5.3 EARTHQUAKE GROUND MOTION: ESTIMATION TECHNIQUES

Measuring Earthquake Ground Motion

Seismic waves and the resulting ground motion were divided into weak motion (from distant or small earthquakes) and strong motion (from nearby or large earthquakes).

In seismic hazard analysis estimates of ground motion are dealt with strong motion. Strong-motion instruments are designed to make usable records of earthquake ground motion which can destroy whole cities.

Instrumentation technique

Strong motion instruments are specially designed seimographs (accelerographs) configured to provide useful records of acceleration (accelerogram) from nearby earthquakes.

The heart of the accelerograph is a high frequency seismometer (accelerometer), the output of which is directly proportional to ground acceleration over a wide frequency range.

In Digital instruments, data can be easily processed. The earthquake ground motion can be estimated by the following techniques viz.,

1. Statistical regression techniques.
2. Theoretical ground motion modelling.
3. Semi-empirical techniques.
4. Semi-Theoretical techniques.

Statistical regression technique

Statistical regression techniques allow bringing together the available strong motion data, recorded under different source, travel path, and local site conditions, to define empirical correlations that permit the estimation of ground motion for many earthquake scenarios.

The basic functional form for ground motion regression equation is given by

$Y \boldsymbol{\alpha} f_1 (M) f_2 (R) f_3 (M, R) f_4 (P_i) \boldsymbol{\varepsilon}$ [or]

$Y = \mathbf{B}\ f_1 (M) f_2 (R) f_3 (M, R) f_4 (P_i) \boldsymbol{\varepsilon}$

Where,

Y $\longrightarrow$ Strong motion parameter to be estimated (dependent variable).

B $\longrightarrow$ Constant scaling factor.

f_1 (M) ⟶ Function of the independent variable M (magnitude or earthquake source size).

f_2 (R) ⟶ Function of the independent variable R (source to site distance).

f_3 (M, R) ⟶ Joint function of M and R.

f_4 (P_i) ⟶ A function, or functions, representing possible source, site, and building effects and

ε ⟶ An error term representing the uncertainty in Y.

Almost all ground motion regression analyses assume a relationship of this form. The different variable or parameters used in these regressions and their estimation technique is as follows.

Estimation of f_1 (M), f_2 (R) and f_3 (M, R)

For computing the strong motion parameter "Y", two parameters are very important viz,

1) The earthquake size which is, usually described by magnitude (M).
2) The second necessary parameter is source to site distance (R).

