Design And Analysis of Prestressed Precast Concrete Pavement Panel

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Abstract- *Precast pre-stressed concrete pavement (PPCP) has various benefits over asphalt or concrete pavement alternatives. Benefits might include thinner pavement, quicker construction, longer durability, better concrete, efficient material usage, improved economy via repetition, and considerable cost savings for users. Precast post-tensioned concrete pavement construction does have some disadvantages, however, including the need for more specialized & currently non-standard construction equipment, a potential overall reduction in ride quality, higher costs for small projects, a construction process that is different from or undefined from the standard rigid and flexible pavement, and a relatively complex construction process. However, two of the main advantages lower user costs due to quicker construction and thinner pavement are especially alluring in urban pavement maintenance and expanding clearances for bridges and underpasses. The current study aims to design and analyze the behaviour of a pre-stressed precast concrete pavement panel model. To investigate various methods of Pre-Stressed Precast Concrete Pavement and to conduct Non-Linear Dynamic Analysis of Precast roads for IRC Loading. To design and analyze the Pre-Stressed Precast Concrete Pavement when vehicle load and soil type vary. The analytical study will examine how dynamic loadings and non-uniform subgrade capacity of the structure affect pavement responsiveness. Studies in dynamic loadings are anticipated to produce recommendations for the minimum pavement thickness or the effects of subgrade reaction for dynamic response.*

Keywords- pre-stressed pavement, pre-restressed precast pavement, Concrete pavement, pavement performance, precast concrete, precast concrete pavement., etc.

I. INTRODUCTION

New, effective, & long-lasting techniques for maintaining and building roadway pavements are required due to the increasing volume of traffic and failing infrastructure across our country. The majority of pavements in use today were not made to withstand the volume of traffic present or the frequency and amplitude of rather significant loads. The installation of traditional cast-in-place concrete pavement is delayed because removing the existing pavement takes a lot of time. Pavement modules made of precast prestressed concrete can be constructed rapidly or with little preparation[1].

1.1 Precast Pavement Concept

Continuous applications & sporadic repairs of concrete pavements are the two different forms of precast concrete pavement applications.

Sporadic concrete pavement repairs with this method, precast concrete slab panels are used to carry out isolated pavement repairs. Full-panel replacement for badly cracked or broken slabs & full-depth repairs for degraded joints or cracking is the two forms of potential fixes. Additionally, as will be covered soon, full-depth repairs could be employed to fix degraded cracks and punch-outs of continually reinforced concrete pavement. Full lane width repairs are always made. The length of merely a repair area is the only difference between full-depth repairs & full-panel replacements; otherwise, the procedure is the same for both[2].To carry out a repair comparable here to the dowel bar retrofit technique, slots are cut into precast concrete panel 1 and dowel bars are placed into it. The fast-setting patching material is then inserted into the dowel slots. In a variant of this plan, the precast concrete panel does not have any dowel bars implanted in it; instead, dowel bars are added to use the dowel bar retrofitting technique after the panel has been placed.Another method for carrying out intermittent repairs involves drilling & epoxy grouting to position the same dowel bars in concrete pavement & fabricating time slots for dowel bars with the assistance of repair panels along the bottom of transverse sides. This method is similar to performing full-depth or full-slab repairs in cast-in-place concrete. Then, a group that fast sets fill in the spaces around the joint's border and the slots. Regarding the load transmission provisions, each of these

panel installation techniques has some benefits and drawbacks that are mentioned subsequently[3].

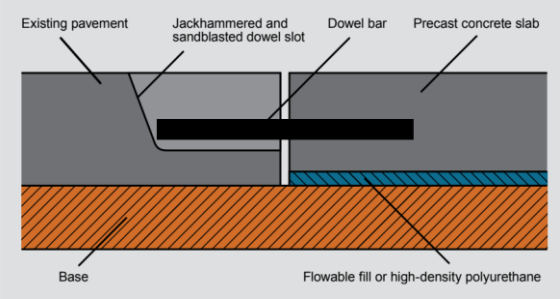

Figure 1. Schematic of the intermittent repair application. Source: Data from Hall and Tayabji (2008).

