

Teknologi **Beton** — dan — **Infrastruktur Sipil**



Teknologi Beton dan Infrastruktur Sipil

Prof. Dr. Ir. Hamkah, M.T., IPM., dkk.

Editor: Rizki Nur Ismail, S.Pd.

PT BUKULOKA LITERASI BANGSA

Anggota IKAPI: No. 645/DKI/2024



Teknologi Beton dan Infrastruktur Sipil

Penulis : Prof. Dr. Ir. Hamkah, M.T., IPM., Arifah Kurnia
Nazwah Syafei, Imanuella Gloria Lesnussa, Rastika
Zikra Syahril, Julfia Hasyafi, Eugiunie Mandy A.
Loupatty, La Ode Idris, Lendi Sahetapi, Charly
Lekahena, Verell Timoti Riry, Tigrisia Latuasan, dan
Anisah Devi Imtiyaz Alfyyah
ISBN : 978-634-324-065-5 (PDF)
Penyunting Naskah : Rizki Nur Ismail, S.Pd.
Tata Letak : Rizki Nur Ismail, S.Pd.
Desain Sampul : Novikean Keysah Sanisri

Penerbit

Penerbit PT Bukuloka Literasi Bangsa

Distributor: PT Yapindo

Kompleks Business Park Kebon Jeruk Blok I No. 21, Jl. Meruya Ilir Raya
No. 88, Desa/Kelurahan Meruya Utara, Kecamatan Kembangan, Kota
Adm. Jakarta Barat, Provinsi DKI Jakarta, Kode Pos: 11620

Email: penerbit.blb@gmail.com

Whatsapp: 0878-3483-2315

Website: bukuloka.com

© Hak cipta dilindungi oleh undang-undang

Berlaku selama 50 (lima puluh) tahun sejak ciptaan tersebut pertama kali dilakukan pengumuman.

Dilarang mengutip atau memperbanyak sebagian atau seluruh isi buku ini tanpa izin tertulis dari penerbit. Ketentuan Pidana Sanksi Pelanggaran Pasal 2 UU Nomor 19 Tahun 2002 Tentang Hak Cipta.

Barang siapa dengan sengaja dan tanpa hak melakukan perbuatan sebagaimana dimaksud dalam Pasal 2 ayat (1) atau Pasal 49 ayat (1) dan ayat (2) dipidana dengan pidana penjara masing-masing paling singkat 1 (satu) bulan dan/atau denda paling sedikit Rp1.000.000,00 (satu juta rupiah), atau pidana penjara paling lama 7 (Tujuh) tahun dan/atau denda paling banyak Rp5.000.000.000,00 (lima miliar rupiah).

Barang siapa dengan sengaja menyerahkan, menyiarkan, memamerkan, mengedarkan atau menjual kepada umum suatu ciptaan atau barang hasil pelanggaran Hak Cipta atau Hak Terkait sebagaimana dimaksud pada ayat (1) dipidana dengan pidana penjara paling lama 5 (lima) tahun dan/atau denda paling banyak Rp500.000.000,00 (lima ratus juta rupiah).

KATA PENGANTAR

Puji syukur ke hadirat Tuhan Yang Maha Esa atas segala rahmat dan karunia-Nya sehingga buku *Teknologi Beton dan Infrastruktur Sipil* dapat diselesaikan dengan baik. Buku ini disusun sebagai upaya untuk memperkenalkan kepada masyarakat mengenai pentingnya teknologi beton dan perannya dalam pembangunan berbagai infrastruktur yang menjadi penopang aktivitas kehidupan modern.

Perkembangan pembangunan yang semakin pesat menuntut hadirnya material dan teknologi konstruksi yang mampu menjawab kebutuhan akan keamanan, ketahanan, efisiensi, dan keberlanjutan. Beton sebagai salah satu material konstruksi yang paling banyak digunakan terus mengalami inovasi untuk mendukung pembangunan yang lebih berkualitas. Oleh karena itu, pemahaman mengenai teknologi beton dan infrastruktur sipil menjadi penting tidak hanya bagi kalangan teknik, tetapi juga bagi masyarakat luas.

