International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 4, Issue 6, June-2018

# PRE-CAST CONCRETE PANELS FOR ACCELERATED CONSTRUCTION OF RIGID PAVEMENTS

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***ABSTRACT-The ability to construct the overall pavement within the stipulated time frame is of paramount importance. It is important to complete all the construction activities which will enhance the operational capabilities within the desired time frame. Hence, in order to reduce the construction time of rigid pavements to include rigid portion of runway, multiple activities are required to be clubbed and done simultaneously. Also, during construction stage only, the long-term planning for repair and maintenance should also be considered and hence the designing part of various segments should be done in such manner that incase of any repair required in particular portion, it can be done within limited time without disturbing the overall functionality of the overall runway.***

***Presently, themethod used for construction of rigid portion of pavement is by cast-in-place, high-strength concrete. The cast-in-place method is labourand time intensive work. The method which is being talked by us incorporates use of pre-cast pre-stressed concrete panels being placed on the prepared area.This pre-cast panels can also be used in construction of rigid road pavements***

***The study carried out can be beneficial forfuture researcher for improving the methodology for construction of rigid pavements for both runway and roads.***

***KEYWORDS: Runway, Operational Capabilities, Pre-Cast Concrete Panel, Rigid Pavements, High Strength Concrete***

## I. INTRODUCTION

Pavements to include runway sare strategic assets which function as the heart of any developing nation. A structurally and functionally sound pavement increases the operational and functional efficiency of countries transport sector manifold besides providing flexibility for providing strategic air operational capabilities to armed forces. Runway/pavements construction are cost and time intensive works which involve mass concreting / laying of bituminous hot mix. Meticulous planning and strict quality control during execution has to be ensured to deliver a quality end product.

Pre-cast concrete pavements slabs can be effectively be used for highways, lane widening, exit ramps , non load bearing surface on edges of parallel taxi tracks and above all for speedy surface repair or new construction.

Using a fully cured concrete slabs in either new construction or in reconstruction or repair results in accelerated construction ,resulting in reducing work zone timeframe without jeopardizing the quality , durability and long term performance.

The aim of this study is to ensure delivery of quality end product in rigid pavements related works.

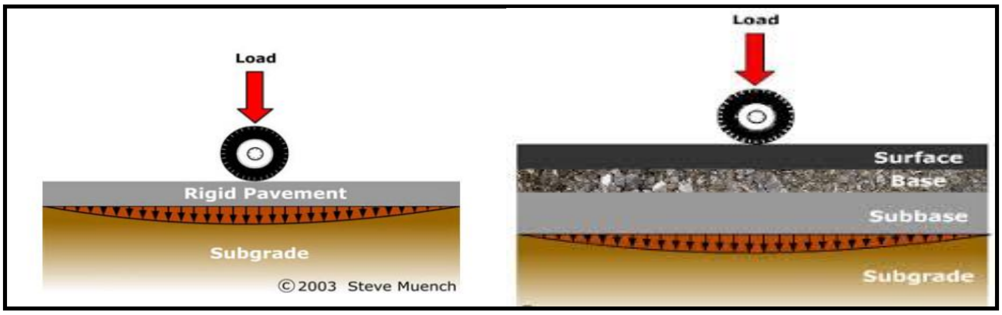
## II. PRECAST PAVEMENTTECHNOLOGY

### 2.1 Pavements:-

Pavements are divided into two main categories: **Rigid** and **Flexible**. The wearing surface of a rigid pavement is usually constructed of Portland cement concrete such that it acts like a beam over any irregularities in the underlying supporting material. Rigid pavements may or may not have a base course between the sub grade and the concrete surface.

The wearing surface of flexible pavements, on the other hand, is usually constructed of bituminous materials such that they remain in contact with the underlying material even when minor irregularities occur.

Flexible pavements consist of a sub-grade (prepared roadbed), the sub-base, the base and the wearing surface. Flexible pavements are usually composed with several layers to provide the support of the wheel loads; hence, the load will be transferred from one layer to another. Rigid pavements on other hand apply the wheel loads all over the slab. The load distribution over the flexible and rigid surface is shown by the help of the diagram underneath.




