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Study Of Shear Behavior Of Sandwich Wall Panel

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Abstract: This study was carried out to find the shear behavior of sandwich wall panels in both simply supported connection and in rigid connection. Sandwich panels has become a topic of interest among researchers in the recent years. Sandwich panels consists of Expanded Polystrene foam as core material with the thickness of 75 mm caged within the weld mesh. The dimension of the sandwich panels were 1000mm x 500mm x 130mm. The skin material used is standard concrete of grade M40 of thickness 25 mm. River sand of nominal size 2 mm is used as fine aggregate. Addition of GGBS improves the strength of concrete with the ratio of 30% GGBS and 60% concrete. Sandwich wall panels were casted individually and cured in ambient temperature. The sandwich wall panels were connected using high strength bolt of grade 8.8, thus a framed structure is formed. The compressive strength of concrete sandwich wall panel is 42.5Kn/m2. Glenium is used as superplasticzer to reduce the water percentage and also imparts high strength to concrete at early age. By using bolted connection the frame acts as simply supported, thus the end moments are restricted and it has the advantage to counter effect dynamic load. In rigid connection steel bar of 6mm diameter of 'W' shaped connection in used.These wall panels can be used as load bearing walls, partition walls, window panels and other shapes that provide attractive, functional and durable facade. These sandwich wall panels can be best alternative solution for the low cost energy efficient building.

Keywords: Expanded Polystyrene Foam, Shear Connector, Composite slab, Flexural behavior.

1.INTRODUCTION

This paper deals with the study of sandwich panels, which is used as structural walls and floors. This panel consist of Expanded Polystyrene Foam (EPS) sandwiched between two concrete layers. These layers are connected by shear connectors, which transfers the longitudinal shear between the layers so that fully composite or semi-composite behaviour is achieved. The degree of composite action depends on how effectively the shear is transferred between the layers. The shear transfer capacity depends purely on shear connectors. The prefabricated panel is made of EPS foam, reinforced by two metallic meshes connected by means of connectors. Metallic meshes reduces the formation of shrinkage cracks and thus it is similar to behaviour of Ferro cement.

The EPS foam is also called as STYROFOAM, which is actually a trademarked term for closed-cell extruded polystyrene foam made for thermal insulation and craft applications. EPS foam is the correct term for any form of expanded polystyrene. Expanded Polystyrene insulation is a lightweight, rigid, closed cell insulation. EPS is available in several compressive strengths to withstand load and back-fill forces. This closed-cell structure provides minimal water absorption and low vapour performance.

The behaviour of sandwich panel is much easier to predict than the panels constituting real building walls. Sandwich panel has the combined advantage of both precast technology and light weight structure. If the panels acts fully composite, then the panel behaves homogeneously and thus ultimate load carrying capacity increases. Sandwich panels can be also used as load bearing walls. These type of walls will carry load more effectively than conventional walls with reduced thickness, thus the dead load acting on a structure gets reduced, which results in reduced cross-section of columns and beams. It is observed that, the thermal and acoustic insulation in more in three Wythe panel - when compared to two Wythe sandwich panel. Most tests were performed on full scale panels to study the real behaviour of panels under axial, eccentric and flexural loading.

1.1 Scope

- Sandwich panels have high strength to weight ratio.
- Sandwich panels can be used as load and non-load bearing walls with reduced thickness.
- It has the advantage of both light weight and precast technology.
- Casting and erection of sandwich panel is much easier than conventional walls.

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- The degree of thermal and acoustic insulation is high in sandwich panels.

