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Experimental Investigation Of Flexural Behaviour Of Ferrocement Trough Type Folded Plate

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Abstract: ***Ferro cement is one of the construction emerging material as substitute for the conventional RCC in many aspects. Ferro cement is the future of the low cost houses and precast houses. Folded plates are solution for the longer span roofs in economical and ascetical manner. This project combines the advantages of both Ferro cement and folded plate and compared the results with RCC folded plate. The trough type Ferro cement folded plates of size 0.6 m x 1.82 m x 0.15 m is casted by considering different journals & RCC folded plates in consideration while fixing dimensions. In first phase of experiment different properties of materials used for casting are tested and compressive strength of the mortar used is tested, the test is carried out at 1:3 of cement: sand ration & 0.35 water cement ration. In second phase the specimen is casted with chicken mesh of 12 mm spacing is used and 2 layers on front and back sides of 6mm dia 150m spaced skeleton steel is laid.The casted specimens is tested for 28 days strength in loading frame and the results are compared with theoretical analysis RCC folded plates for load vs deflection and suitability of Ferro cement application in folded plates are studies. The test results are shown good results, finally with low expenditure & low self weight Ferro cement structures are good alternate for RCC.***

Keywords: Ferro cement, Trough type folded plate, Compressive & Flexural Strength.

I. INTRODUCTION

Ferro cement (also called thin-shell concrete or Ferro-concrete) is a system of reinforced mortar or plaster (lime or cement, sand and water) applied over layer of metal mesh, woven expanded-metal or metal-fibers and closely spaced thin steel rods such as rebar, metal commonly used is iron or some type of steel. It is used to construct relatively thin, hard, strong surfaces and structures in many shapes such as hulls for boats, shell roofs, and water tanks. Ferro cement originated in the 1840s in France and is the origin of reinforced concrete. It has a wide range of other uses including sculpture and prefabricated building components. The term "Ferro cement" has been applied by extension to other composite materials, including some containing no cement and no ferrous material. Today cement usually means Portland cement, Mortar is a paste of a binder (usually Portland cement), sand and water; and concrete is a fluid mixture of Portland cement, sand, water and crushed stone aggregate which is poured into formwork (shuttering). Ferro-concrete is the original name of reinforced concrete (armored concrete) known at least since the 1890s and in 1903 it was well described in London's Society of Engineer's Journal but is now widely confused with Ferro cement.

A. OBJECTIVES

- ✓ To study the application of Ferro cement in trough type folded plate.
- ✓ To study the Flexural behaviour of folded plate.

- ✓ To study the behaviour of Ferro cement folded plate compared to RCC folded plate.
- ✓ To study the load-deflection behaviour of Ferro cement folded plate.

II. LITERATURE REVIEW

Onet.T, Magureanu.C et al., In this paper Ferro cement crack width at working load remains very small compared to that of reinforced concrete, thereby leading towards to good impermeability, stiffness and durability.

Arif.M, Akhtar.S, et al., In this paper Square welded wire meshes perform better in bending than the other meshes. This is due to the transverse wires in welded meshes provide a better anchorage for bond zone, thereby strengthening the matrix through biaxial confinement. Hexagonal mesh has the poorest performance among the wire meshes.

Naaman, In this study the specific surface of reinforcement does not have as strong an influence on the cracking behavior in bending as in tension. The average crack width in Ferro cement bending elements is primarily a function of the tensile strain in the extreme layer of mesh and transverse wire

Montesinos.G.P and NaamanA.E In this study The compressive strength of mortar does not seem to have much influence on the bending resistance of Ferro cement beams. Everything else being equal, an 80% increase in mortar compressive strength with an average increase of only 11% in bending strength.

Train Onet , C. Magureanu In this paper Ferro cement elements of plate and beam types tested have a good behavior under working load due to the fact that the width of cracks appears to be very small than in the reinforced concrete. Consequently, the impermeability, stiffness and durability of the Ferro cement elements is much improved. The good behavior at failure regarding the aspect of ductility and ultimate moment of the elements.

