THE EXPERIMENTAL STUDIES TO DEVELOP OF PRECAST AND PRESTRESSED CONCRETE SYSTEM FOR RIGID PAVEMENT IN INDONESIA

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ABSTRACT

Since 2014, Indonesian government conducted acceleration of infrastructure construction for all regions in Indonesia. Roadway or highway is essential part of infrastructure because it is responsible for transportation connectivity in supporting efficient economic activity. In Indonesia construction quality and highway preservation have not been optimal as evident by unable to reach minimum service standard and design service life. This is because technologies (flexible or conventional rigid pavement) used for highway construction often failed to satisfy minimum specification requirement and the difficulty to control traffic load passing the highway. Use of prestressed precast technology for rigid pavement has been introduced in Indonesia since 2007, its application has not reached massive scale. Starting 2015, the development of precast and prestressed technology has been started again to support an accelerated infrastructure program. At early stage of development, comparative study on the performance of various precast and prestressed technologies that have been implemented. New system is then developed using unbonded posttensioned technology that has characteristic of self-centering so that it can reduce the impact of overload and is able to overcome imperfect subbase, subgrade and poor existing soil condition. Construction method is also developed to produce the construction method that is efficient so as to minimize obstruction to highway users. This paper present experimental program conducted in the development proses to validate numerical models developed earlier in the process.

Keywords: Rigid pavement; Precast, Prestressed.

1. INTRODUCTION

Roadway or highway pavements are essential part of transportation system that should be adequately strong and durable for their design life. Early damages to pavements may cause traffic disruption and thus lead to negative user experiences and economic impact. Unfortunately, many pavements constructed in Indonesia fail to reach their design service life. Among major factors contributed to early damages to the pavements in Indonesia are unfulfilled specified pavement construction specifications dan traffic overload.

Traditional Highway Construction often faces difficulties such as supporting preparation work which is not optimum, shortage in asphalt delivery in flexible pavement case, highway obstructions in case of conventional rigid pavement (jointed plain concrete pavement, JPCP, shown in Figure 1), thus inability to meet quality specification in case of rigid pavement. In addition, the drainage system often time is addressed properly. This condition demands new pavement technology to be developed and implemented in pavement construction in Indonesia.

Figure 1 Conventional rigid pavement (JPCP)

A relatively recent innovative technology developed for highway pavement is precast concrete pavement. Since the precast concrete pavement system normally fabricated under controlled environment, it offers several potential advantages over traditional highway pavement system such as shorter construction time, higher quality (need less maintenance) and efficient use of materials. There have been several applications of precast concrete pavement system in Indonesia. It started with the use of Prestressed Precast Concrete Pavement (PCP) technology in a section of Cakung-Cilincing highway, Jakarta in 2007 (Figure 2). It was then followed by the use of Precast Concrete Pavement Panel (PCPP) system in Suryacipta Industrial Estate (2013, Figure 3) and Precast Prestressed Concrete Pavement (PPCP) in Kanci-Pejagan Toll Highway (2011, Figure 4).

