Structural Engineering and Mechanics, Vol. 9, No. 3 (2000) 257-268

DOI: http://dx.doi.org/10.12989/sem.2000.9.3.257

A review of seismic design recommendations in Jordan

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Abstract. The seismic design recommendations of the Jordan Code for Loads and Forces (JC) are evaluated, based on comparisons with analytical studies and the Uniform Building Code. It was established that the overall safety ensured by the implementation of these recommendations is not consistent with the established seismic risk in Jordan and the intended objectives of the code. A new zoning map is proposed with effective peak ground acceleration values. The different period formulae of the code were studied and were found to grossly underestimate the fundamental period when compared with analytically derived values or other codes' formulae. Other factors including the dynamic, soil, importance and behavior factors are discussed. It was determined that the JC's lateral load distribution formulae clearly lead to smaller internal forces than both dynamic analysis and UBC loads, even when those loads are normalized to give the same base shear. The main reason for this is attributed to the limited allowance for a backlash force in the JC.

Key words: earthquake; seismic; code; lateral load.

1. Introduction

Jordan is situated in a moderate seismic zone, which is roughly equivalent to zone 2 to zone 3 as defined by the Uniform Building Code (UBC 1997). It has a history of earthquakes that is apparent from observing numerous archaeological sites in the country. Jordan was hit by more recent earthquakes, the latest of which shook the City of Aqaba in late 1995 and measured 6.2 on the Richter scale.

Recommendations for design of earthquake resistant structures were published in 1985 (JNBC 1985) and they basically cover the computation of equivalent lateral loads to be used in design. The Jordan Seismic Code (JC) is based on codes of countries in the conterminous area and reflects the knowledge and understanding prevalent twenty years ago. A wealth of knowledge has, in the meanwhile, been gained by the scientific community world-wide on the behaviour of structures, soil effect, philosophy of design of earthquake resistant structures, etc. This is reflected in the development of seismic codes in many regions in the world and in particular in the US (Luft 1989, McIntosh and Pezeshk 1997).

At the same time, the seismicity of Jordan has been studied by a number of researchers in recent years (Abou-Karaki 1987, Al-Tarazi 1992, Fahmi *et al.* 1992, Malkawi and Fahmi 1996) using historical data, seismological records and strong motion data recorded since 1993. A network of 15 strong motion stations now covers the whole seismically active zone in Jordan.

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An examination of the JC is thus overdue. This paper sheds light on the shortcomings and limitations of the present code and seeks to propose modifications to be incorporated in the new version of the code, which is currently under study. The bases of the evaluation of code clauses shall be: other codes (particularly the UBC), experimental data reported by others, observations from recent earthquakes in Jordan and other locations, and finally analytical studies involving more subtle representations of structures than those involving linear static modelling. A number of studies were performed with the aim of evaluating Jordan's recommendations for seismic loading (Kabalawi 1997, Al-Qudah 1996, Saffarini *et al.* 1989, Saffarini 1998). Some of these findings will be reported and discussed here. In this paper an attempt is made to examine the different versions of seismic recommendations in the UBC. This will serve to reveal the process of their development and thus allow better understanding of the philosophy behind their empirical formulae and also shall provide a motivation for the revision of the JC.

2. Synopsis of the Jordan recommendations for earthquake loads

The JC stipulates that the equivalent lateral force per floor is to be calculated using the following formula:

$$F_z = \alpha \cdot \beta \cdot \gamma_z \cdot \delta \cdot \theta \cdot \eta \cdot W_z \tag{1}$$

Where, α is the intensity factor, β is the dynamic factor, γ_z is the height factor, δ is the soil factor, θ is the behaviour factor, η is the importance factor and W_z is the floor weight to be assumed in the analysis. The latter is equal to the dead load plus a fraction of the live load.

3. Seismicity and the intensity factor

The Code divides Jordan into four zones with a varying from 0.1 for zone D in the eastern desert to 0.75 for zone A in the Jordan Valley and Aqaba region. This is shown in Fig. 1. It must be noted that over 90% of Jordan's population reside in zones A and B. Many studies were conducted on the seismic hazard of Jordan since the publication of the code. Most notably Al-Tarazi (1992) completed a Ph.D. dissertation in 1992 in which he compiled a new comprehensive earthquake catalogue, based on a number of sources, for earthquakes occurring in Jordan and adjacent vicinity in the period 1-1989 AD. Al-Tarazi proposes two zoning maps for Jordan, one based on a point source model (PSM) and the other based on a line source model (LSM). The latter gives higher PGA values in the near-field. The map produced based on the LSM model appears to be conservative and in fact is not consistent with other studies including the one conducted by Fahmi *et al.* (1996). The PSM map is reproduced in Fig. 2. This seems to be more realistic and compares reasonably well with available literature, while significant deviations in magnitude from Fahmi *et al.* (1996) remain due to the stochastic nature of the problem. The study by Al-Tarazi depends on the upper bound magnitude of the Dead Sea-Wadi Araba fault alone.

