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Improved Seismic Energy Transmission through Proper Tamping of Explosive and use of Cement and Bentonite Clay

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Summary

In land seismic surveys placement of shot (blasting of explosive) in an appropriate near surface layer plays an important role in terms of transmission of shot generated energy. An optimally placed shot is expected to result in good energy transmission and better data quality. Normally a higher velocity layer is expected to give rise to better energy transmission and conversely in case of lower velocity. Results of the data analysis show that increased sand content in the shooting medium (the layer in which explosive is blasted), lowers the quality of recorded data in terms of energy (Signal to noise ratio, S/N) and frequency. In sandy formations, shot hole drilling is very challenging because of water loss as well as hole collapse. Use of bentonite clay mixed in mud while drilling shot holes prevents water loss and hole collapse. Cement and bentonite clay act as plugging material and they fill the pores in the formations and form a compact material around the shot holes. This also increases velocity of the shooting medium around bore hole walls leading to better transmission of seismic energy. This study is based on an experiment conducted, in Cambay Basin, India, to study the effect of (i) cement and bentonite plugging in shot holes on transmission of energy in sandy formations and (ii) bentonite clay mixed in drilling water mud during drilling as well as only washing the shot hole.

Introduction

Halisa –Limbodra area in Cambay Basin comprises the rising flank of eastern basin margin in Ahmedabad tectonic block. The area comprises of Eastern margin of Cambay basin and the adjoining Nardipur Low, between Halisa and Limbodara fields (Fig. 1). Sabarmati River bisects the area into two parts. The near surface lithology is predominantly sandy with minor binding clay. Fig. 2 depicts the percentage of sand content in the shooting layer. This may probably be due to shifting of paleocourses of the Sabarmati River. More sand content in near surface layers causes seepage of water in shot holes into the surrounding media during the time gap between loading the explosive and shooting operation. This affects the tamping of the explosive and in turn the energy transmission. To reduce water loss/ seepage and improve energy transmission, it was thought to study (i) the effect of cement plug or pouring cement slurry or bentonite clay into the hole after loading explosive and allow sometime to pass for settling of the cement or bentonite; (ii) the effect of bentonite clay mixed in mud used during drilling and (iii) the effect of use

of bentonite mixed in water for washing the bore hole (after drilling).

Bentonite is a rock composed primarily of montmorillonite, expandable magnesium aluminium silicate clay mineral. It is swelling clay, when hydrated; it expands up to more than 15 to 20 times its original volume (Miles, 2008). Bentonite slurry has two important physical properties, namely water adsorption and thixotropy (behaving like a liquid when stirred or shaken and setting back to gel when allowed standing (Teplitzkiy et al., 2005). These two properties of bentonite slurry make it useful in shot holes as tamping, sealing or plugging material. Bentonite forms a tough plug which seals the hold and provides a barrier to the explosive charge, keeping the energy down hole. Unlike most other clays, bentonite structure has an affinity for water. In the presence of free water, bentonite electrochemically adsorbs the water molecules and this hydration process results in expansion or swelling of the bentonite structure. The ability to absorb water and swell, exerting pressure against confining surfaces, is what gives the material its tremendous



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advantages over other mediums for filling void spaces in and around bore holes (Stichman, 1990). In porous and sandy shooting medium, bentonite slurry once flushed into formations, swelling of bentonite clay takes place and it fills up the void space making the formations compact and impermeable. This prevents water loss in shot holes and also provides a desired compact shooting medium (Towler et al., 2008).

Cement, used as powder or slurry or wet mixture with stone chips, forms a heavy plug on top of the bore hole mud column and results in better tamping and energy transmission.

Cement slurry or dry cement, bentonite slurry or dry bentonite powder poured into the shot hole after loading of charge forms a heavy plug on top of bore hole mud column and or bentonite slurry used during shot hole drilling or washing of shot holes, fills the porous sandy formations, if found around the shot holes. This makes the surrounding material compact and increases the velocity of the shooting medium in the vicinity of bore hole walls. As a result, better transmission of seismic energy is achieved.

In the area of study, near surface is predominantly sandy. In order to attempt improvement in energy transmission in sandy near surface, bentonite slurry, dry bentonite powder, cement slurry and dry cement powder were used in shot holes to achieve effective energy transmission to the formations. The present paper encompasses the study of results obtained in the form of recorded seismic data with various combinations of plugging materials like cement and bentonite.

