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To cite this article: Z Md Yusof *et al* 2024 *IOP Conf. Ser.: Earth Environ. Sci.* **1347** 012064

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Deformation of peat soil reinforcement settlement using single-layer bamboo dendrocalamus asper

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Abstract. As a unique soil, peat soil has extreme characteristics such as very high compressibility when any load applies to it. It has the condition of partially decomposed plant and animal make it unsuitable used as a foundation for construction. Due to this, the reinforcement of peat must be improved or stable. The stability of peat was more stable when the reinforcement is held or tied with a strong material that can be used for the long term. Therefore, this study to identify the deformation settlement of single-layer bamboo Dendrocalamus asper that using as reinforcement for the peat. The testing at the laboratory and physical model were conducted to fulfill the objective of the study which is to identify the physical properties (water content, specific gravity, organic content, fiber content, degree of decomposition), mechanical properties (consolidation test), and displacement of settlement through physical modeling at the laboratory. The result shows that the soil collected at Kampung Parit Puteri Menangis, Benut, Johor has a moisture content of 672%, specific gravityof 1.23, organic content of 88.34 – 96.19%, fiber content of 38.1%, and categories H4 to H6 (Hemic). The compression index (C_c) was determined in the range of 0.13 to 1.54, the consolidation coefficient (C_v) was determined in the range of 0.62 to 4.925, while the coefficient of compression (C_α) was determined in the range of 0.02 to 0.048. For the displacement of the settlement of peat show the bamboo reinforcement reduce the settlement under different load. The settlement decreased by 59% of the final load 4 kg/m^2 during 2 hours in the displacement 9.543 mm to 3.867 mm. It is shown that the properties of peat react with the soil and began to settle down slowly until the reading remained constant.

1. Introduction

Construction must start with soil improvement to avoid any suspension or structure failure in the long-term period [1]. In full-fill the process of soil improvement, it is essential to properly handle the weak or soft soil, especially to avoid risk settlement [2]. Construction on weak or soft soil gives major challenges to engineering work especially to deal with the soil's physical and mechanical properties. This condition needs with to use the appropriate method for the construction due to the instability and severe settlement [3]. Soil can be categorized as organic or inorganic materials. The soil from inorganic materials made from rock slowly breaks over many years into smaller particles such as sand,clay, silt, and loam [4].

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Organic soil provided from water and organic matter has more than 75% of organic content and is categorized as peat soil. The classification of peat soil is based on decomposition and fiber content. The classification of peat according to humification level is categorized into different stages including fibrous, hemic, and sapric. The physical and mechanical properties of peat soil are different. The settlement of peat is very extreme making it need treatment before the construction process. The physical properties can store the water making it has high water content. In mechanical properties, peat has high compressibility, poor shear strength, and as well as high settlement. As lower quality than mineral soils, the foundation of peat has a significant problem for the development of infrastructure. Furthermore, the environment of peat is an organic material that comes from the formation of vegetation that begins in shallow lakes [5]. Yusof [6] stated that peat soil treatment is needed for peat to avoid failure and settlement due to the construction.

Waruwu [7] suggested that laminated bamboo can be used to reduce the settlement compare with other methods in soil stabilization, especially in the construction of buildings and highways. In industry, the usage of bamboo Dendrocalamus asper has a major negative influence. The strength of bamboo gives twice the strength of concrete. Mostly in soil improvement, the soil stabilization method is commonly used. For raft construction, bamboo is the best alternative material compared with timber. The materials of bamboo can save energy and reduce pollution. The requirement of soil treatment considers the combination method of construction. For peat soil, laminated bamboo has beenapplied to improve its properties and performance [3].

The techniques of strength improvement such as preloading, surcharging, and stage construction. The stabilization techniques such as chemical binder agents and sand or stone column. While for the techniques of reinforcement such as geosynthetics and raft construction. Bamboo raft construction or bamboo raft structure is used for foundation pit support and protection, especially peat soil [3]. Wahab [3] also adds that peat soil has an extreme settlement issue in the long term. When the load is applied, other issues also happen such as bearing capacity failure, and slope instability. Therefore, the settlement of peat deals with suitable techniques such as pre-loading, cement columns, raft surface structure, and other methods. For soil that has an excessive settlement, bamboo raft foundations are more suitable compare with other methods [7].

