CHAPTER-VI

DYNAMIC CHARACTERIZATION TEST RESULTS AND DISCUSSION

6.1 INTRODUCTION

The cyclic secant shear modulus (G) is the parameter that is most frequently used to characterize the stiffness and to assess the shear deformation when evaluating the mechanical behavior of geo-materials under cyclic loading. In addition to shear modulus, the damping ratio (D) is also utilized to analyse the response of the geo-materials in the practice of soil dynamics. In recent decades, many researchers have explored the seismic responses of soil-structure systems subjected to earthquakes, blast forces, traffic loading, and ocean wave loading. After taking into consideration the response of different types of soil deposits, many researchers recommended corrective measures to reduce the risk to lives and structures. Moreover, most of the investigations were conducted under static loading despite the fact that comparatively few studies were done with dynamic loading. The research must be effective under both static and cyclic loading conditions. The assessment of low and high-strain stiffness parameters had been discussed through conducting various laboratory experiments, including resonant column tests, piezoelectric bender element tests, ultrasonic pulse tests, cyclic triaxial tests, cyclic torsional tests imposed under the low shear strain and high shear strain category (Erken and Ulker 2007; Karl et al. 2008; Mohanty and Patra 2016; Choobbasti et al. 2019; Rawat and Mohanty 2022). According to the previous research, soil behaves much differently at larger strain levels (>0.01%) than at low strain levels (<0.001%), mainly because of the non-linear stress-strain response and damping properties at larger strain levels (Ingale et al. 2017; Atkinson 2000). With the increasing fly ash concentration, G of the expansive clay increased while D was reduced, and the curing time had a minor impact on G/G_{max} and D of the treated samples (Saride and Dutta 2016). The plasticity index is the primary element in regulating the crucial dynamic parameters in various cohesive soils (Vucetic and Dobry 1991). In addition, numerous researchers have reported empirical models based on changes in the dynamic parameters (G and D) of soil specimens due to cyclic triaxial experiments with various confining pressures (Sun et al. 2015; Lei et al. 2016; Kaya et al. 2021).

In view of the environmental concerns and subsurface contamination, the soil improvement technique based on silica nanoparticles can replace conventional stabilizers such as cement and lime owing to its minor disruption in the surrounding environment, sustainable development, and cost-effectiveness (Kannan and Sujatha 2022; Munda and Mohanty 2024). Furthermore, the crucial element of Nano-SiO_2 is silicon dioxide, which is identical to pure clay and is mostly nontoxic. As a result, it is both safe and environmentally favourable to employ in soil improvement (Huang and Wang 2016). Because the growth of stress dissipation and energy absorption was more pronounced when combining Nano-SiO_2 with bio enzyme-cement-treated high plastic clay, these behaviours tend to enhance the dynamic characteristics (Thomas and Rangaswamy 2020). The inclusion of silica nanoparticles as an additional pozzolanic element to cement was found to have a significant impact on the static and dynamic characteristics of clay soil (Heidarizadeh et al. 2021). The soft clay treated with 7% lime and 1% Nano- SiO_2 exhibited a higher small strain shear stiffness as the curing time prolonged, particularly during the first month (Jafari et al. 2021). The resonant column tests revealed that the G_{max} of the cement-treated silty clay and a combination of cement-fly ash-treated silty clay increased with the increment in confining pressure, stabilizing agent, and curing period. Conversely, D was reduced with the rise in confining pressure and curing time but increased with the rise in stabilizing agent (Lang et al. 2020). Therefore, the efficient use of fly ash and Nano-SiO_2 has emerged as a key sustainable development solution for carbon footprint and environmental protection.

As per the literature, Nano-SiO_2 was widely utilized as one of the most effective nanoparticles for stabilizing soil in comparison to other nanoparticles because of its versatility and efficacy in various applications. In order to address the earthquake engineering challenges from a geotechnical perspective, it is important to ascertain the dynamic characteristics of the soils as determined by laboratory measurements. However, the majority of the previous studies concentrated on the dynamic behaviour of clay that had been treated with a traditional binder. The research on the dynamic shear modulus and damping characteristics of clay soil treated with Nano-SiO_2 and fly ash is relatively scarce. This study presents an investigation on the dynamic properties of clayey soil by employing fly ash and Nano-SiO_2 as stabilizing additives under various cyclic shear strain. A total of 48 CTX experiments were conducted with a wide range of cyclic shear strain, a loading frequency of (*f*) 1 Hz, and an effective confining pressure of (σ'_c) 100kPa.

6.2 RESEARCH SIGNIFICANCE

The present study attempts to explore the performance of silica nanoparticles in combination with fly ash-treated clay soil under cyclic loading conditions. Although many explorations have been done on the static strength behaviour of soil that has been treated with Nano-SiO_2, minimal research has been done and is available on its dynamic behaviour. A number of unconfined compressive strength (UCS) and static triaxial (Unconsolidated Undrained) laboratory experiments were performed to establish the optimum additive dosages. The California bearing ratio (CBR) of untreated and treated soil was evaluated for 0 day and 28 day curing periods. The dynamic parameters of the clay soil were then assessed using multiple sets of cyclic triaxial tests, both with and without treatment, for the 28-day curing period. All the experiments were carried out with the compaction parameters of the soil specimen. The primary intent of this research is to study the dynamic properties (G and D) of the treated and untreated clayey soil through CTX test results. The suggested results can be used in soil behaviour modelling or dynamic response analysis of the Nano-SiO_2 and fly ash-treated clayey soil. Furthermore, the carbon footprint and cost analysis of Nano-SiO_2 and fly ash-treated clay soil were compared with the traditional stabilizing additives in the chapter VIII. Also, the utilization of Nano-SiO_2 and fly ash-treated clay soil for various civil engineering applications has been addressed in the present study.

6.3 ASSESSMENT OF DYNAMIC PROPERTIES OF UNTREATED AND TREATED SOIL

The typical cyclic response achieved from the CTX tests on the clay specimens, prepared at MDD of 1.61 g/cm^3, OMC of 20 %, and tested at γ = 3 %, f = 1 Hz, σ'_c = 100 kPa is illustrated in Fig. 6.1. Fig. 6.1 (a) depicts the response of axial strain with time. Fig. 6.1 (b) depicts the response of deviator stress with axial strain; the hysteresis loop can be utilized to assess the dynamic parameters of the soil specimen. Fig. 6.1 (c) illustrates the response of excess pore water pressure (PWP) ratio (r_u) with time. Under cyclic loading, the maximum value of the excess PWP ratio (r_u) was noticed to be 0.55. Therefore, the soil was found to be non-liquifiable soil. A similar observation was also seen in the past study (Thomas and Rangaswamy 2020). In other words, in saturated soil samples, the cyclic loading increases the PWP, which declines the intergranular forces, effective stress, and soil stiffness. Fig. 6.1(d) depicts the response of deviator stress with time; initially, the stress reduced at lower cycles, and then the stress became constant. Fig. 6.2 (a) depicts the typical response of deviator stress with axial strain for Clay+1%NS sample. Fig. 6.2 (b) depicts the typical response of excess pore water pressure (PWP) ratio (r_u) with time for Clay+1%NS sample. Fig. 6.2 (c) depicts the response of deviator stress with time for Clay+1%NS sample. Under cyclic loading, the maximum value of the excess PWP ratio (r_u) was noticed to be 0.5 for Clay+1%NS sample. Fig. 6.3 (a) depicts the typical response of deviator stress with axial strain for Clay+1%NS+20%FA sample. The deviator stress increased with the axial strain in the stabilized soil. Fig. 6.3 (b) depicts the typical response of excess pore water pressure (PWP) ratio (r_u) with time for Clay+1%NS+20%FA sample. Fig. 6.3 (c) depicts the response of deviator stress with time for Clay+1%NS+20%FA sample. After stabilization, the excess pore pressure ratio decreased in the stabilized samples. Because of the stabilization process, the excess PWP ratio (r_u) of the untreated soil was approximately 0.55 at its highest, but it dropped to 0.5 for soil treated with optimum nano silica content and 0.42 for soil treated with optimized nano silica and fly ash dosages. The decrease in pore pressure build-up could be due to the soil matrix's decreased porosity, since the C-S-H gel that forms inside it clogs more voids. Therefore, the Clay+1%NS and Clay+1%NS+20%FA sample was also found to be non-liquifiable.