T.Chandra sekhar Rao, T.D.Gunneswara Rao et al In this paper presents an experimental study on the strength and behavioral aspects of voided Ferro cement channel type units for pre cast beams. As these beams are lighter in weight, they find their place in seismic resistant design of structures. Eight channel type Ferro cement units were tested for four points loading. The variable parameter includes the number of layers of wire mesh.The flexural strength of the voided channels was compared with that of solid channels too. The test results indicate that the drop in flexural strength with the voids is very negligible compared to the decrease in the weight of the member. The Moment curvature response of the voided members under flexural loading improved with the post ductility of the member with increase in the number of layers.

III. MATERIALS

A. CEMENT

S. No	Property		Test Result
1.	Normal consistency		33%
2.	Setting times	Initial (Minutes) Final (Minutes)	55 295
3.	Specific Gravity		3.15
4.	Soundness (Le-Chatlier Exp)		1.00 mm
5.	Compressive strength of cement (28 days)		53 MPa
6.	Specific surface area		369 m^2/Kg

Table 3.1: Properties of Cement

B. STEEL

Ultimate strength of hexagonal mesh = 270 N/mm^2
Yield strength of 6mm MS bar, f_y = 250 N/mm^2

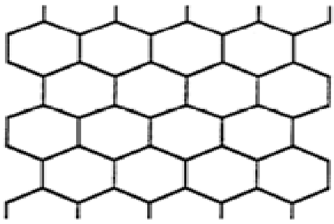

Figure 3.1: Hexagonal mesh

C. SAND

Locally available river sand in dry condition was used for the preparation of specimens. The grading of sand conforms to zone-II. As per IS:383-1970. The specific gravity sand was 2.54.

S. No.	Property	Test Result
1.	Specific Gravity	2.60
2.	Bulk density (Kg/m3)	1750
3.	Fineness Modulus	2.74
4.	Zone	II

Table 3.2: Properties of Fine Aggregate

D. WATER

Clean potable water was used for mixing concrete. Water used for mixing and curing shall be clean and free from injurious amounts of oils, acids, alkalis, salts, sugar, organic materials or other substances that may be deleterious to concrete and steel.

S.No	Impurity	Max. Limit	Results
1	P^H Value	6 to 8.5	7
2	Suspended matter (mg/lit)	2000	220
3	Organic matter (mg/lit)	200	20
4	Inorganic matter (mg/lit)	3000	150
5	Sulphates (SO4) (mg/lit)	500	30
6	Chlorides (Cl) (mg/lit)	2000 for P.C.C. 1000 for	60

		R.C.C.	

Table 3.3: Permissible Limits of Water as Per IS: 456-2000

IV. THEORETICAL ANALYSIS

A. METHODS OF ANALYSIS

Folded plates can be analyzed by the following methods:

- ✓ Beam method
- ✓ Elasticity method`
- ✓ Slab beam analysis

a. BEAM METHOD

In this method the folded plate is treated as a beam of irregular cross section in the longitudinal direction and as a continuous slab in the transverse direction. The results of rigorous analysis show that their results are not satisfactory.

b. ELASTICITY METHOD

In this method for the calculation of stresses in folded plates is difficult to carry out by ordinary calculations.

c. SLAB-BEAM METHOD

In this method popularly known as the "folded plate theory", is the most convenient and satisfactory method for engineering Design. This method is used for the theoretical comparision for the work.

B. ANALYSIS OF TROUGH TYPE FOLDED PLATE

a. FIXING OF DIMENSIONS OF FERRO CEMENT FOLDED PLATES

The inclination of the plates to the horizontal should not be more than 40 degrees for easiness in placing concrete. A slope below 30 degrees is considered too flat for action as a folded plate

Thickness of member is taken as ≥ 20mm (since material is Ferro cement).

Length and breadth are fixed using width to span ratio should be less than 1 / 3 & span to depth ratio is 3, shear behavior is predominant and thereafter flexural behavior is predominant.

b. CASTED DIMENSIONS OF FOLDED PLATE

Angle of inclined plate is taken as 36 °.

Thickness of member is taken as 25mm.

Length to breadth ratio is taken as 7.28

Horizontal plate at top taken as 10cm, and 5 cm at bottom sides.