Penulis menyadari bahwa buku ini masih memiliki berbagai keterbatasan. Oleh sebab itu, kritik dan saran yang membangun sangat diharapkan demi penyempurnaan pada masa mendatang. Semoga buku ini dapat memberikan manfaat, menambah wawasan, dan menjadi sumber inspirasi bagi para pembaca dalam memahami peran teknologi konstruksi dalam membangun masa depan yang lebih maju, aman, dan berkelanjutan.

Jakarta, Juni 2026

Tim Penyusun

DAFTAR ISI

KATA PENGANTAR	iii
DAFTAR ISI.....	iv
Bab 1: Beton Pasir Pantai.....	1
Prof. Dr. Ir. Hamkah, M.T., IPM.	1
1.1 Karakteristik Pasir Pantai sebagai Material Beton	1
1.2 Penggunaan Air Laut dalam Campuran Beton	6
1.3 Kuat Tekan Beton Berbahan Pasir Pantai.....	11
1.4 Metode Kematangan dalam Prediksi Beton	16
Bab 2: Beton Shotcrete	23
Arifah Kurnia Nazwah Syafei.....	23
2.1 Konsep Dasar Shotcrete	23
2.2 Shotcrete pada Struktur Lereng	28
2.3 Evaluasi Kinerja Shotcrete	33
2.4 Penerapan Shotcrete pada Proyek Bendungan	38
Bab 3: Beton Perkerasan Jalan.....	44
Imanuella Gloria Lesnussa.....	44
3.1 Dasar Perkerasan Jalan Beton	44
3.2 Faktor Perencanaan Perkerasan Beton	49
3.3 Desain Tebal Perkerasan Beton	55
3.4 Penerapan pada Akses Bendungan	60
Bab 4: Beton Tahan Sulfat	67
Rastika Zikra Syahril	67
4.1 Beton pada Lingkungan Agresif.....	67
4.2 Material Penyusun Beton Tahan Sulfat	73
4.3 Rumusan Campuran Beton Struktur.....	78

4.4 Beton untuk Struktur Pelabuhan.....	84
Bab 5: Tiang Pancang Beton.....	90
Julfia Hasyafi	90
5.1 Konsep Fondasi Tiang Pancang	90
5.2 Daya Dukung Fondasi Tiang.....	96
5.3 Fondasi Tiang pada Struktur Dermaga.....	102
5.4 Evaluasi Fondasi Tiang Pancang.....	107
Bab 6: Analisis Teknis dan Yuridis Pengendalian Biaya	114
Eugiunie Mandy A. Loupatty.....	114
6.1 Pengendalian Biaya Proyek Jalan Raya	114
6.2 Pembayaran Bersyarat dalam Proyek.....	120
6.3 Aspek Yuridis dalam Kontrak Konstruksi	126
6.4 Strategi Pengendalian Risiko Biaya	132
Bab 7: Beton Serat Nylon	138
La Ode Idris	138
7.1 Beton Serat dalam Konstruksi.....	138
7.2 Karakteristik Serat Nylon.....	144
7.3 Pengaruh Serat Nylon terhadap Beton K-225	150
7.4 Evaluasi Mutu Beton Serat Nylon.....	155
Bab 8: Metode Analisis Tebal Perkerasan Aspal.....	162
Lendi Sahetapi.....	162
8.1 Dasar Perkerasan Lentur	162
8.2 Faktor Penentu Tebal Perkerasan	169
8.3 Analisis Tebal Lapisan Aspal.....	174
8.4 Penerapan pada Ruas Jalan Saparua–Haria.....	180
Bab 9: Daya Dukung Fondasi Tiang Bor Beton	186
Charly Lekahena	186
9.1 Fondasi Tiang Bor Beton	186

