Seismic Refraction and Cross-Hole Techniques for Investigate the Top Soil and Water Table Beneath the High Pumping Station Hall of Al-Hussian water Supply Station, Kerbala, Iraq

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أستكشاف التربة و مستوى المياه الجوفية باستخدام الطرق الزلزالية الانكسارية السطحية والبئرية تحت قاعة محطة الضخ في مشروع ماء الحسين في كربلاء –العراق

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Abstract

The present study aims to investigate the possible causes of cracks, in the walls of buildings and storage tanks, in Al-Hussian water project of Kerbalaa city. Eight seismic refraction profiles and seven cross-hole sections were made to investigate the pumping station hall in the studied site.

Two refractors were obtained. The first one is at depth range 1–2.5 meters, which coincides with the water table level and base of foundation (two meters below the ground level). The second refractor is depending on cross-hole results of depth range 4- 4.5 meters; which confirms to the top of the dense sand layer.

It is believed that water seepage from broken pipes and its infiltration through the soil play the great role in washing the soil and changing the water table level from one point to others. The differential washing of soil causes differential settlement beneath the buildings which is appears as cracks at the walls.

المستخلص

استهدفت الدراسة الحالية استكشاف اسباب التشققات في جدران المباني وخزانات الماء الكونكريتية في مشروع ماء الحسين في مدينة كربلاء في العراق. انجز قياس ثمانية مقاطع زلزاليةانكسارية سطحية وسبعة مقاطع زلزالية بئرية لدراسة الموقع.

أمكن تحديد سطحين لانكسار الموجات الزلزالية ،الاول على عمق يتراوح 1-2.5 متر ،والذي يتوافق مع عمق المياه الجوفية وقاعدة اسس المباني .أما السطح الثاني والذي حدد بالاعتماد على نتائج المسح الزلزالي البئري فيقع على عمق 4-4.5 متر ،والذي يتوافق مع السطح العلوي لطبقة الرمل المضغوط . في ضوء نتائج الدراسة نعتقد ان نضوح الماء من الانابيب المتكسرة وتسربه الى التربة يعمل على غسل التربة من الجبسوم وتذبذب مستوى الماءبشكل مستمر وهذا يؤثر في تغير نسبة الهبوط في التربة تحت البناية من موقع الى اخر،والتي سببت بدورها الشقوق في الجدران .

Introduction

Al-Hussian water supply station is the only station that is supplies Kerbalaa city by water for domestic uses. This project was established in 1972, when the water table level is about 7 meters below the ground level. This project includes many precipitation and storage concrete tanks, in addition to the filter hall and the high pumping station hall.

The problem in Al-Hussian water project is represented by occurrence of many cracks in the walls of tanks and buildings, plat 1,2and 3. This problem demands a geophysical survey to investigate the soil condition below the foundation. Seismic refraction and cross-hole techniques were used successfully in previous works to solve the problem of foundation and soil condition, (Dutta 1984, Haeni 1986, Steeples and Miller 1990, Hamdi et al 1996, NCCL 2000, Stephenson et al 2002).

The seismic refraction and cross-hole were used in the present study to achieve the investigation of soil condition and water table level below the high pumping station hall of Al-Hussian water supply station in Kerbalaa city.

Geology of the studied site

The studied area is located in Kerbalaa city, center of Iraq figure 1. The ground of the site is covered with Alluvium sediments of Quaternary deposits, (Buday and Jassim 1987). Many wells were drilled in the region to depth of about 30 meters penetrated three sedimentary layers, (NCCL 1980). First layer, which includes brown slightly gypseous clayey sand, extends from the ground surface to about 1.5 meters. The second layer, which extends from 1.5 to 5 meters, includes slightly gypseous silty sand with some small size gravel. The third layer is very dense sand. The foundation of buildings penetrates the soil to a depth of about two meters.

Instruments and field works

ABEM terraloc Mark II seismic system and a hammer weight about 20 kilogram are used to generate and record the longitudinal wave velocities for seismic refraction survey, (ABEM 1983). The SPT hammer is used as source in one borehole to generate waves in cross-hole survey in order to determine the true velocity under the studied site. A special system of three components geophones (suspension P-S logging system) is used as a receiver for cross-hole measurements, (OYO corporation, 1983). Eight surface seismic refraction profiles were carried out to measure the longitudinal waves. Also seven cross-hole traverses are considered to investigate the variation of velocities from the ground surface to 6 meters depth beneath the building of pumping station with half-meter interval, (figure 1).

