

The Thermal Response of Multi-Storeies Concrete Frame Building in the Arabic Area

Ikhlass Sydnaoui, Roslli Bin Noor Mohamed, Mariyana Aida Binti Ab.Kadi*

Abstract: *In this paper, there will be an analysis study to figure out the impact of the environment thermal loads, shrinkage and creep at multi-storeies reinforced concrete frame buildings in the Arabic area. Etabs models will be prepared considering time dependent properties of concrete and non-time dependent properties, considering two columns heights as 3m and 6m, and two supports conditions as fixed and hinged to define the major aspects affect the thermal response of multi-storey concrete frame buildings concentrating at the thermal deformations and the columns reactions, then it will be compared with the thermal response of existing concrete building considering both methodologies of time dependent properties and non-time dependent properties of concrete to define the optimum methodology to be recommended and followed. The generated Etab models confirmed that the time dependent properties method is the optimum with a clear conversion between time dependent properties model and the existing parking thermal deformations. The increment in horizontal reactions under thermal loads due to column support condition is accompanied with a reduction in horizontal slabs deformations. Column height is inversely proportional to horizontal reaction values, finally, the importance of analyzing thermal loads fluctuation at columns reactions for multi storeies buildings whereas the reactions of multi storeies cannot be predicted from single storey analysis.*

Keywords: *time dependent, thermal; diversion; strains*

I. INTRODUCTION

It is essential for design to understand the behavior of reinforced concrete at early stages of construction and at whole life span of the structure, the concrete properties are not constant values, the mechanical properties vary with time in function of the progress of hydration process. This includes the concrete strength, the modulus of elasticity, shrinkage and creep [1]. Analyzing the structural response of reinforced concrete structure versus time changes in the volume of concrete is very complicated phenomenon. It is important to mention that CEP FIP,1990 code [2] provides complete process for time dependent properties of concrete considering creep effects and coefficients, concrete strengths range can be from 20 to 50 N/mm². The CEB FIP code provided estimated figures for total shrinkage for 70 years period in ordinary reinforced concrete with range of compression strength from 20 to 50 N/mm² in addition to values of concrete creep

coefficient. It will be inserted in ETABS model, time dependent properties input values. It is possible to construct super-long concrete members and slabs without providing joints hence the induced tension stresses are lesser than the tension capacity of concrete (Jun Lu et al., 2012) [4]. It will eliminate the appearance of tension cracks. The largest permitted length of concrete slab was fifty-five meters in Chinese standard. In some cases, stresses due to changes in climate temperature exceeded other loads values. This is noticed in constrained slabs while the effect of temperature fluctuation is ignored in non-restrained slabs. It is clear that the loads of temperature are composed of two main parts, these parts will be considered in my analysis too. The 1st part is related to seasonal climate changes and the 2nd part is related to shrinkage impact and equivalent thermal effects [4]. It was clear that creep coefficient at 20°C is 3.5 times lesser than as at 80°C. Superposition and interaction of humidity and temperature changes with the creep and the shrinkage of concrete are with similar nature. They impose increment in concrete deformations and creep [5] (Bazant and et al, 1997).

II. METHODOLOGY

A. used methods

Thermal expansion coefficient of concrete: the thermal expansion coefficient of concrete value of $9.9 \times 10^{-6} / ^\circ\text{C}$ can be used for unknown conditions of aggregate type and saturation degree of concrete [2]. Accordingly, this figure will be inserted in the finite element ETABS model. The Concrete compressive strength (f_c') is 40 N/mm². This value is commonly used in the Arabic area. Modulus of elasticity (E) is 30000 MPa as per ACI 318-14 equation [3].

$$E_c = 4750 \sqrt{f_c} \dots \dots \dots (1)$$

The mass of concrete per unit volume is 2400 kg/m³. The used temperature fluctuation between summer and winter is around 40°C as shown in figure 1 below, considering data collected for the last 30 years [5]. It clarifies the maximum mean value of daily temperature, the minimum mean value of daily temperature and the difference between these values. The maximum value of differences is noticed in Abu Dhabi, so it will be considered in this analysis. The maximum difference in temperature between January and August is in 2013. We will presume the construction took place in January under temperature 9°C. The highest temperature took place in August 48°C. In this case the difference is $48 - 9 = 39^\circ\text{C}$

Revised Manuscript Received on November 05, 2019.

