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Strength and Behavior of Reinforced Concrete Model Beams Containing Liquid Additives

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***Abstract**: The aim of this paper is to study the effect of liquid additives on strength and behavior of reinforced concrete model beams as well as cracking and deflection of these model beams .*
The liquid additives (High-range water reducing/super plasticize) in different proportions by weight of cement in the range of 0%, 0.4%, 0.8%, 1.2%. 1.6% . 2% were used.
The compressive strength of concrete •was measured at different ages (7and 28 days) and modulus of elasticity, shear modulus, modulus of volume change. Poissons ratio, deflection and cracking at 28 days. Has been calculated.
Best results were achieved then using the ratio's of 1.6% by weight regarding compressive strength , modulus of elasticity in concrete , shear modulus , modulus of volume change, Poissons ratio and deflection.
Also results showed that additives have no effect on cracking behavior (both at first cracking stage and ultimate load).

I. Literature review

1.1 Introduction

Beams are horizontal members carrying lateral loads from roofs. floors etc. and resisting the loading in bending, shear and bond.

This research provides an overview of the principles of design and behavior of reinforced concrete beams. Reinforced concrete beam are designed to fail under an overload condition that has a small probability of being exceeded during the service life(1). A beam after designed for safety is checked to assure that it will perform in a satisfactory manner under service conditions(2). The serviceability checks usually involve assuring that deflections and crack widths satisfy appropriate criteria for the intended use(3).

The axis of a beam deflects from its initial position under action of applied forces. The deflection of beam depends on its length, its cross-sectional shape, and its the material, where the deflecting force is applied, and how the beam is supported. Deflections may be calculated, but in normal cases span4o-effective depth ratios can be used to check compliance with requirements(4).

Visible cracking occurs when the tensile stresses exceed the tensile strength of the material(5). Visible cracking is frequently a concern since these cracks provide easy access for the infiltration of aggressive solutions into the concrete and reach the reinforcing steel or, other components of the structure leading to deterioration. Crack widths can be calculated, hut in normal cases cracking can be controlled by adhering to detailing rules with regard to bar spacing in zones where the concrete is in tension.

1.2 Admixtures:

Many researchers conducted test on beams containing additives.(6) Admixtures for use in concrete are defined as "material added during the mixing process of concrete in small quantities related to the mass of cement to modify the properties of the fresh or hardened state of concrete.

Admixtures are now widely accepted as materials that contribute to the production of durable and cost-effective concrete structures. The contributions include improving the handling properties of fresh concrete, easy-fying placing and compaction, reducing the permeability of hardened concrete, and providing freeze/thaw resistance (7).

1.3 Compressive strength

Compressive strength is the main parameter which determine the quality of a concrete construction [(8)]. Other parameters than strength, such as durability, volume stability and impermeability are important in evaluating the concrete quality [(9)]. In general, most people think that by increasing the strength means that other parameters are also increased. However, this assumption is not always true. For example, the use of excessive cement will increase the strength but at the same time it also produces shrinkage and creep.

The compressive strength is the most important properly of concrete. Compressive strength in determine by standard cubes of dimension 150 or 100 mm for aggregate not exceeding 25 mm in size crushed at age of 28 days..

The compressive strength according to the cube strength (fcu) is defined as :

f_{cu} = P/A where ………..(1)

where : P: is the applied load A: cube area

and the relation between the cube strength and the cylinder strength f'c is

f'c=0.8lfcu ……………….(2)

1.4 Factors Affecting Concrete Strength

In general, compressive strength of concrete is influenced by the following factors:

a) Water/cement ratio used in the concrete mixture - increased in water /cement ratio will decreased the strength
b) method of compacting concrete mixture
c) type and characteristic of cement
d) type and characteristic of aggregates
e) aggregates / cement ratio
f) Additive materials used
g) porosity content which can be affected by the above factors
h) type of specimen and geometry (cube or cylinder and size)
i) method of testing (stress rate, moisture content)
j) sample maturity (age and type of treatment given)

1.5 Elastic Modulus

Elastic modulus is important in the calculation of beam deflection, the stress lost in pre-stress concrete due to elastic movements., changes in stress to strain and etc. Elastic modulus (modulus Young) from non-linear stress-strain curve is difficult to determine. The elastic modulus in a true elastic area is approximated from early tangent modulus that is the curve at the early stage. This modulus involved a small change of strain which is also called as dynamic elastic modulus which can be determined by ultrasonic method.

For a material such as concrete which is in general have a non -linear stress-strain curve the elastic modulus can always be defined in four different ways(3) as shown in Figure 1. Between the four modulus, secant modulus is more practical and represents the average elastic modulus. Table I gives a comparison for determination of modulus value in accordance to the various international standards According to BS8110(2) the relationship between elastic modulus and static (secant) modulus for normal concrete is as follows(3):

Ec I .25Ed ± 4 kN/mm^2 ……………………….(3)

Ed (kN/mm^2) = 1.36$^2 f_{cu}^{0.33}$ x 10^{-6} ……….……(4)

Where: f_{cu} : is cube strength in N/mm^2

E_c : is the modulus of elasticity

E_d : is the secant modulus of elasticity

the elastic constants has been calculated from the following empirical formula

$$Ec = \quad 33\, \gamma_c^{1.5} \sqrt{f}\backslash_c \dots\dots\dots\dots\dots\dots\dots\dots\dots.(5)$$