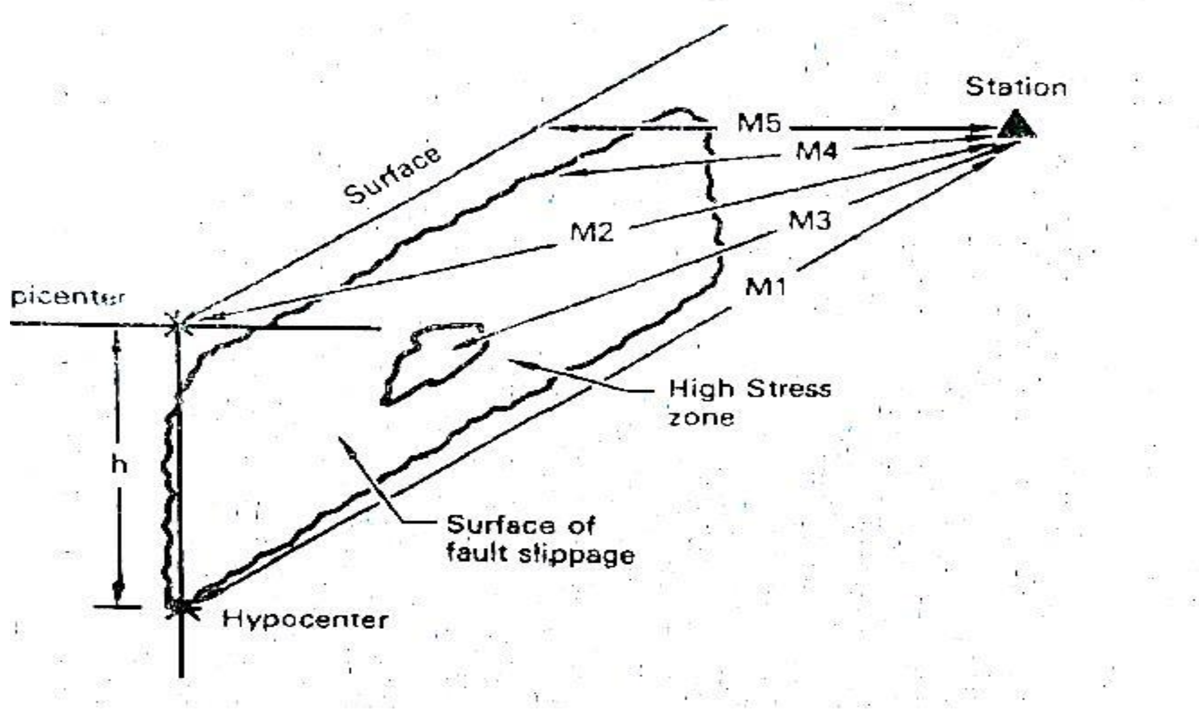

Fig:5.3.1- Estimation of f_1 (M), f_2 (R) and f_3 (M, R)

Fig.shows the schematic illustration of methods of distance measurement used in the determination of the distance value to be associated with a ground motion observation.

Here,

- M_1 is the hypocenter distance (focal depth is h).
- M_2 is the epicenter distance.
- M_3 is the distance to the center of high-energy release (or high localized stress drop).
- M_4 is the closest distance to the slipped fault; in this case, the fault rupture does not extend to the surface.
- M_5 is the closest distance to the surface projection of the fault rupture.

Measurement:

1. The hypo central distance (M_1) and epicentral distance (M_2) can be determined easily from knowledge of the recording station location and the earthquake catalog.
2. M_3 which is the distance to the energetic zone, in turn represents the strongest source of ground motion can be measured by the distribution of strong-motion recordings with respect to the magnitude and distance used in regression analysis.
3. M_4 and M_5 which are the closest distance to the lipped fault or its surface projection will be widely measured using experimental methods.
4. The joint distance magnitude function f_3 (M, R) shown in equation (1) implies the relative change in ground motion due to change in magnitude and distance and are not independent of each other.
5. A function, or set of functions f_4 (P_i) which is shown in equation (1), has to be included

in the regression to account for local site conditions, source characteristics other than size, and the effect of structure upon the motion. By calculating the above functional, parameter we can estimate the earthquake ground motion.

(2)**Theoretical Ground Motion Modeling**

Theoretically based numerical ground motion modeling techniques are used in applied seismic hazard analysis Theoretical ground motion models may be classified into two main types viz., (i) Dynamic and (ii) Kinematic.

Kinematic model

This is a very Simple model in which simple uniform slip (dislocation), travels at a constant rupture velocity on a rectangular fault as shown in Fig. 5.3.2 The following steps are adopted to determine the total ground motion by using kinematic ground motion modeling.

1. Initially the slip functions are measured at various points on the hypothetical fault surface (F) with respect to the Hypocenter.

2. Graph is drawn by taking time along X-axis and slip along Y axis for the various points as shown in Fig. 5.3.2

3. For each plot (graph), depictions of Green's functions in an x,y,z Co-ordinate system was made as shown in Fig. 5.3.3

4. From Fig. 5.3.3, we can see that the individual points on the fault surfaces at A,B,C,...F undergo instantaneous unit-amplitude slip resulting in ground motion (Green's functions) at observation point X_0.

5. The slip functions for each fault segment dF is convolved with the appropriate Green's function.

- The resulting ground motions from each segment are summed to get the total ground motion at X_0 as shown in Fig. 5.3.4

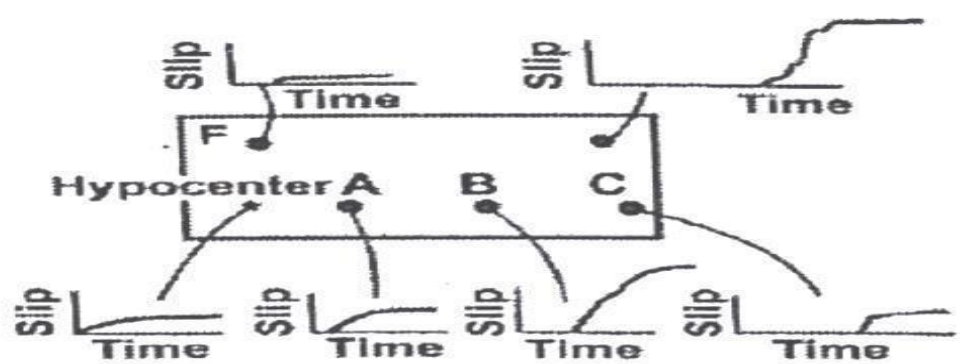

Fig:5.3.2- Kinematic ground motion modeling.