Additionally, there are various ways to install the panel itself and the base support underneath it. These methods include: placing the panel directly over the prepared base; placing and raising the panel to the right elevation utilizing expandable polyurethane foam; maintaining the panel in place with build & support beams & bedding material injected beneath the panel; adjusting the panel's height using bedding material and setting bolts[4].

The following requirements must be met by applicants for sporadic repairs: Excellent support there under panels, minimal elevation changes, limited height changes between both the panel and also the existing pavement, optimal load transfer in transverse joints, & satisfactory long-term performances of repair area[5].

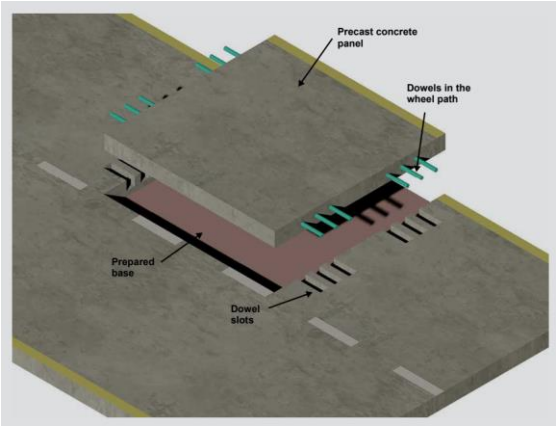

Figure 2. One scheme for intermittent repairs.

General Precast Pavement System Categories

Precast pre-stressed concrete pavement (PPCP) & jointed pre-stressed concrete pavement (JPCP) are two major categories into which PCP systems can be divided (JPrCP). Although the latter is the focus of this tutorial, both families are succinctly covered below[6].

1.2 Precast Pre-stressed Concrete Pavement (PPCP)

Typical PPCP Characteristics

Precast concrete pavement (PPCP) is a type of precast pavement that is also made by post-tensioning several transversely prestressed precast panels together with others to produce substantially longer pavement slabs (typically 150 to 250 feet in length) that seem to be essentially "jointless" as a result of the post-tensioning process. A prestressed pavement slab with two directions is the end product of the assembly. Prestressing forces reduce load and temperature-related stresses, improve the structural qualities of the slabs both in directions, or maintain firmly closed joints within the slabs[7]. Three distinct designs that are often utilized for PPCP systems are shown in Figure 3. The top of the pavement is post-tensioned through surface slots in the first two versions. Doweled joints (used for load transmission) or even expansion dams located between two precast slabs, at least one of which forms part of the PPCP slab arrangement, can be used to account for thermal expansion. In the third design, post-tensioning is carried out using the vertical faces there at the ends of the slab. Here between the post-tensioned slab, an existing pavement, or the next PPCP slab, a doweled expansion joint panel was installed. The post-tensioned assembly of panels does not include this gap panel. Typically, polypropylene sheets or any comparable low-friction surface are used to manufacture the panels to accommodate slab movement during the post-tensioning process. While injectable void-filling solutions (such as grout, urethane, etc.) may be applied & graded here on the foundation to give somewhat consistent support before placing panels, this is not usually the case in the building process[8].

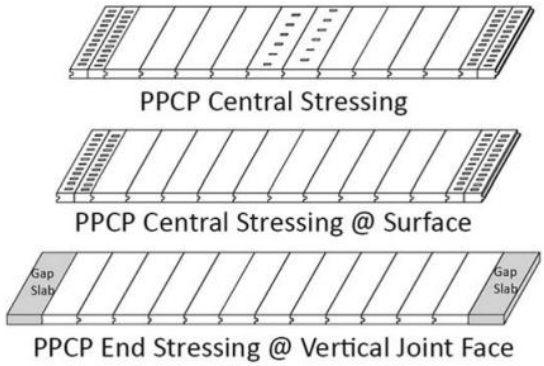

Figure 3 Schematics showing alternate PPCP design and construction options.

