THE EFFECT OF HOLE SIZE CONFIGURATION TOWARDS WAVE REDUCED LEVEL OF PERFORATED CONCRETE BLOCK BREAKWATER
Tamrin, Shaleh Pallu, Herman Parung And Arsyad Thaha .................................................. 85

MISCONCEPTIONS ABOUT MECHANICAL AND FLUVIAL EROSIONAL STRENGTH: IMPLICATIONS TO STREAMBANK STABILITY
T.E. Sutarto, A.N. Thanos Papanicolaou, C.G. Wilson, E.J. Langendoen .................................. 93

PATTERN STUDY OF EXPERIMENTAL HYDROGRAPH AND SYNTHETIC UNIT HYDROGRAPH NAKAYASU
Ratna Musa, Muhammad Saleh Pallu, Lawalenna Samang, Mukhsan Putra .................................. 101

THE INFLUENCE OF CONFIGURATION TO CURTAIN ON DEFORMATION ZONA PILLAR
Nenny, Muh. Saleh Pallu, M. Arsyad Thaha, Farouk Maricar .................................................. 108

ANALYSIS OF IRRIGATION WATER REQUIREMENT BASED ON CROPPING SCHEDULE AT DESA TERITIP KOTA BALIKPAPAN
Agustia Estu Wiridiana, Tamrin, Citra Anggita ............................................................................... 118

NEW APPROACH DESIGN FOR RUBBLE MOUND BREAKWATER
M. A. Thaha .................................................................................................................................. 125

SEDIMENT TRANSPORT ANALYSIS TO PREVENT SEDIMENTATION (CASE STUDY: UPPER JENEBERANG RIVER)
M. Lukman, S. Pallu And F. Maricar ................................................................................................. 131

PART 2
MATERIALS AND STRUCTURAL ENGINEERING

COMPARATIVE THEORETICAL STUDY OF RESPONSE OF R.C SLAB FOR HARD MISSILES IMPACT
Faiza Alama, Hamed Alama, Dr. Osama A. Daoud, Dr. Mahjoob O. Mahjoob, Dr. Eltaeeb H. Onsa .................................................. 139

DUCTILITY OF PRECAST CONCRETE ON INTERIOR BEAM-COLUMN JOINTS UNDER CYCLIC LOADING
Mardewi Jamal, Herman Parung, M. Wihardi Tjaronge, Victor Sampebulu ............................ 149

WORKABILITY AND COMPRESSIVE STRENGTH OF SELF COMPACTING CONCRETE USE SEAWATER AS MIXING WATER
Erniati, Wihardi Tjaronge, Rudy Djamaluddin, Victor S. Zuharnah .................................................. 157

LATERITE CONCRETE BORNEO (LACOBON)
Muhamad Nahrowi, Reza Delizar, Abdul Karim Sidik, Sujiati Jepriani ........................................... 165
AN EXPERIMENTAL STUDY ON CHLORIDE ION DIFFUSION COEFFICIENT OF CONCRETE MIXED WITH GROUND GRANULATED BLAST-FURNACE SLAG FOR DURABILITY IMPROVEMENT
Yasutaka Sagawa .......................................................... 170

KAMPER WOOD CONNECTION LAMINA AN ALTERNATIVE STIFFNESS AND WOOD SOLID COLLAPSE
Joko Suryono ............................................................... 180

EFFECT OF STYROFOAM FILLED CONCRETE IN TENSION ZONE OF REINFORCED CONCRETE BEAM TO THE FLEXURAL CAPACITY
Yasser, H. Parung, M.W. Tjaronge, R. Djamaluddin .................. 188

EFFECT OF SEA WATER TO THE GFRP BONDING OF CONCRETE BEAMS STRENGTHENED USING GFRP-SHEET
Arbain Tata, Herman Parung, Wihardi Tjaronge, Rudy Djamaluddin ........... 196