Figure 2 PCP in Cakung-Cilincing Highway 2007

Figure 3 PCPP in Suryacipta industrial estate, 2013

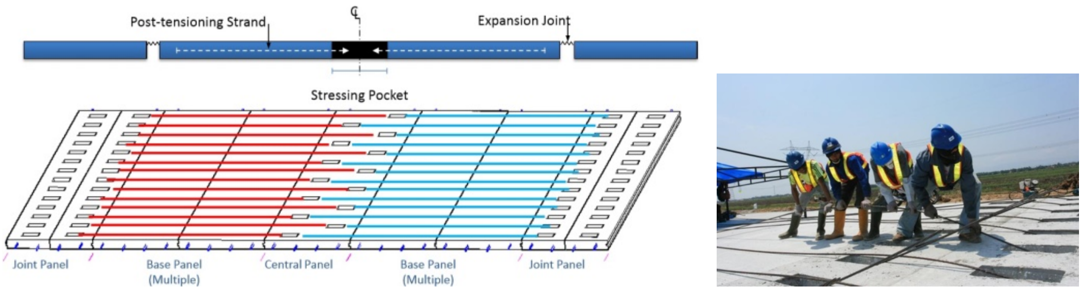


Figure 4 PPCP Kanci-Pejagan Tollway 2011

Study on various application of precast concrete pavement systems in construction condition Indonesia by Nurjaman et. al. (2017) reveals that Prestressed Precast Concrete Pavement technology demonstrates best performance. It is part of integrated development effort on highway rigid pavement technology based on precast prestressed concrete system initiated since 2015, by performing qualitative and quantitative research. Qualitative research was carried out on qualitative performance on the application of precast system in several highway constructions from 2010 to 2015, and in comparative study in United States in 2015. Quantitative research was carried out on performance of application of precast system in highway construction from 2010 to 2015, and in development experimental program from 2015 to 2017. This study will focus on the experimental/testing program developed to produce a precast pavement system that is durable and economics.

2. EXPERIMENTAL PROGRAM

2.1. System Development

This technology is inspired from the re-centering capacity of unbonded post-tensioned prestressing in resisting earthquake forces in buildings, Nurjaman et. al (2014). Re-centering capacity in highway construction would anticipate imperfection in sub-base and sub-grade as well as overload condition, Suaryana (2016). This technology has been applied in several internal roads in precast plant (2015-2016) as seen in Figure 5. Design process of the system with finite element method which considered overload condition in standar subgrade specification and undersubgrade specification data can be seen on work conducted by Nurjaman et. al. (2017).

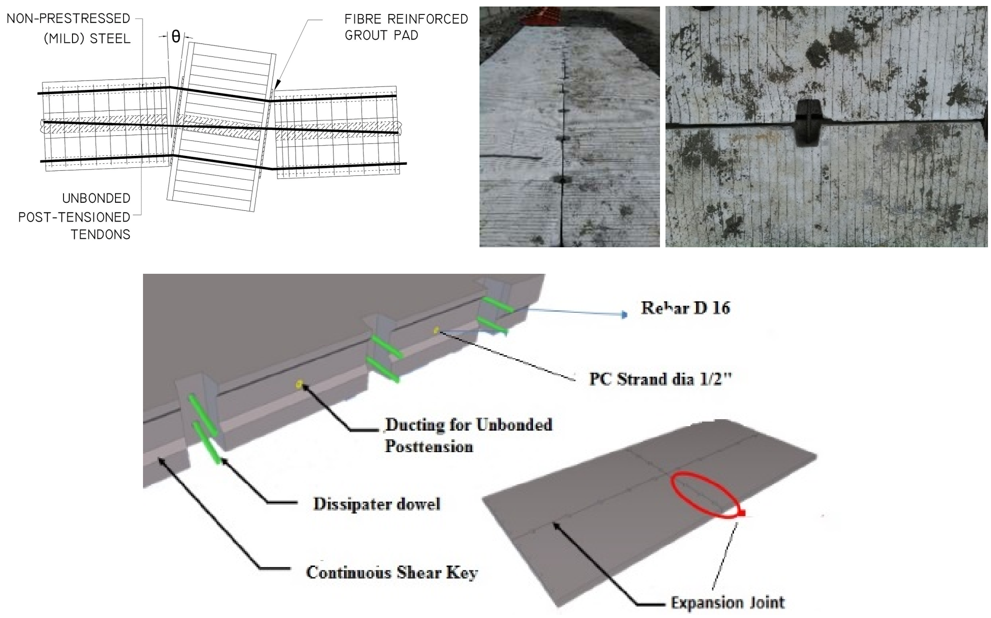


Figure 5 PCP unbonded post-tensioned technology with re-centering capability. Precast module is 12000x1800x180 and 12000x3600x180 with concrete quality fc' = 41.5 MPa

2.2. Experiment

Under the loading the critical part of a rigid concrete pavement system is at the connection system. The connection mainly undergoes internal flexural bending moment, shear forces as well as tensile force action. To develop a reliable precast and prestressed concrete system for rigid pavement, it is necessary to develop an experimental program that addresses those actions. Thus, in this study three (3) experimental tests had been programmed, i.e.: (1) Pull-Out Dowel Activator Test; (2) Flexural Test and (3) Shear Test. Details of testing specimens and procedures will be given below.