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III. RESULT AND DISCUSSION

A. Analysis of deformations at peripheral columns

Tables (I) and (II) clarify the lateral deformations for external columns M, N and O. These deformations (UY) directions are parallel to axis Y and to the slab length as shown in figure 3. The results of 3D multi-storeies concrete frame buildings with hinged columns conditions are presented in table I, while deformations of 3D multi-storeies finite element models with fixed columns conditions are shown in table II. Slab thickness is considered 30cm. Columns heights are 3m and 6m. Temperature loads impose different horizontal deformations at peripheral columns M, N and O.

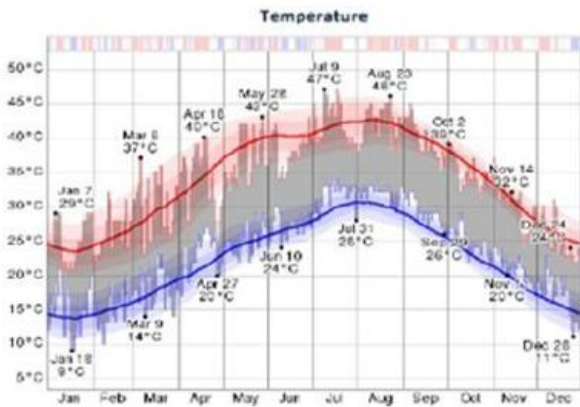


Fig. 1. The daily lowest and highest temperature during 2013(A.D.I.A, 2015)[5]

An analytical study was conducted to investigate the impact of temperature loads fluctuations on 3-D multi-storeies concrete frame buildings by using Etabs models to get better understanding of the temperature fluctuation impact on joints deformations and reactions. Figures (2) and (3) show the 3D view and the top view of a typical model. The discussion in the following section will compare the deformations and the reactions results for the peripheral columns M, N and O. at axis (a). These columns are shown in figure (3) which have the most critical values than internal columns. The reactions and the deformations of columns at axis (a) are similar to reactions and deformations at slab edge at axis (k) too (edge columns will suffer from maximum stresses and deformations under thermal loads).

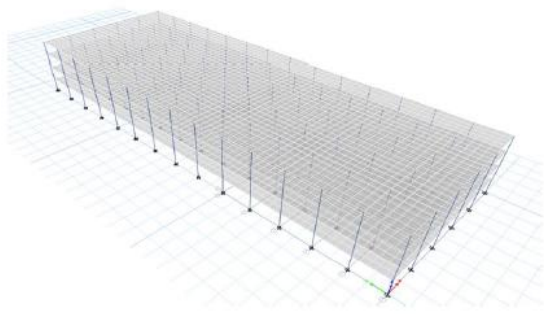


Fig. 2. Three dimensional view of the Etabs model for multi-storeies reinforced concrete frame building

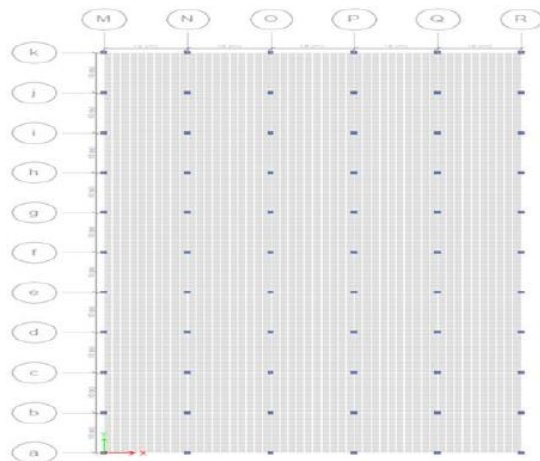


Fig. 3. The two dimensional plan view of the concrete frame building in Etabs model