**(a) Rigid Pavement** **(b) Flexible Pavement**

***Fig 1: Distribution of load stress in Pavements***

With the growing number of air traffic and vehicle movements on pavements, thecapacityof the constructed pavements overrun's its original design load capacity in much faster time frame. Moreover, the overloaded traffic makes thedeterioration of the pavement faster thus it becomes more important to find out the best way to build pavements, which satisfies the quality and quantity within the shortest time and lowest budget. In the conventional way of building pavements, highways need to be closed for further construction or renovation. This unquestionably results in greater traffic congestion. In order to minimize the potential problem, precast pavement may be a good solution.

**2.2 Pre-cast Concrete Pavements:-**

**2.2.1 Overview of Precast Concrete Pavement:-**

Precast concrete pavement systems are systems that are essentially fabricated orassembled off-site, transported to the project site and installed on a prepared foundation(existing pavement or re-graded foundation). These systems do not require field curingfor the precast concrete panels and require only minimal time for system components toachieve strength before opening to traffic. Precast concrete members can be assembled and fastened together on the jobsite.

The major advantages of the precast concrete are two-fold. First, it is the speed of construction. Precast members can be cast in precast plant or on the project site. They can be stored and transported to the project site whenever they are needed. There is no on-site construction time for form building, concrete mixing, curing, or form removing. Second, it permits mass production of precast members on a casting plant floor or on the ground near the construction site in protected locations where better qualitycontrol can be maintained.

**2.2.2Design Criteria: -**

The design of precast concrete involves many reasonable factors' the important step is todetermine the specific values of various independent variables. However, the determination has to be based on a thorough understanding of the factors affecting the design, thus allowing the precast concrete to sustain the traffic loads and environmental influences within its life.

The slab is prepared in the factory and the requisite strength is achieved by curing to ensure that the product that is strong, watertight, and durable. Curing is the chemical reaction that occurs between the cementitious materials and water, to form a Calcium Silicate Hydrate (CSH) gel, or the "glue" that binds all of the ingredients together. In order to achieve complete hydration, it is important that moisturedoes not evaporate from the product, and that the product be in a heated environment.

One of the most common methods, used at precast plants, is accelerated curing where strength gain is accelerated by the use of live steam, radiant heat or heated beds. The use of commercial accelerating admixtures is also commonly used by some precast manufacturers.

A typical accelerated curing cycle consists of four parts:

1) **Preset (or Pre-heating)**- Preset allows the product, a period of time to commence hydration. Subjecting the product to higher temperatures before the product has begun hydration can result in thermal shock, and cracking.
2) **Ramping** – This is the period during which the product is raised from the preset temperature to the curing target temperature, and must be done at a controlled rate of between 10°C to 20°C per hour. The minimum temperature of 10°C/hour is required to rapidly activate the hydration process, while the maximum temperature of 20°C/hour is necessary to prevent thermally shocking the product.
3) **Holding Period** –The product is placed at the target curing temperature (60°C to 70°C) until the desired concrete strength is developed.
4) **Cooling Period** – The product temperature is cooled at a maximum rate of 15°C/hr and the internal temperature is monitored until the concrete temperature is not more than 20°C above the ambient temperature. The product may be stripped, handled and placed outdoors during this period.

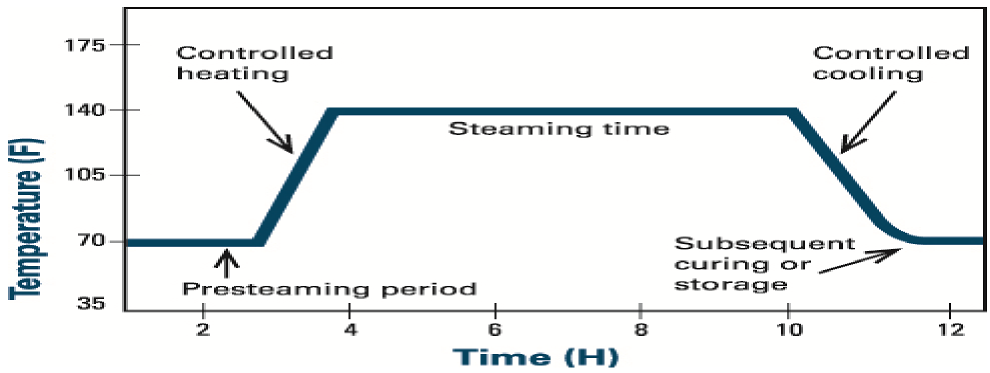



*Fig 2. Idealized Accelerated Curing Cycle*

In general, the higher the curing temperature, the faster the desired concrete strength is achieved. Precast concrete typically achieve 28 day strengths at stripping times of 16 hours or less, depending on the concrete mix design. This curing cycle enables them to reuse their forms on a 24 hour cycle.