Methodology

The present study is based on an experiment conducted during 3D seismic data acquisition in North Cambay Basin, India. The acquisition geometry consisted of 14 receiver lines with orthogonal shooting pattern with explosive source. Along with the normal data acquisition, the experiment was carried out at a number of locations for different aspects of energy transmission involving more than one shot hole drilled at a particular shot hole to compare the results of the normal hole (with simple water mud) with another with cement or bentonite application. Shots were blasted with different combinations to study the following aspects.

1. Effect of cement plug created after loading of explosive
2. Optimization of quantity of cement to be used
3. Effect of cement slurry versus fully filling of muddy water
4. Effect of cement versus bentonite plug in shot holes
5. Effect of shot hole drilling with water based mud versus bentonite slurry based mud.

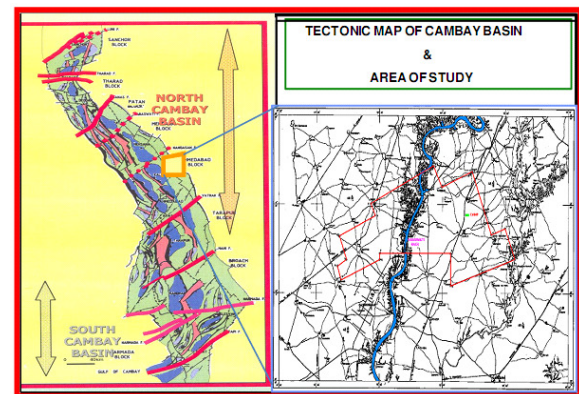


Fig.1 Location of study area in tectonic map of Cambay Basin

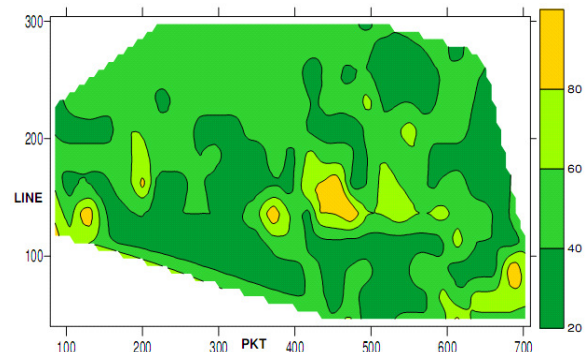


Fig.2 Contour map of sand percentage

In the first case, a shot hole was drilled with normal water as mud and left for 4 hours after loading the explosive (depth: 31.0m and charge: 5.0 kg) and then the shot was blasted. In another shot hole(drilled with water mud) at the same location, 50 kg dry cement was poured into the shot hole after loading the charge (depth 31.0 m, charge : 5.0 kg). The cement was allowed to settle for 4 hours before the charge was blasted. In another location a shot hole was drilled with normal water as mud and left for 4 hours after



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loading the explosive (depth: 31.0m and charge: 5.0 kg) and then the shot was blasted. In another shot hole in the same location, wet mixture of 50 kg cement with stone chips was poured into the shot hole after loading of explosive (depth 31.0 m, charge: 5.0 kg). The cement mixture was allowed to settle for 4 hours before blasting. The monitor records observed in these four cases are shown in Fig. 3(a), Fig. 3(b), Fig. 3(c) and Fig. 3(d) respectively.

In the second case (optimization of quantity of cement), four shot holes were drilled at the same location. In the first hole, water mud was poured into the shot hole after loading of explosive (depth: 28 m, charge: 5.0 kg). In the second hole a slurry of 5 kg cement was poured after loading of explosive (depth: 28.0 m, charge: 5.0 kg) and the slurry was allowed to settle for 2 hours. In the third hole, a slurry of 10 kg cement was poured after loading of explosive (depth: 27.8 m, charge: 5.0 kg) and the slurry was allowed to settle for 2 hours. In the fourth hole, a slurry of 15 kg cement was poured after loading of explosive (depth: 28.0 m, charge: 5.0 kg) and the slurry was allowed to settle for 2 hours. The monitor records observed in these four cases are shown in Fig. 4(a), Fig. 4(b), Fig. 4(c) and Fig. 4(d) respectively.

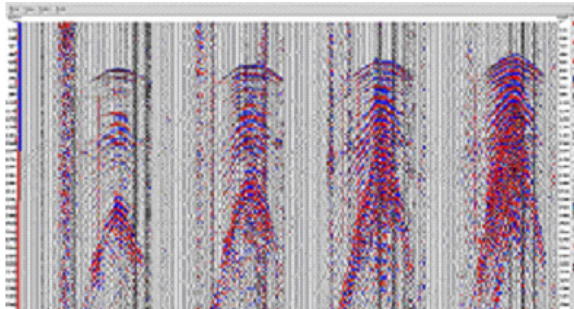


Fig.3 (a) Monitor record of normal shot hole filled with water/mud.