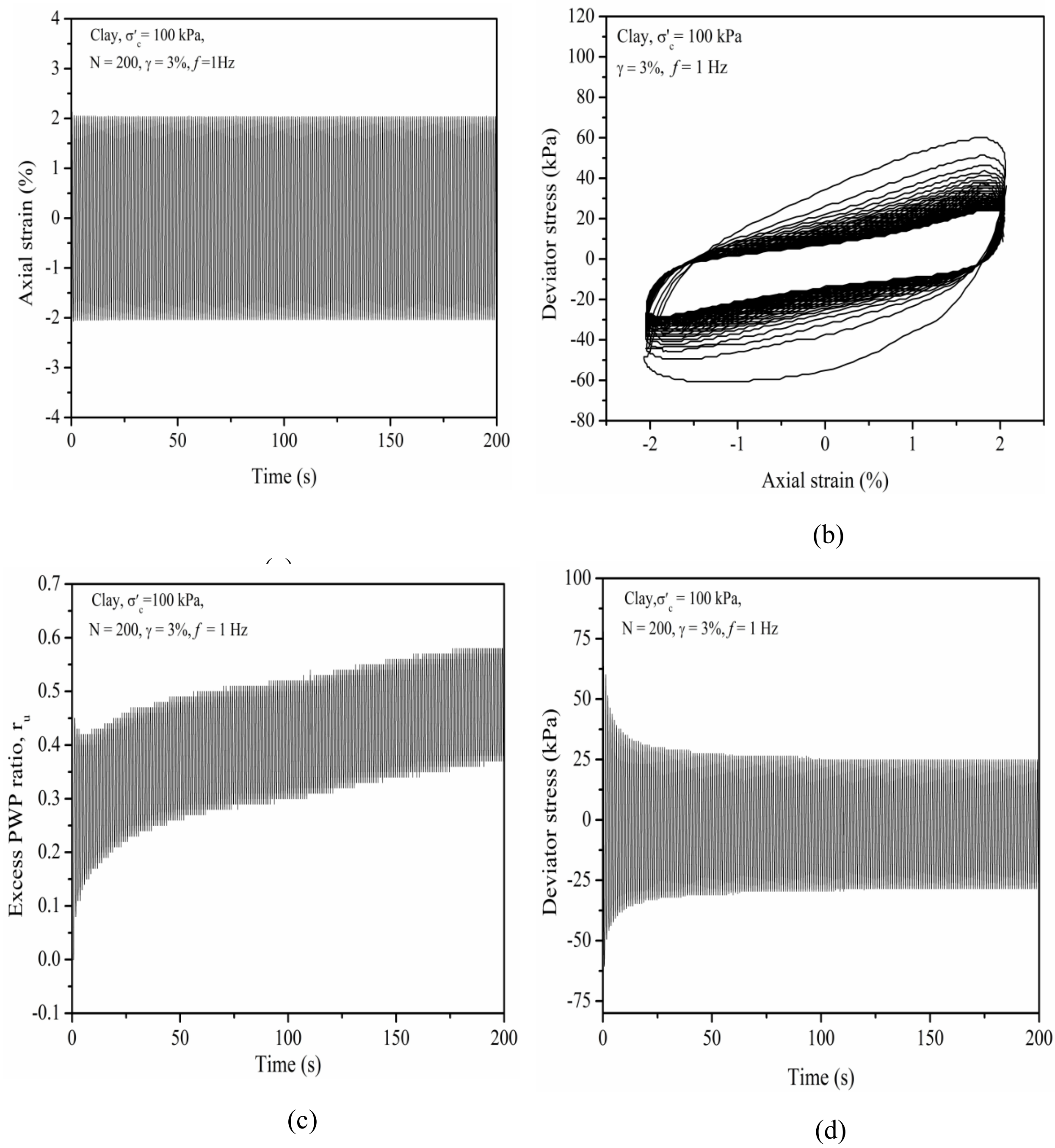
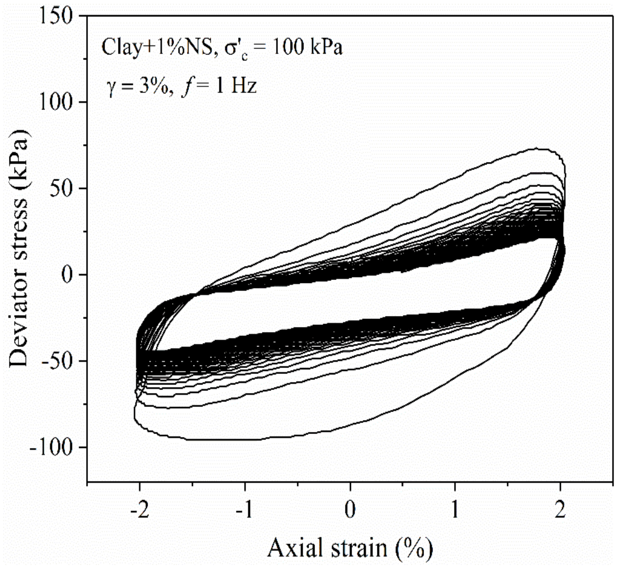


Fig. 6.1. Typical cyclic response of clay (a) variation of axial strain with time, (b) variation of deviator stress with axial strain, (c) variation of excess pore water pressure ratio with time, and (d) variation of deviator stress with time.



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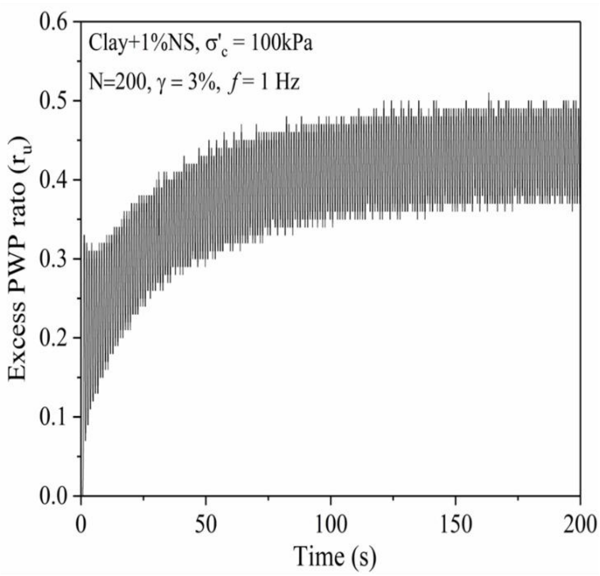

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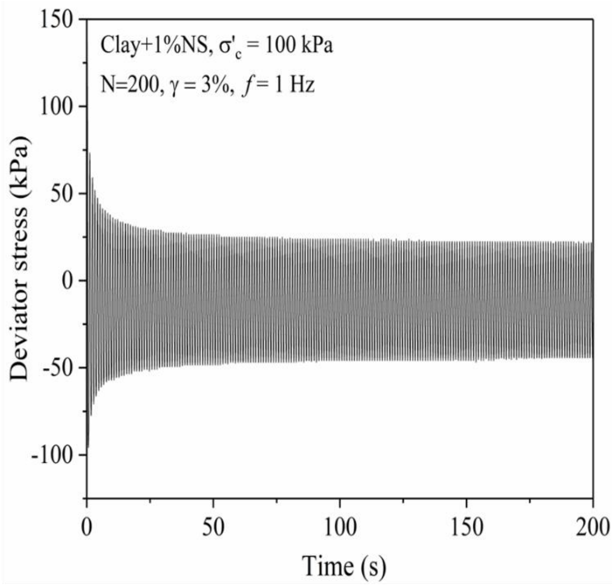


(c)

Fig. 6.2 Typical cyclic response of Clay+1%NS sample (a) variation of deviator stress with axial strain, (b) variation of excess pore water pressure ratio with time, and (c) variation of deviator stress with time.

