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RELIABILITY OF HYDRAULIC STRUCTURES ON LOESS SUBSIDENCE SOILS

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Abstrakt. *The practice of irrigation development of loess lands shows that the violations that have occurred so far in the operation of hydraulic structures are explained by insufficient knowledge and lack of consideration in the design of the features of joint work and interaction of structures with their subsidence bases. The design of hydraulic structures also does not fully take into account these features.To ensure the long-term, reliable, and economical operation of hydraulic structures on subsident soils, it is necessary to improve the methods of their design and construction, taking into account the peculiarities of interaction with loess bases. This article is devoted to this issue.*

Keywords: *subsidence of soil, infiltration, degree of humidity, calculation of deformations, hydraulic structures, loess grounds, the process of moistening, terms of preliminary soaking.*

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CHO‘KUVCHAN LYOSS GRUNTLARDAGI GIDROTEXNIK INSHOOTLARNING ISHONCHLILIGI

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Annotasiya. *Cho‘kuvchan lyoss erlarda sug‘orishni rivojlantirish amaliyoti shuni ko‘rsatadiki, gidrotexnik inshootlarning ishlashida shu paytgacha sodir bo‘lgan buzilishlar bu sohadagi bilimlarning etishmasligi va ularni birgalikda ishlash xususiyatlarini loyihalashda va tuzilmalarning cho‘kish asoslari bilan o‘zaro ta’sirida hisobga olinmaganligi bilan izohlanadi. Gidrotexnik inshootlarning tuzilishi ham bularni to‘liq hisobga olmaydi. Bunda gidrotexnika inshootlarining quruq tuproqlarda uzoq muddatli, ishonchli va tejamkor ishlashini ta’minlash uchun lyoss asoslari bilan o‘zaro ta'sirning o‘ziga xos xusυsiyatlarini hisobga olgan holda ularni loyihalash va qurish usullarini takomillashtirish zarur. Ushbu maqola ana shu masalaga bag‘ishlangan.*

Kalit so‘zlar: *gruntning cho'kishi, infiltratsiya, namlik darajasi, deformatsiyalarni hisoblash, gidrotexnik inshootlar, lyoss asoslar, namlash jarayoni, dastlabki namlash shartlari.*

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НАДЕЖНОСТЬ ГИДРОТЕХНИЧЕСКИХ СООРУЖЕНИЙ НА ЛЕССОВЫХ ПРОСАДОЧНЫХ ГРУНТАХ

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Аннотация. *Практика ирригационного освоения лессовых земель показывает, что имевшие место до сих пор нарушения в эксплуатации гидротехнических сооружений объясняются недостаточными знаниями и неучетом при проектировании особенностей совместной работы и взаимодействия сооружений с их просадочными основаниями. Проектирование гидротехнических сооружений также не в полной мере учитывает эти особенности. Для обеспечения длительной, надежной и экономичной эксплуатации гидротехнических сооружений на просадочных грунтах необходимо совершенствовать методы их проектирования и возведения с учетом особенностей взаимодействия с лессовыми основаниями. Этому вопросу и посвящена данная статья.*

Ключевые слова: *просадка грунта, инфильтрация, степень влажности, расчет деформаций, гидротехнические сооружения, лессовые грунты, процесс увлажнения, сроки предварительного замачивания.*

Introduction

Currently, large-scale measures are being implemented all over the world, including in the Republic of Uzbekistan, to extend the service life of hydraulic structures on irrigation systems that are built and are being built on loess subsidence soils, to reduce damage from their breakdowns and failures, as well as to develop safety criteria. The works of some researchers devoted to this problem are known [1-8, 15, 18]. Despite this, some issues related to the stress-strain state of the subsidence soils of the foundations of hydraulic structures that are operated in a difficult continental climate and water scarcity in the south of the Republic of Uzbekistan remain unresolved [16-21].

Methods

The experiments were preceded by the development of a methodology, their careful preparation, and the choice of methods for processing the results obtained by the recommendations of M. N. Goldstein [10].

At the planning stage of the experiment, the factors influencing the result were determined, and then the experimental levels of these factors were selected.

