

Research Article

The influence of borax addition on setting behavior and mechanical properties of class F fly ash geopolymer concrete

Angelina Eva Lianasari* , Henri Perdana Natio

ABSTRACT: The role of borax as a setting-time modifier in Class F fly ash-based geopolymer concrete is not yet well understood. Particularly with respect to its effects on mechanical and fresh properties. This research investigates the influence of borax incorporation on the properties of geopolymer concrete. Class F fly ash from the Tanjung Jati B power plant was used. Borax was added at fly ash weights of about 0%, 5%, 10%, and 15%. Tests were arranged to observe setting time, compressive strength, elastic modulus, and slump value to assess mechanical performance and workability. The results represent, borax effectively prolongs the initial and final setting times, with greater effectiveness in Class F fly ash (low CaO) than in Class C fly ash (high CaO). The addition of 5% borax resulted in a higher compressive strength and modulus of elasticity. However, higher borax dosages reduced mechanical properties by inhibiting geopolymerization. An increase in borax content reduced slump values, reflecting lower workability due to higher mixture viscosity. While borax can effectively regulate setting time in Class F fly ash-based geopolymer concrete, its dosage must be carefully optimized to prevent negative effects on strength and fresh concrete performance.

Keywords: Geopolymer concrete, Borax, Class F fly ash, Setting time, Workability

1. INTRODUCTION

The construction of infrastructure raised the demand for concrete; therefore, it has an impact on increasing cement consumption [1]. During the calcination stage, the cement manufacturing process produces CO₂ gas, approximately 0.869 tons for every ton of clinker. As a result, cement contributes to global climate change and accounts for 8% of global CO₂ emissions that pollute the environment. [2]. Replacing partial cement with pozzolanic materials to reduce cement consumption in concrete has been widely implemented. Pozzolanic materials are materials that contain Silicon Dioxide (SiO₂) and Aluminum Oxide (Al₂O₃), like fly ash and GGBFS [1], kaolin, rice husk ash, and zeolite. In conventional concrete practice, replacing cement with pozzolanic materials is usually partial, whereas complete cement replacement is used in geopolymer concrete technology [2].

Geopolymer concrete is a different binder system that uses inorganic polymers instead of Portland cement. These binders are made by activating aluminosilicate materials that are contained in fly ash and GGBFS (alkaline environment) [3]. Under highly alkaline conditions, silica (SiO₂) and alumina (Al₂O₃) dissolve from the precursor materials and subsequently polymerize into a three-dimensional aluminosilicate network through the geopolymerization process [3]. Compared to Portland cement concrete, geopolymer concrete (fly ash-based) offers lower carbon emissions, higher strength, improved fire resistance, and better durability, including reduced permeability and greater resistance to high temperatures and alkali-silica reactions [3], [4].

The mechanical performance of fly ash-based geopolymer concrete is affected by duration and temperature of curing, type of base activator, and alkalinity of fly ash, as these parameters affect the reaction and efficiency of geopolymerization [5]. Longer curing times and higher curing temperatures have been shown to enhance geopolymerization and increase compressive strength [6]. The type of alkali activa-

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tor also has an important role: activators containing silicates, such as sodium or potassium silicate, increase the reaction rate faster than hydroxide solutions alone [7]. Sodium-based activators generally produce geopolymer concrete with better mechanical properties than potassium-based systems [8].

Furthermore, studies on geopolymer paste formulated with various NaOH concentrations (6M–14M) and an activator ratio of 5:2 (NaOH: Na_2SiO_3) have shown that optimal compressive strength is achieved at a NaOH concentration of 8M, under a curing method consisting of initial ambient curing followed by oven curing at 60°C and continuous ambient curing. [9]. The choice of alkali cation also affects microstructure development, with Na-based geopolymers reported to exhibit higher porosity but greater resistance than K-based geopolymers [10].

Despite its mechanical and durability advantages, fly ash-based geopolymer concrete commonly exhibits rapid setting under highly alkaline conditions, which significantly increases mixture viscosity at early ages. The combination of rapid geopolymerization and high viscosity leads to severe slump loss, reduced workability, and difficulties in mixing, casting, and compaction [6], [11]. Without adequate control of setting kinetics, these characteristics limit the practical use of geopolymer concrete, particularly in field conditions. Therefore, the use of chemical retarders is necessary to regulate the geopolymerization process and extend the workable time of fresh geopolymer mixtures.

