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The Clock Tower (Ghantaghar)
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A Note from the Publication Committee

First of all, we would like to express heartfelt gratitude to all the contributors and well-wishers including the authors and readers. We also wish a very happy new year 2054 B.S. to all !

The present issue of the journal is in a way a special issue on 'Earthquake' as it covers articles on earthquake problems and possible measures to be adopted in building structures for overcoming possible loss of life and property in future. Most of the articles were presented in a seminar on earthquake organized by Nepal Engineering College (nec). The journal also contains some other articles related to science and technology.

From December 27 to December 28, 1996, nec had organized a seminar on EARTHQUAKE DESIGN CRITERIA FOR NEPAL, the first seminar of its kind held in Nepal on the national level, under its policy to organize seminars and talk programs along with its regular teaching-learning activities. The seminar was really significant in producing fruitful results. It was actively participated by many national and international experts. To name a few, Prof. Ram Krishna Poudel from the Institute of Engineering (IoE); Prof. Prem Nath Maskey from IoE; Dr. A. K. Jain, the Visiting Professor to nec, from the University of Roorkee, India; Dr. R. P. Lohtia, the Visiting Professor to IoE, from the University of Calgary, Canada and Prof. Li Tianchi from China, currently engaged in ICIMOD were among the participants.

Due to some circumstances the publication of SCITECH Nepal, the journal was delayed. We deeply apologize for it. We will make all our efforts to bring the subsequent issues of this journal on time.

Efforts have been made to publish the articles as they were presented by the authors as far as practicable. The ideas and information contained in the articles are the writers' own. The Committee does not assume any responsibility for the adverse effect (if any) resulting from them.

Finally, we look forward to getting comments and suggestions for the betterment of the coming issues of the journal.

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SEISMIC DESIGN OF BUILDING IN NEPAL - AN APPRAISAL OF NBC 105 - 1994

*Prof. Dr. Ashok K Jain**

SUMMARY

The design of buildings to resist earthquake forces should now conform, to the newly introduced NBC 105-1994 code of Nepal. This document has been written in a simple and precise language. The specifications are brief without any ambiguity. It makes use of a single curve to estimate the basic seismic coefficient for the seismic coefficient method as well as for the modal response spectrum method. It is largely based on the New Zealand Code NZS 4203-1992 and IS:1984 code. Suggestions are made to make the Nepal NBC code more useful.

INTRODUCTION

The evolution of codal specifications is an iterative process. The specifications are updated as more data become available from laboratories and field experience. In December 1995, Nepal introduced her first code on seismic design of buildings NBC 105-1994. It

has been presented in a very simple language. The seismic analyses of buildings can be carried out either statically or dynamically depending whether the building is regular or irregular. Some codes define regularity based on the geometric considerations while others make use of storey displacements. Most codes prescribe that the point of application of the inertial forces be displaced from the nominal

location of the centre of mass by quantities: additional eccentricity and accidental eccentricity. The former is prescribed when a static analysis is performed and it aims at taking into account the possibility of the increase in in-plane torsion due to dynamic effects. The accidental eccentricity intends to take account of the uncertainties on the distribution of masses and spatial variation in earthquake motion. It is applicable both in static and dynamic analyses.

NEPAL NBC 105 - 1994

It recommends two methods of analysis for lateral loads: seismic coefficient method for buildings up to 40 m in height, and modal response spectrum method for buildings with irregular configurations and abrupt changes in strength or stiffness and buildings more than 40 m in height. The base shear is given as :

$$V = C_d w = CZIKW \quad (1)$$

(for seismic coefficient method)

$$V = C_d (T) W = C(T) ZIKW \quad (2)$$

(for response spectrum method)

Where C is a function of natural period of vibration of the building and the soil conditions at the site under considerations. Three types of soil are defined: Type I soil - Rock or stiff soil; Type II soil - Medium soil; and Type III

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soil - Soft soil. The soil may be a cohesive soil or cohesionless soil. Z is zone factor which varies from 1.0 to 2.0 and K is structural performance factor which varies from 1.0 to 4.0.

Vertical Distribution of Lateral Forces

The base shear is distributed along the height for the building using a linear distribution similar to that used in UBC 1994 code and NS 4203-1992.

$$F_i = V \frac{W_i h_i}{\sum W_i h_i} \quad (3)$$

A concentrated force is applied at the top storey in the following cases:

- i. Where the height to width ratio of the horizontal force resisting system is equal or greater than 3, then a force equal to 0.1 V is applied at the top storey and the remaining 0.9 V is distributed using the above equation.
- ii. For chimneys and similar structures, a force equal to 0.2 V is applied at the top while the remaining 0.8 V is distributed using the above equation
- iii. For overhead water tanks, the entire force V is applied at the centre of gravity of the top container.

Torsion

Buildings with unsymmetric distribution of stiffness, mass and strength suffer severe damage as demonstrated in the past earthquakes. Such buildings undergo coupled lateral and torsional motions resulting in non-uniform displacements and strength demands in certain seismic load resisting elements. The torsional response of buildings is quite complex and depends on radii of

stiffness and mass, structural eccentricity, and floor aspect ratio. There are three aspects of design of structures for torsion that a code must define:

- i. A code must define regularity in plan and elevation.
- ii. A code must be very specific when an equivalent static analysis or a 2D response spectrum can be carried out and when a 3D dynamic analysis must be carried out.
- iii. A code must specify design eccentricities including the accidental eccentricity. The accidental eccentricity is necessary for the analysis of symmetric structures as well as for dynamic analysis for torsion.

The element strengths are specified in accordance with the code torsional provisions based on the elastic considerations as follows:

$$f_i = f_i^o \left(1 + \frac{e_d}{\rho_k} \right) \quad (4)$$

and

$$e_{da} = \alpha e + \beta b \quad (5a)$$

$$e_{db} = \gamma e + \beta b \quad (5b)$$

Where α and γ are the dynamic amplification factors, β the accidental eccentricity factor, $e = e_m - e_s$ is the structural eccentricity, b the dimension of the floor deck normal to the direction of the earthquake, $f_i^o = F(k_i/K)$ is the strength of the i -th element in the corresponding torsionally balanced system, F is the total design base shear in the torsionally balanced system, k_i is the stiffness of the i -th element, e_d the design eccentricity, one of e_{da} or e_{db} which ever gives a

higher value, and ρ_k is the normalized radius of gyration of stiffness.

The structural eccentricity is defined in terms of either the distance between the shear centre and the cumulative centre of mass of the storey or the distance between the centre of rigidity and the centre of mass of a floor (Annigeri and Jain 1994, 1995). The design strength of flexible side elements is governed by e_{da} , while the design strength of the rigid side elements depends on e_{da} or e_{db} whichever gives higher value.

The design eccentricities and the related torsional provisions in the NBC 105 are specified vide clause nos. 8.2.2 and 11.4. The eccentricity e_c is computed as the distance between the centre of mass and the centre of rigidity at each floor. Clause 8.2.2 requires that :

- i. If the computed eccentricity $e_c < 0.1b$ and number of storeys < 4 , then, the design eccentricity is taken as zero.
- ii. If $e_c < 0.3b$,
 then $e_{da} = e_c + 0.1b$ (6a)
 and $e_{db} = e_c - 0.1b$ (6b)
 whichever is the most severe for the element under consideration.
- iii. If $e_c > 0.3b$, a 3D dynamic modal response analysis must be carried out. The mass at each level must be displaced by $\pm 0.1b$ and the most severe effect considered.

Number of Modes

While carrying out the modal superposition analysis, the number of modes considered must be such that at least 90 % of the mass must participate in

the direction under consideration. Care must be taken to account for closely spaced modes. The modes shall be considered as closely spaced if their natural frequencies are within $\pm 15\%$. The standard gives freedom to the designer to choose any appropriate method for superposition of the response quantities, such as:

- i. Sum of the absolute values in each mode
- ii. Square root of the sum of the squares in each mode (SRSS values)
- iii. CQC method.

It is often noticed that the base shears computed using the seismic coefficient method and the response spectrum method are quite far apart. Clause 11.3.3 ensures that the dynamic base shear is at least equal to or more than 90% of the static base shear. This is done through a scale factor S such that:

$$S = \frac{0.9C_d W}{V_m} > 1.0 \quad (7)$$

where V_m is summation of combined modal base shears. Since the National Building Code of Nepal is essentially based on the New Zealand code, it retains many salient features of the latter.

NEW ZEALAND CODE NZS 4203 - 1992

It is a very comprehensive code based on the latest research efforts. It is the only code that accounts for different limit states in the seismic design as well as ductility levels for different structural systems and materials. It gives detailed steps for the use of time history method

of seismic analysis. The Nepal NBC 105 is a simplified document in comparison with the NZS 4203. Some of the salient features of the NZS code with regards to torsion are discussed in the following.

The design eccentricity is the same as given by Equations 6. It is significant to note that the NZS code defines eccentricity as the distance between the centre of mass and the shear centre, while the Nepal code defines it as the distance between the centre of mass and centre of rigidity. The former has some inherent advantages (Annigeri and Jain 1994). The code makes it explicit that the equivalent static method of analysis may be used provided one of the following criteria is satisfied:

- i. The height of the building is less than 15m.
- ii. The fundamental period of vibration computed using the Rayleigh method does not exceed 0.4 sec.
- iii. The structure satisfies the horizontal and vertical regularity criteria, and has a fundamental period less than 2 sec.

Horizontal Regularity

It gives two alternative criteria to verify the horizontal regularity for the use of the equivalent static or 2D model response spectrum and 2D numerical integration time history methods of analysis.

- i. The first one is based on the geometric considerations and requires that the distance between the shear centre and centre of mass be less than 0.3 times the maximum plan

dimension, nor change sign over the height of the structure. or,

- ii. The other criteria is based on displacements under static lateral forces. It requires that the ratio of the minimum storey drift to the maximum storey drift shall be in the range $3/7$ to $7/3$. It is the same as saying that the ratio of maximum to average storey drifts be less than 1.4. and,

The floor diaphragms shall not contain abrupt variations in stiffness or major re-entrant corners such as could significantly influence the distribution of lateral forces in the structure.

Vertical Regularity

The vertical regularity is satisfied if the lateral displacement of each level is reasonably proportional to its height above the base. In the case of irregular buildings, it is mandatory to carry out 3D dynamic analysis including the effects of accidental eccentricity. It clarifies that in doing so there is no need to modify the rotational inertia of the floor about the nominal centre of mass. Once again the dynamic base shear used in dynamic analysis must be the same as for static analysis in the case of irregular structures, and not less than 80% of that value in the case of regular structures.

IS:1893-1984

There is little difference between the 1975 edition and the 1984 edition. This code is now under revision for the last few years but it has yet to take a concrete shape. The salient features with regard to torsion in the 1984 edition are as follows:

The design eccentricity is given by a single equation :

$$e_{da} = e_{db} = 1.5e \quad (8)$$

There is no accidental eccentricity. Moreover, the code does not permit any reduction in the shears. It lays down the following criteria for the analysis of multistorey buildings:

- i. It permits equivalent static analysis using the seismic coefficient method for buildings less than 40 m in height in each of the five seismic zones.
- ii. It recommends modal analysis for buildings of all heights in each of the five seismic zones.
- iii. For buildings taller than 90 m in seismic zones III, IV, and V, it recommends modal analysis using the site dependent response spectra, or time history analysis using a site specific accelerogram.
- iv. It recommends a check for storey drift and torsion for all buildings particularly for those taller than 40m.
- v. It recommends modal analysis for buildings having irregular shapes or irregular distribution of mass and stiffness in vertical for horizontal planes.
- vi. It recommends a parabolic distribution of base shear along the height of the building, whereas most other codes recommend a linear distribution as given by Equation 3.

IS:1893 - draft 1996

It is proposed to revise the philosophy of earthquake resistant design. The present design philosophy is to specify very low seismic coefficients or values of spectral

accelerations, and then magnify them based on the importance of the structure, ductility and its performance etc. This philosophy does not give any idea regarding the actual forces that could be experienced by a structure during the expected earthquake and has been mostly discontinued in the codes of many countries.

In the second philosophy, maximum credible earthquake (MCE) in various zones are first specified based on the seismicity of the region and probabilistic studies. These are then scaled down corresponding to return period of the earthquake for a given structure at a given site to obtain the design basic earthquake (DBE). Further reduction factors are specified depending on the importance of the structure, ductility, and performance. It is proposed to introduce this design philosophy in the next revision of IS:1893 code.

RECOMMENDATIONS

The earthquake design provisions of three national codes, NBC 105-1994 of Nepal, IS: 1893-1984 of India and NZS 4203-1992 of New Zealand are discussed. Based on the critical review presented for the three national building codes and experience, the following suggestions are made to make the NBC 105 standard more useful:

1. The philosophy of earthquake resistant design of structures accepted worldwide is to enable most structures to resist minor earthquakes without damage, resist moderate earthquakes without significant structural damage but with some nonstructural damage, and resist a

major earthquake without collapse or loss of life. It is understood that structures will normally experience more severe forces in an earthquake than the one envisaged in the design forces specified in this standard. However, in view of the energy absorbing capacity available in the inelastic range, a ductile structure is expected to follow the above design philosophy.

At present the earthquake resistant design philosophy is not made clear in the code. It gives a false impression that a building designed as per the code is now 100% earthquake proof. Its limitation should be clarified in the code itself.

2. The code is vague about the uniformity of storey stiffness, that is, horizontal and vertical discontinuities. These are very well explained through figures in the American UBC 1994 or Canadian NBCC 1995 codes and may be reproduced in the NBC 105.

3. Clause 8.2.2 does not appear to be very clear regarding the applicability of the accidental eccentricity in a 100 % symmetrical structure. It should be made explicit.

4. The centres of mass and rigidity must be clearly defined within the code including their methods of estimation.

5. Clause 0.2 and Table 8.2 refer to IS: 4326-1976 code for detailing of reinforcement to achieve ductility. This code has now been revised and split into two parts: IS: 4326 - 1993 and IS:13920-1993. It is suggested that a new Nepalese standard be prepared with suitable changes to meet the local requirements.

There are already very detailed Nepalese codes NBC 201, 203 and 205 on the guidelines for masonry and concrete buildings.

6. The commentary should be provided in the main body of the code itself to make it more effective.

Other Related Issues

Certain practices have been followed in India which are now very difficult to change. Among them:

There are four codes on concrete structures: IS:456-1978, IS:1383-1980 and IS:4326-1993 and IS:13920-1993. It is quite cumbersome to use these codes and many requirements are difficult to locate. Moreover, there are many conflicting requirements which are difficult to understand. Most national building codes have a single unified code on reinforced and pre-stressed concrete structures such as the American ACI 318 code, Canadian concrete code, and European code EC2. They have a separate section on earthquake detailing. Most users and students of civil engineering find it easy to have all specifications at one place. Moreover, commentary is provided side by side of each clause so that the user is able to appreciate the implications.

The NBC 110-1994 on plain and reinforced concrete relies on IS:456-1978 code and, therefore, carries some of its major drawbacks which are difficult to rectify at this stage. Such as:

i. The reference to M15 grade concrete in terms of 1:2:4 proportion by volume has caused unexpected problems. This specification seems to

have come from the Central Public Works Department, New Delhi where a 1:2:4 volume batching for the given materials conform to M20 grade concrete. However, most field engineers and architects use this proportion for any locally available fine and coarse aggregate which was not intended. This leads to a very bad concrete from strength as well as durability point of view.

- ii. Volume batching of materials.
- Very poor inspection clause.
- iv. Very complicated acceptance criteria for concrete.
- v. No respect for quality assurance and quality control.
- vi. No explicit requirement to prepare structural drawings.

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The draft code on IS:456 has proposed the following significant changes :

- i. A minimum grade of M20 concrete for all works from durability point of view.
- ii. Weigh batching at sites as far as possible
- iii. A simplified but tough acceptance criteria for concrete.
- iv. Detailed specifications for durability of concrete.
- v. Revised rules for cover to reinforcement based on durability criteria.



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REQUIREMENTS OF A SEISMIC CODE - OVERVIEW OF NEPAL BUILDING CODE NBC 105 - 1994

*Prof. Prem Nath Maskey**

INTRODUCTION

The need and existence of building codes are known since long time back. The code of law set by Hammurabi, king of Babylonia about 2100 B.C. perhaps is one of the first documents of such kind. Though the Hammurabi's code basically addressed the legal requirements, and it contained no specific technological specifications, its goal was specific, to build a structure adequately strong to shelter the habitants. The clauses were more like building regulations which sounded very stringent. In Nepal itself, the then builders, who were basically artisans and masons, used to plan and build traditional houses and temples, on a set of guidance stipulated in a sort of document. This is another form of code which basically addressed how a structure is designed and built, and it contained no legal aspects other than possible ominous consequences in case of adopting the prescribed details or ways of building. The "set guidance" was well accepted by the builders and owners, although it was not statutory and was not regulated by any governmental agency. Those were basically inherited from generation to generation, and most of the clauses were basically reasoned with astrology and religious faith. The numerous existing temples, traditional and monumental structures of Kathmandu Valley, and of other parts of the country have been built

following the provisions given in such documents. The performance and the endurance of these buildings for a long time, vouch for a strong logic behind the then adopted ways of planning, design and building, which were described in those documents.

The concept of a Building Code, in its process of evolution, has been entirely different from the previous forms of the then available documents. Along with the history of civilization, now we have governmental or public regulating agency replacing the royal court of King Hammurabi, qualified and specialized Architects and Engineers instead of mere artisans and tradesmen, innovation in terms of needs and fulfilment of building, breaking the requirements limited to that of shelter only, and hence the Building Codes with thorough description of all the aspects related with the building process.

SEISMIC CODES

For countries, geographically lying in earthquake prone area, seismicity and earthquake resistant design are of prime concern. Due to this reason the seismic design code either covers a great part of the country's building Code, or the whole building code is centered around the seismic requirements of design and building. However there are over sixty

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countries in the world where earthquakes should be considered in design. About thirty of these countries are identified with high seismic risk rating, Nepal being one of such countries. Many countries are yet to have Seismic Codes of their own. Nepal also used to have no such Codes until recently when the draft of the Nepal building Code was completed. It is believed that the proposed Nepal Building Code will soon be among the concerned community, for use by designers and builders. Until the official publication and implementation of the Nepal Building Code, Nepali designers will have to continue relying on the existing foreign Codes.

