

Attenuation of seismic refraction waves in sedimentary layers between Al-riyadh and baiji area,Kirkuk governorate

Fitian R. Al-Rawi Salman Z. Khorshid* Abboud S.Ishag***

**College of Science - University of Baghdad*

***University of Red Sea - Sudan*

Abstract

A study of attenuation of seismic refraction waves in sedimentary layers is carried out at two sites near Al-Riyadh and Baiji towns, Kirkuk Governorate in order to determine the attenuation coefficients of the two sites. The distance between these two sites is about 40 Km. Calculation of attenuation coefficients is based upon analysis of seismic field records, which consist measurements using both vertical and horizontal geophones. The geometrical spreading factors for both longitudinal (n_p) and transverse (n_s) waves and their attenuation coefficients (α_p , α_s) are determined from the seismic data. The predominant frequency (f_p, f_s) with the quality factors (Q_p, Q_s) for both waves are also determined. The calculated values for n_p , n_s , α_p , α_s , f_p , f_s , Q_p , Q_s and α_s/α_p at the first site are 2.106, 1.66, 0.057, 0.073, 55, 30.2, 7.2, 2.8 and 1.5 respectively. For the second site, only longitudinal wave is used to calculate the attenuation coefficient α_p , predominant frequency (f_p) and quality factor (Q_p). The obtained values for n_p , α_p , f_p and Q_p are 2.21, 0.055, 51 and 3.6 respectively. The obtained values can be considered as representative to the sedimentary layers in this area and can be of useful applications.

Introduction

Attenuation consideration in seismic studies was started for long time due to the capability of attenuation to define the quality of rocks and its ability to differentiate between saturated and unsaturated sediments (Hartherly,1986). It was observed that the change in velocity is accompanied with a change in attenuation (Born,1941). The change in attenuation value is greater and more obvious than the change in velocity (Winkler & Nur,1982). Due to this fact, attenuation is considered as a good tool and an aid in enhancing seismic interpretation (Tonn,1991). The attenuation phenomena are some how more complex since its measurements are too difficult from practical points. This is due to interference of all types that take place randomly, which in turn will increase or decrease the amplitude of seismic waves. These interferences included frictional mechanism, scattering mechanism, and geometric dissipations of wave front (Al-Tikriti, 1985).

Frictional mechanisms is the most common in dry and wet rocks (Winkler & Nur 1982). It is due to the relative movements that take place between edges, grain borders and fractures, in which parts of seismic energy is transformed into heat. Scattering mechanism dissipate wave energy by multiple reflections at thin layers, pores and irregularities in layers. The resulted attenuation from this mechanism will be a straight line depending upon frequency (Johnson et.al., 1979). The effect due to this mechanism cannot be removed from amplitude information. The other mechanism factors are fluid effects and viscosity (Johnson et.al., 1979). Also there are other factors influence attenuation of seismic waves such as pressure (Gardner et. al., 1964) porosity, heat and permeability (Gordon & Davis 1968). The aim of the present paper is to determine the attenuation coefficients at two sites (Fig.1) from field measurements in which the calculated values will be useful for any seismic application in the area.

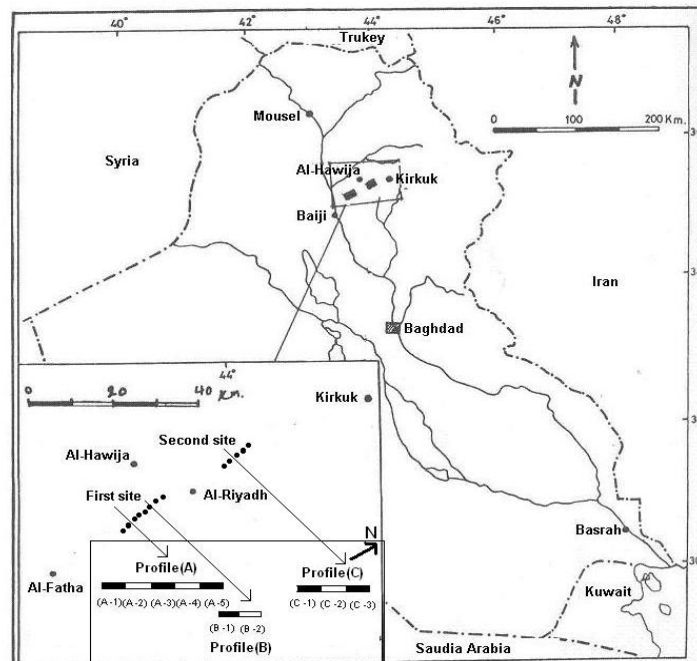


Fig.(1):Location map of the study area with the Seismic spreading profiles at the two sites