BONDING STRESS DISTRIBUTION OF GFRP FOR FLEXURAL STRENGTHENING ATTACHED OF RC BEAMS
Mufti Amir Sultan, Herman Parung, Wihardi Tjaronge, Rudy Djamaluddin ........... 203

DURABILITY DESIGN FOR INDONESIAN CLIMATE
Rita Irmawaty, Hidenori Hamada, Hendra Wutanto ..................... 210

FLEXURE STRENGTH OF RC BEAMS EXTERNALLY REINFORCED WITH WIRE MESH
A. Arwin Amiruddin, Herman P., Kartika S., Miranda R. M., Riswal K, Harmonis R, Hery D, Ma'rifah I ........................................ 219

BRICK LIGHTWEIGHT Autoclave Aerated Concrete (AAC)
Amiruddin Basir, Athirah Pratiwi ........................................... 226

PART 3
GEOTECHNICAL AND GEOENVIRONMENTAL ENGINEERING

EXPERIMENTAL STUDY OF SURFACE RUN OFF WITH RAINFALL INTENSITY EFFECTS AND DIFFERENT SLOPE GRADIENT ON THE SLOPE EROSION RATE FOR SILTY SAND SOIL
Abdul Rivai Suleman, M.S.Pallu, J.Patanduk And T.Hariano ............... 231

APPLICATION OF MICROBIOLOGY AND EMPTY FRUIT BUNCH OF PALM OIL FIBER (EFBPOF) TO IMPROVE MECHANICAL PROPERTIES OF SOIL
Insan Kamil ................................................................. 241

STUDY THE BEHAVIOR OF SOIL CEMENT MIXED WITH PALM FIBERS
Priyo Suroso, Lawalenna Samang, Wihardi Tjaronge, Muhammad Ramli ............... 247
PART 4
TRANSPORTATION AND URBAN PLANNING MANAGEMENT

EXPERIMENTAL STUDY PERMEABLE ASPHALT PAVEMENT USED DOMATO STONE (QUARSITE DOLOMITE) AS COURSE AGREGATE FOR SURFACE LAYER OF ROAD PAVEMENT
Firdaus Chairuddin, Wihardi Tjaronge, Muhammad Ramli, Johannes Patanduk .................................................. 275

EFFICIENT CONTAINER PORTS DEVELOPMENT IN SOUTH SULAWESI – INDESIESIA IN SUPPORTING INTEGRATED TRANSPORTATION
Syarifuddin Dewa, Muh. Saleh Pallu, Muhammad Isran Ramli, Muhammad Alham Djabbar ................. 282

STUDY OF THE CHARACTERISTIC OPERATIONAL OF INFORMAL PUBLIC TRANSPORTATION IN CITY OF MAKASSAR
Ahmad Yauri Yunus, Wihardi Tjaronge, Nur Ali Dan Sakti Adji Adisasmita .................................................. 290

TEST OF MICROSTRUCTUR PERMEABLE ASPHALT PAVEMENT USED DOMATO STONE (QUARSITE DOLOMITE) AS COURSE AGREGATE FOR SURFACE LAYER OF ROAD PAVEMENT
Firdaus Chairuddin, Wihardi Tjaronge, Muhammad Ramli, Johannes Patanduk .................................................. 295

EXPERIMENTAL STUDY ON STABILITY AND RAVELING RESISTANCE OF ASPHALT CONCRETE BEARING COARSE (AC BC) MIXTURE USING BUTON GRANULAR ASPHALT (BGA)
Abdul Gaus, Tjaronge M. W., Nur Ali, Rudy Djamaluddin .......................................................... 304

STUDY ON THE DISTRIBUTION OF PASSENGER VEHICLES HEADWAY TRAFFIC HETEROGENEOUS IN MAKASSAR
M. Thahir Azikin, Ramli Rahim, Sakti Adji Adisasmita And Sumarni Hamid .................................................. 309