A Seismic Building Code would have been ideal if it could stipulate all the provisions required for systematic and stepwise procedures for design, construction, risk factors during earthquake and reconstruction after earthquake, as proposed in Tentative Provisions for the Development of Seismic Regulations for Buildings. However, a Seismic Code should give guidance on three main topics, namely, loading and risk, overall structural performance criteria, and seismic detailing.

NBC-105 PROVISIONS AND REQUIREMENTS

Nepali designers, in absence of their national code, have been using the codes from other countries. Before using the newly developed codes, the designers would be more cautious and would like to assure that the provisions in the code are better or at least at par with the ones given in the codes previously used.

Furthermore, simplicity and comprehensives are other factors which will encourage the designers to accept the documents.

The paper reviews some of the provisions of the NBC 105 - 1994 and discusses the requirements normally expected in similar documents.

Scope and General Principles

The code, in general, specifies the scope for design of modern buildings up to height of 90 m. It is encouraging that it emphasizes greatly on ductile seismic design and detailing as provided in section 3. However, in view of the local condition and the prevailing practice, it would be necessary to stipulate the requirements of different lateral load resisting systems. It has become more than necessary to clarify that the purpose of seismic design is not to achieve full earthquake proof building.

Building Configuration

It has been established that the configuration of a building can significantly affect its performance during a strong earthquake which produces the ground motion contemplated in the design provisions. The plan configuration and the vertical configuration of buildings are two important aspects to be considered in the design. The code provisions are basically derived for buildings having regular configurations, and the past earthquakes have repeatedly shown that the buildings with irregular configurations suffer greater damage. The requirements regarding symmetry and uniformity of storey stiffness as

given in sec. 3.4 and 3.5 of the NBC 105-1994 are encouraging but may not be adequate in the aspect of configuration. The recommended reliance on IS:4326-1976, in this regard, may not be practicable for various reasons including the reason of the said code being under revision.

Analysis Procedure

Out of the two methods of analysis recommended in the code, the Seismic Coefficient Method is expected to be extensively used in view of the prevailing regulations and requirements. The code allows the method to be used for design of buildings up to a height of 40 m, as provided in sec. 5.2, and probably for regular buildings. It would be advisable to extend the application of the method to irregular buildings with consideration of storey shear at the levels of importance treated as the base shear. It is to be noted with caution that the codes like UBC stringently specifies that the seismic forces calculated by the Seismic Coefficient Method should be minimum.

Horizontal Seismic Base Shear

The main component of Seismic Coefficient Method is Formula 10.1 of the code for seismic base shear, which gives the total seismic force V in terms of two factors, a seismic coefficient, C_d , and the total gravity load of the building, W_t .

The total gravity load of the building, W_t , shall be taken equal to the total weight of the structure, and applicable portions of other components including, but not limited to, the partitions and permanent equipment including operating contents,

portion of the applicable live load, depending upon the usage, and the effective snow load, if applicable. It should be noted that the inclusion of partitions and permanent equipment greatly affects the flexibility of the structure, which in turn will influence the calculated period of vibration.

Periods of Vibration

Section 7.1 of the code specifies the need of computing the periods of vibration, and sec. 7.2 recommends the use of Rayleigh's method to calculate periods of vibration for Seismic Coefficient Method. Methods of mechanics can not be employed to calculate the period of vibration before a design of the building, at least a preliminary design. Simpler formulas for calculating periods of vibration, before the building is designed, like stipulated in IS:1893-1984, would have greatly facilitated the designers' work. In the Rayleigh's Formula, the calculated period increases with an increase in flexibility of the structure, because the d_1 term appears to the second power in the numerator to only the first power in the denominator. Thus, ignorance of the contribution of nonstructural elements to the stiffness of the structure, during calculating the deflections may lead to the exaggeration of deflections and the calculated period is lengthened.

Vertical Distribution of Seismic Forces

Section 10.2 of the code recommends the vertical distribution of the seismic force in a linear fashion. If IS:1893-1984 still recommends the parabolic distribution, in case of

determination of actual period as envisaged in Nepal Code, the distribution formula could be as proposed by the code, as given below:

$$F_i = \frac{W_i h_i^{k_i}}{\sum W_j h_j^{k_j}} V$$

where, k is an exponent related to the building period as follows:

For buildings having a period of 0.5 seconds or less, $k = 1$.

For buildings having a period of 2.5 seconds or more, $k = 2$.

For buildings having a period between 0.5 and 2.5 seconds, k may be taken as 2 or may be determined by linear interpolation between 1 and 2.

Overturning

The code has not given any specific clause on overturning, but every building shall be designed to resist overturning effects caused by the seismic forces determined in the relevant sections.

Drift Determination

Section 9 of the code specifies the drift requirements in terms of inter-storey deflections. In sec. 9.1, the recommended multiplying factor of $5/K$ to determine the lateral deformation may confuse the designers, as K stands for Structural Performance Factor as given in sec. 8.1.8.

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OTHER GENERAL COMMENTS

- Basic philosophy of the Building Code shall be stated.
- Basic reference to the codes of other countries may mislead the designers, and hence shall be discouraged as far as possible.
- Material Requirements shall be explicit.
- Building Configuration and Seismic Detailing shall be major and integral parts of the code.
- Seismic Code Provisions on retrofitting of traditional and monumental structures for seismic resistance shall be advisable.
- Nepali Designers should be taken into confidence for the improvement and extensive use of the codes.

CONCLUSION

Seismic resistant design of buildings continues to be the main area of concern for the designers of buildings in Nepal. Design and construction of new buildings shall incorporate the seismic part as mandatory in view of the vulnerability of the country and the region. The draft proposal of Nepal Code at this juncture shall be welcome, and shall be finalized with improvements. The code, the first document of such kinds in the country, is expected to be complete in design requirements and conducive to the local conditions.

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LOW-COST HOUSING IN NEPAL : AN OVERVIEW

*Dr. Jiba Raj Pokharel**

INTRODUCTION

Food, shelter and clothing have since long been recognized as three of the basic human needs. Nepal is facing problems in all these three fronts by some degree or the other. This is one of the reasons why Nepal finds itself at the bottom of the list of the developing countries. Unless Nepal becomes self sufficient in these three areas, it cannot elevate its international stature. The import of commodities related to these three basic needs has strained its economy severely. As a result, the overall state of the country continues to follow a downward trend.

Recognizing this, the Government has been according top priority to agriculture since the adoption of planned development back in the sixties. Right from the First Five Year Plan, agriculture has been given maximum attention. This has produced mixed results. While there have been achievements in some areas, others continue to remain in their preliminary undeveloped state.

Shortage of Houses

If this is the situation in the agricultural front, it is not any encouraging in housing. A survey has shown that there are 3 million houses in Nepal out of which 3 hundred thousand houses are in urban area and the rest are in the rural area. Half of these are of temporary

nature, 41 per cent are semi permanent type and the rest 9 per cent are made of more permanent materials such as bricks and concrete. It has been found that 23000 houses need to be built in the urban area and 124000 in rural area every year to accommodate the growing population. But only 10500 houses in the urban area and 111000 houses in rural area are constructed annually. It shows that the country is facing a shortage of 36000 houses every year. The existing houses are marked by overcrowding and the absence of basic services. 85 per cent of the persons have their houses while the remaining population are living in rented houses.

It is estimated that Nepal needs 2.5 million houses during 1995-2006 of which 434000 units will be needed in the urban areas and 2.1 million in the rural areas which comes to be 17 and 83 percent respectively. Significant number of houses, in fact some 732000 of them need to be upgraded during the 15 year planning period, of which 60000 units will be in urban areas. It has been forecast that 19000 units in the urban area and 215000 units in the rural area will have to be upgraded in the eight plan period only.

There are several factors which have contributed to the present state of affair. But the more prominent is indeed a weak economy of the majority of the people in

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Nepal. The cost of the material has been increasing in such an alarming rate that the savings cannot just keep pace with it. Moreover, there is also an absence of a concerted effort to alleviate this problem.

Housing

Housing is a multidimensional entity. It encompasses several aspects. It is thus not an easy task to present an overview of the activities related to such an overwhelming concept. But man is a strange being in that he finds a solution however partial of any problem. Since time immemorial, human being has been managing adequately or in-adequately the most difficult of the tasks.

In early times, man did not have a clear vision of the universe as we do these days. But it is not that they simply did not have one. Now it can be said that it was an erroneous perception. For example, the people of Babylon from where one of the most ancient civilizations is believed to have begun, thought of the world as being a closed box or chamber the floor being the earth. In the centre the floor rose to snowy regions, in the midst of which was the source of Euphrates. Round the earth lay a moat of water, and beyond it stood celestial mountains supporting the sky.

Similar is the case with God. God is supposed to be all embracing, supernatural entity. But even God was reduced to a human form. That is how people tried to understand God.

Housing is not certainly as complex a concept as the Universe or the God. We

can thus certainly try to gain an understanding of housing. Understanding of an object is obviously gained by the use of a theory. For example, if we like to understand about force we should take the help of Newton's laws of motion because it tells a great deal of things about force. The first law gives a definition of force. The second law provides the measure of the force. The third law explains the nature of the force. Similarly, if we want to gain an understanding of housing we should look around for such a theory.

An object is a general name which can address everything in this earth. Housing can thus be viewed upon as one of the objects. The question that we have to take at our point of departure is that how is it that we can gain an understanding of an object that too of a concrete object as housing.

A block is understood by its dimensions of length, breadth and thickness. Similarly objects have physical, social and cultural dimensions. Through the study of these dimensions, we can gain an understanding about an object. Now such objects are visible and hence they have some physical dimension. They fall in some hierarchical structure due to which we make their comparative analysis and hence they have social dimensions. Objects are identifiable and hence they have cultural dimensions. In short, we can say that objects possess three dimensions and they are physical, social and cultural. We can thus conduct an overview of low cost housing if we can encompass their physical, social and cultural aspects.

Architecture was described as *firmitas*, *utilitas* and *venustas* in Latin by a first century Roman Architect Vitruvius which was translated into durability, commodity and beauty by Henry Watton. Durability is a physical concept, commodity or convenience is a social concept and beauty is obviously a cultural concept. Hence, housing can be substantially grasped if the study is made in these three realms.

Physical Aspects

Physically, housing addresses three entities which are land, infrastructure and the building. There has to be a land on which the building is built and it has to be provided with infrastructural facilities like water supply and sewerage, electricity, telecommunication and such other facilities.

Land

The price of land is ever increasing. In Kathmandu, it seems to have stabilized since the last year. In Nepal, the situation is that it has to be bought by the person with the landlord. Recently, estate companies have started to sell the land in a slightly more planned manner. These agencies buy a huge chunk of land, plan the roads inside and divide them into plots of different sizes. These are advertised in the newspaper or one can make a personal contact with them to receive land.

Some of the agencies have gone a step ahead. They buy land and make houses on them. They sell such plots to those who want to buy them. There are

indications that a house will be available by the payment of 20 per cent at the outset and payment has to be made in different stages till the whole of the payment is made in a few years time when the building enters into the total possession of the person. This will take some time to materialize because the beginning has just been made.

The price of land is varying. It is the highest in the city centre and it decreases as one goes farther from the center.

The Government has initiated several approaches towards the inhabitation of the people in the urban areas. They are the Site and Services Approach according to which the Government buys land, makes roads and drains and sell the plots to the Government employees. This approach was adopted in Kuleshwore in Kathmandu. Guided Land Development was the second approach in which the Government would widen the existing pathways if requested by the plot owners of the land. The third approach is Land Pooling in which the Government upon request from the landlords of the area will first take the land in its possession, create infrastructures and give back the land to the respective owners. The land owners receive slightly reduced a land plot because some of it will go in creating the necessary infrastructure. This approach has been initiated in many places including in Lubhu.

At the present, Integrated Approach Planning, has been used. This is one of the planning tools and it can be effective where there is rapid pace of urbanization but the funds are not adequate.

Basic Infrastructure

Approach roads, water supply, sewerage, telecommunication are the infrastructural facilities that are essential for a good housing. These have obviously to be provided in a lesser amount in order to be bracketed under low cost housing.

Roads and Drainage

A proper road and approach enhances a building considerably. The drainage is another component which when provided properly contributes to the health of the dwellers. There are ways which can make better roads in cheaper prices. This needs to be deliberated in order to arrive at cost effective housing.

Water Supply and Sewerage

Water provides life to the people. Attention should be paid to the supply of pure water because water borne diseases account for 90 per cent of all the diseases. There are cheap as well as costly methods of water conveyance to the buildings. Sewerage is another aspect which can provide good environment in the housing surrounding. Cheaper septic tanks are being used and so are the sanitary appliances which consume less water.

It has been found that these infrastructures cost more than 20 per cent. In Land Pooling Projects, these facilities are provided in advance. Similar is the situation in Site and Services approach.

Electricity and Communication

Electricity provides not only illumination inside the building but it also provides

the power for the carrying out of household works. It has been assuming increasing degree of importance with the passage of time. Communication is another essential feature of the modern era. The new century is known as the era of communication. Communication has made the world into much smaller an entity.

There are cheaper ways by which the electricity and communication can be provided in a building which need to be worked out. Concealed wiring has been preferred to surface wiring not only of its neat appearance but also because of its lesser cost. It has been found that only 29.9 per cent of the households use electricity for illumination and 2.03 per cent for cooking in average in the country. The urban population use most of it. In the urban area, 81 per cent use electricity for illumination and 6.4 per cent for cooking. This is very high in comparison to 22.83 per cent using electricity for illumination and 1.43 per cent for cooking in rural areas.

Building Construction

Construction of residential buildings in Nepal is carried out at an individual level. More than 95 % of the residential buildings are owner built and non engineered. There is very little or no technical/engineering input by professional technicians/engineers. Institutional involvement in the construction of residential buildings is a new concept and has just been started by a few organizations.

Owner builders in the hills and valleys give more importance to the foundation

and the depth of the foundation in these buildings are provided more than what is required. Massive walls and heavy roof on the top are other characteristics of the buildings in the hills and valleys. This is the main reason of their high vulnerability to horizontal loads alike earthquakes and wind. On the contrary the buildings in *Tera*i do not have foundation at all. According to the foundation of national housing survey 40% of the existing owner built buildings do not have foundation. These buildings have wattle and dab filler walls between timber pillars and thatch roof on top. Others make use of heavy mud walls and tiled roof over a layer of mud.

There is a clear indication that these owner built buildings can be made more durable in lower cost. Efforts have been made in the past to study the current housing trend and to prepare recommendations emphasizing on safety and cost effectiveness. Various governmental, non-governmental institutions and private individual as well as organizations involved in this field include: Department of Building, RONA*ST*, RECA*ST*, DCS. Some private consultancy firms and a few housing companies have also entered into this arena very recently.

The construction of a building accounts for the most of the fund that goes into housing in the rural areas whereas it is comparable to the cost of land in the urban area. Hence, the building should be designed prudently to bring the cost within an affordable limit. It has been found that a building square in plan is cheaper than the one which is rectangular

in plan. Incremental type of housing allows for stagewise construction and it has been found to be highly convenient for construction as and when the fund is available.

Reduction of construction cost has to be made without compromising strength and durability of the building. This means quality of the building shall not be decreased if not increased as compared to the materials used in the construction but the cost has to be made minimal. Compact incremental planning of dwelling units helps considerably to reduce the cost. A house basically consists of foundation, superstructure and roof. Hence, saving has to be made in these three components through the use of cost effective technology.

Foundation

Foundation cost can be minimized through the use of a proper depth. The notion that a deeper foundation contributes to the durability of a building is true only within a particular range. Generally, we provide more foundation than is necessary and it is responsible for unnecessary high cost.

Bricks and stones have been used in housing since time immemorial. The normal trend is to fill the whole foundation trench with stone or brick masonry which can be reduced considerably by making strip foundation. It can be further reduced by choosing appropriate building materials like stone concrete blocks. Use of hollow blocks and prefabricated reinforced concrete components reduce

the total weight of the building which will in turn reduce the size of foundation and make it more affordable. The use of mud mortar also contributes to reduction in cost but it is not an engineering material. Even if it has been used since the beginning of housing by human beings it is been increasingly replaced by cement.

Superstructure

The superstructure consists of the construction of the wall, the floor, the doors and the windows.

Stone brick and mud are the main materials used in the walls of indigenous Nepali owner built buildings. Stone walls need to be constructed thicker than required as it is very difficult to reduce the wall thickness. Dressing of stones can reduce the wall thickness but the cost of dressing is very expensive. Bricks are not available in all the parts of the country and further it requires to be burnt which consumes lot of energy. It is environmentally counterproductive. In this context, concrete block comes out to be a potential alternative walling unit. The owner builders are hesitant to use hollow concrete blocks as they consider it to be weak as compared to thick stone or brick walls due to its hollow core and thin wall thickness. Most of those who use hollow blocks have used it as partition walls on a framed structure, compound walls and factory sheds. Further the production is restricted to urban areas and still unavailable to majority of the owner builders. Some entrepreneurs have started to produce solid concrete blocks in certain specific locations along the

riverside and it has gained popularity in a shorter time as compared to the hollow blocks. The cheaper option to this is the use of stone concrete solid block which uses about 60 to 70 % stone blocks and 30 to 40 % 1:5:8 concrete. These blocks are found to have good strength comparable to burnt bricks. Walls made of this block is 25 to 35 % cheaper as compared to brick walls. These blocks can be produced with a very little technical expertise and can create more jobs to produce cost effective masonry units.

Different form of rat trap bonds have been tried and it is found to save 25 to 35 % as compared to the normal English or Flemish bond. This can be adopted to construct cost effective buildings where stone blocks can not be fabricated by one or the other reason.

Thus the construction of wall can be reduced to a minimum of 25 % as compared to the conventional walls without decreasing the strength, durability and other quality parameters.

The other potential option is to develop soil stabilized blocks to replace conventional permanent masonry units. There are instances of experimental production and use of stabilized soil blocks in buildings. One of them is serving as a canteen in the DOB Complex and the other is a school building in Kailali district. Analytical study of the former is not available and the latter was found to be expensive than the conventional burnt brick building. Experts involved in the research of the stabilized soil blocks face a challenging task in making these units

cheaper as compared to conventional masonry units. The material has been RECAST.

Openings for entry, exit, ventilation and openings cost times the construction optimization. The circulation is considerable construction material used. The rocket resulted in timber. The frames curved reinforced concrete. Amos steel is with option is the a mere 5 to frames. All shutters still. Instances of have been found and it seems adopted to suit.

With a good appropriate walls and or when construction system.