Three shots are applied for each surface seismic survey, two of them at the end of profile and the third at the mid point of it. Many attempts are applied to improve the S/N ratio using the high and low cut filters. The distance between geophones were varied from 1, 1.5 and 2 meters according to the length of profile and geophones number.

Three boreholes were considered to achieve the cross-hole traverses, first borehole as source, while the second and third boreholes as receivers.

Results and interpretation

A- Surface seismic refraction survey:

Mainly two methods are applied, in addition to the least square (critical distance and intercept time) method, to interpret the seismic measurements. These are the Plus-Minus and ABC methods, (Hagedoorn 1959, Cummings 1979, Dampaney and Whitely 1980, Sjogren 1984). It was found that the velocity of the top layer (first layer) range between 304-500 m/sec, while the second layer velocity range between 878-1454 m/sec. The Plus-Minus and ABC interpretation methods show nearly similar results, (figures 2and 3). The depth of refractor detected by seismic refraction method varied along the measured profiles. This may depend on variation in the soil elastic properties beneath each geophone. Generally the depth of the refractor found to be range between 1.0-2.5 meters along profiles 1, 2, 3, 4, 5, 6, 7 and 8.

B- Cross-hole survey

The distance and the travel time, to the near bore-hole Tp, far bore-hole $\overline{Tp}$ and the difference time ΔTp, are measured to determine the longitudinal wave velocity Vp, $\overline{Vp}$, and ΔVp respectively. The shear wave velocity was also determined, after measuring Ts, $\overline{Ts}$ and ΔTs for near and far bore-holes and the distance and time between them.

The mentioned velocities are determined for all cross-hole traverses except traverses 4 and 5, where only the Vp and Vs are applied. Velocity variation of longitudinal waves with depth in the boreholes is drawn to define the sharp changes related to the refractors, (figure 4). This figure show two abrupt changes in velocity, first change, at depth range 1.5-2.5 meters, is nearly coincide with the water table level and base of foundations. Second change observed at depth of 4 meters below the ground surface, (figure 4). The later refractor defined the top surface of the very dense sand layer.

Discussion and Conclusions

Surface seismic refraction and cross-hole techniques show similar results. Two refractors were obtained in the studied site; the shallow refractor coincides with water table level, while the deeper refractor confirms the top surface of the very compacted sand. The shallow refractor proves the change of water table level, from seven meters depth during the establishment of the project in 1972, to about two meters at the present time. It is believed that the causes of water table change may be related to the infiltration of water, from the broken pipes on the surface, to the soil.

At the present time the potential surface (the water table) exerts a pressure that increases the strength of the soil against the loading force of the studied building. In the same time, the infiltration water, from the surface, weakens the soil through the process of gypsum washing. It is believed that, the differential response of soil particles, from place to another, to the washing process and continuous water table fluctuation causes the differential settlement and cracking in the walls of buildings and tanks.

Many direct measurements of water table in the borehole encouraged the seismic results, which, it is found that the water table ranges between 2.2-2.6 meters below the ground surface. These measurements indicate that the water level change from place to another in the studied site, which may depends on the amount and position of seepage water. Comparison of profile P4 of surface refraction method and C4 of cross-hole shows that, the results of these techniques are integrated to define the main refractors in the studied site.

Depending upon the results of the study, it is strongly recommended to replace or repair the broken pipes to prevent water seepage in first stage. Secondly, in such case it is suitable to build up a monitoring system for the water level and composition, in order to define any probable external sources of water from the surrounding area.