**2.2.3 Design Factors:-**

The following design factors are to be reviewed and are to be kept in mind while designing the pre-cast concrete panel.:

**2.2.3.1 Elasto-Plastic Behavior Under Loads:-**

The magnitude of the extreme fiber stress in the pre-cast concrete members can beincreased by an amount equal to the pre-stress. In the designbeing used presently the incorporated concepts are still conservative. They are restricted within the elastic range that neglects the re-distributionof partial plastic ranges in the pre-cast concrete and thus results in the potential increase in loadcarryingcapacity. Thus during the design of these pre-cast panel these elasto-plastic behavior has to be taken into consideration.

**2.2.3.2 Load Repetition:-**

Pre-cast concrete has a fatigue endurance level that is a dependent variable of applied stress levelsand number of repetitions. For a given load, these factors either increase the required pre-stressedlevel for a given pavement thickness or increase the thickness for a given pre-stress level.

**2.2.3.3Subgrade Restraint:-**

Differential movement between a pre-cast concrete slab and the sub-grade is resisted by friction, whichinduces restraint stress in the pavement. The magnitude of the restrained stress is a dependent function ofthe co-efficient of sub-grade friction and the dimensions of the slab this is at the maximum at the midlength and midwidth of the slab.Thus during designing the slab the consideration for this differential movement has to be accounted for.

**2.2.3.4 Temperatures Curling:-**

The precast concrete slab will curl toward the side with the lowertemperatures and this curling is resisted by the weight of the slab. Consequently, tensile stresses develop on the side that has the lower temperatures while compressive stresses develop on the other side. Thus the factor of curling has to be accounted for during design stage and temperature curling is to be avoided by provision of uniform temperature throughout the slab.

**2.2.3.5 Moisture Warping:-**

Tensile stresses develop on the top surface of the precast concrete slab due toits relative dryness and hence compressive stresses develop on the substantially saturated bottom;consequently, warping occurs. Thus in order to avoid warping the complete slab should be kept in the equi saturated state till the time requisite strength is achieved. This factor has to be augmented during the design of the pre-cast concrete panel.

**2.2.4 DesignVariables: -**

The design variables to be considered include the following:

**2.2.4.1 Foundation Strength:-**

The stress in pre-cast concrete panelsfor a given load is inversely proportional to the strength of thesupporting foundation and the ability of the pre-cast concrete panels to withstand repetitive loads is in proportion tothe strength of the supporting foundation.

**2.2.4.2 PCP Thickness:-**

Factors affecting the design of pre-cast concrete panel's thickness include foundation strength, concretestrength, and magnitude of pre-stress and expected traffic loads. Pre-cast concrete panels thickness has beendetermined on the basis of providing the minimum allowable concrete cover on the pre-stressingtendons than on the basis of load-carrying consideration.

**2.2.4.3 Slab Length:-**

The two main factors that must be considered while selecting the maximum slab length forpre-cast concrete panels are:

1) The pre-stress force required to overcome the frictional restraint between the sub-gradeand the slab, and to provide the desired minimum compressive stress at the midlengthof the slab is proportional to the slab length.
2) The number of transverse joints is inversely proportional to the slablength

**2.2.4.4 Slab Width:-**

Slab width refers to the distance between the two exterior longitudinal free edges of thecompleted pavement.

In many instances it is not feasible to construct the full width of either a new pavement oran overlay on an existing pavement in a single operation and, hence as a result, the pavement must be constructed in two or more successive, contiguous longitudinal strips. Construction joints must be provided between adjacent pavement strips with this type of construction. This type of construction is necessary due to equipment limitation and to accommodate the public and the construction traffic.