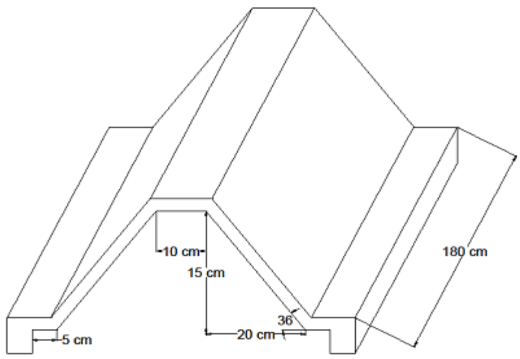

Figure 4.1: Dimensions of trough type folded plate

C. STEP BY STEP PROCEDURE FOR ANALYSIS OF TROUGH TYPE FOLDED PLATE

- ✓ Calculation of dimensions of folded plate.
- ✓ Calculation of geometrical properties.
- ✓ Calculation of loads (DL + LL).
- ✓ Calculation of support moments (using transverse analysis) & final moments by moment distribution method.
- ✓ Calculation of joint reactions.
- ✓ Calculation of stresses (using longitudinal beam analysis)
- ✓ Distribution of stresses (winter –pie distribution method)
- ✓ Calculation of deflections.

Considering the symmetry of folded plate, left half portion load deflection behavior equal to right half portion load deflection behavior.

a. CALCULATION OF DIMENSIONS OF FOLDED PLATE

Dimension of folded plate are analyzed in table 4.1

Plate no	Plate width in 'm' w_n	Horizontal projection In 'm' l_n	Inclination to horizontal A	Angle b/w plate &next plate 'Ø'	Thickness of plate, t_n 'm'
1	0.05	0.05	0	323°8'	0.025
2	0.25	0.2	36°52'	36°52'	0.025
3	0.1	0.1	0	36°52'	0.025

Table 4.1: Dimensions of folded plate

b. CALCULATION OF GEOMETRICAL PROPERTIES

Geometrical properties of folded plate are calculated in table 4.2

S.No	Description	R_0(kN)	R_1(kN)	R_2(kN)	R_3(kN)
1	UDL (left span)=w/2	0	1.2	6/2 =3	2.6/2 = 1.3
2	UDL right span	0	3	1.3	3
3	$M/d_n\cos Ø_n$**(left span)**	0	0	0.252	0
4	$M/d_n\cos Ø_n$**(right span)**	0	-0.252	0	-0.252
	Total	0	3.948	4.552	4.048

Table 4.2: Geometrical properties

Calculation of 'P' loads, resolve 'R' into P:

$$P_n = \left(\frac{-R_{n-1}}{\sin \alpha_{n-1}}\right)(\cos \phi_{n-1}) + \left(\frac{R_n}{\sin \alpha_n}\right)(\cos \phi_{n+1})$$

Plate 1:

$P_1 = 0 + R_1 \cos Ø_2 / \sin\alpha_n$

$= 3.948 \cos 36°52' / \sin 323°8'$

$= -5.26$ kN

Plate 2:

$P_2 = (- R_1 \cos Ø_1 / \sin \alpha_1) + (R_2 \cos Ø_3 / \sin \alpha_2)$

$= (- 3.948 \cos 0° / \sin 323°8') + (4.552 \cos 0° / \sin 36°52')$

$= 6.58 + 7.58$

$= 14.16$ kN/m.

Plate 3:

$P_3 = (- R_2 \cos Ø2 / \sin \alpha_2) + (R_3 \cos Ø_4 / \sin \alpha_3)$

$= (-4.552 \cos 36°52'/\sin 36°52') + 4.048 \cos 323°8'/\sin 36°52'$

$= - 6.07 + 5.39$

$= - 0.68$ kN/m.

c. CALCULATION OF STRESSES (USING LONGITUDINAL BEAM ANALYSIS)

Bending moment $M = WL^2/8 = W \times (1.828)^2 / 8$

$= 0.417W$ kN-m

Bending stress 'f' = M / Z

Plate no	M_{max}	Z (m^3)	'f '(kN/m^2)	Joint	Stress 'f' (kN/m^2)
1	0.417x-5.29	1.04×10^{-5}	$\pm 212.10 \times 10^3$	1	212.10×10^3 22.71×10^3
2	0.417x14.16	2.6×10^{-4}	$\pm 22.71 \times 10^3$	2	-22.71×10^3 -0.067×10^3
3	0.417x-0.68	4.16×10^{-5}	$\pm 0.067 \times 10^3$	3	-0.067x10 22.71×10^3

