Numerical Methods in Rock Engineering - Introduction of the course(Week1, 8 Mar 2021)

Ki-Bok Min, PhD

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Department of Energy Resources Engineering
Seoul National University

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Introduction
Schedules, Room and Instructors

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- Lectures (3 credits)
  - Mon: 15:30 – 16:15
- Lecture Room: 38-323
- Instructor and Teaching Assistant
  - Ki-Bok Min, Room:38-303, kbmin@snu.ac.kr
  - Hwajung Yoo, Room:135, yhj0313@snu.ac.kr

Introduction
Objectives of the course

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- Objective;
  - Be familiar with essential concepts of various numerical methods applied in rock engineering or other related subsurface engineering.
  - Understand the basic principles of numerical methods FEM, (FDM, BEM) and DEM
  - Be able to apply numerical methods in rock mechanics/geomechanics problems.
  - Emphasis on hands-on experience of applying numerical methods to actual problem of interest

Introduction
Contents of the course

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	주(기간)	강의내용
강의 계획 Schedule	week 1, 3/8	- Introduction of the course - Numerical approach in rock engineering/Geomechanics
	week 2, 3/15	- Finite Element Method (Gallerkin FEM) - Home assignment #1: Summary of Paper by numerical method
	week 3, 3/22	- Finite Element Method (1D)
	week 4, 3/29	- Finite Element Method (1D & 2D)
	week 5, 4/5	- Finite Element Method (2D)
	week 6, 4/12	- Finite Element Method (2D elastic problem) - Home assignment #2: Coding of FEM program
	week 7, 4/19	- Finite Element Method (Exercise, COMSOL)
	week 8, 4/26	- Discrete Element Method (Introduction) - Explicit Discrete Element Method (Particulate system) - Home assignment #3: FEM exercise
	week 9, 5/3	- Explicit Discrete Element Method (Blocky system)
	week 10, 5/10	- Explicit Discrete Element Method (Blocky system) - Home assignment #4: DEM paper reading
	week 11, 5/17	- DEM Exercise (PFC, UDEC)
	week 12, 5/24	- DEM (implicit method: Discontinuous Deformation Analysis and Numerical Manifold Method) by invited speaker (Prof Tomofumi Koyama (Kansai University, Japan, tentative) - Home assignment #5: DEM exercise
	week 13, 5/31	- Presentation of progress of term paper & Consultation with instructor
	week 14, 6/7	- Outstanding issues in numerical methods for geomechanics
	week 15, 6/14	- Presentation of Term Papers - Final Exam - Home Assignment #5: Submission and Presentation of Term paper

References

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- References (FEM & DEM)
  - Overview
    - Jing L, 2003, A review of techniques, advances and outstanding issues in numerical modelling for rock mechanics and rock engineering. Int J Rock Mech Min Sci, **40**(3): p. 283-353.
  - FEM
    - Burnett DS, 1987, Finite Element Analysis - from concepts to applications, Addison-Wesley Publishing Company, 844p (or other numerous FEM textbook)
  - DEM
    - Jing, L. , Stephansson O, 2007, Fundamentals of Discrete Element Methods for Rock Engineering: Theory and Applications. Elsevier Science
    - Cundall PA, 1979, Discrete Numerical-model for granular assemblies, Geotechnique, 29(1): p.47-65
    - Potyondy DO, Cundall PA, 2004, A bonded-particle model for rock, Int J rock Mech Min Sci, 41(8): p.1329-1364
    - Cundall PA, 1988, Formulation of a 3-dimensional distinct element model. 1. A Scheme to detect and represent contacts in a system composed of many polyhedral blocks, Int J Rock Mech Min Sci & Geomech Abstr, 25(3):p.107-116
    - Hart R, Cundall PA, 1988, Formulation of a 3-dimensional distinct element model. 2. Mechanical calculations for motion and interaction of a system composed of many polyhedral blocks, Int J Rock Mech Min Sci & Geomech Abstr, 25(3):p.117-125