1.2 Objective

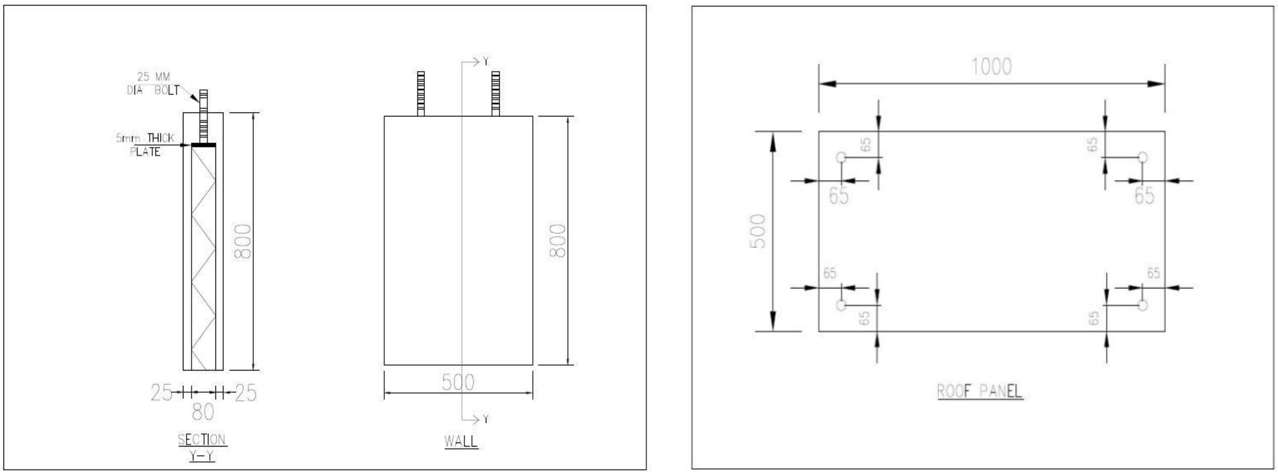
- The main objective of the project is to find the shear behaviour and Stiffness at the connection of sandwich panel frames.
- To compare the ultimate loads obtained from experimental tests and analytical result.
- To determine the wall drift of the frame.
- To compare the results of simply supported and fixed frame.

2. EXPERIMENTAL INVESTIGATION

Based on the various researchers, it is observed that sandwich panels are proved to be more advantageous in terms of both strength and light weight. Truss shape shear connectors are more efficient to transfer the shear throughout its thickness. Concrete wythes are responsible to take up the shear and hence M40 grade of concrete partly replaced by GGBS tends to be more effective. The strength of the frame depends on effective transfer of shear from slab to wall.

Table 1: Panel Dimension

SN.	Panel Size	Type of Connection
1	1000x500x130 mm slab panel 800x500x130 mm wall panel	Simply Supported Connection with 8.8 grade bolt
2	1000x500x130 mm slab panel 800x500x130 mm wall panel	Rigid Frame with ‘W’ rod of 6mm dia.



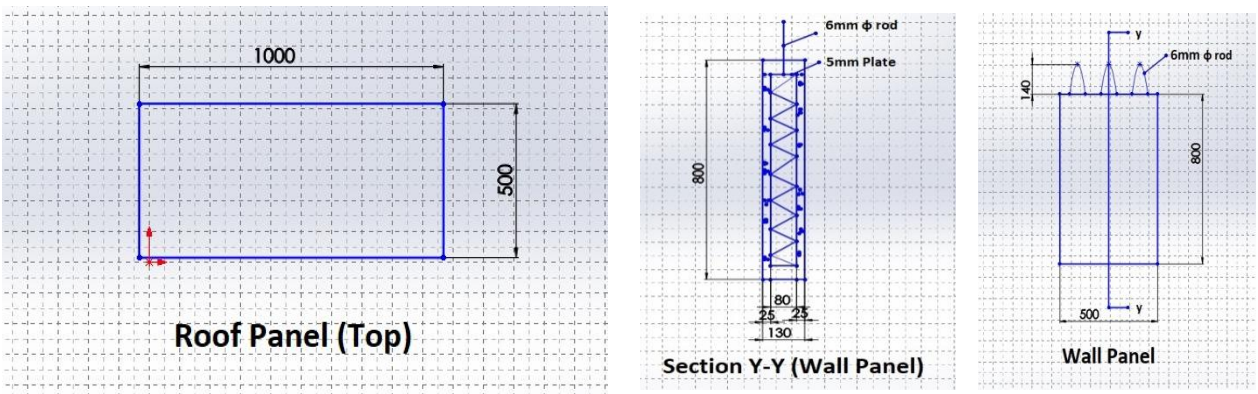


Figure 2- Rigid Frame with ‘W’ connection

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2.1 Materials used and Mix Proportion

A. Concrete

Ordinary Portland cement of 43 grade conforming to IS: 1269-1987 was used. Locally available manufactured sand free from silt, organic matter and passing through 4.75mm sieve conforming to zone II of IS: 383-1970 was used as Fine aggregate. The tests on fine aggregate were conducted to determine the specific gravity and fineness modulus. Locally available crushed granite aggregate passing through 20mm sieve and retaining on 4.75mm sieve was used as Coarse aggregate. The aggregate was conforming to IS:383-1970.The tests on coarse aggregate was conducted in accordance with IS:2386-1963 to determine specific gravity.