For this study, the peat soil from an oil palm plantation at Kampung Parit Puteri Menangis, Benut, Johor has the potential for growing development in the future. Currently, the peat is in problematic condition and needs improvement in its stability for the long term. In the process of fulfilling the requirement of the current development, there must be an alternative to maintain the settlement continuously. The reinforcement bamboo Dendrocalamus Asper (giant bamboo) materials are the current application for soft soil settlement in construction, but it's less used. Therefore, further research is needed such as in this study to study the deformation settlement of single-layer bamboo Dendrocalamus asper that is used as reinforcement for the peat.

2. Material and methods

In this point, the material and methodology were explained for this study. The materials that were used in this study are peat and bamboo types of Dendrocalamus asper.

2.1. Site location and sample collection

Kampung Parit Puteri Menangis at Benut, Johor was chosen as the site location for peat materials. The location area engaged in coconut palm and pineapple farming. There is also, natural farming from other plantation materials at the near location. The peat in the Benut area has slightly decomposed in muddy brown color. Located around 40 km from Universiti Tun Hussein Onn Malaysia (UTHM), peatwas collected as the main sample for this study. From the topsoil (0 m to 0.3 m), the peat soil exhibits characteristics of unwanted plant materials. Therefore, it is unsuitable to use as a sample for the peat characteristics and was removed and uncollected. Soil samples were dug from 0.3 m to 0.6 m depth. The sample was collected properly and kept in suitable packaging with the label. The process transported of peat samples is complicated for undisturbed peat compared to disturbed peat. All the samples were transported to the RECESS Laboratory at UTHM. The storage box of samples has been prepared early at the laboratory to facilitate the storage.

2.2. Sample preparation and testing

The sample preparation was divided into three types which are physical properties, mechanical properties, and physical modeling for settlement test. All the sample preparation for physical and mechanical properties are according to the stipulated standards as shown in Table 1.

Table 1. Physical and mechanical properties standard

Testing	Standard
Moisture content	ASTM D 2216-19
Specific gravity	ASTM D854-14
Organic content and fiber content	ASTM D1997-91
1 – Dimensional consolidation	ASTM D 2435

Physical properties - The sample has been prepared for physical properties testing such as moisture content, specific gravity, loss of ignition and organic content, and fiber content. The moisture content was using an undisturbed sample. The undisturbed sample was placed in a small container and wrapped properly (this container was immediately placed in an oven for 24 hours after reaching the laboratory) and immediately tested by oven-dry method after the sample was collected from the site. The three specimens were prepared for this testing to identify the average of the result. The specific gravity and density were using disturbed samples. The disturbed sample was placed in a container and wrapped properly. The sample brings to the laboratory and the procedure was followed as stipulated according to ASTM D854-14, testing using a small pycnometer method. The organic content and fibercontent were using disturbed samples. The disturbed sample was placed in a container and wrapped properly. The sample brings to the laboratory and the procedure was followed as stipulated according to ASTM D1997-91, organic content was evaluated by monitoring the weight loss of ignition, while the fiber content was determined using the dry mass method.

Mechanical properties - The sample for mechanical testing using a disturbed sample. The sample of peat was extruded at the site using the experimental mold (size 75 mm in diameter and 20 mm in height) and wrapped properly. It was stored in the proper container and transported to the laboratory. The procedure of the testing was stipulated according to ASTM D 2435 (1 – Dimensional Consolidation) with the load of the test are 5, 10, 20, 40, and 80 kPa.