Introduction
Assessment

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- Assessment
  - Home Assignment : 50 % ~5 home assignments
  - Final Exam : 20 %
  - Term paper : 20 %
  - Participation : 10 %

Introduction
Home Assignments (40%)

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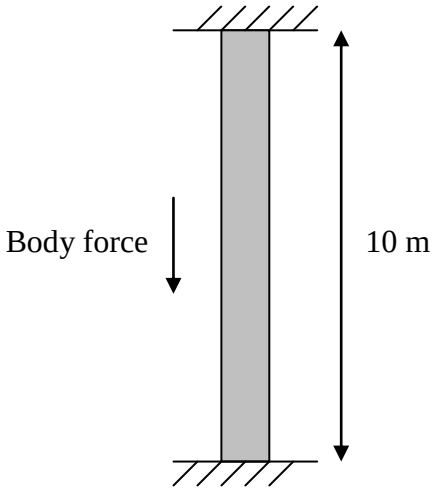
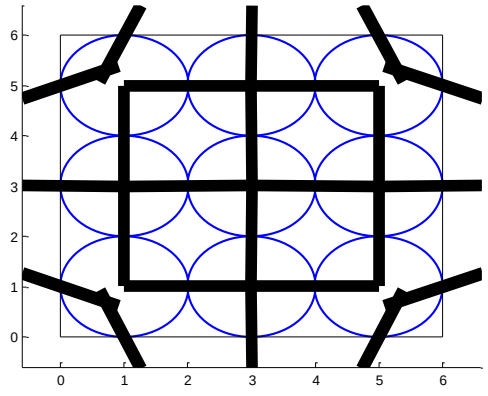
- #1 1 page summary of selected papers on numerical analysis
- #2 1D(or 2D) coding of FEM/FDM (use excel, matlab, or other codes)
- #3 Exercise with FEM code (comsol multiphysics)
- #4 Paper reading (DEM) – classical paper of your choice
- #5 Exercise with UDEC/PFC





Introduction
Term Project (20%)

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- Select a subsurface engineering problem of your interest and conduct a numerical analysis using any available codes.
- Term paper must include;
  - Clear objectives
  - One or two verification cases
  - Thorough formulation of the chosen numerical method
  - Concise presentation and discussion on the results
- Timeline
  - 31 May — Proposal (1 page) & 10 minutes presentation
  - 7 June — Consultation with instructor
  - 14 June — Presentation and submission of Term Paper

Introduction
Term Project

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- A list of example topics
  - Reproduction of published landmark papers
  - Borehole Stability problem in Anisotropic Media (FEM or FDM)
  - Fracture propagation in petroleum/geothermal reservoir (BEM or DEM)
  - Calibration of micromechanical parameters for transversely isotropic rock rock (DEM)
  - Coupled (thermo) hydromechanical analysis in porous medium
  - CO2 injection in saline formation
  - Thermomechanical analysis for geological repository of nuclear waste
  - Slope Stability in fractured or continuum rock
  - Reinforcement of tunnel
  - Determination of equivalent properties of fractured rock mass (DEM)

- Presentation
  - Presentation is an extremely important part of your professional life. Therefore, you have a good reason to be serious about this.
  - 10 minutes + 5 min (questions)