Pavements made of joined precast concrete

Precast concrete pavements with joints resemble cast-in-place pavements with joints. Precast concrete pavement

with joints performs similarly to the concrete pavement with joints that are cast in situ after they are in place. The following are some significant variations that affect how well the jointed precast concrete pavements perform: The panels are mounted horizontally. As a result, these don't show curling or warping brought on by construction. The steel reinforcing is included in the panels. As a result, any in-service cracks that could appear because of traffic loading over time may be kept in check. Aggregates interlock could be depended upon to transmit stress at these joints since its panel's transverse joint side is smooth (cast surfaces)[9].

The United States uses precast concrete pavements with transverse joints for weight transmission. In actuality, any jointed precast concrete pavements must include load transfer features. Round dowel bars, usually steel bars, are used in joined precast concrete pavements to transmit loads methodology used in Figure 4 with the interrupted repair is essentially similar to one load transfer technique, shown in Figure 5. In this arrangement, the bottom of the panel includes slots on one side for the dowel bars and dowel bars are inserted in the slots on the opposite side. After installation, slots or gaps around the joint's border are filled with a fast-setting group[10].

Figure 4 Two layers of reinforcing steel in each direction in a JPrCP fabrication

Figure 5 Photo of JPrCP fabrication in a prestressing bed.

Pavement made of precast concrete

PCI & also the Federal Highway Administration (FHWA) had created criteria for owner agencies to follow in choosing the best application of precast concrete pavement systems through the process of reaching consensus (PCPS)[11].

These papers again describe the benefits of PCPS for the general public who travel, such as how reduced traffic commotion is felt as a result of the enhanced quickness, durability, security, or even all construction[12].

According to site clearance restrictions, Prestressed Precast Concrete Panels (PPCP) can commonly be built in sizes to meet the width of one, two, or three lanes of pavement. This makes it possible to simultaneously reconstruct one or more lanes of an existing pavement. Precast panels are typically positioned perpendicular to the road's centerline and may have one, both, or both shoulders. During construction, these panels are frequently pretensioned within the longer direction; following installation, they are typically post-tensioned together in groups that are lengthwise and facing the traffic to act as continuous slabs. In rare circumstances, the panels may be post-tensioned during building in both directions in addition to plant pretensioning. The prestressing must be delivered in both directions regardless of the arrangement if the full advantages of prestressing need to be achieved. The panels are assembled, fastened together, & rendered accessible to traffic after being placed on a prepared base. A typical PPCP is depicted schematically in the image below[13].

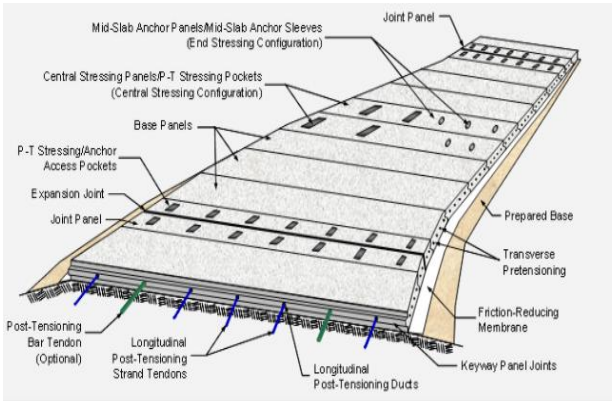

Fig.6 Typical PPCP

Similarities to Cast-In-Place Systems

A precast panel and set of panels are put on a correctly laid base during the precast pavement procedure. To work as little more than a concrete pavement system, the panel or sequence of panels must be entirely supported and securely secured.To create a completed pavement that behaves & performs similarly to excellent cast-in-place concrete

pavement, the project's PCP construction must nevertheless integrate essential elements of successful cast-in-place pavement operations. Recognizing such characteristics might help you appreciate their significance in PCP systems[14].

Figure 7. String line controlled slip-form paver approaching dowel basket (note vibrators for consolidation).

Figure 8 Plastic concrete extruded to correct grade and the cross slope behind the slip-form paver.