The inclusion of the 1995 Aqaba earthquake in the statistical analysis is likely to influence this proposed map particularly in the Aqaba region. Malkawi and Fahmi (1996) conducted a study on the seismic hazard of the City of Aqaba and produced a seismic risk map for the Aqaba region.

As these referenced studies estimate the peak ground acceleration (PGA) with 10% probability of

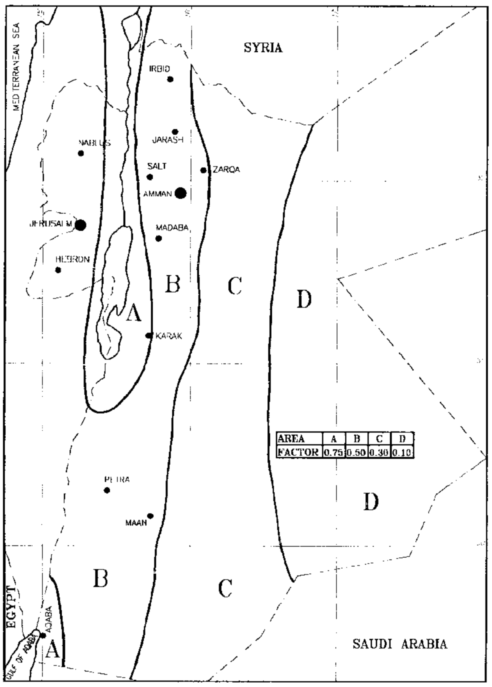

Fig. 1 Zoning map of the JC (JNBC 1985)

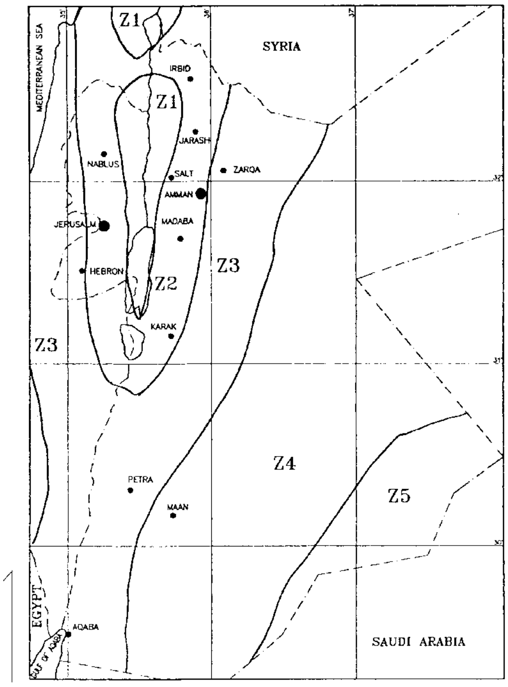

Fig. 2 Jordan's zoning map reproduced after Al-Tarazi using PMS model (Al-Tarazi 1992)

Table 1 Zoning modified from proposal by Tarazi (1992)

Zone	PGA (cm/s^2)	EPA (g)
Z1	>250	0.25
Z2	200-250	0.20
Z3	150-200	0.16
Z4	75-150	0.12
Z5	<75	0.06

being exceed in 50 years, they need to be adjusted to give the effective peak ground acceleration EPA. This may be obtained by multiplying the PGA by 0.82 (Gulkan 1990). The resulting expected EPA values are listed in Table 1.

Based on the aggregate results of the previous studies and using interpolations and rounding up, a proposed map of EPA with 90% probability of not being exceeded in 50 years is shown in Fig. 3. It is suggested that as is implied in the Uniform Building Code (UBC 1997), these values would be used directly as intensity factors. This, of course, would require a modification of the form of the code formula. This is further elaborated in the paper.