Rapid setting in geopolymer concrete is shown when it is produced with high-calcium fly ash (Class C), due to accelerated calcium-related reactions during early-age geopolymerization [12]. Although Class F fly ash generally exhibits slower initial setting compared to Class C fly ash, high pH conditions ($\text{pH} > 11$) can still promote rapid hardening and flash setting [13]. In geopolymer systems without retarders, rapid setting often causes reduced workability and difficulties during practical construction operations. To mitigate this problem, chemical retarders such as borax have been widely applied in Class C fly ash-based geopolymer systems, where high CaO content makes time-controlled setting more critical. [12]. However, the effect of borax in fly ash-based geopolymer systems of Class F, which are dominated by silica-alumina reactions and contain relatively low CaO, remains poorly understood and limited in the existing literature.

Indonesia is one of the countries with the largest number of coal-fired power plants (PLTU) in Southeast Asia, so the production of fly ash waste as a combustion residue is also very large. Several large-capacity PLTUs that are predominantly located on the island of Java include PLTU Paiton, PLTU Suralaya, PLTU Cirebon, and PLTU Batang, which are the main sources of national fly ash because their generating capacity reaches thousands of megawatts [14]. Based on coal waste management data, the PLTU Suralaya unit in Banten produces the highest FABA (fly ash and bottom ash) in Indonesia, followed by PLTU Paiton in East Java and PLTU Tanjung Jati B in Central Java, with hundreds of thousands of tons of FABA managed in just one semester [15]. The fly ash comes from the combustion of coal, which chemically generally contains silica oxide (SiO_2), alumina (Al_2O_3), and variable levels of calcium oxide (CaO). According to standard classifications and industry reports, fly ash from burning bituminous coal tends to have a low CaO (<10%), categorized as Class F, which is pozzolanic [16].

In Indonesia, much of the fly ash comes from bituminous coal

combustion and is classified as low-calcium (Class F), making its behavior in geopolymer systems particularly important to understand. Even though chemical additives have been widely studied to control geopolymer setting time, most studies on borax focus on high-calcium (Class C) fly ash, where rapid setting is more likely. Studies on the effect of borax in Class F fly ash-based geopolymer concrete are still limited, despite its dominance in Indonesia. So, further research is needed to evaluate the effectiveness of borax in controlling setting time and enhancing workability without influencing mechanical performance.

Although borax has been shown to effectively delay rapid setting in Class C fly ash-based geopolymers, its effectiveness in low-calcium Class F systems remains insufficiently understood, particularly in the Indonesian context where Class F fly ash predominates. Therefore, this research examines the effect of borax on Class F fly ash-based geopolymer concrete. The focus is on setting time, workability, and mechanical performance. The aim is to determine an optimal borax dosage that delays setting without reducing mechanical performance. The findings of this research are supposed to assist in the development of more workable, practically applicable geopolymer concrete mixtures for field implementation.

2. EXPERIMENTAL

This research method is an experimental study, in which concrete samples were directly tested at the Structures and Materials Laboratory, Department of Civil Engineering, Universitas Atma Jaya Yogyakarta. The materials used to produce geopolymer concrete in this study included water, fly ash, an alkaline activator, fine aggregates, and coarse aggregates.

The fly ash utilized in this research was from the Tanjung Jati B power plant in Jepara and was supplied by PT Solusi Bangun Beton. The specific gravity of the fly ash was 2.298 g/cm^3 . The chemical composition of the fly ash was analyzed by the BPTBA Laboratory of LIPI Yogyakarta. In Table 1, the results of fly ash, SiO_2 , Al_2O_3 , and Fe_2O_3 oxide testing are grouped together, as these oxides collectively form the main aluminosilicate framework that is important for pozzolanic reactivity and geopolymerization. These oxides affect the setting time, mechanical strength, and microstructural stability of geopolymer. Specifically, SiO_2 and Al_2O_3 are the main constituents of the geopolymer gel phase (N-A-S-H and C-A-S-H), which affects the development of the geopolymer matrix's strength and durability. Meanwhile, Fe_2O_3 contributes to the overall aluminosilicate structure and affects the reactivity of fly ash in an alkaline environment.

