بسم الله الرحمن الرحيم

FLEXURAL BEHAVIOUR OF REINFORCED CONCRETE ONE WAY SLAB WITH OPENING

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Introduction

- Reinforced concrete (R.C) solid slab has been widely used for the multi-story building. Small openings are required in the slab to accommodate the mechanical and electrical services such as heating, plumbing and ventilating risers. Meanwhile, substantial size openings are required by lift, stairways and elevator shafts as shown in figures (1). The structural effect of small openings is often not considered due to the ability of the structure to redistributed stresses. However, for large openings, the static system may be altered when it involves a significant amount of concrete and reinforcement bar that need to be removed. This may lead to decrease in ability of the structure to withstand the imposed loads and the structure needs .
- For newly constructed slabs, the locations and sizes of the required openings are usually predetermined in the early stages of design and accommodated accordingly.

Figure(1) shows different figures with opening.

The effect of opening on the slab

- The proposed opening in a roof of a building may affect in one or all of the following ways:
- The design live load is increased at the new stair landing area, thereby overloading adjacent portions of the slab·
- The original structural design assumptions (e.g., continuous beam, arch action, etc.) may not be satisfied with the opening·
- In the case of a T-beam, the flange is partially or completely removed at the opening side, thereby reducing flexural resistance and stiffness.
- Structural capacities are undermined when floor reinforcement is eliminated or cut off when creating an opening in a concrete slab .

Aims of the Study

- This study investigates the flexural behavior of R.C one-way slab with opening which include the effect of:

1. The size of the openings(4.2% , 7.4% , 11.6% of the slab volume) .
2. The shape of the opening (square ,circle and rectangular openings).
3. The configuration of steel reinforcement around the opening .
4. the number of steel bars surrounding the opening.

Experimental Work

Table (١) Specimen Details

Specimen	Opening shape	Opening dimension (mm)	% opening	Internal strength (mm)	configuration of strengthening
S1	-	-	-	-	-
S2	Square	200	7.4	-	-
S3	Square	150	4.2	-	-
S4	Square	250	11.6	-	-
S5	Rectangular	151*265	7.4	-	-
S6	Circle	D = 225.7	7.4	-	-
S7	Square	200	7.4	1 ϕ 10	Surrounding
S8	Square	200	7.4	1 ϕ 10	Diagonal
S9	Square	200	7.4	1 ϕ 10	Surrounding and Diagonal
S10	Square	200	7.4	2 ϕ 10	Surrounding

Table (٢) Groups Details

Group	Specimen	Parameter
G1	S1 ,S2 ,S3 ,S4	The effect of the opening size.
G2	S1 ,S3 , S5 , S6	The effect of opening shape.
G3	S1 , S3 ,S7 ,S8 ,S9	The effect of configuration of steel reinforcement.
G4	S1 ,S3 ,S7 ,S10	The effect of No. of additional steel bars surrounding the opening.

Materials

Figure (٢) Coarse and Fine Aggregate stocks.

- The American mix design method was adopted as the guidance for designing the concrete mixes to have a target 28 days characteristic compressive strength (fcu) equal to (40 MPa) , with a slump equal to 120 mm ,and the mix proportions are given in Table (1) below:

Table (٣) Concrete Mixture Design (by Weight).

Designation	Cement content (kg/m3)	Aggregate (kg/m3)		Water (kg/m3)	W/C	Slump (mm)
		sand	Gravel			
C40	450	855	855	240	0.53	120

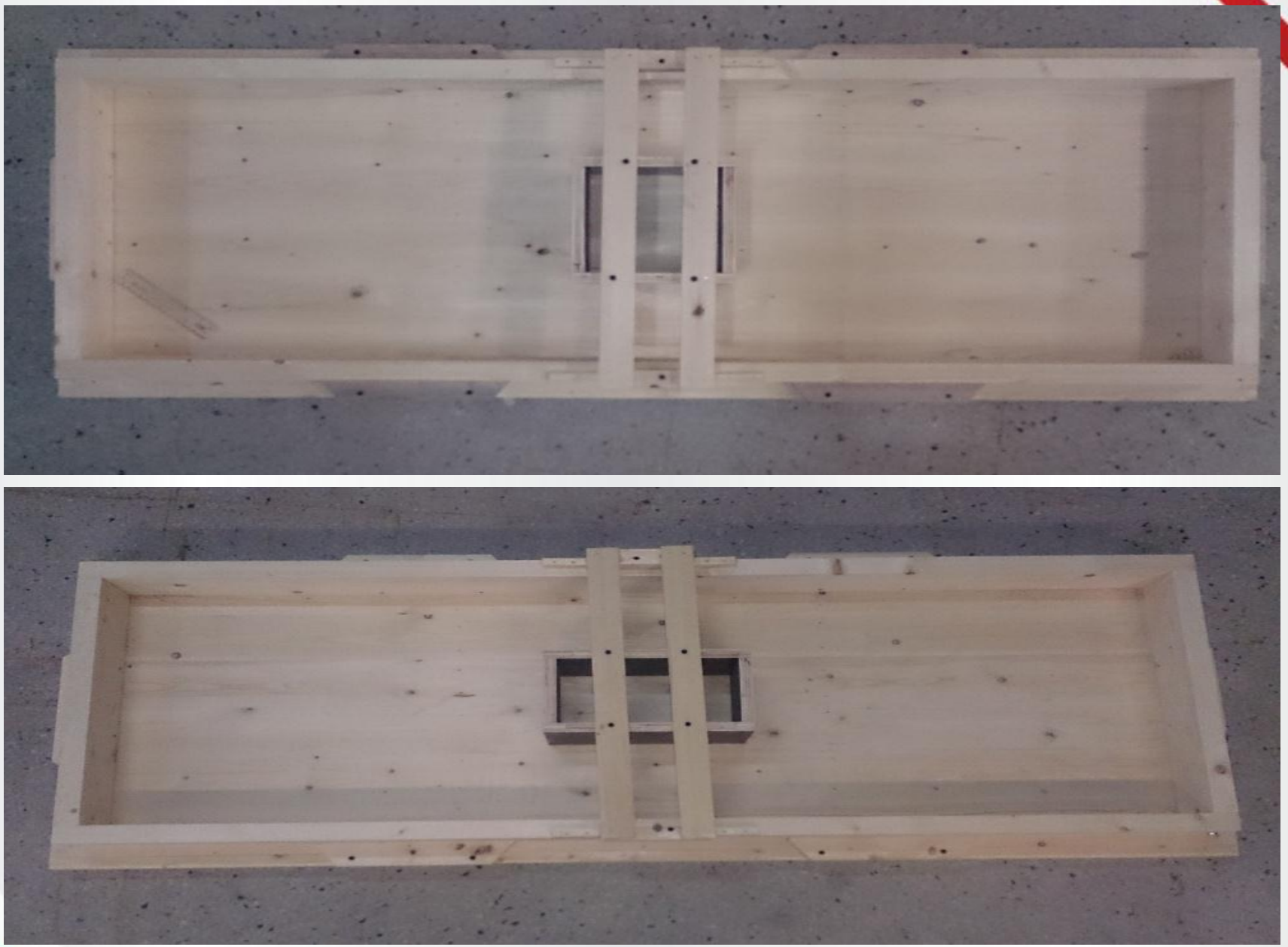
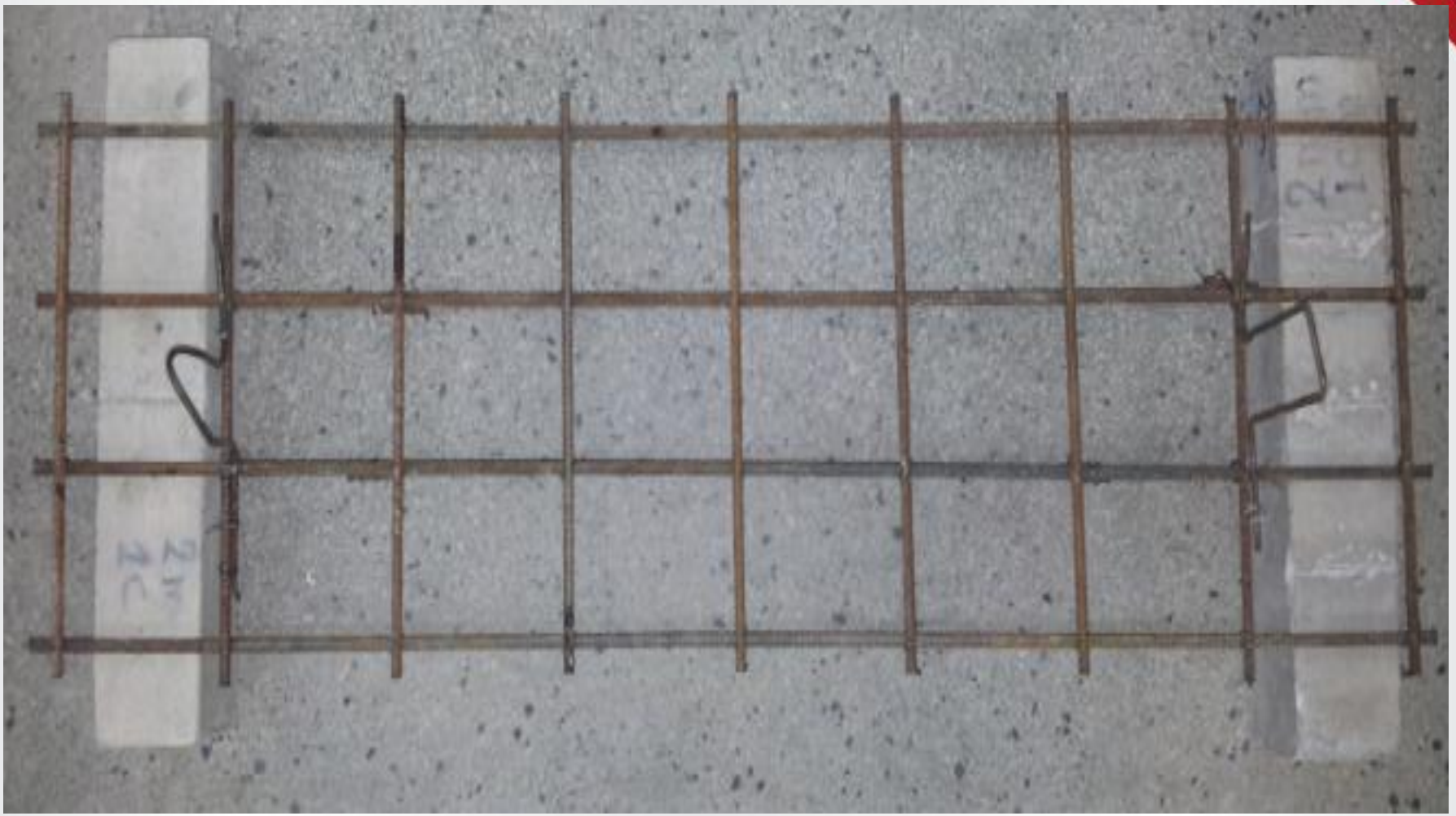


Figure (٣) wooden mold for slabs.



Figure(٤) the slab system plan.

Figure (٥) group1 slabs reinforcement details.

Figure (٦) group2 slabs reinforcement details.

Figure (٧) group3 slabs reinforcement details.

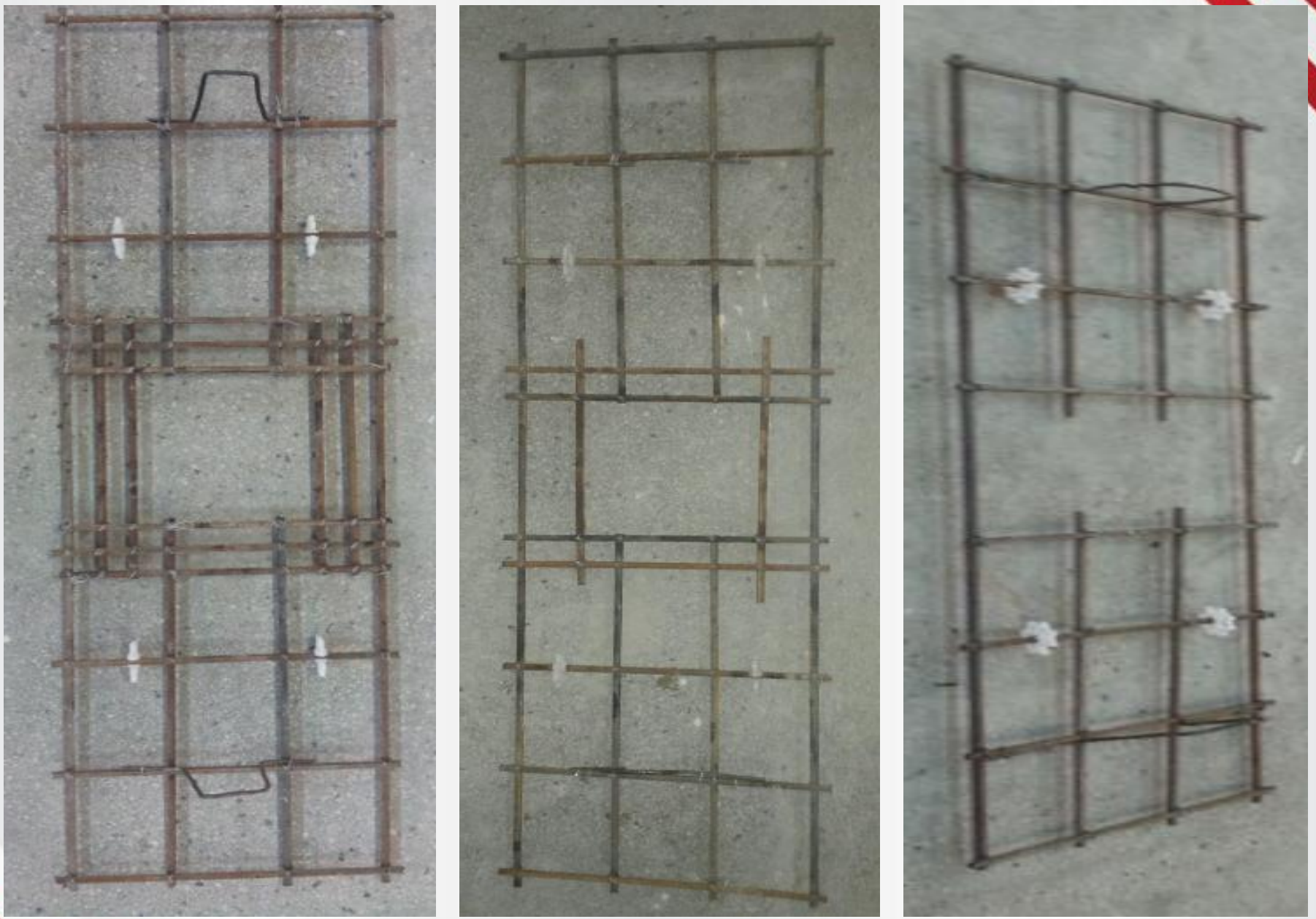


Figure (^) group4 slabs reinforcement details.

Figure (٩) Preparing Wooden Molds for Slabs and Openings.