4. Dynamic factor

The dynamic properties of the structural system and the properties of the expected earthquake are

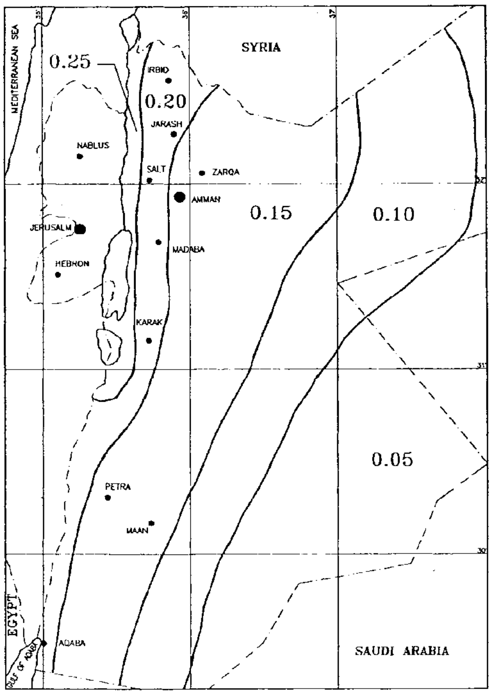

Fig. 3 Proposed zoning map showing EPA values

expressed in terms of the dynamic factor. This factor is basically taken from a simplified response spectrum, which is expressed in the JC using inverse cubic root functions of the period ($T^{-1/3}$) with upper and lower limits. Multi-story buildings are categorised into two cases, one with normal density partitions and the other without partitions or with low-density partitions. The dynamic factors are plotted in Fig. 4. The same figure shows the UBC dynamic factor formulae for the (UBC 1985) and (UBC 1988) versions. The 85 version of the UBC contained parameters which are similar to those of the JC. The seismic zone factor ranges from zero to one. Zone 3 in UBC 85 has a seismic zone factor value of 0.75 while zone A in JC has an intensity factor of 0.75. The importance and type of structure factors of UBC 85 are almost identical to those of JC. It is thus easy to compare these two codes. However in 1988 the UBC underwent substantial changes and was not changed substantially there after until 1997. The 88 factors are thus normalised to enable comparison with the 85 factors and the JC. This is achieved by dividing the UBC 88 dynamic factor C by 2.5 as the zone factor definition has changed from 1.0 to 0.4 for zone 4. The UBC 88 dynamic factor is also divided by 8 to account for the new approach to allowing for ductility and redundancy. Rock foundation is assumed once and alluvium another time. For the JC, soil magnification is taken as one. That is, no amplification or de-amplification are assumed.

It is clear from Fig. 4 that the dynamic factor implied by the JC is substantially lower than that of the UBC particularly for the case of lower buildings of short periods and where normal density partitions are used. This construction is in fact the most prevalent system in Jordan. It must also be born in mind that the fundamental periods of structures, as a matter of common practice, are computed for the bare structural frame and do not incorporate the partition stiffness. As the latter influences the system's stiffness and thus the real response, a gross error in the period calculation is to be expected which is then added to an underestimation built in the dynamic factor formula to give critically low estimates of the equivalent static loads.

The difference in approach between the recent UBC 97 code and the JC makes the comparison of the JC's dynamic factor with a corresponding parameter in the UBC 97 code rather difficult. The UBC 97 uses seismic coefficients *Cv* and *Ca* which incorporate the zone as well as the soil factors. The lower limit is also made dependent on the type of structure to avoid unreasonably small seismic forces in ductile structures. The JC coefficients are normalised for comparison with UBC 97. A plot is made in Fig. 5 of the *VR*/*W* values for the UBC 97 and their corresponding values in the JC. *V* is the base shear, *R* is the ductility factor and *W* is the seismic weight. It must also be noted that UBC 97 gives loads based on strength approach, thus they are boosted by a multiplier of about 1.4 as will be pointed out later. This is allowed for in the normalisation of JC values. The underestimation of forces by the JC is evident for low period values. What is also clear is the flatness of the JC spectrum. This is numerically due to the use of $T^{-1/3}$ relationship. In the UBC 97 the relationship in the *Cv* expression is based on T^{-1}, while in the UBC 88 and 94 it was based on $T^{-2/3}$. The UBC 85 used $T^{-1/2}$. In other words the JC is the flattest and the UBC expressions for the dynamic factor have continuously been made steeper from 1985 up to 1997. As a result of the increase in the exponent fraction in the newer UBC versions, the plateau of the spectrum in the low period range widens. The JC plateau is quite narrow as can be seen in Fig. 5.