The nature of the stress distribution in the soil foundations of hydraulic structures depends on some factors: physical and mechanical properties, structure, humidity, heterogeneity of the soil, the size of the foundation of the structure, the magnitude of the transmitted pressure on the base, etc. The abundance of these factors makes it difficult to make a theoretical decision on the reliable determination of stresses in soils. In this regard, for a more accurate determination of stresses in the ground foundations of structures, it is necessary to resort to an experimental way.

The study of stresses in soils, which is technically quite a difficult task, is complicated by the lack of a single generally accepted experimental methodology. In particular, there is no generally accepted method of installing mesdoz at the depth of the soil mass of the undisturbed structure serving as the base of the structure. For a long time, the most common method of installing mesdoz was to place them in layers in a vertical well, followed by plugging this well with recycled soil [11, 13]. Later, a different method of installing mesdoz was proposed and used during die tests of loess soils [9, 11-14].

To experimentally study the patterns of transformation of the stress-strain state of loess soil, which serves as the basis of hydraulic structures, on the irrigation and reclamation network of the Karshi steppe under the guidance of Prof. S.V.Zasov [12-14], we conducted several field tests on models of flutbets of hydraulic structures. The models were round and rectangular stamps.

Results and Discussion

So, when planning the number of tests of loess soils of the channel 4 area of the Turkmenistan massif with round stamps with an area of 1 m2, two factors were selected: 1-the amount of pressure transmitted by the stamp to the base; 2-the ratio of the pit and foundation areas.

The experimental levels for these factors were respectively 5 and 3. Thus, 15 tests with round stamps were carried out in the area of distributor 4.

Similarly, the question of the required number of stamp tests in the area of the distributor of the 2-X array "Abdulla Kodiriy" was solved, as well as when planning other types of experimental work.

Field studies of the stress-strain state of subsidence foundations under the models of flutbets of hydraulic structures were carried out in four sections of the southwestern and northeastern parts of the Karshi steppe of the Republic of Uzbekistan. The plots were located in the construction areas of channels 4 and 2, which take water through the distribution from the Karshi main canal, as well as in the end part of the same canal. The sites selected for research were typical for the Karshi steppe region and belonged to the second type of soil conditions in terms of subsidence.

The terrain in the studied areas did not have sharp natural elevation changes. The studied sites are composed of loess sandy loam and loam.

The physical and mechanical characteristics of soils were determined in the laboratory of the Department "Operation of Hydraulic Structures and Pumping Stations" of the Karshi Engineering and Economic Institute, selected from pits at experimental sites and using a device for studying the filtration and deformation properties of soil in the walls of the pit [14; 20].

Soils contain a significant amount of water-soluble salts and gypsum, which to a certain extent determines its deformability when moistened.

The relative subsidence of soil studies depending on pressure, obtained from compression tests, is given in Table 1.

The filtration coefficient was determined during laboratory tests of soils and had values in the range of 0, 18 ... 0, and 48 m/day.

The zone of channel 2 of the Abdullah Kodiriyv array is based on the principle of placing pressure sensors in depth under the base of the stamp from a pit located close to it. This method also has disadvantages: compaction of the soil around the crushed sensor, the need for a pit near the investigated soil mass, and the passage of horizontal wells. At the same time, it has the advantage that the entire column of soil above the sensor installed in this way retains an undisturbed structure.

In the works [11; 15], the authors used different methods of installing ground pressure sensors. However, conclusions on the basic patterns of stress distribution in the subsidence soils of the stamp bases were made similar. At the same time, the authors do not have a consensus on the specific distribution of pressures in the array of the ground foundation of foundation (stamp).

To determine the actual stress-strain state of the bases of hydraulic structures, we conducted 50 stamp tests of subsidence soils under various conditions of their soaking.

In the course of these numerous stamp tests of loess soils, their stress-strain state was studied both at the contact with the stamp and along the depth of the array. The stresses in the soil of the stamp bases were measured using string acoustic sensors of the design of the NIS Gidroproekt GD-128 and strain gauge mesdoz of the design of the TSNIISK. CS-5 and ISD-3 stations were used as recording equipment.

Vertical movements of the ground surface were determined by leveling surface marks, as well as marks installed at specially selected points on the structure. The measurement of soil deformations was carried out by leveling deep marks and using a constructed device [13].

