Effect of Using Bracing Members in Reducing Thermal Effects in Long Buildings

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Abstract

The objective of this research is to know if a reinforced concrete one-story long building can be build in hot weather countries like Iraq without dividing it into segments by expansion joints. Three case studies were chosen in this research, the first case represents an analysis of a building (150 m length with nearly equal spans) subjected to gravity loads. This building is designed using the specification ACI-318M-08. In the second case study the same building is analyzed with two types of loads, the same gravity loads and thermal load by exposure the building in the same time for 19 ^{0}C (66 F) uniform temperature increasing. Also, and to minimize the lateral deflection producing from temperature effect, bracing beams are added at external bays in the long direction of the building. In the third case study, the applied load in the second case study is used to analysis the building but without bracing beams.

The analysis results show that the bracing beams have large effect on the structure, the axial forces in the beams are increased by 1775%, the moments in the columns are reduced by 80% and the lateral displacement of the building is reduced by 77%. In spite of the increase in the axial forces in the beams as a result of bracing and thermal load, the strength capacity for beams in the second case is adequate to resist the increase in axial loads with the same ratio of reinforcement required to resist the flexural moments for the beams in the first case.

الخلاصة

أن الهدف الرئيسي من هذا البحث هو معرفة هل بالإمكان تنفيذ بناية كونكريتية مسلحة طويلة مؤلفة من طابق واحد في بليعتبر من البلدان الحارة كالعراق وبدون استخدام مفصل تمددي . من اجل ذلك تم دراسة ثلاث حالات، الحالة الأولى هي تحليل البناية بطول 150 م وبفضاءات متساوية تقريبا بتسليط الأوزان الطبيعة للمنشأ ومن ثم القيا م بالتصميم بالاعتماد على مواصفات المدونة (ACI-318M-08 Code). إما الحالة الثانية فقد تم تحليل البناية مع نوعين من الأحمال ،نفس حمل الجاذبية وحمل حراري عن طريق تعريض البناية إلى درجة حرارة مقدارها 19درجة مئوية . ومن اجل تقليل الإزاحة الجانبية الناجمة من التأثير الحراري فقد تم إضافة جسور متقاطعة عند الفضاء الدبعيدة وبالاتجاه الطولي للبناية . إما الحالة الثالثة فقد تم تحليل البناية بعد تعريضها للحمل الحقيقي المسلط والحمل الحراري ولكن بدون استخدام جسور متقاطعة.

لقد تبين من نتائج التحليل أن للجسور المتقاطعة تأثير كبير على المنشأ حيث أن القوى المحورية بالجسور أزادت بنسبة 1775% والعزوم بالأعمدة انخفضت بنسبة 80% بينما الإزاحة الجانبية انخفضت بنسبة 77 %. وبالرغم من الزيادة الحاصلة بالقوى المحورية نتيجة لتقيد البناية والحمل الحراري للحالة الثانية ألا أن الجسور وبنفس كمية حديد التسليح المستخدمة للحالة الأولى هي كافية لمقاوم أجهادات الانحناء والاجهادات المحورية .

1- Introduction

Thermal expansion joints in buildings may be determined initially on an empirical basis .If results are deemed by designer to be too conservative or if the empirical approach is not sufficiently to be applicable to the type of structure being investigated, a more precise analysis should be undertaken (Hendry A.W.,2003) .As empirical basic, Table (3) is published by the ACI committee 224-3R-95 . In this Table spacing of expansion joint are range from (9-60) m depending on the type of structure. As an alternative to the empirical basics, Martin and Acosta (1970) present an analytical method for calculating the maximum spacing of expansion joints in one-story frame with nearly equal spans (ACI 224 .3R-1995). From the chart proposed from Martin and Acosta, the maximum spacing of expansion joint is 130 m. To avoid damage of external wall, Martin and Acosta limited the maximum allowable lateral deflection to (h/180), while the lateral deflection for masonry structure is limited to (0.002) times the floor high by professor Schierle (AL-Sharmani,2007) .In this research, two criterion are considered, the value of reinforcement in beams and the lateral deflection of the structure, therefore the principle goal from this research is to study the effect of long building construction without expansion joints on its structural behavior

2-Suggested Procedure for Design of Buildings Against Thermal Changes

As in most structural problems, the investigation of the thermal effects is reduced to basic understanding of distributed forces and deformation within the structure. If deformations are resisted the resulting force system in structural members may exceed the members' strength and cause structural failure: if they are not resisted the change of geometry in the structure may interfere with its overall performance. Therefore, the designer's task is to select one of the following three board basic approaches (the national academy of sciences,1974).

