Shallow Refraction Survey Avoiding Explosive Permanently and Consistently

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Summary

In the hilly terrain of fold belt area, the lithology and thickness of the weathering zone varies abruptly, posing a challenge in deciding the optimum depth. That is why, more number of uphole as well as shallow refraction surveys are being carried out by all seismic crews. The cost of these many numbers of SR survey using explosive is recurring and cumulative. More so due to the logistics involved in arranging security, licensed shot-firer etc. In this paper, the methodology of performing SR survey, using thumping or sledge hammer as a source, has been systematically established and consistently tested in actual field conditions. This is a need-based and cost-effective method which does not require explosive and associated logistics. The uniqueness of the project lies in the interfacing of thumping source with the Summit system, the establishment of accuracy of timing in laboratory condition, achievement of sufficiency in energy through the design of base plate and stacking, and validation of the method against Uphole and SR with explosive / dynamite source in varying field conditions.

Introduction

The crux of any quality seismic data revolves around two points – placement of charge at optimum depth and accurate static corrections. Other quality parameters like geophone plantation, instrument specification etc. are more or less standardized internationally. In present day seismic recording instruments e.g. SN388, 408UL etc., the quality of geophone plantation could be viewed quantitatively and instantly by the click of a mouse, even well before taking a production shot. Hence, geophone plantations are corrected efficiently. Similarly, it is well known that the noise could peep in at the analog level only. Once the signal is digitized the ambient electromagnetic noise has no effect. Previously, in the DFS-V systems, the nano-volt level analog signal has to travel several kilometers through cables before it was digitized inside the instrument van. In SN388 system, analog signal travels half of the length of a line cable i.e. upto several hundred meters. In 408UL-FDU system, it travels only the length of geophone string i.e. several meters and finally, in 408UL-DSU system, it travels zero meter. Even the test tape results, of all the channels for all specification parameters, could be viewed in a few seconds. Therefore, most of the quality parameters are optimized, standardized and corrected by all seismic crews, leaving a lot of scope for improvement in optimization of depth and calculation of static corrections (Cox, 1999).

In Assam and Assam-arakan fold belt, deciding OD is a real challenge. In other areas, where the change in weathering zone is smooth and gradual, one uphole survey in every one or two kilometer is sufficient to derive OD. But, in this fold belt area, the change in elevation is very abrupt, so also is the change in thickness and velocity of sub-weathering zone. Hence, one uphole survey at every one kilometer and one SR survey at every 200 meters is generally appropriate.

This requires quite a large number of SR surveys (at least three to four SRs per day) in every seismic field crew. Due to security reasons, a separate SR security crew also has to be mobilized for protecting explosive. Explosive, necessary arrangement of security personnel, licensed shot-firer, vehicles etc. increase the operational time and cost, which are recurring and cumulative.

In view of above, a need-based and cost-effective effort was initiated to conduct SR survey using thumping source. In the past, some stray efforts were made in this direction using Bison system. But the same was neither continued nor documented, because the energy was very less etc. Therefore, efforts were made with the Summit SR systems, currently acquired and presently operational with the crew, with hammer as seismic source. The authors explain the innovations made and initiatives taken and validations carried out alongwith the results in this paper.

The seismic crews in ONGC were provided with twenty of Summit acquisition systems in January, 2005, for uphole and shallow refraction surveys. Each system is equipped with 24 acquisition channels and each channel is designed with state-of-the-art 24-bit Delta-sigma A/D converter technology and they were provided to use explosive as seismic source in Jorhat. In order to use thumping as source, "Time Zero" and "Source Impact" have to be synchronized with micro-second accuracy and it is necessary to provide sufficient energy to cover, say, 125 meter spread. Also, the first breaks should be clear, distinct and pick-able. Moreover, the existing alternative techniques of air gun / motorized weight drop etc. could not be adopted as these would involve more hardware, big vehicles etc., where in more logistics are involved.