Benefits

The potential expedite construction is precast pavement's most obvious benefit. Precast panels enable construction to be finished overnight or on the weekends, allowing for almost immediate traffic here on the pavement. Unlike conventional concrete pavement, this type of concrete does not require additional time to reach the proper strength before opening for traffic. Reduced user costs are how expedited construction achieves its financial benefit. User costs are the expenses that motorists face simply as a result of the construction, such as higher fuel prices & decreased productivity[15]. However, these costs are hard to measure, and the general driving public is aware of them. Another crucial aspect of precast pavement is durability. Precast facilities provide better control over generating a homogeneous concrete mixture and guaranteeing the panels are properly cured by casting and curing precast pavement panels in a controlled environment. This will lessen or even get rid of issues like built-in curl/warp (caused by temperature and humidity gradients), subsurface strength loss (caused by inadequate curing), and insufficient air entrainment that are common with conventional concrete pavement. Durability is also improved by post-tensioning. In addition to reducing the required pavement thickness, post-tensioning also significantly reduces or even eliminates cracks. This not only increases the lifespan of the pavement but also significantly lowers maintenance costs[16].

II. LITERATURE REVIEW

For the literature review,the data was collected from online websites and national and international journals. The study on Pre-Stressed Precast Concrete Pavement Panel Evaluation and Panel Design for PPCP.

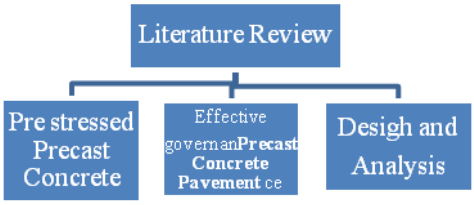

Fig. 9 Flow chart of Literature review

S. Tayabji (2010), presents the findings of the data analysis and emphasizes the field test data that have been acquired thus far from both continuous application projects and intermittent maintenance activities.Additionally, problems with the effectiveness of particular precast pavement methods are explored. The author described how precast pavement systems are manufactured or assembled off-site, transported to the project site, and thereafter installed on a prepared foundation. Before opening to traffic, system components need just a brief period of field curing time to reach strength. The precast technique may be applied to extensive, ongoing rehabilitation or spot fixes. Research is being conducted to create instruments for precast concrete pavement structure, construction, installation, maintenance, & assessment.

Kukjoo Kim's (2016) Precast prestressed concrete pavement (PPCP) technology was created as a full-scale prototype and evaluated under actual traffic load conditions. A three-dimensional finite element model was developed to perform a stress study on PPCP under severe loading conditions. An increase in either the concrete modulus or the temperature expansion coefficient led to a sharp rise in maximum stresses

within the concrete. Under critical load-temperature conditions, the concrete's elastic modulus increases, which causes a reduction in the expected stress-to-strength ratio. Variations in the base and sub-base properties had little to no impact on the maximum produced stresses in concrete. The PPCP method is suitable for a variety of sub-base & subgrade circumstances.

Hari Nurjaman (2017), This study's methodology employed a mix of qualitative and quantitative methods. Examples of qualitative approaches in use include a 2015 comparison research conducted in the USA and the performance of traditional highway building techniques, precast and prestressed concrete parameters are listed used on the surface of highway projects in multiple projects from 2007 to 2014. The idea put out is that, if design and construction are started concurrently, precast/prestressed concrete built industrially may enable highway building more quickly or with higher quality than conventional systems. If this integrated construction is done using the life cycle cost technique, it will perform better from a cost perspective. The topic of this article is a construction idea that emerged between 2015 to 2017.The idea of using green building techniques is based on an integrated manufacturing industry that starts with the design and ends with demolition. The three sub-layers of the highway—the subgrade, subbase, and surface—as well as the drainage system, are all affected by the idea. Soil dislocation, chemical improvement, or concrete mattresses are all possible subgrade improvement techniques. In contrast to typical materials, sub-foundation material employs foam mortar, which makes quality monitoring easier. Precast & prestressed concrete elements with regulated quality are used in the pavement material, which swiftly transforms into the flexible pavement and may also foresee severe loads. Cost estimation is done taking into account the entire life cycle, including the original investment, construction delays, and operational maintenance expenses.This invention has passed testing for both the technical parts of construction methods and the construction work between 2015 and 2017, therefore it is now ready to enable infrastructure building acceleration that meets the quality standards required as of this point. This idea is anticipated to serve as an alternative for Indonesia's improvement of performance in developing countries & highway construction maintenance, supporting better service to users, promoting economic activity, and contributing to sustainable development, which is now viewed as a component of the global movement to stop climate change.