The content of $\text{SiO}_2 + \text{Al}_2\text{O}_3 + \text{Fe}_2\text{O}_3$ is a standard parameter for classifying fly ash according to ASTM C618, namely if the total oxide content exceeds 70%, it identifies Class F fly ash. This Class F fly ash reflects pozzolanic properties and relatively low calcium content, which will affect its behavior in geopolymer systems [17].

The result of Scanning Electron Microscopy (SEM) is shown in Figure 1, which presents the shape of fly ash grains. The fly ash grains tend to be perfectly round, affecting the workability of concrete more easily.

Figure 2 presents the EDS (Energy Dispersive X-ray Spectroscopy) of fly ash. That showed fly ash was dominated by O, Si, and Al as major peaks. Minor peaks were detected for Fe, Na, K,

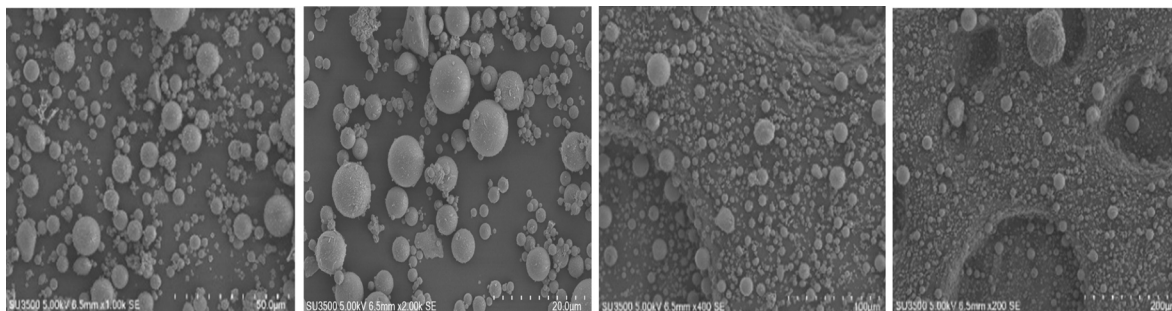


Figure 1. Fly ash’s Scanning Electron Microscopy (SEM) (50-200µm).

Table 1. The oxide of the fly ash.

Chemicals	Formula	wt%
Silicon Dioxide	SiO ₂	53.04
Aluminum Dioxide	Al ₂ O ₃	25.83
Iron Oxide	Fe ₂ O ₃	8.01
	SiO ₂ + Al ₂ O ₃ + Fe ₂ O ₃	86.88
Lime	CaO	1.58
Magnesium Oxide	MgO	1.47
Sodium Oxide	Na ₂ O	0.63
Potassium Oxide	K ₂ O	0.56

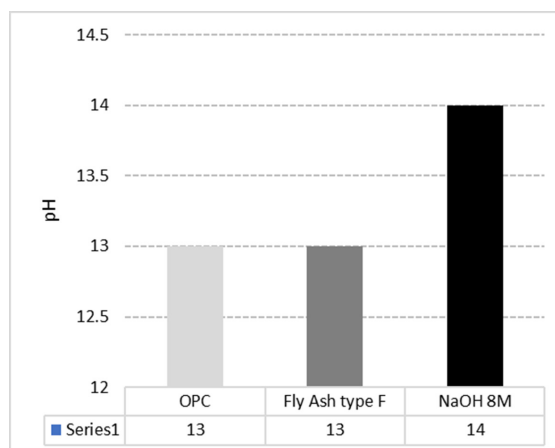


Figure 3. pH value of OPC, fly ash, and NaOH 8M.

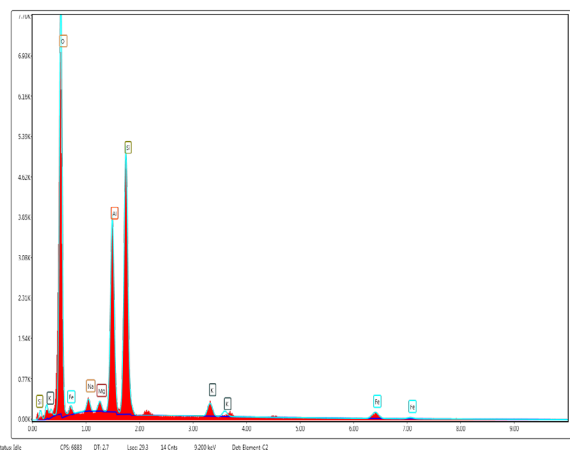


Figure 2. EDS spectrum fly ash.

and Mg. Ca was not detected, thus concluding that there was no high calcium component. Therefore, fly ash is classified as Class F. These dominant Si–Al–O elements indicate the potential reactivity of the material as a pozzolanic source for geopolymer or cementitious applications.