Physical modeling (load settlement) - The top surface of the peat soil was cleared of any roots and debris. The unwanted soil from 0 to 0.3 m was removed, to excavate the original peat (in the range of 0.4 m to 1.5 m). The sample was excavated and placed in the container as shown in Figure 1. The container size 50 x 50 x 70 cm (also shown in Figure 1) was transported and prepare early at the Laboratory for experimental physical modelling work. The scale of physical modelling is 1.714:1.8: 1.8 as considering according to [8]. The peat soil sample in wet appearance conditions was collected from the site and prepared at the laboratory. At the laboratory, it was added into the physical box in a slow and careful manner until it reached a height of 40 cm. The initial soil depth in the container is 40 cm for the purpose of placing the bamboo 40 cm x 40 cm with a height of 1 cm. The bamboo was placed on topsoil which is a 10 cm gap between the soil and the bamboo. A square plate base (polystyrene) in the size 10 cm x 15 cm is used on it as the foundation. The load was applied on top of the foundation in consistency (the weights are 1 kg/m^2, 2 kg/m^2, 3 kg/m^2, and 4 kg/m^2). The foundation was placed above a bamboo layer in the container together with peat soil before starting to measure the displacement of the settlement. The displacement of settlement was taken using a dial gauge and added with the metal ruler on the side of the glass container to facilitate the measurement reading. The displacement of the settlement without bamboo was observed, as well as the load was added. Following with bamboo, the load was applied by repeating loading. Two different types of time(1 hour and 2 hours) were measured to identify the settlement performance.

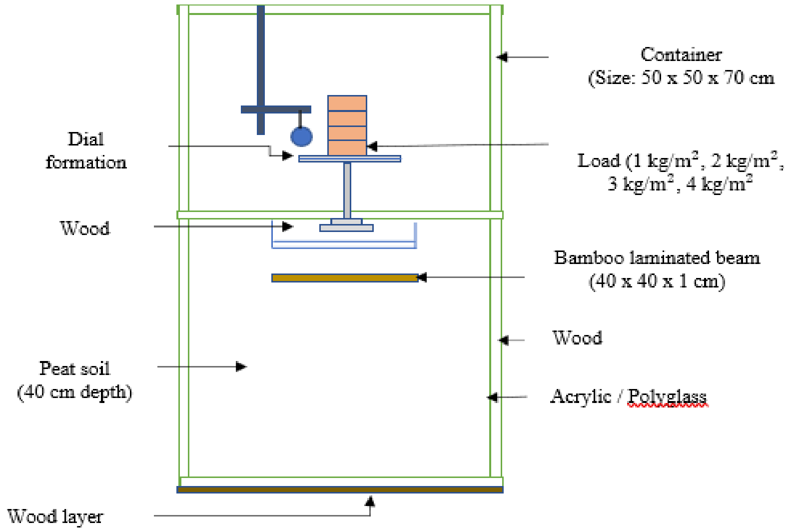

Figure 1. Physical modelling load settlement schematic

3. Results and discussion

This part presents the results and discussion of this study divided into sub-section which are physical properties, mechanical properties, and load settlement.

3.1. Physical properties results and discussion

Table 2 shows the summary of the physical properties results. Based on the experimental works, the moisture content was identified in the range of 672%. The results show that the sample taken below 0.4 m depth from the top surface has a very high-water content and it is shown that the peat soil has sponge characteristics because it keeps the water in the soil. According to the previous studies by Zainorabidin *et al.*, [9] and Razali *et al.*, [10], the water content they identified in Pontian peat was in the range of 658% to 848.7%. The result of specific gravity for this study was identified in the range of 1.23. It is shown that the specific gravity of peat soil is low because it is not mineral soil, and it is affected by the organic matter in the particles of peat soil. The low the specific gravity reduces the compounded specific gravity of peat soil. It is also supported by the findings from Razali *et al.*, [10] that the Pontian Peat has a specific gravity of 1.28. In this study, the organic content was identified as 88.34 – 96.19%. It is because the place where the sample collected was possibly has more organic content compared with another area or different location. According to Wahab *et al.*, [3] and Razali *et al.*, [10], the organic content of peat soil in Peninsular Malaysia is in the range of 70% to 98%. They also mention that the organic content gives extra contribution to the peat soil in the physical properties of high-water holding capacity, low shear strength, and high compressibility. The results for fiber content for this study were identified as 38.1%. It is determined that the peat soil sample in this study is hemic and the humification level is between H4 to H6. It is very difficult to identify the botanic origin for highly decomposed peat with low fiber content. In a study by Zainorabidin *et al.*, [9] and Kamaruidzaman *et al.*, [11], the range of fiber content was 33% to 67% for hemic peat soil.