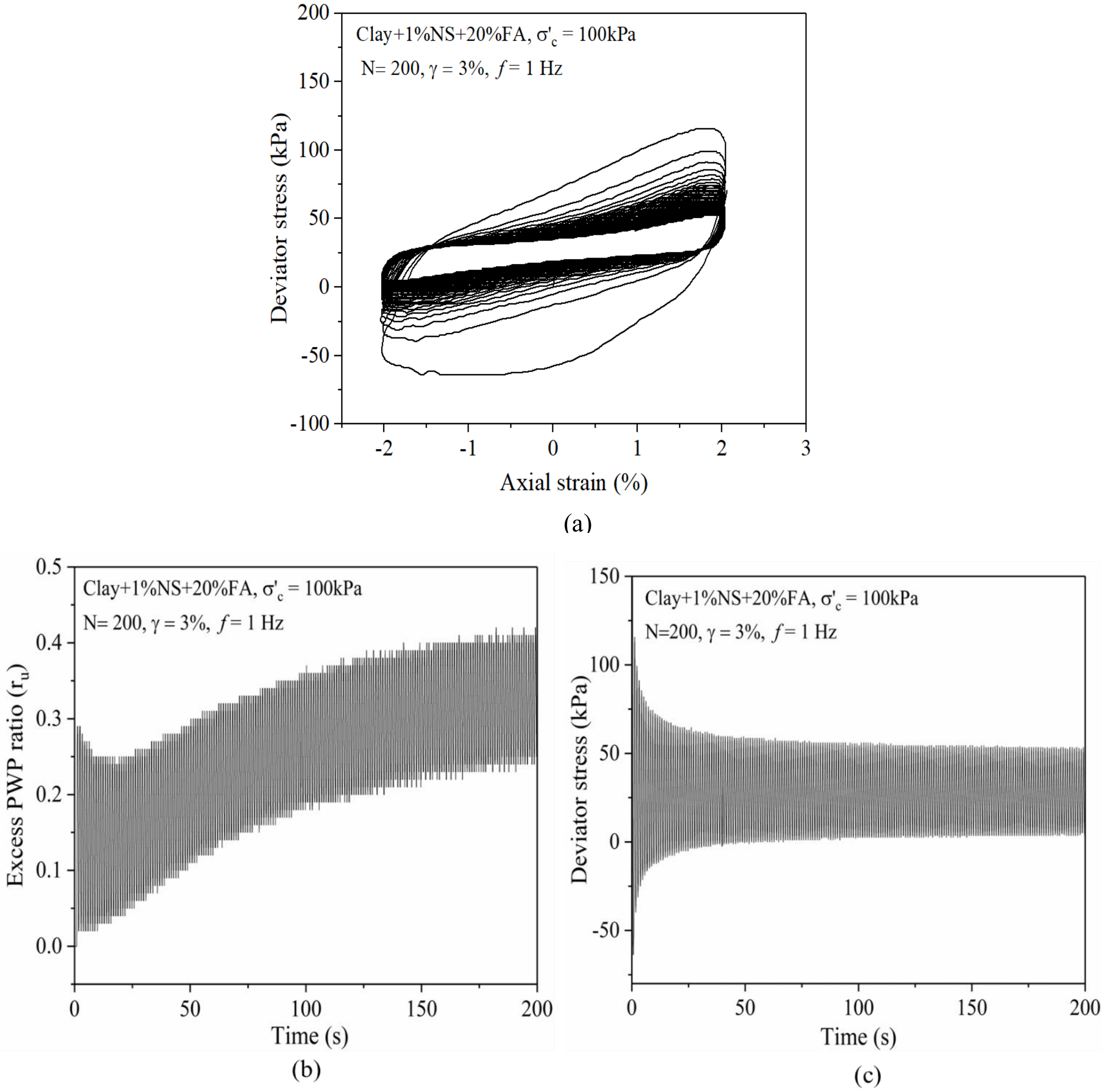


Fig. 6.3. Typical cyclic response of Clay+1%NS+20%FA sample (b) variation of deviator stress with axial strain, (c) variation of excess pore water pressure ratio with time, and (d) variation of deviator stress with time.

6.3.1 Assessment of Dynamic Shear Modulus of the Untreated Soil

The seismic response of soil under cyclic loading is non-linear in nature and is influenced by a number of variables, including soil type, shear strain, confining pressure, loading cycles, and loading magnitude. The effect of γ on the G of the untreated soil has been addressed. Fig. 6.4 depicts the response of G of the untreated and treated soil. With the rise in γ, the dynamic shear modulus steadily declined. Fig. 6.5 (a) and (b) illustrate the variations of G with a varied cyclic shear strain of clay samples plotted with loading cycles up to 200 cycles under 0 day and 28 days of curing age. The dynamic shear modulus decayed gradually as γ increased. The G gradually declined up to 60 cycles and then became almost constant up to 200 cycles. The G of the untreated soil dropped from 4.71 to 0.78 MPa, with the rise in number of cycles under varying γ from 0.6% to 3.0%. The reduction in G with increasing loading cycles could be that more plastic deformation accumulates as a result of greater loading cycles (Thakur et al. 2021). Further, G decreased from 5.0 to 0.98 MPa with varying γ from 0.6% to 3.0% at 28 days of curing age. The shear modulus increased to about 6.15 % and 25.64 % at lower cyclic strain (γ = 0.6%) and at higher cyclic strain (γ = 3%) under 28 days of curing age of virgin soil. During the initial stage of loading, the dynamic elastic modulus is rapidly deformed. Cyclic loads disrupt the basic soil structure, promoting soil deformation. When the deformation arrives at a specific strain value, the dynamic elastic modulus steadily weakens (Liu et al. 2014).

6.3.2 Assessment of Dynamic Shear Modulus of the Optimum Nano-SiO_2 Treated Soil

The response of G with varied cyclic shear strains of an optimum mix of clay + 1%NS is depicted in Fig. 6.6 (c) and (d). The G decreased drastically over the initial loading cycles and became constant. The shear modulus of optimal dosage of Nano-SiO_2 treated soil decreased from 5.59 to 0.98 MPa with the rise in a number of cycles at γ ranging from 0.6% to 3.0%. Furthermore, G reduced from 8.9 to 1.27 MPa at γ, varying from 0.6% to 3.0% at 28 days of curing age. The shear modulus increased to about 59.21% and 29.59 % at lower cyclic strain (γ = 0.6%) and higher cyclic strain (γ=3%) under 28 days curing age of 1% optimal content of Nano-SiO_2 treated soil. The enhancement in the G of the specimens can be attributed to the development of cementitious gel and the growth of pozzolanic activity with curing ages. The treated soils exhibited more rigid behavior than the untreated soils, resulting in greater dynamic shear modulus values (Fahoum et al. 1996).

6.3.3 Assessment of Dynamic Shear Modulus of the Optimum Nano-SiO_2 and Fly Ash Treated Soil

The response of G with varied cyclic shear strains of clay + 1%NS + 20%FA of samples are depicted in Fig. 6.7 (e) and (f). The shear modulus of the optimum content of silica nanoparticles and fly ash-treated soil decreased from 5.39 to 0.90 MPa with the rise in a number of cycles at γ ranging from 0.6% to 3.0%. Further, the shear modulus reduced from 11.38 to 1.35 MPa at γ ranging from 0.6% to 3.0% at 28 days of curing time. The rate of increment of shear modulus was about 111.13 % and 50 % at lower cyclic strain (γ = 0.6%) and higher cyclic strain (γ = 3%) under 28 days curing age of the optimal content of Nano-SiO_2 and fly ash treated soil. The addition of fly ash and Nano-SiO_2 to the soil attributed to the development of CSH and CASH gel owing to cementitious and pozzolanic reactions, resulting in a denser composite than the untreated soil and a higher value of dynamic shear modulus. Moreover, the pozzolanic reactions between fly ash and clay provide a confinement effect at the interfaces between clay particles. As a result, the treated specimens become more rigid, which increases their shear stiffness (Saride and Dutta 2016). Soil stabilization under dynamic conditions, particularly during seismic events, is complex due to the interaction between composite soil materials and pore water pressures. The behavior of stabilized soils under dynamic loading, such as during earthquakes, differs substantially from static conditions, with water content playing a pivotal role. Increased pore water pressure during seismic excitation can lead to a significant reduction in shear strength, potentially resulting in the liquefaction or failure of stabilized soils or ash samples, as noticed in previous studies (Mohanty and Patra 2016; Reddy et al. 2018; Reddy et al. 2020). A comparative analysis of Ground Motion Prediction Equations (GMPEs) using a logic tree approach allows for a probabilistic assessment of seismic hazards. This method enables the integration of multiple models, each weighted according to expert judgment or statistical performance, enhancing reliability in hazard estimation (Güllü and İyisan 2016). The seismic hazard assessment for Gaziantep demonstrates the importance of regional studies (Güllü et al. 2008). This work highlights how localized geological and seismological data can lead to more accurate hazard maps, which are crucial for designing effective soil stabilization systems in seismically active regions.