Where γ_c : concrete density

The shear modulus Gc and the modulus of volume change in concrete Kc arc also calculated from the equations:

G_c250*(2000 ± f_c)…………………….. (6)

G_c = E_c/2 (I+v) ……………………….…….(7)

K_cE_c /3 (l-2v) …………………………….(8)

Where v: Poissons ratio of concrete

1.6 Prediction of Deflections & Cracks:

1.6.1 Deflection :

Calculations of deflection in center of these beams δ. Can be determined from the following formula:

δ = PL^3 / 48E_c I………………………… (9)

Where I: moment of inertia, L : effective length of beam

1.6.2 Cracking:

Calculation of cracking in beam is namely governed by the following equations (see fig 1):

$$\varepsilon_m = \varepsilon_1 = \frac{b_1(h-x)(a'-x)}{3EA(d-x)} \dots\dots\dots..(10)$$

$$\text{design crack width} = \frac{3a_{cr}\,\varepsilon_m}{1 + 2\,(a_{cr} - c_{min})/(h - x)} \ldots\ldots\ldots..(1)$$

Where : a_{cr} is the distance of the point considered to the surface of the nearest longitudinal bar
ε_m is the average strain at the level where the cracking is being considered
ε_I is the strain at the level where the cracking is being considered
c_{min} is the cover to the tension steel
h is the overall depth of the member
x is the depth of the neutral axis
bt is the width of the section at the centroid of the tension steel
d is the effect depth
a' is the distance from the compression face to the point at which the crack width is required
Ec is the modulus of elasticity of steel
A is the area of tension reinforcement

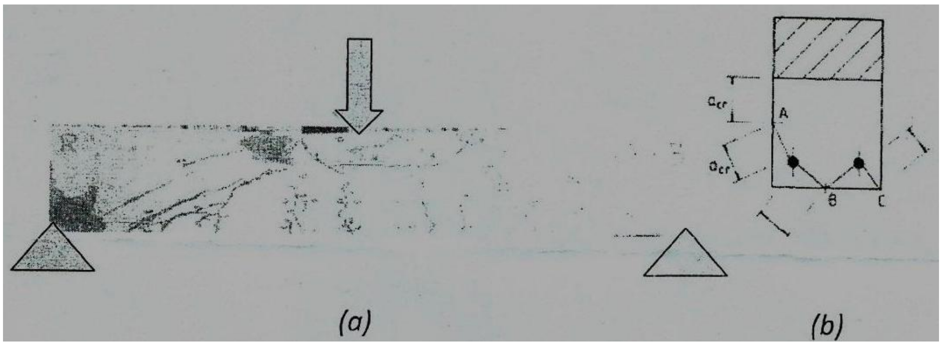

Fig 1 (expected section - cracks)

Using equations (10) & (11) , It can be shown that the crack width at:
1) point A, a_{cr} =32.84mrn
2) point B, a_{cr} 2l.42mm
3) point C, a_{cr} 58.8mm
from equation (11)
(a) The design crack width at point 003 mm
(b) The design crack width at B 0M19 mm
(c) The design crack width at C 0.0 13 mm

II. Experimental work:

2.1 Control specimens:

The total number of the tested beam specimens was 6. All dimensions are constant and mix designs are variable. The beams were classified into six different groups. Table (1) shows the six groups. With each beam 6 cotnrol specimens in a form of 100* 100* 100 mm cubes were casted and tested at 7 days and 28 days [10,11].

Table 1: Beams dimensions and additives

Beam identification	Dimensions h*b*L (mm*mm*mm)	Additives % added
B1	200* 100* 100	0.0
B2	200* 100* 100	0.4
B3	200* 100* 100	0.8
B4	200* 100* 100	1.2
B5	200* 100* 100	2.0

Where h, b and L are depth, width and length of the beams

2.2 The beams specimens:

In this research, a total of 6 reinforced concrete beam specimens were tested. The size of a beam is (200* 100* 100 mm). all beams are crated and tested at 28 days. With each beam the 6 control specimens tested, three of them tested at 7 days and the other three at 28 days [12]. Tables (2, 3, 4 and 5) below present the result.

Table 2: Compressive strength of control cubes at 7 days

Specimen designation	*Average wt of . cube (gm)*	*Average density (kg/m^3)*	*Average failure load (PKN)*	*Average compressive strength (f_{cu} N/mm^2)*
B1	2650	2650	290.00	29.00
B2	2700	2700	320.00	32.00
B3	2700	2700	341.67	34.16
B4	2700	2700	360.00	36.00
B5	2700	2700	400.00	40.00
B6	2650	2750	281.67	28.16

Table 3: Compressive strength of control cubes at 28 days

Speci design	*Ave weight (gm)*	*Ave. density (kg/m^3)*	*Ave. failure load (KN)*	*Ave. f_{cu} N/mm^2*	*$fc=0.81 f_{cu}$ N/mm^2*	*Ec N/mm^2*	*G N/mm^2*	*K N/mm^2*	*V*
B1	2650	2650	373	37.3	30.237	27.0	11.007	16.071	0.22
B2	2700	2700	415	41.5	33.615	28.5	11.852	15.833	0.20
B3	2700	2700	540	45.0	36.45	29.7	12.650	15.468	0.18
B4	2700	2700	480	48.0	38.88	31.0	13.168	15.656	0.17
B5	2700	2750	533	53.3	43.19	32.0	14.245	14.035	0.12
B6	2650	2700	370	37.0	29.97	26.9	10.940	16.011	0.00

Where for concrete: Ec is the modulus of elasticity, G is the shear modulus, k is the modulus of volume change and v s Poissons ratio.