STUDY EFFECTIVITY GROWTH OF ROAD URBAN FACILITY AT MAMINASATA METROPOLITAN AREA
Yusuf Harun, Wihardi Tjaronge, Sakti Adji Adisasmita; Nur Ali .................................................. 316

STUDY SYSTEM PARKING AREA AGENCY ON THE ROAD TOUR - SHOPPING IN MAKASSAR
Anugrah Yasin, M. Isran Ramli, S. Hamid Aly, Lawalenna Samung .................................................. 327
BONDING STRESS DISTRIBUTION OF GFRP FOR FLEXURAL STRENGTHENING ATTACHED OF RC BEAMS

MUFTI AMIR SULTAN
Doctoral Course Student of Civil Engineering Department, Hasanuddin University, Makassar, 90245, Indonesia

HERMAN PARUNG, WIHARDI TJARONGE, RUDY DJAMALUDDIN
Civil Engineering Department, Hasanuddin University, Makassar, 90245, Indonesia

ABSTRACT: Fiber-Reinforced Plastic (FRP) reinforcement has been utilized for concrete structures expecting its high durability to corrosion and insulation property. The application of FRP in various form such as grid, rod and sheet. GFRP sheet is most commonly used due to its relatively lower cost compared to the other FRP materials. This study consisted of five beams which categorized into two groups. The span of beam is 3300 mm. The cross section was 150 x 200 mm. The beams of the first group (BN) were tested without strengthening GFRP, totaling two beams. The beams of the second group (BF) with GFRP sheet strengthened on the bottom before loading, totaling three beams. The Samples were tested simply supported and subjected in two point load symmetrically placed at equal distance (150 mm) from the centerline of the beam. The results show the advantage of using GFRP sheets in strengthening or upgrading RC beams. Value of interface shear stress (t) is 8.25 MPa and ratio of resistance moment (Ms/Mp) of 1.50. Failure is a general loss of bond between GFRP and concrete beam which called debonding.

Keywords: GFRP Sheet, debonding, Shear stress

1. Introduction

Generally, steel reinforcing bar is used as reinforcement of concrete structures. However, it is a serious problem that corrosion of steel reinforcing bar occurs due to cracking. Therefore, in the recent years, Fiber-Reinforced Plastic (FRP) reinforcement has been utilized for concrete structures expecting its high durability to corrosion and insulation property. Typical types of FRP are Carbon Fiber- Reinforced Plastic (CFRP), Glass Fiber-Reinforced Plastic (GFRP) and Aramid Fiber-Reinforced Plastic (AFRP)[1]. FRP has applied to many purposes for civil engineering structures not only for new structure but also for strengthening of the deteriorated structures. FRP have been developed in the various form, such as grid, sheet and plate. Glass fiber sheet as show in Figure 1 is most commonly used due to its relatively lower cost compared to the other FRP materials.

![Figure 1: Glass fiber sheet](image_url)

Some researches have been carried out in the last few years to investigate the bond behavior between FRP and concrete. Several different set-ups have been used to study the strain (stress) distribution in FRP along the bond length, bond and force transfer mechanism, the effective stress transfer length and the bond strength [2], [3]. Some existing FRP-to concrete bond strength models are semi-empirical analysis where a bond stress-slip constitutive model is assumed [4]. The value of the ultimate bond stress is not influence by the bond length, but increases as concrete compressive strength increases [5]. Type of adhesive has an effect on both the effective bond length and the bond strength of FRP-concrete...
strengthening system. This paper presents an experimental study on the bond behavior of externally bonded GFRP concrete members using a beam test.

The experimental observations that failure occurs at the adhesive-concrete interface when the plate is cut off near the support in a region of low bending moment and high shear force. It can be envisaged that there exists a limiting interface shear stress value, between the bonded plate and the concrete beam, which becomes critical near the plate cut off end, Figure 2 show concept of interface shear stress [6].