Figure (1٠) Preparing and Weighting Materials

Figure (1١) Mixing and Casting Concrete

Figure (١٢) Compacting with Rod Vibrator

Figure (١٣) Slump Tests

Figure (١٤) Concrete Mixing and Placing

Figure (١٥) Concrete Mixing and Placing

Figure (١٦) Curing

Figure (١٧) Curing

Figure (1٨) Compressive Strength Test

Figure (19) Compressive Strength Test

Figure (20) Splitting Tensile Strength Test

Figure (21) Flexural Strength Test

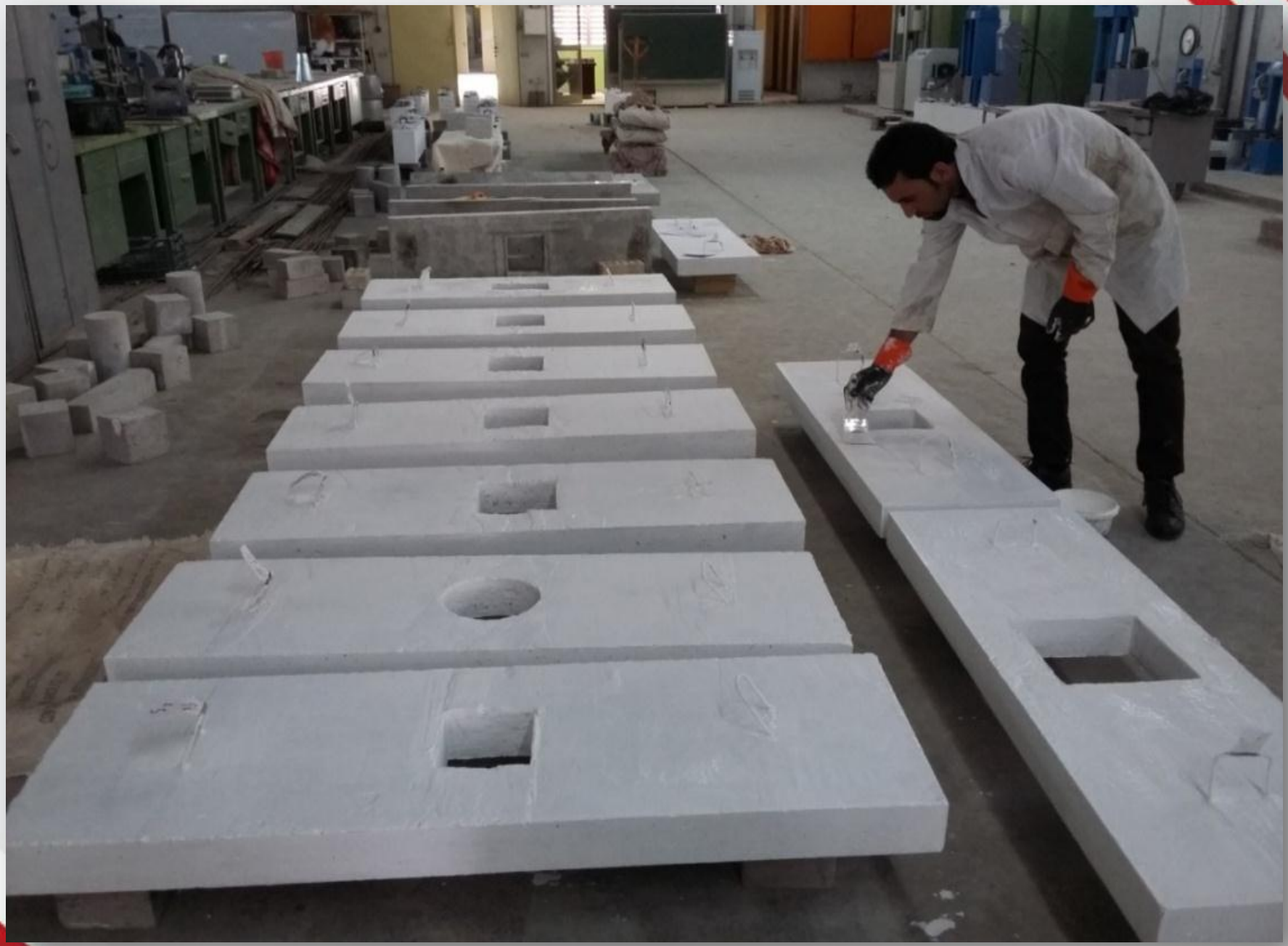


Figure (22) painting slabs.

Figure (2٣) Strain Gauges Arrangement

Applying CN-E adhesive

Applying a constant pressure

Coating with SB tape

Figure (2٤) Strain Gauges Installing

Testing Machine

Figure (2٥) Testing Machine

Concrete Strain Measurement

Figure (26) Strain Gauges Arrangement.

Data logger TDS-530

Figure (2٧) Data Logger TDS-530.

Crack Width Measurement

Figure (2^) Optical Micro-Meter.

Deflection Measurement

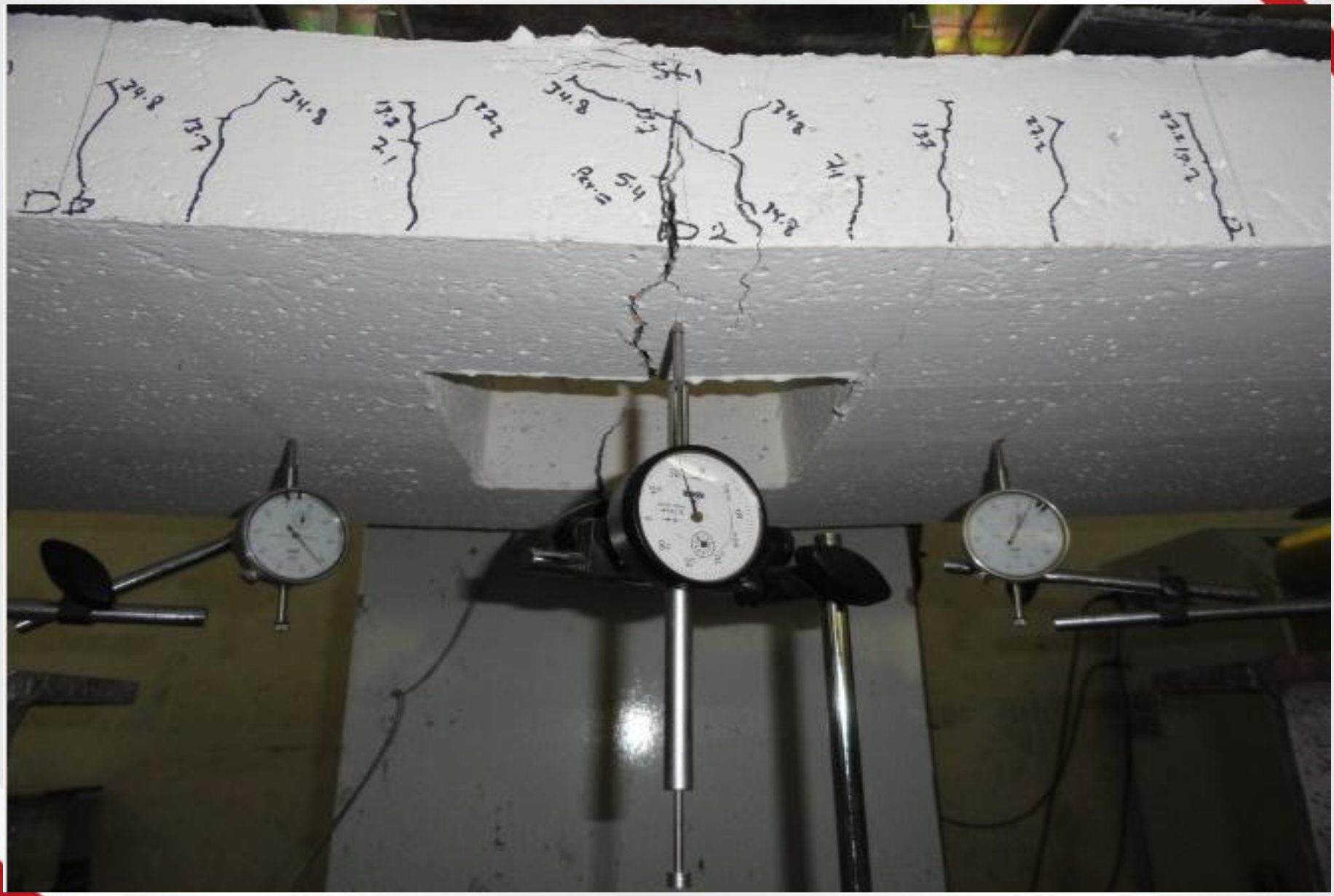


Figure (2٩) Dial Gauge Position.

Figure (٣٠) Dial Gauge Reading.

Experimental Results and Discussions

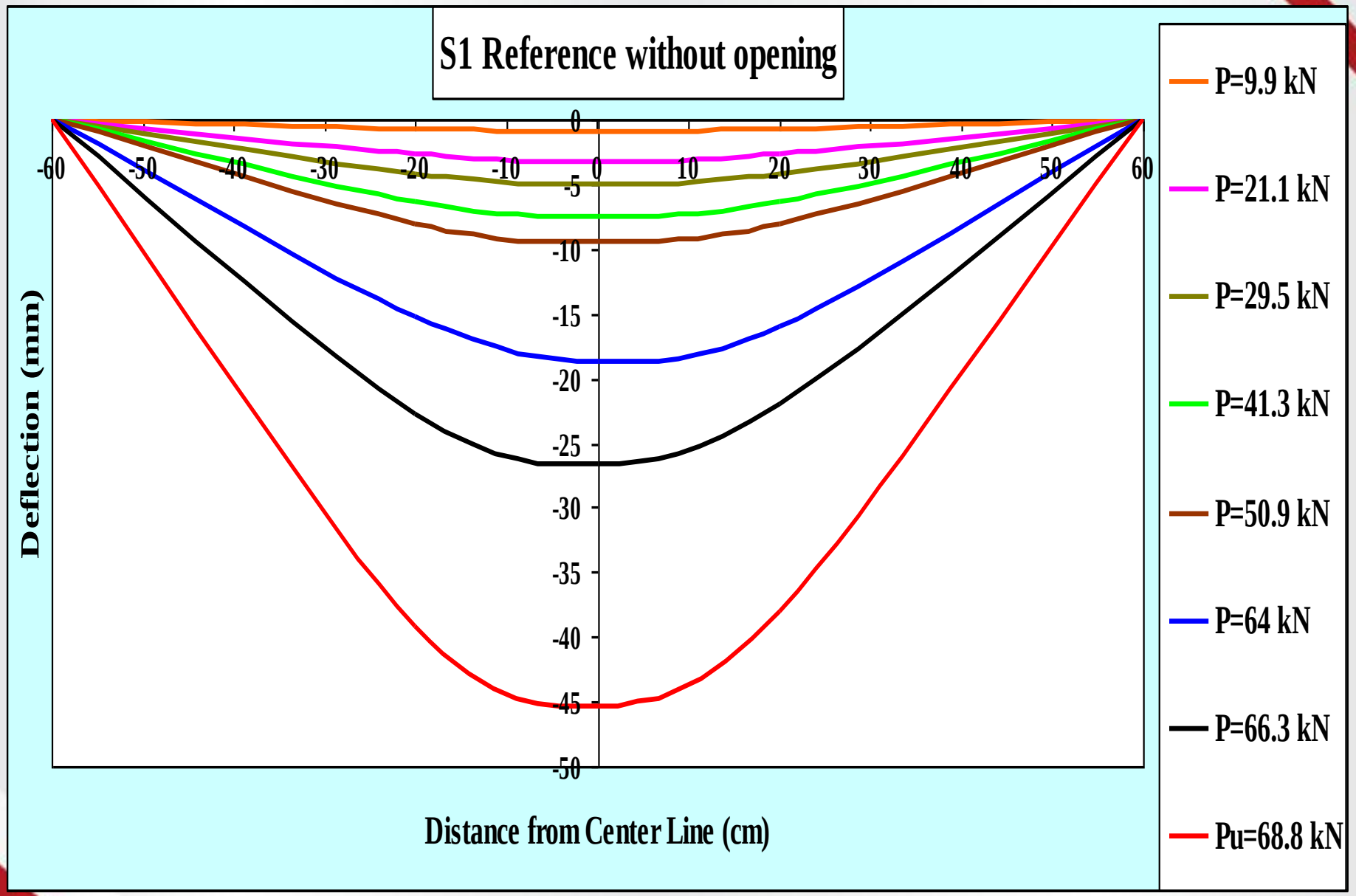


Figure (3١) Deflection profile for specimen S1.

Figure (3٢) Crack pattern of specimen S1.

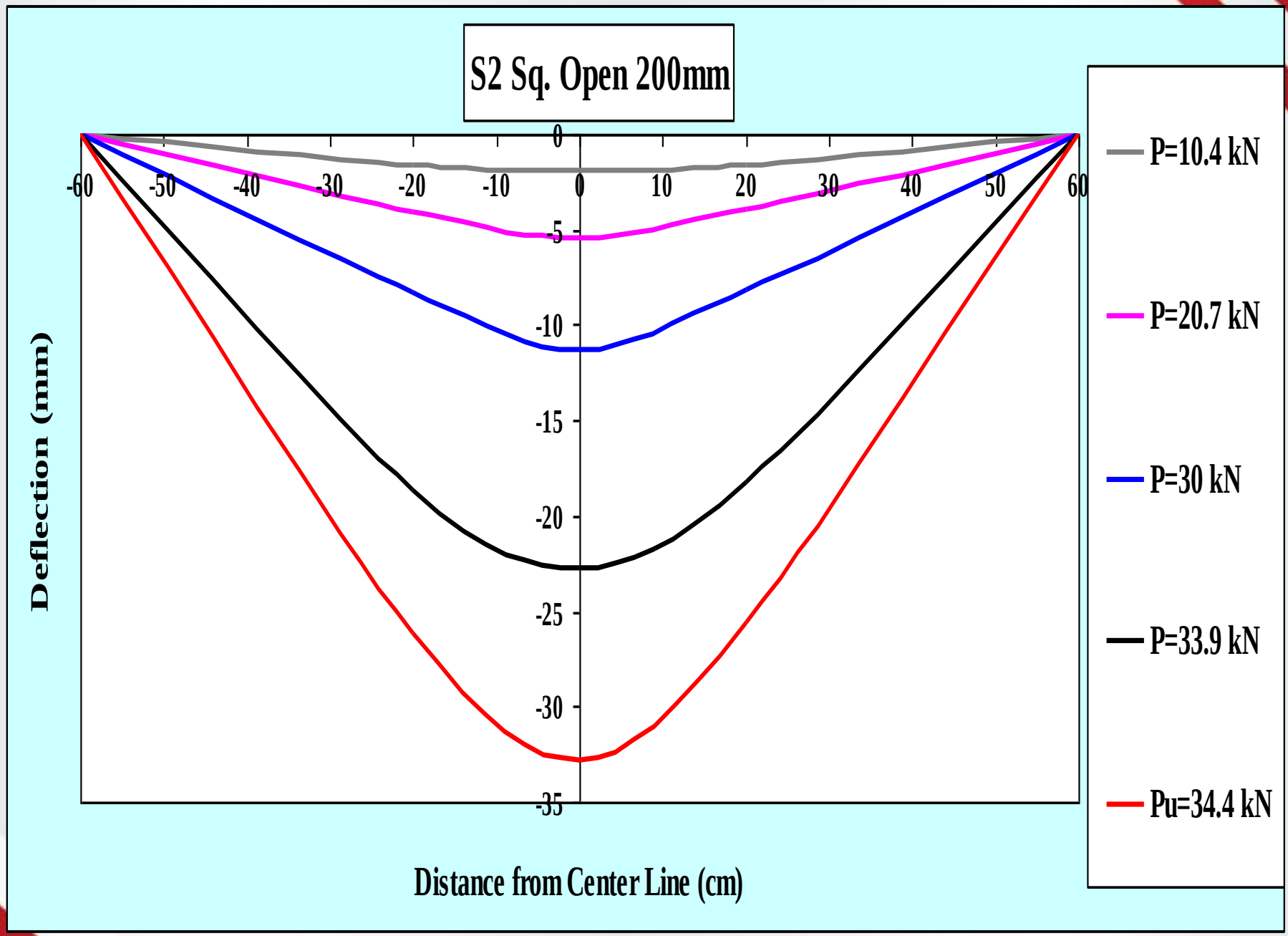


Figure (٣٤) Deflection profile for specimen S2.