9.2 Parameter Tanah untuk Fondasi	192
9.3 Analisis Daya Dukung Tiang Bor	198
9.4 Fondasi Tiang Bor pada Abutmen Jembatan	204
Bab 10: Perkerasan Lapis Penetrasi Makadam	210
Verell Timoti Riry.....	210
10.1 Konsep Lapis Penetrasi Makadam	210
10.2 Tahapan Pekerjaan Lapis	216
10.3 Analisis Biaya Pekerjaan Lapis.....	222
10.4 Efisiensi Biaya pada Ruas Jalan.....	228
Bab 11: Beton Substitusi Limbah Karbit	234
Tigrisia Latuasan.....	234
11.1 Limbah Karbit sebagai Material Alternatif	234
11.2 Silica Fume dalam Campuran Beton.....	240
11.3 Substitusi Material terhadap Beton $f_c' 25 \text{ MPa}$	246
11.4 Evaluasi Kuat Tekan Beton	252
Bab 12: Material Sungai Penyusun Campuran Beton Normal	258
Anisah Devi Imtiyaz Alfiiyah	258
12.1 Material Sungai dalam Konstruksi Beton	258
12.2 Kelayakan Material Sungai	264
12.3 Campuran Beton Normal.....	270
12.4 Evaluasi Material Sungai di Pulau Seram	276
Profil Penulis.....	282
Daftar Pustaka	303

Daftar Pustaka

- ACI Committee. (2021). *Guide for Design of Jointed Concrete Pavements for Streets and Local Roads*. American Concrete Institute.
- Ahmed, S. F. U., & Mihashi, H. (2022). *Fiber Reinforced Concrete: Principles and Applications*. Springer.
- Ahmed, S. F. U., Mihashi, H., & Ahmed, S. F. (2020). Mechanical properties of fiber reinforced concrete containing synthetic fibers. *Construction and Building Materials*, 248, 118665.
- Althoey, F., Zeyad, A. M., Tayeh, B. A., & Yusuf, M. O. (2023). Sustainable performance of cementitious composites containing supplementary cementitious materials: A review. *Case Studies in Construction Materials*, 18.
- Alwesabi, E. A., Bakar, B. H. A., Alshaikh, I. M. H., & Akil, H. M. (2021). Effect of nylon fibers on mechanical properties and durability of concrete. *Materials Today: Proceedings*, 42, 2384–2390.
- Amin, M., & Suhatri, M. (2022). Utilization of carbide waste as supplementary cementitious material in concrete production. *Materials Today: Proceedings*, 65, 2481–2486.
- ASTM International. (2021). *Standard practice for estimating concrete strength by the maturity method (ASTM C1074)*. ASTM International.

- Budhu, M. (2020). *Soil mechanics and foundations* (4th ed.). Wiley.
- Chang, X., Wang, F., & Liu, Y. (2022). Development and application of wet-mix shotcrete technology in underground construction. *Construction and Building Materials*, 347, 128543.
- Choi, S., Won, M., & Kim, Y. (2021). Evaluation of traffic loading effects on concrete pavement performance. *International Journal of Pavement Engineering*, 22(9), 1125–1135.
- Das, B. M., & Sivakugan, N. (2018). *Principles of Foundation Engineering* (9th ed.). Cengage Learning.
- Gupta, T., & Kumar, S. (2021). Influence of silica fume on mechanical and durability properties of concrete. *Construction and Building Materials*, 293, 123526.
- Hamkah, dkk. (2018). Prediction model of compressive strength of concrete composed of Portland composite cement, marine sand, and sea water using maturity method. *International Journal of Applied Engineering Research*, 13(3), 1748–1754.
- Hamkah, dkk. (2022). *Teknologi beton*. CV Tohar Media.
- Huang, Y. H. (2004). *Pavement Analysis and Design* (2nd ed.). Pearson Prentice Hall.
- Ismail, M. A., & Ramli, M. (2021). Properties of concrete containing carbide waste as partial cement replacement. *Construction and Building Materials*, 287, 122993.
- Kerzner, H. (2022). *Project management: A systems approach to planning, scheduling, and controlling* (13th ed.). Wiley.