Attenuation calculation methods

Several methods have been used to calculate the values of attenuation. These are the decay of amplitude with distance, spectral ratio, rise time, phase modeling and frequency modeling. It is possible to calculate attenuation in the laboratory and in the field. In the present work, the decay of amplitude with distance has been used. In this method, a study of wave amplitude

variation with distance is carried out, where the maximum wave amplitude for each distance has been measured. Then the relation between amplitude and distance has been plotted on logarithmic or semi logarithmic paper. The geometrical spreading factor(n)and attenuation coefficient(α)are obtained through the calculations of best fitting line. Field measurements of attenuation are some how difficult particularly in unconsolidated and saturated sedimentary rocks(Badri & Mooney,1987). In the present paper the seismic refraction records have been used, which are depending upon reverse spreading after the following conditions are taken in consideration (McDonald et. al.,1958; De Bremaeker et. al.,1966). Align the geophones in straight line to reduce the effect of anisotropy. All geophones have been fixed at the same gain and response to give equal amplitudes and frequencies and then all have gathered in one place and connected to the recording instrument. After first shot, the amplitude traces have been checked on screen and channel responses. Recording has been done from one shot and gains of all channels have the same amplification in order to observe actually the amplitude variations with distance. Also,wide frequency band filter was used.

Seismic attenuation determination for the study sites

The amplitude of seismic records with distance is used for the calculation of attenuation at the two sites according to the variations of seismic body wave. The relation will provide useful information about elastic properties of the different rocks. The maximum amplitude of twenty two seismic field records has been measured. The amplitude is measured from peak to peak and for a complete seismic wave period divided by two. This procedure was applied to whole seismic traces recorded in the field.

Geometrical spreading factor (n)

To find the attenuation value that is due to an elastic layer, where advance seismic waves are refracted, the part of attenuation that belongs to geometrical spreading should be corrected (Kumar & Raghava,1981).

For extent layer with constant velocity the decay in amplitude of the refracted wave is found from the following relation (Kumar & Raghava, 1981).

$$A(x) = A_0/(x/x_0)^n \quad \dots(1)$$

Where:

x =Distance from the shot point.

A_0 = Amplitude at distance (x_0).

$A(x)$ = Amplitude at distance (x).

n =Geometrical spreading factor.

Then (n) is calculated according to:

$$n=- d\ln (Ax/A_0)/d\ln(x/x_0) \quad \dots(2)$$

The geometrical spreading factor (n) is found graphically from the amplitude distance plot data on log-log paper for 22 records of normal, central and reverse seismic field works for both longitudinal and transverse waves. The best fitting lines are obtained and the calculated geometrical factor (n) for the first site of longitudinal and transverse waves are 2.106 and 1.66 respectively. The estimated value for the second site for longitudinal wave only is equal to 2.21 (Tables 1 and 2), Figs(2a,b&3).

Table(1): The result of attenuation study for longitudinal and transverse waves at the first site.

Spreading Number	np	n	ap neper/ m	as neper/ m	Aver. velocity for P wave (m/s)	Aver. velocity for S wave (m/s)	Pred. Freq. for P wave f (Hz)	Pred. Freq. for S wave f(Hz)	Qp	Qs	ax/ ap I
A	1.86	1.6	.0413	0.12	1197	405	48	42	3.1	2.7	2.9
A	2.38	1.7	0.082	0.087	1042	480	63	30	2.3	2.3	1.1
A	2.00	1.6	0.044	0.06	1157	498	42	25	2.6	2.4	1.4
A	2.44	-	0.065	-	1287	-	49	-	1.8	-	-
A	1.35	-	0.067	-	1180	-	42	-	1.7	-	-
B	1.47	2.1	0.049	0.056	1283	507	53	18	2.7	2.0	1.2
B	2.38	1.8	0.056	0.061	1250	482	63	30	2.8	3.2	1.1
B	2.22	1.0	0.036	0.054	1158	489	56	34	4.2	4.0	1.5
B	2.49	-	0.052	-	1245	-	70	-	3.4	-	-
B	2.47	-	0.078	-	1236	-	66	-	2.2	-	-

Table(2): The result of attenuation study for the longitudinal wave at the second site.