Rectangular and round dies made of sheet steel or reinforced concrete were installed in pits with a depth of 0.5 meters and loaded with reinforced concrete slabs weighing 15 kN each, or using lever devices. The bottom of the pit was a carefully planned horizontal soil surface of natural composition. To improve the accuracy of measurements, the loading of stamps was carried out in small steps (0.015 MPa) with the systematic taking of readings of devices registering stresses in the soil mass and its contact with the stamp.

Table 1.

Deformability of moistened soils of experimental areas

Location of the site	**Relative subsidence at a pressure equal to**			
The zone of channel 4 of the array "Turkmenistan"	0, 031	0, 063	0, 086	0.096
The zone of channel 2 of the Abdulla Kodiriy array	0.015	0.027	0, 033	0.043
Channel zone 3 of the Samarkand array	0, 011	0, 019	0.028	0.031
Channel zone of the Surkhan array	0, 019…0, 031	0, 027…0, 055	0, 038…0, 079	0.034....0.091

After the load on the stamp reached the set value, the ballast was secured with stretch marks to avoid an accident. The characteristic points for leveling were selected on the structure. As a rule, they served as the centers and corners of the upper load plate.

After stabilizing the process of soil precipitation, water was supplied to the pit.

During the experiments, as well as during the calibration of mesdoses, it was taken into account that the devices register the stressed state of the soil, distorted by the presence of a foreign inclusion-a ground dynamometer (mesdoses).

To account for this distortion, experiments were carried out at the experimental site in the area of channel 4 of the Turkmenistan array, the purpose of which was to identify the influence of the mesdoz installation technique in the ground on the wear readings when measuring stresses arising in the ground.

In order to identify the most rational way of installing mesdoz at the base of structures and their models, special methodological experiments were conducted. During these experiments, the stresses at the base of a rectangular die 32x32 cm were measured. At the base of the stamp in each experiment, at a depth of 35 cm, the mesdose of the TSNIISK design was installed. The ISD-3 station was used as secondary measuring equipment.

When installing strain gauges, various methods were used.

1. Mesdoses were installed in vertical wells, followed by layer-by-layer ramming of the soil tamponing the well to a density equal to natural (Curve 1, in Fig.1).
2. Wells were tamponed with recycled soil without ramming (curve 2, in Fig. 1.).
3. The soil tamponing the well was thrombed to a density significantly exceeding the density of the soil of an undisturbed structure (curve 3, in Fig.1)
4. Mesdoses were installed at the base of the stamp from the pit through a horizontal pioneer well, followed by filling this well with soil with a density close to the density of the soil of the undisturbed structure (curve 4, in Fig.1).
5. Mesdoses were installed at the base of the stamp from the pit through the pioneer well without subsequent plugging of this well (curve 5, in Fig.1).

In all cases, the pressure transmitted by the stamp to the ground was 0.1 MPa.

As can be seen from Fig.2. when filling the cavity formed during the installation of the mesdose with recycled soil without its further filling, the sensor reacted to the pressure transmitted from the stamp to the soil only 5-7 hours after the start of soaking. The soil moisture around the sensor by this time exceeded the value of ω = 20%.

The reverse pattern occurs when the soil filling the well is compacted to a density greater than the raised one. The significant stresses recorded by the sensors when they are installed using this method should be explained by the fact that the soil laid in the well works similarly to a soil pile.

The curves obtained in similar experiments using a method close to optimal should lie between curve 3 on the one hand and curves 2 and 5 on the other.