2.2.1 Pull-Out Dowel Activator Test

The connection system between precast panels uses reinforcing bars called dowel activator. As the role of dowel activator is to connect between two precast pavement panel, it must be able to distribute forces due to traffic load. The ability of dowel to distribute forces is determined by conducting pull-out test.

Specimens for dowel pull-out tests were prepared by embedding the dowel into a concrete block to simulate the actual connection system. Two types of specimens were prepared, one for representing the precast panel thickness of 180 mm (SpRigWP_18) and the other for precast panel thickness of 200 mm (SpRigWP_20). The preparation and final form of specimens for pull-out dowel activator test is shown in Figure 6.

Figure 6 Preparation and final form of specimens for pull-out test on dowel activator

The setup configuration for pull-out dowel activator test is shown in Figure 7. Testing is carried out according to standard tensile test for reinforcing bar.

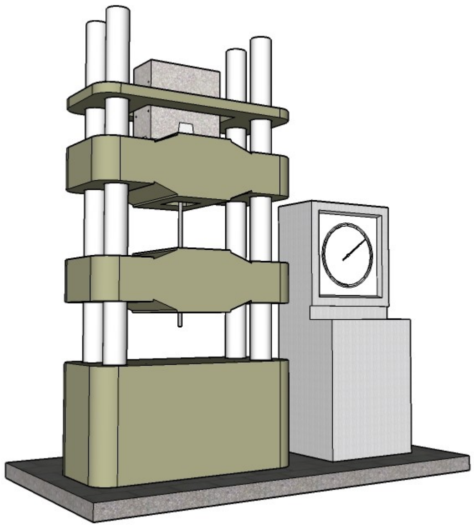


Figure 7 Setup configuration for pull-out dowel activator test

2.2.2. Flexural Test

The purpose of flexural testing on two precast concrete panel connected with dowel activator is find out the performance in terms of connection capacity under flexural load. The setup configuration of flexural test is shown in Figure 8. The testing load will be applied incrementally until the connection fails near the support where the maximum moment taken place. Two (2) specimens were prepared for the test, one with precast panel thickness of 180 mm and the other with thickness of 200 mm.