Introduction
Term Project

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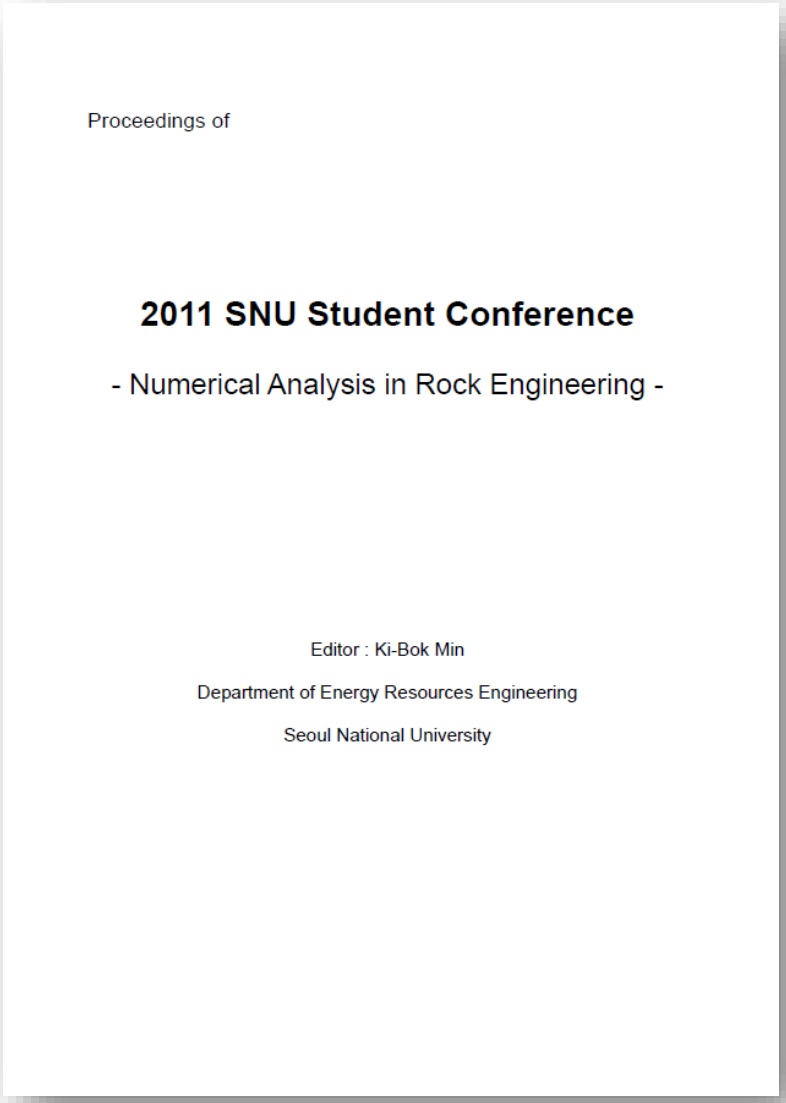
- Your term papers will be published as proceedings.
- Your term papers may be developed into journal papers in the future.


Proceedings of

2011 SNU Student Conference

- Numerical Analysis in Rock Engineering -

Editor : Ki-Bok Min

Department of Energy Resources Engineering

Seoul National University

Introduction
Final Exam (Take home)