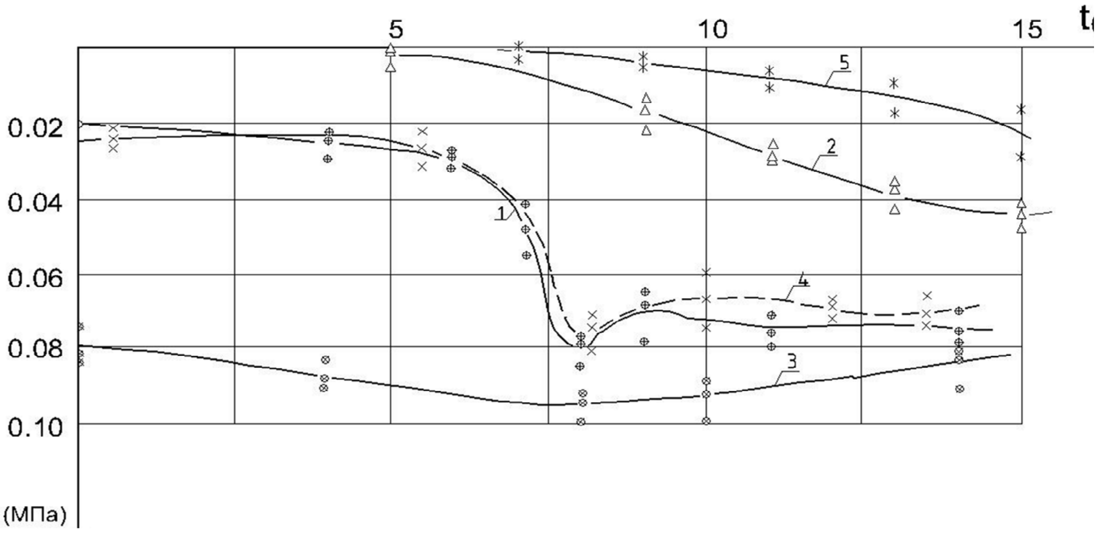

Fig 1. Graphs of changes in the mesdose readings established by various methods inthe silenced loess base of the stamp

For comparison, we conducted experiments using the methods given in [11 and 14], the results of which correspond to Curves 1, 4 in Fig.1.

Consider the experimental relationship between the vertical stresses σ and the soil soaking time t. In both groups of experiments, during the period t = 7-8 hours, a surge of vertical stresses was recorded associated with the passage of the soil moistening front through the experimental horizon.

For the regions t< 7 h and t > 8 h, smoothed dependencies (parabolas) can be carried out through the experimental points corresponding to the first method of setting mesdoz. Their equations, found by the least squares method, are :

$$\sigma = 1,016\ t2 - 3,45\ t + 20,74\quad t \leq 7,1$$

and

$$\sigma = 0,452t^2 - 10,36\ t + 133,38\quad t \geq 8$$

The standard deviation of the experimental points from the proposed dependencies is $\Delta 1 = \pm 0.005$.

The group of experimental points corresponding to the fourth curve in Fig.2 agrees well with the above dependencies. Their mean-square deviation is $\Delta 4 = \pm 0.0055$. The average deviation from the curve is $\sigma = -0,0029$. The value of t (Student statistics) is= 2.2

This value corresponds to a confidence probability of 0.95, which indicates a statistically insignificant difference between the methods of installing mesdoz 1 and 4.

Based on the results of the research, the method of installing mesdoz was chosen, corresponding to curve 1 in Fig.1.

The calibration of mesdoz was carried out using a special device [13] in soils of natural composition. The load on the ground was transmitted through a 32x32 cm stamp. The side of the stamp in contact with the ground is made in the form of an elastic cushion filled with liquid, which guaranteed a uniform distribution of pressure along the plane of contact of the stamp with the ground.

The sensors were installed in the base of the stamp at a depth of 5 cm. Since this depth is much smaller than the side of the stamp, it was assumed that the normal stresses at this horizon are almost equal to those occurring at the contact of the stamp with the base.

Mesdoses intended for measuring the horizontal components of the stress tensor were installed for taring into the base of the stamp to the same depth through horizontal wells, followed by their padding. This made it possible to bring the calibration conditions of the sensors as close as possible to the conditions of their operation - the measurement of the component of the stress tensor perpendicular to the axis of the well.

In the course of fieldwork, in parallel with the study of the stressed state of the soil mass, studies of the features of the process of its humidification were carried out. For this purpose, models of hydraulic structures' flutbets and pits were equipped in such a way that, with the help of the neutron humidity indicator NIV-1, it was possible to constantly monitor the process of extending the humidification front in the base under the bottom of the pit. The humidification contour of the array away from the side of the pit was controlled by drilling with the determination of humidity by the depth of the thermostatic method.