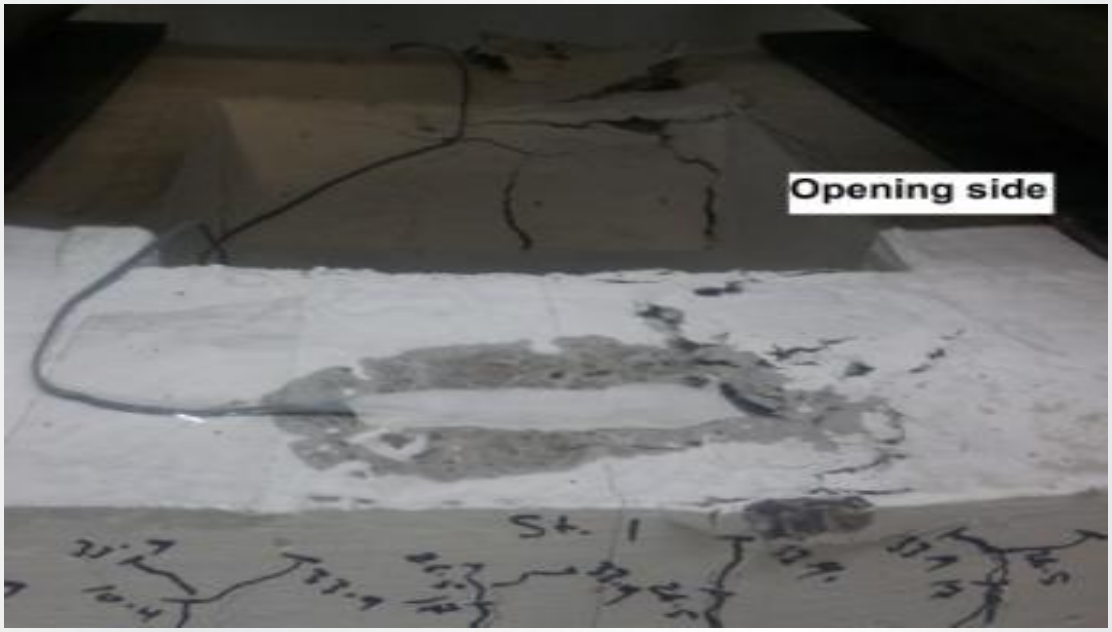


Figure (3٤) Crack pattern of specimen S2.

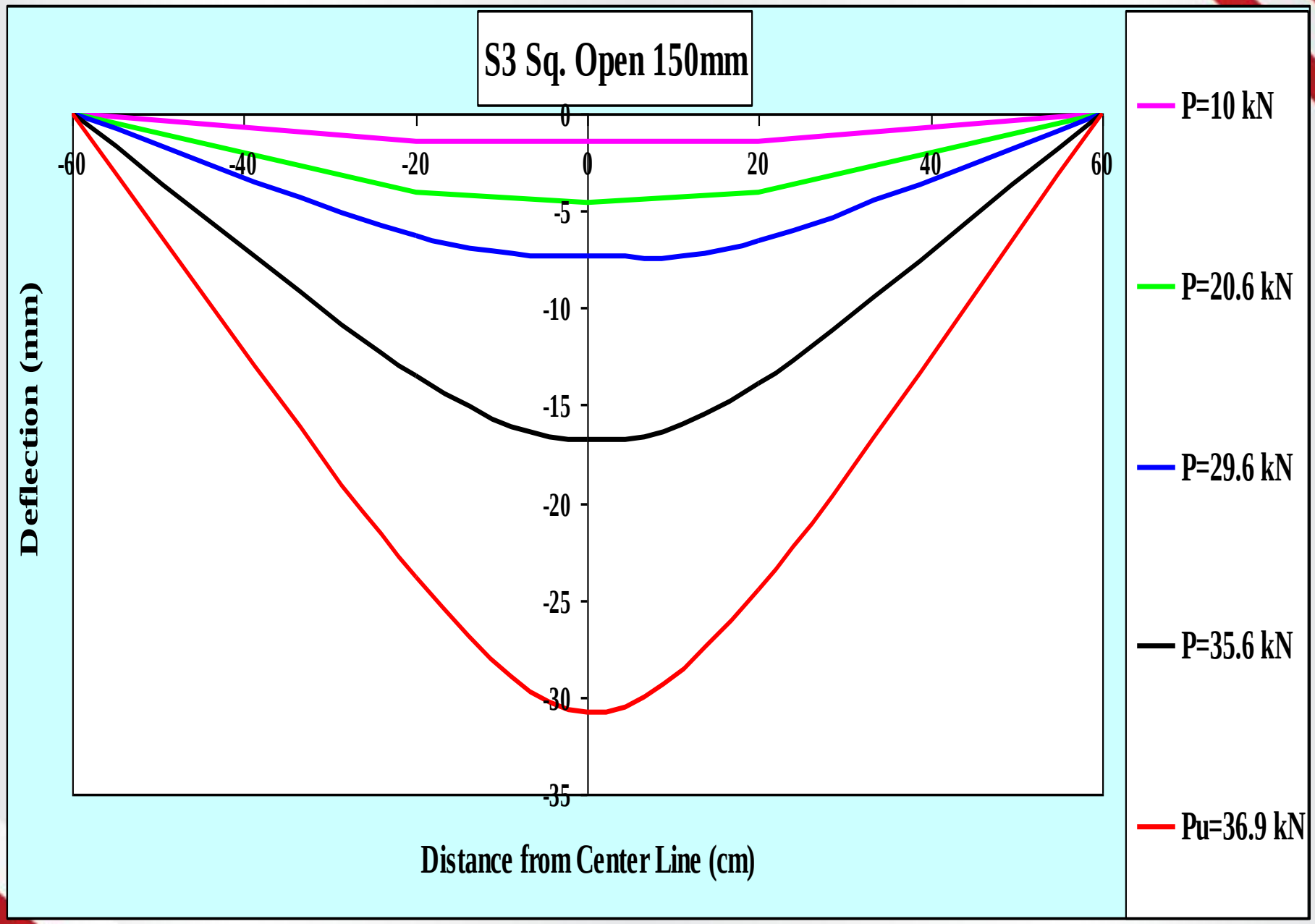


Figure (3٥) Deflection profile for specimen S3

Figure (٣٦) Crack pattern of specimen S3.

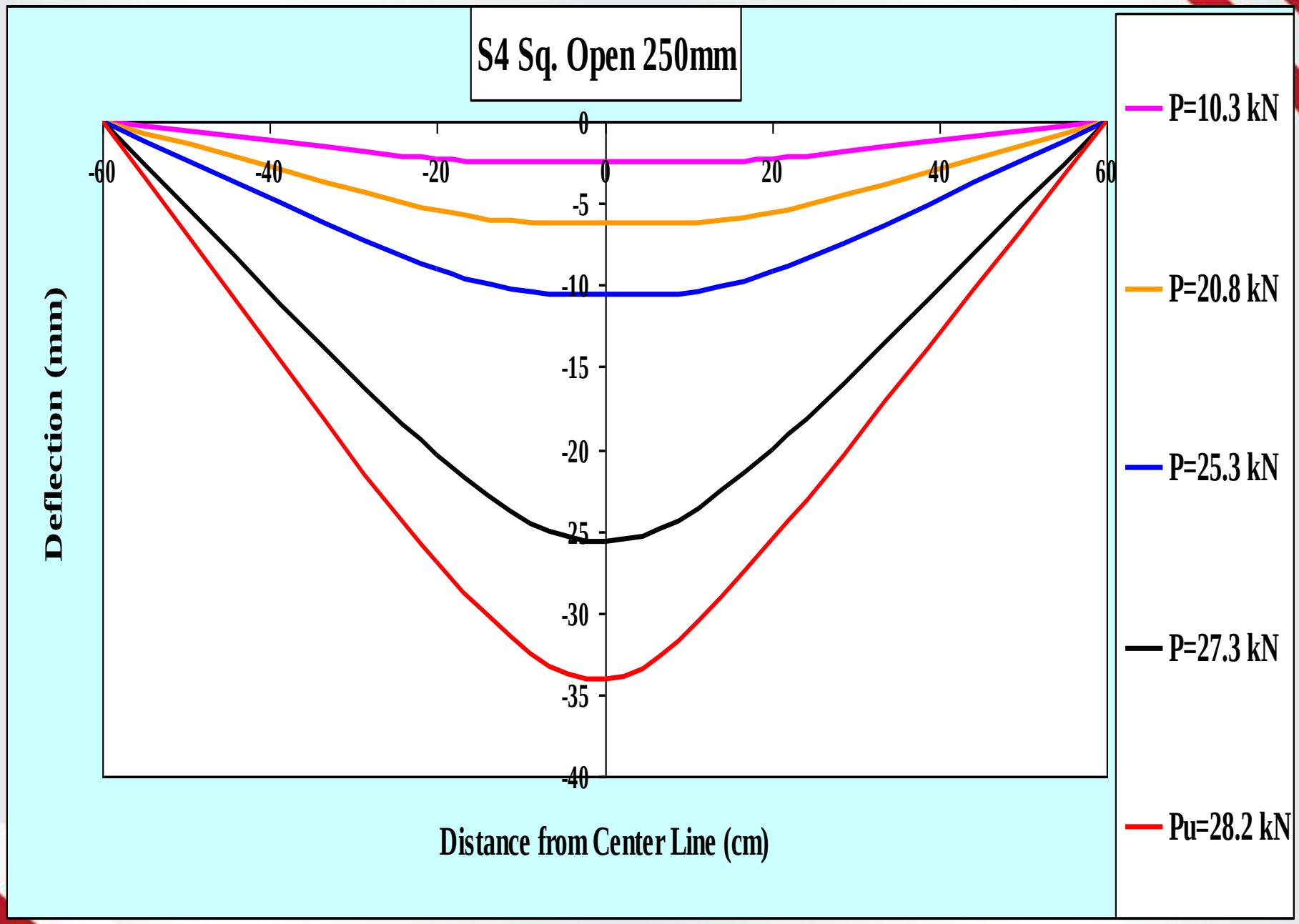


Figure (3ᵛ) Deflection profile for specimen S4

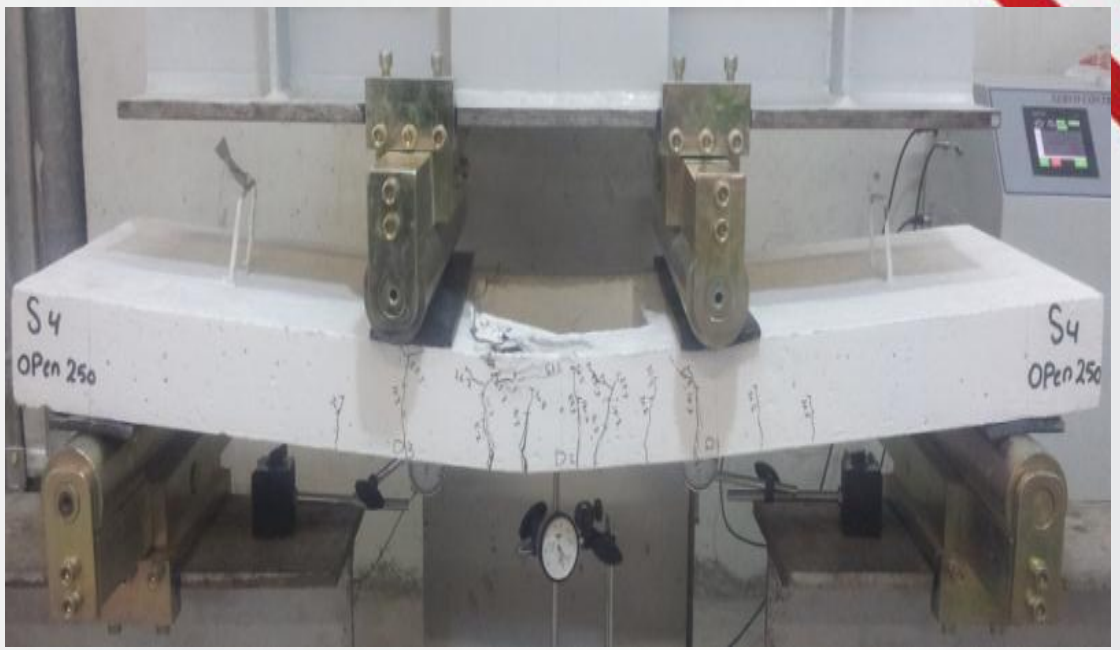


Figure (3^) Crack pattern of specimen S4.