1. Limit the potential for deformation in the structure (without causing failure) by designing the appropriate members to be substantially stiffened and strengthened.
2. Allow substantial movement of the building's structural and nonstructural components will not be adversely affected. Such a structure will require partially no additional strength of members to withstand thermal effects.

3. Strike a compromise between capacity to resist stress and ability to withstand deformation without sacrificing building performance.

In the present research, the first point is adopted and the movement due to temperature is prevented by using bracing beams to increase the strength of structure

3- Computation of Design Temperature Change (Thermal Load)

Since construction is carried out over considerable period, the various element of the structure are installed at different temperatures. The temperature changes causing displacements and stresses in structure are changes from theses installation/erection temperatures, over which the designer has little, if any, control. Yet while it is apparent that temperature change is one of the most important factors influencing the potential linear expansion /contraction of a building, there is no possibility of establishing exactly the maximum expected temperature change because this change is not the same for all parts of the structure and is not known during the design phase for any one particular part of the structure. From the above reasons the national academy of sciences ,1974, was developed the following guidelines to serve as an aid to computation of design temperature change :

- It should be assumed that structures will be built when the minimum daily temperature are above 32 F (0 ^{0}C))
- Mean temperature (Tm) should be based on only the construction season(the contiguous period during which the minimum daily temperature is above 32 F).
- The anticipated high-temperature extreme (Tw) should be considered as the temperature that is exceed, on the average, only 1 percent of the time during the summer months (June through September) in the locality of the building .
- The anticipated low-temperature extreme (Tc) should be considered as the temperature that is equaled or exceed, on the average, 99 percent of the time during the winter months (December through February) in the locality of the building.
- Using the data described above, the design temperature change (Δ t) can be uniquely defined according to Δ t =(Tw –Tm)or (Tm –Tc) whichever is greater.

4-Computer Analysis

4-1 STAAD.pro 2004 Software

The structural analysis and design program is the most popular structural software in Iraq; it is used in most of the structural consulting offices and Universities of Iraq. This program is used in analysis and design of all types of structural systems and materials, this program is used as the main tool in this investigation.

4-2 Data Analysis

4-2-1 Load

Two types of load are used in the analysis; gravity load and thermal load .Wind load aren't included in the analysis because of the limited height of building under consideration

1-Total factored gravity load equals 15 kN/ m^2

2-Thermal load:

According to guidelines of the national academy of sciences,1974 , Temperature change should be computed in accordance with the formula:

$(\Delta t) = Tw - Tm$ or $(\Delta t) = Tm - Tc$

Whichever is greater.

. The value of Tw, Tm and Tc for Al-Najaf city are calculate according to statistical data (Table,4,5,6) published by ministry of Iraqi Transport and Communication / The General Authority of Weather, for average of past 30 years (1971-2007). (الاسدي، 2008)

$Tw = 42.75\ ^0C$

$Tc = 6.6\ ^0C$

$Tm = 24.32\ ^0C$

$(\Delta t) = Tw - Tm = 42.75 - 24.32 = 18.43\ ^0C$

or $(\Delta t) = Tm - Tc = 24.32 - 6.6 = 17.72\ ^0C$

Therefore, temperature change $(\Delta t) = 18.43 \sim 19\ ^0C$.

The data of temperature change has been provided in the STAAD. Pro. program under the field of temperature change of axial elongation

4-2-2 Geometry and Materials

One-story reinforcement concrete building 150 m long is investigated in this research. The cross-sectional elevation of the chosen building is shown in Fig. (2).