**2.2.4.5Magnitude of Pre-stress**

Many factors must be taken into account to assure that the desired pre-stress level isobtained, including: magnitude of frictional restraint between slab and subgrade, slab thickness,slab length, maximum temperatures fluctuation anticipated during the life of the pavement, pavement curling and warping, foundation conditions, magnitude of expected traffic loads, and number of traffic load repetitions.  ranging from 150 to 300 psi longitudinally and from 0 to 200 psi transversely.

**2.2.5Construction Methodology: -**

This process can be divided into three parts (i) construction of panels (ii) preparing the ground where the panels are required to be placed and (iii)laying and placement of pre-cast panels. The following Figures used in the paper have been taken from **CTR**, UT-Austin and they illustrate the construction, fabrication, and installation procedure of pre-cast concrete panels

**2.2.5.1 Construction of Panels: -**

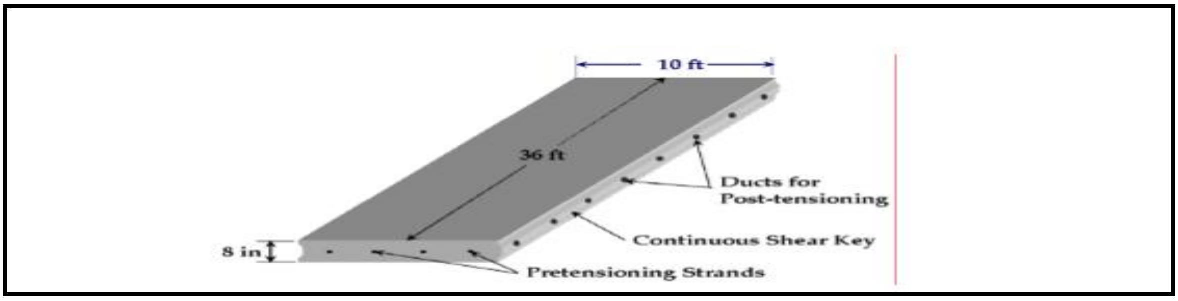



*Fig 3.1Schematic Diagram of Panel*

*Fig 3.2Reinforcement and Dowel Bar Placement in the Formwork*

*Fig 3.3(a) Concrete Placement* *(b) Texturing of Fresh Concrete.*

*Fig 3.4 (a)Curing of Precast Slabs* *(b)Stacking the Panels*

**2.2.5.2Preparation of Ground: -**

*Fig 3.5(a) Preparing Sub-base (b) Place Thick Asphalt Leveling Course*

*Fig 3.6Transport Panels to Worksite*

**2.2.5.3Laying and Placement of Panels: -**

*Fig 3.7 (a) Place Polyethylene Sheet (b) Place Panel over the Leveling Course.*

*Fig 3.8 (a) Panel Installation (b) Panel Installation and Alignment*

*Fig 3.9 (a) Stabilized Slab* *(b) Epoxy Filing and Finishing*

**2.2.6 Performance Evaluation: -**

Load transfer is a main parameter in the analysis and design of the precast panels. Load transfer depends on different environmental conditions such humidity,temperature,condition of the base,moisture content, joint spacing, load transfer devices such as dowel rods,construction quality, panel placement technique, magnitude of the wheel load and number of load applied.

Performance of the pavement constructed by using pre-cast panels can be evaluated by using an HWD. The weight of the impact load in the falling weight deflectometer (FWD) device simulates the load in the pavements.HWD testing is used to measure the plastic deformations caused. This data is used to evaluate the performance of the pavement constructed by using pre-cast panels.

**2.2.6.1 Determination of Load Transfer using HWD: -**

An HWD with load levels ranging from 30-240 kN is generally used to evaluate the structural capacity of pre-cast pavements (used in airfield). Plastic deformations resulting from the drop of the load at two sides of the joint, at several distances, are measured by a series of geophone sensors. The recorded responses and layer thicknesses are in turn used to back-calculate the modulus values of each layer. This information can be used to determine the structural capacity and the effectiveness of the pre-cast panel.

*Fig 4.1 Heavy Weight Deflectometer (HWD)*

Fig 4.2 schematically describes the deflection caused from the impact load. As shown in this fig, the HWD load is applied at one side of the slab and the deflections were measured under load, at several radial distances in the unloaded slab.

