THE CIVIL ENGINEERING DEVELOPMENTS IN CONJUCTION WITH SUSTAINABLE WORLD

Roesdiman Soegiarso[1]

[1]*Civil Engineering Program, Tarumanagara University*
Letjen S. Parman No1, Jakarta 11440
Email: rsoegiar@dnet.net.id

ABSTRACT

The progressive development in Civil Engineering discipline has changed the life style of the people. Particularly in big cities, the needs of places for working, living and enjoying life have increased significantly. The Super-blocks, Central Business District (**CBD**) and Real Estate concepts have become the trend of the city development. Many high-rise buildings have been built along with the development of the building materials, the method of construction and the theoretical aspects of civil engineering. Despite all the reasons behind the construction of high-rise buildings, this phenomenon has become the trend in construction. The nations are competing to become the best, the tallest, the largest, the longest and all attributes related to being number one. Consequently, our planet has to be explored and industries have to be developed. Do we believe this trend will continue or do we believe this trend will reach a saturated point? In which direction we are heading for our future.

When we further explore, due to this exploration, the environment is affected. The global warming, green house and natural disaster have haunted our life. It seems that we are acting against the nature. As we are approaching the end of the twenty first century, the sustainability issues have brought the attention of the researchers included the civil engineers. Many conferences have been held and papers have been published on the issues related to Civil Engineering. The sustainable construction is one of the issues related to our future trend in construction. In order to discuss these issues, several studies have been made. In this paper, we would like to address the issues related to the development in civil engineering, the trend of construction industry and the challenge for the engineers to balance the needs of the people and the impact to the environment in fulfilling these needs.

Keywords: high-rise, construction, materials, sustainable.

1. INTRODUCTION

Civil engineering is considered as the oldest discipline in the field of engineering and it is closely related to human beings. In the human history, people always seek for a better life which civil engineers can contribute to it. The needs are considered as the human nature such as, better shelters for living, food for eating, water supply for drinking and taking showers and they are inherent in human life and called the primary needs. The next needs basically are related to convenience such as, an easy transportation, communication, electric power for human comfort, and etc. These are categorized as complementary needs. When the primary and complementary needs have been fulfilled, for a certain people particularly those who have influence, they are seeking for another form of satisfactions. They want to be recognized in the human history with their achievements. They want to show their influence and wealth. The great of Pyramid of Giza in Egypt, the Great Wall in China, Borobudur in Indonesia, and the Khalifa tower in Dubai are among this category. These prominent structures show the evidence of the hard work of civil engineers in the design and construction. The brief history of the construction will be outlined in this paper.

Many projects have been built to meet not only the primary needs of human beings but also the dream and the pride of the people. It ranges from the simple structures in the old days up to modern and sophisticated structures such as, the 830m the Khalifa tower in Dubai, Akasi Kaikyo bridge, the longest suspension bridge in the world. The dream of Indonesian to connect the Java and Sumatera islands with Sunda straight bridge has started with the preliminary studies. This is a challenge not only for the civil engineers but also for the government of Indonesia in materializing this dream. The engineering study on those projects will involve many aspects of science included civil engineering. The civil engineering field is so broad so that it has to be divided into at least eight majors. They are Structural Engineering, Environmental Engineering, Water Resources Engineering, Geotechnical Engineering, Transportation Engineering, Construction Engineering, Material science, Urban and Community Planning. People may ask where the trend of civil engineering is heading and which major will be developed aggressively along with the development in computer technology, communication network, environmental studies and other fields of science.

The question is how the development of these eight majors? In broad, we identify *three parameters* contribute to the future developments of civil engineering. The first parameter is the development in civil engineering itself. The second parameter is the development in the related fields, such as, computer technology, methods of solution and global network. The third is the concern of the people toward the environment and the sustainability of our planet. As we may aware of, as the results of the development of the industries, our planet has been explored and the environment is affected by the global warming, greenhouse and other sustainability issues. These issues have brought the attention of scientists included the engineers from different disciplines. It is important to note that directly or indirectly, civil engineering discipline is related to this exploration.

It is obvious that each discipline will give an impact to the developments in other disciplines. Hence, the future trend of civil engineering depends not only on the developments in civil engineering itself but also on the developments of other fields. Particularly, with the recent development in the internet, all information in many aspects of science can be obtained from unlimited sources. The future trend in civil engineering depends also upon the developments in related science and the demand in the market. In this paper, we will outline the development both theoretical and construction aspects in civil engineering and sustainable construction.