![Interface shear stress between bonded plate and concrete](image)

Section at distance L₁ and L₂ (L₁>L₀ and L₂>L₁) from the support is considered arbitrarily within the shear span of the beam. Any set of values for L₁ and L₂, under point loads, will produce a constant interface shear stress value. Load a plate debonding failure = 2P, in case of a beam tested with two point loads. The external plate force Fₚ₁ at L₁, Fₚ₂ at L₂, and internal rebar force Fᵣ₁ at L₁, Fᵣ₂ at L₂. Interface shear stress:

\[ F_p = A_p E_p S_c \left( \frac{dp - h}{h} \right) \]  \hspace{1cm} (1)

\[ F_r = A_s E_s S_c \left( \frac{hs - h}{h} \right) \]  \hspace{1cm} (2)

\[ \tau = \frac{F_{p2} - F_{p1}}{(L_2 - L_1) bp} \]  \hspace{1cm} (3)

Relative moment of resistance of plate

\[ M_S = \frac{F_{p1}(hs - p)}{F_p} = \frac{F_{p2}(hs - p)}{F_p} \]  \hspace{1cm} (4)

204
2. Specimens and Test Set Up

The specimens were consisted of five beams categorized into two groups. The span of beam was 3300 mm. The cross section was 150 x 200 mm. All beams have reinforced bars with 2φ6 in compression side (top) and 2D14 in tension side (bottom). All beams were tested simply supported and subjected to two point load symmetrically placed at equal distance (150 mm) from the centerline of the beam. Further detail of the specimen is shown in Figure 3 and Figure 4, respectively. The beam of the first group (BN) was tested without strengthening GFRP, totaling two beams. The beams of the second group (BF) with strengthened (before loading) with GFRP sheet on the bottom, totaling three beams.

2.1. Preparation of the Specimens

The GFRP Sheets were bonded to the tension face of the beams after 28 days casting. Before applying the epoxy, the concrete surface was roughened and cleaned to insure a good bond between the epoxy resin and the concrete surface. The epoxy resin was applied on the treated surface using a soft roller before patching of the impregnated GFRP sheets to the treated surface. The patched GFRP sheets were positioned with the application of slight pressure using soft roller. Then beams were kept for three days to allow the hardening of resin. Table 1 show the material properties of the manufacturer data sheet of glass.
fibers and GFRP, and Table 3 shows the manufacturer data sheet of epoxy resin, respectively. The installation of GFRP can be seen in Figure 5.

<table>
<thead>
<tr>
<th>Items</th>
<th>Glass Fiber</th>
<th>GFRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>SHE-51A</td>
<td></td>
</tr>
<tr>
<td>Tensile strength (MPa)</td>
<td>3240</td>
<td>575</td>
</tr>
<tr>
<td>Modulus young (GPa)</td>
<td>72.4</td>
<td>26.10</td>
</tr>
<tr>
<td>Laminate thickness (mm)</td>
<td>0.36</td>
<td>1.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Items</th>
<th>GFRP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tensile strength (MPa)</td>
<td>72.4</td>
</tr>
<tr>
<td>Modulus young (GPa)</td>
<td>3.18</td>
</tr>
<tr>
<td>Bonding strength* (MPa)</td>
<td>2.12</td>
</tr>
</tbody>
</table>

2.2. Test set up

The Samples were tested simply supported and subjected to two point load symmetrically placed at equal distance (150 mm) from the centerline of the beam. At the bottom of the beam fitted with 3 pieces LVDT to monitor deflection. Position of LVDT is in the middle of the span, 150 mm left and right according to the position of the point load. Steel and concrete strain using a strain gauge connected to a data logger. In beams with GFRP reinforcement, strain gauge coupled into 4 pieces, 1 piece placed on the middle span of the GFRP and 3 pieces placed to the right of the center span with distance 47 mm, 93 mm and 140 mm from the top side of beam. Left of center span fitted with 2 pieces belt, 200 mm width and fitted at 150 mm from the point load and at the end of the GFRP sheet. It is intended to isolate the power so hopefully there is a failure in that area fitted with a strain gauge. Figure 4 shows installation of GFRP sheet on the beam.