Roof

Traditional expensive combustible

cheaper as compared to the conventional masonry units. One building using such material has been recently completed by RECAST.

Openings are required to facilitate the entry, exit and provide light and ventilation to the rooms. The cost of openings comes out to be almost three times the cost of masonry wall construction. It is thus clear that optimization of the size of openings for the circulation, light and ventilation will considerably reduce the cost of construction. Timber is the conventional material used for the doors and windows. The rocketing price of timber have resulted in use of various alternative to timber. The major alternatives to timber frames currently adopted are metal, reinforced concrete and frameless openings. Among these three alternatives steel is widely accepted. The cheapest option is the frameless openings that cost a mere 5 to 10 % of the cost of timber frames. Alternatives to conventional shutters still needs to be developed. Instances of using ferrocement shutters have been found to be successful in India and it seems that this system can be adopted to suit in the Nepalese context.

With a good planning and selection of appropriate alternative one can make walls and openings with 30 % lower cost when compared to the conventional system.

Roof

Traditional roofs are either heavy and expensive or light but highly combustible and create fire hazards every

year. The alternatives used in the roofs include CGI Sheets, RBC/RCC slabs and Concrete Roofing Tiles. All these are expensive when compared to the traditional thatch or clay tile roofing system but are durable, strong and safe. CGI Sheets is one of the oldest roofing materials and they are used in Nepal to replace traditional thatch and clay tile roofs of different types. Concrete Roofing Tile is a comparatively new addition and it is comparable to the cost of CGI sheets in the semi urban areas. Such tiles when used with timber supporting structure is as costly as RCC slabs in the urban areas and still it is much cheaper in the rural areas as the use of cement is minimized while using this. On the site prefabricated RCC/ RBC flooring system and partially precast RCC/RBG roofing system is one of the cheapest flooring and roofing system for the urban areas. It is cheaper than the conventional cost in site flooring/roofing RBC/RCC slabs.

Social Aspects

Social objects are known through the study of their behaviour. They enable us to study the society as distinct from the individual in terms of all that happens to the human beings by virtue of their reaction to each other. These reactions may be observed, described and classified under three major headings: social structure, social function and social change. Under structure, for instance, one might study the various units of social organization, family and kinship, various kinds of social or working groups, larger groups such as the neighbourhood, the city and so on. The

study of social functions might include those factors which tend to hold groups together: political, legal, economic, administrative or institutional, not to mention cooperation, control and discipline. Social changes might start with defiance and conflict, it will be concerned with differentiation, stratification, and mobility within society.

Social Structure in Housing

In order to understand social structure, we have to take atomic structure as an example. In an atomic structure, we study about electrons, neutrons and protons. So, in a structure we essentially study about such entities which constitute it. In an atomic structure we study about entities which go on to make an atom. In a structure, there are components in which some play a primary role while others are content in performing a secondary role. Electron can be said to be a primary element in an atomic structure while the others are secondary or even tertiary.

In a Nepali society as we see, in the case of housing, these are owner built housing, rental housing, squatter housing and institutional housing. These typologies are found to be used quite frequently by authorities who are responsible for its diffusion to the people in Nepal.

Owner built houses account for almost 85 per cent of the houses in Nepal. In Kathmandu, 35 per cent of the people stay in rented houses. Squatter housing is more prominent in Terai but now it has reared its ugly head in the capital city as well.

Social Functions in Housing

When we consider social functions in housing, we have to concentrate on political, legal, economic, administrative or institutional aspects. It also deals with the cooperation, control and discipline.

Political

The constitution of Nepal has promised for a dignified living for the people of Nepal. This is not possible without the provision of a good housing. It is against this backdrop that a housing policy has been formulated by the Government in line with its commitments made by it to Global Strategy for Shelter adopted by the United Nations.

Very recently, a shelter policy has been put forward by the Government which seeks to solve the problem of housing in two phases.

Legal

There are quite a few legal provisions made by the Government with respect to housing. Very recently, laws have been enacted with respect to group housing. Policies have been formulated regarding the development of the cities.

Economic

The economy of the majority of the people in Nepal has been found to be very weak to be able to afford a decent housing. Medium monthly household income is Rs 2517 in the urban area and Rs 1264 in the rural. The Government also has not been able to make a substantial budgetary provision for housing.

Administrative

Housing is administered by the Ministry of Housing and Physical Planning under a separate department known as Department of Housing and Urban Development. The Government has intended to play the role of a facilitator than a executor or implementor in this process. It will encourage public or private initiatives in housing.

Cooperation

The Government has received cooperation and loans from international and bilateral organizations. For example, UNDP/UNCHS helped the Government for making a study culminating in the preparation of a document entitled Proposed Nepal National Shelter Policy and Implementation Strategy.

Control

In the Municipal areas, building permits have to be obtained before going ahead with the construction of a house. In the Village Development Centres it is not required. But it has not been enforced effectively and there are many problems which have arisen due to this negligence.

Cultural Aspects

A dwelling unit is also a cultural object. Hence, housing cannot be considered in isolation with culture. It has been found that people have rejected the house given to them which showed disregard to their culture. In some of the instances, it has been seen that people have made changes through the addition of their cultural objects such as a carved door or

a window in the building provided to them by the Government or other organizations.

In Nepal also, the question of retaining architectural identity is being seriously considered. That the houses have to be designed in view of the architectural heritage of the place has been widely recognized. What is it that injects Nepalese identity in the modern houses has been a topic of deliberation and discussion.

Some opine that only such aspects of heritage should be incorporated in the design of houses which are timeless and one of them is the climate. Only such elements should be blended into the new designs which have climatic imperative. Such elements should be exclusive to Nepali architecture and these should be such that they provide identity. One of such elements have been identified as the sloping roof with straight inclined struts. These days sloping roofs are seen to have been added to the modern houses but not adequately. At the first instance, the struts are not provided and the sloping roof is finished by cutting plaster into shape of clay roofing tiles. The Jhingatti is not being used. Unless, the houses are rendered with sloping roof supported by inclined struts having jhingatti or Manglôre tiles, the requisite amount of identity will not be attained. This adds to the cost but ways can be found by which this can be done rather at lower cost.

Conclusion

It can be seen that there have been some efforts made in the area of Low Cost Housing but much yet remains to be

done. In fact, one of the reasons for not being able to make much headway in this direction is due to the absence of an Institution which can deal with this aspect exclusively. In India and other neighbouring countries, Building Research Institutes have been established which have been working in this area. Due to this, there has been significant achievements made in Low Cost Housing.

Nepal also has institutions like RECAST and RONAST but these do not focus only on housing. These institutions undertake diverse kind of research activities. Progress can be made in the case of Nepal only if an institution concerned with Low Cost Housing is set up immediately.



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EARTHQUAKE DESIGN BASICS FOR ARCHITECTS AND BUILDING DESIGN PROFESSIONALS

Donn Treese*

INTRODUCTION

Virtually all of the country of Nepal is in a seismically active zone where there is likely damage to structures in nearly certain future earthquakes. Large earthquakes are rare having probable re-occurrence periods of several decades to several centuries. Because of their infrequent occurrence it would thus become prohibitively expensive to make all structures perfectly safe for a hypothetical 8.5 scale earthquake.

Our regional earthquake predicament is brought about by the fact that our neighbor to the south, India, is slowly but surely moving closer to Tibet. India and Indian Tectonic plate moves 2cm/year closer to Tibet as it slides under the Asian Tectonic plate deep below the earth's surface. This means that as this pressure in the rocks builds up a future earthquake is only a matter of time. There is possibly a 30% slippage as the plates may slide smoothly across one another to some degree, but there is certainly a considerable built up pressure since the last major earthquake in this area, the 1934 Kathmandu or Bihar earthquake. Some areas to the west between Kathmandu and Dehra Dun, Uttar Pradesh, may not have had this mounting pressure released in centuries and an M8 earthquake is possible. So we are sitting on a time bomb that is ticking

away and building up explosive energy with every tick of the clock.

DEFINITION

An earthquake results from the sudden shaking of the ground that occurs when masses of rock change position below the Earth's surface. The shifting masses send out shock waves that may be powerful enough to alter the surface of the Earth, thrusting up cliffs and opening great cracks in the ground.¹

CAUSES

Most of the worst earthquakes are associated with changes in the shape of the Earth's outermost shell, particularly the crust. These so-called tectonic earthquakes are generated by the rapid release of strain energy that is stored within the rocks of the crust, which on continents is about 35 kilometres thick. A small proportion of earthquakes are associated with human activity. Dynamite or atomic explosions, for example, can sometimes cause mild quakes. The injection of liquid wastes deep into the Earth and the pressure resulting from holding vast amounts of water in reservoirs behind large dams can also trigger minor earthquakes.

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The strongest and most destructive quakes, however, are associated with ruptures of the Earth's crust, which are known as faults. Although faults are present in most regions of the world, earthquakes are not associated with all of them. Pressures from within the Earth strain the great rock masses beneath the Earth's surface. The strain builds until suddenly the masses move along faults, thereby releasing energy. The masses slip and slide in opposite directions along this fracture in the rock, shaking the ground above. The masses may move up and down, sideways, or vertically and horizontally. On the Earth's surface displacement of the ground may vary from several centimetres to many metres. Some fault lines are visible on the surface of the Earth.

SHOCK WAVES

The shifting rock in an earthquake causes shock waves called seismic waves to spread through the rock in all directions. In a great earthquake shocks may be felt by people thousands of kilometres away from the centre.

There are two broad classes of seismic waves: interior and surface. In addition, there are three basic types of seismic waves. The primary waves, known as P waves, spread in the crust from the point of rupture, which is called the focus of the earthquake. The point on the Earth's surface immediately above the focus is termed the epicentre of an earthquake. P waves alternately compress and expand the rock through which they pass and vibrate in the same direction in which the waves travel. These P waves are

responsible for the vertical movement at the beginning of an earthquake. Secondary waves, known as S waves, vibrate at right angles to the direction of wave travel. These secondary waves are the waves that move particles up and down or from side to side. The speed of S waves is always less than that of P waves. By comparing the arrival times of both P waves and S waves at seismological observatories, scientists can determine the location of an earthquake many thousands of kilometres away. Finally, after both P and S waves have moved through the body of the Earth, they are followed by two types of surface waves known as L (I) and L (II) waves. Because of their larger amplitude, these L waves are responsible for much of the destructive shaking that occurs far from the epicentre. These surface waves, which travel more slowly than the interior waves, are the most powerful shock waves.

The focus of an earthquake may occur from quite close to the surface of the earth down to a maximum depth of about 700 kilometres. More than 75 percent of the seismic energy produced each year, however, is released by earthquakes with foci less than about 60 kilometres deep. These are the dangerous earthquakes that pose a significant hazard to populated regions. They are known as shallow-focus earthquakes.

CALIBRATING EARTHQUAKES

The measurement of earthquakes is done with a seismograph which records the patterns of shock waves on a revolving drum of paper. The wavy lines show the

strength of the seismic waves and the times they occur. Some instruments, such as the electromagnetic pendulum seismometre, record induced tension that passes through an electronic amplifier to a recording galvanometer. A photographic seismic recorder scans a rapidly moving film, making sensitive time-movement registration. Refraction and reflection waves are usually recorded on magnetic tapes, which are readily adapted to computer analysis. Strain seismographs, employing electronic measurement of the change in distance between two concrete pylons about 30 metres apart, can detect compressional and extensional movement in the ground during seismic vibrations. The Benioff linear strain seismograph detects strains related to tectonic processes, those associated with propagating seismic waves, and tidal yielding of the solid Earth. Still more recent inventions include rotation seismographs; tilt metres; wide-frequency-band, long-period seismographs; and ocean-bottom seismographs.

commonly used by seismologists to determine the amount of destruction caused by an earth-quake. The *Intensity* of the earthquake at a particular location is estimated from the damage caused by the earthquake. This 'Intensity' is taken as a measure of the effect of the quake on structures and is indicated by a number according to the scale used. The most widely used intensity scales used to day are the Modified Mercalli [MM] (1931) and the MSK or UNESCO Scale (1964). The Modified Mercalli scale rates the degree of observed damage by Roman numbers ranging from I to XII.²

The *Richter Magnitude Scale* grades earthquakes on a 1 to 10 scale. It is based upon the amount of energy released by the rock movements rather than upon surface damage. *Magnitude*, M of shallow quake defined by Richter scale uses logarithm to base 10. The scale is such that a magnitude one greater measures an earthquake with 30 times the energy of the previous number. This

Energy values of various Richter Scale Magnitude earthquake ratings:

Richter scale M :	5.0	6.0	6.5	7.0	7.5	8.0	8.4	8.6
10 ²⁰ Energy E :	0.08	2.5	14.1	80	446	2500	10,000	20,000

Seismographs of exactly the same character are deployed at stations around the world to record signals from earthquakes and underground nuclear explosions. The World Wide Standard Seismograph Net-work incorporates some 125 stations.

The strength of an earthquake may be measured either by the amount of damage done or by instrument readings. The *Modified Mercalli Intensity Scale* is

Richter scale is measuring the energy released at the epicentre of an earthquake and measured at a distance of 100 kilometres from the epicentre. The Richter scale thus measures the size of the earthquake.

FORECASTING

Forecasting of earthquake timing and location has met with little success. Of the

² Modified Mercalli scale explained in Appendix-1.

many attempts to find clues for predicting the location, time, and strength of future earthquakes, the best results seem to be associated with seismicity studies using earthquake observatories (Chinese researchers, however, have achieved some success using, in part, signs of animal restlessness for forewarning.) Other methods are based on detecting gaps in the seismic record of a region. Segments along a fault where displacement has not taken place for a long time are more likely to release built-up stresses.

RESULTS OF EARTHQUAKES

Certainly the best known result of earthquakes is the damage to man made structures. In the damage to buildings also results loss of life and serious injury to people as well as property damage.

There are also residual results of earthquakes that can greatly compound the loss of life and property. The results from ruptured gas lines igniting or electrical lines falling on wooden structures. Many times fallen structures and bridges close transportation routes making rescue and fire fighting much more difficult. Fire produced the greatest property loss following the 1906 San Francisco earthquake, when 521 blocks in the city centre burned uncontrollably for three days. Fire also followed the 1923 Tokyo earthquake, causing much damage and hardship for the citizens.³ The recent quake in Kobe, Japan also ignited dozens of fires which burned for hours as fire fighting equipment could

not reach many areas and the large number of fires meant that there was not enough emergency water stored to fight the fires.

Another major hazard from earthquakes would be flash flood damage from broken man made dams or from the bursting of temporary natural dams caused by earthquake induced landslides. Landslides can also close roads which, in the case of Kathmandu and many cities in Nepal; can lead to shortages of fuel, medicine and emergency help needed after a major earthquake. The breakdown of transportation system can lead to a shortage of food which can result in starvation and suffering. Also, with ruptured water mains, breakdown of electrical supply and a closure of many roads, diseases can spread rapidly and uncontrollably.

DESIGN PROBLEMS FOR EARTHQUAKE FORCES

Vertical Acceleration

Vertical acceleration greater than 1g (10 metres/second squared) can happen during a severe earthquake. This is a vertical force sufficient to throw rocks into the air. Most buildings are not built to withstand a vertical force of this magnitude. Many design accelerations of about 0.5g are common and thus many buildings can fail in this way.

Lateral Acceleration

The most severe movement in an earthquake is usually in the horizontal direction. Most buildings are first made

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strong to resist the force of gravity carrying their own dead load as well as projected live loads and then some lateral wind loads. However, the severe lateral force of a major earthquake is several times greater than other design loads and must be taken into consideration separately in the design process.

With the horizontal movement, the building fixed in the ground tends to act like an inverted pendulum causing greatest stress near the ground, where the combined weight of the structure above is trying to move laterally in response to the earthquake, and the ground floor is taking that combined stress as it tries to hold the building to the ground.

Soft Soil vs. Bedrock

Soft ground usually worse than bedrock
The San Francisco quake of 1906, Bihar quake of 1934; Monte Negro (Yugoslavia) 1979; and Kobe quake of 1995 all showed that structures built on

soft ground suffered damage many times greater than similar structures on hard rocky foundation. This is because on soft ground structures encounter greater shaking due to lower elastic modulus of soil than rock. Also, the soft ground can amplify shock waves resulting in greater intensity of shock waves on the soft ground. Many times the dynamic interaction between soil and structure with different natural periods means that oscillation of the building is magnified. Also, the vibration of soft non-cohesive alluvial soil may compact into smaller volume causing excessive settlement which can be disastrous for a building.

Problem of Liquefaction of Soil

Soil may lose its shear strength and become liquefied during earthquakes. This leads to sand fountains, as sand rises to top of the soil. Soil liquefaction can also cause floating of septic tanks and lighter structures. A major problem for

Types of foundations in decreasing order of preference⁴ (depending on height, size and importance of the building) :

1. Foundation built on solid rock where available.
2. Bearing piles in cohesionless material resting on stiff soil having high penetration value.
3. Friction piles in cohesive material.
4. Solid raft under the whole building.
5. Continuous reinforced concrete strip footings running in both directions intersecting and monolithic with each other.
6. Individual reinforced concrete footings connected together by plinth beams.
7. Continuous unreinforced strip footings with plinth level band reinforced concrete runner.
8. Un-connected individual footings or unreinforced strip footings.

buildings is that soil liquefaction can cause settling of heavier objects (like

⁴ Masonry & Timber Structures including Earthquake Resistant Design, Anand S. Arya p. 341.

buildings) and cause excessive sinking and tilting of buildings leading, to severe damage or destruction.

DESIGN PARAMETERS

With these problems caused by the violent movement of an earthquake, what specific steps in design and construction can the architect and building design professional take to decrease the dangers to man made structures ?

Foundations

Buildings should be built on rock where available; otherwise following types of foundations may be used in decreasing order of preference depending on height, size and importance of the building :
(See Chart)

Strong Ground Floors (No Soft Floors)

Soft (very flexible) storeys in buildings are a major cause of structural failure during earthquakes. Many times even large concrete frame structures, like hotels and commercial buildings, have large lobbies, restaurants and open window display area on or near the ground floor. This puts a weak layer of building structure at the most critical part of the building near the ground which will take the most stress in an earthquake. Very often in earthquakes, it is the ground floor which fails allowing the upper floors to crash down on top of the ground floor. Though this is sufficient to destroy a building, the extra stress on the upper floors as they crash into the ground floor is sometimes sufficient to crumple upper floors as well, causing extensive death, injury and property damage.