2. THE DEVELOPMENT OF CIVIL ENGINEERING

Since civil engineering is the oldest discipline, it has a long history of developments. However, in this paper we focus our discussion on the latest issues of the theoretical aspects in structural engineering and sustainability. At first, the development gained its momentum in the seventeenth century where the theory of elasticity was introduced. Prior to this concept, the analysis was based on the strength without considering the deformation of the structure. For instance, the stress on the building is based on the load acting upon the member without considering the deformation of the related members. In the elastic design, the deformation of the structures due to the external loads will determine the element forces. It is understood that in computing the deformations of a complex structure, a long numerical computation is needed. A simple tool or method cannot solve the problem accurately. The second momentum when the digital computer was made available to perform calculations. The method of solution was formulated in a matrix form and a complex problem was solved using high speed computer. In 1970s when the high speed computers were made available eventhough it was still limited but many papers had been published on the matrix analysis. Since then, the research in finite element grew rapidly. The formulation of element stiffness based on displacement, stress shape functions or and hybrid formulations. The error estimation concepts also have been developed during this time. Oden J.T., Hinton, E. and R.J. Owen, Przemiencki, J.S., Zienkiewicz , Bathe, K.J., and E.L. Wilson are among the pioneers in developing finite element analysis. Today, thousands of papers and books have been published related to "Introduction to Finite Element". In 1990s the development reached the maturity stage and today, many commercial softwares have been developed and applied in analyzing the structures.

Parallel to the development in finite element analysis, the matrix analysis also gained its momentum. In 1970s the research on structural optimization was recognized by engineers in obtaining the minimum weight of the structure. In broad, there are two camps in structural optimization. The first camp is called mathematical programming. A number books have been published to solve optimization problems. Among them are Vanderplaats G.N., (1984), Arora J.S., (1989), and many others. This approach is more general but the computational time is relatively high. Another camp is called optimality criteria. It utilizes the nature of the stiffness matrix i.e., symmetry and positive definite and criteria for minimum weight. This method is less general but the computational time is low compare with mathematical programming. Prager, W. (1968), Venkayya (1971), Berke, L and Khot, N.S. (1974) are among the researchers that introduce the concept of optimality criteria. Later on, discrete optimization of steel frames using standard sections was developed by Grierson and Lee (1984). In general, optimization of large structures needs high computer time. Along with the development of computer technology such as, Cray YMP, the computation is performed in parallel vector fashion to solve structural optimization problems. (Adeli and Soegiarso, 1998). Besides the classical approach, several other concepts have been introduced. For instance, the genetic algorithm concept is adopted for searching the minimum weight of a structure. Genetic algorithms are developed from the idea that comes from the biology where the creatures breed to produce the offspring. The offspring of a particular creature will inherit the good and bad characters from the parents. In the genetic algorithms, the character of each individual in a creature is defined string chromosome. Goldberg, D.E. (1989) elaborated the concept of genetic algorithm and it has been adopted in solving many engineering problems included the structural optimization problems (Soegiarso and Bonifacious, 2000). Another concept called neural dynamics where Lyapunov function is adopted to find the stability in searching as proposed by Hirsch and Smale (1974) and applied in structural optimization by Adeli and Park (1995, 1998). The neural network concept also can be applied to solve other engineering problems such as, to compute the column reinforcement due to axial and biaxial bending loads (Soegiarso and Indra, 2001). Recently, fuzzy logic concept also has been used as a tool to solve civil engineering problems such as, to determine the cause of crack of reinforced concrete structures, (Soegiarso and Laurence, 2000)

3. THE TREND OF WORLD TALL STRUCTURES

In broad, we distinguish the free standing tall structures into two categories. The first category is called "tower". The **CN** tower in Canada, Ostankino tower in Russia, Shanghai tower and Canton tower in China are in this category. The purpose of constructing this tower is mainly for broadcasting and telecommunication. Another category of tall structures is called "building". The Sears tower in the **USA**, Taipei 101 in Taiwan, Petronas tower in Malaysia, Khalifa tower in Dubai are among the structures in the second category. The main function for this building is for office or apartment. Even tough there are still some controversial issues regarding the name either tower or building and how to measure the height of the structures but it is not crucial for our discussion. We focus our discussion on tall structures that are related to buildings even though we use the term tower for buildings. In the discussion we would like to address two aspects. The first is the history of construction tall structures and the second is the design aspects of tall structures and sustainability construction.