Table 2: Material characterization

Test	Results
Cement	
Specific gravity	3.15
Fine aggregate	
Specific gravity	2.54
Coarse aggregate	
Specific gravity	2.7

Based on the properties of the materials obtained and the specifications as per IS: 10262-2009 the mix proportion for M40 grade of concrete was obtained as **1 :1.87:2.34** with a W/C ratio of **0.45**. The obtained mix proportion is shown in Table-3.

Table 3: **Mix Proportion**

Cement (Kg/m^3)	Fine Aggregate (Kg/m^3)	Coarse Aggregate (Kg/m^3)	Water (Kg/m^3)
438	592	1257	197

B. Ground Granulated Blast Furnace Slag

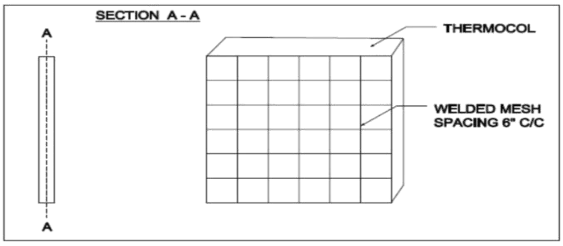
Blast furnaces produce pig iron, together with a slag by-product: a tightly controlled and stable material with the same constituent's qualities are preserved. Dried and ground to a fine powder, GGBS can be used to make quality, sustainable concrete. To ensure its activation, GGBS is most often used with normal cement. It will typically replace 30-70% of cement on an equal weight basis. The manufacture of normal cement results in the emission of 930kg of CO2 tone of cement approximately 50% from decarbonation of the limestone raw material (process emissions), 40% from fossil fuel consumption, and 10% from generating the electricity used in the process. GGBS manufacture typically releases 35kg of CO2 tone of GGBS: less than 4% of the carbon of normal cement.

C. EPS Foam

EPS is Expandable Polystyrene. A versatile plastic available in the form of sheets in varying thickness, moulded and cut pipe section for low temperature insulation of cold stores to preserve perishables, industrial plants operating at temperatures below ambient temperature, thermal insulation in building and versatile packaging material which can be moulded into any shape and design for packing electronics, glassware and other fragile products. Milky snow white EPS improves present ability of the product packed in it. EPS is also used for manufacturing ice boxes, picnic boxes and containers to keep the food hot. From the view point of construction, the roof no matter of what design is the most vulnerable part of the building for absorption of solar radiation particularly in tropical countries like INDIA. If the roof is to fulfil its protective function, EPS will play a significant role in providing thermal protection. Whether a flat roof or a pitched roof, a home or an office building, a factory, workshop or warehouse, EPS will always be an advantage because of its outstanding insulation property. Specific thermal movement for large areas and lengths where the temperature gradients are such that substantial thermal movement of various construction materials vary, EPS can be successfully used as an expansion jointing material. While designing specific joints the relative movement of construction materials used should be taken into account.

D. Shear Connector

Welded mesh is mesh is a metal wire screen that is made up of low carbon steel wire or stainless steel wire. It is available in various sizes and shapes. A grid consisting of a series of parallel and longitudinal wires with accurate spacing are welded to cross wires at the required spacing. Machines are used to produce the mesh with precise dimensional control. The product can result in considerable savings in time, labor and money.