Plan and Elevation

Buildings irregular in plan or elevation develop torsional stresses. Having symmetry in plan and elevation are better from an earthquake point of view. Compact plans are seismically better than extended plans with several projections. Buildings of complex shapes, like E, U, T, or L shaped plans, must have structural separation from roof to plinth or footing to reduce their structural integrity to a collection of rectangular units.

If two separated parts are similar in height, weight and rigidity, the gap between them may be like an expansion joint. But if the parts are dissimilar, the gap should be a minimum of 1.5 cm per storey.

Roofs and Floors

Where roof and floor units are independent units as opposed to monolithic slabs, they should be tied together and fixed to the supporting members to prevent loosening during the shaking of an earthquake. The larger corrugated iron or asbestos sheets are better than earthen tiles or slates in this regard. Joints of timber or reinforced concrete should be blocked at the ends and tied together to prevent displacement relative to one another.

Projecting Parts

Overhanging elements like balconies, parapets, chimneys and projecting cornices are the first to fail during an earthquake. There is not only damage to the building when such members fail, but

these can easily injure people who may be fleeing the house or moving in the streets. Such projections should be avoided or sufficiently reinforced to anchor them securely to the main structure.

Masonry Construction and Earth Construction

Good quality bricks, hollow concrete blocks or dressed stones of adequate strength should be used for masonry construction. Random rubble masonry is extremely weak against shaking and should be avoided.

There is extensive use of earthen construction in Nepal; more than 50% of all structures. Though earthen structures are good in low cost, aesthetics, acoustics, heat insulation and low energy consumption; they are very weak under earthquake forces and water action. Disadvantages can be reduced to some extent with preventative measures.

The height of unreinforced masonry and earth construction should be kept as low as possible; preferably to one storey. Where a light sheeted roof is used an attic floor may also be made. The unsupported length of walls should be limited to 7 metres and where longer walls are required buttresses should be used at intermediate points not less than 3 metres apart. Since openings in walls reduce their strength, openings should be as small as possible and centrally located in the walls. The combined width of all openings in a wall should not exceed one-third the wall length.

To prevent the delamination of walls, through stones of a full length equal to

the wall thickness should be used every 900 mm of height not more than 1.2 metres apart horizontally. If full size stones are not available, stones in pairs, each of about $\frac{3}{4}$ of the wall thickness may be used in place of one full length stone so as to provide an overlap. In place of through stones, bonding elements of steel bars 8 to 10 mm diameter in S-Shape or as a hooked line may be used with a cover of 25mm from each face of the wall. Alternatively, wood bars of 38mm x 38mm cross section may be used for through stones. Wood should be well preserved through seasoning and chemical treatment to be durable against weathering and insect attack. Use of long stones should be made at corners and junction of walls to break the vertical joint and provide bonding between perpendicular walls.⁵

TYPES OF CONSTRUCTION

*Categories of Earthquake Resistant Construction*⁶

1. **Highly suitable** constructions are properly designed and constructed steel or reinforced concrete rigid frames and diagonally braced timber buildings. Such buildings have minimum weight, high strength to lateral forces and high ductility or deformation capacity which are the desirable qualities for resisting the applied forces and absorbing the kinetic energy fed into the structure by the ground shaking.

2. **Moderately suitable** constructions are reinforced block or reinforced brick masonry and timber frames with brick

⁵ Ibid.

⁶ Ibid., pp. 335-339.

nogging or sufficient brick walling acting within it. These buildings have moderate weight, high lateral load resistance and moderate ductility.

3. **Feebly suitable** constructions are unreinforced brick, block or stone masonry buildings with horizontal runners of timber, reinforced concrete or reinforced brickwork at plinth, floor and roof levels having proper connections at corners; or the same type buildings without the runners but constructed in wood, cement or lime mortars and having flat roofs like reinforced concrete slabs. These buildings have large weight, some amount of lateral strength and little ductility. They can be much improved by introducing vertical steel bars at corners and junctions of longitudinal and cross walls, and reinforced concrete band at lintel levels of all storeys as well. With such strengthening measures the buildings can be brought to almost the same level of suitability as reinforced block or reinforced brick masonry.

4. **Unsuitable** constructions are unreinforced brick or block or stone masonry construction in mud or weak mortars, composite constructions, earthen and adobe houses and huts. Such buildings have large weight, little or no lateral strength and almost no ductility. These also can be improved with earthquake resisting features.

Retrofit Programs

Probably the most important lesson learned from recent earthquakes is that seismic strengthening and risk-reduction programs proved very effective, both in saving lives and in reducing structural

damage to buildings. Places that had implemented such programs in Los Angeles can point to some major successes in structural integrity of the buildings, surviving the 1994 North ridge earthquake. Several large companies that had strengthened their buildings beforehand had minimal business interruption and avoided substantial losses, potentially totaling in the hundreds of millions of dollars in some cases. Many of the highway overpasses that were strengthened, survived the quake while unstrengthened sections of highway collapsed. The challenge is to convince building owners, developers, architects, and government officials that engineering and construction costs to develop more earthquake-resistant buildings are cost-effective and practical. The long-term benefits are worth the upfront investment. With examples of recent earthquakes in Los Angeles and Kobe, we have examples that show beyond doubt that investing in retrofits for existing, vulnerable buildings will yield safety and financial benefits.

CONCLUSION

Earthquakes are a major threat to life and property in Nepal and architects and building designers need to have sufficient knowledge and information to construct suitably earthquake resistant structures. The information is available, the basic design parameters are known and our professional responsibility requires that we provide buildings with adequate structural integrity to withstand normal earthquake forces at least to the point of keeping buildings sufficiently intact to limit human fatality and serious injury.

APPENDIX-1

MODIFIED MFRCALLI INTENSITY SCALE OF 1981 (ABRIDGED)⁷

Intensity	Description
I	Not felt except by a very few people under specially favorable circumstances.
II	Felt only by a few persons at rest, specially on upper floors of buildings; and delicately suspended objects may swing.
III	Felt quite noticeably indoors, specially on upper floors of building, but many people do not recognize it as an earthquake; standing motor cars may rock slightly; and vibration may be felt like the passing of a truck. Duration estimated.
IV	During the day, felt indoors by many, outdoors by a few. At night, some awakened; dishes, windows, doors disturbed; walls make creaking sound; sensation like heavy truck striking the building; and standing motor cars rocked noticeably.
V	Felt by nearly everyone; many awakened; some dishes, windows, etc. broken; a few instances of cracked plaster; unstable objects overturned; disturbance of trees, poles, and other objects, noticed sometimes; and pendulum clocks may stop.
VI	Felt by all; many frightened and run outdoors; some heavy furniture moved; a few instances of fallen plaster or damaged chimneys. Damage slight.
VII	Everybody runs outdoors, damage negligibly in buildings of good design and construction; slight to moderate in
VIII	Damage slight in specially designed structures; considerable in ordinary but substantial buildings with partial collapse; very heavy in poorly built structure; panel walls thrown out of frame structures; falling of chimney, factory stacks, columns, monuments, walls; heavy furniture overturned; sand and mud ejected in small amounts; changes in well water; disturbs persons driving motor cars.
IX	Damage considerable in specially designed structures; well designed frame structures thrown out of plumb, very heavy in substantial buildings with partial collapse; buildings shifted off foundations; ground cracked conspicuously; and underground pipes broken.
X	Some well built wooden structures destroyed; most masonry and framed structures with foundations destroyed; ground badly cracked; rails bent; landslides considerable from river banks and steep slopes; shifted sand and mud; and water splashed over banks.
XI	Few, if any, masonry structure remain standing; bridges destroyed; broad fissures in ground, underground pipe lines completely out of service; earth slumps and landslides in soft ground; and rails bent greatly.
XII	Total damage; waves seen on ground surfaces; lines of sight and level distorted, and objects thrown upward into the air.

⁷ *Masonry & Timber Structures including Earthquake Resistant Design*, Anand S. Arya.

APPENDIX-2

GENERAL CONCEPTS / DEFINITIONS: STRUCTURAL PROPERTIES

Structural Behavior and Scale

Strength The ability to sustain load.

Stiffness Push per move; the ratio of deformation to associated load level.

Stability The ability of a structure to maintain position and geometry. Instability involves collapse that is not initiated by material failure. External stability concerns the ability of a structure's supports to keep the structure in place; internal stability concerns structure's ability to maintain its shape.

Ductility The amount of inelastic deformation before failure, often expressed relative to the amount of elastic deformation.

Meanings at Various Levels of Scale

Material Strength Material strength is measured by a stress level at which there is a permanent and significant change in the material's load carrying ability. For example, the yield stress, or the ultimate stress.

Material Stiffness Material stiffness is most commonly expressed in terms of the modulus of elasticity: the ratio of stress to strain in the linear elastic range of material behavior.

Material Stability As it is most commonly defined, the concept of stability applies to structural elements and systems, but does not apply to materials, since instability is defined as a loss of load carrying ability that is not initiated by material failure.

Material Ductility Material ductility can be measured by the amount of inelastic strain before failure compared to the amount of elastic strain. It is commonly expressed as a ratio of the maximum strain at failure divided by the yield strain.

Element Strength Element strength is measured by the amount of load that an element can sustain before reaching some damage level, such as permanent deformation or complete collapse. For example, the strength of a beam could be measured in terms of the maximum distributed load that it could carry without becoming inelastic.

Element Stiffness Element stiffness is measured by the ratio of a displacement somewhere on the beam (typically the maximum displacement) and an applied load. Since stiffness is primarily a concern for service loads, stiffness is commonly measured by the maximum displacement at service loads.

Element Stability Element stability concerns the ability of the element to maintain its shape and position. An example of an unstable element would be a joist that lacks end blocking to keep it from rolling over under load. An example of internal instability would be a cable loaded in compression, since it is unable to maintain its shape under that load.

Element Ductility Element ductility concerns the amount of inelastic deformation that an element experiences before collapse. As with materials, element ductility is commonly measured by comparing the displacement at failure to the maximum elastic displacement.

System Strength System strength is measured by the amount of load that a system can sustain before reaching some damage level, such as permanent deformation or complete collapse. The collapse of a system typically involves a sequence of element failures; a well designed system may experience severe damage in many elements before while continuing to sustain higher loads.

System Stiffness System stiffness is measured by some characteristic deformation relative to an applied load. For example, the deflection at the top of a high rise building under wind loads. Or the vertical deflection of a long span bridge under gravity loads.

System Stability System stability concerns the ability of the system to maintain its shape and position. An example of an externally unstable system would be a house that slides off its foundation in an earthquake. An example of an internally unstable system would be an open frame that lacked cross bracing folded over under wind loads. Folding lawn furniture is an example of a structure that is designed to be unstable under certain loading conditions.

System Ductility System ductility concerns the amount of inelastic deformation that a system experiences before collapse. As with materials, system ductility is commonly measured by comparing the displacement at failure to the maximum elastic displacement. In earthquake design, it is common to create ductile systems by using specially detailed regions of the structure as "crumple zones" to absorb damage and allow large inelastic deformations of the system without collapse.

APPENDIX-3

Common Earthquake Myths DON'T BE FOOLED !

MYTH # 1

"Big earthquakes always happen in the early morning"

This myth may be so common because we want it to be true. Several recent damaging earthquakes have been in the early morning, so many people believe that all big earthquakes happen then. In fact, earthquakes occur at all times of day. The 1933 Long Beach earthquake was 5:54 p.m. and the 1940 Imperial Valley event was at 9:36 p.m. Even recently, the 1990 Upland earthquake was at 3:43 p.m. and the 1989 Loma Prieta event was at 5:02 p.m. It is easy to notice the earthquakes that fit the pattern and forget the ones that don't.

MYTH # 2

"Its hot and dry—earthquake weather !"

Many people believe that earthquakes are more common in certain kinds of weather. In fact, no correlation with weather has been found. Earthquakes begin many kilometres below the region affected by surface weather. People tend to notice earthquakes that fit the pattern and forget the ones that don't. Also, every region of the world has a story about earthquake weather, but the type of weather is whatever they had for their most memorable earthquake.

MYTH # 3

"We have good building codes so we must have good buildings."

The tragedy in Kobe, Japan, one year after the North Ridge (Los Angeles) California earthquake, painfully reminds us that the best building codes in the world do nothing for buildings built before that code was enacted. Fixing problems in older buildings-retrofitting-is the responsibility of the building's owner.

MYTH # 4

"Head for the doorway"

An enduring picture after an earthquake is the image of a collapsed earth home with the door frame as the only standing part. From this came our belief that a doorway is the safest place to be during an earthquake. True if you live in an old, unreinforced earth house. In modern houses, doorways are no stronger than any other part of the house and usually have doors that will swing and can injure you. You are safer under a table.

MYTH # 5

"And the earth opened ..."

A popular literary device is a fault that opens during an earthquake to swallow up an inconvenient character. But unfortunately for

principled writers, gaping faults exist only in novels. The ground moves across a fault during an earthquake, not away from it. If the fault could open, there would be no friction. Without friction, there would be no earthquake.

MYTH # 6

"The vertical earthquake"

Some people think that because some earthquakes happen on a thrust fault, lifting up

the ground in the area of an earthquake, that the shaking must have been vertical. This is like saying that because your thumb moves up when snapping your fingers, the air vibrating in your ear when you hear the snap is also vibrating vertically. In fact, as in all earthquakes, the horizontal shaking is on average twice as large as the vertical shaking.

APPENDIX-4

General Interest

Excerpts from The Code of Hammurabi (circa 1780 B.C.)

228. If a builder build a house for some one and complete it, he shall give him a fee of two shekels in money for each sar of surface.
229. If a builder build a house for some one, and does not construct it properly, and the house which he built fall in and kill its owner, then that builder shall be put to death.
230. If it kill the son of the owner the son of that builder shall be put to death.
232. If it ruin goods, he shall make compensation for all that has been ruined, and inasmuch as he did not construct properly this house which he build and it fell, he shall re-erect the house from his own means.
233. If a builder build a house for some one, even though he has not yet completed it, if then the walls seem toppling, the builder must make the walls solid from his own means.

An Excerpt from Monty Python's The Architect's Sketch

(circa 1970 A.D.)

Mr. Wymer : Frankly, I think the central pillar may need strengthening.

Client 2 : Is that going to put the cost up ?

Mr. Wymer : I'm afraid so.

Client 2 : I don't know we need to worry too much about strengthening that. After all, these are not meant to be luxury flats.

Client 1 : Absolutely. If we make sure the tenants are of light build and relatively sedentary and if the weather's on our side, think we have a winner here.



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NATIONAL BUILDING CODE FOR NEPAL DEVELOPMENT PHILOSOPHY & MEANS OF IMPLEMENTATION

Yogeshor K. Parajuli*

BACKGROUND

Nepal has the recorded history of earthquake occurrences and the related deaths as well as damages from 1255 AD. Some 18,000 buildings were either collapsed or damaged in the earthquake of 1833 (Magnitude 7, on Richter scale with maximum Intensity IX mm scale). 1934 Bihar - Nepal earthquake (Magnitude 8.4 Richter scale, Intensity IX mm scale), caused the destruction/damages of 2,07,248 buildings (Collapse: 80,893; Damages : 126,355). The book entitled "The Great Earthquake of 1934 (*Nabbe Sal Ko Maha Bhukampa*)" written by Brahma Shamsher JBR gives the detailed account of deaths, damages and destructions, and describes how the government then managed the crisis following the disaster. The book also records the lesson learnt, and provides generalistic recommendations in order to remain safe from similar future disasters and suggests areas in the Kathmandu valley that should be discouraged for the development of human settlement.

But unfortunately after the resumption of normal life the whole issue was once again easily forgotten. Experiences were not institutionalized and internalized by the government in any of its policies in order to minimize possible problems in future.

After 1988 eastern Nepal (Udaipur) earthquake (Magnitude 6.4 on Richter scale), which killed 721 people and injured 6433, in the course of damage/destruction of 71,373 buildings (Collapses : 22,328, Damage : 49,045), HMG Nepal, with the assistance of the World Bank and UNDP initiated an "Earthquake Affected Areas Reconstruction and Rehabilitation Project, (EAARRP)" to provide technical and financial assistance to the affected, in the repair / reconstruction of damaged / collapsed residential buildings and to undertake the reconstruction / repair of schools and other public buildings. One of the objectives was to disseminate the information on earthquake resistant construction technology and to institutionalize the experiences gained.

INTRODUCTION

The deaths and damages caused by the 1988 earthquake drew the attention of the policy makers towards the need for changes and improvements in the existing building construction and design methods in Nepal. The project like EAARRP had no mandate to develop regulations or documents to set "national requirements" or "good practices" which could initiate a process for required changes and improvements in the design

Mr. Parajuli has worked as the Team Leader for the formulation of draft national building code and for the development of alternative building materials and technology together with the Team Leader from BECA WORLDWIDE INTERNATIONAL, New Zealand. Mr. Parajuli is currently the Managing Director of TAEC Consult P. Ltd.

methods and construction practices for achieving satisfactory strength in buildings in the long run. Ministry of Housing and Physical Planning (MHPP) requested technical assistance from UNDP. Subsequently, a program of "Policy and Technical Support" was set up with MHPP with UNDP assistance. One of the sub-components of the program was the development of "regulations and documents for achieving satisfactory strengths in buildings". "National Building Code" to set out requirements and/or good practice, and "A Management Plan for the Introduction of a National Building Code", providing recommendations for institutional as well as legal framework and comprehensive plan for necessary trainings and public awareness raising for effective implementation of the code were prepared within the overall framework of the program. Other complementary works undertaken in conjunction with the formulation of the building code include :

- i Seismic Hazard Mapping and Risk Assessment, and
- ii Development of Alternative Building Materials and Technologies.

EXISTING SITUATION

To-date, most residential buildings even in urban areas of Nepal do not receive any rational design for strength. Even though most municipalities (36 altogether) do have system of granting building permit, there is no provision for strength criteria. Building permit process takes into account only the compliance related to planning (ground coverage,

FAR) and building by laws (height, provision of toilet, liquid waste disposal). Kathmandu and Lalitpur municipalities now require some *structural drawings* (not design) for buildings with more than 1000 sq. ft. plinth area. Thus there is poor institutional and technical capacity within the local authorities in implementing strength related provision if introduced in the building permit process.

In the professional front too, there is also no system of controlling professional standards of engineers/designers through reference to professional qualifications/membership or by legal means. Since engineers working in Nepal have received their graduations from various countries (Nepal, former Soviet Republic, India, China, Philippines, Pakistan, Bangladesh etc.) there is a possibility that they are not aware of the requirements of Indian code which gives some seismic loadings for Nepal.