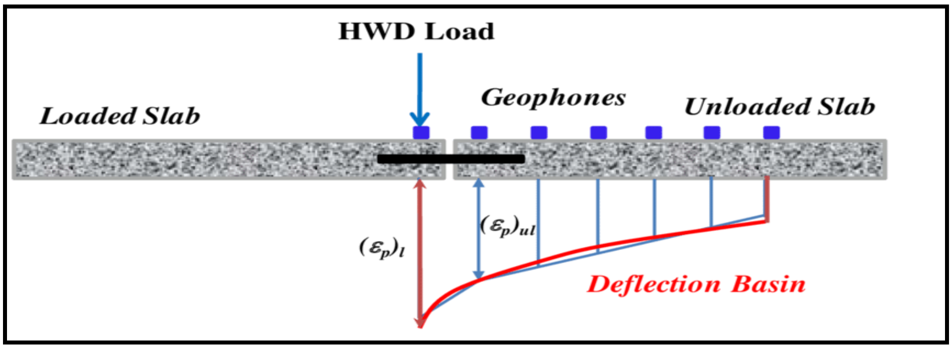



*Fig 4.2. Deflection Basin Resulting from FWD Loading System*

Proper design will reduce the rate of change in gradient of the deflection basin. Larger differences between the slope of the deflection basin on the two sides, is an indication of poor load transfer capability of the load transfer devices or loss of foundation support. If for the pavements there is discontinuity in the deflection basin on either side then it corresponds to ideal load transfer capability.

#### 2.2.6.2 Load Transfer Efficiency (LTE): -

When the vehicular movement occurs over the joint in a concrete pavement, both approaching and departingslabs deform due to load transfer between the slabs. Load transfer mechanisms such as steelreinforcement (dowel rods), aggregate interlock, and foundation support result in distribution of the load between the PCC slabs at the joints. Therefore, pavement responses such as stresses and strains are significantly lower compared to situations where no load transfer device is present.

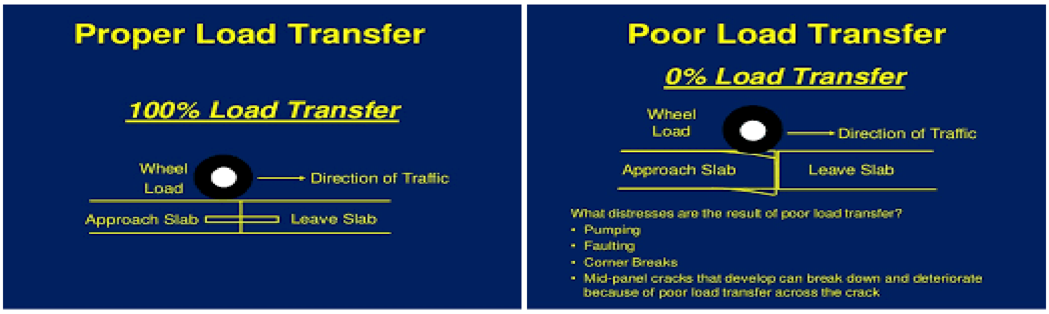



*Fig 4.3. Load Transfer Mechanism*

Fig 4.3 describes the efficiency of the load transfer devices to distribute the loads acting on the current slab to the surrounding slabs is an important design parameter which is specified by LTE. LTE is a measure to determine the contribution the load transfer devices in reducing the stresses and strains in the loading slab.LTE based on plastic strains under the loaded and unloaded slabs.

## III. ADVANTAGES AND DISADVANTAGES OF PRE-CAST CONCRETE PANEL'S

Based on study the following recommendations are suggested for use of pre-cast panels in pavements:

a. Reduce the slab length i.e. take limited length at a time.

b. Slab thicknesses considered should be based on the strength of concrete slab taken.

c. The precast panel should be connected to each other using dowels to ensure proper joint flexibility and load transfer.

d. Multi-tasking should be encouraged during the complete process of construction, transportation and placement of pr-cast panels to reduce overall time.

e. Even the pre-cast panel construction site selected should be in close proximity of the site where the actual placement of pre-cast panel is to be carried out.