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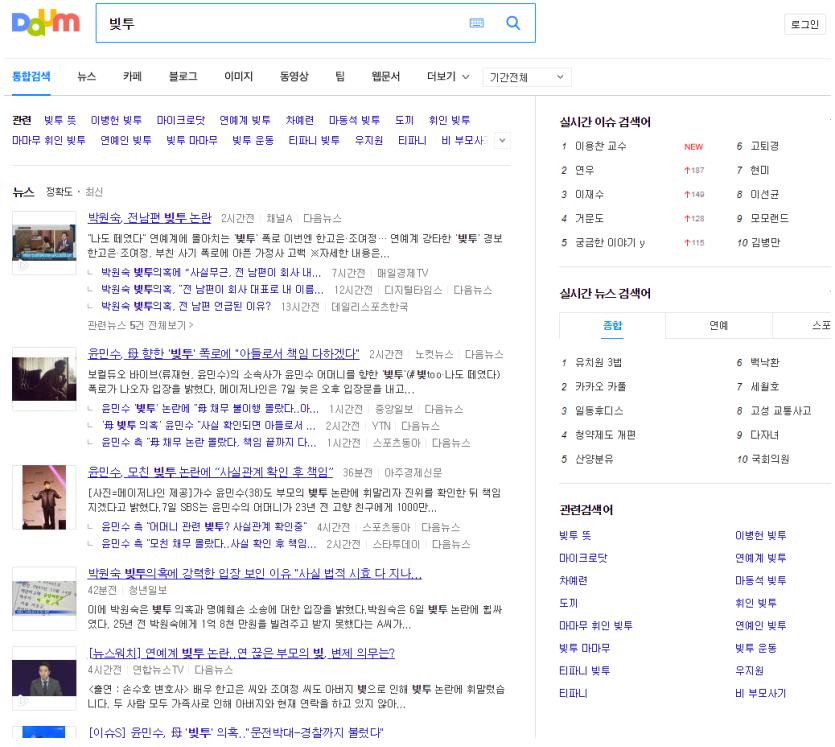
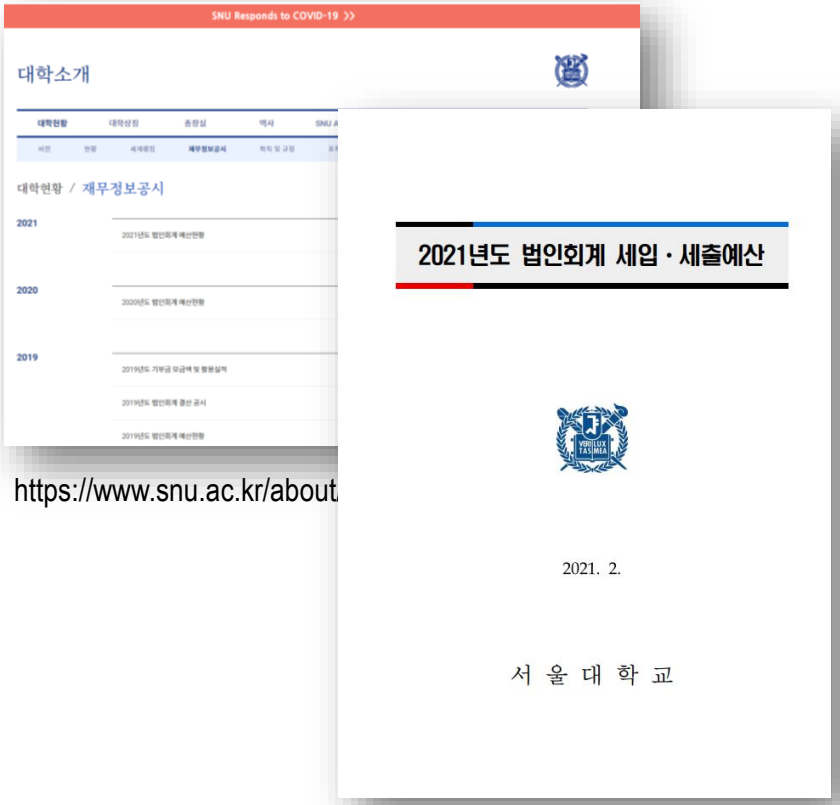
- Demonstration of basic concepts and principles on numerical method, FEM & DEM.. Or numerical skills
- The details will be announced later.

SNU and our society

- 서울대의 두가지 빚 (**빚TWO**) Social responsibility of Seoul National University (two kinds of debts)
  - 국내 (government)
  - 국외 (overseas)



“Beyond Reservoir Geome
Being SNU Students/Alumn



https://www.snu.ac.kr/about

정부출연금: **512,353,000,000 KRW (~5,123억원)**
등록금(학부 및 대학원): **178,705,000,000 KRW (~1,787억원)**

512,353,000,000 ÷ 178,705,000,000 = 2.87
4년 등록금 x 2.87배 = 졸업시 정부출연금 혜택 총계

Ⅲ 세입 총괄

(단위: 백만원)

구 분	2020(A)	2021(B)	증감(B-A)
합 계	**863,485**	**911,954**	**48,469**
정부출연금 수입	486,565	512,353	25,788
소계	**486,565**	**512,353**	**25,788**
등록금 수입[1]	180,278	178,705	-1,573
교내 타회계전입금 수입[2]	21,786	25,920	4,134
교육부대 수입[3]	27,285	25,957	-1,328
전기 일반 이월금[4]	16,500	41,300	24,800
부설학교 수입[5]	475	0	-475
소계	**246,324**	**271,882**	**25,558**
보조금[6]	15,101	16,730	1,629
수입대체경비[7]	115,495	110,990	-4,505
소계	**130,596**	**127,719**	**-2,877**