Spreading Number	np	ap neper/m	Aver. velocity for P wave(m/s)	Pred. Freq. for P wave f(Hz)	Qp
C	2.05	0.046	820	36	3.0
C	2.37	0.052	878	42	3.1
C	2.19	0.035	860	42	4.4
C	2.22	0.061	847	57	3.5
C	2.26	0.059	818	69	4.5
C	2.17	0.076	843	57	2.8

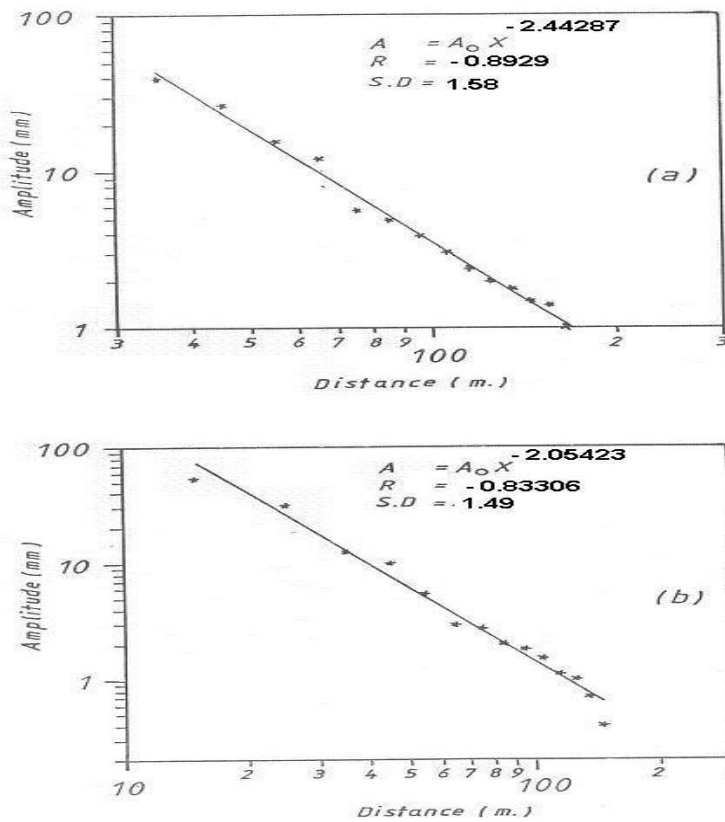


Fig.(2): A plot of wave amplitude against distance from seismic record to calculate geometrical spreading factor for longitudinal wave.
(a):First site, (b):Second site.

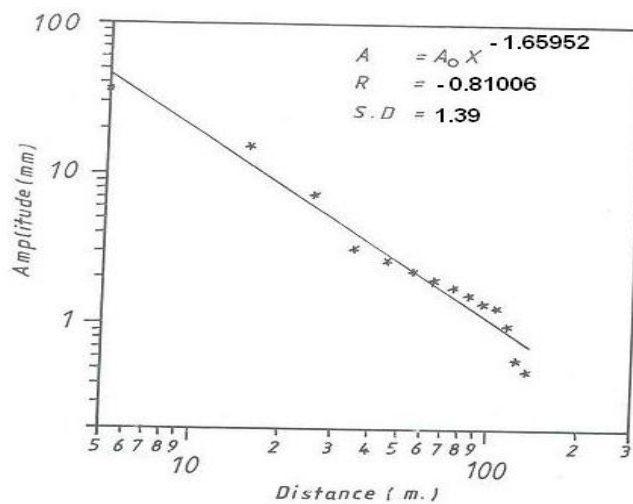


Fig.(3): A plot of wave amplitude against distance from seismic record to calculate geometrical spreading factor for transverse wave at the First site