Table- I : Deformations UY(M), UY(N) &UY(O) in (mm)at all levels , slab thickness 30cm with hinged columns condition

Slab Length(m)	Hinged columns conditions			Hinged columns conditions			Level
	Columns Height (3m)			Columns Height (6m)			
	UYM	UYN	UYO	UYM	UYN	UY O	Δ_0
50	9.902	9.902	9.902	9.9	9.9	9.9	10
60	11.871	11.871	11.871	11.9	11.9	11.9	12
80	15.8	15.8	15.8	15.8	15.8	15.8	16
100	19.76	19.76	19.76	19.8	19.8	19.8	20
120	No need, deformation exceeded allowed limit 16.67mm			23.8	23.8	23.8	24
140				27.7	27.7	27.7	28
160				31.7	31.7	31.7	32
180				35.6	35.6	35.6	36
200				39.6	39.6	39.6	40
50	9.87	9.87	9.87	9.9	9.9	9.9	10
60	11.88	11.88	11.88	11.9	11.9	11.9	12
80	15.9	15.9	15.9	15.8	15.8	15.8	16
100	20.1	20.1	20.1	19.8	19.8	19.8	20
120	No need, deformation exceeded allowed limit 16.67mm			23.7	23.7	23.7	24
140				27.7	27.7	27.7	28
160				31.7	31.7	31.7	32
180				35.6	35.6	35.6	36
200				39.6	39.6	39.6	40
50	10.1	10.1	10.1	10	10	10	10
60	12.3	12.3	12.3	12	12	12	12
80	16.4	16.4	16.4	16	16	16	16
100	20.65	20.65	20.65	20.1	20.1	20.1	20
120	No need, deformation exceeded allowed limit 16.67mm			24.1	24.1	24.1	24
140				28.3	28.3	28.3	28
160				32.5	32.5	32.5	32
180				36.6	36.6	36.6	36
200				40.7	40.7	40.7	40
50	9.22	9.34	9.37	9.8	9.8	9.8	10
60	10.94	11.1	11.14	11.7	11.7	11.8	12
80	14.17	14.47	14.49	15.5	15.6	15.6	16
100	17.24	17.6	17.65	19.2	19.3	19.4	20
120	No need, deformation exceeded allowed limit 16.67mm			22.9	23.1	23.1	24
140				26.5	26.7	26.7	28
160				30.1	30.2	30.3	32
180				33.5	33.7	33.8	36
200				36.6	37.1	37.2	40

Table- II : Deformations UY(M), UY(N) &UY(O) in (mm)at 1ST ,2nd 3rd and 4th level for slab thickness 30cm with fixed columns conditions.