The pH value of fly ash in this research is high (alkaline) because the test results show a pH value of 13. That value is categorized as a strong base. Fly ash with alkaline pH conditions will accelerate the setting time (cause flash-setting in the geopolymer concrete) [13]. Figure 3 shows a comparison of the PH values of OPC [18], fly ash (test results), and NaOH [18].

The properties of fly ash in geopolymer concrete have a role in assigning the characteristics of the final product. The pH level of fly ash can impact the setting time of the geopolymer, with high pH fly ash potentially leading to flash-setting in the concrete [13].

Aggregate that was used in this study: Coarse aggregates from Clereng, Yogyakarta, Indonesia has a maximum grain size of 10mm, and fine aggregates are from the Progo River, Yogyakarta. The fine and coarse aggregates were examined to ensure they met the requirements of ASTM C33/C33M-08 and were acceptable aggregates (shown in Table 2).

The preparation of geopolymer concrete specimens follows a systematic procedure that differs from that of Portland cement concrete. The alkali activator was prepared by mixing an 8 M NaOH solution with Na₂SiO₃ at a mass ratio of 5:2. To ensure chemical stability, 8 M NaOH is prepared by dissolving NaOH in water and allowing the solution to reach room temperature for 24 hours. For mixtures containing borax, borax is dissolved directly into the NaOH solution before adding Na₂SiO₃ to ensure uniform dispersion in the activator matrix. Borax contents of 0%, 5%, 10%, and 15% (by weight of fly ash) were used. All mixtures were mixed in a concrete mixer at 25 rpm until a uniform consistency was achieved, using the same mixing procedure.

The solid components, consisting of fly ash, fine aggregate, and coarse aggregate, were proportioned with an aggregate to binder ratio of 70:30 and a coarse aggregate to fine aggregate ratio of 65:35. Fly ash and alkali activator were mixed at a ratio of 74:26. During the mixing process, the activator was combined with fly ash

Table 2. The aggregate test result.

Description	Specific gravity	Absorption	LA-Test	Modulus of grain	Gardner color standard	Mud content
Coarse aggregates	2.64	2.43%	23.28%	7.92	-	-
Aluminum Dioxide	2.59	2.05%	-	3.59	5	6.52%

to form a homogeneous geopolymer paste, followed by the gradual addition of aggregate until a uniform consistency was obtained. The fresh mixture was assessed using a slump test to determine its workability before being cast into molds. Specimen preparation was performed under controlled laboratory conditions with a constant mixing duration applied uniformly across all mixtures.

Specimen preparation and casting were conducted at an ambient laboratory temperature of about 25 °C. After molding, the specimens were stored at room temperature for 24 hours. Thermal curing was carried out in an oven at 60°C for 24 hours to accelerate the geopolymerization process. After oven curing, the specimens undergo moist curing at room temperature until the specified test ages of 28 and 56 days. Full details of the geopolymer concrete mix design are in Table 3.

Table 3. Material composition.

Material	Volume (m ³)	Specific gravity	Weight (kg)
Coarse aggregates	0.455	53.04	1.199.84
Fine aggregates	0.245	25.83	635.04
Fly Ash	0.222	8.01	510.16
Borax (5%)	0.0111	86.88	19.2
Borax (10%)	0.0222	1.58	38.41
Borax (15%)	0.0333	1.47	57.61
Na ₂ SiO ₃	0.05571	0.63	111.428 lt
NaOH	0.02229	0.56	44.571 lt

Observations were made on freshly mixed geopolymer concrete to assess setting time and workability. Mechanical testing was performed on hardened concrete, namely elastic modulus, compressive strength, and split tensile strength, with 3 cylinder specimens for each variation, each measuring 150x300 mm in according to ASTM C39 [19] guidelines at 28 and 56 days of age. The slump test was conducted using a standard Abrams cone [20]. The setting time test was made using a Vicat apparatus with a test specimen with an upper diameter of 60mm, a bottom diameter of 70mm, and a height of 40mm [21] The experimental values are reported as the average of 3 specimens for each test.