Table 4: Load- deflection for all beams

Load kN	**Deflection B1 (mm)**	**Deflection B2 (mm)**	**Deflection B3 (mm)**	**Deflection B4 (mm)**	**Deflection B5 (mm)**	**Deflection B6 (mm)**
0	0	0	0	0	0	0
2	0.09	0.16	0.05	0.02	0.01	0.02
4	0.2	0.27	0.05	0.09	0.06	0.04
6	0.35	0.27	0.07	0.2	0.11	0.25
8	0.46	0.34	0.19	0.33	0.12	0.39
10	0.54	0.45	0.21	0.44	0.12	0.49
12	0.63	0.48	0.32	0.5	0.12	0.6
14	0.72	0.76	0.9	0.54	0.19	0.7
16	1.1	0.91	0.67	0.88	0.19	0.79
18	1.1	1.06	0.8	1.13	0.2	0.92
20	1.27	1.18	0.94	1.22	0.26	0.95
22	1.52	1.27	1.09	1.34	0.54	1.04
24	1.62	1.31	1.19	1.43	0.68	1.17
26	1.97	1.46	1.24	1.45	0.78	1.45
28	2.16	1.79	1.36	1.59	0.88	1.6
30	2.36	1.96	1.67	1.88	0.98	1.75
32	2.5	2.08	1.89	2	1.08	1.9
34	2.63	2.17	2.04	2.15	1.09	1.97
36	3.09	2.25	2.17	2.29	1.16	2.02
38	3.27	2.3	2.22	2.4	1.22	2.37
40	3.38	2.44	2.39	2.43	1.58	2.55
42	3.49	2.58	2.74	2.52	1.66	2.7
44	3.64	2.95	2.91	2.85	1.73	2.9
46	4.44	3.11	3.15	3	1.83	2.95
48	4.44	3.19	3.2	3.15	2.03	3.17
50	4.44	3.31	3.39	3.3	2.08	3.62
52	4.72	3.53	3.79	3.41	2.17	3.92
54		4.01	3.89	3.55	2.33	
56					2.63	
58					2.98	

Table 5: Moment- rotation (in radians) for all beams

Moment kN.m	Rotation* (radians) B_1 (10^{-4})	Rotation* (radians) B_2 (10^{-4})	Rotation* (radians) B_3 (10^{-4})	Rotation* (radians) B_4 (10^{-4})	Rotation* (radians) B_5 (10^{-4})	Rotation* (radians) B_6 (10^{-4})
0.0	0.00	0.0	0.0	0.0	0.0	0.0
0.5	1.80	3.2	1.0	0.4	0.2	0.4
1.0	4.00	5.4	1.0	1.8	1.2	0.8
1.5	7.00	5.4	1.4	4.0	2.2	5.0
2.0	9.20	6.8	3.8	6.6	2.4	7.8
2.5	10.8	9.0	4.2	8.8	2.4	9.8
3.0	12.6	9.6	6.4	10.0	2.4	12.0
3.5	14.4	15.2	7.8	10.8	3.8	15.8
4.0	22.0	18.2	13.4	17.6	3.8	14.0
4.5	24.0	21.2	16.0	22.6	4.0	18.4
5.0	25.4	23.6	18.8	24.4	5.2	19.0
5.5	30.4	25.4	21.8	21.8	26.8	20.8
6.0	32.4	26.2	23.8	28.6	23.6	23.4
6.5	39.4	29.2	24.8	29.0	15.6	29.0
7.0	43.2	35.8	27.2	31.8	17.6	32.0
7.5	47.2	39.2	33.4	37.6	19.6	35.0
8.0	50.0	41.6	37.8	40.0	21.6	38.0
8.5	52.6	43.4	40.8	43.0	21.8	39.4
9.0	61.8	45.0	43.4	45.8	25.0	40.4
9.5	65.4	46.0	44.4	48.0	30.0	47.4
10.0	67.6	48.8	47.8	48.6	31.6	51.0
10.5	69.8	51.6	54.8	50.4	33.2	54.0
11.0	72.8	59.0	58.2	57.0	34.6	58.0
11.5	73.0	62.2	63.0	60.0	36.6	59.0
12.0	75.0	63.8	64.0	63.0	40.6	63.4
12.5	88.8	66.2	67.8	66.0	41.6	72.4
13.0	94.4	70.6	75.8	68.2	43.4	78.4
13.5		80.2	77.8	71.0	46.6	
14.0					52.6	
14.5					59.6	

*As the beam is symmetrical the rotation of each beam is calculated at left support.

III. Discussions of Results:

* From table 2, and of results table 3, fig:2 has been drawn. The compressive strength of control specimen and thus beam increases by increase in additives in the range (0% - 1.6%) and decreases by increase in additives in the range (1.6% - 2%) for the both ages of 7 day and 28 days. For both ages of 7 days and 28 days, the best results has been achieved in the ratio of 1.6%.