Slab Length (m)	Fixed columns conditions			Fixed columns conditions			Δ_o	Level
	Columns Height (3m)			Columns Height (6m)				
	UYM	UYN	UYO	UYM	UYN	UYO		
50	9.9	9.9	9.9	9.902	9.902	9.902	10	4th
60	11.9	11.9	11.9	11.88	11.88	11.88	12	
80	15.816	15.816	15.816	15.84	15.84	15.84	16	
100	19.78	19.78	19.78	19.80	19.80	19.80	20	
120	No need, deformation exceeded allowed limit 16.67mm			23.8	23.8	23.8	24	
140				27.7	27.7	27.7	28	
160				31.7	31.7	31.7	32	
180				35.6	35.6	35.6	36	
200				39.6	39.6	39.6	40	
50	9.9	9.9	9.9	9.88	10	9.88	10	
60	11.9	11.9	11.9	11.85	12	11.85	12	
80	16	16	16	15.8	16	15.8	16	
100	20.2	20.2	20.2	19.75	20	19.75	20	
120	No need, deformation exceeded allowed limit 16.67mm			23.7	23.7	23.7	24	
140				27.69	27.69	27.69	28	
160				31.7	31.7	31.7	32	
180				35.6	35.6	35.6	36	
200				39.75	39.75	39.75	40	
50	10.2	10.2	10.2	10	10	10	10	2nd
60	12.3	12.3	12.3	12.01	12.01	12.01	12	
80	16.35	16.35	16.35	16	16	16	16	
100	20.3	20.3	20.3	20.18	20.18	20.18	20	
120	No need, deformation exceeded allowed limit 16.67mm			24.3	24.3	24.3	24	
140				28.5	28.5	28.5	28	
160				32.7	32.7	32.7	32	
180				36.6	36.6	36.6	36	
200				40.8	40.8	40.8	40	
50	8.3	8.5	8.6	9.58	9.64	9.66	10	
60	9.6	9.9	10	11.39	11.49	11.52	12	
80	11.9	12.48	12.58	14.89	15.1	15.1	16	
100	13.99	14.68	14.8	18.24	18.5	18.55	20	
120	No need, deformation exceeded allowed limit 16.67mm			21.5	21.8	21.87	24	
140				24.54	24.89	24.95	28	
160				27.3	27.7	27.8	32	
180				32.5	32.7	32.8	36	
200				32.6	33.1	33.2	40	

The deformations of the 2nd storey are slightly more than the other levels deformations (1st, 3rd and 4th). Deformations of the upper levels above the 2nd storey seem very close to the 1st storey displacements. Third and fourth levels deformations at all peripheral columns M,N and O have very close values with respect to the column height. The deformations of column O for all different slabs lengths from 50 to 200m are more than other analyzed columns M and N displacements at 1st storey level. The maximum deformations for hinged columns conditions aren't recognized at one column location, whereas all analyzed columns deformations have almost same values at same level, while, the maximum horizontal deformations for fixed columns conditions are recognized at column O at 2nd level as shown in table II. Due to this result, column deformations must be analyzed in multi-storeies concrete frame buildings considering the critical column O,. The columns M, N and O horizontal deformations above 1st slab level are close to Δ_o .

$$\Delta_o = \frac{1}{2} L_o \alpha \Delta t \quad (2)$$

Δ_o is thermal deformation for unrestrained slabs. It facilitates the structural engineer's prediction for displacements values. It is obvious that thermal strains at different levels have minor differences, so we can predict the thermal deformations from single storey models and utilizing same observations and equations formulas for deformations of single storey moment frame buildings at multi-storeies buildings. Consequently, we can use same allowed expansion joints spacing for single storey to be implemented in multi-stories buildings. whereas expansion joints spacings between two adjacent segments of the building are limited to the maximum allowed lateral deformations of H/180.

B. Analysis of reaction forces at peripheral columns

Tables III and IV present the horizontal reactions (FY) at peripheral columns M, N and O for fixed and hinged columns supports respectively. These reactions are parallel to the slab length.

Table- III: Reactions FY(M), FY(N)&FY(O) in (KN) for slab thickness 30cm with fixed columns conditions

Slab Length(m)	Fixed columns conditions			FYM/ FYO	Fixed columns conditions			FYM/ FYO
	Columns Height (3m)			Ratio	Columns Height (6m)			Ratio
	FYM(KN)	FYN(KN)	FYO(KN)		FYM(KN)	FYN(KN)	FYO(KN)	
50	1750	1868	1891	93%	313	322	323	97%
60	1978	2137	2165	91%	369.5	382.88	384	96%
80	2362.5	2585	2620	90%	476	497	499	95%
100	2667	2935	2975	90%	576	603	606	95%
120					675	709	712	95%
140					759	799	802	95%
160	These slabs lengths results will be ignored because deformation exceeded allowed limit 16.67mm				825	870	873.5	94%
180					890	940	930	96%
200					955	1008	1012	94%

Table- IV: Reactions FY(M), FY(N)&FY(O) in (KN) for slab thickness 30cm with hinged columns conditions