3.2. Mechanical properties results and discussion

Table 2 also shows the summary of the mechanical properties results. The consolidation parameters in this study were determined compression index (C_c), consolidation coefficient (C_v), and coefficient of secondary compression (C_α). The C_c, C_v, and C_α were determined as in the range 0.13 to 1.54, 0.62 to

4.925, and 0.02 to 0.048 respectively within the consolidation pressure from 5 kPa to 80 kPa.Duraisamy *et al*., [12] stated that the C_c values for Hemic peat soil range from 1.3 to 2.78.
While Johari *et al*., [13] mentioned that in their study that the C_v values for the conventional 1 – Dimensional consolidation were in the range of 0.696 to 17.379. Duraisamy *et al*., [12] also stated that the C_α values for hemic peat soil in their studies were in the range of 0.0225 to 0.0881.

Table 2. Physical and mechanical properties of peat soil result

Physical Properties	Results	Mechanical Properties	Results
Moisture content (*w*)	672%	Compression index (C_c),	0.13 – 1.54
Specific Gravity (G_s)	1.23	Consolidation coefficient (C_v)	0.62 – 4.925
Organic Content (OC)	88.34 – 96.19%	Coefficient of secondary compression (C_α)	0.02 – 0.048
Fibre Content (FC)	38.1%		
Subgroup Name	Hemic		
Degree of Humification	H4 to H6		

3.3. Displacement of load settlement
The displacement of load settlement results and discussion for this study were presented in two types which are without bamboo and with bamboo.

3.3.1 Load settlement without bamboo
Figure 2 shows the displacement of load settlement for the physical modeling without bamboo. The results show that the experimental works were conducted in 1 hour and 2 hours' time as scheduled. The load was applied regularly in kg/cm^2 starting from 1, 2, 3, and 4 kg/cm^2. In a period of 1 hour, the settlement shows 2.509 mm displacement in 1 kg/cm^2. However, after applying a load of 2 kg/cm^2, the settlement increased to 52% which is 5.201 mm displacement. While in 3 and 4 kg/cm^2 load, the displacement also shows follow a similar trend. The studies of Yusof *et al*., [14] also show a similar trend of displacement upon the load application until it stabilizes.

3.3.2 Load settlement with bamboo (single layer)
Figure 3 shows the displacement of load settlement for the physical modeling of single-layer bamboo. The results show that the experimental works were conducted in 1 hour and 2 hours' time as scheduled. The load was applied regularly in kg/cm^2 starting from 1, 2, 3, and 4 kg/cm^2. In a period of 1 hour, the settlement shows 0.982 mm displacement in 1 kg/cm^2. However, after applying a load of 2 kg/cm^2, the settlement increased to 52% which is 1.993 mm displacement. While in 3 and 4 kg/cm^2 load, the displacement also shows follow a similar trend. In a period of 2 hours, the settlement shows 1.429 mm displacement in 1 kg/cm^2. However, after applying a load of 2 kg/cm^2, the settlement increased to 39% which is 2.325 mm. The result shows the higher load gave effectiveness to the reduction of the peat soil compression.

3.3.3 Load settlement within time (1 hour)
Figure 4 shows the displacement of load settlement for the physical modeling of load settlement within time (1 hour). The peat without bamboo reinforcement shows displacement in the range from 2.509 mm to 8.919 mm. It shows that around 72% of the displacement increases regularly in kg/cm^2 starting from 1, 2, 3, and 4 kg/cm^2. However, with a bamboo single layer, the displacement is in the range of 0.982 mm to 3.58 mm. It shows that around 73% of the displacement increases regularly in kg/cm^2 starting from 1, 2, 3, and 4 kg/cm^2 also. The reinforcement bamboo reduced the displacement of the settlement by around 61% to 62% under load 1 kg/cm^2 and as well as 60% under load 2 kg/cm^2

and 3 kg/cm^2. As stated by Zainorabidin *et al*., [9], the performance of bamboo reinforcement shows it effectively supports and decreases the displacement of the settlement of peat under a load.