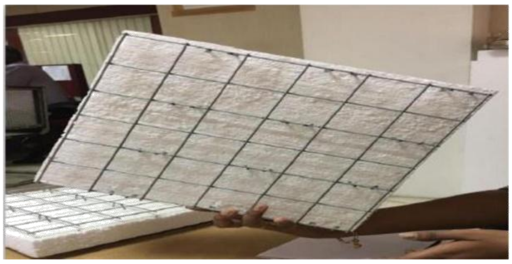


Figure 4 –EPS FOAM

2.2 Casting of Frame

The raw materials for casting are cement, fly ash, ground granulated blast furnace, chips, manufactured sand, glenium and water. All these materials have been collected and the aggregates are cleaned and preserved. The preliminary test of materials are specific gravity of fine aggregate, coarse aggregate, fly ash and manufactured sand. The proportioned mix design for the sandwich panel is M 40 grade of standard concrete. Cement is partly replaced by GGBS and fly ash. Dry mixing of aggregates and source materials by mixing all the materials manually in the laboratory at room temperature. The panels were casted individually and after a curing period of 28 days, a framed structure is formed with the help of high strength bolt of grade 8.8.The rigid frame is casted monolithically with the help of form work and for curing Gunny bags are used and cured for 28 days. The wall panel frame is tested in the laboratory using Universal Testing Machine and the strength was calculated after 28 days.

2.3 Testing Procedure

The highest or maximum bend stress occurs under the loading anvil in three point flexural bend tests. In four point bend tests, the maximum flexural stress is spread over the section of the beam between loading points. Also, a three point test best applies where the material is homogeneous, such as plastic materials. A four point test tends to be the best choice if the material is not homogeneous, such as composites or wood. The stress concentration of a three point test is small and concentrated under the centre of the loading point, whereas the stress concentration of a four point tests is over a larger region, avoiding premature failure. A three point test is easier to perform than a four point test. The deflection measurement in three point tests is commonly measured using the machine's crosshead position sensor (typically a digital encoder), whereas the four point bend test is commonly measured using a deflectometer..

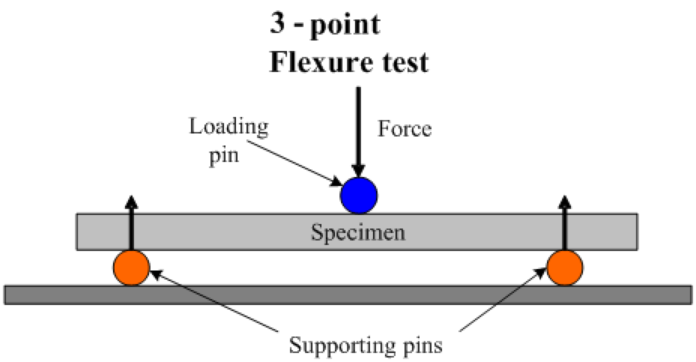


Figure 5- Loading arrangements

Load was applied gradually using Hydraulic jack in increment till failure of the specimens. The behaviour of the frame was observed throughout the loading range till the specimen failed. The deflection of slab and wall were obtained by using dial gauge. Load Deflection curves for each beam was obtained manually for each loading. Also the appearance of separation, propagation of cracks and slip were observed and recorded.

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Figure 6 – Experimental Loading Setup

3. EXPERIMENTAL RESULT

3.1 FOR SIMPLY SUPPORTED FRAME

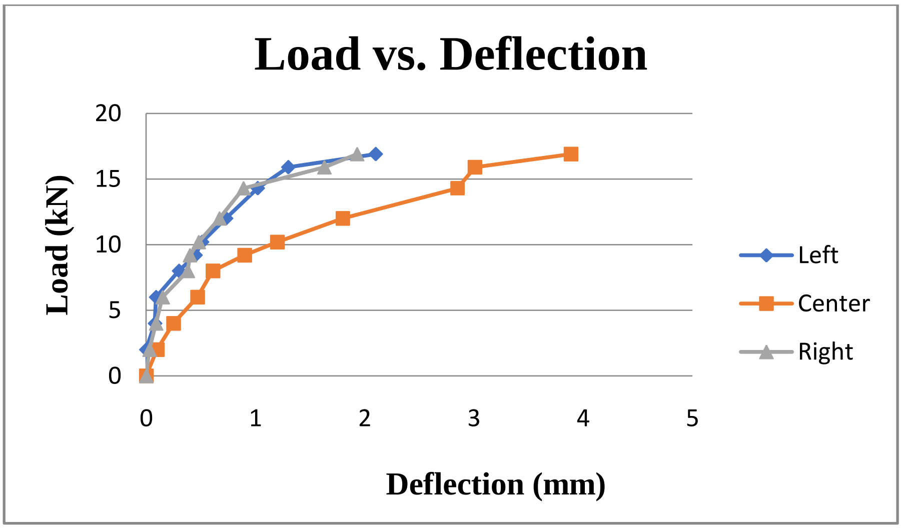
Simply Supported connection is best suited for single span structures. Analysis and design of simply supported connection is easy and this type of connection does not transfer any moment to supports, hence these connections can be suited for structures in loose grain soil. The bending moment at the bottom of slab is more thus it requires greater depth to resist the moment.

