The Influence of Base Course Types on Rigid Pavement Concrete Strength

Purnawan\textsuperscript{1,2*} and S Utami\textsuperscript{1,2}

\textsuperscript{1}Department of Civil Engineering, Andalas University, Padang, Indonesia
\textsuperscript{2}Transport Research Group, Andalas University, Padang, Indonesia

*purnawan@gmail.com

Abstract. This study presents a comparison of the strength of rigid pavement using different five base courses. The experiment was conducted at structural and material laboratory, the samples of concrete pavement were represented by concrete cube that placed on different base material. First sample concrete cube was placed directly on the subgrade, the second sample was placed on the granular base course, the third sample was on the granular sub-base course with prime coat, the fourth sample was on the lean concrete, and the fifth sample was on lean concrete separated using impermeable membrane. The result of concrete strength is shown in values of concrete compressive strength, the concrete sample placed on lean concrete base using impermeable membrane has the highest strength compared another concrete on another base course material. The use of impermeable membrane on lean concrete is the possible factor that could produce the highest compressive strength. This membrane would retain cement water in concrete mix, so the strength of concrete is still high.

1. Introduction
In recent year, rigid pavements are widely used as street local in resident areas, the pavements usually are directly supported by subgrade. As the result, this pavement usually cannot withstand to traffic load for a long time, the concrete slab is usually starting with hair crack and then become alligator crack followed by disintegration. Several factors cause these problems, such as subgrade condition, subgrade construction and environment situation \cite{1,2}. In this street, the concrete slab usually is placed directly on the subgrade or constructed without base course, this is used because of light traffic. In other cases, sometimes contractor build rigid pavement on granular base course without prime coat, and some of them using prime coat on granular aggregate base course. In government project, rigid pavements are usually build on lean concrete base course, some of them laid down directly on the lean concrete base course, another project using impermeable membrane on the lean concrete base course. Those different concrete slabs on different base courses would result different concrete strength. For rigid pavements project owned by government, it is usually build on lean concrete base course. These pavements are stronger than rigid pavement built by people in resident areas. The reductions of concrete strengths occur because the water content of concrete mix reduced infiltrate to layer below. Permeable material base course would reduce more water content of concrete mix than semi permeable and impermeable material base course. From those cases, base course has important role to protect rigid pavement from external factor that would ruin the pavement. Jung \textit{at al} stated that the base course has purpose and function to provide a stable construction platform, provide uniform...
support, prevent erosion of the pavement support, facilitate drainage, provide increased slab support and provide a gradual vertical transition in layer moduli. Untreated aggregate base showed poor performance as base course rigid pavement, however treated or stabilized subbase material are better [2,3]. Uniform base courses are required to obtain better support of concrete slab, although the traffic load is supported by concrete slab, distribution of the load to subgrade requires better subbase condition [4,5,6,7]. Figure 1 shows the cracks of rigid pavement caused by base course problems. These cases need to investigate the problem behind failing of rigid pavement. This research shows the result of experiment the effects of using different base courses material on rigid pavement strengths.

![Figure 1. Crack of rigid pavement caused base](source: Jung [2])

2. Methods
This experiment is to imitate the condition of rigid pavement using different base course in the field. Five types of base courses were used during experiment. The type of base courses is as follow, (1) Without base course; (2) Granular aggregate base course; (3) Granular aggregate with tack coat base course; (4) Lean concrete base course; (5) Lean concrete base course with impermeable membrane. The rigid pavement concrete slabs are represented by cube concrete, these cubes were placed on the base course. Each 18 group concrete cube samples were placed on base course as Figure 2 to 4. The concrete cube samples compressive strengths are designed using 350 kg/cm$^2$ (34.3 MPa) [3,8]. From mix design, the compressive strength samples reach 33.54 MPa. The subgrade CBR for the first condition is 14.77%, granular aggregate CBR base is 42.04%, lean concrete compressive strength is 11.79 MPa.