5. Empirical period formulae

As stated earlier, the dynamic factor and thus the equivalent loads are sensitive to changes in period estimates. The JC does allow the computation of period from empirical formulae or by other more rigorous procedures. The results of these two approaches often diverge. In a study by Saffarini *et al*. (1989) to evaluate the period formulae of the JC as well as those of the UBC 85, it has been shown that the empirical formulae of both codes grossly underestimate the period of the structural frame. In that study a large number of buildings were designed and their exact and empirically based periods were calculated. The empirical estimates were as low as one quarter the theoretical evaluations. Smith and Crowe (1986) had reported that the simple UBC formula underestimates the

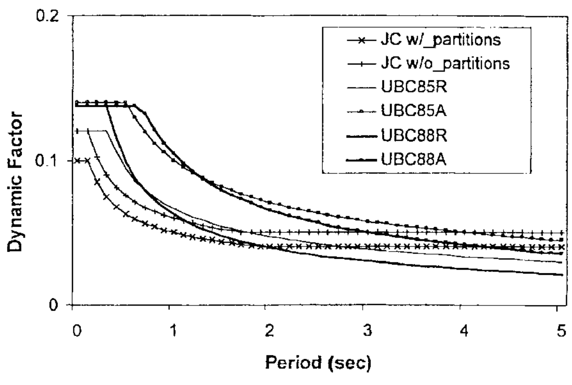

Fig. 4 Normalized dynamic factor of the JC, UBC 85 and UBC 88

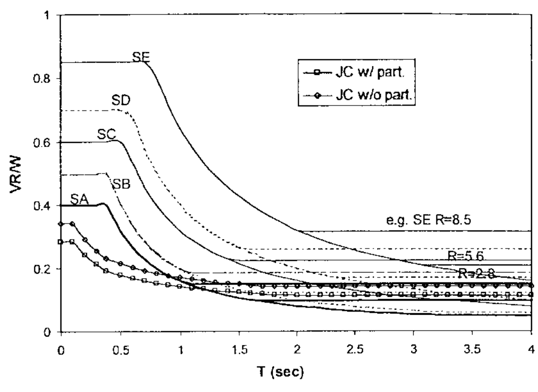

Fig. 5 Lateral load coefficient of the UBC 97 and the corresponding values of the JC (For each soil type a lower limit is set depending on *R*)

period for coupled walls, braced frames and particularly for rigid frames. The UBC formula has, nonetheless, been modified since the publication of the above two studies. Furthermore the UBC have recognised the importance of minimising the gap between lateral forces computed on the basis of the empirical period T_A and those using analytically derived periods. It is stipulated in the UBC 97 that the lateral forces should not be less than 80% of those based on the empirical period. An upper limit is also imposed on the computed period values. This limit is $1.3T_A$ for zone 4 and $1.4T_A$ for zones 1-3. This is perhaps to avoid using longer theoretically calculated periods, which may not account for the contributions of secondary structural members and non-structural elements.

Fig. 6 shows a comparison between the different code formulae of the JC and the two versions of the UBC. The formulae that are compared are specifically:

1. UBC 97 formulae for steel and concrete moment resisting frames and that of "other" types, which are denoted St 97, RC 97 and O 97 respectively. These formulae have been incorporated in the UBC since 1988.
2. UBC 85 specifies one formula for both concrete and steel moment resisting frames and this is denoted here as StRC 85. Period formula for "other" structural systems is dependent on building depth thus two depths are investigated, namely 20 m and 40 m. The results are denoted 85 D20 and 85 D40, respectively.
3. The notation for the JC formulae are almost self-explanatory, with J for common construction in Jordan, JSW for shear wall buildings and JRC and JSt for moment resisting concrete and steel frames respectively. The depth of the building is expressed as D20 and D40 for 20 m and 40 m deep buildings.