Correction of amplitude aiplitude for longitudinal and transverse waves

Equation (1) is used to perform correction of amplitude on different traces for longitudinal and transverse waves by adding the decrease in value of amplitude due to geometrical spreading factor. Here, the calculated amplitude from the equation is added to the measured amplitude value with distance for the various traces to obtain the corrected amplitudes. The value of 2.106 and 2.21 for (n) are used to correct the amplitude of longitudinal wave for the first and second sites respectively. For transverse wave, the value of 1.66 for (n) is added for the first site.

Calculation of attenuation coefficient (α)

The residual attenuation coefficient is defined as the increment of seismic wave attenuation on attenuation value due to geometric scattering factor. This type of attenuation is due to elastic absorption, scattering and other effects (Kumar & Raghava,1981). The attenuation is determined through using the relation between amplitude at the shot point at distance (x_0) and amplitude at distance (x) from the shot point. Attenuation coefficient is determined from amplitude at two locations of geophones (x_1, x_2) from the relation below (Toksoz & Johnston, 1981):

$$\alpha = 1/(x_2 - x_1) \ln A(x_1)/A(x_2)$$

Attenuation coefficients are found for longitudinal and transverse waves from the plots of corrected amplitudes against distances on semi-log paper. Best fitting lines are taken and the determined attenuation coefficients for longitudinal and transverse waves are 0.057 neper/m and 0.073 neper/m for the first site (Table 1) and the value for longitudinal wave is 0.055 neper/m for the second site (Table 2). The procedure of calculation of attenuation coefficients is illustrated on Figs.(4 and 5a, b) for certain seismic records.

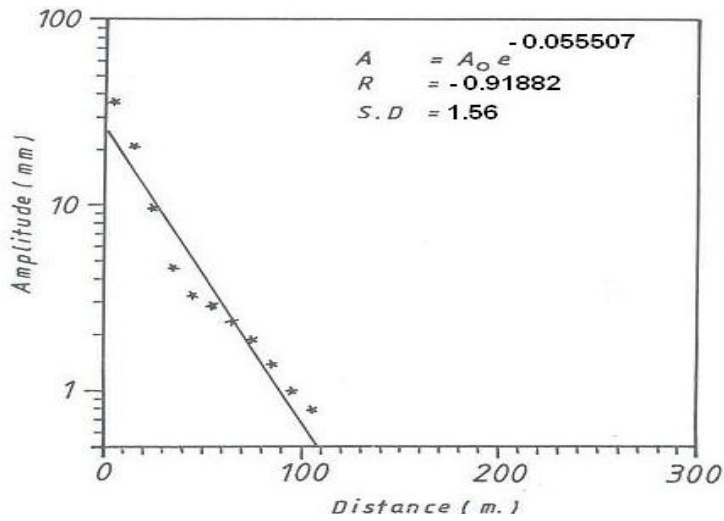


Fig.(4): A plot of wave amplitude against distance from seismic record to determine attenuation factor for transverse wave at the first site

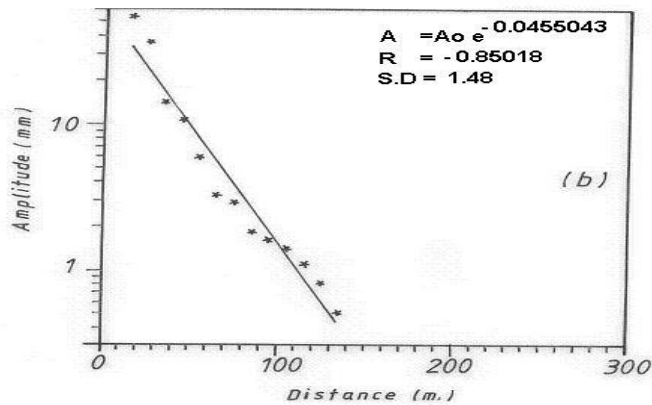
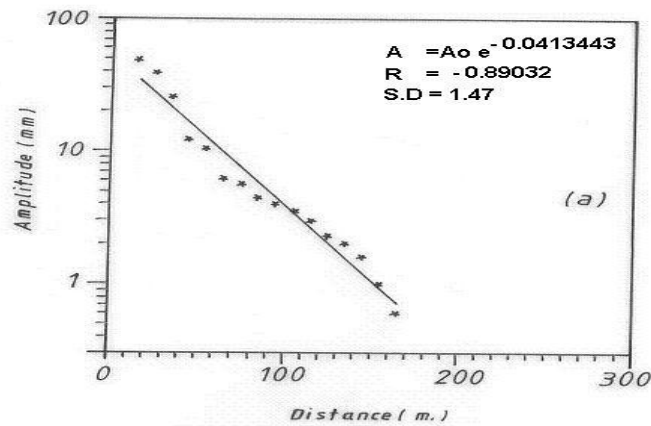