3.1 The construction history of tall structures

The trend of the development of tall structures in the world is shown in Figure 1. We can observe that the movement of the construction of tall structures was started in Africa and then move to Europe and later on to America. The end of the twentieth century the activities started to move to Asia. In order to obtain the global trend, let us review the tallest structures in the world from the ancient time up to the present time. The construction of tall structures was started around 2700 BC in Egypt. In 2560 BC the Pyramid of Giza with the height of 146m was constructed in Egypt and it became the tallest structure in the world. All structures were built in Africa with the material of stone. However, trend of the construction of tall structures was discontinued for thousand years. In the eighteenth century, people started to build high-rise buildings particularly in Europe. In 1311, the Lincoln Cathedral was constructed in England with the height of 157m. From 1300s to 1900, most of the construction of tall structures took place in Europe. As it was approaching the end of the eighteenth century, the United States of America (**USA**) started to build tall structures. As shown in Figure 1, from 1970s to 1990s, not only there tall structures were constructed in North America, but the **USA** and Canada also dominated the theoretical development. In 1884, the Washington Monument, with the height of 169m was constructed in the **USA** as the tallest structure in the world. So, the tallest structure in the world was shifted from Europe to the **USA**. In 1930, Chrysler Building, the 77-story building with the height of 319m was constructed in the **USA**. One year later, on May 1, 1931, the Empire State Building, the 102-story building with the height of 381m was officially inaugurated in New York City with the presence of Governor Franklin D. Roosevelt. There are two important aspects we have to remember related to this building. The first, this building became the tallest building in the world when it was completed. This record was maintained for **43 years**. The second, this tower was constructed when the world was under recession and the **USA** was under the great depression. The project started just several weeks before the crash of the stock market in 1929. John D. Rockefeller as the owner of the building was able to manage his finance during the Great Depression of the 1930 and to complete the construction. In terms of economy of the country, the construction will give the positive impact particularly during that recession. On the other hands, due to the Great Depression, the leasing office space of this project suffered badly. It became the "Empty State Building". However, when the crisis was over in 1950s the Empire State Building became the most profitable building in New York City and at the same time became the icon of the **USA** even today. In December every year, the New York Christmas tree is located at this Empire State Building. I believe that Rockefeller is a visionary person even during the recession he had a great vision beyond the recession. In 1972, for 40 years after the Empire State Building held its title as the tallest building in the world, the 110-story twin towers of towers were built when the future of New York is uncertain but later on it became another land mark of New York and at the same time became the financial center. A great determination to build this tower should come from a great visionary person. David Rockefeller is one of the visionary people who pushed this project so that the confidence of the people on the economy can be restored. In 1974**,** the 108-story **Sears Tower** was also built in Chicago. It became the tallest tower in the world to replace the Empire State Building. Before the Sears Tower was completed, in 1969 the 100-story John Hancock Center with the height of 344m was completed in Chicago. In broad, in the twentieth century, the construction of tall structures was dominating by the **USA**. Many seminars and conferences on the issues of structures were held in the **USA**.

In 1998, the 88-story Petronas Twin Tower with the height of 452m was completed in Kuala Lumpur, Malaysia. It became the tallest building in the world to replace Sears Tower after being the tallest tower in the world for **24** years. This is the first tallest building located in Asia. This building has become the symbol of emerging Asia in terms of construction. Asian countries started their roles on the theatre of tall structures. In 2003, five years after the Petronas Twin Tower kept the position as the tallest building in the world, the 101-story Taipei 101 in Taiwan was