Assumption

- All beams are of same size (500 x 250) mm.
- All columns are of same size (400x 250) mm.
- Slab thickness is 150 mm.
- Bracing beam (750 x250) mm.

- High of building is 4 m
- Compressive strength of concrete is (21.7) N /mm^2.
- Yielding stress of steel is (420) N /mm^2.

5-Results of the Analysis and Design

As mentioned in the abstract, three case studies are done in this research to study the effect of bracing beams on a structure subjected to constant temperature equals 19^{0}C, which represents the design temperature change for Al-Najaf city calculated according to guidelines of the national academy of sciences, 1974. Table (1) shows the results of the analysis and design of these cases.

To development the present study, the same restrained structure is subjected to different temperatures ranging from (19-40) ^{0}C. In 40^{0}C the lateral displacement of the structure nearly reaches the allowable value that proposed by professor Schierle. Table (2) shows results of the analysis and design of this case. .

Table (1) Results of Analysis and Design (19^{0}C)

Analysis no	Beam			Column		Δ	ρ	0.002 h (mm) Allowable lateral displacement
	Max. M.	Max. S	Max. N	Max. M	Max. N			
1	125	104	5	35	487	-1.2	0.0074	8
2	131	101	750	19	459	3.5	0.0060	8
3	132	103	40	95	475	15	0.0074	8

Analysis No.1 = an analysis with applied gravity load only.

Analysis No. 2 = an analysis with applied gravity load and thermal load with bracing beams.

Analysis No. 3 = an Analysis with applied gravity load and thermal load without bracing beams

M= maximum bending moment (kN .m).

N= maximum axial force.(kN).

S= maximum shear force (kN).

Δ=lateral displacement at the upper edge of building (mm).

.ρ = ratio of reinforcement of beam.

h= height of the building (m).

Table (2) Results of Analysis and Design (19-40) ^{0}C

(Δ t)	Beam			Column		Δ	ρ	0.002 h (mm) Allowable lateral displacement
	Max. M.	Max. S	Max. N	Max. M	Max. N			
19	131	101	750	19	459	3.5	.0074	8
25	136	103	860	28	459	5.5	0.013	8
30	145	104	1030	34	459	6.6	0.020	8
35	154	107	1200	39	459	7.7	0.025	8
40	164	110	1370	44	459	8.2	0.029	8

6-Discussion of Results

From table (1), the axial load in beams is the largest variable in the three cases studies, Fig.(1) shows the axial forces in these case studies. Results in table (1) refer that the crossing beams have a major role to increase the axial forces on beams and minimizing the lateral displacement of the structure. The ratio of reinforcement required to resist the axial force and moment for a beam in the analysis No.(2) is lesser by 19% than the ratio required to resist nearly the same moment in the analysis No.(1). From the above discussion, we can conclude that in spite of the increasing in axial load as result of exposure the structure to 19^{0}C, the beams don't need to strengthen. A second goal has achieve as result to use crossing beams by minimizing the lateral displacement by 77 %,where the lateral displacement in the analysis No.(1) is 15 mm while it is 3.5 mm in the analysis No.(2).

From Table (2), as a result to increase in the temperature change from (19-40) ^{0}C, moments in beams are increased by 20% , the axial forces are increased by 83% and the ratio of reinforcement is increased by 291%. For columns , moments are increased by 131%.The lateral displacement for the structure is increased by 134%.

From results above, we can conclude that the lateral displacement reaches to the allowable displacement in 40^{0}C, but the beams in this temperature need to strengthen according to the high ratio of reinforcement required. In all temperature changes except 19^{0}C, beams need to strengthen

5- Conclusions and Recommendations

In the present study, the following points has bean concluded:

1-To analyze long building, thermal loads must be applied in the same time with other types of a loading.

2- Using the analytical method instead of empirical approach to determination numbers and locations of expansion joints for the buildings is more exact.

3- Using the structural solutions like the bracing beams is suitable to construction a reinforced one-story building subjected to 19^0C without expansion joints for length equals 150 m .