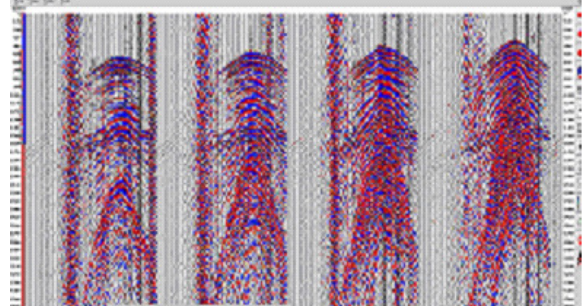


Fig. 3 (b) Monitor record with 50 kg dry cement poured in the shot hole after loading

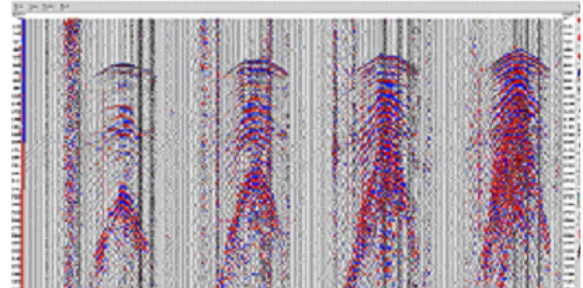


Fig.3 (c) Monitor record of normal shot hole filled with water/mud

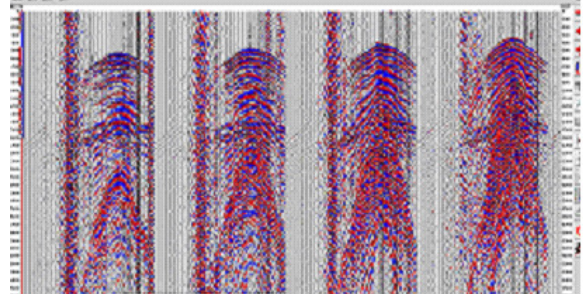


Fig.3 (d) Monitor record with slurry of 50 kg cement with stone chips poured in the shot hole after loading

In the third case (cement slurry versus fully filling of muddy water), two shot holes were drilled at the same location. In the first hole, water/ mud was filled after loading of charge (depth: 26.0m, charge: 5.0 kg). Before shooting, the hole was topped up with water. In the second hole, a slurry of 10 kg cement was poured after loading of explosive (depth: 26.0 m, charge: 5.0 kg) and the slurry was allowed to settle for 2 hours. The monitor records observed in these two cases are shown in Fig. 5(a) and Fig. 5(b) respectively.