Methodology

The project encountered an initial bottleneck, as no transducer was available with the system for interfacing sledge hammer. However, from the old spares of Regional Equipment workshop, four nos. of piezo-electric crystal transducers were available. Then the transducer was attached to the handle of a small hammer with an adhesive tape and it was measured in oscilloscope where it was observed that with each impact, a sharp pulse of nearly 500 mV was available at the output. This pulse, which was viewed in oscilloscope and was used for the start of recording, was fed to a data channel, in parallel, with proper attenuation for recording alongwith a normal geophone channel and was, subsequently, plotted through Summit system during testing of accuracy (Fig.1).

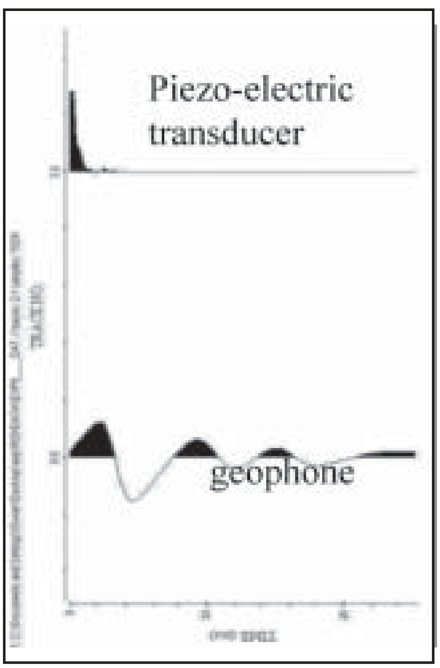


Fig. 1: Transducer output

The second part was the interfacing. The Summit system provided a solid metal block with a hole through which the shooting wire had to pass (Summit User Manual). It was understood that the block is nothing but an induction transformer for getting the induced pulse from high voltage to detonator, while working with explosive. The metal block was removed and the transducer output was fed into the "Trigger Slope" input (Fig.2).

Fig. 2 : Interfacing for explosive & hammer

The most important and critical phase was the testing of accuracy. The synchronization accuracy was tested in laboratory environment (Fig.3a). The tripod test geophone, provided with the

Fig. 3a: Lab. equipments

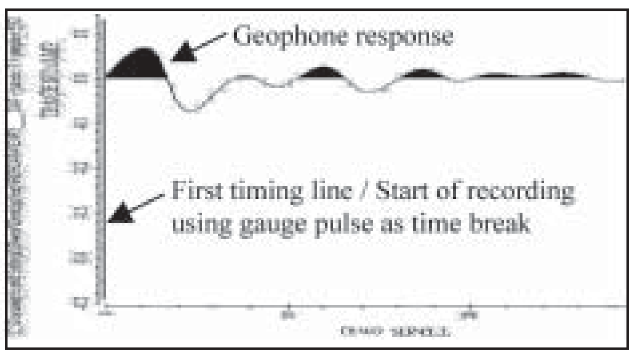


Fig. 3b: Synchronization accuracy

SMT100 Geophone analyzer, was used for this purpose. Hammering was done at the same place where the geophone was placed, while taking a data record. In the plot of the record, it was observed that the first timing line was aligned with the rising edge of the pulse, even in a extended time-scale plot (Fig.3b).

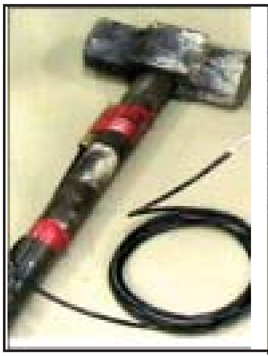
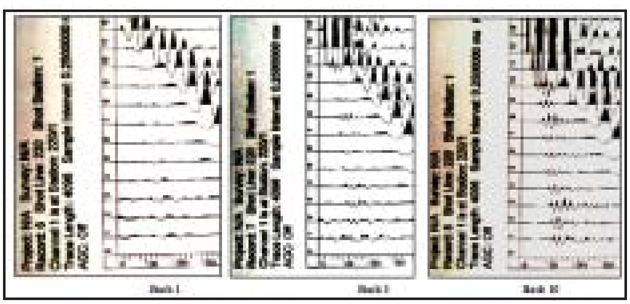