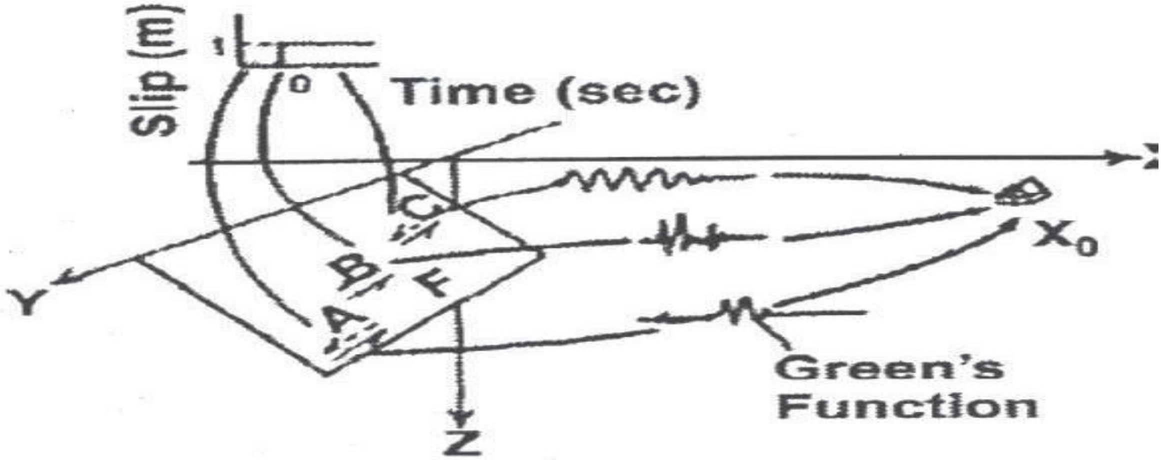

Fig:5.3.3- Depictions of Green's functions in an x,y,z Co-ordinate

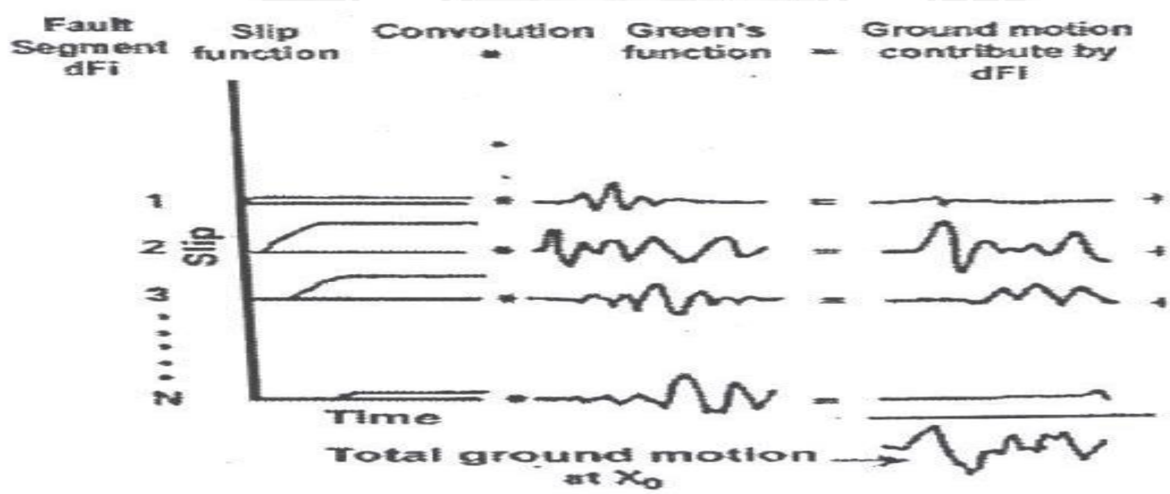

Fig:5.3.3- Total ground motion

Limitations

1. It is not possible to accurately estimate the ground motion in the near field.
2. Close to the earthquake source the contribution of high frequencies to the overall level of ground motion can be quite high.
3. It is limited only to low frequency ground motion.
4. The relative lack of close-in data results in large uncertainties at these distances.