It should be noted that conducting a significant number of experiments to study the joint operation of models of flatbets of hydraulic structures and their loess subsidence bases requires a lot of labor. In addition, the study of the advance of the humidification front into the depth of the array of the base of the flutbet model using a neutron humidity meter has the disadvantage that the soil moisture is recorded only along the axis of the well into which the radiation source is lowered. Humidity at a point located at some distance from the axis of the well cannot be determined in this way.

A similar disadvantage has a device for measuring layer-by-layer deformations of the soil, which we used during fieldwork. The deformation of the soil with its help can be recorded only near the well in which the device is installed.

In this regard, scientists Frolov N.N., Zasov S.V., Dokin V.A. [12-14] created a device that allows to obtain more complete information simultaneously about the processes of humidification and transformation of the stress–strain state of the bases of models of flatbets of hydraulic structures, in addition, with the help of this device, it is possible to study the physical and mechanical properties of the soil in the walls the pit.

During the tests, the load on the ground is transmitted through the stamp using a lever loaded with weights and held by the frame. A transparent screen makes it possible to monitor the deformations of the soil at the base of the stamp. At the same time, with the help of strain gauge elements mounted on the screen, it is possible to investigate the process of stress transformation at the contact of the screen and the soil mass. When soaking the base of the stamp, the device allows you to monitor the process of moistening the soil.

In the process of conducting experiments, we used stamps having the shape of a rectangle or a semicircle. The semicircular stamp during installation was in contact with the screen of the device along the length of its diameter. Due to the high rigidity of the screen, this made it possible to simulate the processes occurring at the base of a round die of the same diameter.

The use of the proposed device makes it possible to replace several devices [13] installed with different orientations.

In most cases, an experiment conducted using this device allows you to replace several experiments conducted with traditional equipment. So, to study the deformation properties of a loess subsidence base, in practice it is necessary to conduct a series of identical stamp tests with the installation of reference points in an array of soil and with the opening of the bases of stamps in each of the experiments at one of the stages of the experiment. In addition to traditional indicators, as the main design parameters of the stages of the loess soil deformation process, it is also necessary to establish the end of the sediment deformation, the moment of formation of subsidence cracks, and the end of post-subsidence compaction. These experiments can be replaced by one experiment using the proposed device. No expensive equipment is required for its installation. Two workers can prepare him for the experiment within 3-4 hours. During the research period, more than a hundred experiments were conducted with the device in question.

In the objects under consideration, together with S.V.Zasov, experimental studies of the stress-strain state of the loess bases of tubular crossings-the differences most prone to accidents during the first year of operation were carried out. The peculiarities of the operation of tubular drops were studied on the example of temporary structures of the inter-farm distributor of the Surkhan array, installed without preliminary preparation of their bases. The structural parts of the structures were equipped with control and measuring equipment devices for measuring the movements of parts of structures and layer–by-layer deformations of the soil, sensors for measuring contact stresses along the edges of the head (GD-128 complete with the CS-5 station), and stresses in the soil array (M-70 complete with the ISD-3 station).

The specifics of the interaction of the water supply parts of irrigation facilities with subsidence bases are considered in sufficient detail in [13]. However, the presence of a large number of violations in the operation of the heads - diaphragms of tubular structures required the study of the features of work on subsident soils and these elements.

In the process of work, a pattern of changes in natural stresses in an array of low-moisture loess soil in the bases of stamps was established when the latter was loaded to 0.2 MPa.

The stress distribution over the depth of the base in the soil of natural moisture under the centers of round and square stamps with an area of $1m^2$ is illustrated by Curve 1 in Fig.2 and Curve 1 in Fig.3. Due to the uneven distribution of stresses along the contact of the stamp with the ground, their values under the centers of the stamps differ significantly from the average.

Conclusions

Thus, the discrepancy between the calculated and the results obtained during stamp tests can be explained by the structural features of loess soils, which are dispersed anisotropic media.

The conducted experiments have shown that when calculating the core in low-moisture loess soils according to the generally accepted methodology, it is necessary to take into account the features of these soils as the foundations of structures. The proposed calculated dependences make it possible to clarify the depth of the active (compressible) zone in the foundations of structures erected on low-moisture loess soils and the peculiarities of stress distribution in them.