4-the lateral displacement for a reinforcement one story building subjected to different temperature change may be limited by using bracing beams

5- As a result of large axial force producing in the beams from the construction of the beams in the ends of the buildings(Axial forces are increased in beams by 1775 % according to present study), the designer must consider the following requirements

- all beams should be designed as a beam column and the reinforcement should be equally distributed in top and bottom of the beam .
- the reinforcement in top and bottom of beams should be continue along the beam and no bar cut off used..

References

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Table (3): Expansion Joints Spacing Published by ACI committee 224-3R-95

Author	Spacing
Lewerenz (1907)	75 ft (23 m) for wall.
Hunter	80 ft (25 m) for wall and insulated roof ,30to40 ft (9to12m) for un insulated roofs
Billig (1960)	100ft (30)m maximum building length without joints. Recommended joint placement at abrupt changes in plan and at change in building height to account for potential stress concentration
Wood (1981)	100 to 120 ft (30 to 35 m) for wall
Indian Standards institution (1964)	45 m(148 ft) maximum building length between joint
PCA (1982)	200 ft (60 m) maximum building length without joints
ACI 350R-83	120 ft(36) in sanitary structures partially filled with liquid (closer spacing required when no liquid present)

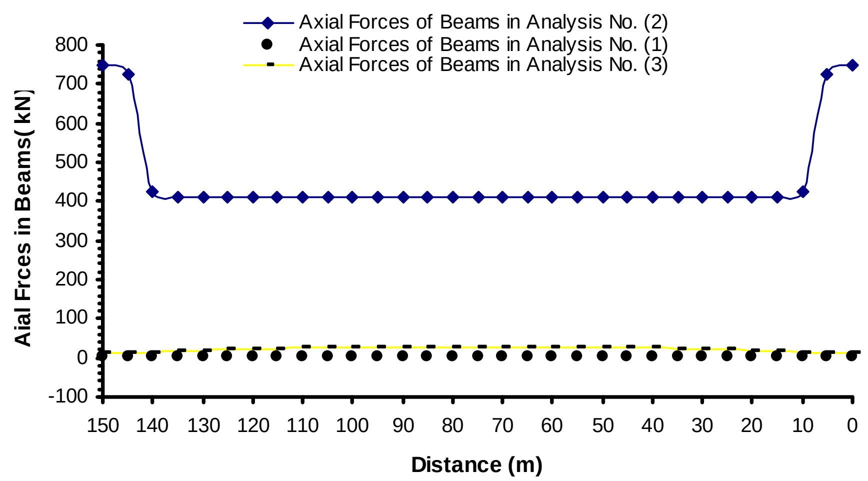
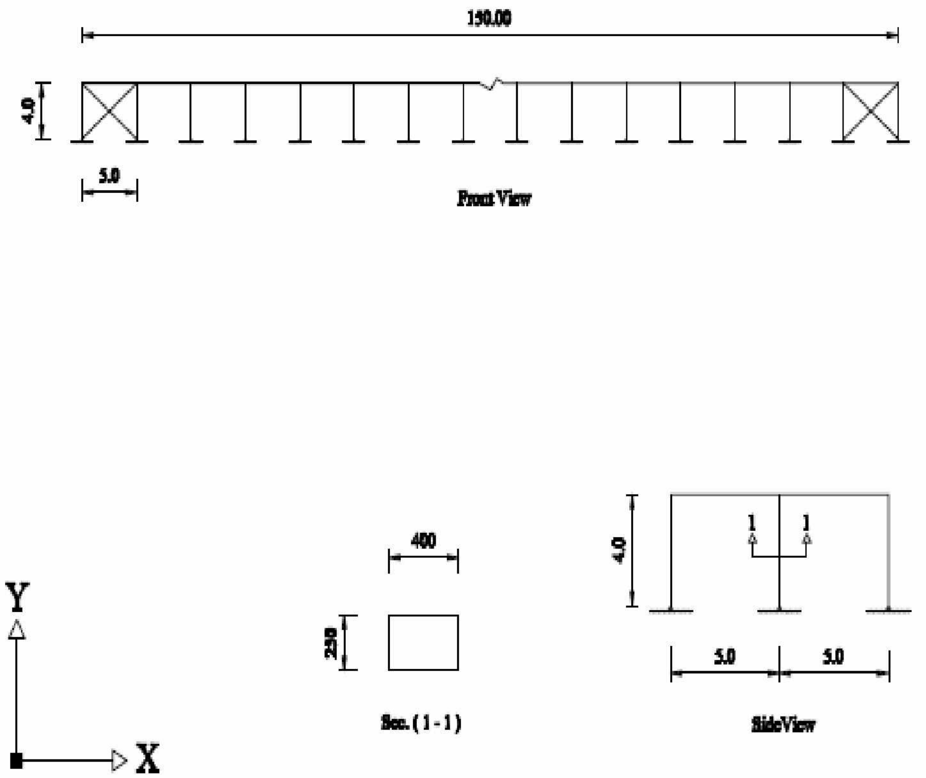