**ADVANTAGES:**

a**) Expedited Construction:** As extra time is not required for the concrete to reach sufficient strength before opening to traffic, as with conventional concrete pavement, the pace of pre-cast concrete construction is expedited.

b) **Possibility for All Year Round Construction:** The panels can be precast in the factory or some place near the actual construction site and then transported hence, it allows construction of pre-cast panels throughout the year.Even overnight construction is possible hence definitely reduce the construction time.

c) **Low User Cost:** The costs incurred by the users in terms of long work time for completion of pavement can be shortened by multiple activities together hence saving upon time and labor cost. Also, as the traffic can be immediately opened for vehicular movement after placements of pre-cast panels, hence again it will impact towards saving the overall cost.

d) **High Quality and Aesthetical Value:** Pre-cast panels are manufactured in a area where critical factors including temperature, mix design and stripping time can be closely checked and controlled; and this will ensure that the quality of precast products are better than cast-in-situ concrete.

e) **Cleaner and Safer Construction Sites:** Pre-cast construction reduces the problem of site wastages and the related environmental problems. The prefabricated products also provide a safe working platform for workers to work on.

f) **Improved Quality:**Pre-cast panelsare produced in plants using modern techniques and machineries. All raw materials used such as concrete, sand, and reinforcement bars etc. are under high level of quality control. Thus, these panels have a higher density and better crack control, offering better protection from harsh weathers and sound insulation.

**DIS-ADVANTAGES:**

a**) High Capital Cost:**A large amount of resources must be invested initially to set up a precast concrete plant. Sophisticated machineries are expensive and require heavy investment.

b) **Transportation and Handling Difficulties:** Pre-cast concrete panels are more prone to damage during handling. Generally, precast panels are large and heavy, creating difficulties in transportation. Upon arrival at the sites, portable cranes or tower cranes will lift the precast components into place for erection. Usually, to increase the speed of construction, several cranes are used requiring large space. Proper construction planning and site management is a must.

**Table I: COMPARISION OF PRE-CAST AND CAST IN-SITU CONCRETE**

| PRECAST CONCRETE | CAST-IN-SITU-CONCRETE |
|---|---|
| Panels are manufactured in a controlled casting environment and have it is easier to control mix, placement and curing. | It is difficult to control mix, placement and curing in cast-in-situ concrete. |
| Quality can be controlled and maintained easily. | Quality control and maintenance are difficult. |
| Less labour are required. | More labours are required. |
| Less skilled labours are required. | More skilled labours are required. |
| Precast concrete construction is quick as it can be installed immediately and there is no waiting for it to gain strength. | In situ concrete construction is slow as gaining of strength requires time. |
| On-site strength test is not required. | On-site strength test is required. |
| Panels can be casted in advance. | Cannot be cast in advance. |
| Weather condition has no effect on casting work. | Weather condition can delay the casting work. |
| Precast concrete is a cheaper form of construction if large structures are to be constructed. | In situ concrete is a cheaper form of construction for small structures. |
| Total construction time is less as compared to cast-in-situ. | Total construction time is more as compared to precast. |
| Precast concrete does not offer a monolithic character. | In situ concrete offers a monolithic character. |
| Precast concrete requires heavy machinery and cranes for handling i.e. lifting and installation of heavy elements. | Cast-in-situ concrete does not require such handling equipment. |
| In precast concrete construction, details at the joint become very critical and needs careful attention. | No serious attention is required for joints in cast-in-situ concrete construction. |

## IV. CONCLUSION

In today's fast developing world the vehicular traffic load on the pavements to include the rigid pavements of runways have tremendously increased manifold causing the deterioration of pavement at a faster rate. Also, with increased pace of development reconstruction /construction of existing pavements or new pavements for overall development of country is a necessary requirement, hence in order to constructs the highways, pavements, runways at much faster pace pre-cast concrete pavements can be studied as an alternative option.

In this study an endeavor has been made to formulate a mechanism through which the pavements can be constructed with help of pre-casted concrete panels. Due, to paucity of adequate resources, proper trials cannot be undertaken but the study is open for future implementations.

Throughout the world lot of studies have been carried out towards repair and maintenance of concrete pavements by help of pre-cast concrete panels , but complete constructional activity of a complete stretch of pavements is yet to be undertaken in totality. By the study of pre-cast concrete panel one thing is sure that once it is being used as an alternative manner for pavement construction problematic areas related with pavement construction by in-situ casting of concrete such as greater trafficcongestion, delays, and user costs can be addressed.

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