Slab Length(m)	Hinged columns conditions			FYM/ FYO	Hinged columns conditions			FYM/ FYO
	Columns Height (3m)			Ratio	Columns Height (6m)			Ratio
	FYM(KN)	FYN(KN)	FYO(KN)		FYM(KN)	FYN(KN)	FYO(KN)	
50	832	871	877	95%	73.5	76	76	97%
60	531	569	575	92%	87.3	91	91	96%
80	652	707	714	91%	114	119.3	119.6	95%
100	755	824	833	91%	139.3	146.3	146.8	95%
120					165.5	174.6	175.1	95%
140					188.5	199.3	200	94%
160	These slabs lengths results will be ignored because deformation exceeded allowed limit 16.67mm				210	222.6	223.2	94%
180					230	244.5	245	94%
200					249.5	265	266	94%

It is clear from these tables that the horizontal reactions for columns M, N and O are not constant for one slab length. Columns (N) and (O) reactions seem close to each other especially in hinged models. The corner column (M) reaction imposed by thermal loads seems lesser than reactions at columns (N) and (O). Column (M) reaction (the corner column) to internal columns reaction ratios varies from 94% to 97% for the hinged and the fixed columns conditions respectively. It gives us a clear idea about these loads' effects at footings sizes for these columns. Column N and O reactions seem very close for hinged conditions models. Due to the fact that column O reactions are more than the other two columns reactions for fixed columns conditions, column O reactions will be considered in the following discussions for more detailed analysis.

C. Results and analysis of reactions

In this section a detailed analysis is conducted to investigate the impact of temperature loads fluctuations in the Arabic area on peripheral columns reactions forces. The study results are presented in Figures 4 and 5. Temperature fluctuation value is 40C°.

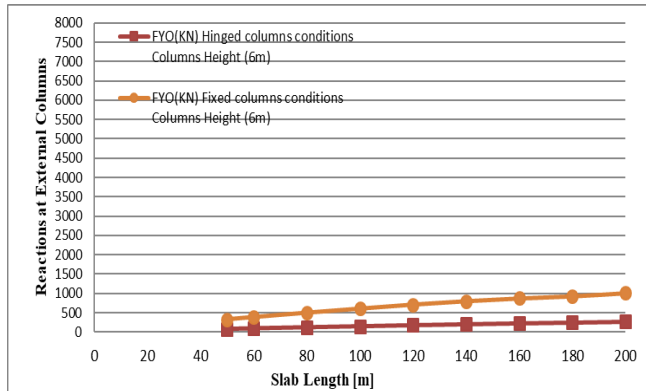


Fig. III. Horizontal reactions at peripheral columns slab thickness 30cm and columns height 6m.

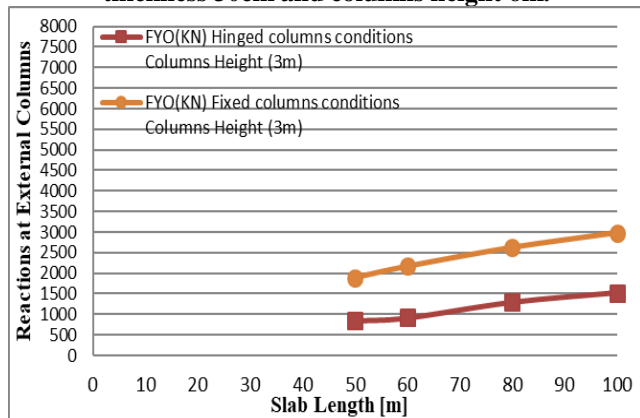


Fig. III. Horizontal reactions at peripheral columns slab thickness 30cm and columns height 3m.