It has already been noted that the building code formulae generally underestimate the period. The UBC 97 estimates of the period are, nonetheless, substantially larger than those of the 1985 UBC code. While the JC has two distinct formulae for moment resisting frames, one for steel and one for concrete, these are not compatible with those of the UBC. The estimate of period for steel frames by the JC may be as high as four times that of the UBC 97 for low buildings. This ratio goes down

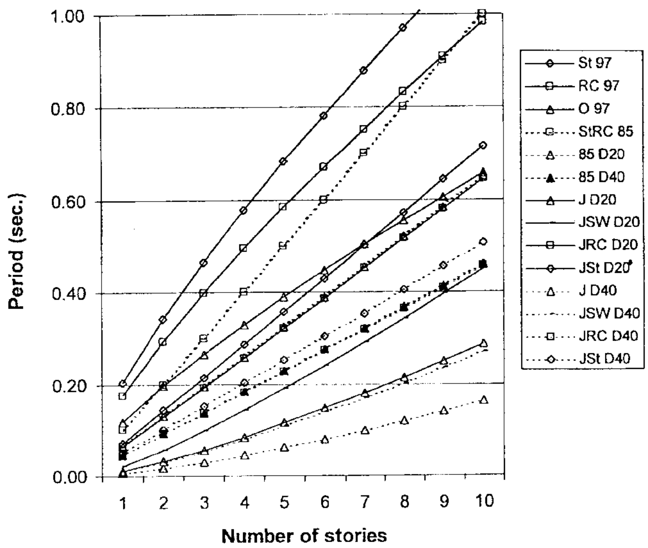

Fig. 6 Empirical period formulae of the JC and UBC

to about two for tall buildings. In general it is observed that the disparity between the JC and the UBC 97 is highest for lower buildings of all types. It is also worth noting that the UBC 85 also underestimates periods of lower buildings but to a lesser extent than the JC. Theoretical values of period are not computed here as those may only be derived for the specific cases where dimensions and sizes are known. However, from the study by Saffarini *et al.* (1989) and from other calculations made by the author, it may be stated that the new formulae of the UBC are much closer to theoretical period values than those of JC and UBC 85. The proposed formula for rigid frames of Saffarini *et al.* (1989) gives even closer values to the theoretical period than the UBC 97 but it requires more designer input about the geometry of the structure.

The present formulae of the JC thus severely underestimate the period but are hence more conservative, and while this tends to offset the underestimation of loads resulting from the dynamic and intensity factors, the level of safety is neither uniform nor consistent. It is to be noted furthermore that the code permits the use of theoretical estimates for the period without any lower limit on the resulting loads. This means that any conservatism in the period estimation may not be relayed on.

6. Soil factor

The JC deals with the issue of soil amplification by the use of the site-structure resonance factor, in a similar way to that of the UBC 85. The formula for the soil factor is:

$$0.8 < \delta = 0.7/(T - T_s)^{1/3} < 1.3 \qquad (2)$$

If the period of the soil T_s is larger than the period of the structure T then δ is taken as 1.3. A plot of the soil factor is made in Fig. 7 for four types of soil, which are expressed in terms of their period T_s (.2, .4, .6, .9 and 1.4 sec.). These are defined in the JC respectively as rock, rock overlain by shallow soil, dense or stiff soil of 15 to 80 m depth, soft or loose soil of up to 140 m depth and finally loose soil of depths exceeding 140 m or fill.

The approach of the JC is to allow for the soil-structure resonance but to maintain a high factor for softer soils even where the periods of structure and soil are not close. This approach is also seen in other codes in the region such as the Turkish and Israeli seismic codes. The UBC has abandoned

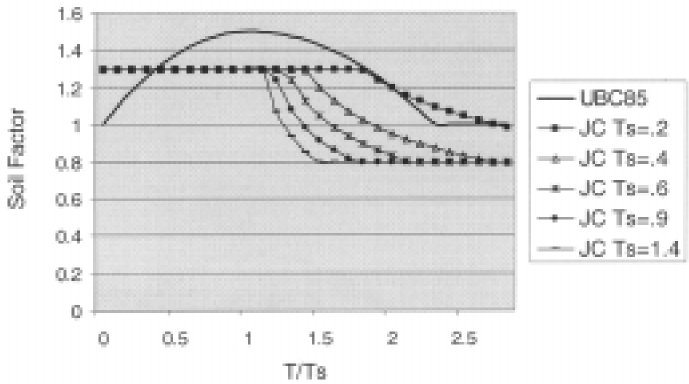

Fig. 7 Soil factor of JC and UBC

since 1988 the site-structure resonance factor in favor of a soil factor, which is purely dependent on the site condition. The value of the new factor ranges from 1 for rock to 2 for deep soft clay profiles. Fundamental modifications were made in the allowance for the soil type in view of studies conducted in the aftermath of the Loma Prieta earthquake (McIntosh and Pezeshk 1997). Soil types S_A through S_F were defined in the NEHRP provisions of 1994 (NEHRP 1995). These were later adopted by the UBC of 1997. The UBC spells out a rational procedure for defining the soil type that is appropriate for the site under investigation.