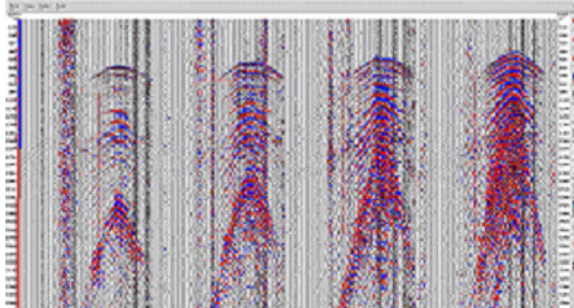


Fig. 4(a) Monitor record without any cement poured into shot hole

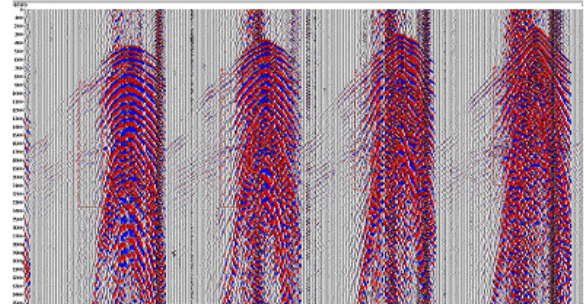


Fig. 4(d) Monitor record with slurry of 15 kg cement

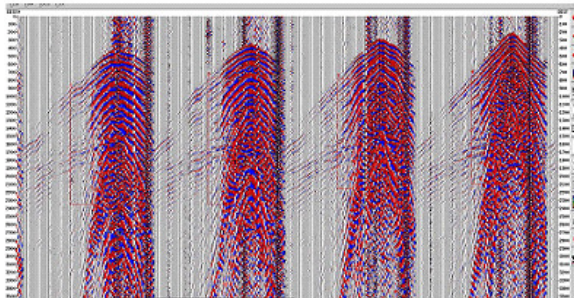


Fig. 4(b) Monitor record with slurry of 5 kg cement

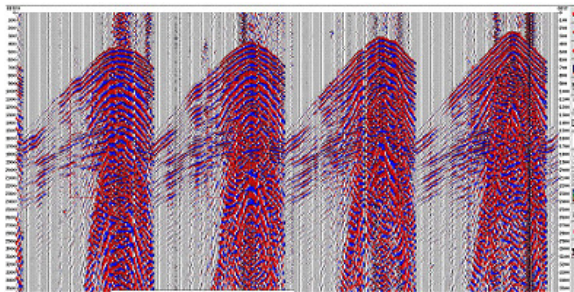


Fig. 4(c) Monitor record with slurry of 10 kg cement

In the fourth case (cement versus bentonite plug in shot holes), it was thought to experiment with bentonite in place of cement as cement in shot holes does not seem to be environment friendly. Two shot holes were drilled at the same location. In the first hole, a slurry of 10 kg cement was poured after loading of explosive (depth: 26.0 m, charge: 5.0 kg) and the slurry was allowed to settle for 2 hours. In the second hole, 50 kg of dry bentonite powder was poured in after loading explosive (depth: 26.0 m, charge: 5.0 kg). The monitor records observed in these two cases are shown in Fig. 6(a) and Fig. 6(b) respectively

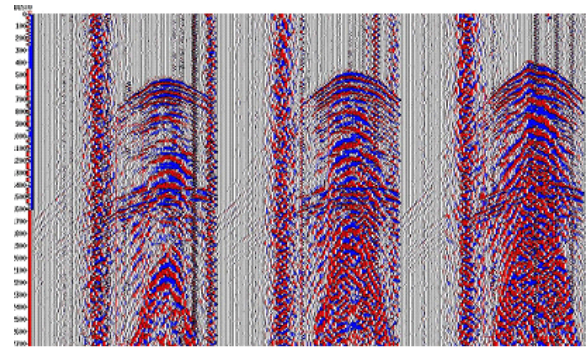


Fig. 5 (a) Monitor record with shot hole filled with water/ mud



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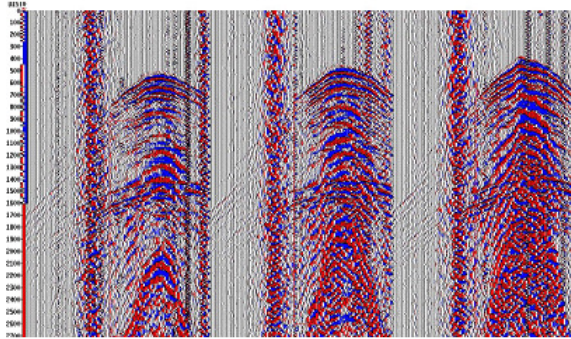


Fig. 5 (b) Monitor record with shot hole filled with cement slurry

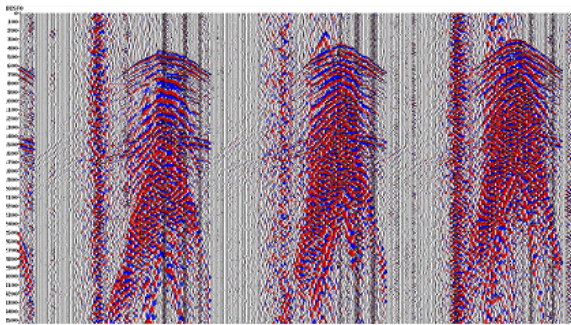


Fig. 6(a) Monitor record with cement slurry in shot hole

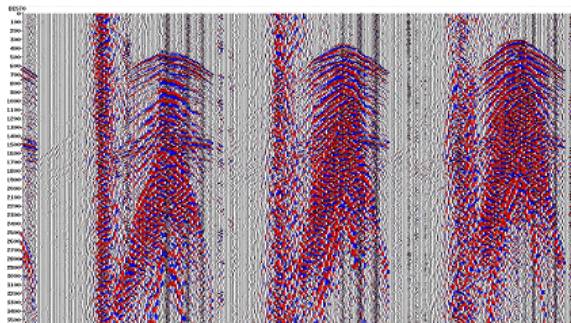


Fig. 6 (b).Monitor record with bentonite plug in shot hole

In the fifth case (normal water/ mud filled hole versus hole washed with bentonite mixed in water), two shot holes were drilled at the same location. In the first hole, water/ mud was filled after loading of charge (depth: 30.0m, charge: 5.0 kg). Before shooting, the hole was topped up with water. The second shot hole was washed with water mixed with 25 kg bentonite before loading of explosive

(depth: 30.0 m, charge: 5.0 kg). The monitor records observed in these two cases are shown in Fig. 7(a) and Fig. 7(b) respectively.