1) 등록금: 2021년도 학부·대학원 수업료 동결, 대학원 입학금 동결
2) 교내 타회계전입금 수입: 부족 재원 보전을 위해 산학협력단 등 교내 타회계 지원금 편성
3) 교육부대 수입: 대학 운영 및 시설물 관리 등으로 발생하는 세입 재원을 계상, 전년 대비 대부분의 항목(예금이자 수입, 재산운용수입 등)에서 세입 감소
4) 전기 일반 이월금: 2020년도 말 자금이월 예상액(약 413억원)을 세입예산에 편성 후 이 중 일부를 적립금(건축·퇴직·장학적립금)으로 운영할 예정
5) 부설학교 수입: 2021년부터 고등학교 전 학년 무상교육 실시에 따른 세입 감소
6) 보조금: 정부 등의 별도 사업비 지원 계상
7) 수입대체경비: 공개강좌, 법인재산활용 사업 등 177개 사업 수입금 계상

"Beyond Reservoir Geomechanics"
Minnesota-SNU project (미네소타 프로젝트)

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- A official development project conducted by University of Minnesota on Seoul National university
  - Sponsor: US FOA/ICA*
  - Duration: 1954 – 1962
  - Budget: ~ 10 million USD (현재가치~1200억원)
  - Target: 3 Colleges
    - Engineering, Medicine & Agriculture
  - Type
    - Training of faculty members
    - Consulting on university operation
    - Infrastructure

From the left: Yung Mo Hwang- Dean of Engineering, Baik Hyun Cho- Dean of Agriculture, Dr. A.E. Schneider- Chief Advisor, Chae Koo Lee- Dean of Medicine.

*FOA: Foreign Operations Administration, ICA: Int Cooperation Administration

Fowler S. Seoul National University, Schneider with Deans.. 1955-01-04. University of Minnesota Libraries, University Archives., umedia.lib.umn.edu/item/p16022coll175:20890 (방문일: 2021년 2월21일).

"Beyond Reservoir Geomechanics"
Minnesota-SNU project

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- SNU faculty's stay in U of Minnesota
  - 3-6 months
  - 1 year (senior faculty members)
  - 2 year (junior faculty members)
- 226 academic members visited U of Minnesota
  - 64 (Engineering, 54 Faculty + 10 lecturer + assistants), 57 (Agriculture), 78 (Medicine)
  - 15 PhD degrees, 71 MSc degrees
- Following work after visit to US
  - Developing new courses
  - Adopting new teaching methods

"Beyond Reservoir Geomechanics"
Minnesota-SNU project

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- Faculty members trained in the US
  - Total # of Faulty member (> fulltime lecturer) in Engineering in 1955: 66
  - >80 % of full time faculty member were trained through Minnesota Project

전공	연수인원	비고
건축학	3	부교수 1, 조교수 1, 전임강사 1
광산학	5	교수 1, 부교수 2, 전임강사2
금속공학	5	부교수 3, 조교수 1, 강사 1
기계공학	7	교수 3, 부교수 2, 조교수 2
섬유공학	6	교수 2, 조교수 2, 전임강사 1, 조교 1
원자핵공학	4	조교수 1, 강사 1, 조교 2
전기공학	7	교수 2, 부교수 2, 조교수 3
전자공학	3	부교수 2, 전임강사 1
토목공학	6	교수 1, 부교수 1, 조교수 2, 전임강사 1, 강사 1
항공조선공학	5	조교수 3, 전임강사 2
화학공학	8	부교수 3, 조교수 1, 전임강사 1, 강사 2, 조교 1
기타 (기초수학, 기초물리, 기초화학 등)	5	교수 2, 조교수 1, 전임강사 1 강사 1
계	64	전임강사 이상 54명, 강사 및 조교 10명

