Characterization of Tipam Sandstone from Digboi Oil Field, Upper Assam, India

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Abstract. Physico-mechanical behavior of reservoir rocks in static condition of an oil field is critical to assess the stability of wellbore and other production related issues. Especially if the rock formation is anisotropic, the problem becomes more complex. An attempt is made in this paper to present test results of anisotropic Tipam sandstone from Digboi oil fields of Upper Assam, India under static conditions. The collected sandstone samples subjected to rock mechanics tests at different angles β=0°,30°,45°,60°,90° were conducted. Also, high-pressure triaxial tests in static loading conducted in dry and saturated conditions. The reservoir 1D and 3D Mechanical Earth model was carried out using Techlog and Petrel software from two wellbore data sets up to a depth of 2400 m to assess the wellbore stability incorporating anisotropy into consideration. The results indicate that the wells are critical at β=45°, under saturated conditions. Necessary wellbore stability measures are recommended based on the results of Digboi oil field.

Keywords: Reservoir rocks, Anisotropy, Static loads, Wellbore stability,1D mechanical model.

1 Introduction

In wellbore stability assessment in petroleum industry is critical for exploration and production. Wellbore stability is a big challenge when it comes to drilling a horizontal, vertical or inclined wellbore. Anisotropic properties of rock influence on fluid pressure (Rao, 1984[1]). To reduce the problem of wellbore instability is required predrilling study of physical and mechanical properties and behavior of reservoir rock under static condition(Bradley, 1979[2]; Bell and Gough, 1979[3]; Zoback et al., 1985[4]; Plumb and Hickman, 1985[5]) . Prediction of reservoir failure mechanism under different loading conditions with mechanical earth model (MEM) helps to minimize the risk and project delivering in less time (Plumb et al., 2000) [6].

Understand deformation and strength behavior of anisotropic hydrocarbon basin is need to design safe mud window for wellbore stability. The anisotropy properties is an influence on the mechanical properties of rock (Wang et al., 2016) [7]. Under static loading, failure mechanism is changing from axial cleavage in dry to shear failure in water saturation specimen (Hawkins and McConnell, 1992) [8]. Also, the geomechanical reservoir analysis and characterization helps to describe the failure mechanism behavior of reservoir rock under dry and saturated conditions. The location of study is in North of Himalayan whiten highly seismic and tectonic active region. For this study selected reservoir rock with anisotropic properties from Tipam sandstone with Miocene age in Digboi oil fields of Upper Assam, India. The two wellbores data up to 2400 m depth used for analysis and characterization wellbore stability with different β.

2 Testing Procedure

2.1 Sample Preparation

Tipam sandstone as reservoir rock selected and specimens at different β=0°,30°,45°,60°,90° with L/D =2, D= 38 mm tested in dry and saturated conditions. The specimens in dry condition 24 hours are kept in oven 101°±3° C and after10 hour cooling strain gauges attached and for saturated condition 29 hours kept in water with strain gauges. The triaxial test procedure is as per (ISRM,1983) [9] standard in static loading condition. The deformation of rock specimens measured with strain gauges assembly horizontal and vertical. Axial and diametrical strains were measured using electrical strain gauges of 120 Ωm during tests. The triaxial test equipment used IIT-Delhi compression unit, and this machine generates confining pressure up to 140 MPa with a frame 1000 kN capacity, as shown in Figure 1. Most of the specimens failed within 3-5 min.

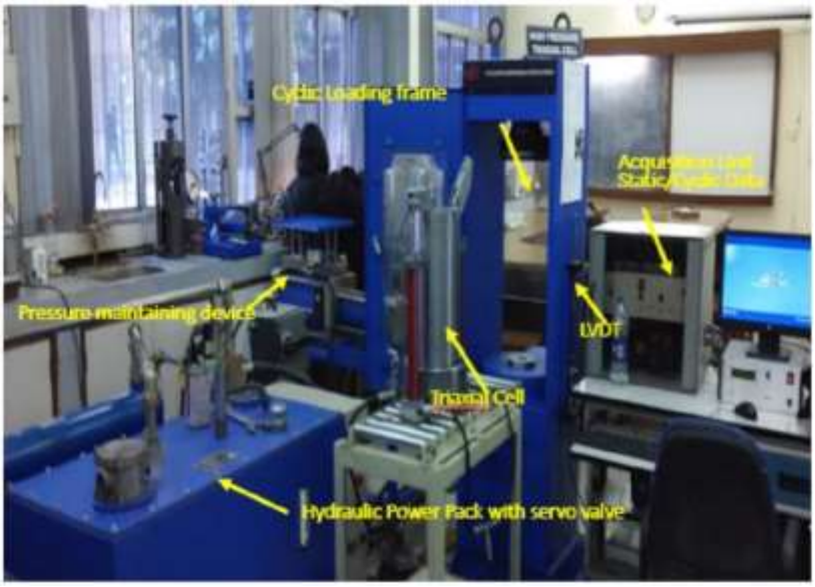

Fig. 1. Control system and control software of static loading unit of IIT-Delhi

Fig. 2. Prepared specimens for Point load test at different β

2.2 Physical and Mechanical Properties

Physical and mechanical testing provides valuable data to design per-drilling 1D and 3D MEM with different anisotropy angle. All index properties of anisotropic Tipam sandstone are listed in Table 1 in dry and saturated condition. These average results used to design the 1D and 3D MEM model under static loading.