- Khan, M. I., Ali, M., & Abdullah, M. (2022). Effect of nylon fibers on fresh and hardened properties of concrete. *Case Studies in Construction Materials*, 16, e01035.
- Kim, B., & Reinschmidt, K. F. (2021). Cost management practices for infrastructure construction projects. *Journal of Construction Engineering and Management*, 147(6), 04021045.
- Kim, J., Choi, H., & Lee, S. (2021). Evaluation of shotcrete performance using non-destructive testing methods in tunnel structures. *Construction and Building Materials*, 301, 124342.
- Kim, S., & Lee, J. (2021). Structural behavior analysis of bridge abutment foundations under combined loading conditions. *Journal of Bridge Engineering*, 26(9), 04021067.
- Kusumawardani, R., & Nugroho, A. (2021). Legal aspects and contractual obligations in Indonesian construction projects. *Journal of Legal, Ethical and Regulatory Issues*, 24(5), 1–9.
- Lee, H., Kim, J., & Park, S. (2024). Evaluation of concrete compressive strength prediction using the maturity method incorporating various curing temperatures and binder compositions. *Materials*, 17(23), 5794.
- Li, X., Zhang, Y., & Wang, H. (2021). Application and performance evaluation of shotcrete support technology in slope stabilization engineering. *Construction and Building Materials*, 287, 122978.

- Li, Z., Zhang, Y., & Wang, P. (2020). Effect of silica fume on pore structure and chloride resistance of concrete. *Materials*, 13(15), 3375.
- Liu, H., Wang, X., & Zhang, L. (2020). Axial bearing behavior of pile foundations in soft soil conditions. *Soils and Foundations*, 60(5), 1123–1135.
- Liu, H., Zhang, Y., & Chen, X. (2021). Evaluation of pile foundation bearing capacity using static load and dynamic testing methods. *Journal of Building Engineering*, 44, 102951.
- Liu, Y., Zhang, X., & Wang, Q. (2022). Structural deformation monitoring and crack assessment in shotcrete-supported tunnels. *Tunnelling and Underground Space Technology*, 126, 104525.
- Love, P. E. D., Smith, J., & Ackermann, F. (2022). Understanding cost overruns in transportation infrastructure projects. *Engineering, Construction and Architectural Management*, 29(4), 1543–1561.
- Mangi, S. A., Ibrahim, M. H. W., Jamaluddin, N., Arshad, M. F., Putra Jaya, R., Shahidan, S., & Ali, N. (2021). Utilization of sea sand and seawater in concrete construction: Current status and future opportunities. *Construction and Building Materials*, 286, 122989.
- Mehta, P. K., & Monteiro, P. J. M. (2020). *Concrete: Microstructure, properties, and materials* (4th ed.). McGraw-Hill Education.
- Mindess, S., Young, J. F., & Darwin, D. (2020). *Concrete* (3rd ed.). Pearson Education.

- Mulyono, A. T. (2021). *Teknologi perkerasan jalan*. Gadjah Mada University Press.
- Neville, A. M. (2011). *Properties of Concrete* (5th ed.). Pearson Education Limited.
- Patel, R., & Desai, A. (2022). Effect of supplementary cementitious materials on concrete compressive strength and durability. *Materials Today: Proceedings*, 65, 1872–1878.
- Poulos, H. G. (2022). *Pile Foundation Design and Construction Practice* (7th ed.). CRC Press.
- Prasetyo, A., & Nugroho, S. (2021). Evaluation of penetration macadam pavement performance on rural roads. *International Journal of Civil Engineering and Technology*, 12(4), 45–53.
- Project Management Institute. (2021). *A guide to the project management body of knowledge (PMBOK guide)* (7th ed.). Project Management Institute.
- Putri, N. A., Hidayat, B., & Saputra, R. (2022). Digital estimation methods in road construction cost analysis. *Journal of Infrastructure and Construction Engineering*, 6(2), 115–124.
- Rahman, A., Yusuf, M., & Hidayat, T. (2021). Influence of river aggregate characteristics on concrete compressive strength. *Materials Science Forum*, 1025, 155–162.
- Rahman, H. A. (2022). Risk allocation and dispute resolution in construction contracts. *International Journal of Construction Management*, 22(14), 2704–2712.