Table 4.6: calculation of stresses (longitudinal analysis)

d. DISTRIBUTION OF STRESSES (WINTER –PIE DISTRIBUTION METHOD)

Calculation of Distribution factors

D.F = 1/A = 1/width of plate

JOINT 1:

$K_1 = 1/0.05 = 20$

$K_2 = 1/0.25 = 4$

$\sum K = 24$

$D.F_1 = 20/23 = 0.833 : D.F_2 = 4/23 = 0.167$

JOINT 2:

$K_2 = 1/0.25 = 4$

$K_3 = 1/0.10 = 10$

$\sum K = 14$

$D.F_2 = 4/14 = 0.286 : D.F_3 = 0.714$

Joints	0	1		2		3 ξ	
Plate	1		2		3		
D.F		0.833	0.16	0.28	0.71		
Stress values	-212.10	212.1	22.7	-22.7	-0.06		
Balancing		-157.7	31.6	6.47	-16.1		
Carry over	78.88		-3.23	-15.8	-8.08		
Balancing		-2.69	0.54	2.21	-5.52		
Carry over	1.35		-1.10	-0.275	-2.74		
Balancing		-0.916	0.18	-0.70	1.76		
Carry over	0.458		0.35	-0.09	0.88		
Balancing		0.29	-0.06	0.28	-0.7		
	-131.41	51.0	51.0	-30.6	-30.6		

Table 4.7: Distribution of stresses (winter –pie distribution method)

e. CALCULATION OF DEFLECTIONS

$$y = \left(\frac{f_{(n-1)} - f_n}{9.6 \times d_n}\right)\left(\frac{L^2}{E}\right)$$

$= (f_{n-1} - f_n / 9.6\ w_n)(1.82^2 / 2 \times 10^8)$

$= (f_{n-1} - f_n / w_n)(1.72 \times 10^{-9})$

Plate no	(f_{n-1}) $\times 10^3$ kN/m^2	f_n $\times 10^3$ kN/m^2	(f_{n-1}) - f_n $\times 10^3$ kN/m^2	w_n 'm'	Y (mm)
1	-131..41	51	-182.41	0.05	-6.2
2	51.0	-30.6	80.6	0.25	0.55
3	-30.6	51	-81.6	0.1	-1.38

Table 4.8: Calculation of deflections

V. EXPERIMENTAL INVESTIGATION

A. TESTING OF COMPRESSIVE STRENGTH OF MORTAR CUBES

a. MIXING

The preparation of mortar cubes for Ferro cement mix involves the following process i.e. preparation of material as per ratio 1:3, hand mixing, casting, curing & testing of samples.

b. COMPACTION

The testing cube specimens are compacted as soon as possible after mixing and in such a manner to produce full compaction of the mortar. Each mould is compacted by two types.

- ✓ Hand compaction each layer
- ✓ Table vibration compaction each layer

c. CURING

All the test specimens are stored in a place free from vibration. After 1day the specimens are demoulded. Ambient curing test specimens are placed in ambient Temperature 30°C to 32°C

d. COMPRESSIVE STRENGTH TEST

Compressive strength test is conducted on 1000 kN capacity compression testing machine at 5.3 kN/s load according to IS: 516-1959. Cubes tested at an age of 28days.

Average strength of three cubes was taken as compressive strength of Mortar of casted ratio. The specimens used for this work are 70.6 x 70.6 x 70.6 mm mortar cubes.

Figure 5.1

S.no	No of Days	Load kN	Compressive strength(Mpa)
1	28	210	42
2	28	200	40
3	28	215	43

Table 5.1: Test results of mortar cubes

B. CASTING & TESTING OF FERRO CEMENT FOLDED PLATE SPECIMENS

a. DESCRIPTION OF MODELS

Two Specimens are tested with dimensions of 0.6m x 1.82m x 0.15 m with thickness of 25mm and 6mm mild steel rods as skeleton reinforcement at a spacing of 150mm c/c (as shown in figure) with chicken mesh (hexagonal) of 12mm spacing are placed on both sides of skeleton reinforcement with a cover of 9mm.