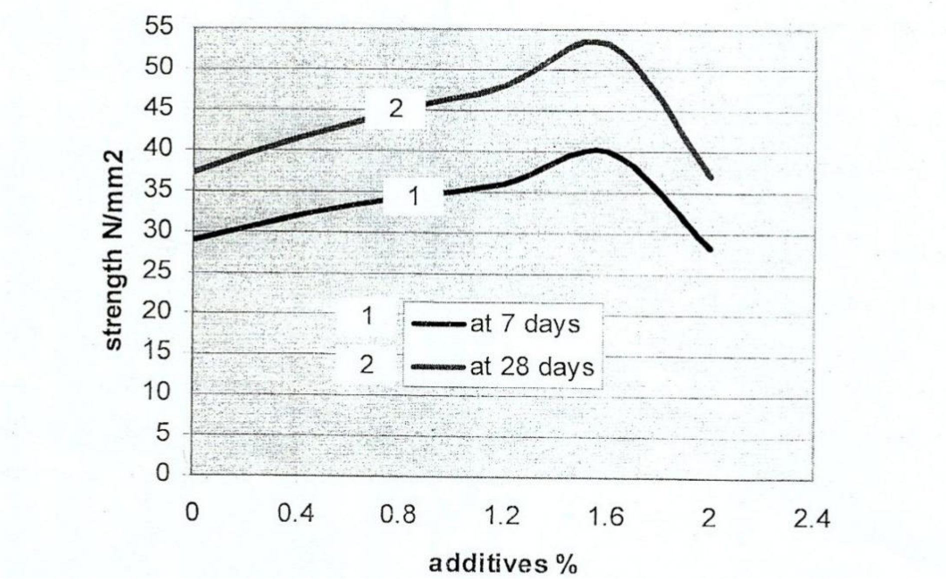

Fig 2: Effect of additives on compressive strength of control specimens of beams

* From Table 3 modulus of elasticity of concrete (Ec) , shear modulus (0) , modulus of volume change (K) were increased by increase in additives in the range (0% - 1.6%) and decreased by increase in additives in the range

(1.6% - 2%) . Again best results have been achieved at the ratio of 1+6%. Fig. 3 shows the effect of additives on the prescribed elastic moduli.

* From Table 3 Poissons ratios (v) decreases by increase in additives in the range (0% - 1.6%) and increases by increase in additives in the range (1.6% -- 2%) , and best results has been achieved at the ratio of 1.6% . (see fig. 3 (a & b)) .

* From Table 4 and Table 5 , fig 4 and fig 5 has been drawn (12) As shown deflection decreases as additives increases in the range (0% - 1.6%) and increases as additives increases in the range (1.6%-2%) and best results has been achieved at the ratio of 1.6% .

* From fig. 6.1 and fig 6.2 the failure crack patterns are found to be nearly similar both theoretical and experimental. The same phenomena has been noticed in all the other tested beams, which means that addition of additives has no effect on the failure pattern of the tested beams.