Fig.(3)
Axial Forces of Beams in case studies



Fig(2)
Cross Section Elevation of the Chosen Building

Table (4)

Annual Average of Normal Temperature In Iraq(C^0)For Period Of (1971-2007)

Average	Dec.	Nov.	Oct.	Sept.	Aug.	July	June	May	Apr.	Mar.	Feb.	Jan.	Station
`18.9	1	13.5	20.8	25.8	31.4	30.6	27	21.4	15.2	10.4	7.1	5.1	Zaku
17.3	6.1	13.9	20.2	25.7	29.6	29.5	26.2	20.4	14.9	9.7	6.2	4.9	Salah- AL Dean
20.5	9.4	14.3	22.7	28.5	33.8	33.9	30.4	24.6	18.3	13.7	9.9	7.5	Mosul
19.2	8.6	14	21.5	28.3	32.5	32.4	27.4	22.8	17.1	12.2	8.3	5.5	Irbil
18.7	10.9	13.5	21.6	28.1	32.3	32.2	28.4	22.1	16.2	10.7	7.3	5.2	Sulaimaniyah
22.2	10.9	16.6	25	30.7	35.5	35.4	31.9	26.5	19.9	14.7	10.8	8.8	Kirkuk
21.5	11.5	15.5	23.7	29.5	33.5	34	31.1	25.7	20.6	14.5	11.2	8.7	Khanagin
23.2	11.4	16.8	25.6	32.1	34.7	35	32.9	28.6	22.6	17.6	12.9	10.1	Baghdad
19.5	9.3	14.2	21.8	27.5	30.4	30.6	28.1	23.9	18.7	13	9.2	7.8	AL-Rutbah
23.6	12.1	17.5	26.2	32.1	34.8	34.3	32.8	29	23.3	17.4	13.2	10.9	Babil
24.3	12.4	18.1	26.4	32.5	35.9	36.5	34.3	29.9	24	17.7	13.4	10.8	Najaf
24.1	12.6	18.5	26.7	32	35.4	35.3	33.5	29.6	24.1	17.3	13.6	11.3	Diwaniyah
25.2	13.8	19.6	28	33	36	36.4	34.4	31	24.8	19.8	14.6	11.8	Nasiriyah
26	14.6	18.9	28.8	33.4	36.4	37.1	34.7	32.1	26.2	21	16	13.4	AL-Basara
	10.7	16	24.2	29.6	33.7	33.8	30.9	26.2	20.3	14.9	11	8.7	Average

Table (5)

Annual Average of Low Temperature In Iraq(C^0)For Period Of (1971-2007)