Fig. 4a : Hammer

Fig.4b : Base plate

The next phase was the transmission of sufficient energy in the geophone spread. A 3.5 kg hammer head was welded with a 3 ft long iron pipe to make the hammer (Fig.4a). In a ground, many number of data records were taken with the Summit system, by feeding a well-planted geophone group and hitting the transducer-fitted hammer at a distance of 150 mt on brick surface / wooden peg etc. But in each case, sufficient energy could not be derived. A slight but consistent improvement in energy was visible when a round-headed base plate was designed and fabricated for hitting (Fig.4b).

Considerable improvement was achieved in energy level and clarity of first breaks using stacking facility of the summit system (Fig.5a). The first breaks were not distinctly visible with single stack. However, when the hammering was repeated followed by vertical stacking of the records, the first breaks were clearly visible as the no. of stacks were increased. It was also observed that a single stack, which is corrupted with man-made noise, could spoil the whole efforts of stacking (Fig.5b). In such case, the particular stack had to be weeded out to improve the signal to noise ratio by stacking.



Stack 1 Stack 5 Stack 10

Fig. 5a : Improvements

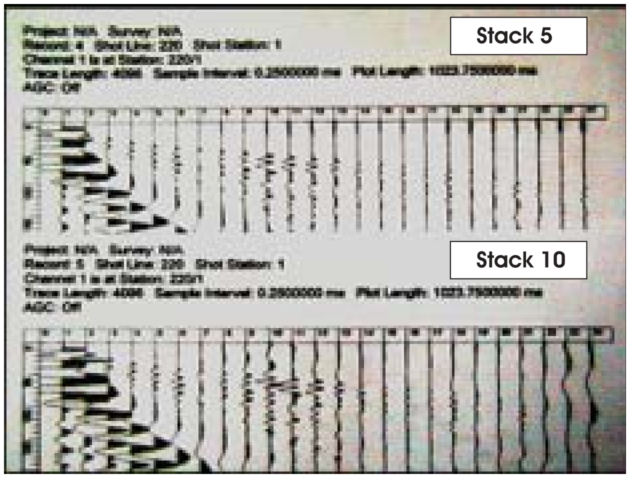


Fig. 5b : Deterioration due to noisy stack.

Initially, the test records were taken to evaluate total harmonic distortion, instantaneous dynamic range, common mode rejection ratio and crossfeed and they were kept within limit. Then the data records are taken followed by stacking and processed with Sandmeier ReflexW (ver 3.5) software with the following steps (Sandmeier K. J., 2004) :-

1. Importing of SEG2 32-bit floating point data files.
2. Combined displaying, filtering and gain application.
3. Definition of geometry.
4. Picking of first breaks.
5. Travel time analysis.
6. Assignment of first layer.
7. Combining the different segments of TT curves.
8. Velocity analysis and wave front inversion.
9. Repetition of 2D TT analysis loop till last layer.
10. Generation of model.

Application

To confirm the accuracy, consistency and acceptability of the above method of shallow refraction survey using sledge hammer, the following three pilot experiments were carried out, using resources of seismic crew in field. These three experiments were carried out mainly to verify the following points :-

1. Sufficiency of energy with different thickness and composition of weathering zones in the actual field condition.
2. Consistency with the Uphole and SR(explosive) data in actual field condition.
3. Clarity and sharpness of the first-breaks.