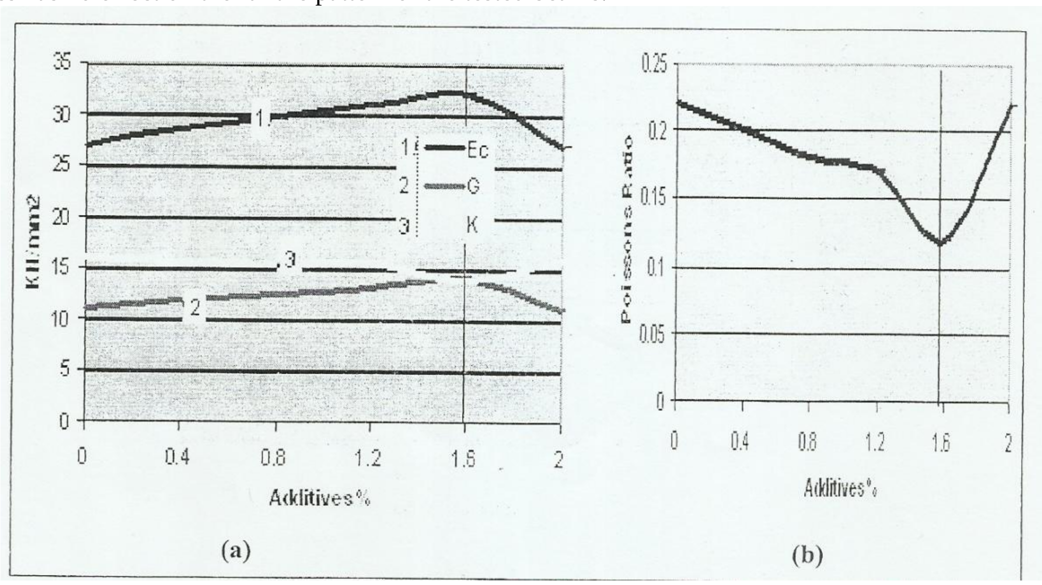

Fig. 3: Effect of additives on elastic modullii

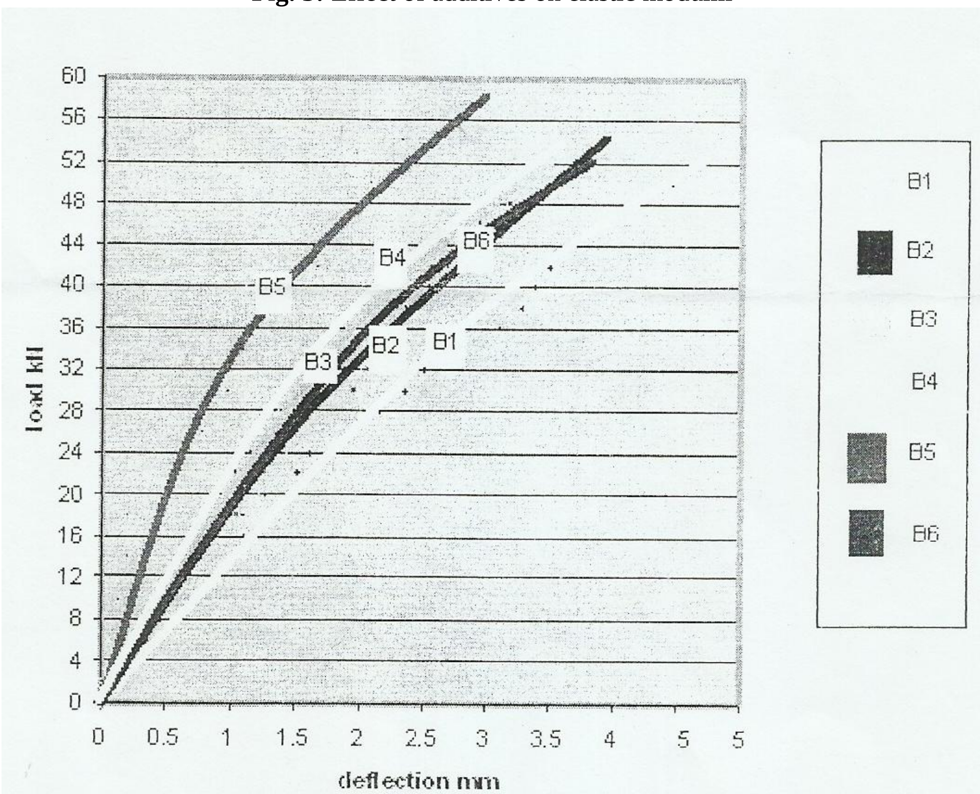

Fig 4: Load-deflection curve for all beams

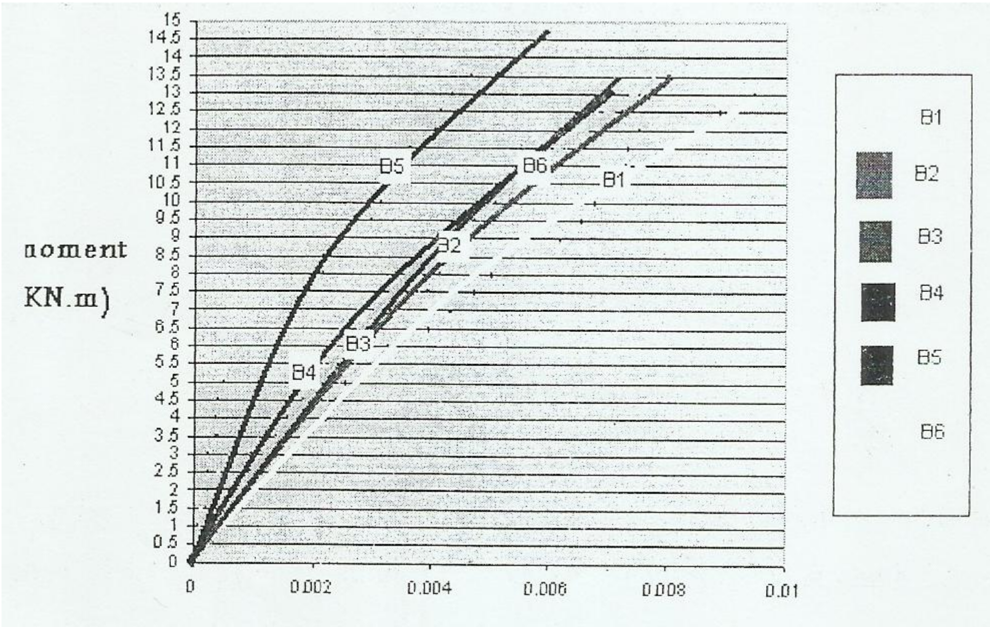

Fig 5: moment- Rotation curve for all beams.

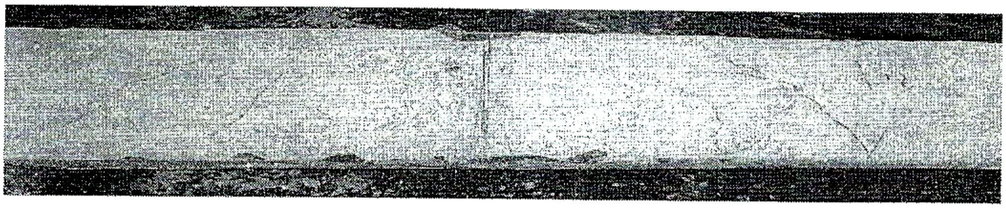

Fig. 6.1 the actual experimental cracks of beam B_1

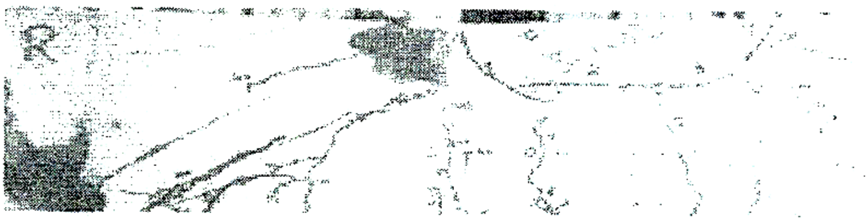

Fig. 6.2: The expected theoretical section- cracks of B_1

IV. Conclusions:

The additive under investigation has the following effects in concrete cubes and beams:

- In the range of 0.4- 1.6% addition it increases the compressive strength (at age of 7 and 28 days), density, modulus of elasticity of different types in compression, in shear and in volume.
- Also in the above mentioned range it decreases poission ratio and deflection.
- Beyond 1.6% addition the above mentioned results were reversed i.e. at 1.6% addition the optimum good results are obtained.
- The additive increases the width of the first crack and its early appearance.