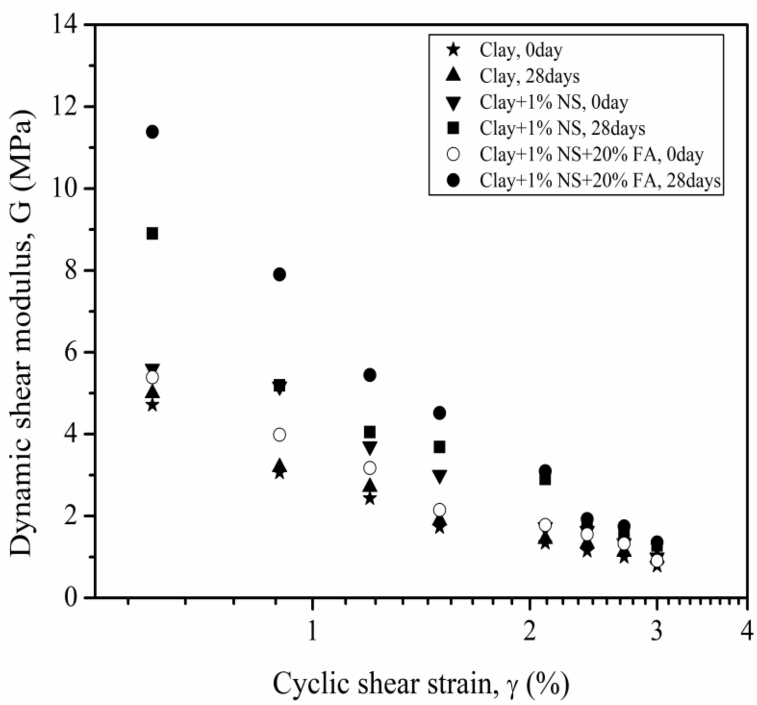
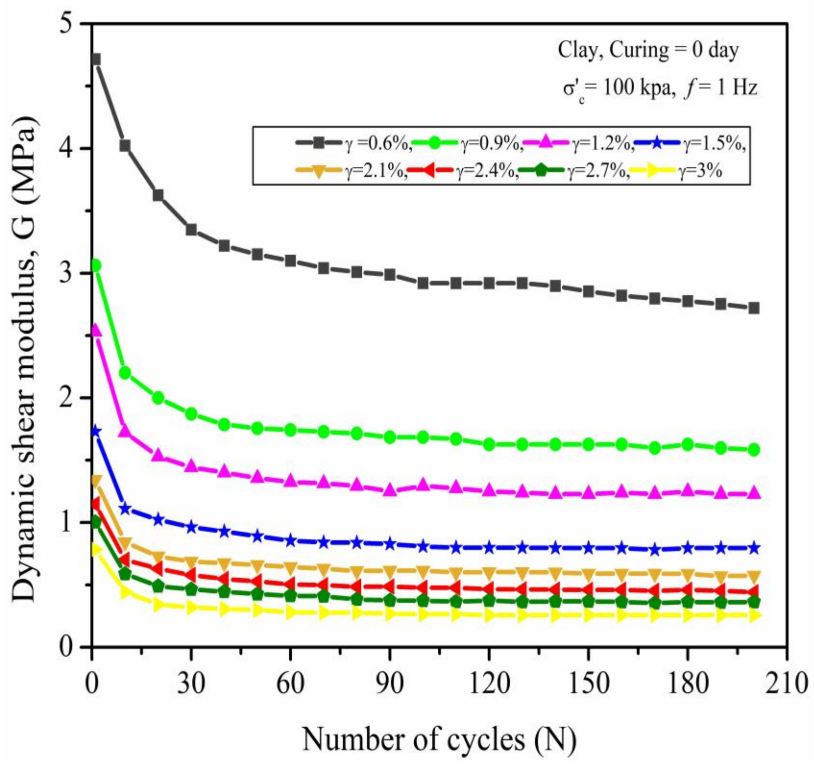


Fig. 6.4. Variation of dynamic shear modulus with cyclic shear strain of the untreated and treated soil.



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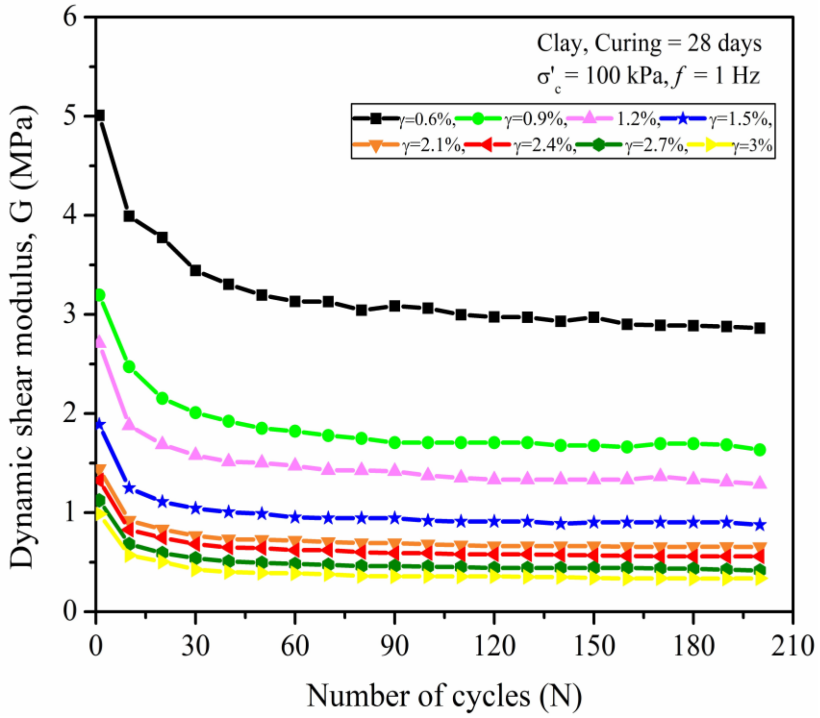
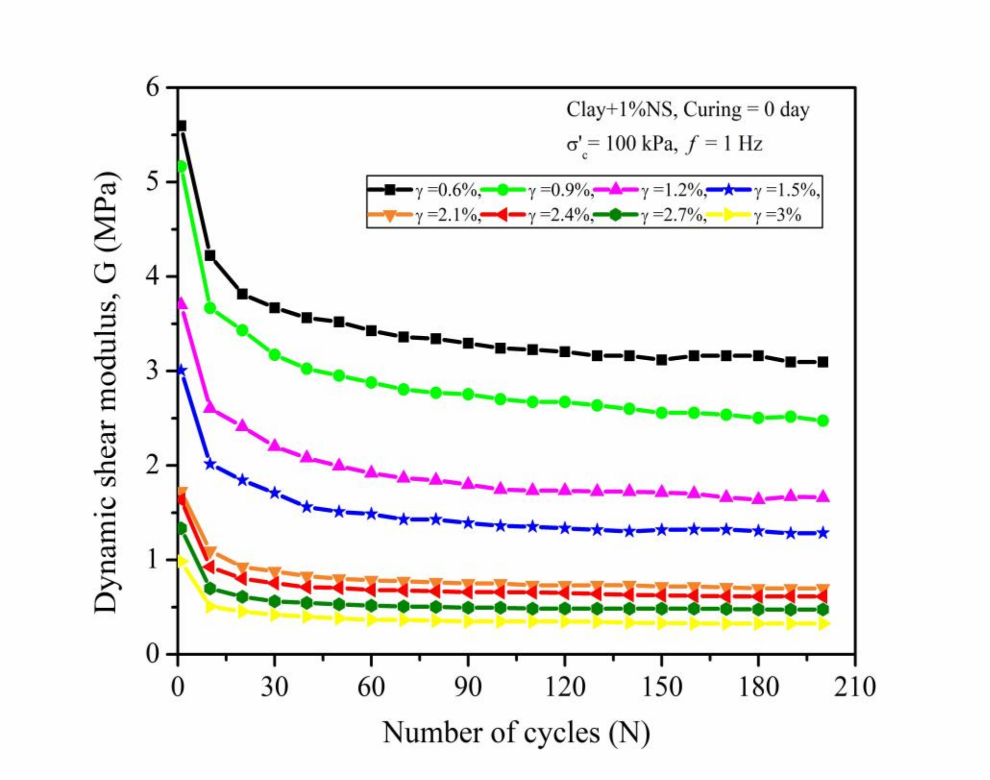