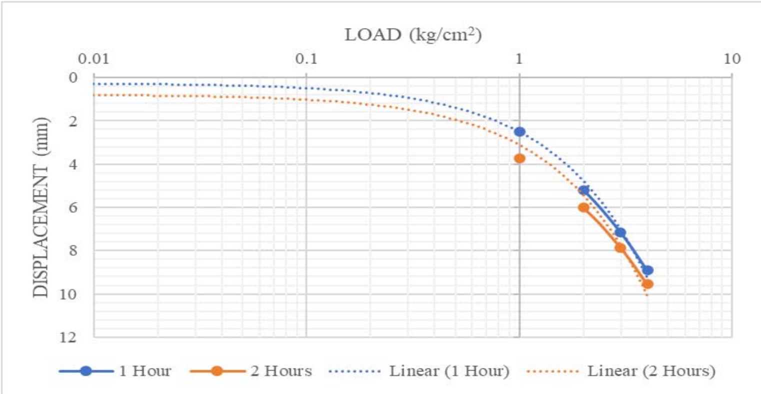

Figure 2. Without bamboo

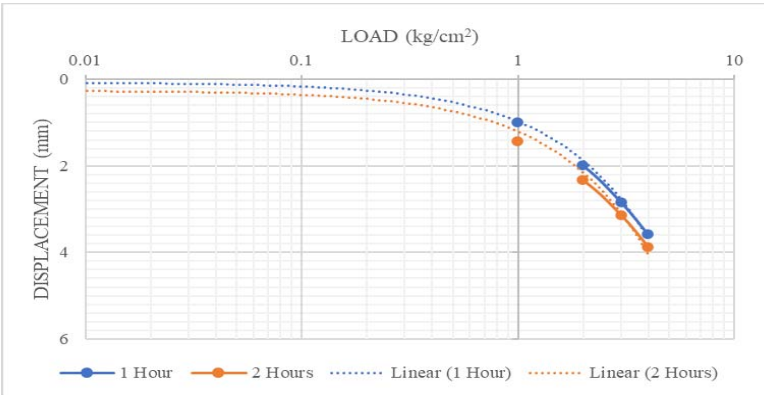

Figure 3. Single - layer bamboo

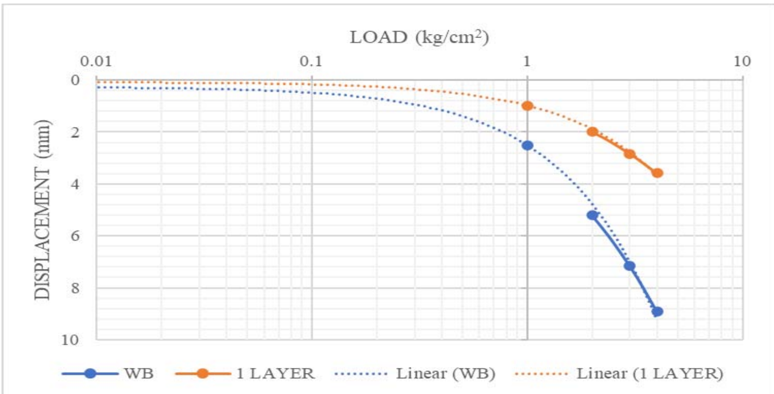

Figure 4. One Hour Period Time

3.3.4 Load settlement within time (2 hour)

Figure 5 shows the displacement of load settlement for the physical modeling of load settlement within time (2 hours). The peat without bamboo reinforcement shows displacement in the range from 3.728 mm to 9.543 mm. It shows that around 61% of the displacement increases regularly in kg/cm^2 starting from 1, 2, 3, and 4 kg/cm^2. However, with a bamboo single layer, the displacement is in the range of 1.429 mm to 3.867 mm. It shows that around 63% of the displacement increases regularly in kg/cm^2 starting from 1, 2, 3, and 4 kg/cm^2 also. The reinforcement bamboo reduced the displacement

of the settlement by around 62% without reinforcement bamboo as well as 60% with bamboo. It continued with decreased of slightly 59% under load 4 kg/cm^2.
As stated by Waruwu *et al.*, [7], the performance of bamboo reinforcement shows it effectively supports and decreases the displacement of the settlement of peat under a load and enhances the bearing capacity of peat.