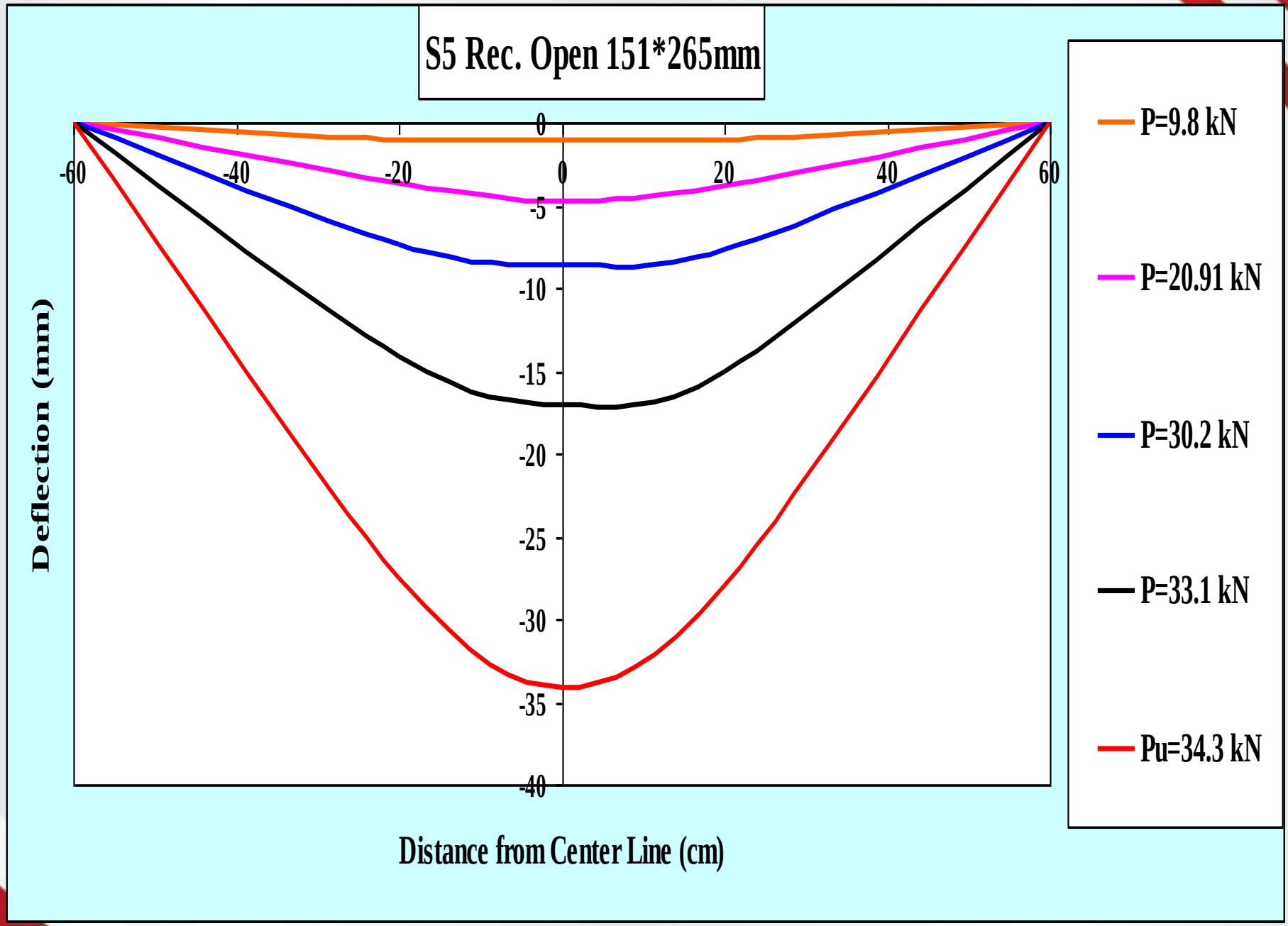


Figure (3٩) Deflection profile for specimen S5.

Figure (٤٠) Crack pattern of specimen S5.

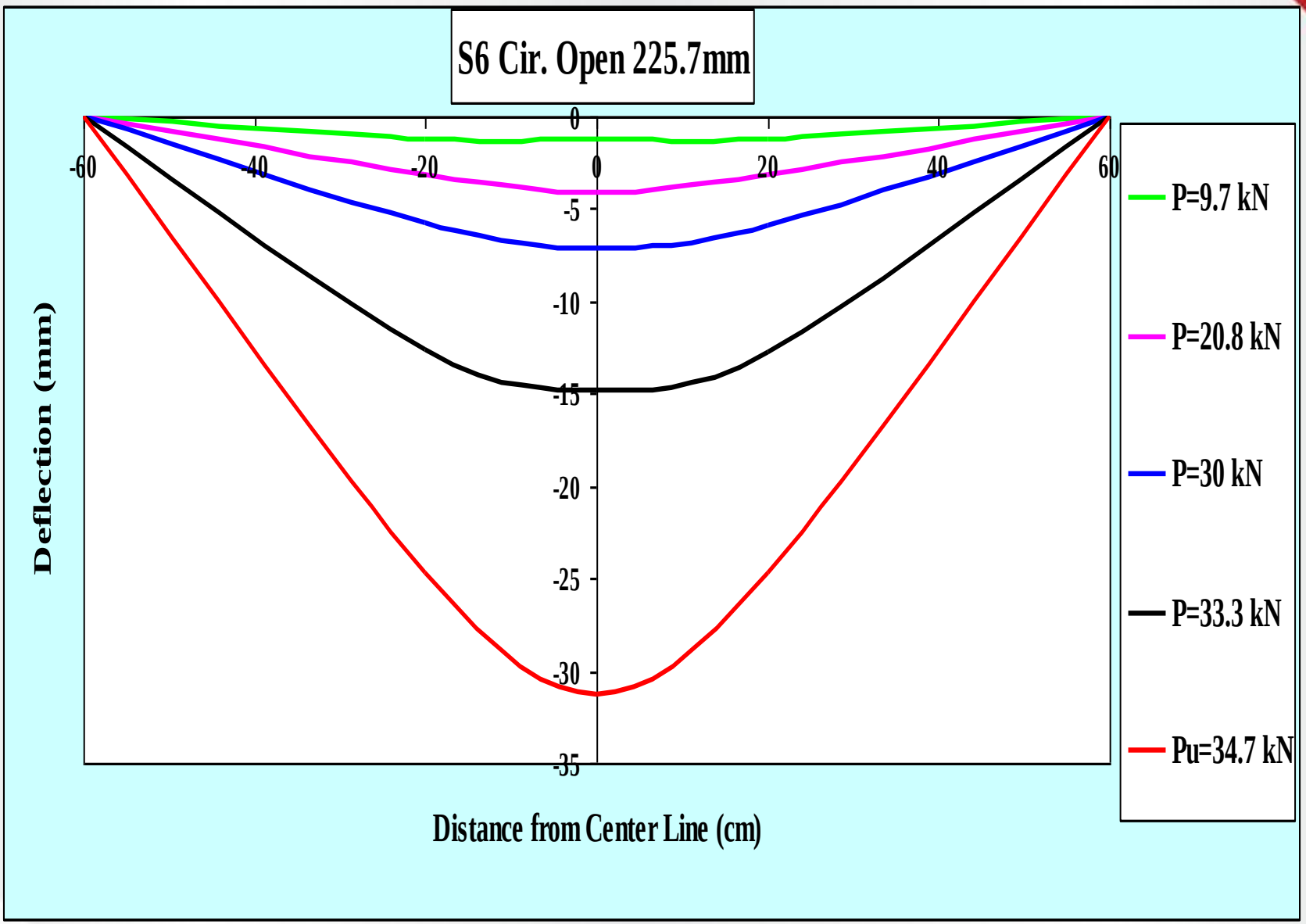


Figure (4١) Deflection profile for specimen S6

Figure (4٢) Crack pattern of specimen S6.

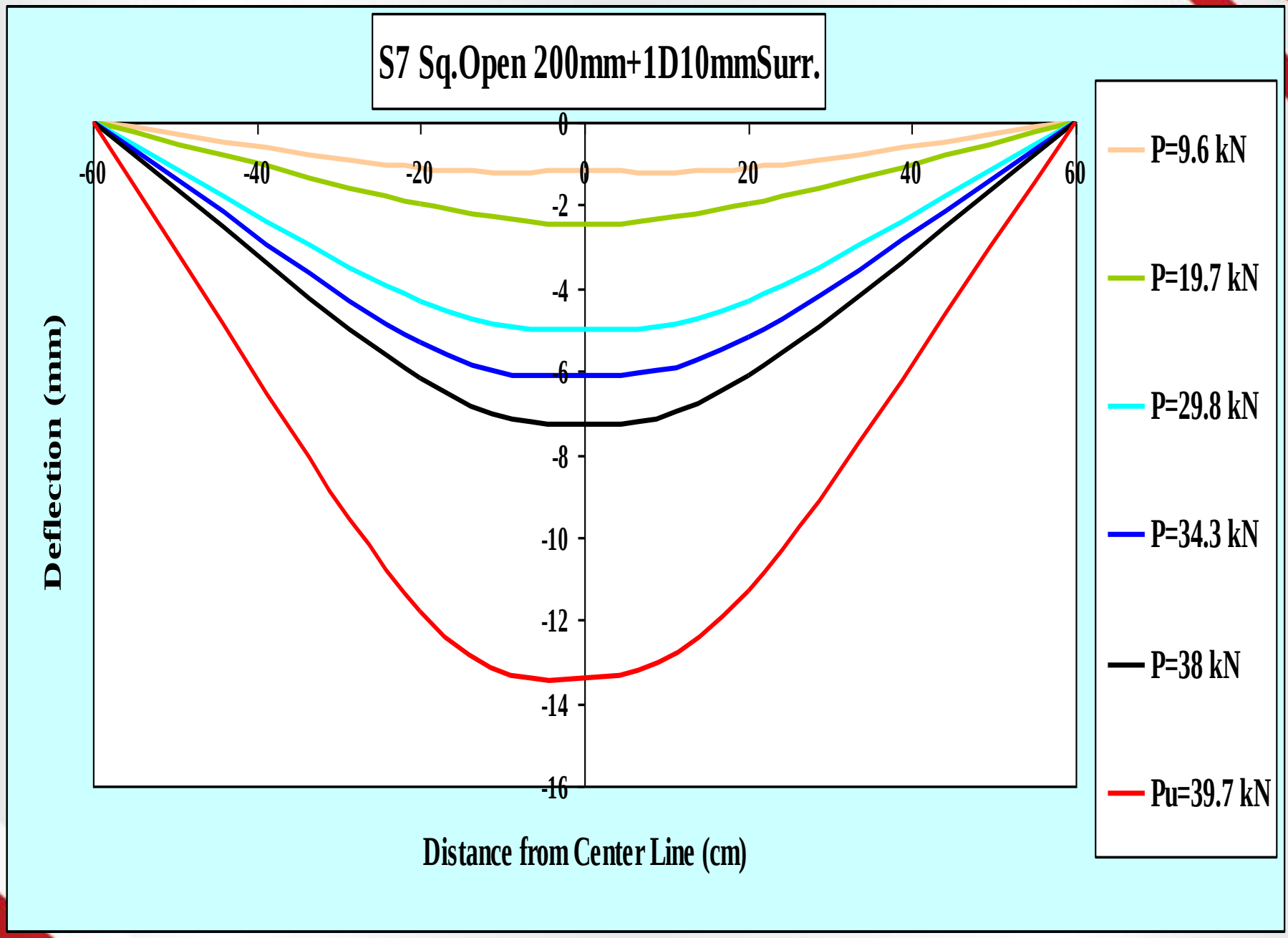


Figure (4٣) Deflection profile for specimen S7.

Figure (4٤) Crack pattern for S7.

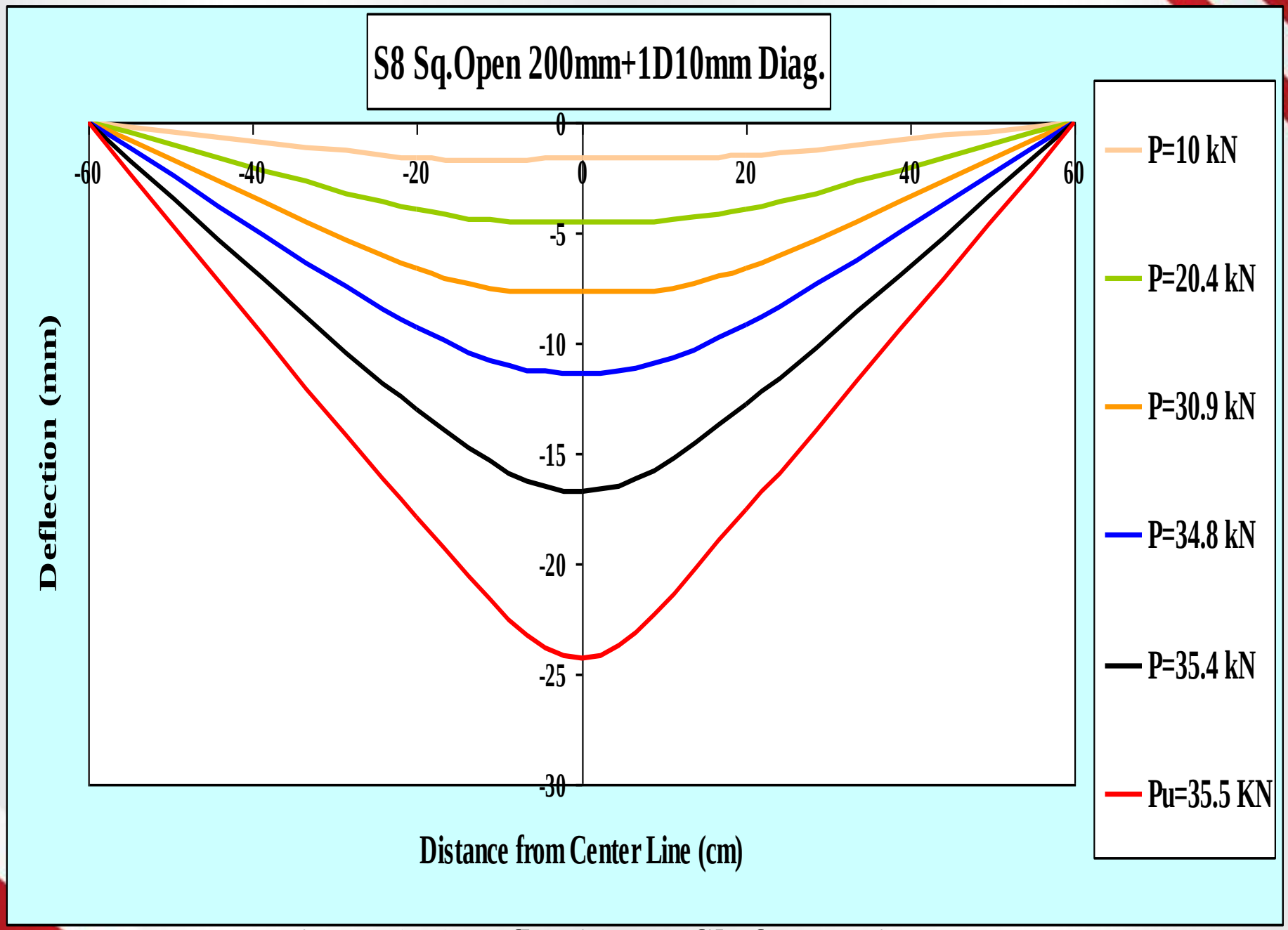


Figure (4٥) Deflection profile for specimen S8

Figure (4٦) Crack pattern of specimen S8.