(b)

Fig. 6.5. Variation of dynamic shear modulus with number of cycles for different curing days (a) Clay, 0day, (b) Clay, 28days



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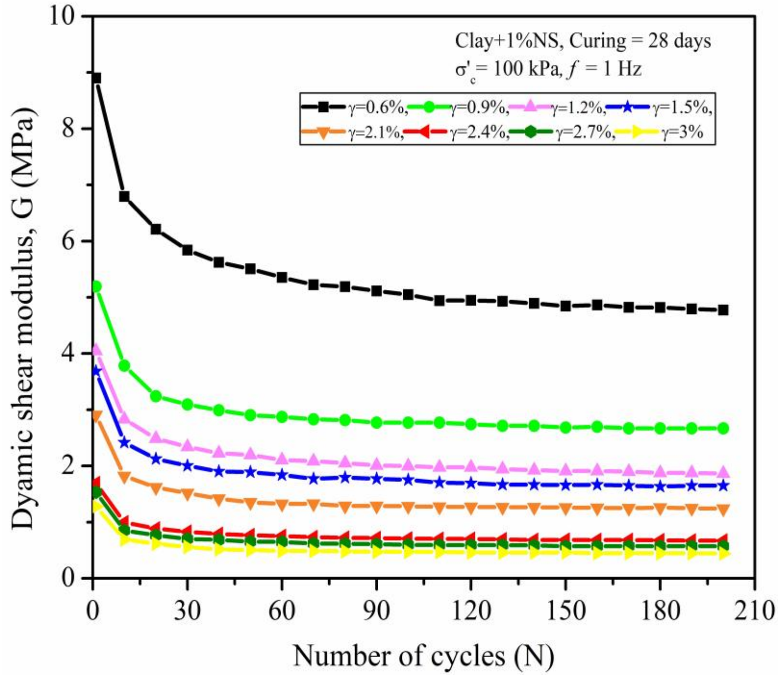
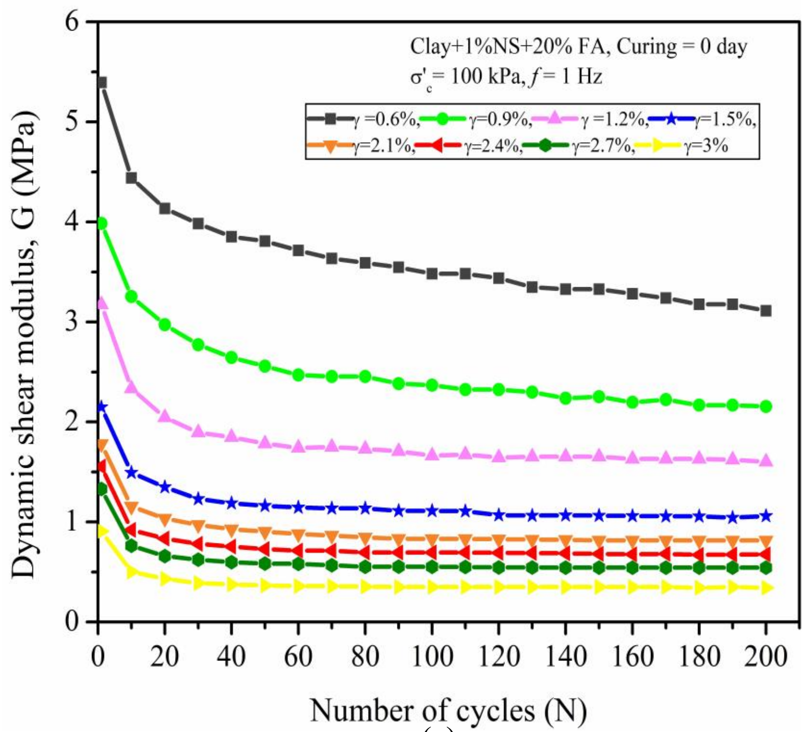
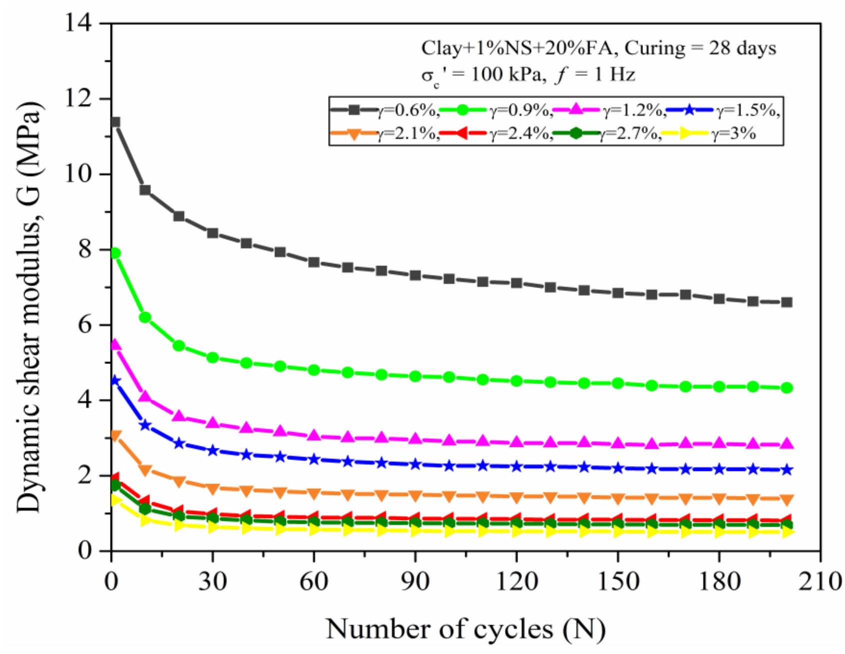


(d)

Fig. 6.6. Variation of dynamic shear modulus with number of cycles for different curing days (c) Clay +1%NS, 0day, (d) Clay+1%NS, 28days.



(e)



(f)

Fig. 6.7. Variation of dynamic shear modulus with number of cycles for different curing (e) Clay+1%NS+20%FA, 0day and (f) Clay +1% NS +20%FA, 28days.

6.3.4 Assessment of Damping Ratio of the Untreated Soil

The amount of energy dissipated due to cyclic loading is known as the damping ratio. The variations of D with γ of the untreated soil are depicted in Fig. 6.8 (a). The D of the untreated soil was increased with the increment of cyclic shear strain. The damping ratio of the untreated soil increased from 18.16% to 28.32%, with the rise in the number of cycles at γ ranging from 0.6% to 3.0%. The damping ratio increased from 17.45% to 26% at γ, varying from 0.6% to 3.0% at 28 days of curing age. It was observed that the damping ratio increased with an increase in cyclic strain amplitude because the specimen was subjected to a greater load at a higher strain amplitude, which led to more energy dissipation (Table 6.1). A similar trend was observed by previous researchers (Thomas and Rangaswamy 2020). For all axial strain amplitudes, it was discovered that the energy dissipation was higher during the 1st cycle and that it reduced as the number of loading cycles increased. The higher energy dissipation was caused by increased internal deformations within the soil matrix. The dissipated energy of soil in the 1st cycle was dropped from 0.44 kJ/m^3, 0.58 kJ/m^3, 0.99 kJ/m^3, 1.12 kJ/m^3, 1.84 kJ/m^3, 2.24 kJ/m^3, 2.63 kJ/m^3, 2.72 kJ/m^3 to 0.29 kJ/m^3, 0.32 kJ/m^3, 0.56 kJ/m^3, 0.78 kJ/m^3, 0.83 kJ/m^3, 1.17 kJ/m^3, 1.32 kJ/m^3, and 1.43 kJ/m^3 up to the 20th loading cycle, at various strain amplitudes of 0.6%, 0.9%, 1.2%, 1.5%, 2.1%, 2.4%, 2.7%, and 3.0%, respectively.