Table 1. Average physico-mechanical properties of Tipam sandstone

PROPERTIES	AVERAGE VALUE
Density Dry (g/cc)	2.40
Density Sat (g/cc)	2.43
Porosity %	0.13
Permeability ($ms^{-1}x10^{-8}$)	9.28
UCS Dry (MPa)	61.75
UCS Saturated (MPa)	38.34
Cohesion, c (MPa)	12.73
The angle of Internal Friction (Degree)	48°
Deere and Miller Classification	DL

3 Experimental Results and Analysis

The values of Tipam sandstone under static loading shows mostly lower in saturated compare to dry condition. Strenght values are much higher at β= 0° and 90° in Brazilian test in dry specimens. The values are comparable with the suggested values from the literature of different anisotropy angle (Rao, 1984) [1]. The UCS test results show minimum values are at β= 45° due to weak bedding planes of saturated rock specimens and higher values at dry situation. The triaxial test was conducted at 5,10 and15 MPa confining pressures with different β in both dry and saturated conditions.

The strength values show an increase with increasing the confining pressure from 5 up to 15 MPa and value at β = 45° is less than other anisotropy angles especially in saturated water content as shown in Figure 2. The failure mode shows most of the specimens splitting in shear planes.

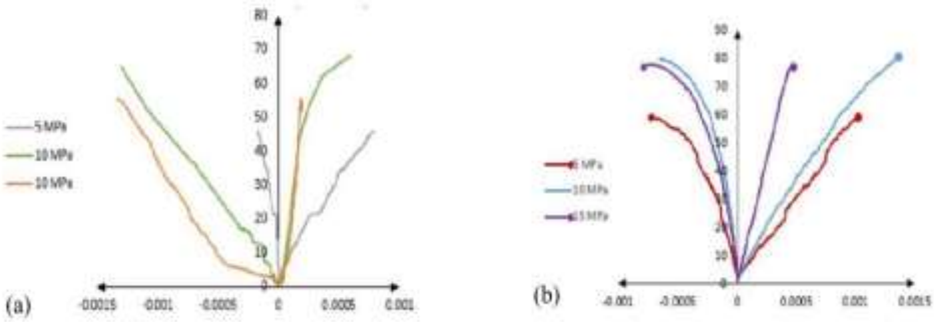

Fig. 3. (a) Stress-strain curves of triaxial dry and (b) saturated conditions at β =45°

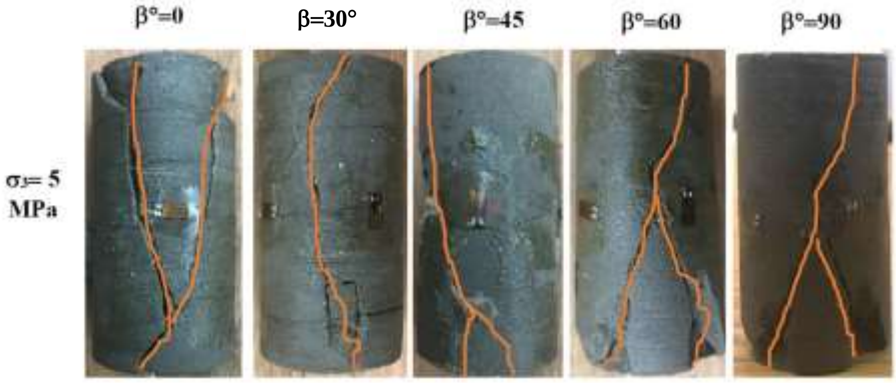

Fig. 4. Failed Tipam sandstone of triaxial test in dry condition at β =45°

4 1D and 3D Mechanical Earth Model (MEM)

The log data help to know about rock properties in subsurface according to the lithology types and geological features. It is essential to study rocks deformation in response to drilling event and production operation. The mechanical earth model in this study, derived from conventional logs, core data and seismic logs with a graphical representation of the state stress and mechanical rock properties in two wellbores, at Digboi oil field of Upper Assam. Using conventional log data is required to generate a mechanical earth model (MEM) and predict instability wellbore in the field with suitable failure criteria. Mechanical earth models represented in 1D around the wellbore and 3D in field scale.

The 1D mechanical earth model of Tipam formation is design based on the experimental data and log data in static condition with incorporate the anisotropic property in different β= 0°,30°,45°,60° and 90° in both dry and saturated conditions. For failure mechanism prediction used Mohr-coulomb criteria to design WBS.