Fig. 7 shows that the soil effect as stipulated in the JC is underestimated, when compared with the UBC 85. In the 1995 Aqaba earthquake it was observed that sites near the shoreline, where deep alluviums constitute the soil profile, recorded more than twice the ground acceleration and also produced significantly higher response spectra (Saffarini 1998). The largest damage was noted in some of the shoreline buildings.

The need for a review of the soil effect in the JC stems from the fact that the code's formula is sensitive to the accuracy of the soil and structure periods. It is often quite difficult to make a good evaluation of the period of the soil. It is also of particular importance that no reduction should be allowed in the lateral loads for flexible structures on stiff soils as in fact is the case in the JC. This reduction can now be up to 20%.

7. Distribution of equivalent lateral load

The JC as with other seismic codes, provides recommendations for distribution of equivalent lateral loads. Two main methods are specified for depicting the lateral loads. The first is a function of height h_z and weight W_z of story and is broadly similar to that of the UBC.

$$\gamma_z = h_z \sum W_z \cdot h_z / \sum W_z \cdot h_z^2 \tag{3}$$

The other incorporates the computed story drift A_z and is thus based on the Improved Rayleigh Method.

$$\gamma_z = A_z \sum W_z \cdot A_z / \sum W_z \cdot A_z^2 \tag{4}$$

The formula in Eq. (3) shall be termed the height method (JCht) and that in Eq. (4) shall be referred to as the displacement method (JCds). In both cases the JC computes the story loads first and then sums for the base shear. The opposite is true in the UBC.

JC allows for a backlash force at the top of the structure for the case where the ratio of building height (H) to the width (D_s) of the main bracing element in the direction of the EQ is larger than 3. For the case of moment resisting frames, such a force is not allowed for. The value of this force F_n and its limit as a portion of base shear V is given in Eq. (5) below.

$$F_n = 0.004\ (H/D_s)^2\ .\ V < 0.15\ V \tag{5}$$

It must be stated that the UBC relates both the magnitude and the need for the top force to the fundamental period of the structure regardless of the framing system. This shall be shown to be more prudent.

To appraise the JC lateral load distribution formulae, these loads are computed for a number of selected buildings using each of the JC's methods and are also calculated using the UBC's formula. The results are then compared with those obtained from dynamic modal analysis of the structure.

The dynamic analysis is based on the UBC recommended design spectrum. Of interest in these comparisons are the distribution of loads along the height and the resulting overturning moment. The latter shall serve to quantify the impact of different load distributions on internal forces. All loads are normalised to give the same base shear.

The buildings that were chosen for the comparison are five (5S) and fifteen (15S) stories in height. Each has three bays of 6m spans. Three structural systems were considered: a) regular moment resisting frame with equal story heights and weights RMRF5S & RMRF15S, b) regular shear wall-moment resisting frame RSWF5S & RSWF15S and c) irregular moment resisting frame with increased mass in the first floor IMRF5S & IMRF15S. Table 2 gives a summary of the error in the formulae as compared to dynamic analysis results.

The load distributions along the height of the building for two of the above six structures are shown in Fig. 8 and Fig. 9 for RMRF15S and RSWF15S respectively. By studying those results and other complementary investigations a clear understanding of the limitations of the JC height formulae may be formulated. These are some of the findings:

- The JC generally underestimates the overturning moment, which is computed from lateral loads using statics. It should be noted that the UBC on the other hand tends to be conservative in computing the OT moment.
- The obvious shortcoming of the JC comes from not permitting a backlash force for all moment resisting frames and limiting its requirement to braced systems and only when the height method is used. It may thus be noted from Fig. 9 and Table 2 that the height method with the backlash force gives much more accurate results than the displacement method, in spite of the additional effort required by the latter. Analysis is repeated for the frames using the JC formulae while