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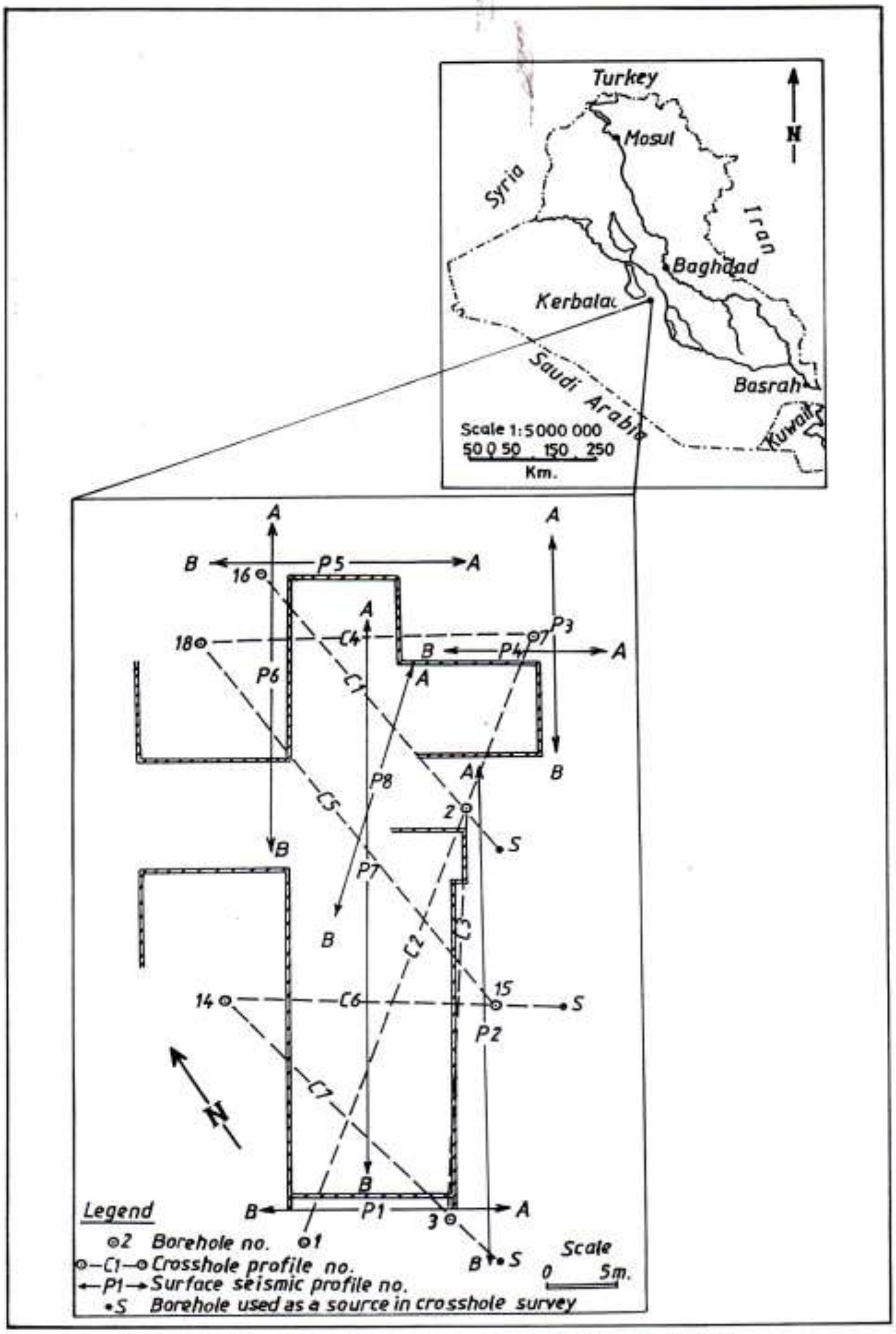


Fig. (1) Surface seismic and crosshole profiles in high pumping station building in Al-Hussain water supply station- Kerbala.