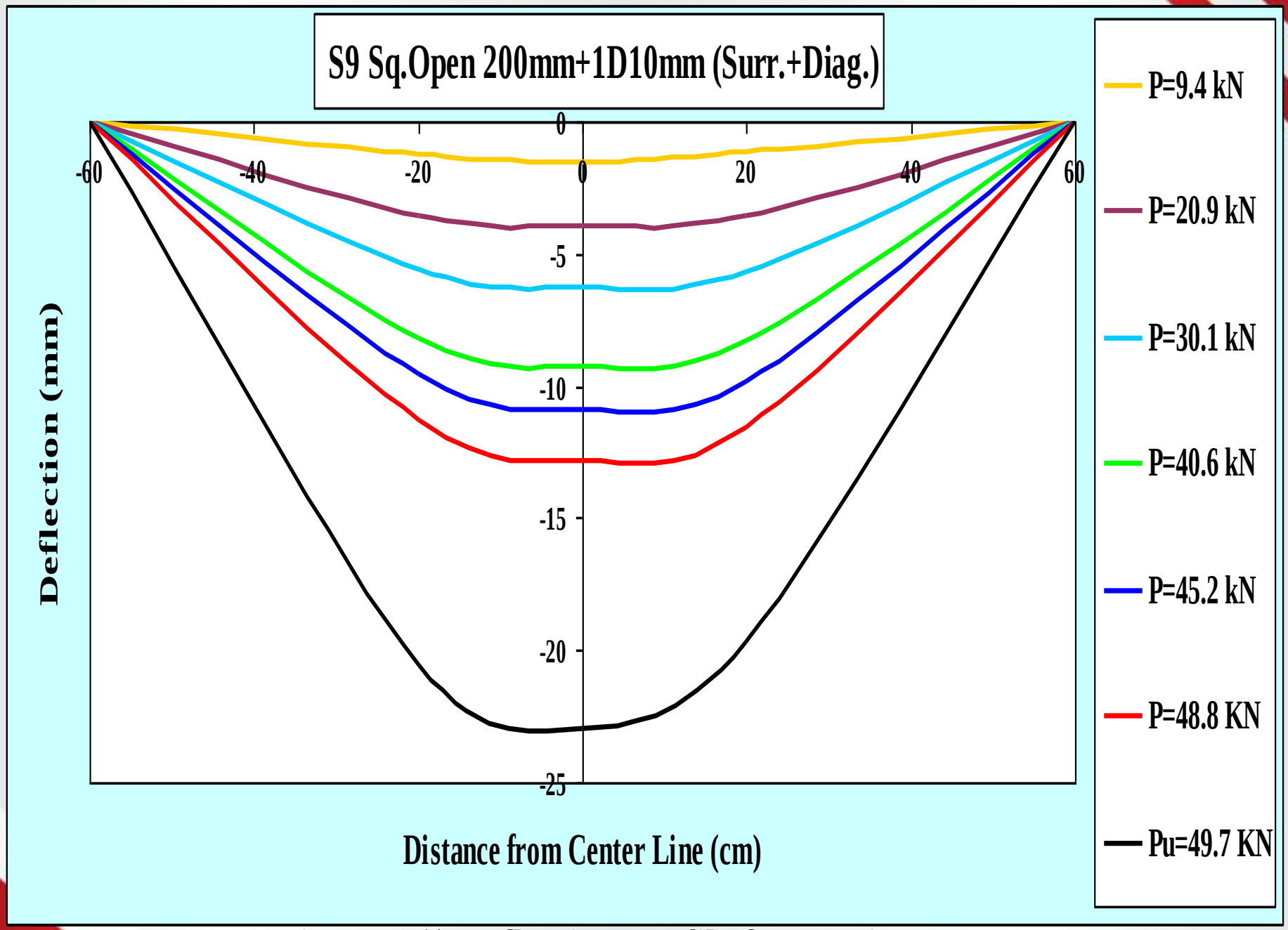


Figure (4ᵛ)Deflection profile for specimen S9.

Figure (4^) Crack pattern of specimen S9.

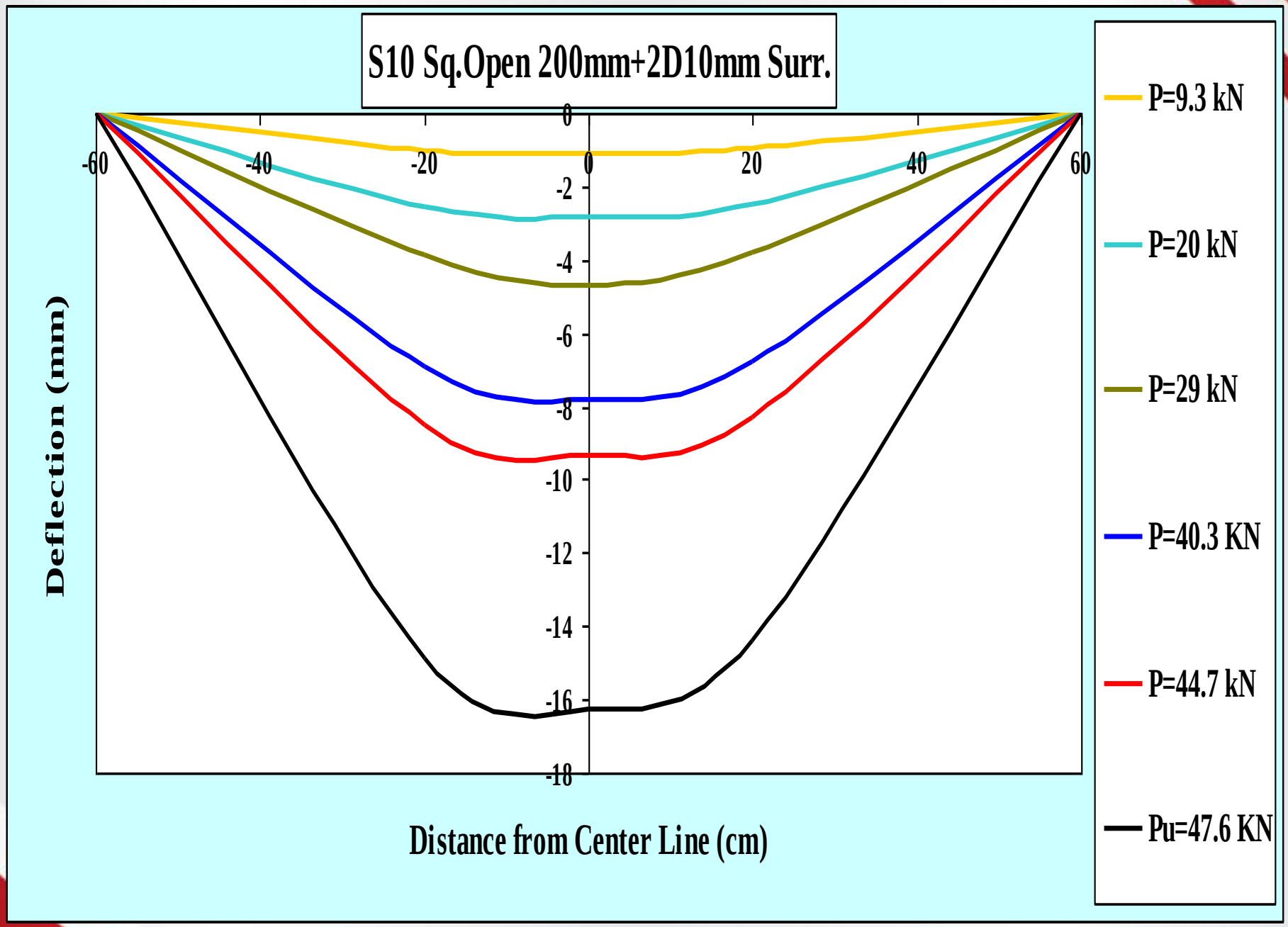


Figure (4٩)Deflection profile for specimen S10.

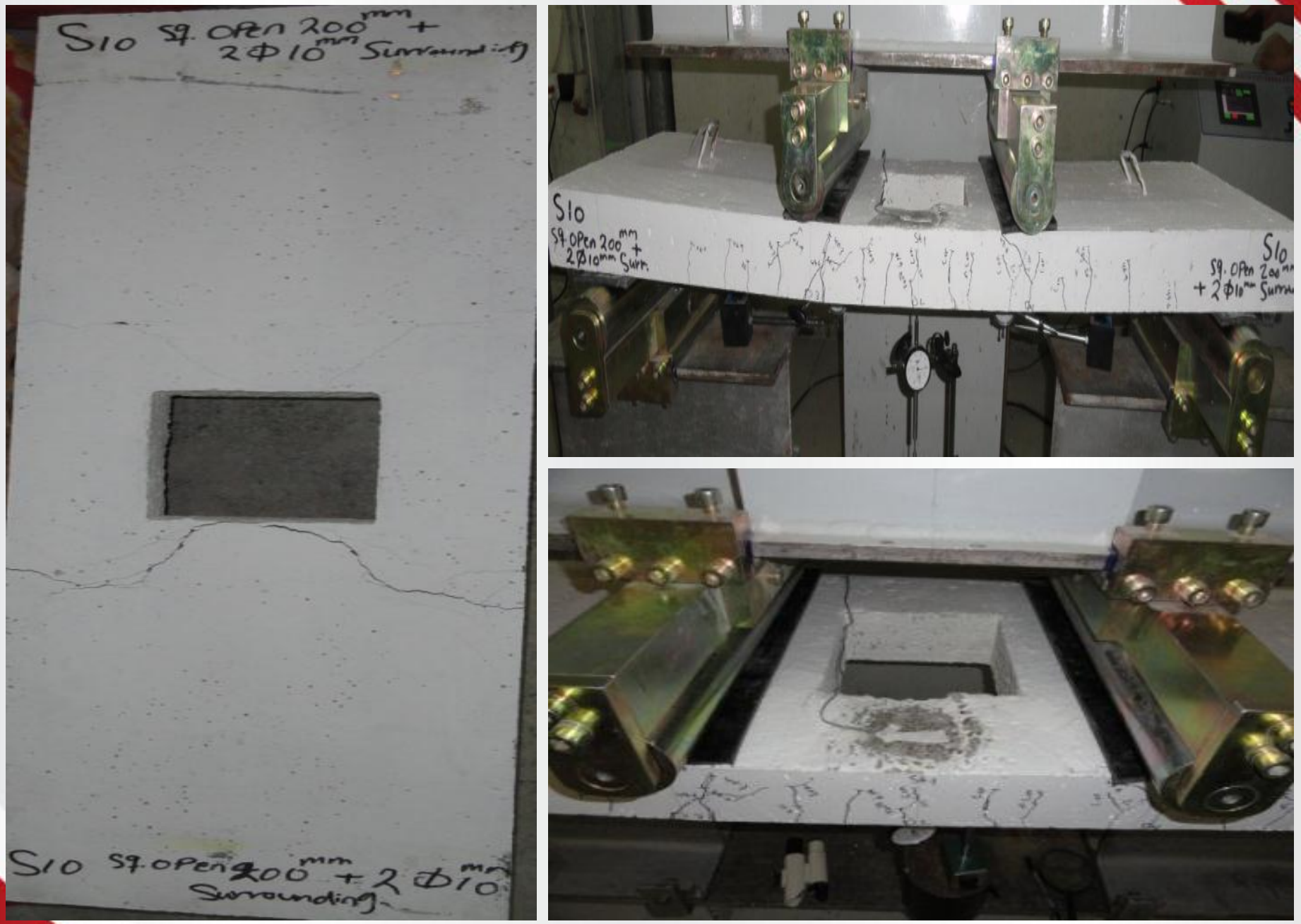


Figure (٥٠) Crack pattern for S10.

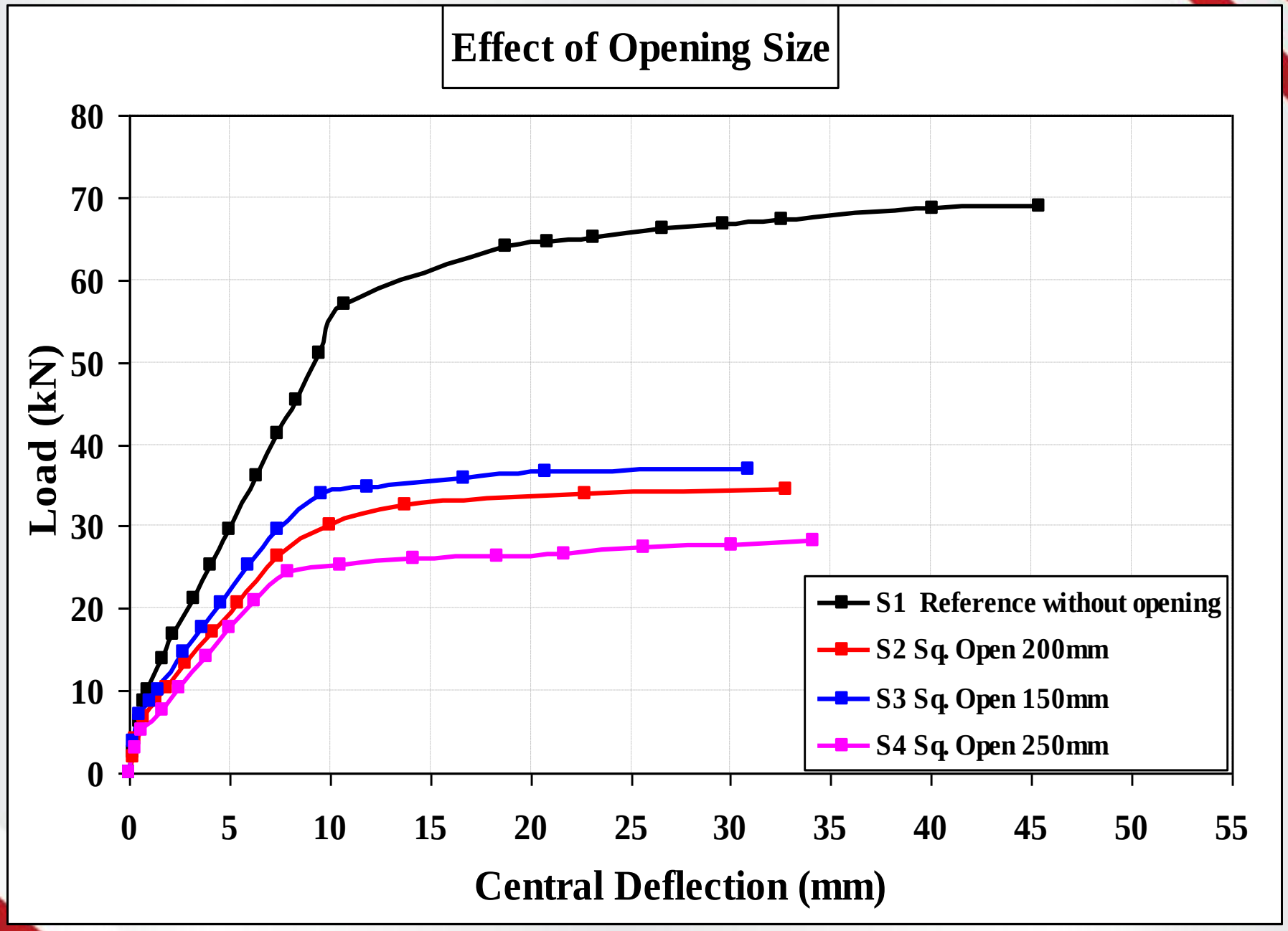


Figure (5١) Effect of opening size on load-deflection curve.