Figures 4 and 5 present that horizontal reactions proportionally increase with slab length increase. Fixed columns horizontal reaction FY (parallel to slab length) are more than horizontal reactions of hinged columns conditions which means fixed columns models require bigger footings size than hinged models under thermal loads. Column height is inversely proportional to horizontal reaction values. It is clear that concrete frames result with fixed supports conditions and three meters of storey height impose the largest and the most critical values of reactions. Regarding the impact of the building height at the lateral reaction result of multi-storeies concrete frame building, table V shows that horizontal reactions related to fixed columns conditions with 3m height are 5 to 5.85 times larger than reactions related to fixed columns conditions with 6m columns height. This ratio increased to around 11 for hinged conditions models. Finite element models showed that this ratio will increase proportionally with the slab length reduction. It is reduced from 11.5 to 10.30 for models with 50m slab length.

Table- V: Ratios of 3m column height reactions to 6m columns height for multi-storeies concrete buildings

SlabLength(m)	Fixed conditions		FYO (3m) / FYO (6m)	Hinged conditions		FYO (3m) / FYO (6m)
	Column Height (6m)	Column Height		Ratio %	Column Height	

		t (3m)		(6m)	(3m)	
	FYO	FYO		FYO	FYO	
50	323	1891	5.8	76	877	11.5
60	384	2165	5.6	91	1026	11.2
80	499	2620	5.2	119	1290	10.8
100	606	2975	4.9	146.8	1514	10.3

Regarding the impact of columns condition support at lateral reaction result of multi-storeies concrete frame building, table VI shows that horizontal reaction related to fixed columns conditions with 6m height are 4 times larger than reactions related to hinged columns conditions with same columns height. This ratio reduced to around 2 for models with 3m columns height. Finite element models showed that this ratio will increase slightly with the slab length reduction. It is increased from 3.8 for slab length 200m to 4.25 for models with 50m slab length and column height 6m, this increment is observed too for 3m columns height models whereas it increased from 1.96 for slab with length 100m to 2.15 for the slab with 50m length.

Table- VI: Ratios of fixed columns reactions to hinged columns for multi-storeies concrete buildings

Slab Length (m)	Hinged column	Fixed column	FYO Fixed /FYO Hinged	Hinged columns	Fixed column	FYO Fixed /FYO Hinged
	Columns Height (6m)		Ratio	Columns Height (3m)		Ratio
	FYO (KN)	FYO (KN)	%	FYO (KN)	FYO (KN)	%
50	76	323	425%	877	1891	215
60	91	384	422%	1026	2165	211
80	119.6	499	417%	1290	2620	203
100	146.8	606	413%	1514	2975	196
120	175.1	712	407%	No need, deformation exceeded allowed limit 16.67mm		
140	200	802	401%			
160	223.2	873.5	391%			
180	245	930	380%			
200	266	1012	380%			

It is clear from previous tables that: the increment in horizontal reactions under thermal loads due to column support condition is accompanied with reduction in horizontal slabs deformations.

These results confirm the importance of analyzing thermal loads fluctuation at columns reactions for multi storeies buildings whereas the reactions of multi storeies cannot be predicted from single storey analysis and the footings are subjected to high horizontal reactions which has major impact at footings size and integrity.

D. Analytical Discussion of Experimental Study Results and Finite Elements Models

A comparison study between Etabs finite elements models for existing parking building and the registered tests results of Aboumoussa and Iskandar [2] experimental study for the thermal response of same existing building within period of five years will be presented.



3D Etabs models will be generated considering time dependent properties and non-time dependent properties of concrete. The results of Etabs finite elements models will be compared with actual thermal response of this building which was presented in Aboumoussa and Iskandar study to get a conclusion about recommended method for predicting thermal responses of concrete frame buildings. Four sensors are fixed in the experimental study, two sensors are at roof level while the others at level C (the third slab level) adjacent to the expansion joint edge. These sensors register the thermal displacement of the expansion joint at the north and the south parts of this building. Four Etabs models are generated considering time-dependent properties and non-time-dependent properties of concrete and reflecting the maximum variation of temperature for each sensor at north side of the building and at the south side too. Figure 6 clarifies displacement at level ©-south part of the building in Etabs non-time dependent properties(N.T.D.P) models, figures 7 and 8 present thermal displacements at roof level for sensor fixed at south part of the building for 4.5 years and 70 years respectively, While Figures 9 and 10 display thermal displacements at level C for sensor fixed at south part of the building for 4.5 years and 70 years respectively