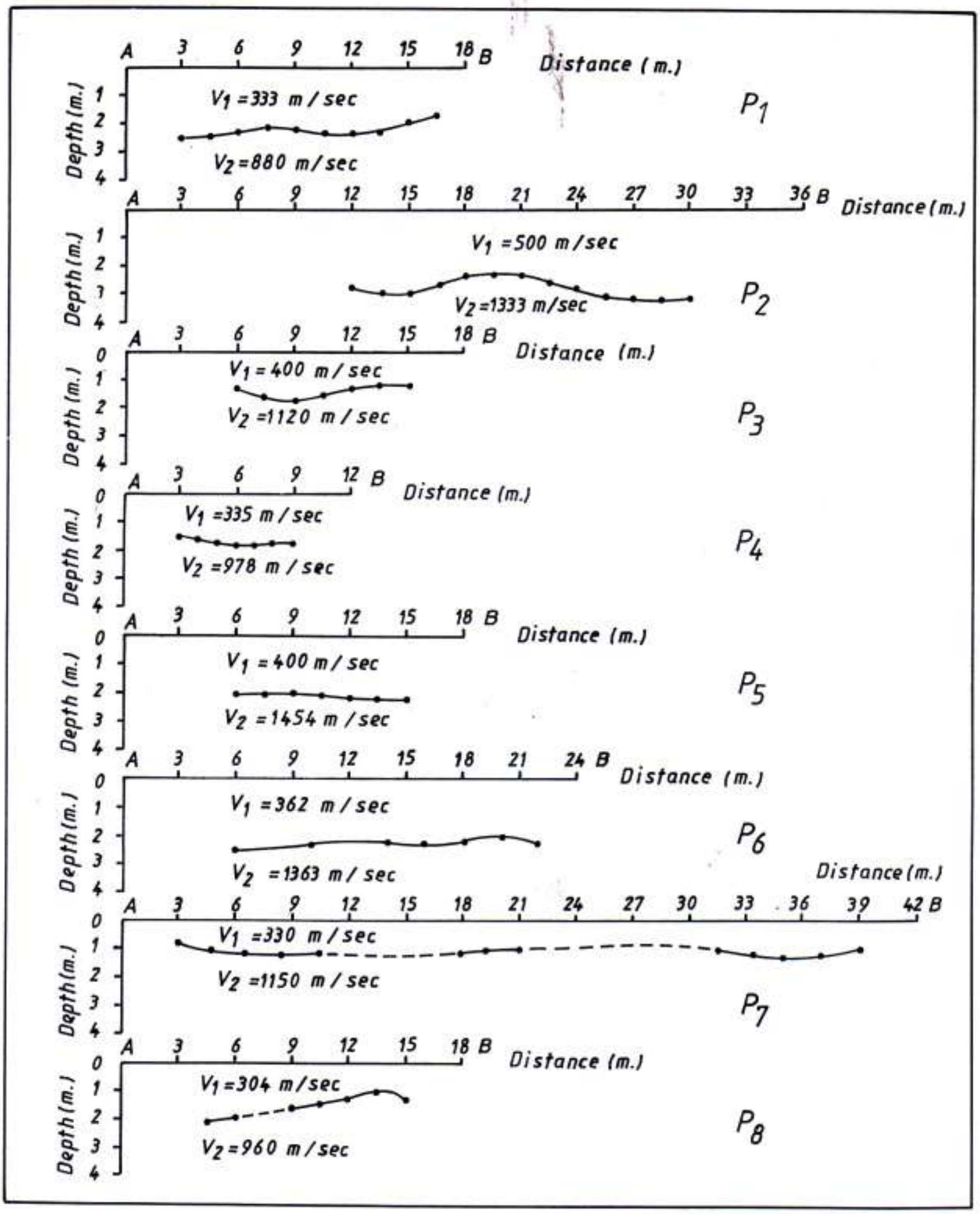


Fig. (2) Interpretution of surface seismic refraction survey using plus-minus method for profiles 1, 2, 3, 4, 5, 6, 7 and 8 at the pumping station of Al-Hussain water supply station, Kerbala.