Table 2 Error % in JC and UBC formulae for lateral load distribution

Framing System	Code Formula	Equivalent Lateral Load			Overturning Moment		
		First	Middle	Top	First	Middle	Top
RMRF5S	UBC97	−15	−2	11	4	6	11
	JCht	−9	7	−4	0	−1	−4
	JCds	−23	16	−11	−2	−3	−11
RMRF15S	UBC97	−65	20	17	7	6	17
	JCht	−59	41	−43	−5	−11	−43
	JCds	−79	54	−49	−7	−15	−49
RSWF5S	UBC97	69	8	−15	−8	−10	−15
	JCht	68	8	−15	−8	−10	−15
	JCds	64	18	−23	−11	−15	−23
RSWF15S	UBC97	18	32	−21	1	−2	−21
	JCht	12	24	−4	5	4	−4
	JCds	−67	42	−47	0	−4	−47
IMRF5S	UBC97	−48	32	0	5	5	0
	JCht	−40	42	−15	−1	−3	−15
	JCds	−40	55	−23	−5	−8	−23
IMRF15S	UBC97	−68	22	15	8	6	15
	JCht	−63	43	−44	−5	−11	−44
	JCds	−81	57	−50	−7	−15	−50

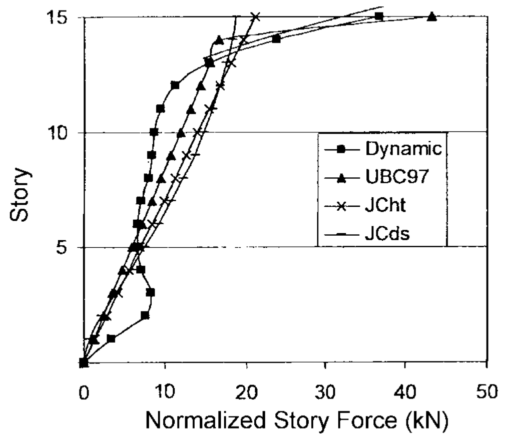

Fig. 8 Lateral load distribution for RMRF15S for JC, UBC and dynamic analysis

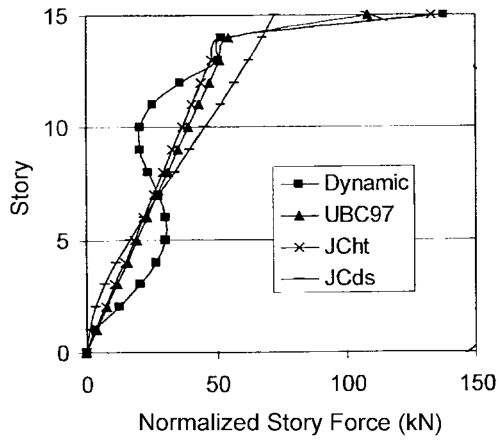

Fig. 9 Lateral load distribution for RSWF15S for JC, UBC and dynamic analysis

incorporating the backlash force contrary to code restriction, and it is found that remarkable improvement is achieved.

- The displacement method does not seem to be effective in improving the level of accuracy of results over the height method where irregularities in story masses are found. This is the case because neither method is able to capture the contribution of higher modes.

8. Other factors

The importance factor in the JC is dealt with as in the UBC 85 except that the factors are 1.3 for essential buildings, 1.2 for assembly buildings and 1.0 for other occupancies. The UBC 85 has the same classification but gives importance factors of 1.5, 1.25 and 1.0 respectively. The UBC 97 is more subtle in handling the issue of importance. It uses smaller factors and imposes additional requirements.

The JC imposes a live load incidence factor for essential buildings. This further increases the lateral loads for such buildings without real justification. Silos and tanks are to be assumed fully loaded. Otherwise no fraction of the live load or snow needs to be assumed as permanent. This is clearly quite different from the UBC requirements. Of particular interest is that the Jordan Code for Loads and Forces specifies snow loads well in excess of 1.44 kN/m^2 for mountainous areas, which is the limit set by the UBC for inclusion of snow as part of seismically active load. The climate in Jordan on the other hand does not allow prolonged snow accumulation and it is recommended that only 25% of snow load be incorporated in seismic calculations when this load exceeds 1.44 kN/m^2.

The behaviour factor θ in the JC corresponds exactly to the structure type factor k of UBC 85. The approach, since the UBC 88, has been changed significantly in view of experience with performance of different systems in previous earthquakes. The values of the ductility factor R in the UBC 97 have been modified from those R_w values in the UBC 88 and UBC 94. The reduction ranges between 1.33 and 1.47 with a nominal value of 1.4. This is because the UBC 94 and earlier versions use a working stress approach while the UBC 97 uses a strength approach.

The scope of this paper does not cover the special requirements that need to be incorporated to deal with vertically or horizontally irregular buildings, nor does it cover dynamic analysis procedures. Major improvements to the JC are needed in this regard.