“Beyond Reservoir Geomechanics”
Minnesota-SNU project

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- Faculty members from SNU Mining Engineering
  - 송태윤 (부교수, 1955년 ~, 15개월)
  - 홍준기 (교수, 1956년 ~, 6개월)
  - 김동기 (전임강사, 1956년 ~, 24개월)
  - 김재극 (부교수, 1956년~, 12개월)
  - 전용원(전임강사, 1957년~, 24개월, 석사학위취득)

"Beyond Reservoir Geomechanics"
Minnesota-SNU project

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- Visiting scholars from U of Minnesota
  - 57 in total (43 associate professor/professor)
  - Advice on education system

Advisors to the College of Engineering (Kim, 2009)

Name	start	end	Duration (month)	role	Affiliation
W. R. Weems	1955. 2. 1	1956. 7. 16	17.5	Overall	MIT
Carl Graffunder	1955. 9. 9	1955. 12. 12	3	Architecture	U of Minnesota, lecturer
S. C. Larson	1955. 9. 16	1955. 12. 19	3	Electrical	U of Minnesota, A/ professor
C. E. Lund	1955. 9. 26 1958. 4. 1	1955. 12. 23 1959. 3. 16	3 11.5	Mechanical	U of Minnesota, professor
C. A. Harris	1956. 6. 4	1956. 9. 1	3	Textile	Lowell U, professor
W.W. Staley	1956. 6. 16	1957. 9. 27	15.5	Mining	Idaho U, Professor
Paul Andersen	1956. 7. 31 1959. 6. 17	1956. 12. 31 1959. 12. 14	4.5 6	Civil	U of Minnesota, professor
Harvey Evans	1957. 4. 1	1957. 7. 12	3.5	Naval architecture	MIT, Profesor
C. E. Schwartz	1958. 8. 7	1959. 9 3	13	Chemical	Virginia U, A/professor
J. W. McCarty	1959. 9. 10	1960. 9. 21	12.5	Textile	Georgia Tech, A/professor
Harold E. Babbitt	1960. 6. 15	1961. 6. 20	12	Civil	U Illinois, Professor
J. P. Hartnett	1960. 10. 17	1960. 10.29	0.5	Nuclear	U of Minnesota, professor

“Beyond Reservoir Geomechanics”
Minnesota-SNU project

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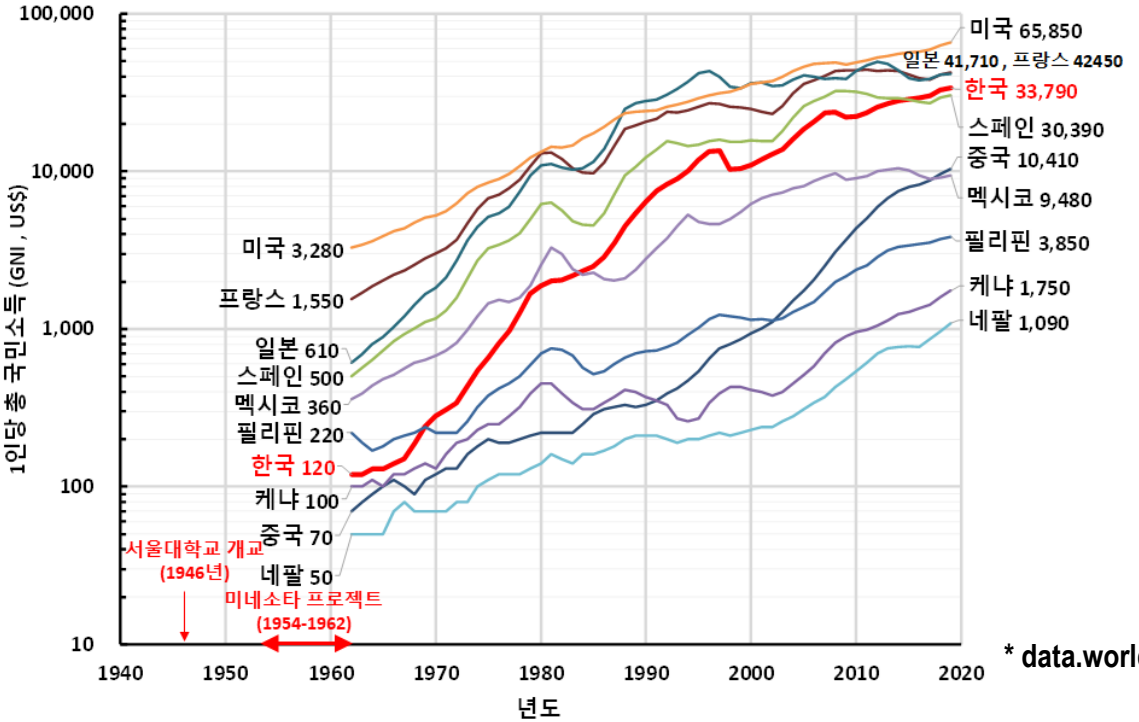
Japanese rule
(1910-1945)