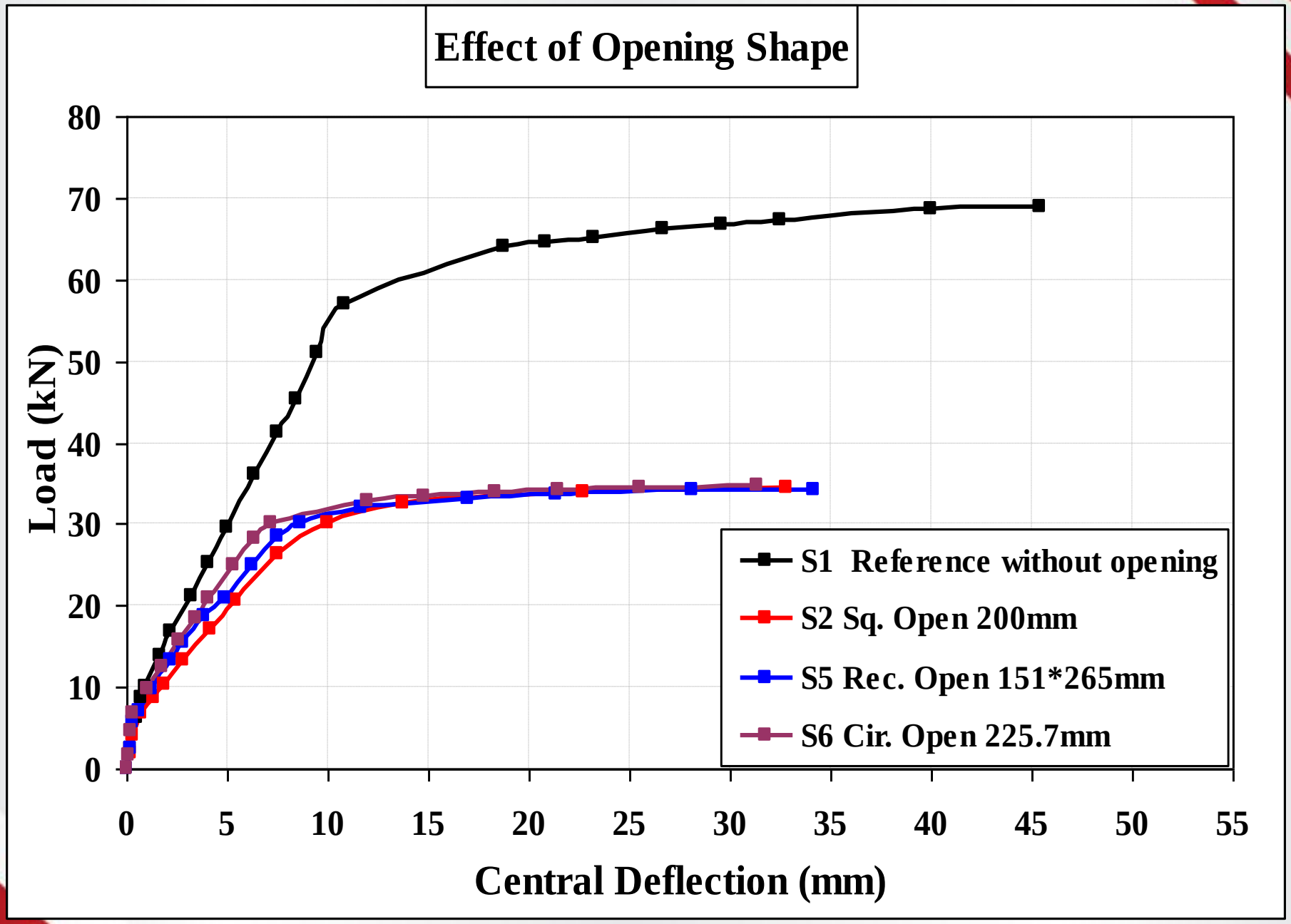


Figure (5٢) Effect of opening shape on load-deflection curve.

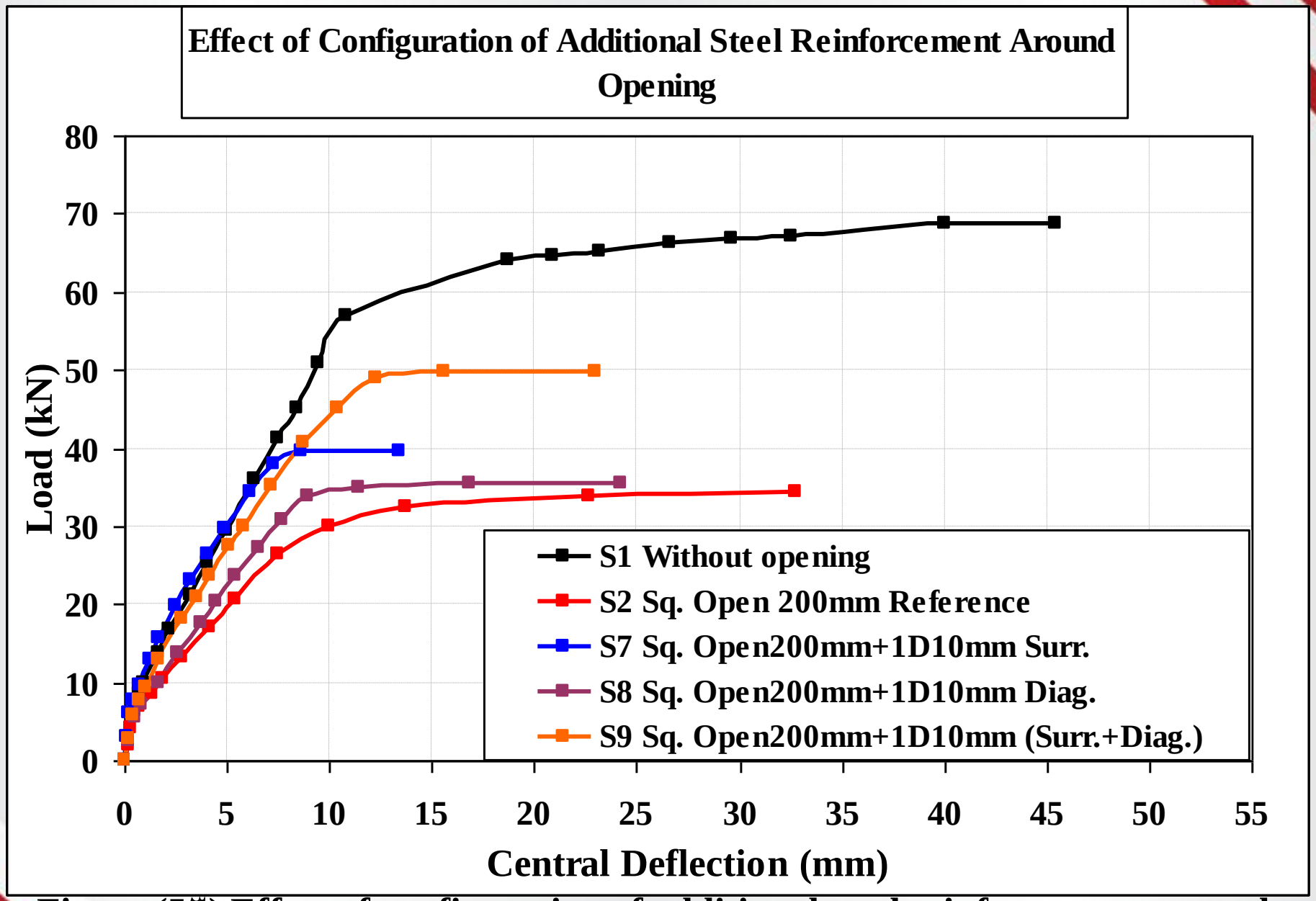


Figure (5٣) Effect of configuration of additional steel reinforcement around opening on load-deflection curve.

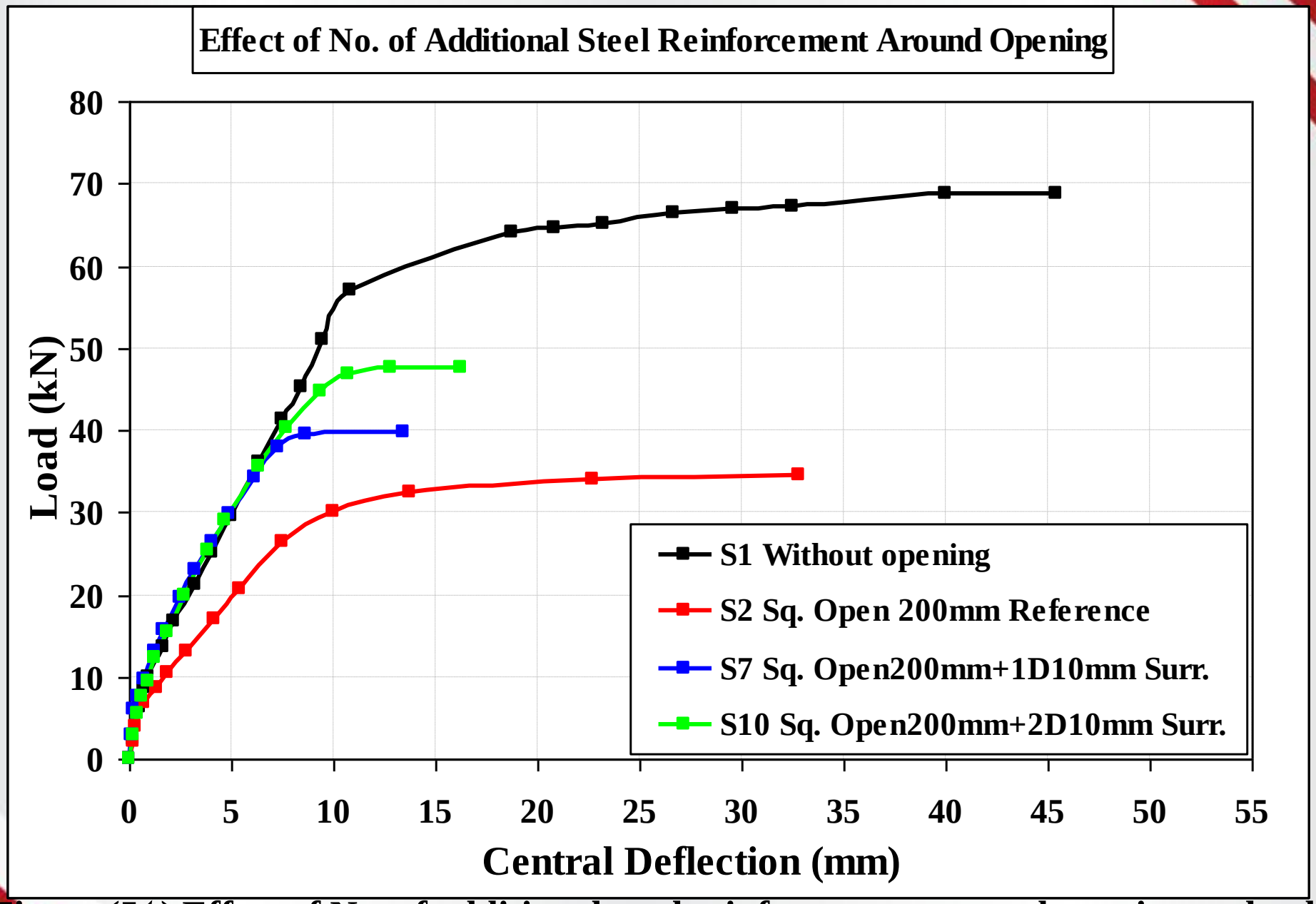


Figure (5٤) Effect of No. of additional steel reinforcement around opening on load-deflection curve.

Table (٤) Ultimate load capacity of specimens .

Specimen	Ultimate load, P_u (KN)	% Pu/Pu Reference	% decreasing in P_u
S1	68.8	Reference	Reference
S2	34.4	50.00	50.00
S3	36.9	53.63	46.37
S4	28.2	40.99	59.01
S5	34.3	49.85	50.15
S6	34.7	50.44	49.56
S7	39.7	57.70	42.30
S8	35.5	51.60	48.40
S9	49.7	72.24	27.76
S10	47.6	69.19	30.81

Table (٥) Enhancement in ultimate load capacity and service deflection due to additional steel reinforcement around the opening.

Specimen	Ultimate load P_u (KN)	Ultimate deflection Δ_u (mm)	Δ@70 % of P_u^* (mm)	% increase in P_u	% decrease in Δ@70% of P_u
S2	34.4	32.80	6.62	Reference	Reference
S7	39.7	13.40	3.50	15.41	47.13
S8	35.5	24.25	5.60	3.20	15.41
S9	49.7	23.00	4.26	44.48	35.65
S10	47.6	16.28	3.50	38.37	47.13

*Deflection at 70% of ultimate load of reference slab S2

Table (٦) Enhancement of concrete compressive strain due to additional steel reinforcement around the opening.

Specimen	Ultimate strain ε_u (mm/mm)	ε@70% of P_u* (mm/mm)	% Decrease in ε@70% of P_u
S2	0.004056	0.001078	Reference
S7	0.001700	0.000711	34.04
S8	0.005000	0.001217	-12.89
S9	0.002012	0.000848	21.33
S10	0.001612	0.000758	29.68