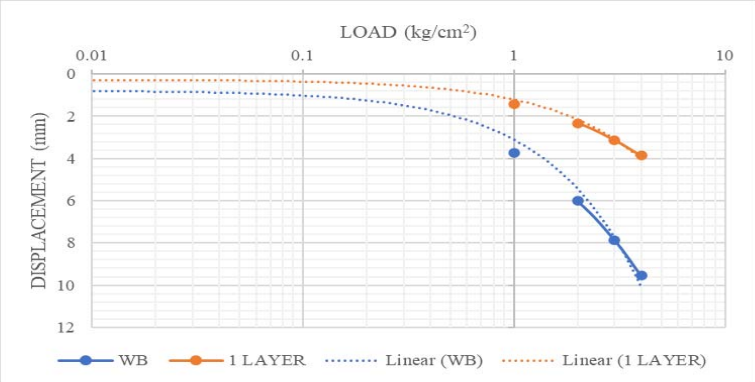

Figure 5. Two Hours Period Time

3.3.5 Load settlement displacement
Figure 6 shows the load settlement displacement for the modeling of peat without bamboo reinforcement and with bamboo reinforcement within time (2 hours). The displacement of the settlement decreases slightly by 60% in 1 hour with a load of 4 kg/cm^2. It decreased by 59% settlementin 2 hours after applying the same load. The settlement increased over time, even the bamboo reduces the settlement. As stated by Zainorabidin *et al.*, [9], the performance of bamboo reinforcement affects the peat soil displacement of settlement.

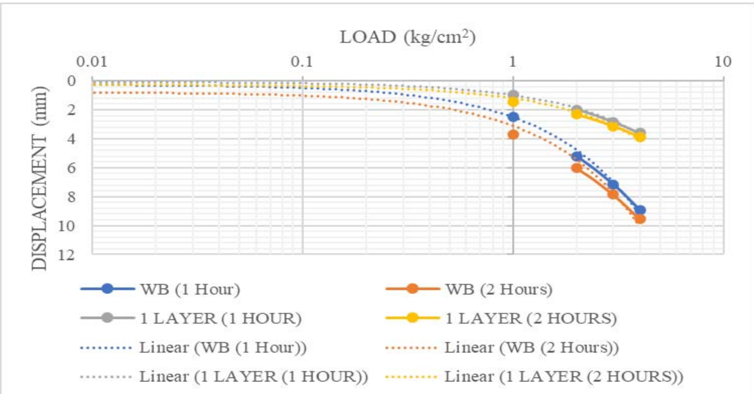

Figure 6. Load settlement displacement

4. Conclusions
In this study, bamboo Dendrocalamus asper is used as reinforcement to observe the displacement of settlement of peat soil. For Kampung Parit Puteri Menangis, Benut, Johor, the physical properties were determined as follows: moisture content of 672%, specific gravity of 1.23, organic content of 88.34 – 96.19%, fiber content of 38.1%, and categories H4 to H6 (Hemic). All these physical properties give different performances of the settlement. The displacement of the settlement of bamboo on peat shows that the peat soil settlement was lower with single-layer bamboo. In different loads (1, 2, 3, and 4 kg/m^2), the bamboo reinforcement decreased the displacement settlement of peat. Peat soil is an organic soil. As soil that has sponge characteristics, it can absorb the water making it soft and not

stabilize in natural conditions. The stability of peat soil needs to improve for stability purposes. The performance of peat settlement depends on peat characteristics.
The different locations of peat show different challenges in the displacement of settlements for construction foundations. In onsite application, the reinforcement of bamboo can reduce the settlement in its stability of peat.

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Acknowledgement
This research was supported by Universiti Tun Hussein Onn Malaysia (UTHM) through TIER 1 (vot Q133). This research was made possible by the help of Prof. Ir. Ts. Dr. Adnan Bin Zainorabidin from RECESS UTHM. The authors also wanted to thank friends from UTHM for their support and UTHM Publisher's Office via Publication Fund E15216.

Deformation of Peat Soil Reinforcement Settlement Using Single-Layer Bamboo Dendrocalamus Asper

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2) Nurul Aina Khairul Anuar (N A Khairul Anuar) is an undergraduate student at the Faculty of Civil Engineering and Built Environment, University Tun Hussein Onn Malaysia (UTHM). N A Khairul Anuar's role as the principal author of this paper is focus on data and writing a good report. She is also writing the methodology, writing the original draft, and writing the review.

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