Study on Rock Mechanics Parameters of Chang 7 Shale in Longdong Area in Ordos Basin

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Abstract. Rock samples from X-1 and X-2 well of Chang 7 shale in Longdong area in Ordos Basin are studied through triaxial compression test and acoustic wave test in order to obtain accurate data about the mechanical characteristics of the stratum and fracturing parameters.The static Young's modulus ranges from 2.213 GPa to 4.195 GPa and the static Poisson's ratio ranges from 0.181 to 0.239 in triaxial compression test. The dynamic Young's modulus ranges from 2.659 GPa to 5.03 GPa and the dynamic Poisson's ratio ranges from 0.20 to 0.29 in acoustic wave test. It can be seen that the dynamic Young's modulus is slightly larger than the static Young's modulus, and the relation between them is E_s=0.8492E_d-0.1349, while the dynamic and static Poisson's ratios are basically same, that is, $\mu_s \approx \mu_d$.

1 Introduction

Rock mechanics parameters include static and dynamic parameters. Static parameter is obtained by triaxial compression test of rock samples. It is accurate and reliable, but time-consuming, laborious and costly[1]. Therefore, it is only suitable for a small number of core samples calibration. Dynamic parameter is obtained by measuring the propagation velocity of ultrasonic wave in rocks, which can dynamically and continuously reflect the mechanical characteristics, but in most cases, it needs to be converted into static parameter. The static parameter in laboratory and the dynamic parameter from well logging are combined in order to establish a suitable rock mechanics parameter model which can accurately reflect the stratum mechanical characteristics[2]. In this paper, static and dynamic rock mechanics parameters of Chang 7 shale in Longdong area and the relation between them are studied, which will provide a basis for the researches of mechanical characteristics, brittleness and fracability of rock.

2 General situation of the study area

2.1 Location of the study area

Ordos Basin is a huge multi-energy mineral basin developed on a stable craton, which contains abundant coal, oil, natural gas and other resources [3,4]. Longdong area is located in the southwestern part of the Ordos Basin, mainly spanning two primary structural units of the Tianhuan Depression and the Yishan Slope (Fig. 1). Chang 7 sedimentary period is the peak of lake basin development of Yanchang period in Ordos basin[5]. Strong tectonic activity and warm and humid climate in the study area resulted in rapid expansion of lake basin and deposited a lot of high-quality source rocks[6]. Rapid expansion of lake basin, continuous and stable deep-water sediments, low salinity and oxygen deficit provide favorable geological conditions for large-scale development of Chang 7shale. The burial depth of Chang 7 shale in the study area ranges from 1200m to 2350m.

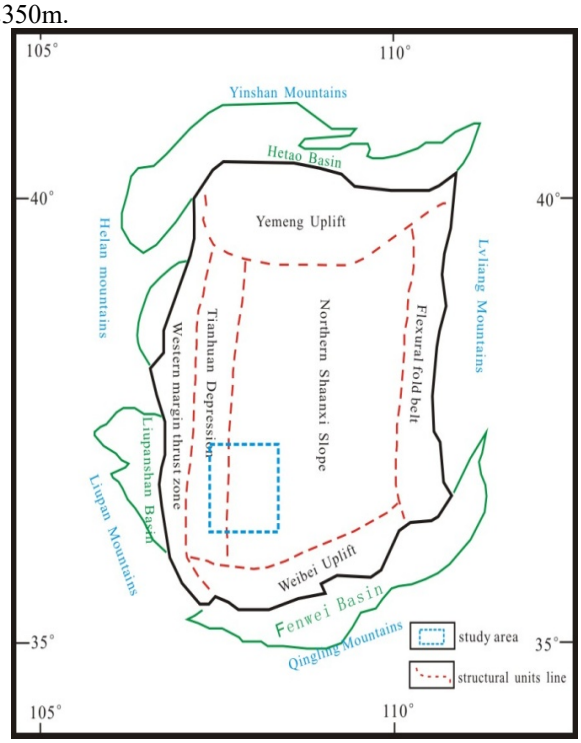

Fig 1. The study area in Ordos Basin

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2.2 Lithological characteristics of Chang 7shale

Chang 7 shale in study area is mainly dark gray, gray-black and black in color, and contains a large number of plant fossils (Fig.2) and a small amount of iron nodules, showing the characteristics of deep and semideep lake facies sediments[7]. The main minerals in the shale are quartz, feldspar and clay minerals, in addition to a small amount of carbonate and pyrite.