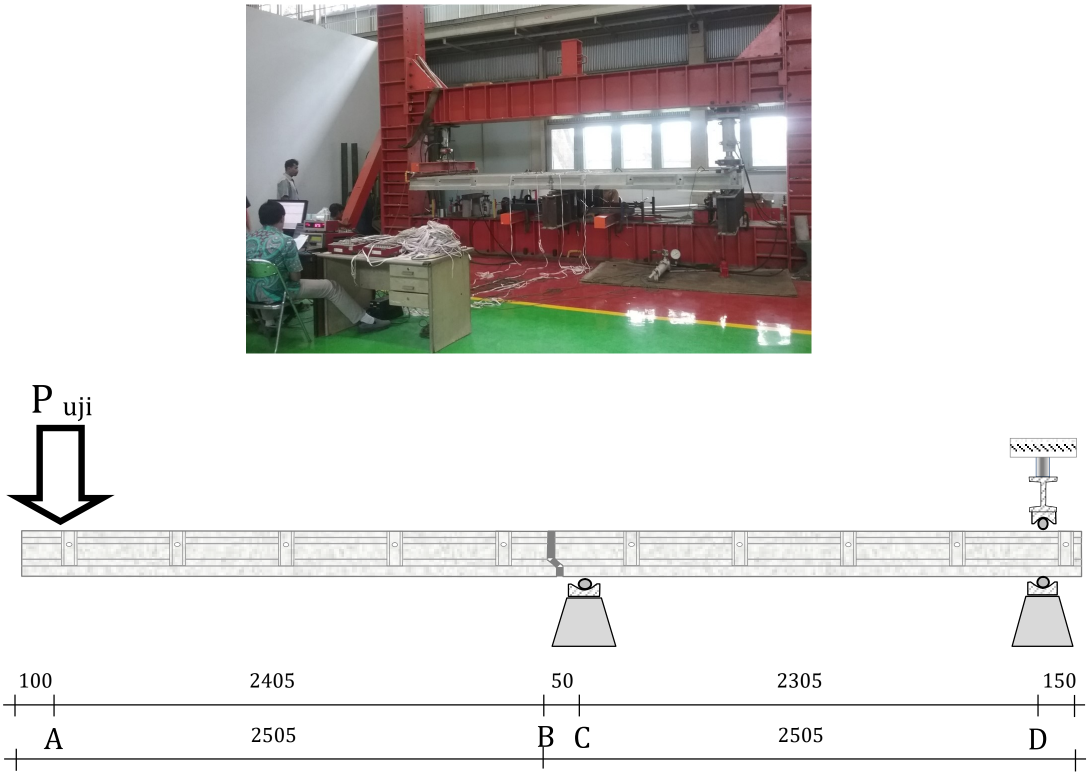


Figure 8 Picture and configuration for flexural test specimen

2.2.3. Shear Test

Shear test was carried out on specimen that consists of two panel connected in the middle and supported by three (3) supports as shown in Figure 9 below. This test is conducted to determine the shear capacity of the connection by applying the vertical load on test specimen until failure load. Two types of specimens were prepared, one with the thickness of 180 mm and the other with thickness of 200 mm. The dimension of specimen is of 5100 mm in length by 1800 mm in width.

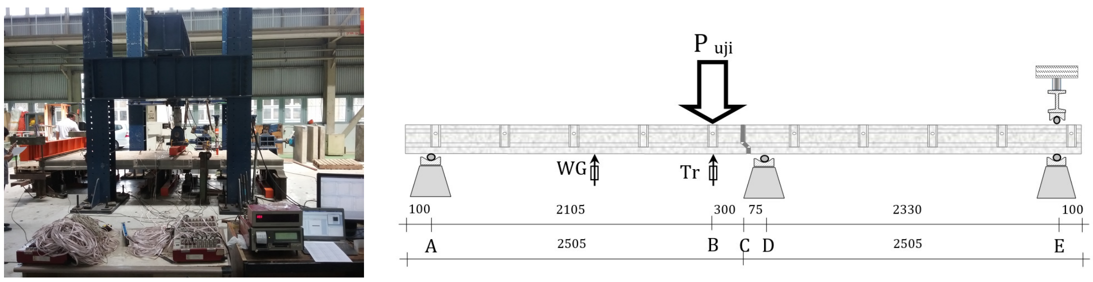


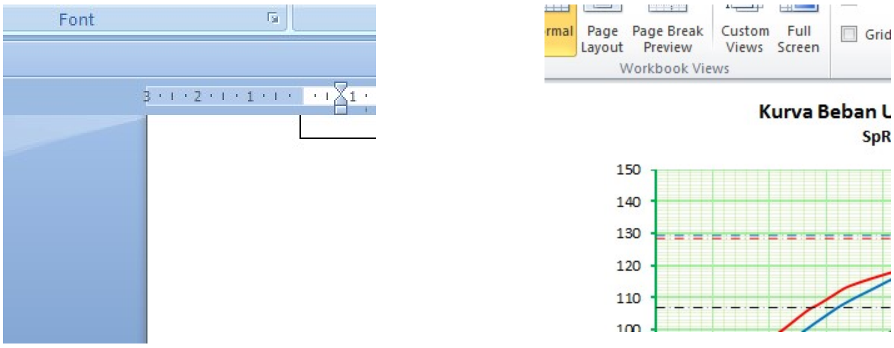
Figure 9 Picture and configuration for shear test specimen

3. RESULTS AND DISCUSSION

Below Results from experimental program described in the previous section will be presented and discussed.

3.1. Results of Pull-Out Dowel Activator Test

Figure 10 (a) and (b) show the relationship between load and elongation for specimens SpRigWP_18 and SpRigWP_20, respectively. The results show that the tensile behavior of dowel is similar to that of reinforcing steel bar.