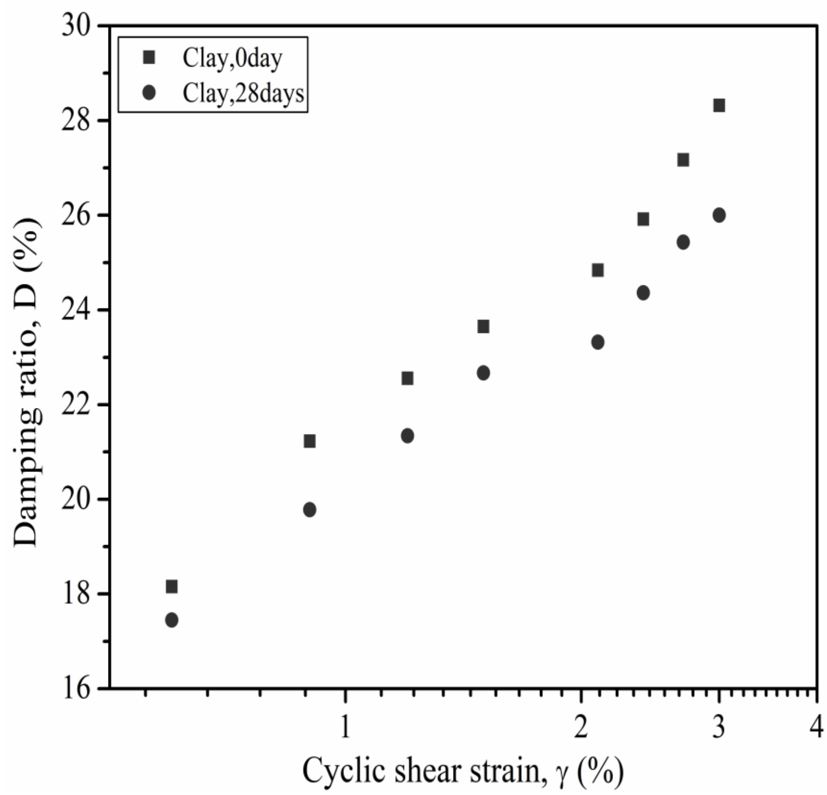
6.3.5 Assessment of Damping Ratio of the Optimum Nano-SiO_2 Treated Soil

The variations of D with a cyclic shear strain of the optimum content Nano-SiO_2 treated soil are depicted in Fig. 6.8 (b). The D increased with the rise in γ. The D of the Nano-SiO_2 treated soil increased from 17.65% to 27.23% with the rise in the number of cycles at cyclic shear strain amplitudes of low strain to high strain. The damping ratio increased from 16.76% to 25.66% at γ, varying from 0.6% to 3.0% at

28 days of curing age. As the shear strain increases, the damping ratio also increases. Particle slippage and rearrangement are more likely to occur at higher strain levels, which raises the damping ratio. Because treated composite materials were found to be stiffer than the untreated soil, and this stiffness increased by the optimum Nano-SiO_2 content, caused by less movement and rearrangement of particles. As a result, the damping ratio would be reduced in treated soils compared to untreated soils (Thomas and Rangaswamy 2020).

6.3.6 Assessment of Damping Ratio of the Optimum Nano-SiO_2 and Fly Ash Treated Soil

The variations of D with the cyclic shear strain of the optimal content of Nano-SiO_2 and fly ash-treated soil are depicted in Fig. 6.9 (c). The damping ratio of the optimal content of Nano-SiO_2 and fly ash-treated soil increased from 16.34% to 26.67% with the rise in the number of cycles at cyclic shear strain amplitudes of low strain to high strain. The damping ratio increased from 15.67 % to 24.75 % at cyclic shear strain amplitudes varying from 0.6% to 3.0% at 28 days of curing time. The rise in D indicates that the internal surface of the hysteresis loop has grown, absorbing more energy. As a result, at higher strain levels, more slippage of particles and, thus, damping can be expected (Thomas and Rangaswamy 2020; Choobbasti et al. 2018). The damping ratio is essentially unaffected by the curing period, which means it can be ignored for any design purpose. The inclusion of fly ash and Nano-SiO_2 makes the specimens stiffer, which tends to reduce particle rearrangement and slippage between the particles, resulting in a lowering of the damping ratio. Similar findings were noticed (Saride and Dutta 2016; Subramaniam and Banerjee 2020; Fahoum et al. 1996; Choobbasti et al. 2018).



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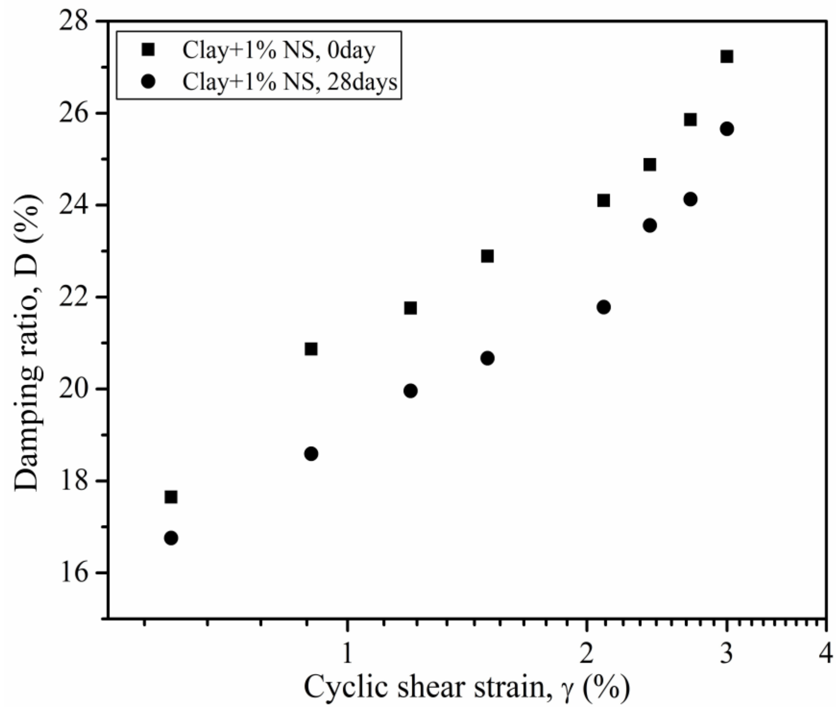
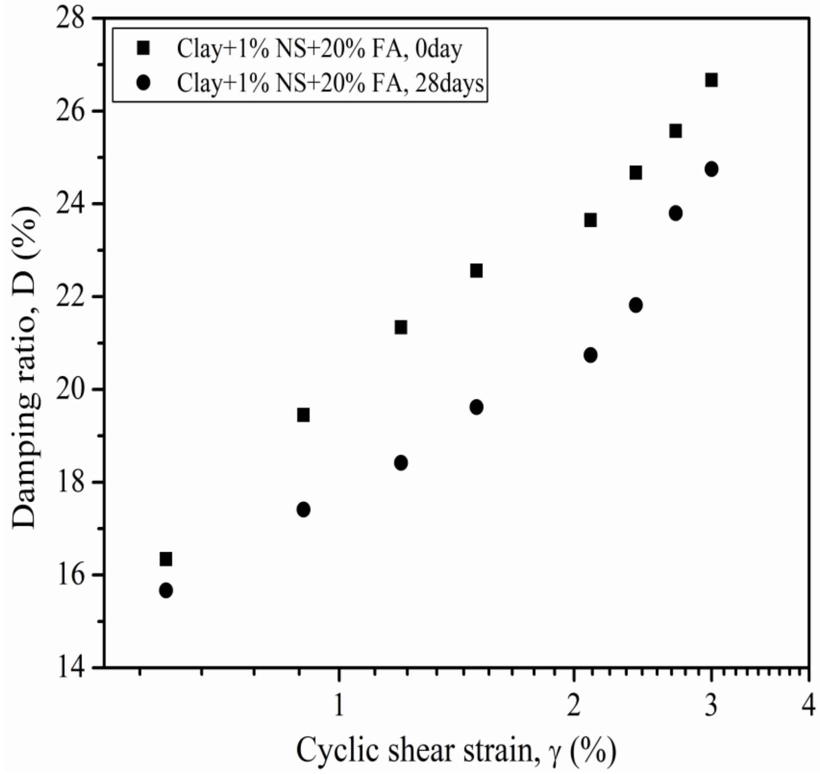


(b)

Fig. 6.8. Variation of damping ratio with cyclic shear strain of the untreated and treated soil (a) Clay and (b) Clay+1% NS.