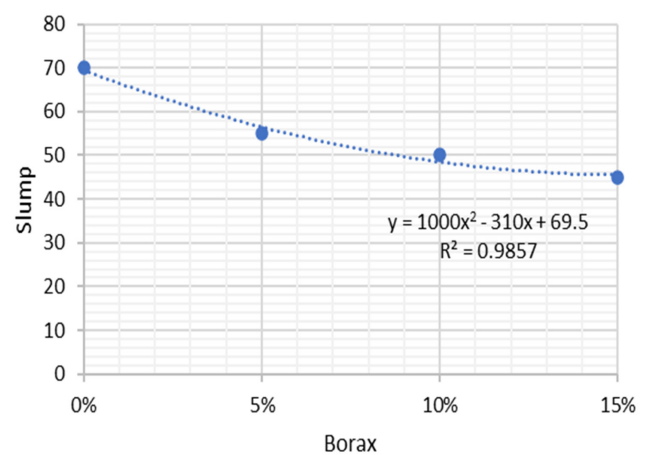
3. RESULT AND DISCUSSION

3.1. Workability. To measure the level of consistency or viscosity of fresh concrete mixtures using slump values. The result of testing the slump value will indicate the viscosity of the concrete mix. This contributes to obtaining the required workability of the concrete and ensures homogeneity, the slump value should range from 50 mm to 150mm [22]. A slump value of less than 15mm of concrete is not plastic enough. and more than 230mm is not cohesive enough [20]. The slump values, as summarized in Table 4, of this geopolymer concrete ranged from 45 to 70 mm. The addition of 5–15% borax by weight of fly ash led to a reduction in slump,

indicating lower workability for this mix. This trend suggests that borax modifies the activator solution and the early geopolymerization process in such a way that the paste becomes slightly more viscous and cohesive, making the fresh mixture stiffer and less flowable, which is reflected in the lower slump values observed in this study. Adding borax results in decreased slump values, ranging from 45-70 mm, which reduces the mixture's workability for placement and consolidation. This poses challenges during pumping or placement due to increased internal friction and reduced flowability, potentially requiring higher pumping pressures or more careful placement techniques. However, these values remain adequate for manual placement and conventional compaction methods, indicating that the mixture can still be handled effectively despite the reduced slump.

Table 4. Slump test value.

Addition of borax by weight of fly ash	Slump (mm)
0%	70
5%	55
10%	50
15%	45

**Figure 4.** Slump vs % borax.

Furthermore, when the slump reduction pattern is visualized graphically, the trend is clearly non-linear. The quadratic curve fitting shows an excellent agreement ($R^2 = 0.9857$) as shown in Figure 4, indicating that each increment of borax has a more pronounced effect on slump at higher dosages. This pattern suggests that borax does not only retard the initial reaction but also influences the rheological behaviour of the mixture in the early mixing phase. The interaction between borate ions and the alkaline activator solution is likely to modify the paste structure, making it thicker and less flowable, so that the reduction in slump becomes more

Table 5. Initial set and final set (minutes) geopolymer paste class F fly ash and C with NaOH 8M.

Addition of borax by weight of fly ash	Class F fly ash		Class F fly ash*		Normalize class F fly ash		Normalize class F fly ash*	
	Initial	Final	Initial	Final	Initial	Final	Initial	Final
0%	28	60	8	32	100%	100%	100%	100%
5%	58	105	10	43	207%	175%	125%	134%
10%	107	165	20	75	382%	275%	250%	234%
15%	165	225	35	100	589%	375%	438%	313%

* Data from Antoni et.al [12]

significant as the borax content increases. These results indicate that the borax-induced increase in viscosity influences the reduction in geopolymer concrete workability observed in this study.