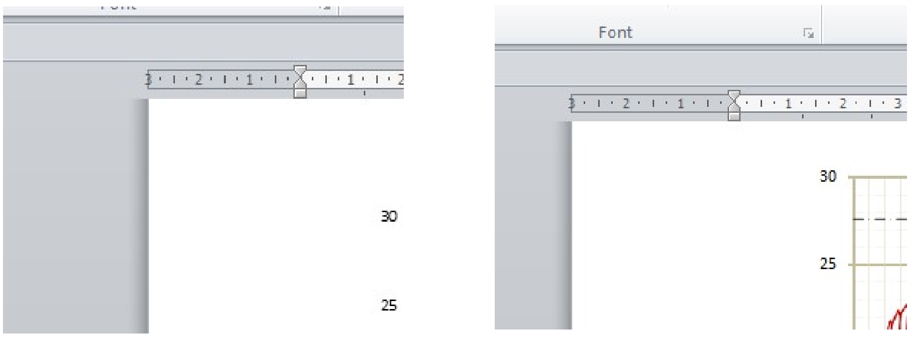


(a) SpRigWP_18 (b) SpRigWP_20

Figure 10 Graph of load vs elongation

3.2. Results of Flexural Test

The flexural test results is given in the form of graphs shown in Figure 11. The graphs present the relationship between load and deflection. From the graphs one can see there are loads that cause initial crack, yielding condition and failure condition on the specimens. From the graph and test specimen configuration, one can derive the moment capacity of tested specimens at yield condition, i.e. M_{test_18} = 44,79 kN.m and M_{test_20} = 46,21 kN.m for specimens SpRigWP_18 and SpRigWP_20, respectively. The nominal moments for specimens SpRigWP_18 and SpRigWP_20 are M_n = 30,82 kN.m and M_n = 37,18, respectively. It shows that the moment capacity of tested specimens is higher than its nominal moment.



\(a) SpRigWP_18 (b) SpRigWP_20

Figure 11 Graph of load vs deflection

3.3. Results of Shear Test

Table 1 and 2 show summary of shear test results. Shear capacity in this case is relatively high (>300 kN), thus shear force is not critical.

Table 1 Shear Performance of Specimen SpRigWP_18

No.	Condition	Beban Uji (P, kN)	Deflection (mm)	Strain (10^{-6})
1.	Crack	172,48	2,19	121
2.	Yield	309,63	4,41	1977
3.	Ultimate	382,20	9,29	2184
4.	Failure	301,84	20,29	14615
5.	Failure	157,78	33,29	**)

Table 2 Shear Performance of Specimen SpRigWP_20

No.	Condition	Load (P, kN)	Deflection (mm)	Strain (10^{-6})
1.	Crack	76,44	1,39	111
2.	Yield	398,96	7,89	1977
3.	Ultimate	415,52	8,59	3626
4.	Failure	370,44	14,49	19633
5.	Failure	129,36	35,59	**)

4. CONCLUSION

Performance of highway construction in Indonesia nowadays is yet to be optimum. Flexible as well as rigid pavement construction generally do not reach their life service, due to the lack of meeting specification or due to unavoidable excessive loading.

Construction based on pre-fabricated components made of local materials will produce good performance products and more efficient compared to conventional construction. Precast/prestressed components have been applied since 2007 but the results are not always optimum since the design and construction are not carried out integratedly.

As part integrated development effort on highway construction based on industrial manufacture has been initiated since 2015, experimental program that include dowel pull-out test, flexural test and shear test were conducted. Overall, the test results are satisfactory. The results validate the good performance shown by internal application of prestressed precast concrete pavement system developed in the study.

The developed pavement system is expected to be an alternative for the performance improvement of highway construction and maintenance in Indonesia so as to enhance service improvement to the users, enhances economic activities and contributes in sustainable development in which nowadays considered as a part of global movement to save the world from climate change.

5. ACKNOWLEDGEMENT

This research funded by Waskita Beton Precast Ltd. Also the writers extend their appreciation to the Indonesian Association of Precast and Prestressed Engineersand to the Research Institute of Human Settlement, and Institute of Road Engineering Ministry of Public Works for providing testing facilities.

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