More than 98% of the buildings in Nepal are built by owner builders following the advice of local craftsmen. Both of them are not aware of the possible disastrous consequences from ^{live} imminent earthquake. Neither do they have any access to information related to safer building practice and incorporation of simple earthquake resisting features with nominal extra cost.

Even the building construction projects funded by national, or multilateral agencies do not spell out any requirements related to seismic safety when they hand over the terms of reference to their consultants.

CODE DEVELOPMENT CONCEPT

In the absence of even simple infrastructure for the implementation of code it was considered rational to make a very cautious beginning. The concept therefore, was to move from *nothing* to *something*. It recognizes that code development is the beginning of a process, which should be continuous and on going. The provision of code should make it possible for incremental application. It recognizes the need to gradually move from Non-engineered level to pre-engineered or semi-engineered level and then finally to 100% engineered level of structures at least in the metropolitan areas.

The concept accordingly visualized four levels of application (depending either upon the level of capability or the importance of building and its location). The four levels are:

- I *State of Art Design* (fully engineered incorporating sophisticated design philosophies and analytical techniques, being followed by wealthy countries.)
- II *Professionally Engineered* (fully engineered following minimum acceptable standards set for Nepal).
- III *(Mandatory) Rules of Thumb* (Pre-engineered for defined building types).
- IV *Advisory Guidelines for Rural Construction* (Non-engineered construction employing Traditional Material and Skill).

Nepal Bureau of Standards and Metrology (NBSM), already has a

process in place to develop (various standards related to construction materials, food/beverages, and many other consumer industrial and consumer items), with individual Serial Number assigned to them. Standards developed for building codes were, therefore, conceived to be series of additional standards developed in line with those of NBSM standards. This would allow flexibility in their cyclic review, and updating by specialized committees concerned.

Considering the time frame of some 12 months allowed for the development of the code and the level of primary and secondary information available within Nepal required for the development of various specific standards, some standards have been adopted from IS. Thus they should be read in conjunction with relevant IS.

Each of the four levels are briefly introduced below :

a) *International State-of-the-Art*

Because the major thrust of the proposed code is aimed at the typical and most common buildings currently being erected in Nepal, it deliberately does not suggest as being practical for everyday consideration as the sophisticated design philosophies and analytical techniques that appear in the codes are more relevant to wealthy countries.

However, it is important that both Nepalese engineers and overseas consultants who can produce such designs in a routine fashion, and can ensure that their designs can be built to

the corresponding standards should not be prevented from doing so. Moreover, these structures should be seen to meet the Nepalese requirements with respect to minimum load and configuration/height. There is then no reason for any designer to argue a case for ignoring the Nepal regulations in their entirety.

A section of the code describes some of the philosophy behind the selection of loads (in particular, the earthquake ones), and allows the sophisticated designer to build up a design philosophy consistent with and encompassing, the basic requirements. The onus will be on the designer to prove that the Nepal Code requirements have been met and /or exceeded.

b) Professionally Engineered Structures

These are the standard code requirements that all professionally qualified engineers will recognize and follow when designing structures in Nepal. It will cover all major structures such as hospitals, meeting halls, factories, multi-storey buildings and larger residential buildings.

Materials analysis and design, construction safety and site considerations are all covered.

c) Mandatory Rules-of-Thumb

This section recognizes that it is not practical at present to insist that all small buildings be designed by professionals. Therefore, for classes of buildings not exceeding certain simple criteria as to height, number of storeys and floor area,

mandatory rules-of-thumb are provided. The explanatory documents are such that an experienced overseer or mason should be able to understand them and present sufficient details at the time of permit application to prove to a non-technical appraiser at the authority that the requirements are being met.

The requirements are in terms of limits on spans and heights, minimum reinforcing and member sizes, positioning of earthquake-resisting elements and other such rules.

d) Guidelines for Non-engineered Construction Employing Traditional Materials and Skills

These guidelines, based on the analysis of some typical 50 prevailing building types in Nepal constructed by employing traditional/vernacular materials and skills have been developed for improved construction for enhanced seismic safety. These buildings were surveyed and documented for undertaking their vulnerability in materials and skills. Two guidelines have been developed; one dealing with low strength masonry and another dealing with earthen buildings. These are recommended to be

- i. mandatory for all types of public building to be built throughout Nepal.
- ii. mandatory for all residential buildings to be built in municipal and urban areas, where building permit process exists.
- iii. advisory for residential buildings in the rural areas.

INSTITUTIONAL FRAMEWORK FOR IMPLEMENTATION AND UPDATING

a) *The Building Council*

There are no existing groups within the central or local government or within the training institutions in Nepal which have the necessary level of experience of implementing and supporting and/or enforcing design rules. Furthermore, agreement on any regulations affecting building construction requires input from key actors in the building industry itself. Hence it is recommended to form an apex body entitled "*the Building Council*" with representatives from key actors and policy makers, with its permanent secretariat located within the "*Department of Building*." Primary roles of "*the Building Council*" are:

- i. to recommend the government, and promulgate from time to time, what are acceptable building standards (i.e. what constitutes the National Building Code).
- ii. to ensure that the development of the NBC continues, and is supported financially.

It will also play a coordinating role for creating proper infrastructure and climate (awareness raising, human resources development, technical support etc.) required to raise the standards of all those involved in the building process, to a level sufficient to support the aims of the NBC.

b) *Support Unit/Department of Building (DoB)*

It is envisaged that the *Building Council* will be permanently supported by a

support unit, established within the Department of Building, staffed by experts in building regulation development and interpretation. This will be a center of expertise, to advise on matters of principle raised by local authorities, and building permit applicants. Such a center would be required, once the implementation of NBC starts.

The Building Council will delegate tasks to the *support unit*. Such tasks could include :

- i. organizing and coordinating training in compliance with the National Building Code.
- ii. providing specialist interpretation of the documents.
- iii. undertaking review of building permit applications, where the subject matter is special any beyond the reasonable resources of a local authority.

The DoB would therefore need strengthening to enable to develop training packages, conduct training, organize higher education programs, conduct workshops and orientation, and conduct training-the-trainers programs. In other words, the department has to do pivotal works, for which it has at present neither funding nor appropriate manpower. The department is expected to draw a detailed action plan following the recommendation on "*Comprehensive Plan for Training and Public Awareness Raising*" by the NBC Development Project Team.

c) Code Development by NBSM

It is recommended that NBSM (National Bureau of Standard and Metrology) takes the role of maintenance and development of building standards (e.g. documents constituting the NBC), just like for any other standard documents *Support Unit of the Building Council* will provide necessary expertise input and other relevant support. NBSM would naturally involve other actors in the industry similar to any other specialized committees created by it. This arrangement would facilitate the procedural re-evaluation, of existing standards and development of new ones by NBSM in its accustomed manner.

d) Other Actors / Partners in Code Implementation

Implementing the NBC will require team work. It is thus necessary to identify the partners and assign appropriate roles for effective and efficient implementation. The most important actors / partners have been identified, and appropriate roles have been defined for them, so far as implementation of NBC is concerned.

As for example DoB has been assigned the following roles ;

- i. Formulate Building Code, and formulate relevant Acts
- ii. Play lead role in Coordinating with all institutions
- iii. Develop training packages & training materials and organize or help organize trainings
- iv. Organize high level or specialized trainings

v. Develop a monitoring system and then implement

Similar roles have been defined for the following agencies. National Building Council with the assistance from the DoB support unit is expected to garner necessary support and coordination from;

- Nepal Bureau of Standards and Metrology
- Ministry of Local Development
- Other Ministries of HMG/N and Departments
- Quasi Government Organizations
- Social Welfare Council
- Department of Housing and Urban Development, MHPP
- Urban Development Training Center, Pokhara
- Institute of Engineering (IoE)
- Nepal Engineers Association
- Society of Consulting Architects and Engineers (SCAEF)
- Society of Nepalese Architects (SONA)
- Tradesmen
- Media
- Local Governments
- The Owner : Individual, Groups, Institutions, etc.

LEGAL FRAMEWORK

Building standards are to be mandatory, as the government wants them to be enforced. Other standards developed by NBSM are to be adopted voluntarily by the concerned producers. Consumers are only encouraged to use products which have been granted NS (Nepal Standard) mark by NBSM. For the building

standards to be enforced mandatory by the government in any defined area, a legal basis is required. Hence a "*Draft Building Act*" has been drafted, which will also authorize the formation of the building council and empower the authorities concerned to ensure the compliance of NBC by builders.

In addition to the *Building Act*, *Engineers Council Act* has also been drafted. This act will require *design engineers* to be registered. Only registered engineers would be authorized to self certify their works as meeting the prevailing code requirements.

The third tool is the local authority by-laws to enable integration of the strength component in the building permit process. This has been drafted as the model by-law which could be tailored by the concerned local authority, (depending upon its institutional and technical capability) to its specific requirement to incorporate different level of strength components in the permit process.

a) *The Draft Building Act*

Its salient features include the provisions for the following :

- i) Formulation of *National Building Council* or *Committee* with responsibility for the formulation and updating of the National Building Code and to assist HMG/N in its implementation. (This is conceived to be the apex body, and is entrusted wide range of responsibilities for the successful implementation of NBC)

- ii) Classification of Buildings to four categories in line with draft NBC philosophy.
- iii) Implementation supervision and its monitoring, for compliance.
- iv) Arrangement and classification of approved designer, in line with the four levels of code and authorizing them for design certification.
- v) Arrangement for building permit and building construction.
- vi) Enquiries and actions for the compliance or otherwise, of the NBC provisions by builders etc.
- vii) Power to prepare and implement regulations/by-laws.

b) *Draft Engineering Council Act*

Its salient features include the following :

- i) Provision for the formation and management of council, with President from Nepal Engineers Association as its Chairman.
- ii) Provision of registrar with defined functions, duties and authority.
- iii) Provision for the registration of engineers and issuance of certificate.
 - appropriate consideration given to the one time treatment of senior engineers (engineers with a least 30 years of age, 10 years of professional experience, to automatically qualify for direct registration within first year of the act coming into force).
 - engineers with minimum of 3 years of experience, who qualify in the examination conducted by the council.

- any person with three years of professional experience, who qualify through the *special* examination conducted by the council.
- iv) Provision for restriction on employing a non-registered engineer, by HMG/N and other agencies.
- c) *Model Local Authority By-laws for Enforcement of NBC*

Its major provisions include :

- i) Applicability and conditions of application of the code (level and conditions of building).
- ii) Requirement of a building section, headed by a building officer with defined power and functions.
- iii) Need to obtain building permit, by all persons and agencies, prior to undertaking construction, and the documents to be submitted to obtain the same.
- iv) Responsibilities and duties of the owner/builder.
- v) Inspection during construction by the authority.
- vi) Connections of utility services to be authorized only to those buildings which have complied with the code. No transfer of ownership to be permitted for buildings, not complying with the provision of code.
- vii) Registration of technical personnel (engineers, architects, overseers etc.), by a local authority who wants to operate within the territory. Only registered technicians to be allowed

to prepare the building approval drawings, and undertake periodic supervision for certification purpose.

- viii) Definition of unsafe buildings and requirements for demolition.

COMPREHENSIVE PLAN FOR TRAINING AND PUBLIC AWARENESS RAISING

a) Assumptions

The intent of the Plan is to bring about positive change in building practices. The multifaceted process addresses the requirements of large and small buildings, built from either traditional or alternative materials. The strategy and action Plan to executive the Building Code programs, define long-term and on-going activities required, to ensure that all construction in Nepal will achieve higher levels of seismic safety.

This plan establishes a local structure for continued education, training, and provision of technical assistance in seismic resistant construction.

The dissemination process is designed to transmit three basic concepts to identified target audiences. The concepts are :

- Define *Why* particular measures are needed.
- Define *What* needs to be done.
- Define *How* it needs to be done.

The second phase of the Plan consists of the long-term implementation strategy. This program is intended to utilize the products developed by the project over a multi-year time frame.

The Plan creates an educational structure, within which efforts to reduce seismic hazards throughout Nepal can be implemented. Legislation and administrative programs will execute and institutionalize the code, while training and education will achieve improved seismic resistance of non-engineered structures.

The implementation strategy addresses :

- What institutional steps should be taken to disseminate information.
- Who best should disseminate the information.
- What information should be disseminated-in what physical form.
- How to inform public that a building code has been developed.

The dissemination program must communicate with people who have different levels of technical expertise. The educational dissemination program must, therefore, be available in both print and visual media, in both the urban and rural areas. This multi-media form of communication is especially critical because of the high illiteracy rate, compounded by the very low level of expertise with respect to issues pertaining to seismic resistance, among all sectors of the construction industry (among professional, technicians, craftsmen, etc.)

b) Objective

The underlying objective of the Plan is to reduce damage and life loss from earthquakes in Nepal. The Plan defines the activities required to ensure that higher level of seismic safety are achieved for all buildings throughout Nepal.

The Plan assumes that the Building Code and standards for small buildings will be adopted incrementally, with the major population centers taking the lead. Concurrent with the upgrading of professional expertise and craftsmen skills, administrative programs and legislation are needed to operate and institutionalise the code. Throughout the implementation process, training of craftsmen and education of owners/builders will result in improved seismic resistance of non-engineered structures.

The target audiences are diverse. Recommendation are, therefore, organized according to the time frame required for implementation. Three benchmark periods are identified :

Short Term (0 - 3 years)

Primary Focus : Training and Education

Key Actions : Supplementary education for professionals on seismic design; education of government and NGO's staff regarding seismic resistance and administrative objectives; training of craftsmen.

Mid Range (3 - 5 years)

Primary Focus : Increases expertise to comply with the Code.

Key Actions : Implement Rules of Thumb to serve as guidelines for improved construction; adopt remaining provisions of code.

Long Term (6 - 15 years)

Primary Focus : Building Code enforcement structure throughout Nepal.

Key Actions : Long term upgrading in building practices.

A combination of activities are proposed for each time frame directed to five distinct (but often overlapping) target groups:

Professionals : Enhance design expertise

Technicians : Skill upgrading

Craftsmen : Skill upgrading

Government Employees : Awareness of seismic resistance principles

General Public : Awareness that seismic resistance can be achieved



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RESOURCE RECOVERY CONCEPT IN SOLID WASTE MANAGEMENT

Sangeeta Singh*

In the materialistic world of today, consumption of goods is ever increasing and so is the associated amount of waste generated. It is becoming apparent that one of the major impacts of technological development is a significant increase in the generation of solid waste. As the consumerage is getting more sophisticated so is the demand for an effective and efficient waste disposal system becoming a challenge, more so for the developing countries, where financial and economic considerations often pose major hurdles in obtaining the objectives of safe waste disposal system.

In the past years, environmental protection has been given increasing attention in the industrialized as well as in most of the developing countries. The questions regarding the ecologically sound methods of waste treatments, in particular have received more and more attention, in analyzing the positive and negative effects of solid waste management. The process of waste handling with the least negative impacts on environment, demands a lot of input of resources, be it economic resources or technical or others.

For the developing countries, that are still striving for the fulfillment of the basic needs of the people in the country, the most pressing factor is the economic

stability of the country, and the availability of sufficient funds to enable the government to provide good standards of service. Very often solid waste problems are being ignored and given minimum priority both by the government and the public sectors. An average of about US\$ 0.60 is spent in most of the Asian cities compared to about US\$ 10/head/year in developed countries.¹ And there is greater total workload in the developing countries due to access problems, the need for daily collection, more complex housing and inefficient traffic systems.

In the developing countries, realization of a proper and sustainable waste handling system might only be possible if the concept of resource recovery is utilized in the waste management, or more if the cost recovery is achieved.

The countries that have not utilized their resources properly, taking into account that their development approaches are different should take heed because the move towards development can become problematic. Science has developed a lot of things and through technology man can utilize and recover resources.

Resource recovery in solid waste management is no exception. Production

¹ SWMRMC, GTZ, *Solide Waste Management and Resource Mobilization*, Vol. C (Kathmandu, 1990)

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of Manure or energy by technical means, is one example of resource recovery using waste. In a way Garbage can be wealth if properly managed. It can yield revenues which can be utilized for efficient and effective disposal of waste, if not for gaining extra profit. But this can only be realized if people are educated on the economic as well as environmental implications associated with the disposal of garbage. Serious thoughts are being given by visionaries and planners to advocate the privatization of garbage collection and the conversion for useful by-products in many countries. A time may come when garbage disposal may even be able to earn some money through privatization. The cities too, could be cleaner as private operators will not leave useful garbage uncollected. While dealing with issues of solid waste management, it is therefore of significance that the various aspects of resource recovery are given due emphasis.

SOME ELEMENTS OF SOLID WASTE MANAGEMENT

Collection, Storage and Transportation

Collection, storage and transportation of solid waste is the main sector demanding the municipal budget in solid waste management. Cointreau² estimates that nearly all of the cost (approximately 90 %) is for collection and transportation, since disposal is most often open dumping, so that it is for these aspects of waste management that improvement in cost-effectiveness are most urgently needed. Moreover it is a service that

relies on equipment which are relatively short-lived and therefore require capital investment, which means that for most of the developing countries, where the equipment is neither assembled nor manufactured locally, they have to compete for the limited foreign exchange.

Being also a labour intensive service, the possibilities for improving both labour and vehicle performance are very much governed by local circumstances. However as a broad principle, any methods which seeks the co-operation of household or occupier to move waste to a collection point offer substantial savings over methods which require the authority to do all the work.

With new trends of haphazard urbanization in the developing countries, transport of collected waste does face numerous problems, even though the disposal site is not far away. This is so because of the combined effect of inadequate roads, narrow roads with very heavy traffic, and small payload vehicles, all of which often means that a high proportion of vehicle operating time is spent on transporting wastes to the disposal sites.

Treatment, Recovery and Disposal

In most of the developing countries, uncontrolled dumping of solid waste has been as easy option of disposal of waste. In view of most experts in the field of wastes management, in developing countries large scale pre-treatment aimed at volume reduction or resource recovery is hardly ever justified since disposal of unpressed waste by tipping on land

² Cointreau J. Sandra: Solid waste collection practice and planning in Developing Countries, p. 151.

continue to be the most attractive option of disposal both on technical and economic grounds.

However on environmental grounds, open dumping of solid waste is no longer acceptable even in the developing countries, and various disposal methods are resorted to that give due consideration to resource recovery. Analyzing the possibilities of cost reduction and resource recovery in waste management, would require that all these elements of waste collection and transportation are taken into consideration.