- Rahman, M., Karim, M., & Hossain, M. (2021). Performance evaluation of flexible pavement under traffic loading conditions. *International Journal of Pavement Research and Technology*, 14(5), 563–572.
- Rahman, M., Karim, R., & Islam, S. (2021). Experimental investigation on compressive strength of concrete using industrial waste materials as partial cement replacement. *Case Studies in Construction Materials*, 15, e00760.
- Roberts, F. L., Kandhal, P. S., Brown, E. R., Lee, D. Y., & Kennedy, T. W. (2020). *Hot mix asphalt materials, mixture design, and construction*. NAPA Research and Education Foundation.
- Sadiq, M., Khan, R., Ahmad, S., & Ali, F. (2025). An investigative study on the mechanical properties of jute, nylon, and synthetic fiber reinforced concrete. *Discover Civil Engineering*.
- Saha, P., & Rajasekaran, C. (2021). Performance of high-strength concrete with superplasticizer and mineral admixtures. *Materials Today: Proceedings*, 45, 6101–6107.
- Scrivener, K. L., John, V. M., & Gartner, E. M. (2018). Eco-efficient cements: Potential economically viable solutions for a low-CO₂ cement-based materials industry. *Cement and Concrete Research*, 114, 2–26.
- Shafiq, N., Nuruddin, M. F., Ayub, T., & Khan, S. U. (2022). Durability performance of concrete containing sea sand and seawater under aggressive environments. *Materials Today: Proceedings*, 48, 1815–1821.

- Shi, C., Wu, Z., Xiao, J., Wang, D., Huang, Z., & Fang, Z. (2020). A review on seawater sea-sand concrete. *Construction and Building Materials*, 243, 118234.
- Shi, X., Xie, N., Fortune, K., & Gong, J. (2020). Durability of steel reinforced concrete in chloride environments: An overview. *Construction and Building Materials*, 30(1), 125–138.
- Siregar, M., & Pratama, D. (2021). Cost efficiency analysis on flexible pavement construction projects. *International Journal of Civil Engineering and Technology*, 12(3), 45–53.
- Soeharto, I. (2020). *Manajemen proyek dari konseptual sampai operasional*. Erlangga.
- Sridhar, M., Kumar, M. V., Nagaprasad, N., Bhagat, S. K., & Ramaswamy, K. (2025). Microstructural and statistical analysis on mechanical performance of novel flattened end nylon fibre reinforced concrete. *Scientific Reports*, 15(1).
- Sukirman, S. (2022). *Perkerasan lentur jalan raya*. Nova.
- Thomas, B., & Gupta, R. C. (2020). Properties and applications of shotcrete in underground construction and slope stabilization. *Materials Today: Proceedings*, 32, 761–766.
- Thomas, M. (2021). *Supplementary cementing materials in concrete*. CRC Press.
- Tomlinson, M., & Woodward, J. (2021). *Pile Design and Construction Practice* (7th ed.). CRC Press.
- Huang, Y. H. (2021). *Pavement analysis and design* (3rd ed.). Pearson Education.

