack pattern of Specimen SOF1
b- Crack pattern of Specimen SOF2 c- Crack pattern of Specimen SOF3

(c)

VII. Conclusion and summary of Results

The main conclusions of the experimental work are:

1. The opening in flat slab in column strips decreases the ultimate load value
2. The increasing of opening size casuses decreasing in ultimate load capacity
3. The strengthening of flat slabs using externally bonded CFRP strips is an easy and feasible method of strengthening.
4. The strengthening of flat slabs using externally bonded CFRP strips gives higher ultimate load than the reference flat slab in the case of square opening and gave the nearest value of ultimate loads on the other opening sizes in comparison with reference slabs.
5. The strengthening of flat slabs using externally bonded CFRP strips gives higher ultimate load than flat slabs with opening and without strengthening.
6. For all slabs the values of the deflection on column strip with opening is higher than that in the column strips without opening.
7. Strengthening flat slabs with CFRP strips not effected on the vlues of deflection.

References

[1]. U.Ebead, H.Marzouk, and L.M.Lye, constructed and experimental study and a finite element analysis of strengthened two-way slabs using FRP laminates and sheets. 2nd World Engineering Congress,Sarawak, Malaysia,22-25 July 2002

[2]. Ola Enochsson "CFRP Strengthening of Concrete Slabs, with and without OpeningsExperiment, Analysis, Design and Field Application" Luleå University of TechnologyDepartment of Civil and Environmental Engineering,Division of Structural Engineering ,2005

[3]. Takahashi, Y., and Sato, Y "Experimental study on the strengthening effect of a CFRP sheet for RC slabs," FRPRCS5, Thomas Telford, Cambridge, UK, 989-996. . (2001).

[4]. Mohamed, T., El-Attar, A., and El-Ibiari, S "Strengthening of Two-WayReinforced Concrete Slabs with Created Central Openings" Accepted to the RegionalConference on Civil Engineering Technology and III International Symposium onEnvironmental Hydrology, Egypt. ., (2002).

[5]. Casadei P., Nanni, A. and Ibell T., "Experiments on Two-way RC Slabs with OpeningsStrengthened with CFRP Laminates", Center for Infrastructure Engineering Studies,(CIES03-39), University of Missouri-Rolla, USA, 2003[6]. P.C.A"Openings in Concrete Floor Slabs"2006

[6]. TayseerMohamed.,"Strengthening of Two-Way Reinforced Concret Slabs With Created Edge And Corner Openings"H.B.R.C , Cairo University.

[7]. Islam, S. and Park, R.. "Yield-Line Analysis of Two-way RC Slabs with Openings," J. Inst. Structure Eng., Vol. 49, No. 6, 269-276 (2010)[9]. ACI Committee 318R-89, "Commentary on Building Code Requirements for Reinforced,Concrete", 1989.

[8]. British Standard: BS 8110:, "Structural Use of Concrete", Part 1, Code of Practice forDesign and Construction of Construction Joint, 1985.

[9]. Australian Standard: AS: 1480-1982.

[10]. Indian Standard: IS: 456-1978.

[11]. Egyptian Code of Practice for Reinforced Concrete Structures: Construction and Design, 2017.

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