Fig. 6. Horizontal displacement at level ©-south part of the building in Etabs N.T.D.P

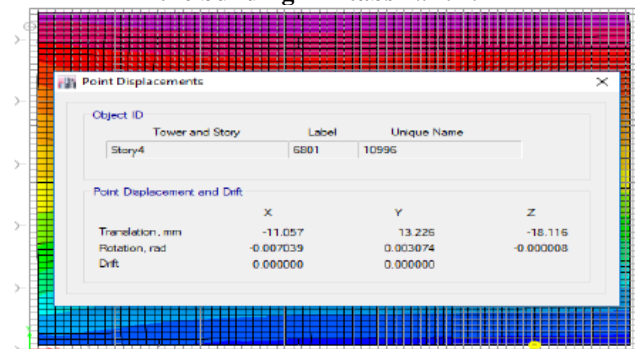


Fig. 7. displacement at roof level-south part of the building in Etabs T.D.P models for period 4.5 years

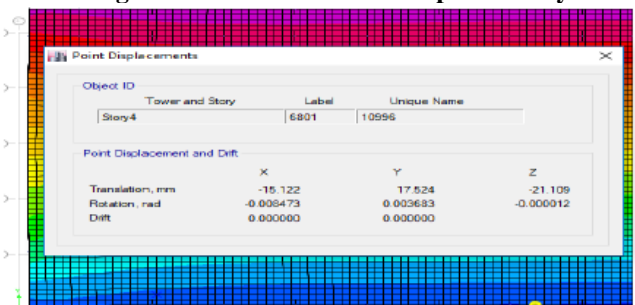


Fig.8. displacement at roof level-south part of the building in Etabs T.D.P models for period 70 years



Fig. 9. displacement at level C-south part of the building in Etabs T.D.P models for period 4.5 years



Fig.10. displacement at level C-south part of the building in Etabs T.D.P models for period 70 years

Table VII shows all ranges of displacements at the tests locations including all different methods. Firstly, the finite element models with non-time-dependent properties of concrete, then the time-dependent properties models with two different periods 4.5 and 70 years and finally the empirical test results by Aboumoussa and Iskandar. The displacements at north side seem very small, the allowed limit is $h/180=2750/180=15.27\text{mm}$, all values within 4.5 years period are lesser than 6mm. The north side displacements are not critical in all methods due to existence of huge retaining wall at north side, this wall reduced thermal displacements, small value of displacements don't have impact at expansion joint location, so north side is not the critical one.

The range of displacements at south side of the building are close to the allowed limit $h/180=2750/180=15.27\text{mm}$. This side deformations are the critical with direct impact at expansion joint location. The used methods presented different values of displacements. It is clear that the displacement of time-dependent ETABS model with 4.5 years period is very close to test results with 1mm approximately difference, while non-time-dependent properties model's results are lesser than tested results within 4.5 Years, so N.T.D. P. don't represent the deformations of all span life of the building since it is even lesser than imposed displacement within 4.5 years. The predicted deformations within 70 years are about 17.5mm, they exceeded the allowed limit 15.27mm. It is clear that the expansion joint location is not within code requirements CEB-FIP for 70 years period, it can be categorized as a reason for observed cracks within this building during its service life.