Among the various issues pertaining to resource recovery in solid waste such as the technical issues, financial issues, institutional issues, socio-economic issues, environmental issues etc. some of the major issues are dealt with in this paper.

TECHNICAL ISSUES IN RESOURCE RECOVERY OF SOLID WASTE

In the light of new technology, solid waste is looked upon as a national resource rather than a nuisance, because new technology is available for recovering and reusing valuable materials. Depending upon the availability of land, its topography, economic viability, available technology and social conditions, the method adopted may vary from country to country. In most of the developing countries, wastes are disposed by crude dumping methods, without any formal regulation or control. It is obvious that this has the implications of environmental hazards, in the form of

pollution of air by pathogens and smoke, production of leachates contaminating surface and ground water, increases of rodents and scavenging birds etc.

However with the rising consciousness for environmental safety, among the people, other methods of disposal such as sanitary landfilling, incineration, and composting etc. are also becoming quite common. This has been possible more often, with the technology transfer from the developed countries. Very often the developing countries are unhesitant in adopting the sophisticated technology from the developed countries, in managing solid waste, without analyzing the economic/ financial impacts of such a technology. Often technologies have been selected to duplicate those of the industrialized countries rather than to suit the local conditions of the country.

With recent technological development it is always better to look into the various technological alternatives that exist in order to select the one which best suits the local conditions and at reasonably reduced unit cost. Several technological options for resource recovery and recycling exists, and this has to be given due consideration, in choosing a suitable method for disposal of waste. Some of the technological options for resource recovery in Solid waste management are dealt with here in brief.

TECHNICAL OPTIONS FOR SOLID WASTE RECOVERY AND RECYCLING

Separation or Initial Recovery

As the name itself suggests, "Initial recovery" can be done at the source,

manually and through physical and mechanical means. Source separation is not a "technical option" in the truest sense, but it greatly facilitates the use of subsequent treatment processes which require sophisticated technology. However for it to be a success, specially in the urban areas, dedication, interest, careful planning and administration and cooperation from the citizens are required. Residents have to be educated, which ultimately means that there should be changes in their daily habits.

Further Treatment Processes

Landfill gas recovery, composting, Pyrolysis, Single cell protein (SCP) production, Anaerobic digestion, Incineration (with energy recovery), and Recycling are some of the methods used for further treatment of the waste.

Landfill Gas Recovery

Landfill is the cheapest and the most common method of waste disposal practiced all over the world. In comparison to the other expensive alternatives available at present, this system will continue to be practiced for many years to come. The developing countries in particular cannot afford to choose the expensive methods of incineration or mechanical composting of waste; so they have to depend on landfill methods most of the time. While landfilling is the cheapest method of waste disposal, it also poses a threat to the environment if the landfill site is not properly selected and managed and if methane gas produced inside the landfill site is allowed to escape into the

environment. The landfill gas or the methane gas which is produced in the landfill site and which escapes into the atmosphere not only pollutes the environment, it also causes the greenhouse effect which also must be prevented.

Research and experiments carried out in this field, however have established that methane gas produced from the landfill site is a valuable non-conventional source of energy and could be commercially exploited and used for the benefit of the community. Income can be generated from this source of energy lying unutilised for years.

There is very little awareness in all developing countries regarding the utilization of landfill gas as a source for mobilizing resources for solid waste management. Landfill gas is produced as a result of biodegradation of organic matter in the absence of oxygen. Production of gas in a landfill takes place within a period of six months to one year, depending upon the moisture content present in the waste.

The methane gas abstraction is a simple technology and gas can be obtained from the landfill site continuously for a period of 10 years. The income derived from there will, if not result into profit, at least make up the cost of energy generation, and protection of the environment will be an added advantage. Tapping of methane gas gives a double benefit. On the one hand, we protect our environment and on the other hand we can get income out of this gas which can be directly used as fuel in the industry or

can be economically utilized for heating purposes, and for the generation of electricity by using biogas engines coupled with a generator.

Land fill gas recovery is rapidly attracting interest in many countries. Traditionally regarded as nuisance, landfill gas is not only a potential source of energy, but its utilization also helps alleviate problems of gas migration from the landfills and improves air quality adjacent to these sites. Landfill extraction is widely practiced on a commercial basis in the USA and also in some of the European countries and they are deriving profits out of gas extraction plants.

Though it is a debatable point whether for the protection of our environment, efforts should be made to minimize the production of gas in the landfill site or to maximize the production and then tap more gas; the fact remains that whatever gas is produced, it has to be tapped and used for commercial purposes if production is economically viable (and it should be burnt away if it is not feasible), to generate income to pay for the cost of production. This will at least protect the environment.

Regional and cheaper technology may be adopted for the extraction of gas and one should learn from the experiences of others for tapping the source. Gas should be supplied directly to the industries as fuel if situated nearby or the industries could be set up nearby and in cases where it may not be possible to supply the gas directly, the gas could be converted into electricity and given on the grid.

Before dumping money into a commercial project, experiments must be carried out to find out whether the site is fit for the commercial exploitation of landfill gas.

Composting

One of the well known form of recovery is the production of compost from organic waste. In the industrialized countries, however the application of compost in the fields is limited due to the fact that waste in these countries have relatively high amount of noxious substances. There are several arguments which speak in favour of composting as a resource recovery option, particularly for the developing countries, and they are:

- The technology is simple.
- The process is readily adaptable to local conditions.
- Only a small amount of residue is left to be disposed of.
- Compost has a low toxic substance burden.
- Compost can be sold to gain revenues.
- Composting meets the requirements concerning hygiene
- Refuse composition is appropriate for composting

Often, marketing of compost produces has been difficult and furthermore composting cannot recover certain valuable materials. Wood, rubber, textiles, metals and plastics are either impossible or very difficult to compost. In the developing countries, where the domestic refuse is in most cases suitable for composting, there are other reasons for the limited production such as:

- From the commercial point of view, composting cannot be regarded as a very profitable business.
- Indirect savings which occur if composting is the alternative to sanitary disposals are not considered.
- Mechanized compost plants require permanent technical supervision and maintenance for which the manpower or the spare parts are not available.
- Compost has to compete in the market with mineral fertilizers which are often subsidized by the government.

In spite of these reasons, waste recovery in the form of compost has attracted growing interest during the past years, particularly from the governments and city councils. Among other reasons, two significant reasons why this is so, are certainly:

- The continual growth in the generation of wastes, the disposal of which poses serious environmental problems particularly in the urban areas.
- A growing awareness that compost is valuable in terms of its nutrient content and its long-term effect as a soil conditioner.

However, the decision to operate a compost plant or not as part of an overall waste management strategy, depends mainly, but not exclusively, on financial/economic considerations.

Pyrolysis

The term "pyrolysis" refers to the act of decomposing organic compounds through the application of heat. More

specifically, it is the process of destructive distillation carried out in an oxygen-free environment. Through Pyrolysis, organic matter can be readily converted into gases, liquids, and inert char. The products of Pyrolysis represents about 50 percent of the initial volume of the original matter, and they can be converted into energy to either sustain or to produce excess power.³

The result of Pyrolysis developmental work in various countries, demonstrates that the process is self-sufficient and regenerative. The gas obtained is sufficient for heating the retort, the by-product tar-oil can be used as a substitute for furnace oil and the coke can be used as domestic fuel. For these reasons, and because solid waste had a high organic content, Pyrolysis appears to be an attractive method of solid waste disposal. However, where Pyrolysis has been applied in the past, such as in the production of charcoal and the recovery of methanol, acetic acid, and turpentine from wood, the feed material was homogenous. Unfortunately, solid waste is not only heterogeneous, but may differ greatly from one batch to the next. Therefore, considerable research and pilot work is required before Pyrolysis can be applied as a full-scale method of energy recovery from solid waste.

Single Cell Protein Production (SCP)

Urban solid wastes that are rich in organic and cellulose can be utilized for SCP production in which a "combined

³ Joseph L. Pavon, John E. Heer Jr., D. Joseph Hagerty, *Handbook of Solid Waste Disposal: Material and Energy Recovery* (1975).

fermentation process where selective use of aerobic thermophilic organisms are used for the formation of protein from cellulose and lignin.

Anaerobic Digestion

Anaerobic digestion has been utilized for many years in wastewater treatment systems to reduce the amount of organic sludge that must undergo final disposal. This reduction in sludge quantity is accompanied by the conversion of a portion of the solids to liquids and gases, and is accompanied by an increase in the sludge's dewatering characteristics. The gas produced in this process is a combination of methane and carbondioxide possessing a high calorific value and therefore has a high potential for reclamation.

Anaerobic fermentation of complex organic material is usually considered to occur in two stages. In the first stage, facultative anaerobic acid producers convert complex carbohydrates, proteins and fats into simple organic acids and alcohol. In the second stage, anaerobic methane fermenters convert these short-chain organic acids and alcohol into methane and carbondioxide. The relative proportions of these two gases are dependent upon the detention time and temperature at which the process is operated.

Since soil waste is composed of essentially the same constituents that make up wastewater sludge (carbohydrate, proteins and fats), it would seem logical that refuse could also successfully undergo anaerobic

digestion. Several investigations have supported this conclusion by demonstrating that organic refuse, especially garbage, can be anaerobically fermented, provided that the proper environmental conditions (temperature, pH, absence of oxygen and nutrients) are maintained.

About 70% methane and 30% carbondioxide, traces of oxygen and hydrogen sulphide are the end products of anaerobic digestion, thus forming a valuable fuel gas. However, the constant requirement of carbon to nitrogen ratio 30:1 cannot usually be met in Asia due to the changing nature of the urban wastes.

Incineration

Incineration process of waste disposal, in general poses environmental problems, if enough precautions are not taken in its operation. A very tall chimney is needed to ensure that the gases are disposed off safely. Water consumption for gas cooling and clinker quenching may be very high which gets polluted to a great extent and this needs further treatment.

In most of the developing countries, the calorific value of refuse is very low, so a fuel supplement may be necessary as part of the incineration process. Incineration process was found to inapplicable to most of the urban wastes in Asia because of high organic and putrifiable fraction, high ash and non-combustibles, high moisture content and rather low calorific values. In the developing countries, incineration might only be economical in such cases where either a self sustaining

combustion reaction can be obtained or where total cost of collection and disposal will be reduced due to its location within the city limits.

With shortages of fuel forecasts, and with the failure of nuclear power to become widely available, increased interest have been generated in the use of solid waste as fuel. In many communities refuse is being processed currently in the incinerators wherein large quantities of heat are liberated and wasted either directly or indirectly to the atmosphere. Consequently, attention is being focused on ways and means of utilizing the heat liberated during incineration. Waste heat recovery incinerators have been used to some extent in Europe and America and will probably become more numerous as fossil fuel prices rise in the future.

The success of these systems is primarily dependent upon long term markets for the steam from the process. In the future, waste heat recovery systems should become more feasible economically because of predicted fuel shortages and the resultant public clamor for the development of a fossil fuel substitute. These systems will have the added economic advantage of eliminating solid wastes disposal charges to a large extent.

Recycling in Developing Countries

Scavenging of Solid Wastes

For proper management of solid waste it is essential to separate garbage, so that reprocessing and recycling of categorized scrap items and proper salvaging can be done. Recycling could also contribute a lot to the recovery of

waste. Recycling in developing countries is highly labor intensive. This is possible only because the rapid rate of population growth in the urban sector, combined with the slow growth of the economy had led to a high level of unemployment and hence, low wages. Under these conditions, handpicking of refuse becomes a viable economic proposition. Crude dumping is almost universal in these countries and often supports a large number of scavengers who extract valuable materials. It is paradoxical that the poorest countries are in this way achieving a high level of recycling despite the small proportion of salable matter in the waste.

However the grim realities of child labor and public health hazards must not be overlooked. As the whole family is usually employed in scavenging, even the very young and the elderly are equally exposed to a wide variety of pollution effects, obnoxious odours and most specially disease vectors which may seriously endanger the health of all workers who come in direct contact with the waste.

Household or Internal Waste Sorting

Mostly in the Asian cities, it is found that some materials in the collected refuse are noticeably low as they are already sorted out at the household level and are either used or sold. for example, coal, coconut shells etc. are extracted for fuel, metal cans are used for domestic vessels and vegetable wastes are fed to the animals. Others for example paper (for repulping), tin cans (for resmelting), glass (for reuse, remelting or abrasive manufacture) and plastic (for re-use or

inferior grade production), are sold to small merchants who operate collection and sorting depots or they are sold to collectors who go around, in the streets collecting all these stuff.

Recycling Potential through organized scavenging

Collection from disposal Sites of the Municipalities : This is practiced to a high degree in developing countries and scavengers perform efficiently as soon as collectors empty their loads at the disposal sites. Sometimes the whole families of scavengers support themselves living on these dump sites and little that are of value are thrown away. this system in effect is selfcontained through the action of middlemen and subsequent interaction with the buyers of the secondary materials. However, although this provides a method of resource recovery, the scavenger who is at the heart of the system, must work under deplorable and hazardous conditions.

Organized Scavenging

The potential for developing organized scavenging in developing countries, specially in Asia, deserves particular emphasis. An example of organized scavenging can be seen in the case of Philliphines, where they launched a prototype solid waste project called "Resource Recovery", which is aimed at demonstrating a more systematic way of recycling starting from the education at the household level to training and fielding of the so called "ecology aides" or "Ecoaides" to the identification of end buyers. The establishment of such a working system provides decent means

of living for scavengers and minimize their exposure to filthy conditions. The project plan is to hire as many of those currently engaged in scavenging as Eco-Aides. They would make the rounds of households and be authorized to buy at predetermined prices those recyclable materials which have been previously sorted by the household into wet organic or dry re-usable items. The materials will be redeemed at redemption centers at about 20-25 % more than what they paid for them, and where the materials can later be sold to junk dealers.

If emphasis is put on a better working standard at the site, vector control measures to prevent diseases, and basic amenities, the scavengers would be a happier group of people. Furthermore if the system is controlled to avoid middlemen cheating the scavengers, organized scavenging could be a prosperous livelihood for many, and economic gain for the city and an achievement in the field of solid waste management.

SOCIO-ECONOMIC ISSUES IN RESOURCE RECOVERY

Costs and Benefits of Resource Recovery and Recycling

The first and the most fundamental step in using economic analysis in waste management is to identify all the relevant costs and benefits that need to be taken into account in the particular decision being examined. The attractiveness of resource recovery and recycling as a method of handling waste depends on how the costs and benefits of the

available resource recovery and recycling methods compare with the costs of conventional methods of waste collection and disposal that would otherwise be employed.

From the viewpoint of the responsible authority of waste management, recovery should be of interest if the cost of collecting the material of product, plus any cost of sorting or separation of the material or by-product generation, less any saving in the overall waste collection and disposal costs is less than the revenue obtained from the sale of the recovered materials. (Figure 1).

Figure 1
Cost and benefit of Resource Recovery

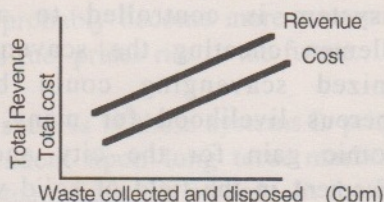
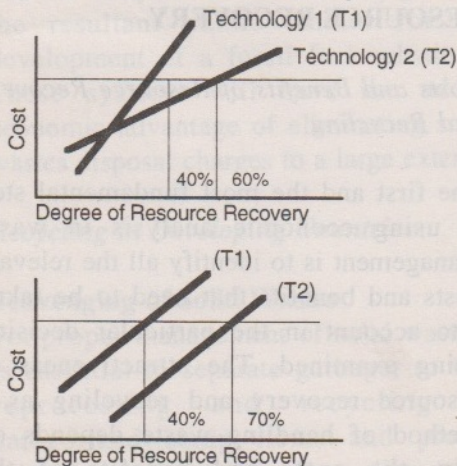


Figure 2
Degree of Resource Recovery and Cost



In both the cases as shown in (Figure 2), technology 2 is superior in comparison to the technology 1, at same cost, because the second technology yields greater percentage of resource recovery.

From the point of view of the buyer of the reclaimed material it will be worthwhile if the cost of buying the reclaimed material or energy is less than the cost of purchasing or producing virgin material or energy, less any extra cost involved in processing and using reclaimed material/energy less any additional transport cost involved in obtaining the reclaimed rather than the virgin material/energy.

In general the scope for using recovered rather than the virgin material/energy and the level of extra costs for the user to be set against any saving in price depends in practice on a number of factors such as:

- the technical ability to turn reclaimed material or by-product into an acceptable substitute material.
- the market's attitude to the final products made with recovered materials.
- the supply conditions for reclaimed material compared with virgin material.
- the location of production facilities in relation to the sources of materials.

SOCIAL ASPECTS

The attractiveness of resource recovery and recycling should also be looked from the viewpoint of the society as a whole, as well.

It is very important to understand that each society has the pattern of environmental behavior it deserves. People's behavior in the field of waste handling reflects their actual consciousness. This consciousness will not change if an institution just offers new technical solution and might even end up in having opposite effects. Some of the issues of interest which should be considered in the assessment of costs and benefits of resource recovery may be at:

- the value of the society regarding the recovery of waste materials
- the value of the materials in terms of saving of imports and scarce raw materials.
- the impact on pollution of the natural environment.
- the effect on public health and safety.
- the acceptance of the recovered materials by the users.

It is of importance that people are aware of the significance of resource recovery for sustainable development of the solid waste management and are willing and motivated to participate. This awareness can be promoted by:

- by school education
- by mass media
- by providing means of motivation

ENVIRONMENTAL ISSUES IN RESOURCE RECOVERY

Economic instruments in environmental policy

Environmental protection is always a major concern in the management of solid waste. The generation of waste is

increasingly a public health problem, due to both waste volumes and toxic elements in the waste streams. To reduce both problems, it is of particular importance that products have longer life, are reused or offered for secondary use and that dispersion of obsolete products with dangerous substances in the environment is prevented.

Several Council Recommendations and OECD Ministerial Declarations call for the use of economic instruments for pollution control, in particular in the fields of water, waste and noise. It is generally recognized that economic instruments provide "more flexibility, efficiency and cost-effectiveness" in environmental policy. OECD work on economic instruments recently culminated in a major study on the use of economic instruments in OECD member countries. This study revealed that the use of economic instruments had increased significantly over the last fifteen years. In the fourteen countries reviewed (in 1987), there were over 150 instances of applications of economic instruments including systems of financial aid.⁴ Nowadays, there is large consensus that, in many cases, economic instruments can be a powerful complement to direct regulations.