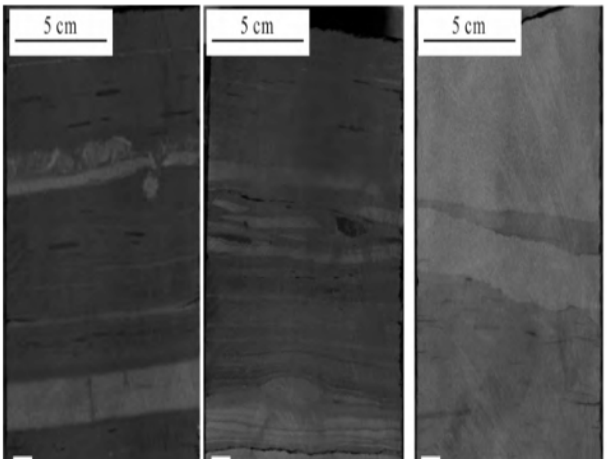

Fig 2. Photos of Chang 7 dark shale in study area

3 Rock mechanics parameters of Chang 7 shale

3.1 Static rock mechanics parameters

Young's modulus and Poisson's ratio of rocks are the main parameters for describing elastic deformation of rocks and measuring their resistance to deformation. According to the stress-strain relationship of the rock samples under loading, the static mechanical parameter is obtained. Triaxial compression test is carried out in rock samples from X-I and X-2 well of Chang 7 shale in Longdong area in Ordos Basin (the size of rock samples is 38.1mm×h76.2mm). The test results are shown in Table 1.

As for the rock samples from X-1 well of Chang 7 shale, The static Young's modulus ranges from 3.697 GPa to 4.195 GPa, with an average of 3.937 GPa, and the static Poisson's ratio ranges from 0.188 to 0.232, with an average of 0.214. The static Young's modulus of rock samples from X-2 well ranges from 2.213 to 2.553GPa, with an average of 2.411 GPa, and the static Poisson's ratio ranges from 0.181 to 0.239, with an average of 0.204.

Table 1. Results of triaxial compression test

Well	Lithology	Depth (m)	Sample	Density ρ_d (g/cm^3)	Confining pressure (MPa)	Young's modulus E (GPa)	Poisson's ratio μ
X-1	Fine sandstone	1407-1412	X1-1	2.665	5	3.697	0.188
			X1-2	2.659		3.818	0.200
			X1-3	2.661		3.826	0.210
			Average			**3.780**	**0.199**
			X1-4	2.666	10	3.886	0.226
			X1-5	2.667		3.932	0.229
			X1-6	2.651		3.899	0.223
			Average			**3.906**	**0.226**
			X1-7	2.670	20	4.167	0.232
			X1-8	2.668		3.999	0.201
			X1-9	2.644		4.195	0.223
			Average			**4.120**	**0.219**
X-2	Mudstone	1758-1759	X2-1	2.589	5	2.303	0.181
			X2-2	2.607		2.451	0.189
			X2-3	2.606		2.213	0.195
			Average			**2.322**	**0.188**
			X2-4	2.598	15	2.385	0.182
			X2-5	2.593		2.384	0.239
			X2-6	2.577		2.493	0.196
			Average			**2.421**	**0.206**
			X2-7	2.624	25	2.519	0.188
			X2-8	2.587		2.457	0.213
			X2-9	2.596		2.553	0.237
			Average			**2.510**	**0.213**

3.2 Dynamic rock mechanics parameters

Under the assumption of homogeneity and isotropy of rocks and based on Newton's law of motion and linear elasticity theory, the equations about the relation between velocity of waves and rock mechanics parameters can be obtained (1), (2).

$$V_p = \sqrt{\frac{E_d(1-\mu_d)}{\rho(1+\mu_d)(1-2\mu_d)}} \quad (1)$$

$$V_s = \sqrt{\frac{E_d}{2\rho(1+\mu_d)}} \quad (2)$$

From the above equations, we can get the following (3), (4):

$$E_d = \frac{\rho V_p^{\,2}\left(3V_p^{\,2} - 4V_s^{\,2}\right)}{V_p^{\,2} - V_s^{\,2}} \quad (3)$$

$$\mu_d = \frac{V_p^{\,2} - 2V_s^{\,2}}{2\left(V_p^{\,2} - V_s^{\,2}\right)} \quad (4)$$

In the equations, E_d is dynamic Young's modulus, GPa, u_d is dynamic Poisson's ratio of rock, dimensionless, ρ is volume density, g/cm^3, V_p is P-wave velocity, m/s, and V_s is S-wave velocity, m/s.

It can be seen that the dynamic mechanics parameters of rock can be calculated if the rock density and the propagation velocity of waves are obtained.

Acoustic wave test is carried out on rock samples from X-1 and X-2 well of Chang 7 shale in the study area (the size is 38.1 mm ×h76.2 mm). The velocity of P-wave and S-wave can be obtained by measuring the propagation time of waves along the length direction, and then the dynamic Young's modulus and Poisson's ratio can be calculated (Table2).