The ultimate load carrying capacity of frame is 16.9 KN with maximum deflection of 3.89 mm. The permissible limit for deflection of slab is 4mm, hence the deflection of slab is within permissible limit.

3.1.1 Load-Deflection table

LOAD (KN)	DEFLECTION (mm)		
	LEFT WALL	SLAB	RIGHT WALL
0	0	0	0
2	0	0.1	0.03
4	0.08	0.25	0.09
6	0.09	0.47	0.15
8	0.3	0.61	0.38
9.2	0.45	0.9	0.4
10.2	0.51	1.2	0.48
12	0.73	1.8	0.67
14.3	1.02	2.85	0.89
15.9	1.3	3.01	1.63
16.9	**2.1**	**3.89**	**1.93**

Table 4- Load- Deflection table



GRAPH 1- Load-Deflection graph

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3.2 For Rigid Frame

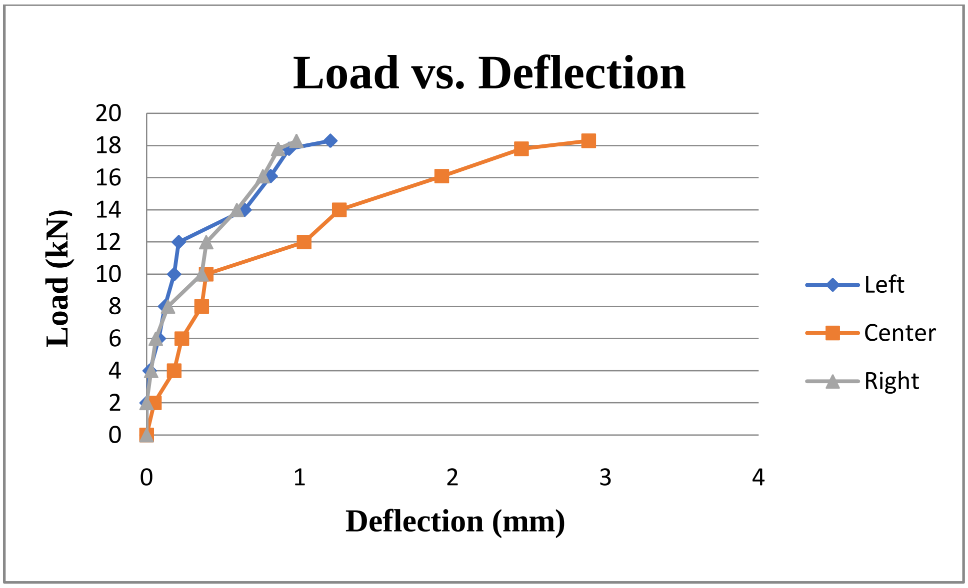
A fully fixed beam will have lesser moments and deflection at midspan than simply supported beam. It allows neither vertical movement nor rotation at the supports. This is the basic difference between a fixed beam and simply supported beam. So in a fixed beam the supports generate vertical reactions as well as rotational moments.

The ultimate load carrying capacity is 18.3 KN and the maximun deflection is 2.89mm which is well within the permissible limit.

3.2.1 Load-Deflection Table For Rigid Frame

LOAD (KN)	DEFLECTION (mm)		
	LEFT WALL	SLAB	RIGHT WALL
0	0	0	0
2	0	0.05	0
4	0.02	0.18	0.03
6	0.08	0.23	0.06
8	0.12	0.36	0.14
10	0.18	0.39	0.36
12	0.21	1.03	0.39
14	0.64	1.26	0.59
16.1	0.81	1.93	0.76
17.8	0.93	2.45	0.86
18.3	**1.2**	**2.89**	**0.98**

Table 5- Load-Deflection Table for rigid frame



Graph 2- Load Vs Deflection Graph

4. RESULTS AND DISCUSSION

4.1 Result Comaprison

Both type of connection shows similar behaviour in bending and the failure pattern observed is **FLEXURAL BRITTLE** type in both frames.