Nasser m Alwehaidah (2013)using the research This research will achieve its main objectives by using design innovations including granular base material to reduce overall thickness & panels with grout gaps here on the bottom to guarantee maximum contact with the granular base. The response of precast prestressed concrete pavement to static stresses will be investigated through experimentation. Analytical studies will look at how the pavement responds to dynamic loads and non-uniform subgrade support conditions. Studies on dynamic loads are expected to lead to recommendations of minimum pavement thickness or the influence of subgrade reaction for dynamic response. The goal of this study is to increase the effectiveness and performance of PPCP.To speed up construction and minimize total pavement thickness, the designs in this research employ aggregate foundation material instead of asphalt levelling base. To reduce the amount of pavement required to prestress and to enhance the load transmission from pavement to the foundation material, the designs additionally incorporate substantial grout gaps within the precast panels. The goals of this research were met by fabricating, assembling, and testing full-scale test pavements to validate the suggested design advancements. The development of gaps and flimsy supporting here between pavement panels & aggregate foundation as a result of uneven base surface grades is one of the main issues with its use.This study shows the precast prestressed concrete pavements may be effectively erected over the compacted granular base material, provided that gaps between the pavement panels or the granular foundation are filled with grout. During assembly, there were no problems with panel levelling or height matching.

Qu Bo(2017) There isn't any structural independent investigation for full-size prefabricated pavement because this study primarily focuses here on performances for smaller-sized prestressed test pieces. We could analyse their deflection characteristics, load transmission capacities, and influencing factors of this pavement construction by assessing the deflection characteristics of this sort of interior prefabricated airport prestressed concrete pavement. Our experiment's findings indicate that three elements—friction between the slab, prestressed steel strands acting as dowel bars, and the capacity of tongue and groove joints to transfer loads—contribute most significantly to the load transfer capacity. Our findings show that an effective strategy to improve load transfer capability is to raise the measured effects level for the slab edge.We also note that the corner of the slabs, which has a poor capacity for weight transmission, is the least advantageous load-carrying location, whereas the middle of the slabs is the ideal load-bearing position. To continually improve the layout of prefabricated airport prestressed concrete, we explored pertinent elements impacting the load transfer capacity by evaluating the load transfer coefficient.

Ashutosh Singh(2019), This paper seeks to conduct a study on the precast concrete pavement system's assessment. The

new scheme of development in highway and road building is presented in this essay. Long-term traffic congestion has been brought on by the conventional cast-in-plane concrete pavement that hasbeen utilised to construct roadways. This pavement technology also has a quick construction time, cheap manufacturing costs, long-term durability, and requires little maintenance. A new precast concrete pavement (PCP) system is illustrated in this research. The primary goal of reviewing precast concrete pavement (PCP) systems would be to identify design techniques that are applied to the development of transportation infrastructure and to get a deeper comprehension of the existing systems.In particular, the deployment of precast pavement technology in the Soviet Union and more subsequently in Russia have been investigated in this research. The numerous advantages listed above demonstrate why rigid pavement is just a sustainable solution. If materials, design, & construction are optimized, it might receive an even higher consistency grade. When concrete pavement is used in highway and road construction, the operational effects of truck fuel savings & light reflection can be reduced to zero. Concrete pavement is a sustainable option due to the decreased frequency of scheduled maintenance or the lengthened pavement life cycle. The case study in this research simply aims to give a preliminary concrete pavement distress analysis.Sometimes, but not always because the causes of the issue were conjectured and could not be conclusively confirmed, the solutions resulted in revisions to specifications or designs. The important outcomes included the structural and functional restoration of new pavement and the use of minimum infiltration repair methods. potential scenario.