Acoustic wave test results show that the dynamic Young's modulus of rock samples from X-1 well of Chang 7 shale in study area is 3.979-5.03 GPa, with an average of 4.457 GPa, and the dynamic Poisson's ratio range is 0.20-0.26, with an average of 0.232. The dynamic Young's modulus of samples from X-2 well ranges from 2.659 to 3.557 GPa, with an average of 2.987 GPa, and the dynamic Poisson's ratio ranges from 0.22 to 0.29, with an average of 0.24.

Table 2. Results of acoustic wave test

Well	Lithology	Depth (m)	Sample	Density ρ_d (g/cm^3)	Confining pressure (MPa)	P-wave velocity (m/s)	S-wave velocity (m/s)	Young's modulus E(GPa)	Poisson's ratio μ
X-1	Fine sanstone	1407-1412	X1-1	2.665	5	4511	2749	4.848	0.20
			X1-2	2.659		4175	2464	3.979	0.23
			X1-3	2.661		4374	2486	4.146	0.26
			Average			**4353**	**2566**	**4.324**	**0.230**
			X1-4	2.666	10	4581	2804	5.030	0.20
			X1-5	2.667		4356	2512	4.201	0.25
			X1-6	2.651		4247	2533	4.162	0.22
			Average			**4394**	**2616**	**4.464**	**0.223**
			X1-7	2.670	20	4585	2595	4.543	0.26
			X1-8	2.668		4460	2591	4.457	0.25
			X1-9	2.644		4486	2687	4.654	0.22
			Average			**4510**	**2624**	**4.551**	**0.243**
X-2	Mudstone	1758.1-1758.9	X2-1	2.589	5	3498	2093	2.767	0.22
			X2-2	2.607		3477	2089	2.768	0.22
			X2-3	2.606		3408	2048	2.659	0.22
			Average			**3461**	**2077**	**2.731**	**0.220**
			X2-4	2.598	15	3559	2105	2.832	0.23
			X2-5	2.593		3585	2148	2.916	0.22
			X2-6	2.577		3672	2105	2.865	0.26
			Average			**3605**	**2119**	**2.871**	**0.237**
			X2-7	2.624	25	3666	2184	3.063	0.22
			X2-8	2.587		4238	2310	3.557	0.29
			X2-9	2.596		3862	2222	3.209	0.25
			Average			**3922**	**2239**	**3.279**	**0.253**

4 Relation between dynamic and static rock mechanics parameters

The fracturing of the strata is a relatively slow static process while the mechanics parameters of rock measured by acoustic wave test are dynamic parameters[8,9]. If the relation between dynamic and static parameter is established, the static mechanics parameter could be obtained.

It can be seen from Table 1 and Table 2 that the static Poisson's ratio and the dynamic Poisson's ratio of Chang 7 shale in Longdong area are basically same, that is, $\mu_s \approx \mu_d$.

Through linear regression of dynamic and static modulus of rock samples from X-1 and X-2 well in Chang 7 shale in the study area, the following equation can be obtained (Fig. 3).

$$E_s=0.8942E_d-0.1349 \quad R^2=0.8673 \qquad (5)$$

In the above equation, E_s is the static Young's modulus, GPa, E_d is the dynamic Young's modulus, GPa, and R^2 is the related coefficient.

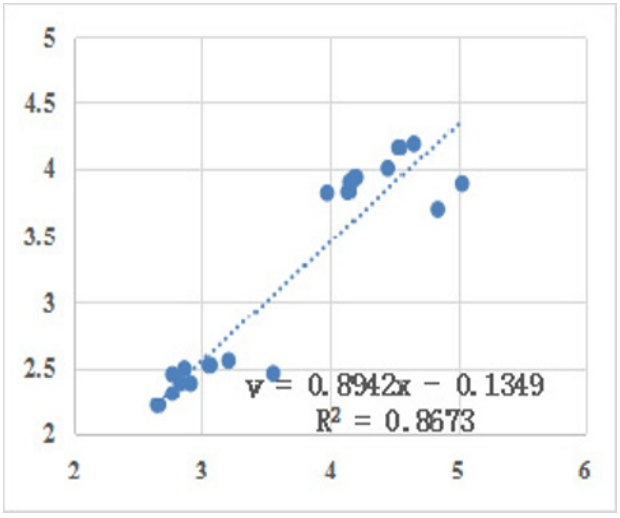

Fig 3. The relation between static and dynamic Young's modulus

5 Conclusion

The static Young's modulus of rock samples of Chang 7 shale in Longdong area is 2.213~4.195GPa, and the static Poisson's ratio range is 0.181~0.239 in triaxial compression test. The dynamic Young's modulus obtained from acoustic wave test ranges from 2.659 to 5.03GPa, and the dynamic Poisson's ratio ranges from 0.20 to 0.29. The dynamic and static Young's modulus of the Chang 7 shale in Longdong area is well correlated, the dynamic parameters are slightly larger than the static parameters, the relation between them is $E_s=0.8492E_d-0.1349$, and the dynamic and static Poisson's ratio are basically same, that is, $\mu_s \approx \mu_d$.

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