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1.1 Other types of crack in buildings maybe summarized as:

- Shrinkage cracks in buildings are unlikely to be of any structural concern but can be a source of water entry or radon entry in buildings and may form a tripping hazard.
- Settlement cracks in a slab indicate inadequate site preparation, such as failure to compact fill on which a foundation was poured.
- Frost heaves or expansive soil damage can cause substantial damage to basement, crawl space, or garage floor slabs in some conditions.
- Crack from settling of new addition. Anew addition has experienced settling as a result of soil consolidation at the new foundation.
- Crack formation due to soil related influences. Ground water can cause soil erosion and reduction of soil compressive strength, reduction load bearing capacity of the foundation, stressing and cracking building materials.
- Illustrate of structural member, which can occur for variety of reason such as defect or deterioration. This stresses on other building components, promoting crack formation.
- Partial collapse of foundation, which is common among older stone foundation. Mortar has deteriorated and stones have fallen into the basement area. The loss of structural foundation support has caused cracking of drywall in the building interior. This is a form of deterioration.
- Cracks in wallboard due to settling.
- Cracks formed instantaneously as a result of a natural gas leakage fueled explosion in the building.
- Cracks in block wall about halfway up the wall. This is an indicator of soil and! or water pressure causing inward deflection of the wall and impending failure. In this case, water drainage toward the foundation had caused an excessive hydraulic load. Lock of maintenance of gutter drainage and grade near the wall has increased hydraulic loading against the wall over time. (see Fig. 2 for the differenftypes of cracks in buildings).

1.2 Limits on crack width:

It is necessary to identify limits of acceptability for crack widths. Max allowable in range of 0.1 mm to 0.4 mm, one reason often given for limitation of crack width is prevention of corrosion of reinforcing steel. Table (1) present the permissible limits of crack widths (3).

Table (1): Permissible crack width:

Member	Crack width (mm)
Dray air protection members	0.4
Humility, moister, soil	0.3
Deicing chemicals sea water and sea water spray	0.15
Water retaining structures	0.1