4. Effectiveness and consistency of stacking and un-stacking capabilities of the system in different varying conditions.

Experiment 1 :- At location no. 1 (Fig.6a), where one SR survey using explosive was carried out earlier, one SR Survey with hammer was conducted at a parallel distance of 15m. The schematic diagram (Fig.6b) shows the ray map for experiments using explosive and hammer. The geometry of this first experiment has been described in Fig.6c. It is well known that there is an inherent bias or tendency towards matching the timings of normal first break pick-ups by rounding off etc. To avoid this bias, different orientation of channels and different shot distances were opted for. 24 records were taken only with hammer with different stacks (1/5/10/15/20) and different sensor combinations (single geophone / one group of ten geophones / two geophone groups in parallel). Three records were chosen for SP1, 2 and 3. Explosive and hammer data were processed separately using ReflexW software and it was found that both the results were similar.

While comparing the first break picks for the farthest channels of hammer and explosive, it was found that the breaks were clear and pick-able. Rather, the first breaks of hammer data are much sharper than the explosive data offering less scope of manual error while picking (Fig.6d).

Fig. 6a: Location Map (after Kumar Brijesh et al.)

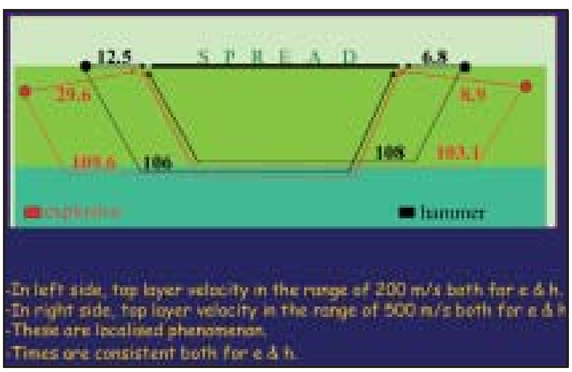


Fig. 6b : Ray diagram of first experiment

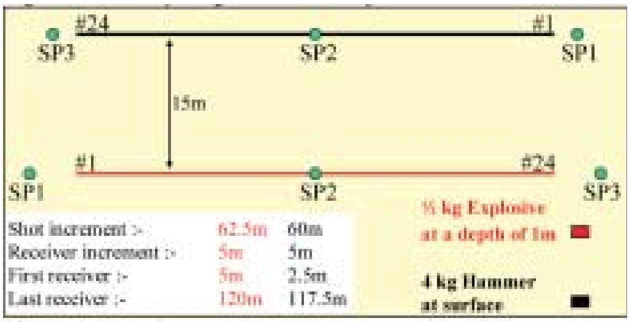


Fig. 6c: First experiment geomery

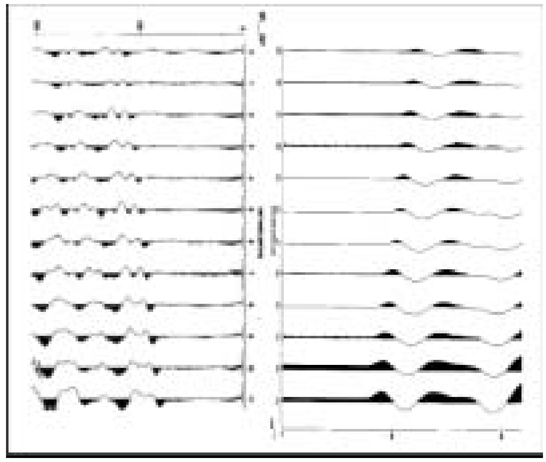


Fig. 6d: Farthest channels :- Hammer & Explosive

In this experiment, the depth of different layers and the slope towards the river-bed are same. But, the difference in velocities (Fig.7) are because of these three reasons – 1) ray path of two SRs were different, 2) ground condition was different in two days, 3) the depth correction of one meter for explosive was not considered during processing.