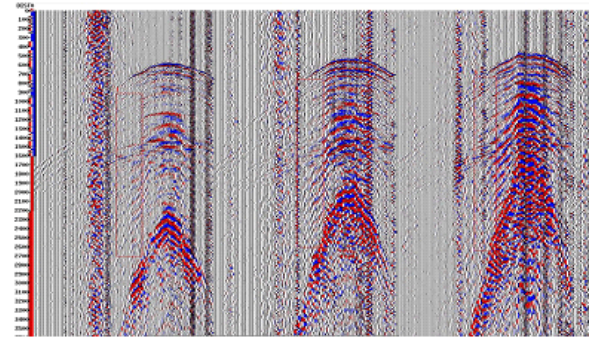


Fig. 7 (a) Monitor record with shot hole washed with water

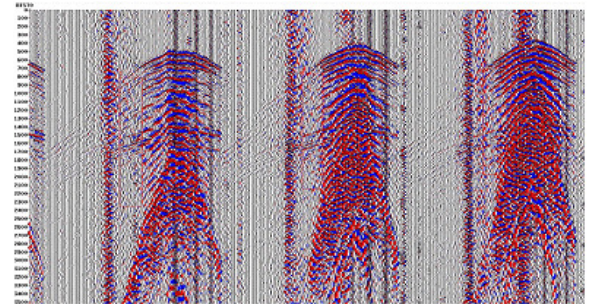


Fig. 7 (b) Monitor record with shot hole washed with bentonite slurry

Results and Analysis

Comparisons of Fig. 3(a) with Fig. 3(b) and Fig. 3(c) with Fig. 3(d) show clear improvement in signal standout in monitors with cement plugs in shot holes. Apparently, more energy has been transmitted down the hole in case of holes with cement plug as compared to the normal hole. Hence pouring of cement slurry or cement creates a plug sort of thing above the muddy water in the hole loaded with explosive and this helps better energy transmission downwards.

A comparison of Fig. 4(a) with Fig. 4(b), Fig. 4(c) and Fig. 4(d) shows clear improvement in signal standouts on records from shot holes that have been poured in with cement slurry. The maximum improvement is observed in



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the record of the shot hole poured with the slurry of 10 kg cement. It can be noted from Fig. 4(a) and Fig. 4(b) that even 5 kg cement provides better result than a normal record.

The records from a shot hole poured with cement slurry (Fig. 5(b)) and that filled with mud/ water (refilled with muddy water before blasting of explosive) (Fig. 5(a)) do not show any appreciable difference. Therefore, ensuring the shot hole to be fully filled with mud and water, before blasting the explosive, creates good tamping of explosive and in turn ensures good energy transmission down the hole. If the hole is to be left for few hours after loading the explosive into the hole, then plugging or creating a dense liquid plug (like that of the cement slurry) is helpful in improving energy transmission down the hole.

The record from the shot hole poured with bentonite powder (Fig. 6(b)) shows signal standouts comparable to that from the shot hole poured with cement slurry made from 10 kg cement (Fig. 6(a)). This prompted to try bentonite for the purpose as it may be more environment friendly, cheaper and practicable.

The monitor record from a shot hole washed with bentonite clay mixed in water (Fig. 7 (b)) shows obvious improvement in signal standout over the record from the normal water/ mud filled shot hole (Fig. 7(a)).

Conclusion

In general, better energy can be obtained on seismic records by properly tamping the explosive and by ensuring full refilling of the shot hole before blasting. In areas having sandy near surface, use of cement slurry or bentonite can result in better energy transmission than what can be achieved with simple water mud.

In case of sandy near surface, if full refilling of muddy water, before blasting the explosives cannot be ensured, then use of cement slurry can be resorted, to have better tamping of explosive for better energy. Use of bentonite mixed in water for washing the shot hole appears to be the best alternative as it is cheaper and more environment friendly.

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Acknowledgements

The authors are thankful to the management of ONGC Ltd. for providing necessary support and guidance to carry out the study. The support provided by Party personnel of Geophysical Party No. 15, Western Onshore Basin, ONGC, Baroda, India is thankfully acknowledged.