- Wang, H., Li, N., & Zhao, Y. (2022). Influence of drainage and base layer quality on flexible pavement performance. *Construction and Building Materials*, 344, 128219.
- Alwesabi, E. A., Bakar, B. H. A., Alshaikh, I. M. H., & Akil, H. M. (2021). Mechanical properties of nylon fiber-reinforced concrete: A review. *Materials Today: Proceedings*, 42, 2510–2516.
- Wang, H., Zhang, Y., & Sun, L. (2021). Mechanistic-empirical pavement design for flexible pavement structures under heavy traffic loading. *Construction and Building Materials*, 278, 122391.
- Wang, T., Li, Z., & Zhang, Y. (2020). Performance of high-performance concrete pavement under environmental loading conditions. *Construction and Building Materials*, 247, 118542.
- Wang, Y., & Li, X. (2022). Stability analysis and reinforcement technology of highway slopes using shotcrete support systems. *Journal of Rock Mechanics and Geotechnical Engineering*, 14(4), 1123–1135.
- Wibowo, A., & Setiawan, B. (2022). Utilization of local aggregates for sustainable concrete construction. *Journal of Civil Engineering and Infrastructure Technology*, 3(2), 89–97.
- Yang, J., Li, P., & Zhao, M. (2021). End-bearing performance of deep pile foundations under vertical loading. *Journal of Geotechnical Engineering*, 147(8), 04021065.

- Yin, J., Li, Z., & Zhao, Y. (2021). Mechanical performance and durability of modern shotcrete materials in tunnel engineering. *Materials*, 14(18), 5312.
- Yoder, E. J., & Witczak, M. W. (1975). *Principles of Pavement Design* (2nd ed.). John Wiley & Sons.
- Yoo, D. Y., & Banthia, N. (2021). Mechanical properties of ultra-high-performance fiber-reinforced concrete: A review. *Cement and Concrete Composites*, 118, 103971.
- Zeyad, A. M., Tayeh, B. A., Althoey, F., & de Azevedo, A. R. G. (2022). Effect of supplementary cementitious materials on mechanical and durability properties of concrete: A review. *Materials Today: Proceedings*, 65, 1691–1698.
- Zhang, H., Liu, Q., & Chen, Y. (2021). Application of shotcrete and drainage systems in slope stabilization under heavy rainfall conditions. *Engineering Geology*, 293, 106321.
- Zhang, J., & Wang, L. (2022). Geotechnical investigation and pile foundation analysis for deep soft soil conditions. *Engineering Geology*, 301, 106615.
- Zhang, P., Li, Q., & Wang, J. (2021). Durability design of concrete structures in marine environments. *Materials*, 14(9), 2338.
- Zhang, P., Li, Q., & Wang, J. (2021). Sulfate attack on concrete: Mechanisms and durability assessment. *Construction and Building Materials*, 293, 123491.
- Zhang, P., Wittmann, F. H., Zhao, T., & Lehmann, E. H. (2021). Durability of concrete structures exposed to marine environment. *Materials and Structures*, 54(2), 1–15.

- Zhang, X., & Li, J. (2022). Pavement performance evaluation using sensor-based monitoring systems. *Journal of Traffic and Transportation Engineering*, 9(4), 563–575.
- Zhang, Y., Liu, J., & Wang, X. (2022). Performance assessment of concrete pavement for heavy-duty construction access roads. *Materials*, 15(18), 6402.
- Zhou, Y., Wang, H., & Liu, Q. (2023). Evaluation of drilled shaft foundations for bridge abutments in soft soil conditions. *Engineering Structures*, 287, 116092.

Teknologi Beton dan Infrastruktur Sipil membahas peran penting beton sebagai salah satu material utama dalam pembangunan infrastruktur modern. Buku ini mengajak pembaca memahami bagaimana beton digunakan dalam berbagai proyek konstruksi, seperti jalan raya, jembatan, gedung, bendungan, pelabuhan, dan fasilitas publik lainnya yang mendukung kehidupan masyarakat sehari-hari. Dengan bahasa yang mudah dipahami, buku ini menjelaskan perkembangan teknologi beton dari masa ke masa serta kontribusinya terhadap kemajuan pembangunan.

Buku ini ditujukan bagi masyarakat umum yang ingin memahami pentingnya teknologi beton dalam pembangunan infrastruktur sipil. Diharapkan buku ini dapat menambah wawasan pembaca mengenai bagaimana teknologi konstruksi berperan dalam menciptakan lingkungan yang aman, nyaman, dan mendukung pertumbuhan ekonomi serta kesejahteraan masyarakat.