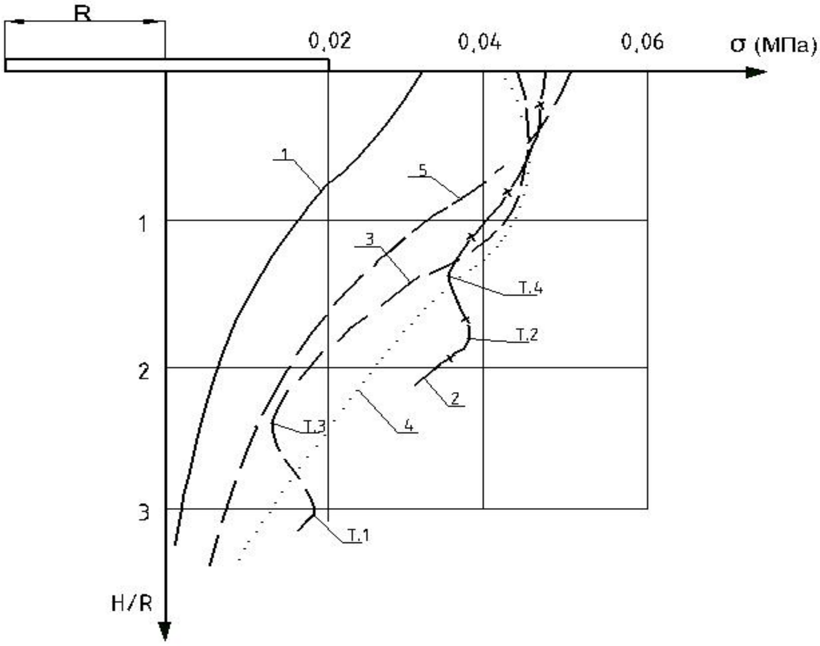

Fig.2. Transformation of vertical stresses along the depth of the base under the center of the stamp F = 1m2 P = 0.05 MPa 1-distribution of measured stresses in the soil of natural humidity: 2-the same at H3-1.3 m; 3-the same at H3 = 1.7 m; 4-the same with a steady humidification circuit: 5-by calculation following the instructions of КМК 2. 02.02-98.

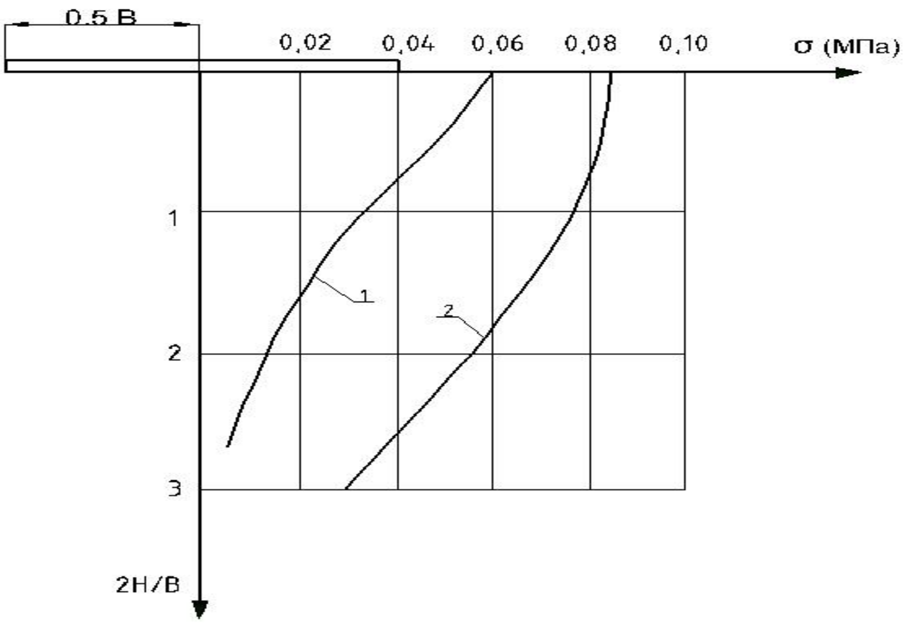

Fig. 3. Distribution of vertical stresses in the soil of natural moisture (curve 1) and after moistening (curve 2) along the axis of the square stamp F = 1m2, P = 0.1 MPa.

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