9. Conclusions

The paper presents a brief critique of the various recommendations of the JC. The following conclusions may now be made:

1. The overall safety ensured by the implementation of the JC is not consistent with the established seismic risk in Jordan and the intended objectives of the code. Of particular concern are the intensity factor, the dynamic factor, the soil factor and the load distribution.

2. The period formulae in the code underestimate the fundamental period and thus overestimate the loads offsetting only partly (1) above. If the designer chooses to compute the period by more rigorous techniques the resulting equivalent loads are likely to remain none-conservative.

3. In lieu of a revision of the JC, it is recommended that the UBC 97 be used together with the zoning map proposed in Fig. 3 of this paper.

4. Revision of the JC is needed in particular with regards to the following:

– Effective peak ground acceleration map needs to be introduced and zoning must be revised.

– The soil factor should be revised to reflect damage caused by soil amplification of ground motion in recent earthquakes in Jordan and other areas. This factor should not be less than 1.0.

– The lateral load distribution formulae clearly lead to smaller internal forces than dynamic analysis or UBC loads, even when those loads are normalized to give the same base shear. An immediate correction to this can be obtained by lifting the restriction on the use of the backlash force in the case of moment resisting frames and in the case where the JC's displacement method is used.

Acknowledgement

This research has been conducted during the sabbatical leave of the author from the Department of Civil Engineering at the University of Jordan.

References

Abou-Karaki, N. (1987), "Synthese et carte sismotectonique des pays de la bordure orientale de la Mediterranee: sismicite du systeme failles du Jourdain Mer Morte", Ph.D. thesis, IPGS, Univ. Strasbourg, 417 (in French).

Al-Qudah, O.M. (1996), "Effect of irregularity of structures on their dynamic response". M. Sc. thesis, Supervised by H. S. Saffarini, University of Jordan.

Al-Tarazi, E. (1992), "Investigation and assessment of seismic hazard in Jordan and its vicinity", Ph.D. thesis, Berichte des Instituts fur Geophysik der Ruhr-Universitat Bochum, 417.

Fahmi, K.J., Malkawi, A.H. and Al-Zoubi, O.Y. (1996), "Seismic engineering ground motion maps for Jordan employing local attenuation relations". *Environmental and Engineering Geoscience*, **II**(1), 23-33.

Gulkan, P., Mayes R.L. and Clough, R.W. (1990), "Seismic testing of single-story masonary houses: Part 1", *J. Struct. Engrg.*, ASCE, **116**(1), 234-255.

Jordan National Building Code (1985), Loads and Forces Code, Chapter Five, Earthquake Forces, Amman,

Jordan.
Kabalawi, H. (1997), "Formulation of design response spectra for Jordan". M. Sc. thesis, Supervised by H. S. Saffarini, University of Jordan.
Luft, R.W. (1989), "Comparison among earthquake codes", *Earthquake Spectra*, **5**(4).
Malkawi, A.H. and Fahmi, K.J. (1996), "Probababilistic earthquake hazard analysis and dynamic site response evaluation of Aqaba port city southern Jordan", Jordan University of Science and Technology & Yarmouk University, Report.
Malkawi, A.H. and Fahmi, K.J. (1996), "Locally derived earthquake ground motion attenuation relations for Jordan and conterminous areas", *Quarterly Journal of Engineering Geology*, **29**, 309-319.
McIntosh, R.D. and Pezeshk, S. (1997), "Comparison of recent U.S. seismic codes", *J. Struct. Engrg.*, ASCE, **123**(8), 993-1000.
NEHRP (1994), "Recommended Provisions for the Development of Seismic Regulations for New Buildings", Ed. (1995) Build. Seismic Safety Council, Washington, D.C.
Saffarini, H.S. (1998), "Characteristics of the Aqaba 1995 Earthquake", Submitted for review, *Engrg. Stuct. the Journal of Earthquake, Wind and Ocean Engrg*.
Saffarini, H.S., Abdel-Fattah, B. and Tayem, A. (1989), "A rational period formula for framed buildings", *Dirasat*, **16**(5), 69-90, University of Jordan.
Smith, S. and Crowe, E. (1986), "Estimating periods of vibration of tall buildings", *J. Struct. Engrg.*, ASCE, **112**(5), 1005-1019.
Uniform Building Code. (1985), International Conference of Building officials, Whittier, Calif.
Uniform Building Code. (1988), International Conference of Building officials, Whittier, Calif.
Uniform Building Code. (1994), International Conference of Building officials, Whittier, Calif.
Uniform Building Code. (1997), International Conference of Building officials, Whittier, Calif.