Fig.(5): A plot of wave amplitude against distance from seismic record to determine attenuation factor for longitudinal wave at the (a) First site and (b) Second site

Predominant frequency determination for P and S waves

Fast Fourier Transform (FFT) was used in various spectral analysis studies to transform the signals from time domain to frequency domain (Davis, 1973). Matlab program is used to transform signal from time domain to frequency domain. Firstly, samples are taken from seismic traces by computer where program Readmark3 associated with ABEM Terraloc Mark3 do this step. The samples are taken from each trace at time interval of 0.5msec. FFT is used to determine the predominant frequency in the area. The predominant frequency for longitudinal wave at the first site is ranging between (42-69) Hz with an average value of 51Hz (Table 2). The predominant frequency for transverse wave at the first site are found between (18-42) Hz with an average of 30Hz. Figure (6a and b) illustrates examples of Fourier analysis to spectral amplitude at the two sites.

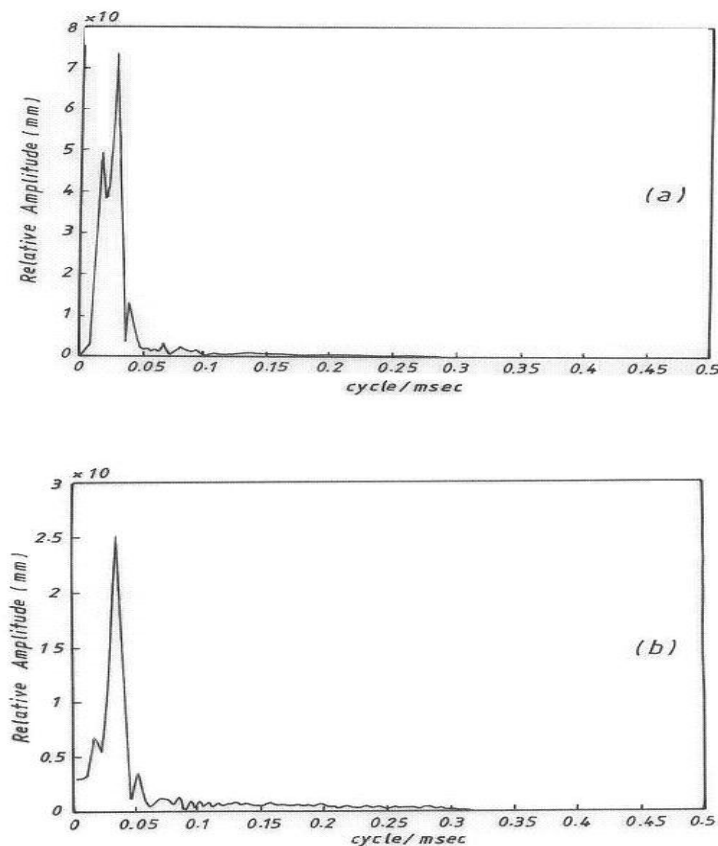


Fig.(6): FFT for spectral analysis of longitudinal waves for one trace at (a)the First and (b) for the Second site

Average velocity determination

Seismic refraction survey has been conducted along three profiles, two profiles at the first site and one profile at the second site. The total lengths of seismic profiles are about 2750m, 2300m of them are for the longitudinal waves and 450m for transverse waves. The total numbers of spreading are 13, ten of them for longitudinal waves while only three spreading for transverse waves. Four sedimentary layers have been found from the interpretation of seismic profiles. Table (3) exhibits part of the interpretation results found along line A-A' run at the first site. It shows the thicknesses of these layers. The average velocity has been calculated from the following equation (Dobrin ,1976):

$$V_{aver} = \frac{\sum_{K=1}^m Z_K}{\sum_{K=1}^m t_K} \dots(3)$$

Where Z= Thickness, t=time, m=number of layers and here=3.