(c)

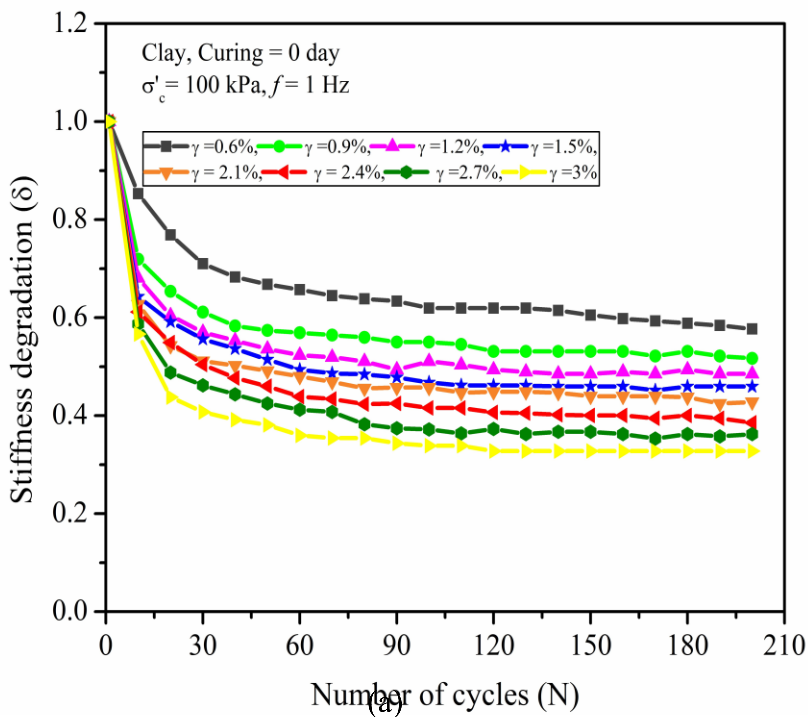
Fig. 6.9. Variation of damping ratio with cyclic shear strain of treated soil (c) Clay+1% NS+20% FA.

Table 6.1. Effect of strain amplitude on dynamic properties of untreated and treated soil.

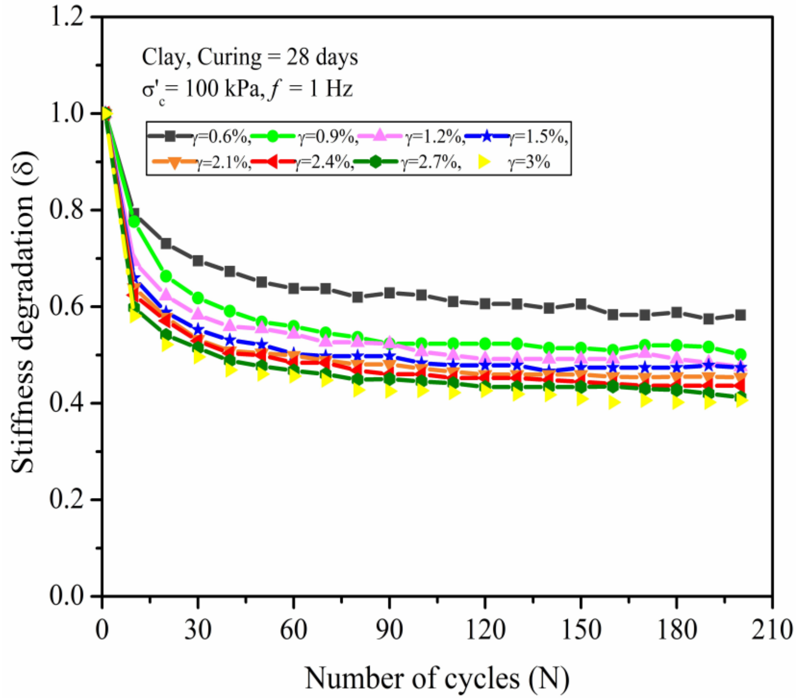
Combinations	Strain amplitude (%)	G (MPa)	D (%)	Number of cycles	Energy dissipated (kJ/m^3)	Effective confining pressure (kPa)
Clay	0.6	5.0	28.15	1	0.44	100
		3.78	17.45	20	0.29	100
	0.9	3.19	31.73	1	0.58	100
		2.15	19.78	20	0.32	100
	1.2	2.71	33.27	1	0.99	100
		1.68	21.34	20	0.56	100
	1.5	1.89	34.76	1	1.12	100
		1.1	22.67	20	0.78	100
	2.1	1.44	38.55	1	1.84	100
		0.83	23.32	20	0.83	100
	2.4	1.33	39.26	1	2.24	100
		0.75	24.36	20	1.17	100
	2.7	1.12	40.02	1	2.63	100
		0.59	25.43	20	1.32	100
	3.0	0.98	42.1	1	2.72	100
		0.51	26	20	1.43	100
Clay+1%NS	0.6	8.9	20.86	1	0.53	100
		6.2	16.76	20	0.36	100
	0.9	5.19	26.24	1	0.88	100
		3.23	18.59	20	0.62	100
	1.2	4.04	29.76	1	1.19	100
		2.48	19.96	20	0.85	100
	1.5	3.68	33.51	1	2.17	100
		2.12	20.67	20	1.19	100
	2.1	2.90	35.57	1	2.45	100
		1.62	21.78	20	1.37	100
	2.4	1.69	36.6	1	2.92	100
		0.89	23.56	20	1.54	100
	2.7	1.53	38.67	1	3.17	100
		0.77	24.13	20	2.08	100
	3.0	1.27	39.79	1	4.12	100
		0.61	25.66	20	2.46	100
Clay+1%NS+20%FA	0.6	11.38	18.75	1	0.63	100
		8.89	15.67	20	0.5	100
	0.9	7.9	20.88	1	1.02	100
		5.45	17.41	20	0.85	100
	1.2	5.45	22.59	1	1.6	100
		3.55	18.42	20	0.98	100
	1.5	4.51	23.46	1	2.52	100
		2.85	19.62	20	1.34	100
	2.1	3.09	24.73	1	2.53	100
		1.87	20.74	20	1.52	100
	2.4	1.92	25.89	1	3.02	100
		1.05	21.82	20	1.65	100
	2.7	1.75	27.66	1	3.58	100
		0.92	23.8	20	2.77	100
	3.0	1.35	28.38	1	4.32	100
		0.68	24.75	20	2.98	100

6.3.7 Stiffness degradation index of the Untreated and Treated Soil

The cyclic degradation index was used to assess the impact of load repetition on soil stiffness degradation. It illustrates the amount of saturated soil stiffness deterioration under cyclic loading. The cyclic degradation index (δ) was calculated for each loading cycle. The variation in δ, versus (N) of Clay, Clay+1%NS, and Clay+1%NS+20%FA for 0 day and 28 days curing periods for different cyclic strains is shown in Fig. 6.10 (a), (b); Fig. 6.11 (c) and (d); Fig. 6.12 (e) and (f). The degradation index was first introduced by Idriss et al. (Idriss et al. 1976; Idriss et al. 1978). The δ is defined as the ratio of the cyclic secant shear modulus G_N in any N^{th} cycle to the cyclic secant shear modulus in the first cycle (G_{N1}) under strain-controlled loading conditions with a constant cyclic shear strain amplitude. Fig. 6.10, Fig. 6.11, and Fig. 6.12 depict the degradation index decreasing rapidly for the first 20-40 cycles, then become almost constant or negligible. Different degrees of cyclic deterioration were encountered by each specimen. Lower cyclic degradation index values showed greater stiffness degradation magnitude. Similar behaviour was observed by past researchers (Ashango and Patra 2014). As the number of loading cycles increases, the resultant cyclic load inside the soil specimen causes plastic deformation, resulting in a considerable loss in cyclic strength and stiffness deterioration (Thakur et al. 2021). The G of the soil was found to reduce as the number of loading cycles increased. It was revealed that the shear modulus degradation rate gradually decreased despite the fact that the beginning rate was high. The potential for improved resonance resistance in foundations, when nano-silica is used, is due to enhanced interparticle bonding and reduced void ratios. The relevance of this effect for pile-supported structures, especially in seismic or vibration-sensitive environments (Tolun et al. 2020).