One basic objective of economic instruments is to ensure an appropriate pricing of environmental resources in order to promote an efficient use and allocation of these resources. If the environment is priced correctly, environmental goods and services are treated

⁴ OECD, *Environmental Policy: How to apply economic instruments* (Paris, 1991).

equal to any other production factor on the marketplace and an economically efficient allocation of the production factors are ensured.

In waste management applying such economic instruments would also mean strengthening of the resource recovery concept, and the purpose is generally financing or incentive. Financing charges (user charges) are aimed at a proper collection, processing and storage of waste or at restoration of old hazardous waste sites. Collective processing and storage of chemical waste should be given due consideration. Incentive charges can have multiple purposes which should be recognized when such charges are designed. Some of them are as enlisted below:

- to minimize (voluminous and/or toxic) waste generation in the production and consumption processes.
- to discourage production and consumption of voluminous and/or toxic waste-intensive products and to promote more "friendly" substitutes.
- to promote recycling which saves deplet-able resources, including space for waste dumping.

THE TYPES OF ECONOMIC INSTRUMENTS APPLICABLE IN SOLID WASTE MANAGEMENT

Generally, emission and user charges, product charges and in particular deposit refund systems are applicable in the field of waste management. In some instances, tradable emission rights are also conceivable.

Emission (Disposal) Charges

Emission (Disposal) charges should be based either on the volume or on the toxicity (or other harmful characteristics) of waste elements. In the latter case, waste containing many substances will cause calculation and monitoring problems. Emission charges can only be applied if discharges are easily controllable, because of possible evasion. In most cases, user charges i.e. payment for waste collection and the use of waste disposal facilities, should be applied. Regarding household waste, a better linkage between the charge bill and the waste volume offered for collection is envisageable by charging per bag. Such a charge will appear as a product charge on waste bags.

Product Charges

Product charges are conceivable in the case of products that will generate waste in the production or consumption phases; They act as proxies in those cases where a direct charging of waste is not effective or efficient. Materials which can be recycled or re-used could be charged in order to induce such course of action. Product charges on non- returning packaging can support deposit-refund systems on returnable alternatives.

Deposit Refund Systems

In the cases where a return of used products to collection or storage sites is very important, a deposit-refund system could be considered. This is desirable when such products can be easily re-used or recycled (bottles, crates) or when such

products contain potentially polluting substances (batteries, cars etc.). Products subject to deposit-refund systems should be large in quantity and a collection system should be easy to create. Standardization will enlarge the possibilities of deposit-refund systems and will, if internationally agreed on, prevent trading problems.

Marketable Permits

In certain situations, "marketable waste disposal" permits could be conceived,

e.g. systems whereby manufacturers are assigned specific percentages of waste recycling and/or safe disposal could trade such permits with other manufactures. Such schemes should, however be completed by prohibition to ship waste outside the regulated area; this would entail monitoring and enforcement problems. Fixing a ceiling on waste discharge is also complicated because of the composite nature of waste streams, the way they are disposed of and hence the uncertainties related to environmental impacts.

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EXPANSION OF TRINOMIAL AND POLYNOMIAL EXPRESSIONS

Kamal Mani Baral*

INTRODUCTION

Research has been the golden key with which the doors to new improvements have been opened. Many philosophers, scientists and mathematicians are continuously in search for new improvements which can be more and more useful for human welfare. With this effort Sir Isaac Newton invented the Binomial theorem.

Binomial theorem can be applied to find the expansion for trinomial and polynomial expressions or multinomial expressions but not properly as the Binomial theorem.

Binomial theorem for a positive integer n :

$$(a+b)^n = {}^nC_0 a^n + {}^nC_1 a^{n-1} b + {}^nC_2 a^{n-2} b^2 + \dots + {}^nC_r a^{n-r} b^r + \dots + {}^nC_n b^n$$

This theorem poses a question as to what will be the root of expansion for

$$(a + b + c)^n, (a + b + c + d)^n, (a + b + c + d + e)^n, \dots, (a + b + c + \dots m \text{ terms})^n ?$$

Based on investigations, to find the appropriate answer to the above question, a fairly easy solution has been encountered. Hence there exists a certain rule to find the general term, total number of terms and other useful properties in the expansion of

$$(a + b + c + \dots m \text{ terms})^n \text{ for all values of } m = 1, 2, 3, \dots, m \text{ \& } n = 1, 2, 3, \dots, n.$$

EXPANSION OF TRINOMIAL AND POLYNOMIAL EXPRESSIONS

As stated in the introduction, the rule of expansion and their properties in the expansion of trinomial and polynomial expressions including the binomial expansion, are explained as follows :

Binomial Expansion

For a positive integer n the binomial expansion (or binomial theorem) is given by:

$$(a+b)^n = {}^nC_0 a^n + {}^nC_1 a^{n-1} b + {}^nC_2 a^{n-2} b^2 + \dots + {}^nC_r a^{n-r} b^r + \dots + {}^nC_n b^n$$

The binomial expansion has the following properties:

- The number of terms in the expansion is $n + 1$ or $(n + 1)C_n$.
- The sum of exponents in each term is n .
- The expansion starts with a^n and ends with b^n . In each term the exponent of a increases by one while the exponent of b decreases by one and conversely.
- The coefficients from the sides are equal.

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By actual multiplication and generalizing the result we can put the binomial expansion in the folded form as follows :

$$\begin{aligned}
 (a+b)^n &= nC_0(a^n + b^n) + nC_1(a^{n-1}b + ab^{n-1}) + nC_2(a^{n-2}b^2 + a^2b^{n-2}) \\
 &+ nC_3(a^{n-3}b^3 + a^3b^{n-3}) + nC_4(a^{n-4}b^4 + a^4b^{n-4}) + \dots \\
 &+ nC_{\frac{n}{2}} \left(a^{\frac{n}{2}} b^{\frac{n}{2}} \right) \left| \text{or } nC_{\frac{n-1}{2}} \left(a^{\frac{n+1}{2}} b^{\frac{n-1}{2}} + a^{\frac{n-1}{2}} b^{\frac{n+1}{2}} \right) \right. \\
 &\text{according as } n \text{ is even or odd.}
 \end{aligned}$$

This clearly shows that

$$nC_{\frac{n}{2}} \left(a^{\frac{n}{2}} b^{\frac{n}{2}} \right) \quad \text{and} \quad nC_{\frac{n-1}{2}} \left(a^{\frac{n+1}{2}} b^{\frac{n-1}{2}} + a^{\frac{n-1}{2}} b^{\frac{n+1}{2}} \right)$$

are the middle terms when n is even or odd.

B. Expansion of Terms Containing Three Terms

By actual multiplication and generalizing we get;

$$\begin{aligned}
 (a+b+c)^n &= nC_0(a^n + b^n + c^n) + nC_1(a^{n-1}b + ab^{n-1} + a^{n-1}c + ac^{n-1} + b^{n-1}c + bc^{n-1}) \\
 &+ nC_2(a^{n-2}b^2 + a^2b^{n-2} + a^{n-2}c^2 + a^2c^{n-2} + b^{n-2}c^2 + b^2c^{n-2}) + \dots \\
 &+ nC_{\frac{n}{2}} \left(a^{\frac{n}{2}} b^{\frac{n}{2}} + a^{\frac{n}{2}} c^{\frac{n}{2}} + b^{\frac{n}{2}} c^{\frac{n}{2}} \right) \left| \text{or} \right. \\
 &nC_{\frac{n-1}{2}} \left(a^{\frac{n+1}{2}} b^{\frac{n-1}{2}} + a^{\frac{n-1}{2}} b^{\frac{n+1}{2}} + a^{\frac{n+1}{2}} c^{\frac{n-1}{2}} + a^{\frac{n-1}{2}} c^{\frac{n+1}{2}} + b^{\frac{n+1}{2}} c^{\frac{n-1}{2}} + b^{\frac{n-1}{2}} c^{\frac{n+1}{2}} \right) \\
 &+ nC_1 \times (n-1) C_1 (a^{n-2}bc + ab^{n-2}c + abc^{n-2}) \\
 &+ nC_2 \times (n-1) C_1 (a^{n-3}bc^2 + ab^{n-3}c^2 + a^2b^{n-3}c + a^2bc^{n-3} + b^2a^{n-3}c + b^2ac^{n-3}) \\
 &\dots \\
 &+ nC_{\frac{n}{2}} \times \frac{n}{2} C_1 \left(a^{\frac{n}{2}-1} bc^{\frac{n}{2}} + ab^{\frac{n}{2}-1} c^{\frac{n}{2}} + a^{\frac{n}{2}} b^{\frac{n}{2}-1} c + a^{\frac{n}{2}} bc^{\frac{n}{2}-1} + b^{\frac{n}{2}} a^{\frac{n}{2}-1} c + b^{\frac{n}{2}} ac^{\frac{n}{2}-1} \right) \left| \text{or} \right. \\
 &nC_{\frac{n-1}{2}} \times \frac{n+1}{2} C_1 \left(a^{\frac{n-1}{2}} bc^{\frac{n-1}{2}} + ab^{\frac{n-1}{2}} c^{\frac{n-1}{2}} + a^{\frac{n-1}{2}} b^{\frac{n-1}{2}} c \right) \\
 &\text{according as } n \text{ is even or odd.} \tag{2}
 \end{aligned}$$

C. Expansion of Terms Containing Four Terms

By actual multiplication and generalizing we can put the expansion in the folded form as :

$$\begin{aligned}
 & (a + b + c + d)^n \\
 &= nC_0 (a^n + b^n + c^n + d^n) \\
 &+ nC_1 (a^{n-1}b + ab^{n-1} + a^{n-1}c + ac^{n-1} + a^{n-1}d + ad^{n-1} + b^{n-1}c + bc^{n-1} \\
 &\quad + b^{n-1}d + bd^{n-1} + c^{n-1}d + cd^{n-1}) \\
 &+ nC_2 (a^{n-2}b^2 + a^2b^{n-2} + a^{n-2}c^2 + a^2c^{n-2} + a^{n-2}d^2 + a^2d^{n-2} + b^{n-2}c^2 + b^2c^{n-2} \\
 &\quad + b^{n-2}d^2 + b^2d^{n-2} + c^{n-2}d^2 + c^2d^{n-2}) \\
 &\dots \\
 &+ nC_{\frac{n}{2}} \left(a^{\frac{n}{2}} b^{\frac{n}{2}} + a^{\frac{n}{2}} c^{\frac{n}{2}} + a^{\frac{n}{2}} d^{\frac{n}{2}} + b^{\frac{n}{2}} c^{\frac{n}{2}} + b^{\frac{n}{2}} d^{\frac{n}{2}} + c^{\frac{n}{2}} d^{\frac{n}{2}} \right) \quad \text{or} \\
 &nC_{\frac{n-1}{2}} \left(a^{\frac{n+1}{2}} b^{\frac{n-1}{2}} + a^{\frac{n-1}{2}} b^{\frac{n+1}{2}} + a^{\frac{n+1}{2}} c^{\frac{n-1}{2}} + a^{\frac{n-1}{2}} c^{\frac{n+1}{2}} + a^{\frac{n+1}{2}} d^{\frac{n-1}{2}} + a^{\frac{n-1}{2}} d^{\frac{n+1}{2}} + b^{\frac{n+1}{2}} c^{\frac{n-1}{2}} \right. \\
 &\quad \left. + b^{\frac{n-1}{2}} c^{\frac{n+1}{2}} + b^{\frac{n+1}{2}} d^{\frac{n-1}{2}} + b^{\frac{n-1}{2}} d^{\frac{n+1}{2}} + c^{\frac{n+1}{2}} d^{\frac{n-1}{2}} + c^{\frac{n-1}{2}} d^{\frac{n+1}{2}} \right)
 \end{aligned}$$

according as n is even or odd.

$$\begin{aligned}
 &+ nC_1 \times (n-1) C_1 (a^{n-2}bc + a^{n-2}bd + a^{n-2}cd + b^{n-2}ac + b^{n-2}ad + b^{n-2}cd \\
 &\quad + c^{n-2}ab + c^{n-2}ad + c^{n-2}bd + d^{n-2}ab + d^{n-2}ac + d^{n-2}bd) \\
 &\dots
 \end{aligned}$$

$$+ nC_1 \times (n-1) C_2 (a^{n-3}b^2c + a^2b^{n-3}c + \dots + b^{n-3}c^2d + b^2c^{n-3}d)$$

$$+ nC_2 \times (n-2) C_1 (a^{n-3}bc^2 + ab^{n-3}c^2 + \dots)$$

$$+ nC_{\frac{n}{2}} \times \frac{n}{2} C_1 \left(a^{\frac{n}{2}-1} bc^{\frac{n}{2}} + ab^{\frac{n}{2}-1} c^{\frac{n}{2}} + \dots \right) \quad \text{or}$$

$$nC_{\frac{n-1}{2}} \times \frac{n+1}{2} C_1 \left(a^{\frac{n-1}{2}} bc^{\frac{n-1}{2}} + ab^{\frac{n-1}{2}} c^{\frac{n-1}{2}} + \dots \right)$$

according as n is even or odd.

$$+ (nC_1 \times (n-1)C_1 \times (n-2)C_1) (a^{n-3}bcd + ab^{n-3}cd + \dots)$$

D. Expansion of Terms Containing Five Terms

By actual multiplication and generalizing we get :

$$(a + b + c + d + e)^n$$

$$\begin{aligned}
&= nC_0 (a^n + b^n + c^n + d^n + e^n) \\
&+ nC_1 (a^{n-1}b + ab^{n-1} + \dots + d^{n-1}e + de^{n-1}) \\
&+ nC_2 (a^{n-2}b^2 + a^2b^{n-2} + \dots + d^{n-2}e^2 + d^2e^{n-2}) \\
&\dots \\
&\dots \\
&+ nC_{\frac{n}{2}} \left(a^{\frac{n}{2}} b^{\frac{n}{2}} + a^{\frac{n}{2}} c^{\frac{n}{2}} + \dots + d^{\frac{n}{2}} e^{\frac{n}{2}} \right) \quad \text{or} \\
&nC_{\frac{n-1}{2}} \left(a^{\frac{n+1}{2}} b^{\frac{n-1}{2}} + a^{\frac{n-1}{2}} b^{\frac{n+1}{2}} + \dots + d^{\frac{n+1}{2}} e^{\frac{n-1}{2}} + d^{\frac{n-1}{2}} e^{\frac{n+1}{2}} \right)
\end{aligned}$$

according as n is even or odd.

$$\begin{aligned}
&\dots \\
&+ nC_1 \times (n-1) C_1 (a^{n-2}bc + ab^{n-2}c + \dots) \\
&+ nC_1 \times (n-1) C_2 (a^{n-3}b^2c + a^2b^{n-3}c + \dots) \\
&\dots \\
&\dots \\
&+ nC_{\frac{n}{2}} \times \frac{n}{2} C_1 \left(a^{\frac{n}{2}-1} bc^{\frac{n}{2}} + ab^{\frac{n}{2}-1} c^{\frac{n}{2}} + \dots \right) \\
&\dots \\
&\dots \\
&+ nC_1 \times (n-1) C_1 \times (n-2) C_1 (a^{n-3}bcd + ab^{n-3}cd + \dots) \\
&+ nC_1 \times (n-1) C_1 \times (n-2) C_2 (a^{n-4}b^2cd + a^2b^{n-4}cd + \dots) \\
&\dots \\
&+ (nC_1 \times (n-1) C_1 \times (n-2) C_1 \times (n-3) C_1) (abcde)
\end{aligned}$$

From the results we have deducted so far from (1) to (4) we can generalize that the general rule or formula for the expansion of trinomial & polynomial expression is :

For any positive integer n :

$$\begin{aligned}
&(a + b + c + \dots + m \text{ terms})^n \\
&= nC_0 (a^n + b^n + c^n + \dots + m^n) \\
&+ nC_1 (a^{n-1}b + ab^{n-1} + \dots + a^{n-1}m + am^{n-1}) \\
&+ nC_2 (a^{n-2}b^2 + a^2b^{n-2} + \dots + a^{n-2}m + am^{n-2}) \\
&+ nC_3 (a^{n-3}b^3 + a^3b^{n-3} + \dots + a^{n-3}m^3 + a^3m^{n-3} + \dots) \\
&\dots \\
&+ nC_{\frac{n}{2}} \left(a^{\frac{n}{2}} b^{\frac{n}{2}} + a^{\frac{n}{2}} c^{\frac{n}{2}} + \dots + d^{\frac{n}{2}} m^{\frac{n}{2}} \right) \quad \text{or}
\end{aligned}$$

$$nC_{\frac{n-1}{2}} \left(a^{\frac{n+1}{2}} b^{\frac{n-1}{2}} + a^{\frac{n+1}{2}} c^{\frac{n-1}{2}} + \dots + a^{\frac{n+1}{2}} m^{\frac{n-1}{2}} + a^{\frac{n-1}{2}} m^{\frac{n+1}{2}} \right)$$

according as n is even or odd.

$$+ nC_1 \times (n-1) C_1 (a^{n-2} bc + ab^{n-2} c + \dots)$$

$$+ nC_1 \times (n-2) C_1 (a^{n-3} bc^2 + ab^{n-3} c^2 + \dots)$$

.....

.....

$$+ nC_{\frac{n}{2}} \times \frac{n}{2} C_1 \left(a^{\frac{n}{2}-1} bc^{\frac{n}{2}} + ab^{\frac{n}{2}-1} c^{\frac{n}{2}} + \dots \right) \quad \left| \quad \text{or} \right.$$

$$+ nC_{\frac{n-1}{2}} \times \frac{n+1}{2} C_1 \left(a^{\frac{n-1}{2}} bc^{\frac{n-1}{2}} + ab^{\frac{n-1}{2}} c^{\frac{n-1}{2}} + \dots \right)$$

according as n is even or odd.

.....

.....

$$+ nC_1 \times (n-1) C_1 \times (n-2) C_1 (a^{n-3} bcd + ab^{n-3} cd + \dots)$$

.....

$$+ nC_1 \times (n-1) C_1 \times (n-2) C_1 \times (n-3) C_1 (a^{n-4} bcde + ab^{n-4} cde + \dots)$$

.....

$$+ nC_1 \times (n-1) C_1 \times (n-2) C_1 \dots (n-m+1) C_1 (a^{n-m} bc \dots m + \dots (m \text{ terms}))$$

From this rule or formula we see the following properties for trinomial and binomial expressions including the binomial expressions also.