* data.worldbank.org

Korean War
(1950-1953)

AFP연합뉴스, https://news.v.daum.net/v/20200625170614933

서울대학교 공과대학
(1955년4월)

Schulte PFC. Seoul National University, Aerial Views. 1955-04-14. University of Minnesota Libraries, University Archives, umedia.lib.umn.edu/item/p16022coll175:20889

“Beyond Reservoir Geomechanics”
Minnesota-SNU project

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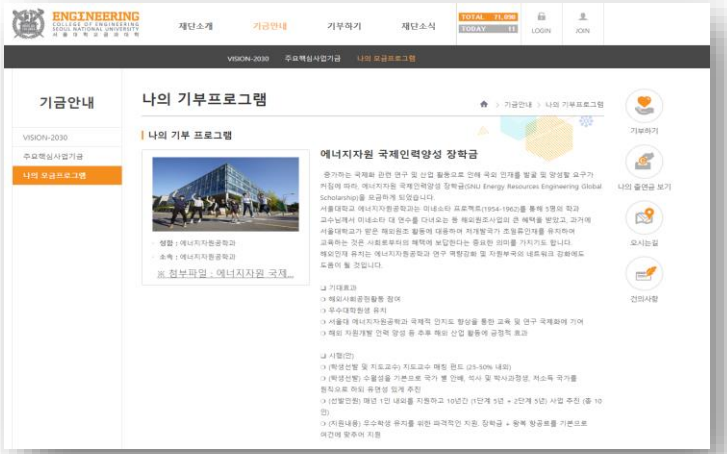
- 에너지자원 국제인력양성장학금 (SNU Energy Resources Engineering Global Scholarship)
  - 10명의 저개발국가 일류인재 양성 (우리가 받은 혜택의 2배)
  - 모금기간 및 목표: 2019.4 – 2029.4 (10년간, 6억)



이정인 명예교수님 (가운데) 약정식 (5,000만원)

김기석 희송지오텍 대표 (오른쪽 세번째) 약정식 (5,000만원)

https://engerf.snu.ac.kr/fundinfo/my_fund_view.php?idx=29

“Beyond Reservoir Geomechanics”
Being SNU Students/Alumni

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We should not forget that
“We are studying in Seoul National University through substantial support from general public expecting both academic excellency and (global and national) social responsibility”

- - 2015년 작고한 정석규 동문(화학공학 졸)은 1967년 태성고무화학을 창업하여 국내최초로 공업용 특수고무 제품을 양산하였으며, 1987년부터 작고할 때까지 총 451억원을 서울대학교에 기부“
- ... 이 세상은 혼자서 살아갈 수 있는 곳이 아닙니다. 반드시 누군가의 도움을 받는 한편 누군가에게 도움을 주면서 살아가고 있는 것입니다. 내가 사회에서 부(富)의 축적을 하게 된 것은 나의 노력의 성과라고도 하겠지만 남의 도움으로 이루어진 것이니 축적된 재물을 사회에 환원하는 것은 당연한 순리(順理)인 것입니다.”

  정석규 동문 신양문화재단 운영 서울대학교 위임식 인사말 중.