Table- VII: The range of displacements in (mm) at tested sensors and finite elements models considering T.D.P and N.T.D.P

Sensor side and level	N.T.D.P models	T.D.P. models		Test -sensors results Aboumoussa and Iskandar 2012
		4.5 years	70 years	
	UYM(mm)	UYM(mm)	UYO(mm)	Δ_s (mm)
Roof -south level	11.989	13.226	17.524	14.85
C-south level	12.06	12.787	17.191	13.89
Roof -north level	5.5	5	14	0.08
C-north level	6	6	13	0.08

IV. CONCLUSION

The temperature loads impose different horizontal deformations (parallel to slab length) at peripheral columns in 1st floor level. Conversion is clear in deformations values, but it is not identical. This difference in peripheral columns horizontal deformations values at first floor level are more recognized in fixed columns conditions than hinged columns. The horizontal reaction for peripheral columns is not constant for one slab length. Corner columns reactions imposed by thermal loads seem lesser than reactions at the other peripheral columns. Fixed columns footings sizes are almost similar under thermal loads while the difference in footings size is recognized in hinged columns conditions. The horizontal deformations values increase proportionally with the increase of column height and slab length. For non-time dependent properties study, the horizontal deformations of peripheral columns developed in unrestrained frame $\Delta_s = \alpha \cdot \Delta t \cdot (1/2L)$ was not exceeded. It can be proposed as the upper bound can be achieved for models with hinged conditions and more height columns. This limit was exceeded in time-dependent properties study. The deformations of the 1st level of multi-storeies are almost identical with single storey models. the deformations at the 2nd storey are slightly more than the other levels deformations (1st, 3rd and 4th). Deformations of the upper levels above the 2nd storey seem very close to the 1st storey displacements. It leads to same allowed values for spacing between expansion joints for both single and multi-stories concrete frame buildings. For multi-storeies buildings, the corner column (M) reaction imposed by thermal loads seems lesser than reactions at columns (N) and (O). Column M reaction (the corner column) to internal columns reaction ratios varies from 94% to 97% for the hinged and the fixed columns conditions respectively. This ratio is higher than was concluded for single story models which varied from %50% to %58% in single hinged concrete frame models and 81%-89% for fixed single storey models. Over all, multi storeies model's ratios are more than single storey models which refers to increment in corner column reaction in multi-storey building under thermal loads effects. the ratios of multi storeies models to single storeies is not proportional to storeies number, for fixed models, this ratio varied from 150% to 180% for both heights while hinged model's reactions ratios of multi-storeies to single storey are around 10 times for models with 3m column height and

reduced to around 4 times for models with 6m columns height. horizontal reaction related to fixed columns conditions with 6m height are 4 times larger than reactions related to hinged columns conditions with same columns height. This ratio reduced to around 2 for models with 3m columns height. Finite element models showed that this ratio will increase slightly with the slab length reduction. It is increased from 3.8 for slab length 200m to 4.25 for models with 50m slab length and column height 6m, this increment is observed too for 3m columns height models whereas it increased from 1.96 for slab with length 100m to 2.15 for the slab with 50m length. These results confirm the importance of analysing thermal loads fluctuation at columns reactions for multi storeies buildings whereas the reactions of multi storeies cannot be predicted from single storey analysis and the footings are subjected to high horizontal reactions which has major impact at footings size and integrity. A comparison study between Etabs finite elements models for existing parking building and the tests results of Aboumoussa and Iskandar (2012) of experiment study for thermal response of same existing building within period of 4.5 years are generated, the range of displacements at south side of the building are close to the allowed limit $h/180 = 2750/180 = 15.27\text{mm}$. This side deformations are the critical with direct impact at expansion joint location. The used methods presented different values of displacements. It is clear that the displacement of time-dependent ETABS model with 4.5 years period is very close to test results with 1mm approximately difference, while non-time-dependent properties models results are lesser than tested results within 4.5 Years, so N.T.D. P. don't represent the deformations of all span life of the building since it is even lesser than imposed displacement within 4.5 years. The predicted deformations within 70 years are about 17.5mm, they exceeded the allowed limit 15.27mm. It is clear that the expansion joint location is not within code requirements CEB-FIP for 70 years period, it can be categorized as a reason for observed cracks within this building during its service life.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the support of this research by UTM, Faculty Of Civil Engineering UTM.

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