Figure 5.2: detailing of reinforcement in folded plate

b. MANUFACTURING OF TEST MODELS

Final proportions of the mix were 1:3 by weight, water cement ratio 0.35.The mortar is mixed by using a mechanical mixer. The mortar was placed in the frame within a few minutes from the time of final mixing and manual compaction was used to compact the concrete in the frame. While casting the specimen the mortal with trowel force should be applied for proper compaction of material since chicken mesh is placed. The surface was finally finished by using steel trowels. After 24 hours of placing the mortar the specimen is demoulded.

The specimen was covered to prevent evaporation of water by use of gunny bags after demoulding of form work. The specimens were cured by ambient curing before the date of testing by gunny bags. The specimens were painted with white lime water solution in order that the cracks were clearly observed during the test. The locations of deflection gauge on bottom of specimens were marked.

Figure 5.3: Casting of specimen

c. EXPERIMENTAL SETUP

Testing Frame

Fig5.3 shows the loading frame consisting of four main channels acting as stanchions and connected at top and bottom with four 10" deep channel sections forming a rectangular frame around the stanchions at a height of 80 cm above floor level. The top framing channels could be moved freely up or down the stanchions and fixed by means of 3/4" (20 mm) bolts in any position to suit the height of the specimen.

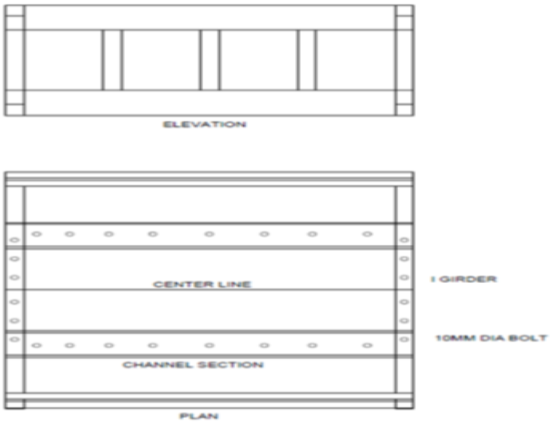

Figure 5.4: Line diagram of loading frame

Boundary Conditions

The support condition for the tested specimen was, simply supported edge. The simply support edge boundary conditions was attained by rested edge of specimen free on the top of flange testing frame to allow rotation to the specimen but not to roll away as shown in Fig. (5.5).

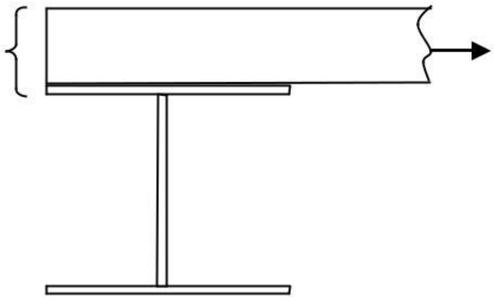

Figure 5.5: Shows testing arrangement for Simply Supported Specimen

d. LOADING SYSTEMS

APPLICATION OF UNIFORMLY DISTRIBUTED LOAD: Uniformly Distributed Load is applied to the specimens on ridge plate by means of manual Jack of capacity 100 tons. The load was measured by a proving ring of capacity 10 tons. A cylindrical steel plate of diameter 8 cm was used to transmit the load from the Jack to the specimen

Setup Test Models For Testing

The test model was taken to its position to the loading frame using electrical crane of capacity 100 ton. The specimens are rested on the top of the testing frame for simply supported edge condition.

Figure 5.6: Placing of specimen on loading frame

Figure 5.7: During testing

Mechanical dial gauges of 50 mm travel length and an accuracy of 0.01 mm were installed for measuring test model. Fig 5.8 shows the position of deflection dial gauge for the test models

Figure 5.8: Shows the View of location of Deflection

Procedure Of Testing

Zero reading of the dial gauges, a proving ring were noted down. The load was noted down. The load was then applied gradually by manual jack and Load readings were taken from the proving ring. After each loading, the readings of deflections were recorded. The procedure was continued until cracks were visible and the load at which the cracks started was noted.

More loading was then applied until the propagation of the cracks was complete. This stage was accompanied by excessive deflections as was clearly indicated by the continuous rotations of the dial gauges and then the failure load was recorded.