3.2. Geopolymer paste setting time. Factors influencing geopolymer hardening time are not solely dependent on the physical and chemical properties of fly ash; factors such as the composition and mixture design also play crucial roles [13], [23]. According to Davidovits [3], Fly ash with a pH above 11 is highly likely to experience flash setting, which occurs within 5 minutes of mixing and hardens. Furthermore, the concentration of sodium hydroxide is important. The strength of the alkali solution in dissolving fly ash influences the setting process of geopolymer mortar; lower molarity will result in a faster initial set.

The Class F-based geopolymer concrete in this study had a high pH of 13 and a molarity of 8M NaOH, which significantly affected the initial hardening rate. Table 5 shows the effect of borax addition on these criteria, where the addition of more borax results in slower setting times and final sets. Testing was carried out by penetration with a Vicat apparatus. The setting time behavior of geopolymer samples without borax reported by Antoni et al. [12] as presented in Table 5 are compared with the baseline results obtained in this study. This comparison confirms that the rapid setting behavior observed in the control samples is consistent with previously published findings for fly ash-based geopolymer systems without retarders. As shown in Table 5, the initial set for the control sample (0% borax) is 28 minutes with a final set of 60 minutes, aligning well with the reported times in the literature. This consistency supports the validity of our experimental setup and the representativeness of our control samples. Based on this study, the initial set time is 28 minutes. This will complicate the concrete casting process, especially if the concrete volume is quite large. Based on ASTM C-150 requirements, the initial and final concrete setting time ranges are 45 minutes and 375 minutes [24]. Therefore, geopolymer concrete without borax addition does not meet the minimum criteria.

Borax addition consistently prolonged both the initial and final setting times for both classes of fly ash, although its effectiveness differed markedly between Class F and Class C fly ash. In Class F fly ash, borax was able to substantially slow down the geopolymerization reaction, as seen from the increase in initial set from 28 minutes to 165 minutes (589%) and final set from 60 minutes to 225 minutes (375%), and all set time values remained within the range permitted by ASTM C-150 (45–375 minutes) [24]. However, in Class C fly ash which has a high CaO content, the calcium hydration reaction proceeds much faster, so that although there is a large relative increase in set time (initial set increased by 438% at the addition of 15% borax), the absolute value remains low (8 to

35 minutes) and does not reach the ASTM minimum limit of 45 minutes. This shows that borax effectively inhibits the Si-Al-based geopolymerization mechanism, but is not strong enough to withstand the rapid reaction of C-(A)-S-H gel formation in high-calcium fly ash. Thus, borax is much more effective for use in Class F fly ash compared to Class C because the basic reaction character of the material allows for a more optimal delay in setting time.

The retarding effect of borax in geopolymer can be explained by its influence on the dissolution and polycondensation processes of aluminosilicate type. In highly alkaline environments, borax dissociates into borate ions. That can interact with dissolved silicate and aluminate types, reducing their availability for rapid geopolymer gel formation [25]. This interaction slows the formation of N-A-S-H gel, thereby delaying geopolymerization and extending both the initial and final setting times.

The effect of borax as a retarder depends on the fly ash used. In Class F fly ash, geopolymerization depends on Si-Al, which is sensitive to borate [26]. Thus, borax can prolong setting times, and according to ASTM C-150 standards [24]. Meanwhile, Class C fly ash with high levels of calcium accelerates the formation of C-A-S-H gel, thereby inhibiting the borax reaction [12], [23]. This difference explains why borax works better in Class F systems than in Class C systems to delay hardening.

Although borax can delay setting time, its optimum dosage must be carefully controlled to balance workability and timely hardening. Excessive retardation may cause workability issues and construction delays, while insufficient retardation can lead to early stiffening during casting. Overall, the chemical and mineralogical characteristics of fly ash govern geopolymer concrete performance, so adjusting additive dosage according to fly ash classification can optimize setting time and workability for structural applications.

3.3. Mechanical properties. Based on the normalized results in Table 6, the addition of borax influences the compressive and splitting tensile strengths of Class F and Class C fly ash-based geopolymer concrete. Compared with mixtures without borax, a low borax dosage (5%) results in a strength increase of approximately 3–10%. This indicates that moderate borax content can help stabilize the early reaction and contribute to the formation of a denser geopolymer matrix.