The information obtained from seismic refraction survey has been used to determine the average velocity. The average velocity for longitudinal waves at the first and second sites are ranging between 1042-12870 m/sec and (405-507) m/sec respectively. The average velocity for transverse waves at the first site is found between (820-860) m/sec.

Table (3): Showing part of the interpretation results of the first seismic refraction survey along line A-A'.

Shot point location (m)	V1 (m/s)	V2 (m/s)	V3 (m/s)	V4 (m/s)	H1 (m)	H2 (m)	H3 (m)
5	313	1111	1743	2300	3.0	8.2	23.4
55	485	1143	1663	2167	5.1	6.6	22.5
115	375	1273	1631	2857	3.8	6.7	21.9
175	533	1143	1585	2286	4.8	7.0	20.0

Quality factor determination

The quality factors (Q_p,Q_s) for longitudinal and transverse waves have been found from the equation (Hartherly,1986)

$$1/Q=\alpha v / \Pi f \dots(4)$$

Where, Q is the quality factor, α is the attenuation coefficient and f is frequency and v average velocity. The determined values of Q_p, Q_s are 2.7 and 2.8 for the first site and Q_p for the second site is 3.6.

Conclusion and recommendation

Although attenuation measurements require certain field preparation, the obtained values for the various factors may be so useful in many applications. The obtained attenuation value for transverse waves is greater than longitudinal waves since α_s/α_p is ranging between 1.1-2.9 which reflect reduction of s-wave velocity as due to the effect of sedimentary rocks on s-wave. The obtained values for attenuation is approximately equal to the published international value which may be due to similar sedimentary rock types. These values can be considered and used for these sites and surrounding areas in any future seismic applications. It is recommended here to carry out the determination of these factors in association with most seismic refraction survey. Such determination will add information that may be so useful in seismic interpretation of any site.

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دراسة توهين الموجات الزلزالية الانكسارية في الطبقات الرسوبية بين منطقتي الرياض - بيجي في محافظة كركوك

فتيان رشيد الراوي* سلمان زين العابدين خورشيد* عبود سليمان إسحاق**
*كلية العلوم - جامعة بغداد
**جامعة البحر الأحمر - السودان

الخلاصة

تم إجراء دراسة توهين الموجات الزلزالية في الطبقات الرسوبية في موقعين بين مدينتي الرياض و بيجي في محافظة كركوك. إن المسافة بين الموقعين حوالي ٤٠ كم. اعتمد حساب معاملات التوهين على تحليل السجلات الزلزالية الحقلية التي تضمنت قياسات استخدمت فيها اللاقطات العمودية والأفقية. تم إيجاد معامل الانتشار الهندسي للموجتين الطولية (np) والمستعرضة (ns) ومعاملات التوهين (ap,as) والتردد الشائع لهما (fp,fs) ومعامل النوعية لكل منهما (Qp,Qs). إن القيم التي حسبت للمعاملات في الموقع الاول (np,ns,ap,as,fp,fs,Qp,Qs) (2.106,1.66,0.057,0.037,55,30,2.7,2.8,1.5) كانت على التوالي وفي الموقع الثاني فقد استخدمت الموجة الطولية فقط لحساب معامل التوهين (np) والتردد الشائع (fp) ومعامل النوعية (Qp). إن القيم المستحصلة للمعاملات (np,ap,fp and Qp) كانت (2.21,0.055,51,3.6) على التوالي. يمكن اعتبار القيم المستحصلة ممثلة للطبقات الرسوبية في هذه المنطقة ولها تطبيقات مفيدة.