Average	Dec.	Nov.	Oct.	Sept.	Aug.	July	June	May	Apr.	Mar.	Feb.	Jan.	Station
12	2.5	8.5	13.9	17.6	23	229	20	15	10.4	6	2.8	1.4	Zaku
12.7	3	8.9	15.9	21.3	23.9	23.4	20.3	15.6	10.5	5.8	2.5	1.5	Salah- AL Dean
12.9	3.9	6.8	13.8	18.5	24	24.8	21	16.2	11.6	7.4	4.2	2.5	Mosul
13.1	4.3	9	16.3	21.4	24.4	23.8	20.6	15.9	11	6.4	2.9	1.6	Irbil
13.1	3.7	8.2	15.1	21.6	25.4	25.2	22.1	15.5	11	6.1	2.9	1.5	Sulaimaniyah
16	5.8	10.5	19.2	23.4	27.5	28	24.8	19.9	14.1	9.3	6.1	4.2	Kirkuk
13.6	6.3	8.1	14.3	19.5	24.1	24.6	21.9	16.8	12.5	7.3	5	2.9	Khanagin
15.5	5.2	9.6	16.7	21.7	25.5	26.3	24	20.7	15.6	10.5	6.5	4.1	Baghdad
12.4	3.7	7.6	14.1	19.2	22.4	22.8	20.3	16.1	11.4	6.6	3.1	2.3	AL-Rutbah
16.4	6.6	11	18.5	24.3	26.4	26	24.6	21.1	16	11	6.9	5.1	Babil
17.4	6.8	12	19	24.1	27.9	28.8	26.6	22.5	17.3	11.4	7.5	5.5	Najaf
16.8	7.3	11.8	18.5	23.1	26.3	26.9	25.2	22.3	17.1	11.2	6.8	5.5	Diwaniyah
17.7	7.7	12.5	19.5	24	27.3	27.7	25.9	23.2	18	12.9	8.3	6.1	Nasiriyah
18.8	8.7	13.4	20.2	24.4	28.1	28.6	26.4	24.9	19.6	14	9.6	7.7	AL-Basara
	5.3	9.8	16.7	21.7	25.5	25.6	23.1	18.9	14	9	5.3	3.7	Average

Table(6)

Annual Average of Max. Temperature In Iraq(C^0)For Period Of (1971-2007)

Average	Dec.	Nov.	Oct.	Sept.	Aug.	July	June	May	Apr.	Mar.	Feb.	Jan.	Station
23.8	10.2	18.8	37.8	34.1	39.8	38.3	34	27.8	20.1	14.9	11.5	8.8	Zaku
21.8	9.2	18.9	24.4	30.1	35.4	53.7	32.1	25.1	19.4	13.7	9.7	8.4	Salah- AL Dean
28.9	14.9	21.8	31.6	38.5	40.9	43.1	39.9	33.1	25.1	20.1	15.6	12	Mosul
25.3	12.9	19	26.8	35.3	40.7	41.1	34.3	29.8	23.2	17.9	13.7	9.4	Irbil
24.3	11.2	18.8	28.1	34.6	39.3	39.3	34.8	28.8	21.4	15.4	11.8	9	Sulaimaniyah
28.4	16.1	22.8	30.9	38	43.5	42.8	39.1	23.1	25.8	20.2	15.5	13	Kirkuk
29.6	16.7	23	33.1	39.6	43	43.5	40.3	34.7	27.8	21.9	17.5	14	Khanagin
31	17.7	24.1	34.6	40.6	44	42.7	41.9	36.5	9.6	24.7	19.4	16	Baghdad
26.6	14.9	20.9	29.5	35.8	38.4	38.5	35.9	31.7	26.1	19.4	15.4	16	AL-Rutbah
30.8	17.6	24.1	34	40	34.2	42.2	41.1	37	30.7	23.9	19.5	16	Babil
31.2	18.1	24.3	33.8	40.6	43.9	44.4	42.1	37.4	30.7	24	19.3	16	Najaf
31.5	18	25.2	34.9	40.9	44.3	43.9	41.8	36.9	31.1	23.5	20.5	17	Diwaniyah
32.8	20	26.7	36.5	42.1	44.8	45.1	42.9	39	31.7	26.7	20.9	17	Nasiriyah
23.2	20.6	24.4	37.4	42.4	44.8	45.6	43.1	39.4	32.8	27.9	32.5	19	AL-Basara
	15	22.3	31.6	38	42	9ز41	38.8	33.5	26.8	21	16.6	13	Average