At higher borax doses ($\geq 10\%$), the compressive and splitting tensile strengths decrease significantly. This decrease is related to borax's nature as a retarder, slowing the initial alkali-activation process. Borate ions from borax can interact with alkali cations and calcium cations, reducing the effectiveness of the alkali solution in dissolving the silica and alumina phases of fly ash. Consequently, geopolymer gel formation is less optimal, and the resulting micro-

Table 6. Normalization results of compressive and split test.

Addition of borax by weight of fly ash	Normalize compressive test Class F fly ash	Normalize compressive test Class F fly ash (56 days)	Normalize compressive test Class C fly ash *	Normalize split tensile test Class F fly ash
0%	100%	100%	100%	100%
5%	107%	110%	103%	103%
10%	80%	83%	85%	81%
15%	63%	67%	77%	77%

* Data from Antoni et.al [12]

Table 7. Mechanical properties.

Addition of borax by weight of fly ash	Modulus of elasticity (MPa)	f'c (28 days), Class F fly ash	f'c (56 days), Class F fly ash	fct (28 days), Class F fly ash
0%	27905	45.09	46.14	5.81
5%	29137.47	48.46	50.66	5.31
10%	23845.48	36.02	38.44	4.18
15%	21945.07	28.32	30.71	4.01

structure tends to be more porous and less polymerized, reflected in the decrease in compressive and splitting tensile strengths at high borax concentrations.

The difference in response between the two Classes of fly ash reflects the different basic reaction mechanisms. Class F fly ash with low CaO content mainly forms N-A-S-H gels, making it highly sensitive to disturbances in the aluminosilicate dissolution and polycondensation processes; as a result, the performance degradation at high borax dosages is more drastic. In contrast, Class C fly ash with high CaO content can still produce C-(A)-S-H gels, so that even though borax inhibits aluminosilicate polymerization, the calcium-based reaction still occurs and the performance degradation is relatively more moderate, as reflected in the normalized compressive strength values of Class C which remain higher than those of Class F at dosages of 10% and 15%.

The modulus of elasticity results presented in Table 7 show a trend consistent with the mechanical behavior of the geopolymer concrete. A minor increase in modulus was detected. at a borax dosage of 5%, indicating that limited borax content can still support the formation of a sufficiently rigid and compact geopolymer matrix. However, at higher dosages (10% and 15%), the modulus of elasticity decreases notably, reflecting a reduction in matrix stiffness. This reduction is resulting from the inhibitory effect of borax on early geopolymer gel development, leading to a microstructure that is less dense and contains a higher proportion of unreacted or partially reacted material. As the stiffness of geopolymer concrete is directly linked to the continuity and rigidity of its binder phase, the diminished gel formation at elevated borax levels results in a more compliant and less elastic material. Consequently, the decreasing modulus values at higher borax contents confirm the adverse effect of excessive borax on the structural integrity and rigidity of the geopolymer binder.

4. CONCLUSION

The addition of borax will affect the hardening of Class F fly ash-based geopolymer concrete. The effect is to slow down both the initial and final setting. This slower reaction makes the mix easier to handle and helps prevent it from hardening too soon while being cast. With the right amount of borax, the setting time can be extended to fall within the range specified by ASTM C-150, which works particularly well for Class F fly ash because it reacts more gradually than Class C. On the other hand, Class C fly ash contains more CaO, causing hydration to proceed very quickly, so borax doesn't have as much impact in keeping the setting time within the standard limit. These observations suggest that the effectiveness of borax as a retarder is affected by the chemical makeup of the fly ash itself.

In practice, adding a small amount of borax can make geopolymer mixes easier to handle because it slows the setting process and gives more time for casting and shaping. The amount used, however, can't be the same for every situation. Each type of fly ash, and even each project, may need a different dose to get the expected results. When the characteristics of the fly ash and the relevant standards are taken into account, borax can serve as a helpful additive for making geopolymers more workable and more practical to apply in construction.

The use of approximately 5% borax improves productivity and work efficiency by delaying hardening without compromising structural strength. However, field trials under various environmental conditions and curing regimes are still required to verify its long-term stability and durability before practical application.

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CREDIT AUTHOR STATEMENT

Angelina Eva Lianasari: Conceptualization, Data analysis and validation, Writing (revision and editing). **Henri Natio:** Methodology, Resources, Investigation, Project administration, Writing original draft.

DECLARATIONS

Conflict of interest The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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