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S.NO	SIMPLY SUPPORTED FRAME	RIGID FRAME
ULTIMATE LOAD CARRYING CAPACITY (Pu)	16.7 KN	18.3 KN
FLEXURE CRACK LOAD	12 KN	14.7 KN
SHEAR CRACK LOAD	14.28 KN	12.78 KN
MAX. DEFLECTION	3.89 mm	2.89 mm
STIFFNESS (K)	4.3 KN/mm	6.3 KN/mm
SHEAR MODULUS (G)	0.56 N/mm2	0.89 N/mm2
MAX AND MIN CRACK SPACING	a max : 81.6 mm a min : 54 mm	a max : 94.7 mm a min : 64.8 mm

5. FAILURE PATTERN

5.1 Failure of Simply Supported Frame

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Figure 7- Flexural failure of slab

Figure 7 b- Flexural failure at the bottom wythe of slab

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5.2 Failure of Rigid Frame

Figure 8- Flexural failure at bottom of slab and shear failure at support.

6. CONCLUSION

6.1 General

- Load carrying capacity is inversely proportional to slenderness ratio.
- Crack width and spacing depends on mesh size and its yield strength.
- Since the panels are light in weight, high strength concrete should be used.
- The failure of the panel is flexural failure, occurring at the bottom wythe of the panel.
- Cracking behavior of precast lightweight concrete sandwich structural panels that fail in flexural mode with the formation of numerous flexural cracks in bottom wythe is similar to ferro-cement. Under flexural loading, volume ratio of reinforcement and specific surface of reinforcement affect cracking behavior in terms of number of cracks and crack spacing of concrete sandwich panels
- Cracking behavior (in terms of number of cracks and crack spacing) of concrete sandwich panels predicted using models for cracking behavior of concrete slabs reinforced with wire mesh is in good agreement with experimental results.
- Stiffness is influenced by shear transfer capacity.
- Metallic meshes increases the stress redistribution of the panels
- Truss connectors transfer the shear force more effectively thus it also increases the degree of composite action.

6.2 Conclusion from experimental analysis

From the experimental comparison test, the following conclusion has been derived

- The ultimate load carrying capacity (Pu) of rigid frame is 8.74% much greater than simply supported frame.
- In rigid frame due to transfer of moment, the maximum positive bending moment is reduced and thus it can be used for long span construction but due to this hogging moment at the joint, these type of construction is not suitable for low bearing capacity soil.
- The modulus of rigidity for rigid frame is 31.74% higher than simply supported frame. However for construction of structures in loose grain soil simply supported frame is suitable for single span structures.
- The failure of frame is flexural brittle type since single crack gets widens when loading is applied and no crazing occurs. Flexural crack occurs at lower wythe of the slab.
- Providing shear connector in longitudinal direction will be of more effective than provision in lateral direction.

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APPENDIX I

CRACK SAPCING CALCULATION

S_t – Spacing of transverse wires (assuming uniform spacing)
L'_t – Length at which force is transferred from wire to concrete
$= K_p \frac{A_{ce} f_t}{\Sigma o}$
K_p – Bond coefficient
A_{ce} – Effective concrete area
$= \alpha \frac{\pi}{4}(h^2 - \varphi^2)$
$\alpha = \left[\frac{2b}{(b+h)}\right]^{1/2}$
b – Breadth of the section
h – Depth of the section
f_t – Tensile strength of concrete
φ – Bar diameter
Σo – Total perimeter of reinforcement
a_{min} – Minimum crack spacing
a_{max} – maximum crack spacing

Sl. No.	Condition	a_{min}	a_{max}
1	$S_t < L'_t$	S_t	$2S_t$
2	$L'_t < S_t < 2L'_t$	$S_t - L'_t$	S_t
3	$2L'_t < S_t < 3L'_t$	$S_t - 2L'_t$	$2L'_t$
4	$3L'_t < S_t < 4L'_t$	$S_t - 3L'_t$	$2L'_t$
5	$nL'_t < S_t < (n+1)L'_t$	$S_t - nL'_t$	$2L'_t$

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