![Figure 2. Concrete formwork placed on (a) subgrade; (b) granular aggregate base](source: Jung [2])
Each sample type has 18 cubes concrete, 3 cubes for 3 days curing, 3 cubes for 7 days curing, 3 cubes for 14 days curing, 3 cubes for 21 curing and 3 cubes for 28 curing. Another 3 cubes are for emergency sample for 28 days, these samples are used when another sample failure during experiments. The compressive strength of concrete cubes sample was tested using Universal Testing Machine (UTM) in Structure and Material Laboratory.

3. Results and discussion

The concrete cubes that have been cured for 3 days, 7 days, 14 days, 21 days and 28 days, then tested using Universal Testing Machine (UTM), the results of concrete compressive strength are as shown in Figure 5. The base courses type is as follow, (1) Without base course; (2) Granular aggregate base course; (3) Granular aggregate with tack coat base course; (4) Lean concrete base course; (5) Lean concrete base course with impermeable membrane.
Figure 5 shows that the pattern of concrete sample strength for different curing days is almost similar, the strength at 3 curing days for different base course is slightly different, it is between 17-22 MPa$^2$. After 3 days, the patterns of concrete strength curve become varied.

Based on the analysis of average concrete compressive strength for five different base courses, the result is shown in Table 1. The highest concrete strength is obtained when the concrete sample that is laid down on the lean concrete base course with impermeable membrane, the compressive strength of this sample is 31 MPa, this strength is almost similar with concrete sample strength from job mix formula (33.54 MPa). This result reveals that the use of impermeable membrane on lean concrete base course could result the highest compressive strength compared the other types of base courses, this is because the use of impermeable membrane could reduce cement water content absorbed by base course. The cement water of concrete mixtures could not infiltrate to base course because of impermeable membrane covered base course layer. However, if porous materials are used as rigid pavement base course, the cement waters infiltrate to base course layer. The percentage of concrete strength reduction for five different base course materials have been compared, all concrete sample strength at those base course types are compared to base course with impermeable membrane on lean concrete, the result is shown in Figure 6.

**Table 1. Average concrete sample strength for different base types**

| No | Concrete sample on different base course type                                      | Concrete sample strength Fc (Mpa) |
|----|-----------------------------------------------------------------------------------|----------------------------------|
| 1  | Concrete sample placed directly on subgrade                                        | 23.1                             |
| 2  | Concrete sample using granular base course                                        | 24.8                             |
| 3  | Concrete sample using granular base course with primecoat                         | 25.2                             |
| 4  | Concrete sample using lean mix concrete base course                                | 26.8                             |
| 5  | Concrete sample using lean mix concrete with impermeable membran                    | 31                               |
Figure 6 shows the percentage concrete sample strength reduction that placed on five different base courses. This figure indicates that concrete sample strength reduction would be higher, if concrete sample is placed on more permeable base course material. The concrete sample strength that is directly laid down on subgrade would has the lowest concrete strength compared using other base course materials, this strength would reduce about 25.5%. This occur because subgrade material is the most permeable material compared another base course material. Percentage concrete strength reduction decrease when using less porous base course material, such as granular base course, granular base course with prime coat and lean concrete base course. The use of impermeable membrane that cover lean concrete base course layer would result the highest concrete strength. It is because the cement water still retains in concrete mixture because the cement water could not infiltrate to the base course layer.

4. Conclusion
Base course material of rigid pavements has essential contribution to the durability of pavement, it could affect the strength of pavement. From the experiment, it can be concluded that the type of base courses that used below rigid pavement affect the concrete strength. This is because of cement water of concrete pavement infiltrate through base course. The lowest concrete pavement strength could occur if those concrete is supported directly by subgrade, this is usually occurring when they build the local street in resident areas. The strength of this concrete would reduce up to 25.5%, it is because the water cement easily infiltrates through subgrade. This type of base course is suitable for rigid pavement with light traffic. The highest concrete pavement strength could be achieved when lean concrete is used as base course and covered by impermeable membrane, in this condition, the cement water could not infiltrate through base course. This type of base course is appropriate for rigid pavement with high traffic volume and heavy load.

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