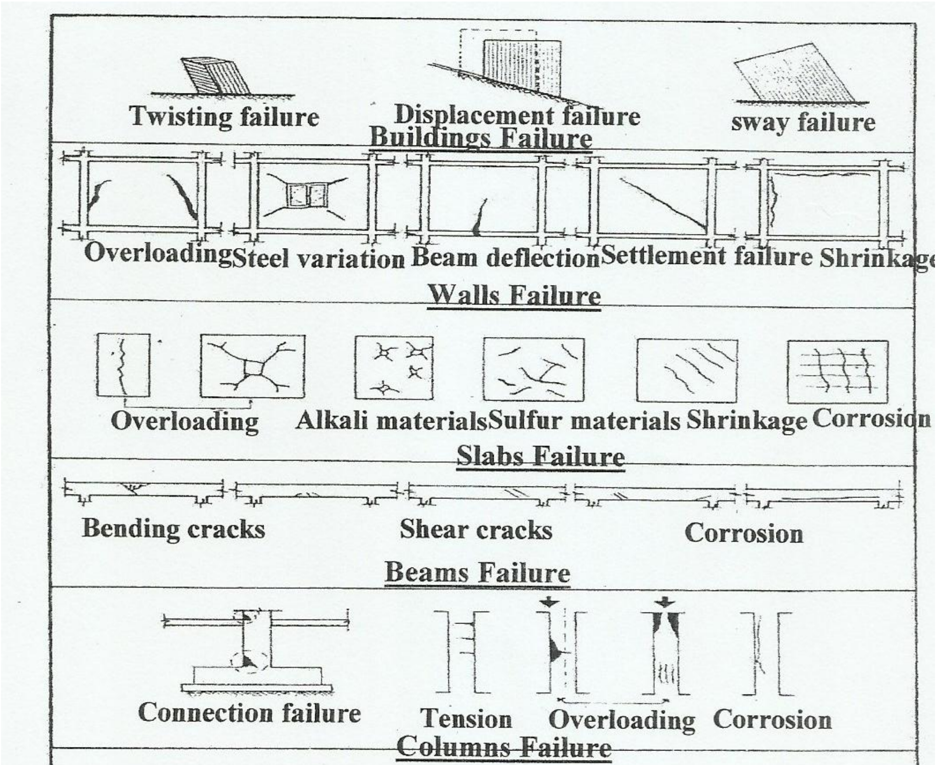

Fig.2 types of cracks in buildings and buildings elements

2. Crack with calcuations
2.1 Standard Formula:

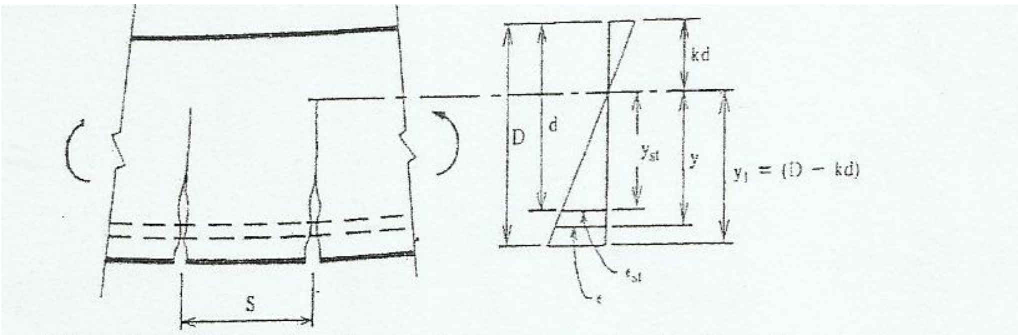

Fig. 3.a: Distribution of average strain in a beam

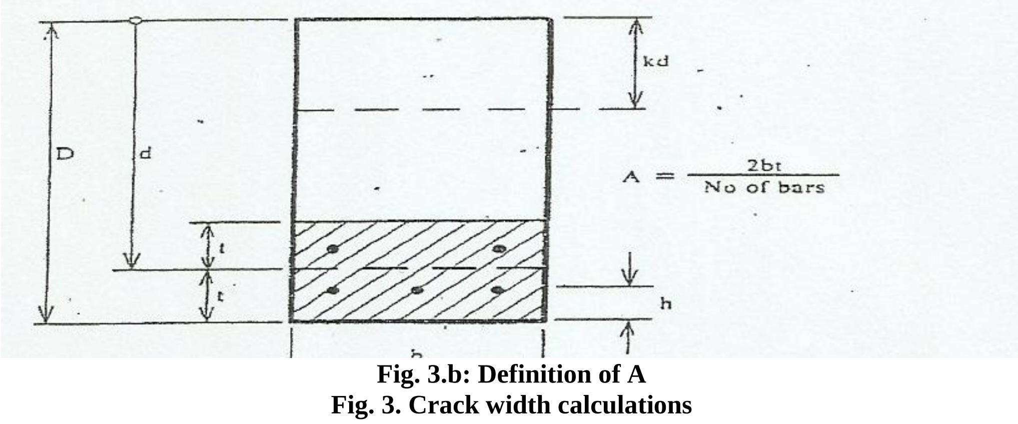

Fig. 3.b: Definition of A
Fig. 3. Crack width calculations

Taking fig.. (a & b) under consideration, Welch and Janjua (4) proposed that the crack spacing S is given by:

$$S = (1.5h + 3.0d) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where h is the concrete cover measured to the bar centre and db is diameter; the same authors proposed the following formula for the maximum crack width;

$$W_{max} = 1.5\,(1.5h + 3.0d_b)\left(h + \frac{\sigma st}{Es} + 0.0001\right)\frac{y_1}{y_{st}} \;\ldots\ldots\ldots\ldots (2)$$

The CEB- FIP model code (5) proposed the following formula for the crack spacing:

$$S = 2\,\left(h + \frac{\sigma}{10} + 0.6\,\frac{d_b}{p_r}\right)\ldots\ldots\ldots\ldots\ldots (3)$$

Where a is the spacing of the reinforcing bars and pr is the ratio of steel bar to effective surrounding area of concrete in tension.

Gergely and Lutz (6) has proposed that

$$W_{max} = 0.011(hA)^{0.33}\left(\frac{D - kd}{d - kd} + 0.0001\right)\sigma_{SI} \times 10^{-3}\ldots\ldots\ldots\ldots\ldots (4)$$

Where h is the minimum cover to the centre of the bar and A is the concrete tension area surrounding each bar.

ACI (7) proposed the following formula for the maximum crack width in fully cracked tensile members.

$$W_{max} = 0.10 fs^3 \sqrt{d_c A \times 10^{-3}}\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Or

$$W_{max} = 0.076\beta fs^3 \sqrt{d_c A \times 10^{-3}}\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where β= ratio of distance between neutral axis and tension face to distance between neutral axis and centroid of reinforcing steel 1.2 in beams.

fs = actual tensile strength of concrete in psi dc = distance from centre of bar to extreme tension fiber in (in.)

A = area of concrete symmetric with reinforcing steel divided by the number of bars (in2).

2.2 Effect of cracking on members stiffness:

When a symmetrical un-cracked reinforced concrete member is loaded in tension the tensile force is distributed between the reinforcing steel and concrete in proportion to their respective stiffness. The load carried across the crack by reinforcement is gradually transferred by the bond to the concrete on each site of crack. As the applied load increases additional cracks form at distance intervals along the member and the stiffness is drop down, as a result of this drop, the member under cracking may finally fail. The contribution of concrete between cracks to the net stiffness of a member is known as tension stiffening.

2.3 Finite element applications:

Extensive researches has been done in recent years on the application of finite elements to modeling the behavior of reinforced concrete and is summarized in a report of the ASCE task committee on finite element analysis of reinforced concrete (8). Two basic approaches, the discrete crack approach and the smeared crack approach have been used to model cracking and tension stiffening.

2.4 Deflection - calculation:

Prediction of deflection is very important in order to avoid damage to finishes and services, although the estimation of exact deflection may be difficult due to some considerable effects on deflection calculation, such as:

- The long term creep effects.
- The effect of finishes, partitions ... etc.
- Shrinkage of the concrete.
- The precise duration of the live load. However, the max deflection (a) in concrete may be calculated using the following formula (9);

$$a = K\,\frac{L^2 M}{E_c I_{ce}}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (7)$$

where K is a coefficient that depends on the load distribution and the end fixity conditions.