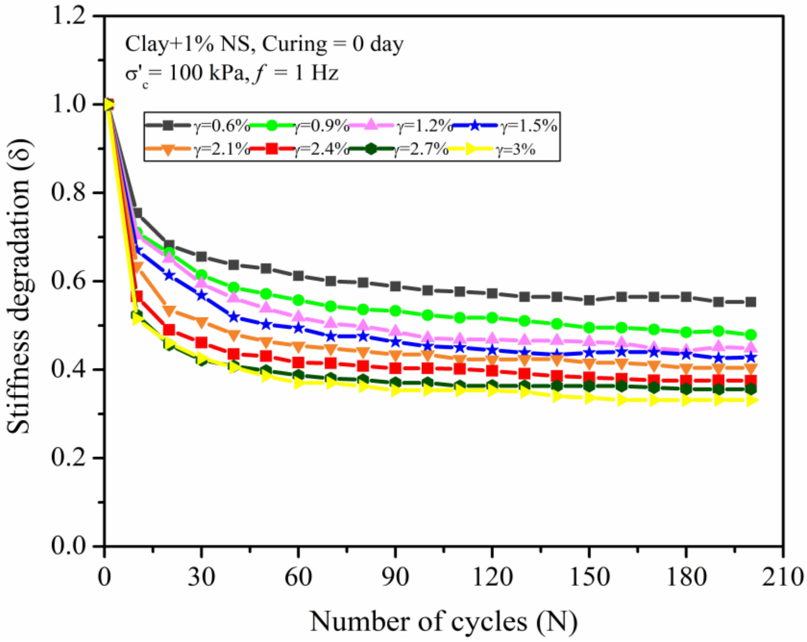


(a)

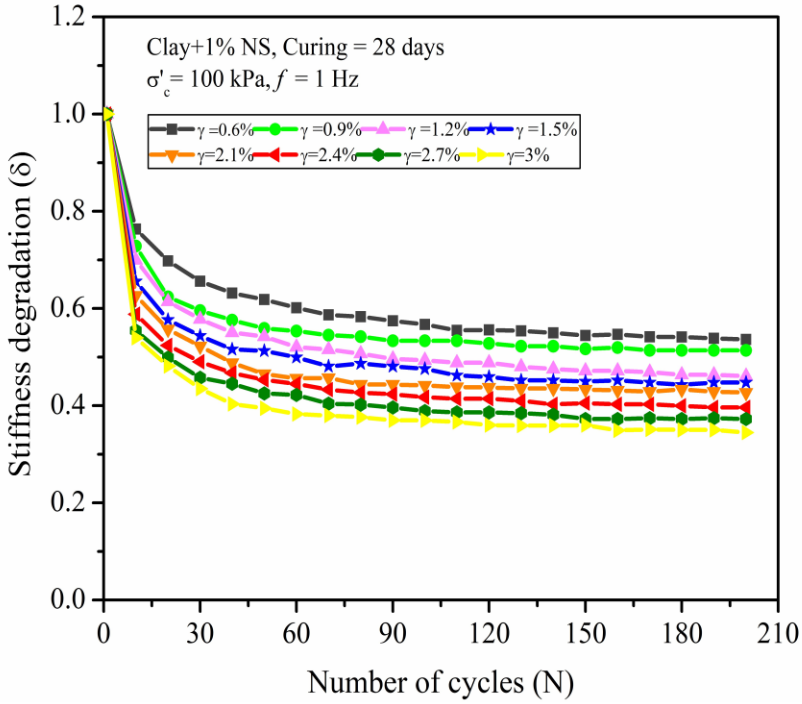


(b)

Fig. 6.10. Variation of stiffness degradation with number of cycles for different curing days (a) Clay, 0day and (b) Clay, 28days.

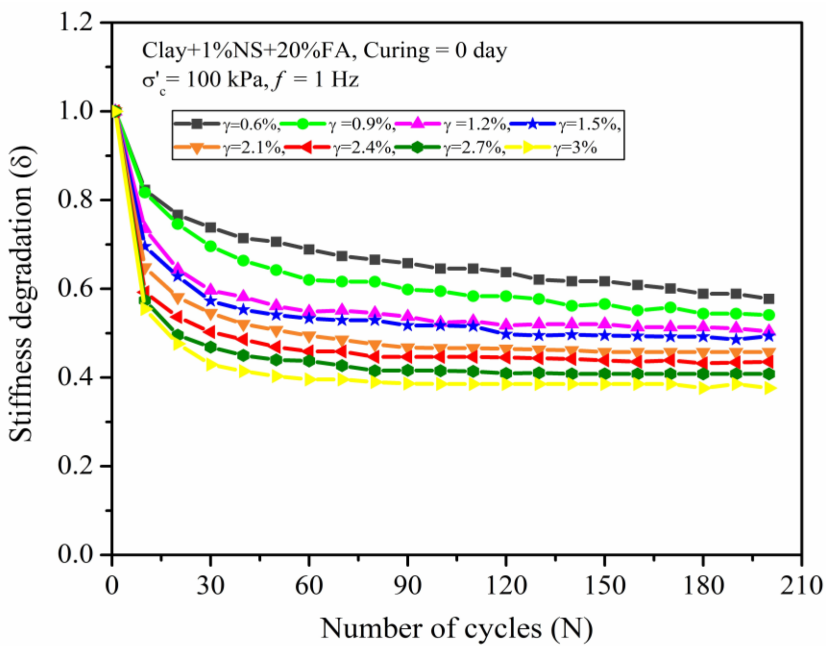


(c)

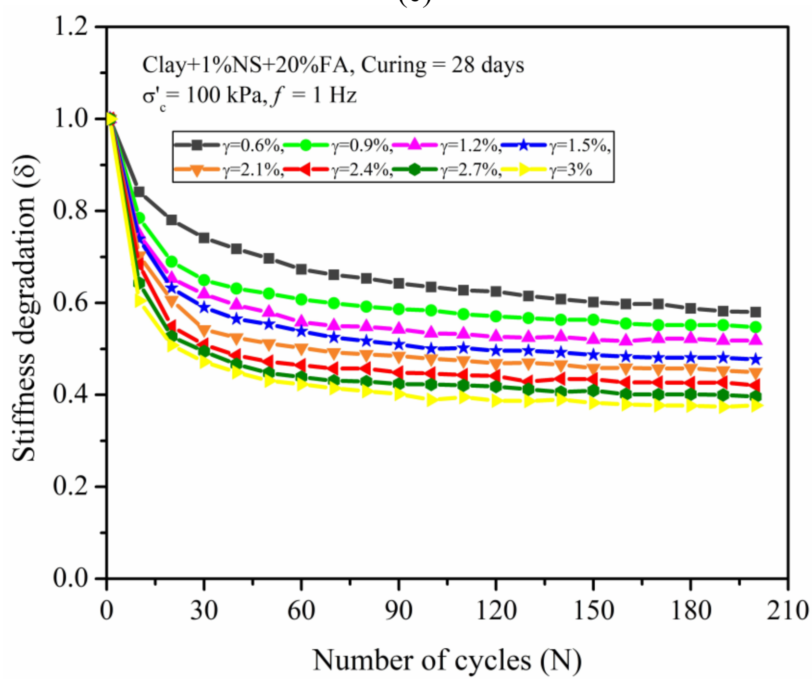


(d)

Fig. 6.11. Variation of stiffness degradation with number of cycles for different curing days (c) Clay +1 %NS, 0day, (d) Clay+1%NS, 28days.



(e)



(f)

Fig. 6.12. Variation of stiffness degradation with number of cycles for different curing days (e) Clay+1%NS+20%FA, 0day and (f) Clay+1%NS+20%FA, 28days.

6.4 SUMMARY

The dynamic characteristics of the parent soil and the soil treated with optimised fly ash and nano silica under various cyclic shear strains were assessed using the consolidated undrained cyclic triaxial test. The study examined the behaviour of both untreated and treated soil with the optimised fly ash and nano silica in terms of dynamic shear modulus and damping ratio. As the number of cycles at γ increased from 0.6% to 3.0%, the shear modulus of the optimal content of Nano-SiO_2 and fly ash treated soil reduced from 5.39 to 0.90 MPa. Additionally, after 28 days of curing, the shear modulus decreased from 11.38 to 1.33 MPa for γ ranging from 0.6% to 3.0%. When fly ash and Nano-SiO_2 react with clay, they create a confinement effect at the interfaces between the particles of clay. As the treated specimens got more rigid, the result was an increase in shear stiffness. The damping ratio of the soil treated with the optimal dosage of Nano-SiO_2 increased from 17.65% to 27.23% as the cyclic shear strain increased from low strain to high strain. At 28 days of curing age, the damping ratio improved from 16.54% to 25.56% under γ ranging from 0.6% to 3.0%. The stiffness degradation index falls rapidly for the first 20-40 cycles, then becomes almost constant or insignificant. Greater stiffness degradation magnitude was indicated by lower cycle degradation index values.