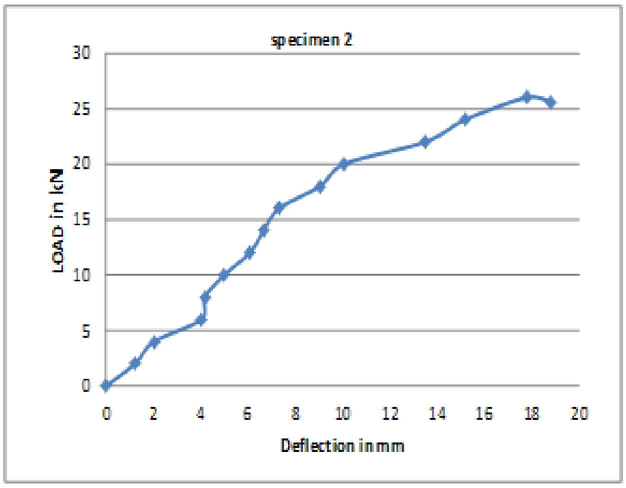

Figure 5.9: Load vs deflection for specimen -1

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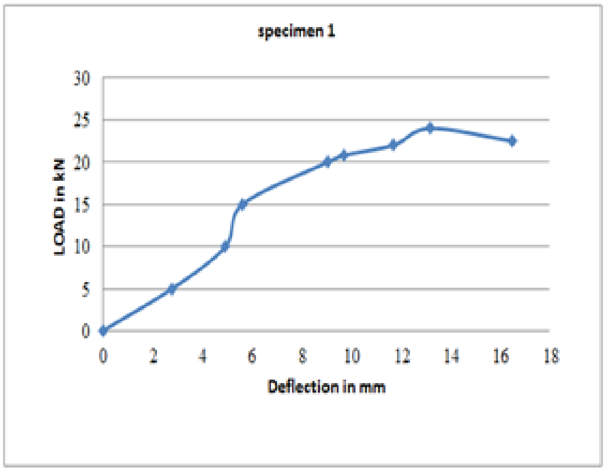

Figure 5.10: Load vs deflection of specimen 2

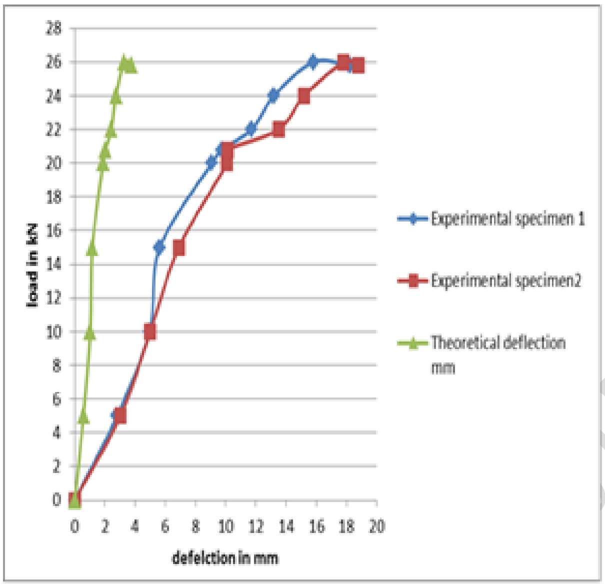

Figure 5.11: Load vs deflection behavior of theoretical and experimental specimens

VI. CONCLUSIONS

- ✓ Ferro cement folded plates respond well and can be used in building roofs with load up to 13.73 kN/sq.m (for selected dimension of tested specimen)
- ✓ The experimental deflections observed are 4.8 times greater than RCC theoretical deflections
- ✓ Ultimate load is 25% greater than the first crack load in experimental observation.
- ✓ The cracks observed in Ferro cement folded plate are started at tension zone and the crack width is comparatively less RCC members
- ✓ Ferro cement structures are high ductile structures failure of members are only by cracking not by sudden failure even at greater loads.

Use of Ferro cement in folded plates given good results since folded plates are useful for longer span the Ferro cement made the members thinner for carrying that load since Ferro cement members are strong on tension as reinforcement is distributed.

PHOTOGRAPHS

Figure 6.1: Crack pattern for specimen 1

Figure 6.2: Crack patterns in the specimens

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Figure 6.3: Crack pattern for specimen2

Figure 6.1: Crack width

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