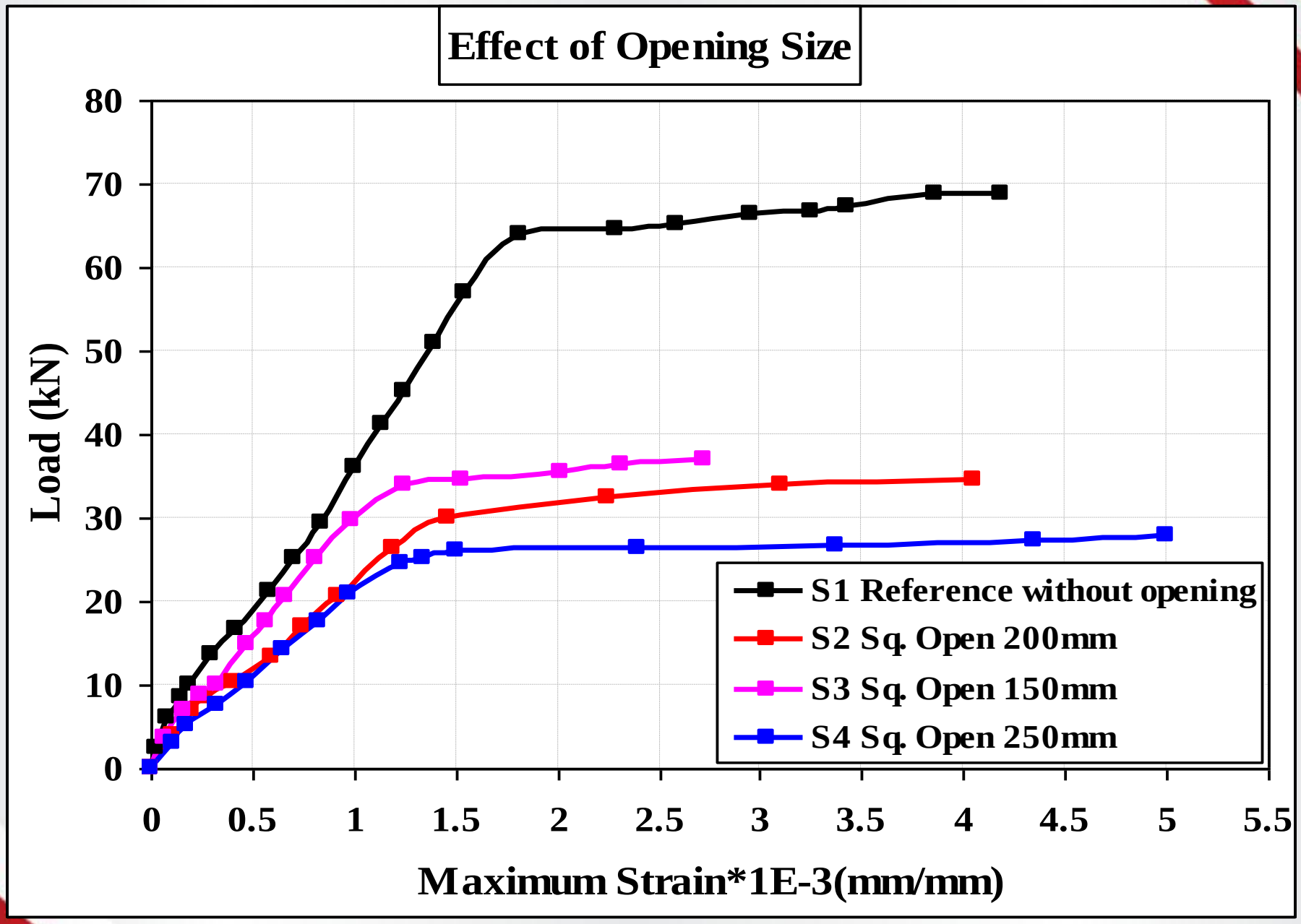


Figure (5°) Effect of opening size on load-concrete compressive strain curve

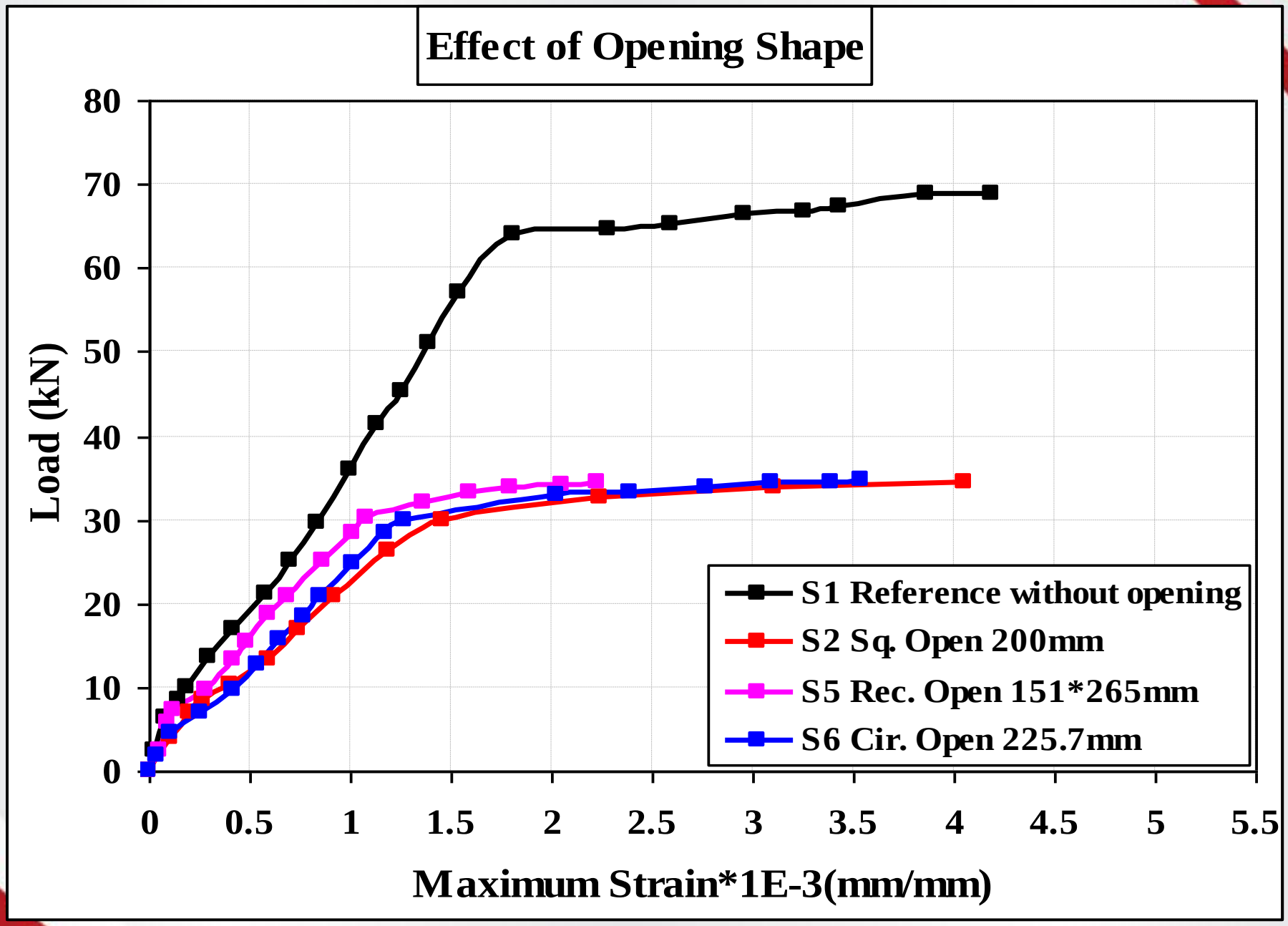


Figure (٥٦) Effect of opening shape on load-concrete. compressive strain curve

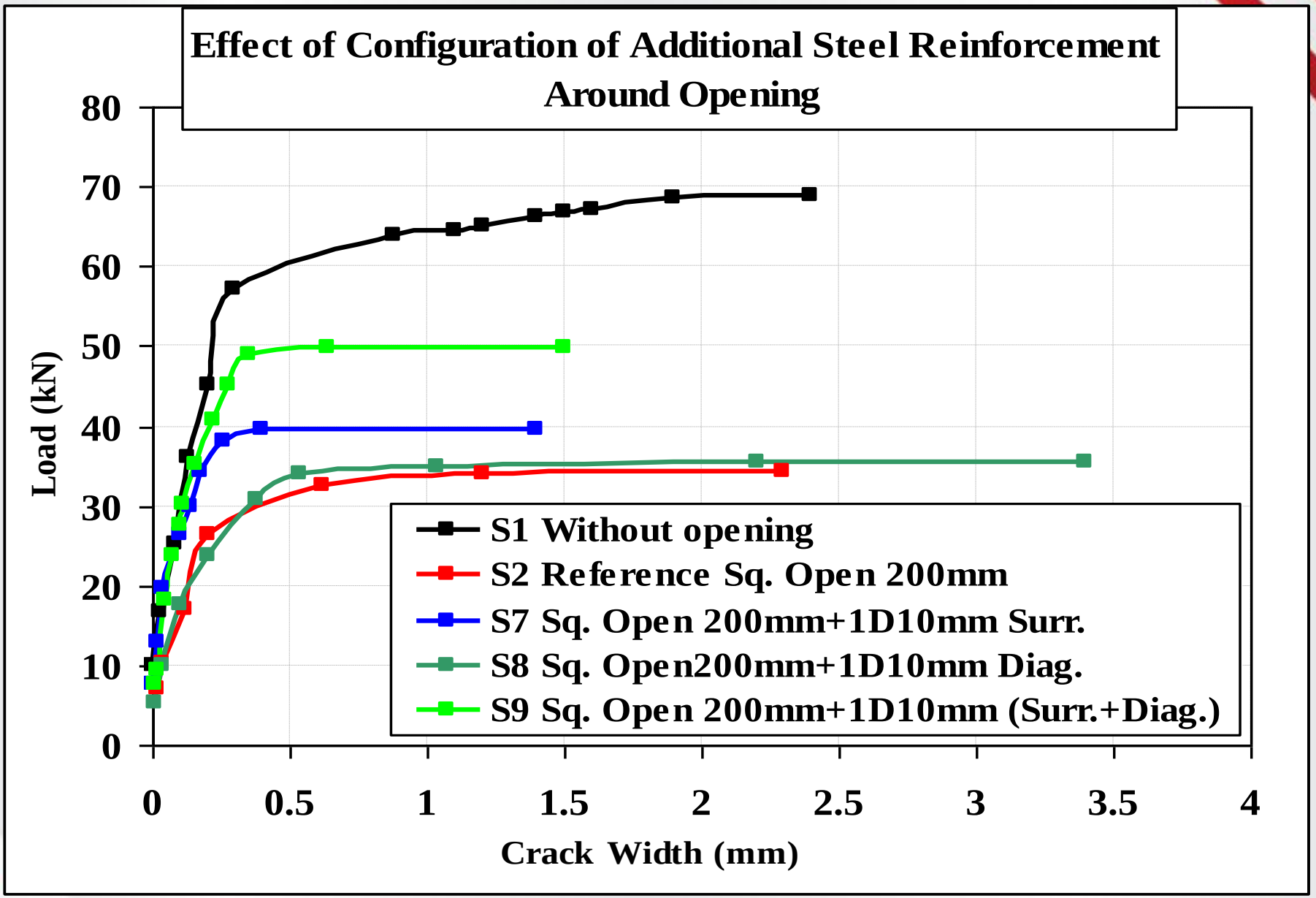


Figure (5٧) Effect of configuration of additional steel reinforcement around opening on load-concrete compressive strain curve.

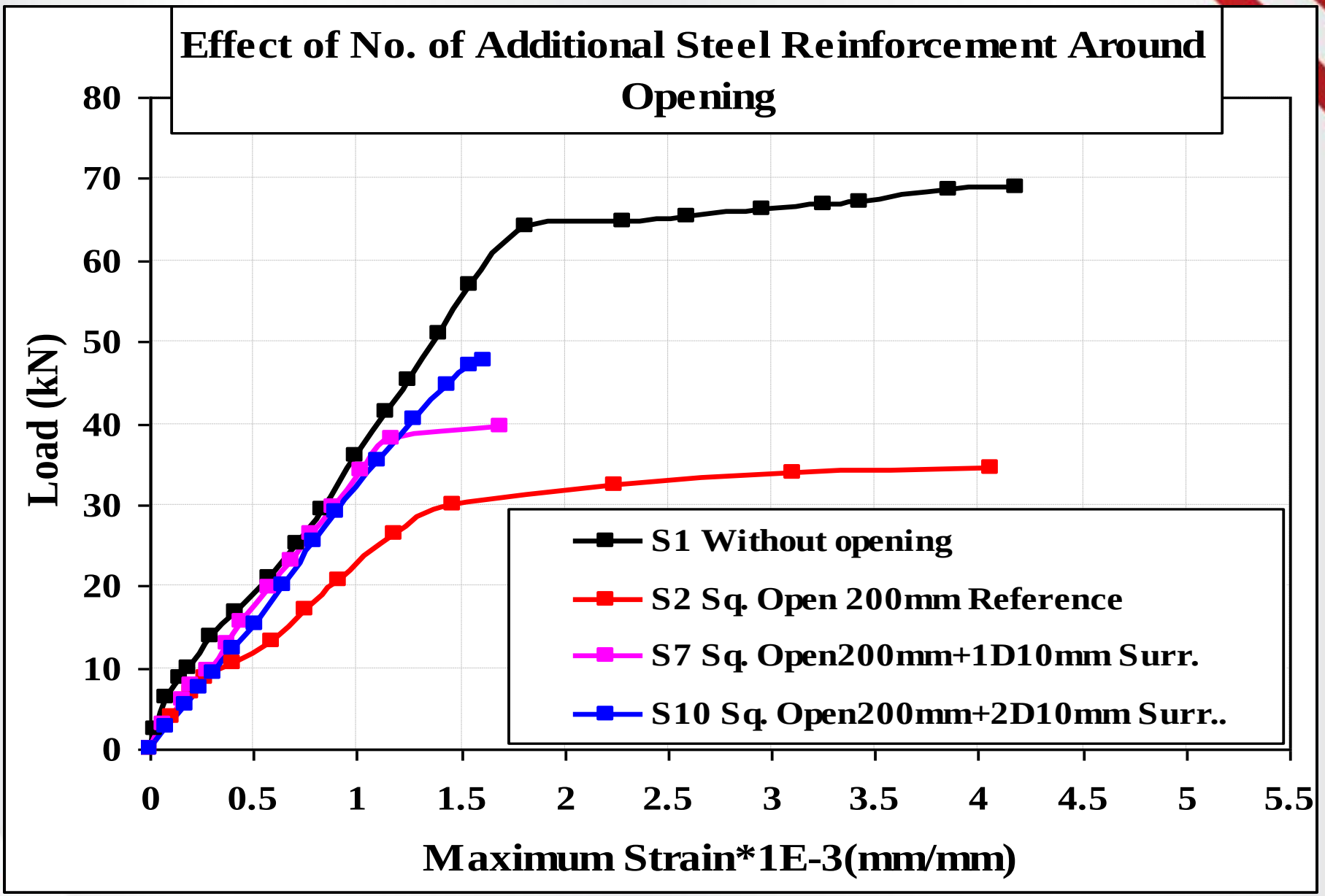


Figure (5^) Effect of No. of additional steel reinforcement around opening on load-concrete compressive strain curve.

Table (٧) Cracking load of specimens.

Specimen	Crack load P_{cr}(kN)	Ultimate load, P_u (kN)	% Pcr/Pu	% Decrease in cracking load
S1	9.9	68.8	14.39	Reference
S2	6.9	34.4	20.06	30.3
S3	7.3	36.9	19.78	26.3
S4	5.2	28.2	18.44	47.5
S5	7.1	34.3	20.70	28.3
S6	6.8	34.7	19.60	31.3
S7	7.7	39.7	19.40	22.2
S8	7.1	35.5	20.00	28.3
S9	7.7	49.7	15.49	22.2
S10	9.3	47.6	19.54	6.1

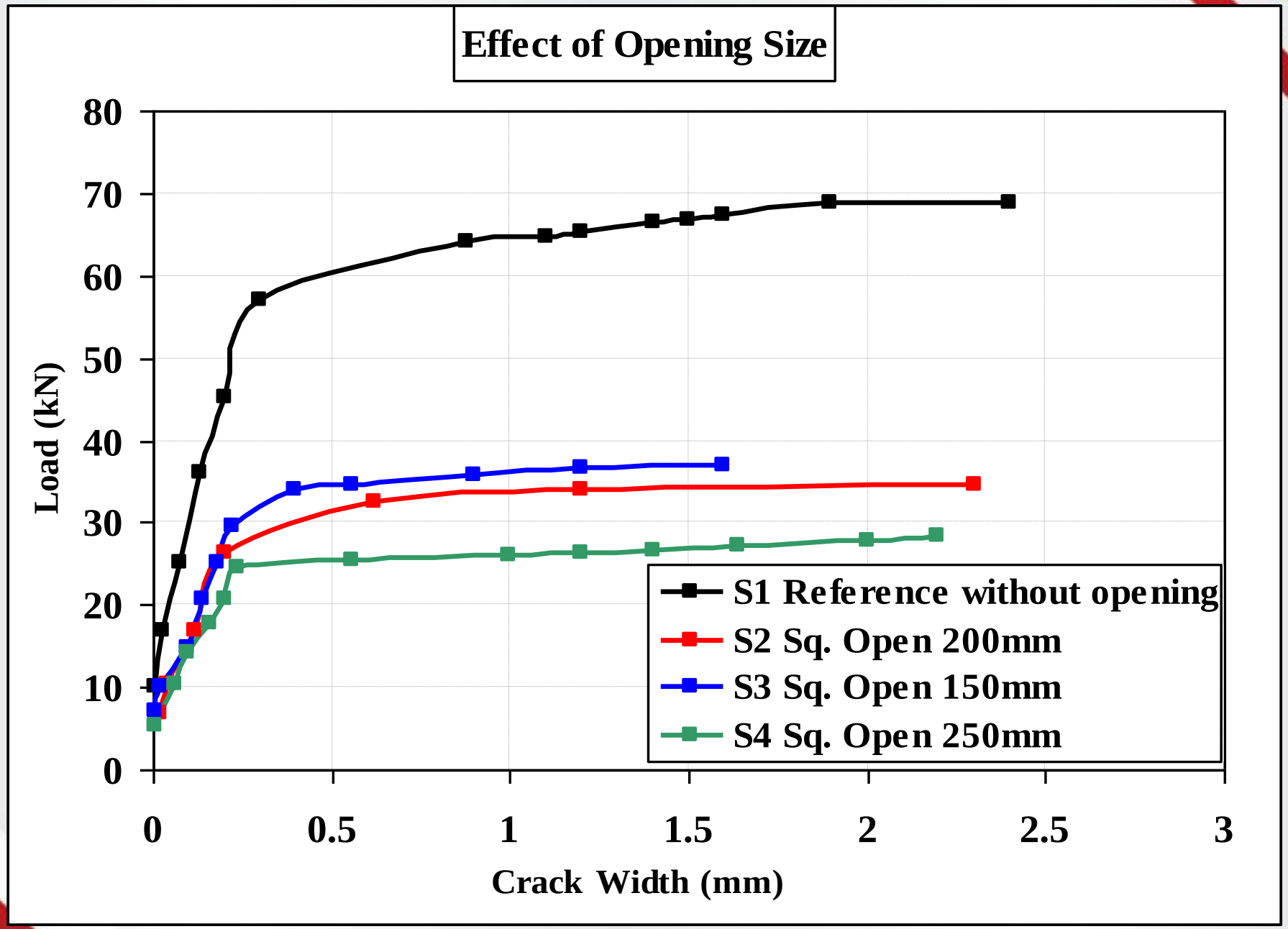


Figure (5٩) Effect of opening size on load-crack width curve.