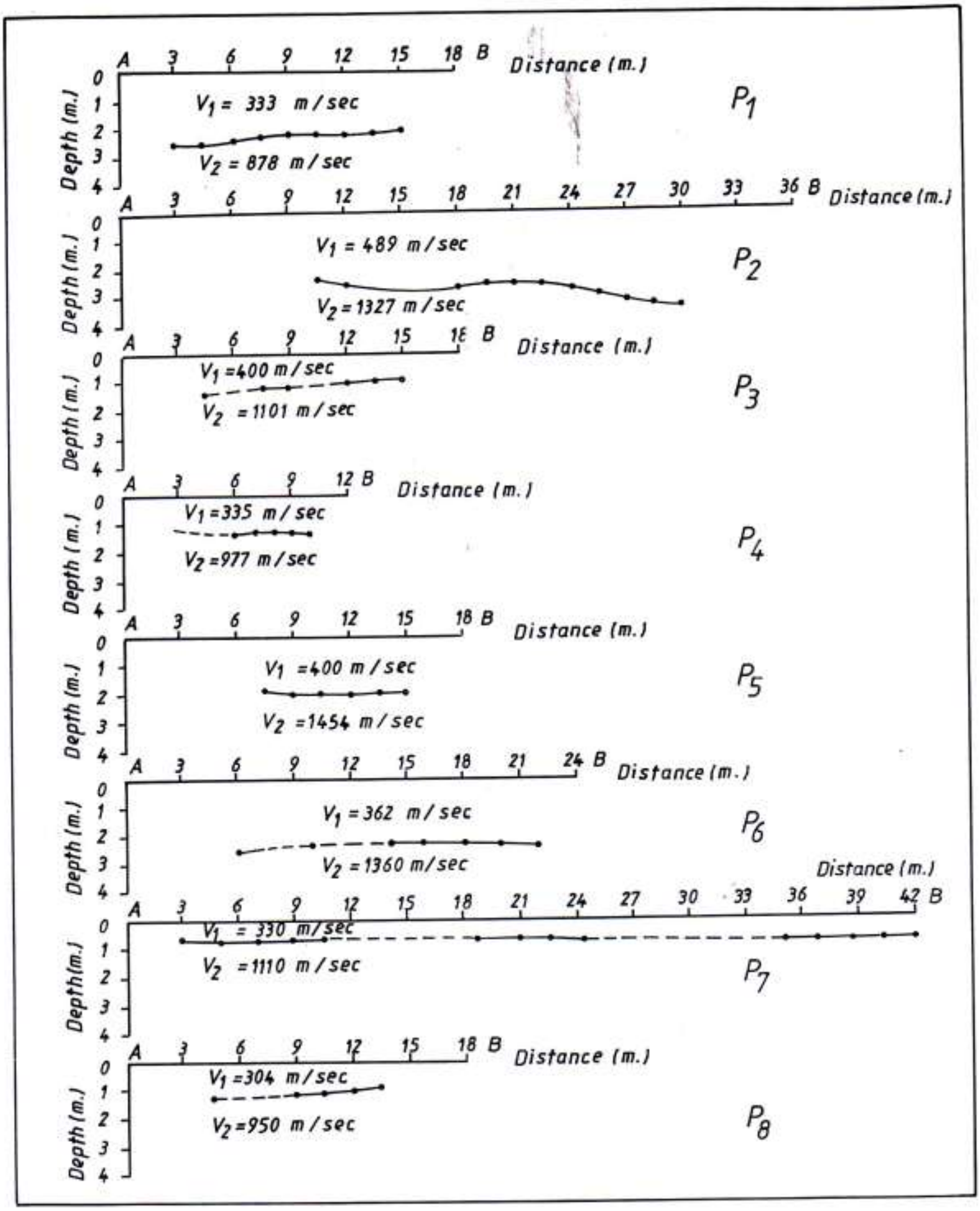
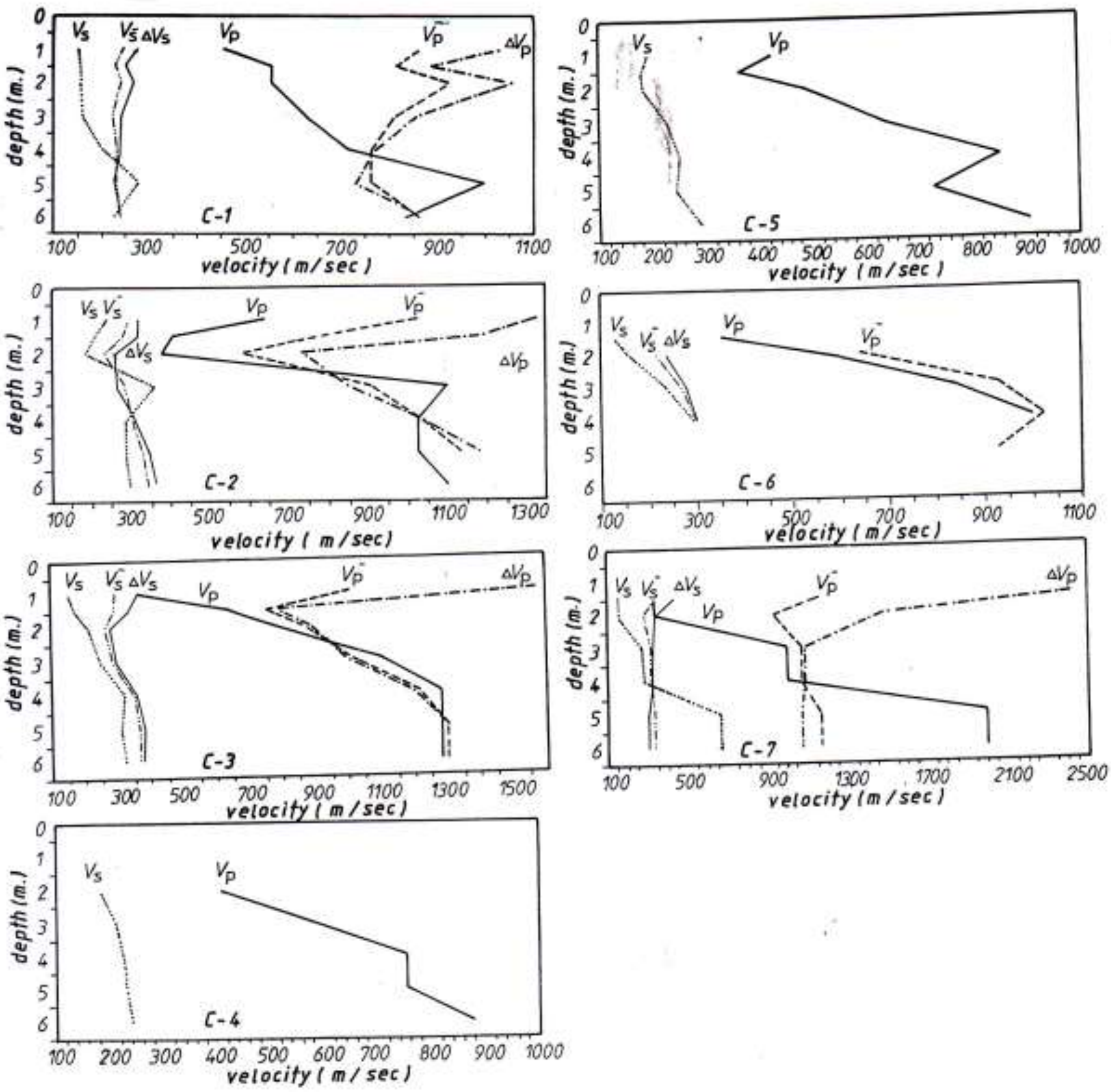