exp	T ms	ham	T ms	Δt (ms)
#12	7.5	#13	7.2	0.3
#13	7.1	#12	6.7	0.4
#14	14.2	#11	15.6	-1.4
#15	20.7	#10	22.4	-1.7
#16	26.7	#9	29.2	-2.5
#17	30.2	#8	34	-3.8
#18	35.6	#7	37.2	-3.3
#19	37.9	#6	41.2	-3.3
#20	41.5	#5	44	-2.5
#21	45	#4	48.4	-3.4
#22	48	#3	51.6	-3.6
#23	51.6	#2	55.2	-3.6
#24	54.6	#1	57.3	-2.7

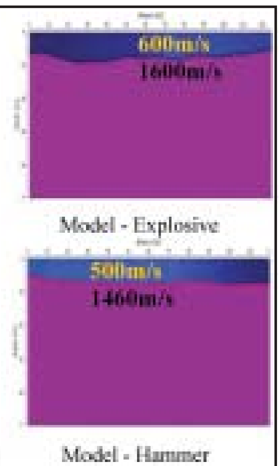


Fig. 7 : Sample travel time picks

Once the consistency with the SR of explosive data was established and stack & sensor parameters were optimized (15 stacks per SP and one group of 10 bunched geophones per picket), the next experiment was carried out.

The geometry of experiment 2 & 3 were same and is described in Fig. 8.

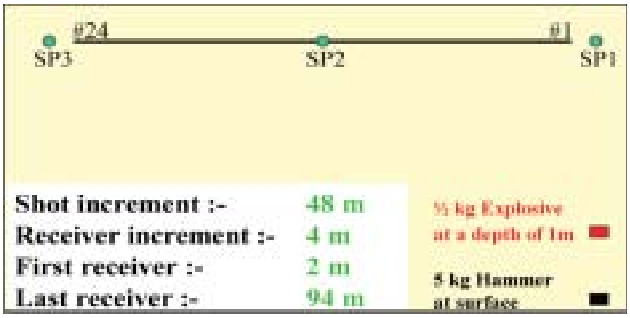


Fig. 8: Geometry of second and third experiments.

Experiment 2 :- At location no. 2 (Fig.6a), where already one Uphole survey using explosive was carried out earlier, one SR Survey with hammer was conducted. Raw stacked data for all the three shot points (SP1, SP2 & SP3) were combined in ReflexW resulting 72 traces (Fig.9a). The details of lithology was collected from the Driller and the time-depth plot of uphole was also generated (Fig.9b).

The velocities and change-over points obtained through Uphole survey were compared with corresponding velocities and change-over points of SR survey with hammer (Fig.9c).

Experiment 3 :- At location no. 3 (Fig.6a), where already one Uphole survey data was available, both SR(Hammer) and SR(Explosive) carried out on same spread one by one on the same day. The trend or slope of the layers were found same. Also, the depth and velocity of different layers were found to be very close and consistent for all the three type of surveys i.e. Uphole, SR (explosive) and SR (hammer) (Fig.10).

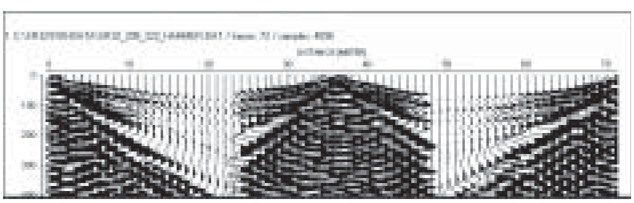


Fig. 9a: Stacked raw record of SR combining all three SPs in ReflexW software.