AMEEN SYED(2019) As he studied, The dimensioning of panels, weight transfer mechanisms, lifting arrangements, stacking arrangements, shipping, and the base preparations for PCP are all specifically covered in this study. The suitability of several PCP varieties for various site circumstances has been examined. The future use of this technology and novel PCP advancements has also been discussed. This presentation covered many PCP applications that have been created and used internationally. It has also given a succinct explanation of certain important technological topics. For the demands of practicing engineers, the suitability of distinct PCP characteristics for various circumstances has been determined.The paper also discusses the novel ideas that have been developed around this technology or its potential applications in the future. The paper gives a brief overview of the different types of PCP that have been applied globally for repairing damaged pavement, continuous pavement construction, airfield applications, & temporary pavement construction. It also covers important PCP components that should be carefully examined before being put into practice.

Josef Novak's (2017), article outlines the initial stages of creating a brand-new precast concrete pavement (PCP) technology suitable for use on highway and airport pavements. Understanding the present systems and design processes utilized for transportation infrastructure is the primary goal of the assessment of PCP systems. It is unclear how PCP systems may be used to construct new pavements. The most comprehensive experience may be traced to the 20th century when the Soviet Union's military airfields were constructed using hexagonal slab panels or the PAG system. due to cast-in-place pavements. The collected results are crucial to the continuing creation of a new PCP pavement construction system, which is scheduled for completion in 2018.The primary objectives of the proposed invention are to construct precast panels employing keyed connections rather than requiring any dowel bars and also dowel slots for transmission of load between adjacent areas as a result of the shortcomings with existing PCP methods that have been recognized.

Shiven Jiten Sompura(2017), In this study, the viability of replacing concrete pavements with precast concrete pavements, which would lead to quicker construction, thinner slabs, and a longer lifespan for the pavement, was examined. When maintaining or rebuilding roads, it has been shown that precast concrete pavement offers a longer construction season year-round and reduces traffic congestion. This study's main goal is to contrast the life cycle expenses for the precast concrete pavement with those of conventional techniques. To do this, it will compare several factors, including the initial cost of precast concrete pavements versus onsite casting, the construction process, the material used, recurring costs, maintenance costs, life assessments, and life expectancies.The study's research highlights the importance of lifetime cost and also the advantages of PPCP over JPC. This benefit can be used to shorten the project's initial construction period & lower maintenance requirements over the project's design life.

Yu-Tzu Chen, A (2015), This article describes a technique for building pavement. Precast prestressed concrete pavement (PPCP) was invented in Texas, Texas, USA. The most recent developments in the PPCP approach will be examined. Following a comparative of 5 demonstration projects, its design principles and field installation techniques will be presented. The comparison shows that PPCP is a crucial alternative for constructing future roads since it is relatively sustainable. The PPCP approach had sustainable variations and was theoretically sound. The technique is offering a sustainable option for paving the future the with aforementioned successful demonstration projects in the United States.

RadanTomekMSc.(2017), This study's goal is to compare the unique prefabrication technique to the traditional cast-in-place building process to determine its advantages and disadvantages. It also aims to draw some general conclusions and suggest some general practices for the construction industry. Summary of the author As traffic volume on that infrastructure continues to rise, users of the European highway system have raised expectations for its degree of comfort and quality. The use of technologies that enable speedy construction is becoming necessary due to the constrained capacity of the building sector. Precasting or prefabrication, whatever occurs first, appears to offer everything needed.

Tinu Mishra, (2013) Precast, post-tensioned concrete pavement and jointed precast, prestressed concrete pavement were both extensively used in the project. The design and execution of a significant precast concrete pavement project that was finished in the United States are summarized in this article. Although the innovation used on Route 680 is specific to the San Francisco Bay region, it sets a standard for other cities throughout the country to follow by being implemented during a routine nighttime highway shutdown construction period. Regular nondestructive evaluations of its performance on precast, post-tensioned concrete pavement & jointed precast, and prestressed concrete pavement should have been conducted.An instrumentation plan was created to monitor prestress loss and the interaction here between the base and the panel during installation. Precast concrete pavements are a trustworthy replacement for cast-in-place concrete pavement repair, although they are not intended to completely displace conventional concrete pavement repair methods. Precast concrete pavement use is site-specific and subject to the owner- and operator-specific requirements.