Fig. (3) Interpretation of surface seismic refraction survey using ABC method for profiles 1,2,3,4,5,6,7 and 8 at the pumping station of Al-Hussain water supply station, Kerbala.



V_p = Longitudinal wave velocity of near borehole
$\bar{V}_p$ = = = = = far =
V_s = Shear = = = near =
$\bar{V}_s$ = = = = = far =
$\Delta V_p = \Delta d / \Delta t_p$, $\Delta V_s = \Delta d / \Delta t_s$
Δd = distance difference between near and far boreholes
Δt_p = time differenc (t_p) = = = = =
Δt_s = = = of (t_s) = = = = =
t_p = travel time of longitudinal wave
t_s = = = = shear =

Fig. (4) Variation of $V_p, V_s, \bar{V}_p, \bar{V}_s$, ΔV_p and ΔV_s with depth for the profiles 1,2,3,4,5,6 and 7 of crosshole survey.

Plate -1- Cavity between the concrete floor and the soil in the high pumping station building.

Plate -2- A seepage below the pipe of water drain, where it is entering the pumping station building.

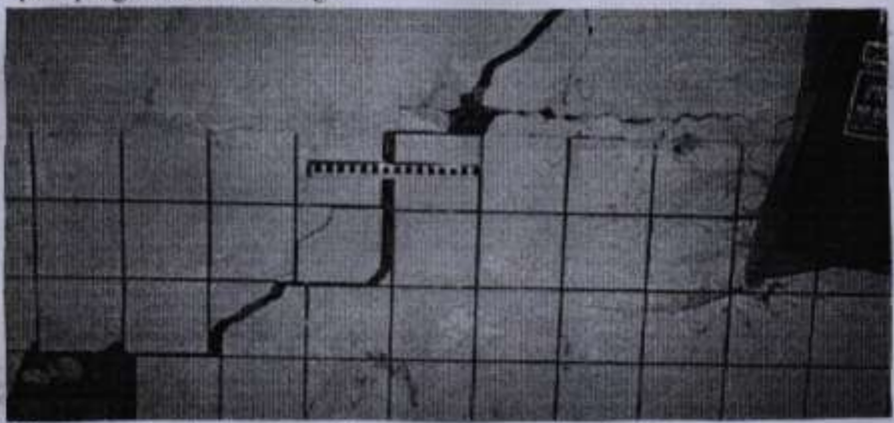


Plate -3- Cracks in the wall of pumping station building.