The strength property of core and log data of Tipam sandstone, calculate and correlate in 1D MEM and later populate in 3D MEM for the entire basin. The 1D mechanical earth model was carried out using Techlog software of two wellbore data up to 2400 m depth to assess the wellbore stability. The stress maps generate form 3D MEM used Petrel software as shown in Figure 5. The stress maps indicate maximum and minimum strength of Tipam sandstone and show minimum values that at β=45°, under water saturated content and is critical due to presence of laminated structures in rocks. The strength of these rocks is found on the map counters from 8 to 23 MPa.

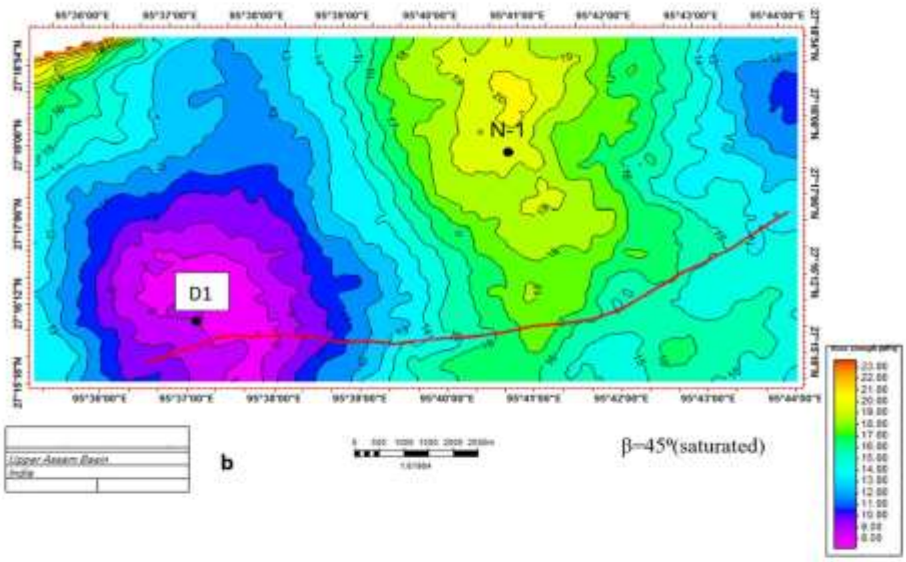

Fig. 5. 3D Stress map of Tipam sandstone at β= 45⁰ in saturated condition

5 Conclusions

The aim of this paper was to study the mechanical properties of reservoir rocks under static loading condition for wellbore stability of anisotropic formations in the oil field. The study investigations suggest anisotropy property effect on wellbore stability and mud weight pressure in Tipam sandstone as reservoir rocks at both dry and saturated conditions. The area selected is the Upper Assam, Digboi oil field as the most productive hydrocarbon zone in India. The strength is increase with increasing the confining pressure from 5 up to 15 MPa at β = 45⁰ . After conducting the mechanical laboratory testing, the 1D and 3D MEM models were developed form different β by populating mechanical and geological property and generate the stress maps for the entire region.

The wellbore stability analysis due to extensive laboratory and field data indicated that wells are fairly safe at β= 0˚ to 45˚. Maps are useful based on the β and the stress contours; it is very easy to locate a suitable well location for drilling event. It is observed the water content effect on the stress map and shows a reduction in values at different β. The stress map indicated the maximum values are for β= 90° and the minimum is betweenβ= 30° and 45° .

References

1. Rao, K.S.: Strength and deformation behaviour of sandstones. Doctoral Thesis, Indian Institute of Technology, Delhi (1984).
2. Bradley, W.B. Mathematical concept – Stress cloud can predict borehole failure. OGJ, 19, pp.75 – 102(1979).
3. Bell, J.S. and Gough, D. I.:North East -South West compressive stresses in Alberta: evidence from oil wells. Earth and Planetary Science Letters, 45, pp. 475-482(1979).
4. Zoback, M.D., Moos, D. and Mastin, L: Well bore breakouts and in-situ stress. Journal of Geophysical Research, 90, pp.5523-5530(1985).
5. Plumb, R.A. and Hickman, S.H.: Stress-induced borehole elongation: a comparison between the four-arm dipmeter and the borehole tele viewer in the Auburn geothermal well. Journal of Geophysical Research, 90, pp.5513-5521(1985).
6. Plumb, R., Edwards,S., Pidcock,G. and Lee, D.: The mechanical earth model concept and its application to high-risk well construction projects. IADC/SPE Drilling Conference, Rock Mechanics as a Multidisciplinary Science, Rotterdam, pp. 63-72 (2000).
7. Wang, Y., Li, X. and Zhang, B.: Analysis of fracturing network evolution behaviors in random naturally fractured rock blocks, Rock Mech. Rock Eng., pp.11(2016).
8. Hawkins, A. B. and McConnell, B. J.: Sensitivity of sandstone strength and deformability to changes in moisture content. Quarterly Journal of Engineering Geology and Hydrogeology 25(2), pp.115-130(1992).
9. ISRM Committee on Laboratory Tests:Suggested methods for determining the strength of rock materials in triaxial compression: revised version. International Journal of Rock Mechanics and Mining Sciences & Geomechanics Abs,20, pp.6(1983).