Ling Yu (2018) The oblique prestress concrete pavement was suggested in this study to enable its application for prestress both in transverse and longitudinal orientations. This study goes into great detail on the choice of raw materials, cement concrete design, anchorage site, length and distribution of prestressed tendons, stress analysis of the slab of concrete, slide layers, side reinforcement, and regular reinforcing from top to bottom. To satisfy the requirements of the fracture criterion and fatigue criteria, the stress analysis was used to estimate the tendons' thickness, size, dispersion angle, and spacing.A demonstration road pavement piece was built by the concept, and it has held up also after 3 years of traffic opening. The report also included a step-by-step explanation of the building.

Prof. Shahrukh Z (2020) This paper explores Precast Concrete Pavement (PCP) with the help of different prime journals. They can change road restoration and fix in high-traffic zones. Notwithstanding the way that they cut traffic stops and improve security during advancement, they can convey better asphalt. After the exploration, the audit shows that ordinary materials are being utilized in PCP. Regular stream sand harms environmental equalization just as influences the groundwater level. Mechanical strong waste is available in extreme sum and yet they are additionally answerable for A worldwide temperature alteration and condition unfortunate. Despite these waste materials' negative angles, we can use them for development reasonsbecause the properties of mechanical waste materials are indistinguishable from the properties of ordinary materials. The use of mechanical strong waste can help in forestalling the consumption of normal assets. This survey utilized in Precast Concrete Pavement research from 2013 – 2019 may want to be a very beneficial useful resource to guide researchers looking out for an appropriate methodology via presenting a right understanding of the methodologies used using other researchers in this field. After analysis, it is observed that the key drawback of Conventional Roadway in situ development and preservation are inconveniences to drivers and additional costs associated with full-size web page operations.

III. METHODOLOGY

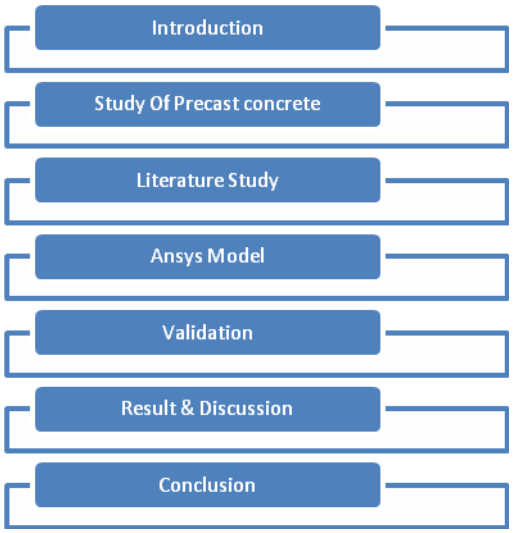

Fig.10 Research methodology flow chart

Concrete that has had early compressive stresses imposed on it during manufacture is known as prestressed concrete. To fortify its concrete against external pressures that will be exerted during usage, this additional process is done. As the concrete is being poured around the steel tendons, which are still tensioned or at their strongest, they are being stretched.

Precast concrete panels have been suggested as a means of building and repairing runways, and this idea has grown out of several important factors that are discussed in the feasibility study report. The usage of full-depth precast panels is the main component of the suggested design for precast concrete pavement. It is claimed that with correct panel alignment and sporadic diamond grinding and bump cutting, smooth enough ride surfaces may be achieved. The panels of the suggested idea are depicted in the picture below.

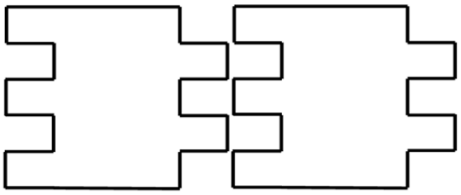

Fig. 11 Proposed Concept Of Precast Slab

In this chapter, the specifics of this idea will be covered. A description of panels that will be utilized, joint details, the panel assembly method, and base preparation are all covered in the discussion.

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