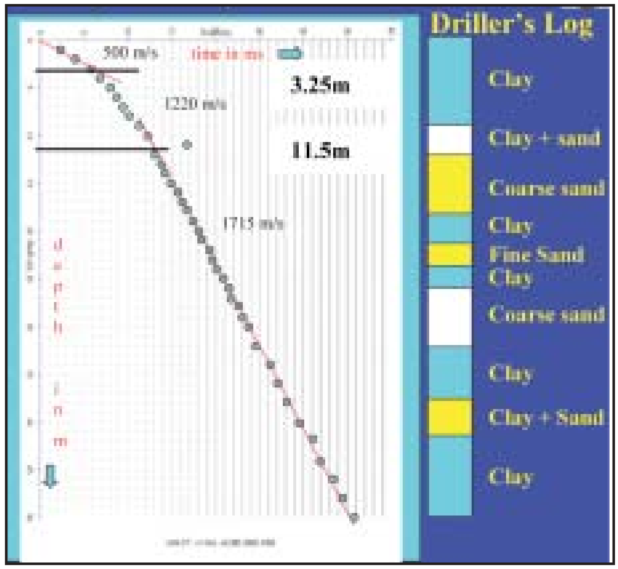


Fig. 9b :T-D plot of Uphole for second experiment

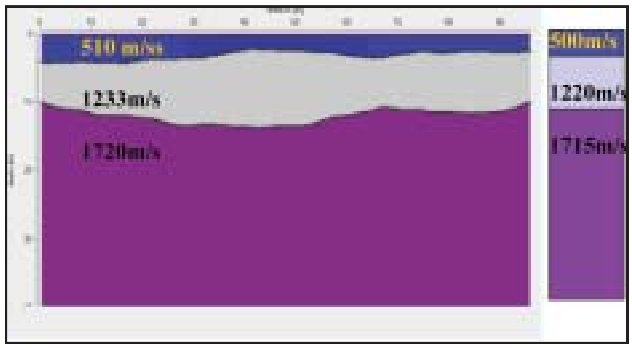


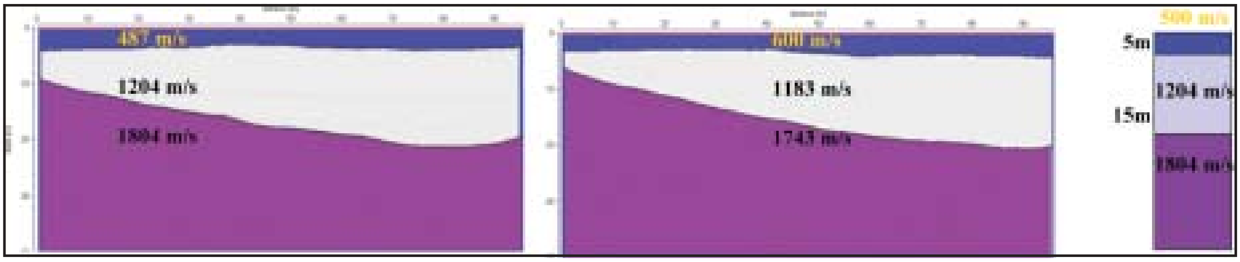
Fig. 9c : Model SR (hammer)

Conclusions

The shallow refraction survey with sledge hammer, as per the described methodology, is consistent with the uphole and SR(explosive) survey and it could replace the shallow refraction survey using explosive. Hence, it is prescribed that one uphole survey should be carried out at every one kilometer and five SR(Hammer) surveys in between two upholes at a distance of every 200 mts. for determining the correct optimum depth in abruptly-varying sub-weathering areas and also for deriving near-surface velocities for static corrections.

Hammer head of 4 to 5 kg and a round base plate with pointed mast should be used for better ground coupling and energy transmission.

It is very cost-effective. The combined cost of hammer, base plate and torque pressure transducer is one



1. Model with hammer 2. Model with explosive 3. Model with Uphole

Fig. 10: Automatically generated by ReflexW:-

time and less than Rs. 5000. Whereas the cost of detonators, explosive, security personnel, shot-firer etc. are recurring and cumulative.

It saves a lot of operational time. As the requirement of resources (Explosive, detonator, Jeeps for explosive and security personnel etc.) and manpower (Shot-firer, explosive handling personnel, security personnel) are reduced, SRs could be conducted with more operational ease. More nos. of SRs could be completed per day as compared to SR using explosive.

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Views expressed in this paper are that of the author(s) only and may not necessarily be of ONGC.

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