L = length of the concrete member.

M = bending moment.

E_c = modulus of elasticity of concrete.

Ice = second moment of area of the section in equivalent concrete units.

The permissible deflection in the building elements should not exceed the values given in table (2)

Table (2) Permissible Deflection

Member	Deflection
Cantilever beam	Length/180
Beams carrying plaster	Span/ 360
All other beams	Span /200
Columns in multi-storey buildings	Height/ 300
Crane girders	Span/ 600

Table (3): the studied buildings

Building No.	Location	No. of Floors	Type of slab	Beams size cm	Column size cm	Type of foundation
	AlGeraif- KRT	11	Flat	-	$\frac{70\times 30}{120\times 30}$	Raft
	Riadh – KRT	7	Flat	-	$\frac{70\times 30}{90\times 30}$	Raft
	Riadh – KRT	6	Flat	-	$\frac{70\times 30}{90\times 30}$	Raft
	alGeraif- KRT	3	FLAT	50 × 20	50 × 20	ISOLATED
	AlNuzha- KRT	Footings	-	-	-	-
	Algeraif- KART	3	Slab-Beam	50 ×25	40 × 40	Isolated
	Khartoum centre	7	Slab-beam	40 ×25	60 × 25	Isolated
	Mamoura- KRT	1	Flat	-	50 × 25	Isolated
	Thawora- Omdurman	2	Flat	-	50 × 25	Isolated
	Sinaat- Omdurman	3	Slab- beam	50 ×25	50 × 25	Isolated
	Saifa- KRT-N	Footings	-	-	-	-
	3rd Class-KRT	6	Flat	-	$\frac{70\times 30}{90\times 30}$	Raft
	Amarat-KRT	11	Flat	-	60 × 30	Raft
	Arkawit-KRT	Footings	-	-	-	-
	Khartoum Center	3	Slab- beam	50 ×25	50 × 25	Isolated
	Amarat-KRT	2	Flat	-	60 × 30	Isolated
	Magran-KRT	4	Slab-Beam	50 ×25	60 × 30	Isolated

Table (4): Types of failures in the different buildings:

Building No	Types of failure						
	Concrete	Slab	Beam	Column	Foundation	Stability	Others
1.	-	Excessive deflection in one cantilever	-	-	-	-	-
2.	-	Excessive deflection in one cantilever	-	-	-	-	-
3.	-	Excessive deflection in one cantilever	-	-	-	-	-
4.	Poor concreting		Bending cracks in beams	-	-	-	Power work, man-ship
5.	-	-	-	-	Insufficient foundations	-	Power work, man-ship
6.	-		Bending cracks in beams		Insufficient foundations	Instability condition	-
7.	Poor concreting	Due deflection low to un standard size of beam	Major cracks in columns	-	-	Instability condition	Insufficient design
8.	Poor concreting	Concrete segregation	Cracks in beams	-	Settlement of foundation	Instability condition	Walls and plasters cracks
9.	-	-	-	In adequate slab-column connection	-	-	-
10.	Poor concreting	-	Cracks and deflection		Settlement of foundation	Instability condition	Walls and plasters cracks
11.	Poor concreting	-	-	-	-	-	-
12.	-	Excessive deflection in columns	-	-	-	-	-
13.	Poor concreting	Concrete segregation	-	Punching shear in slab-column connection	Instability condition		Insufficient design
14.	Poor concreting	-	Cracks in G. Bs.	-	Settlement in foundation	-	-
15.	-	-	-	-	-	-	Cracks in walls and plaster
16.	-	Excessive deflection	-	Punching shear	-	-	Cracks in walls
17.	-	Excessive deflection	-	-	-	-	Cracks in walls

4. Discussion of Results:

The crack width calculations in the different buildings has ranged between 0.7 mm-15mm, all of it is more greater that the permissible crack width shown in table (1).

Regarding deflection in some members it has been recorded in two of the cantilevers of lengths 160 cm as 60 mm which is very excessive in comparison to table (2).

In reference to table (3) and table (4) that 17 reinforced concrete structures has been studied and the main type of failure has been presented and it has been found that the main types of failure is due to construction and lack in design and regarding the structural elements, the slabs and walls are suffering failure more than the other elements. Table (5) present the percentage comparison for the different causes of failure in the studied reinforced concrete elements in tables (3) and (4).

Table (5). Failure % age comparison

No.	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Type of failure	Poor concreting	Poor excessive deflection	Low thickness of slab	Excessive cracks in beams	Punching shear in slabs	Foundation settlement	Instability condition	Insufficient design	Cracks in walls	Inadequate slab column connection	Concrete segregation
%	41%	47%	5.9%	29.4%	11.8%	29.4%	29.4%	29.4%	29.4%	5.9%	11.8%

5. Conclusions:

From the case study in this research, the following conclusions can be drawn:

1) The main cracks in reinforced concrete buildings are due mainly to lack in construction process.
2) Soil testing is very important before the design process of the reinforced concrete building.
3) The flat slab may be one of the main causes of failure in reinforced concrete structures due to the punching shear developed at the column face.
4) Insufficient design and poor detailing may lead to failure in reinforced concrete structures.
5) In design the ability requirements like the expansion joints, the reinforced concrete cores, and the shear walls should be taken under consideration.

6. References:

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