Figure 5. Installation of GFRP sheet on the beams

3. Result and Discussion

3.1. Flexural Capacity

Table 3 shows the summary of the first crack load and the ultimate capacity of the loaded beams, respectively. The experimental results were then compared to the estimated capacity. Most of the first crack load of specimens showed a good agreements with the estimated first crack load calculated using gross section area of the concrete beams. The similarity of first crack load on all specimens could be
understood easily due to the same parameters of all beams before strengthening with GFRP sheet. Ultimate flexural capacity of the normal beam (BN) was 26.73 kN. If it was compared to its estimated ultimate load, results indicated agreement ratio of 1.02%. On the BF beams strengthened using GFRP sheet, the ultimate load achieved 43.10 kN or 61.22% higher than the capacity of the control beam (BN). This clearly shows the advantage of using GFRP sheets in strengthening or upgrading RC beams.

Table 3. Summary of first crack and ultimate capacity

<table>
<thead>
<tr>
<th>Specimen Name</th>
<th>Estimated Pcr (kN)</th>
<th>Estimated Pu (kN)</th>
<th>Experiment Pcr (kN)</th>
<th>Experiment Pu (kN)</th>
<th>(BF/BN)</th>
<th>Exp/Est of Pu</th>
</tr>
</thead>
<tbody>
<tr>
<td>BN-1</td>
<td>5.13</td>
<td>26.09</td>
<td>6.60</td>
<td>27.04</td>
<td>---</td>
<td>1.011</td>
</tr>
<tr>
<td>BN-2</td>
<td>5.13</td>
<td>26.09</td>
<td>5.00</td>
<td>26.44</td>
<td>---</td>
<td>0.989</td>
</tr>
<tr>
<td>BF-1</td>
<td>5.13</td>
<td>42.01</td>
<td>15.40</td>
<td>43.26</td>
<td>1.62</td>
<td>1.015</td>
</tr>
<tr>
<td>BF-2</td>
<td>5.13</td>
<td>42.01</td>
<td>8.70</td>
<td>42.33</td>
<td>1.58</td>
<td>0.993</td>
</tr>
<tr>
<td>BF-3</td>
<td>5.13</td>
<td>42.01</td>
<td>5.50</td>
<td>43.73</td>
<td>1.64</td>
<td>1.026</td>
</tr>
</tbody>
</table>

Figure 6. Test set up

Figure 7. Details strain gauges placement in GFRP
3.2. Strain Distribution

The data collected from the strain gauges was used to develop the strain distribution profile. Each curve is plotted for a given load level. This curve of specimen BF-3 was shown in Figure 9. It can be seen, at early stages of loading, the curve has a non linear shape. The strains decrease along with the distance from the center increase. As the load increases, the profiles tend to attain a linear shape. At a certain load level, the strain distribution curves become linear which means the joint begins failure. This corresponds to the attainment of a uniform bond stress along the portion of laminate which is taking the load. The interfaces failure occur in stages which indicated by the strain distribution. The strain profile becomes horizontal at the beginning of the bonded length, which means that the joint in that portion can not transfer load because the joint has begun to fail. The strain gauges far from the mid span read strain which means the load. By using equation (3) and (4), obtained value of interface shear stress of ($\tau$) 8.25 MPa and relative moment of resistance is $(M_s/M_p)$ 1.50.

![Figure 8. Load – deflection relationship curve](image)

![Figure 9. Strain propagation and distribution for specimen BF-3](image)
Figure 10. Failed specimen photograph

4. Conclusion

This result shows the advantage of using GFRP sheets in strengthening or upgrading RC beams. The interfaces failure occur in stages which indicated by the strain distribution. Value of Interface shear stress (t) is 8.25 MPa and relative moment of resistance (Ms/Mp) of 1.50. Failure is a general loss of bond between GFRP and concrete beam which called debonding.