PROPERTIES OF MULTINOMIAL OR POLYNOMIAL EXPANSIONS

In the expansion of $(a + b + c + \dots + m \text{ terms})^n$

1. The sum of indices in each term is n.
2. The number of elements in each term, in the expansion does not exceed the number of elements.
3. The product of two coefficients such as: $(3C_1 \times 2C_1)$ contains 3 terms: 3 coefficients contain 4 terms and so on.
4. The coefficients of degree 2 in the expansion contains the coefficient $2C_0$ & $2C_1$ only.
5. The coefficients of degree 3 in the expansions contains the coefficients $3C_0$ & $3C_1$ only.
6. The coefficients of degree 4 in the expansion contains the coefficients upto $4C_2$ starting from $4C_0$, i.e. $4C_0, 4C_1, 4C_2$.
7. Coefficients of degree 5 contains the coefficients upto $5C_2$ starting from $5C_0$.
8. Coefficients of degree 6 contains the coefficients upto $6C_3$ starting from $6C_0$.

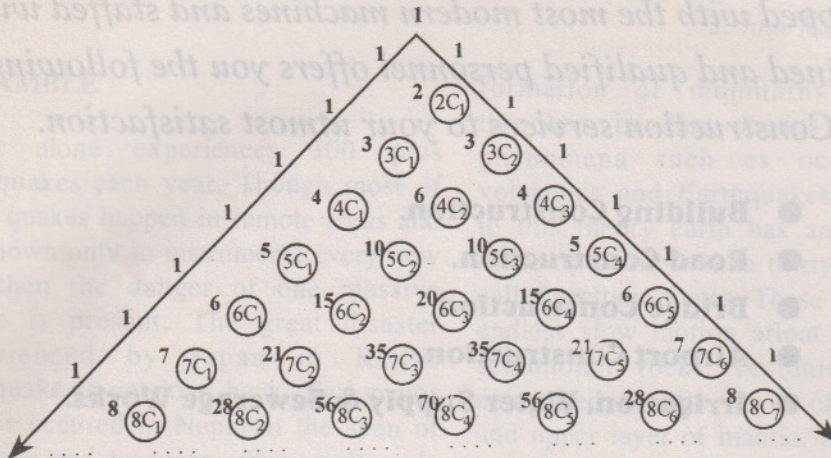
9. This shows that the coefficients can be taken upto $nC_{n/2}$ for n even starting from nC_0 and $nC_{(n-1)/2}$ for n odd starting from nC_0 .
10. In the combination of two coefficients such as $(nC_p \times rC_1)$, the sum of terms such as $(p + r)$ is n .
11. For the combination of the coefficients such as $(1C_p \times qC_r \times sC_t)$, we have the term containing 4 elements such that $s+r=q$, $q+p=1$ & so on. And the indices become; $a^s b^t c^r d^p$.
12. The number of elements exceed by one, than the number of factors of coefficients.
13. Keeping the results in mind, the relation between the degrees of elements and the coefficients should be satisfied. If the degrees repeat; then go to other terms as in the rules stated in (11).
14. Put the elements in the cyclic order which is followed from the rules of coeffs. and the exponents of elements.
15. For $n=1$; $(a + b + c + \dots + m \text{ terms})^n = 1C_0 (a + b + c + \dots + m \text{ terms})$.
16. Take the product of coeffs. upto $2C_1$ (i.e., $nC_1 \times \dots \times 2C_1$) if the indices are not repeated.
17. The total number of terms in the expansion $(a + b + c + \dots + m \text{ terms})^n$ is $(m+n-1)C_n$ which will be established later.

The total number of terms in the expansion of $(a + b + c + \dots + m \text{ terms})^n$

From the expansions we have deduced above, we can find the total number of terms as following, where "m" represents the total number of terms and "n" represents the number of degrees. The total number of terms for different values of "m" and "n" can be found as from the tabular representation shown below :

m	n	1	2	3	4	5	6	7	8	9	10	...
2		2	3	4	5	6	7	8	9	10	11	...
3		3	6	10	15	21	28	36	...	...	...	...
4		4	10	20	35	56	84	...	...	...	...	...
5		5	15	35	70	126	...	...	...	...	...	...
6		6	21	56	126	...	...	...	...	...	...	...
7		7	28	54	...	...	...	...	...	...	...	...
8		8	36	...	...	...	...	...	...	...	...	...
9		9	...	...	...	...	...	...	...	...	...	...
10		10	...	...	...	...	...	...	...	...	...	...
...		11	...	...	...	...	...	...	...	...	...	...
...		...	...	...	...	...	...	...	...	...	...	...

From the help of this table we can make the Pascal's triangle as follows :



According to the rule of expansion; the total number of terms are included in a circle. If we look at these tables carefully we get the relation between terms and degrees i.e. m and n ; which can be easily predicted as follows :

m	n → 1	2	3	4	5	6	7	8	...	n	...
2	2C ₁	3C ₂	4C ₃	5C ₄	6C ₅	7C ₆	8C ₇	9C ₈	...	2+n-1C _n	...
3	3C ₁	4C ₂	5C ₃	6C ₄	7C ₅	8C ₆	9C ₇	10C ₈	...	3+n-1C _n	...
4	4C ₁	5C ₂	6C ₃	7C ₄	8C ₅	9C ₆	10C ₇	11C ₈	...	4+n-1C _n	...
5	5C ₁	6C ₂	7C ₃	8C ₄	9C ₅	10C ₆	11C ₇	12C ₈	...	5+n-1C _n	...
6	6C ₁	7C ₂	8C ₃	9C ₄	10C ₅	11C ₆	12C ₇	13C ₈	...	6+n-1C _n	...
7	7C ₁	8C ₂	9C ₃	10C ₄	11C ₅	12C ₆	13C ₇	14C ₈	...	7+n-1C _n	...
8	8C ₁	9C ₂	10C ₃	11C ₄	12C ₅	13C ₆	14C ₇	15C ₈	...	8+n-1C _n	...
...	...	...	...	...	...	...	...	...	...	...	...
m	m+1-C ₁	m+2-C ₂	m+3-1C ₃	m+4-1C ₄	m+5-1C ₅	m+6-1C ₆	m+7-1C ₇	m+8-1C ₈	...	m+n-1C _n	...
...	...	...	...	...	...	...	...	...	...	...	...

This table clearly shows that the total number of terms in the expansion of $(a + b + c + d + \dots + m \text{ terms})^n$ is $m + n - 1C_n$

This general "polynomial theorem" can be used easily for the expansion of trinomial and polynomial expressions including the binomial expansion. This table will help in facilitating calculations and hence will prove to be an effective tool for the mathematicians in solving complex expansion problems.



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PLATE TECTONICS AND CONSEQUENCES

Jishnu Kumar Subedi*

PREAMBLE

Japan alone experiences 300 plus earthquakes each year. Though most of these quakes happen in remote areas and are shown only in instruments every now and then the danger of one massive quake is present. The great disaster experienced by Japan in KOBE earthquake is not long back. Two major quakes occurred in Nepal in the span of 56 years and frequent other small scale quakes suggest we are in danger of facing great disasters in the future. Even an advanced country like Japan has not been able to predict when and where the next quake can strike. Nevertheless, every body seems to agree about the causes of Earthquake now. Most quakes are assigned to the continental drift, the theory of Plate Tectonics.

Japan lies in the intersection of four tectonic plates and this alone can describe the cause of large number of quakes that is still rocking the country. Nepal being the northernmost boundary of Indian plate, which is still one of the active plates, is in the danger of great Earthquakes. This sword of possible quakes has always been hanging over the Nepalese settlements.

PLATE TECTONICS

Plate tectonics is the theory which now is believed to be able to explain major physical features of earth such as

formation of mountains and deep trenches in the oceans and other phenomena such as occurrence of volcanoes and Earthquakes. According to this theory earth has an outer shell made up of more than thirty rigid plates called tectonic plates. These plates are in endless slow motion afloat on a sea of semimolten rocks. Tectonic plates are comprised of outer layer of earth crust and upper layer of mantle, the layer just below the crust and the whole continents and oceans are embedded in these plates. As these plates move, they carry the continents along with them causing a drastic change in the map.

Though there are many number of plates in the world, earth's Lithosphere can be divided into seven major plates which have been active from 200 million years back.

<i>Eurasian Plate</i>	<i>American Plate</i>
<i>Pacific Plate</i>	<i>African Plate</i>
<i>Indian Plate</i>	<i>Australian Plate</i>
<i>and Antarctic Plate</i>	

EVIDENCE OF CONTINENTAL DRIFT

Different reasons lead to the belief that the present map of earth is not as that of million years back. But rather it was a single supercontinent which in the due course of time splitted and adjusted itself to arrive at present condition. Some of the reasons are :

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1) *Best fit of margins*: The map of South America is placed together with Africa and similarly North America with Europe, after some arrangements they seem to be one unit once, and separated in the due course of time. This alone was sufficient for researchers to think about some relative movement taking place in the earth.

2) *Geological similarities*: South African eminent Geologist, Alexander du Toit, showed that a striking series of correspondences can be recognized in the sediments, fossils, climates, earth movements and ingenious intrusions of the two sides of the Atlantic. Both the regions had essentially the same geological history during the past.

3) *Paleomagnetism*: Paleomagnetism is the study of magnetism in ancient rocks. This study has revealed sufficient evidence of plate movement. The tiny particles of rock when hot and molten, are free to adjust themselves according to the magnetic field. But when the rock solidifies and cools, they won't be able to readjust themselves. So as the continental drifting takes place, current magnetic field at the present position will not be same as that before. But the solid and cool rocks can not change their magnetic orientation, which helps entrapping them of their past location and orientation.

Over the past several hundred million years, plate movement of earth has changed the map of earth drastically. 200 million years back, the earth is supposed to be a single super continent, *Pangaea* (Gr. all earth) which due to continuous fragmentation by rifting,

followed by a drifting apart of the individual masses resulted in the present distribution of continents.

The super continent *Pangaea* consisted of, very broadly speaking, what are now North America, Europe and Asia forming the northern part, and South America, Africa, India, Australia and Antarctica forming the southern part - Gondwana land. However this may be the fact that, prior to the Tertiary Alpine-Himalaya orogeny (formation of mountain by Tectonic movement), Laurasian and Gondwanaland were separated from one another by a long sea way that was called Tethys.

THE GREAT MOVEMENTS

The Atlantic Ocean: The Atlantic ocean can be considered to be an enormously widening rift, with sides still matching 'as closely as the lines of a torn drawing would correspond if the pieces were placed in together. Different Geologists have tried to present the best fit map of the continents margining the Atlantic Ocean. The closeness of the 'fits' between south America and Africa, on the one hand, and between North America, Greenland and Europe on the other, can be taken as vivid example of drifting taking place there resulting in the origin and widening of Atlantic ocean.

At present sea-floor spreading in the Atlantic involves the movement of the four major plates of Eurasia, North and South America and Africa, North and South Atlantic plates rotating and spreading away from the Eurasian and African plates.

The Indian Ocean : Even in the Gondwana, South Africa and South America were one part named as Western Gondwana and Eastern Gondwana comprising of India and Madagascar, Australia, and Antarctica. And 150 million years back almost 40 million years before formation of Atlantic Ocean, a possible break occurred between East and West Gondwana which heralded the demise of Tethys sea and laid platform for origin of orogenic Mountain chain.

The history of movement of India from the very first breaking of Gondwana till now is worth reflecting on. Following the breakup of super continent of Gondwana India first moved southwards along with Antarctica and Australia. It then moved eastwards along with Madagascar and later drifted northwards, as a part of the

African plate, before rapidly moving northwards by itself to collide with Asia. Its spreading rate of 26 cm/year decreased to 10 cm/year after collision with Asia which afterwards decreased to about 5 cm/year.

Conclusion :

The movement of plates in opposite direction to one another causes smashing and grinding against each other and create a labyrinth of cracks, or fault lines, in the earth crust. And scientists believe that these faults breed Earthquakes. Stresses build up and accumulate around the boundary of plates moving in opposite directions and these stresses when released at once cause huge movements of the earth.



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FUEL : USE AND ENVIRONMENTAL IMPACT

Jagannath Ghimire*

The history of fuel goes beyond the pre-historic age of human civilization. Too early to start the present day civilization and too late for the barbarian age, human beings had already started to settle in community thousands of years ago. The first thing that gave them security against the wild animals was the 'fire' which was obtained mainly through difficult procedures only. Nobody knew as how to keep a fire for future use and how to use it safely. Nevertheless, they knew about it, about its power and its importance in their daily life.

As can be gathered from this brief description also, the only fuel our ancestors knew was 'WOOD'. Surprisingly maximum percentage of human population in the world still rely upon this natural, ubiquitous and pre historic fuel because of the simplicity involved in obtaining it and the processing/procedure necessary to bring it from the place of its natural existence to the place where it is used, which is virtually absent. But present day civilization largely depends upon the petroleum fuel which is simple to use, has higher thermal efficiency and can be stored safely for future use also.

Owing to the advanced technology involved in refining and processing the fuel (crude oil), the various fractions obtained can be used in variety of manners extending from kitchen

cooking to launching of aircrafts.

The natural petroleum oil or the crude oil as is commonly known, is the largest single source of all the gaseous, liquid and solid fuels being used nowadays. As the crude oil obtained from deep wells contain many impurities such as water, solid wastes and other unwanted chemicals, this oil has to be made pure and usable by fractional distillation, term used to define the whole process of obtaining various fuels ranging from liquefied petroleum gas to thick tar or asphalt from single source.

The transformation of crude oil into smaller fraction is based on a simple theory which can be explained as follows.

"As the crude oil obtained from the deep oil wells is heated, it is broken down into smaller fractions depending upon the temperature. To get the higher fraction (liquefied petroleum gas) a temperature range from -40°C to -12°C is suitable because the main constituents of liquefied petroleum gas which is propane and butane get evaporated at temperature higher than this. On the other hand a temperature of as high as 600°C is necessary to remove the heavier fractions (heavy oil, pitch, tar etc.). So a fractional distillation chamber is to be designed in such a way that all the useful fractions are obtained with minimum of loss".

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The products obtained from the fractional distillation of crude oil and their properties are given below in brief.

Liquefied Petroleum Gas (LPG): As mentioned above, this fraction is obtained at a temperature range from -0°C to -2°C only. As this fraction will be in a gaseous state at room temperature, this product is stored in metallic containers under pressure in a liquid state to facilitate the users. This gas is used for cooking purposes and often in transportation also.

Gasoline: This is the lightest liquid petroleum fraction. All liquid material whose boiling point (bp) range from 0 to 200°C are generally considered as gasoline. Actually this fraction consists of more than 40 types of hydrocarbons (though the crude oil and refining process have some influence on the composition). Gasoline covers most of the fuels used for the spark-ignition engine. This has very good ignition characteristics and gets evaporated easily at room temperature.

The self ignition temperature being pretty high, this product can be safely stored in a closed container for a long time without any fear of danger.

Kerosene: The liquid with friction heavier than gasoline is called kerosene. Boiling range of kerosene extends from 150°C to 300°C . So there is always a slight overlapping between the gasoline and kerosene. Gasoline can not be separated completely from Kerosene and vice versa. Kerosene is widely used as domestic cooking fuel and in some cases,

modified versions of the spark ignition engine also run on kerosene.

Diesel: This is further down the line and is slightly heavier than kerosene. Diesel actually overlaps both the ends of temperature and hence can be prepared domestically by adding little amount of lubricating oils to kerosene. This has a wide variety of specific gravity and boiling point (ranging from 200°C – 370°C). Being heavier than kerosene and having high ignition temperature, this fraction is generally used for compression in ignition engine. The viscosity of diesel plays an important role in smooth running of an engine. Generally speaking a bus or truck engine should have diesel than the one used in small motor cars. Because of its high ignition temperature and low volatility, it is safer than gasoline and kerosene as well.

Fuel Oils: This is similar to diesel oil distillation range but having the composition range wider than diesel, these oils are used as industrial fuel.

Lubricating Oils: These are the heavy residual oils and are generally used in lubrication.

Tar and Asphalt : Ranging from semisolid to solid residues, these are used for the road pavement purposes. They are not the product of distillation but are achieved as the undistilled residue left behind.

Petroleum Coke: What remains behind after the distillation of crude oil is the petroleum coke. This solid product,

which is similar to the coal in appearance is a better fuel and has more calorie value than coal. This is also used as the industrial fuel.

After the outburst of massive use of the petroleum fuel, human being have now understood the serious repercussions it has on the atmosphere. A fuel, be it the light gasoline or the heavy diesel, when burned, gives off carbon dioxide. Still worse is the half burnt fuel which emits carbon mono oxide which in turn reacts with the atmospheric oxygen, to give off carbon dioxide. So when a gram of say petrol, has to be burnt inside and engine, it requires at least 10 - 15 gm of air for smooth burning. The atmosphere, which consists of about eight percentage of oxygen, gives off about 1 gm. of oxygen for every gm. of fuel burnt. If the total amount of fuel burnt around the worlds is considered, which may include domestic fuel kerosene and other fuels used in transportation, this will reveal an awful fact. In Nepal only, which is one of the least developed countries in the world, around a million littres of fuel (including all types of fuel) is burnt every day consuming about the same amount of oxygen, i.e. 1000000 gm of pure oxygen. Projecting the same amount for the whole year, it can be estimated that around 365 tones of pure oxygen is being burnt with fuel every year in Nepal only.

So if the fuel has given us freedom to move around, and has made our life lot easier, it has at the same time degraded the atmosphere by making it heavily polluted. So much has been talked about the unlimited use of petroleum products and the negative effects it has on the atmosphere that it certainly makes us think of other fuels which are friendly to the environment. But till today it is only the petroleum oil which the mother nature seem to have in affluence. It is not that nothing has been done in this regard. Scientists are working round the clock to find a suitable substitute for petroleum oils. They have indeed come up with few suggestions like Benzol, Alcohol, Ammonia and even water, but nothing has been considered to be as cost effective as the petroleum oil.

There is no gain in saying that petroleum fuel has dramatically changed our lives. We can not imagine a world without petroleum fuel and hence are bound to use them in our lives. But we must leave something behind for our progenies too or may be in the year 2050 A.D. a bottleful of petrol or diesel would be kept in the museums of wealthy countries and people would come to see the 'fuel their ancestors used' riding on their electrics car or solar cars.



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