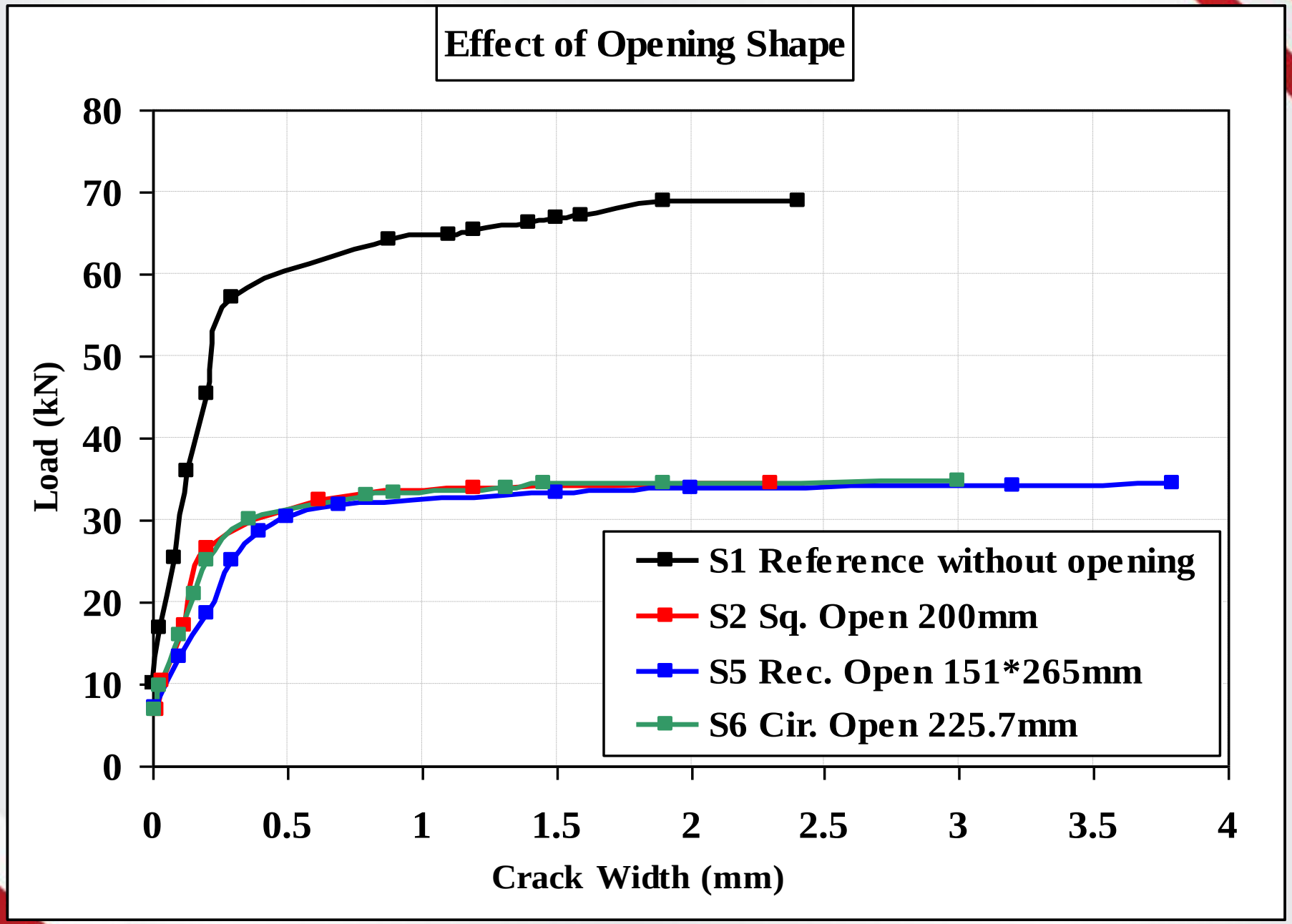


Figure (٦٠) Effect of opening shape on load-crack width curve

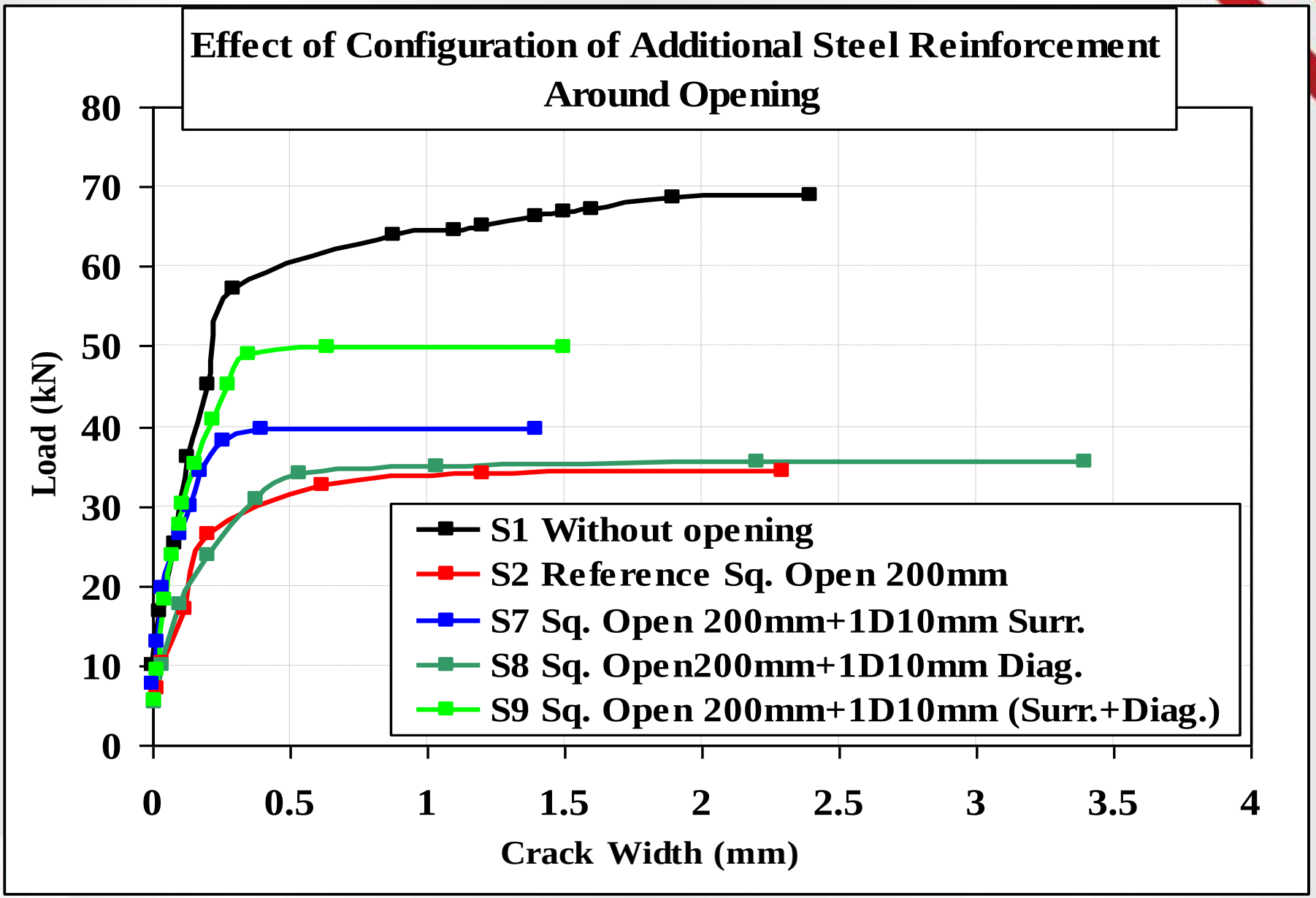


Figure (6١) Effect of configuration of additional steel reinforcement around opening on load-crack width curve.

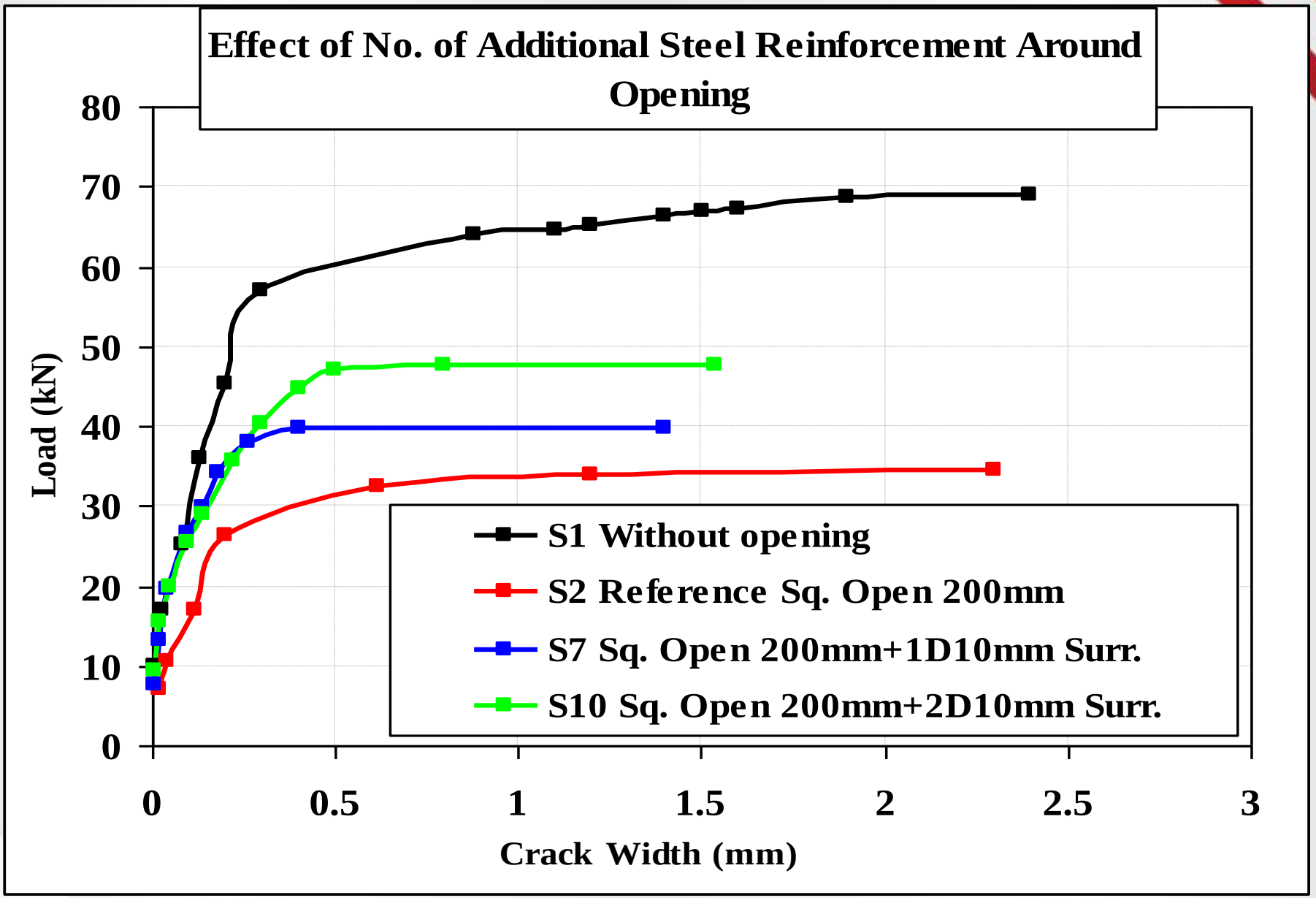


Figure (6٢) Effect of No. of additional steel reinforcement around opening on load-crack width curve.

Table (^) Enhancement of crack width due to additional steel reinforcement around the opening.

Specimen	Ultimate crack width w_u(mm)	(w @ 70% of P_u)* (mm)	% Decrease in (w@70% of P_u)
S2	2.30	0.18036	Reference
S7	1.40	0.07864	56.4
S8	3.40	0.21183	-17.4
S9	1.50	0.07292	59.6
S10	1.54	0.08778	51.3

*crack width at 70% of ultimate load of reference slab S2

Conclusions

Conclusions

- The ultimate load capacity of reinforced concrete slabs with opening ratio of (4.2%, 7.4% and 11.6%) are less than of reinforced concrete one way slabs without opening by about (40%, 50% and 60%) respectively.
- The service deflection, concrete compressive strain and crack width of reinforced concrete slabs with opening are greater than of reinforced concrete one way slabs without opening.

- The ultimate load capacity of reinforced concrete slabs with opening ratio of 7.4% and have different shape of (square, rectangle and circle) are less than of reinforced concrete one way slabs without opening by about (50%) respectively.

- The enhancement of RC one way slab with opening using additional steel reinforcement with form of (surrounding, surrounding + diagonal and double surrounding) gave, an increase in ultimate load capacity by about (15%, 45% and 40%), an decrease in service deflection by about (47%, 36% and 47%), an decrease in concrete compressive strain by about (35%, 20% and 30%), and an decrease in crack width by about (55%, 60% and 50%), respectively.

Thanks for Listening