References

Nakayama, Yuji., Nakai, Hiroshi and Kanakubo, Toshiyuki. (2008), Bond Behavior Between Deformed Aramid Fiber-Reinforced Plastic Reinforcement and Concrete. The 14th World Conference on Earthquake Engineering October 12-17, 2008, Beijing, China
**KARYA ILMIAH : PROSIDING**

**Bonding Stress Distribution Of GFRP For Flexural Strengthening Attached Of RC Beams**

- **Jumlah Penulis**: 3 (tiga) orang
- **Status Pengusul**: Penulis ke 3 (tiga)
- **Identitas Makalah**: Prosiding of The 2ND International Seminar on Infrastructure Development
- **ISBN/ISSN**: 978-979-530-131-8
- **Tahun Terbit**: 2014, Balikpanpan
- **Tempat Pelaksanaan**: Civil Engineering Department, Hasanuddin University
- **Alamat repository**: http://www.unhas.ac.id, PT/web prosiding repository.unhas.ac.id
- **Jumlah Halaman**: 7

**Kategori Publikasi Makalah**:
- ✔ Prosiding Forum Ilimiah International
- ❌ Prosiding Forum Ilimiah Nasional

<table>
<thead>
<tr>
<th>Komponen Yang Dinilai</th>
<th>Nilai Maksimal Prosiding</th>
<th>Nilai Akhir Yang Diperoleh</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Kelengkapan unsur isi buku (10%)</td>
<td>8</td>
<td>0,16</td>
</tr>
<tr>
<td>b. Ruang lingkup dan kedalaman pembahasan (30%)</td>
<td>22</td>
<td>0,54</td>
</tr>
<tr>
<td>c. Kecukupan dan kemutahiran data/informasi dan metodologi (30%)</td>
<td>21</td>
<td>0,54</td>
</tr>
<tr>
<td>d. Kelengkapan unsur dan kualitas penerbit (30%)</td>
<td>25</td>
<td>0,5</td>
</tr>
<tr>
<td><strong>Total = (100%)</strong></td>
<td>87</td>
<td><strong>1,74</strong></td>
</tr>
</tbody>
</table>

**Nilai Pengusul =**

Catatan penilaian paper oleh Reviewer:

Makassar,
**Reviewer**

Prof.Dr.Ir.Herman Parung,M.E.,Eng
NIP. 19620729 198703 1 001

Unit Kerja : Fak.Teknik Jur.Sipil
**LEMBAR HASIL PENILAIAN SEJAWAT SEBIDANG ATAU PEER REVIEW**

**KARYA ILMIAH : PROSIDING**

<table>
<thead>
<tr>
<th>Komponen Yang Dinilai</th>
<th>Nilai Maksimal Prosiding</th>
<th>Nilai Akhir Yang Diperoleh</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>15x0.40:3 = 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a. Kelengkapan unsur isi buku (10%)</td>
<td>9</td>
<td>0.18</td>
</tr>
<tr>
<td>b. Ruang lingkup dan kedalaman pembahasan (30%)</td>
<td>27</td>
<td>0.54</td>
</tr>
<tr>
<td>c. Kecukupan dan kemutahiran data/informasi dan metodologi (30%)</td>
<td>27</td>
<td>0.54</td>
</tr>
<tr>
<td>d. Kelengkapan unsur dan kualitas penerbit (30%)</td>
<td>28</td>
<td>0.56</td>
</tr>
<tr>
<td><strong>Total = (100%)</strong></td>
<td>91</td>
<td><strong>1.82</strong></td>
</tr>
</tbody>
</table>

Catatan penilaian paper oleh Reviewer:

Makassar,  
Reviewer 2

Prof.Dr.Ir. Muh. Ramli Rahim, M.Eng  
NIP. 19531111 198003 1 009  
Unit Kerja : Fak.Teknik Jur.Arsitektur