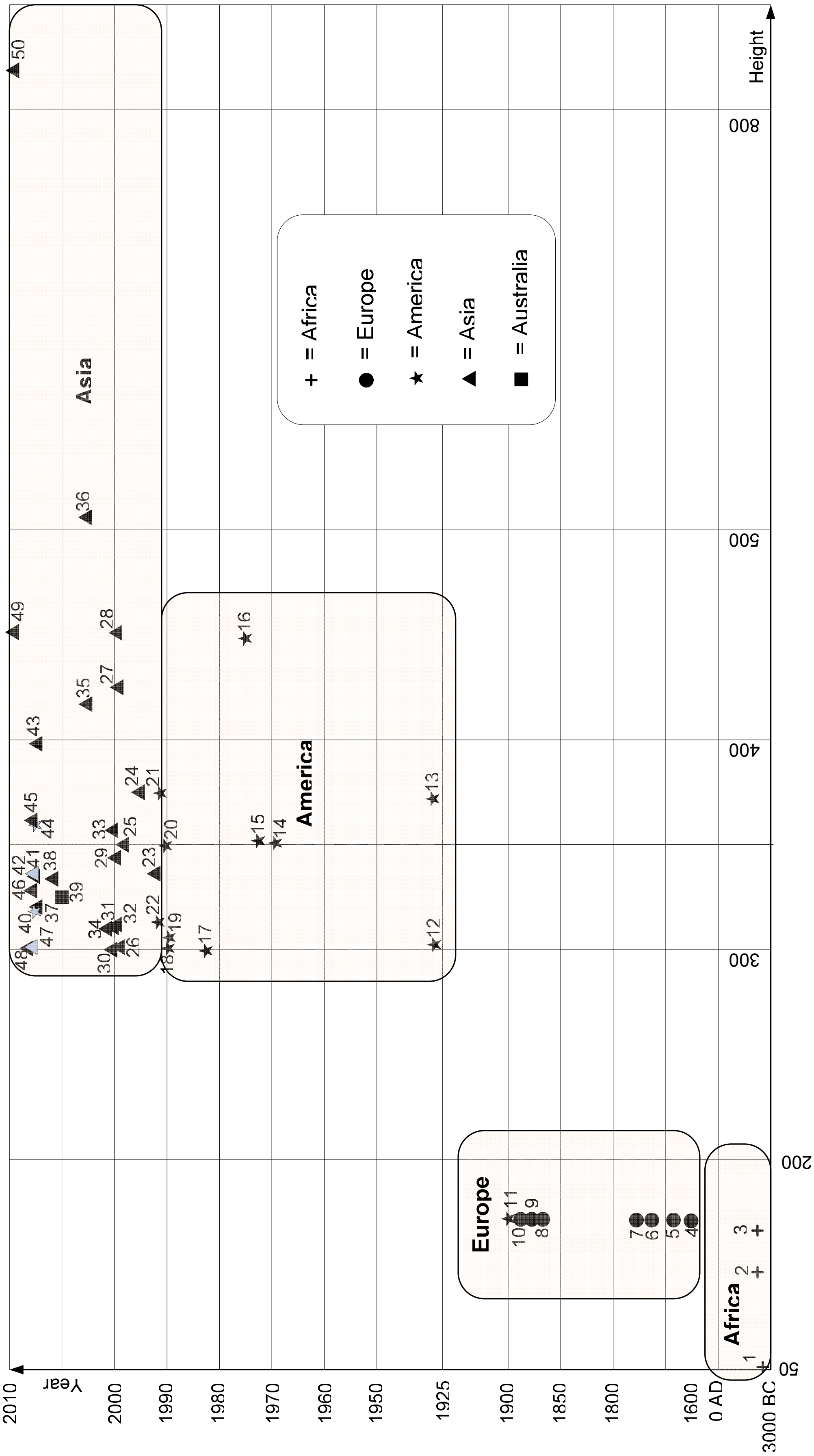

Figure 1: Tall structures in the world

Table 1: List of tall structures in the world

	Year	Name	Height (m)	Floors
1	2700 BC	Pyramid of Djoser, Egypt	62	
2	2600 BC	Red Pyramid of Sneferu, Egypt	105	
3	2570 BC	Great Pyramid of Giza, Egypt	146	
4	1311	Lincoln Cathedral, England	160	
5	1549	St. Olaf's Church, Estonia	159	
6	1625	St. Mary's Church, Germany	151	
7	1647	Strasbourg Cathedral, France	142	
8	1874	St. Nikolai, Germany	147	
9	1880	Cologne Cathedral, Germany	157	
10	1876	Cathedrale Notre Dame, France	151	
11	1884	Washington Monument, USA	169	
12	1930	Chrysler Building, USA	319	77
13	1931	Empire State Building, USA	381	102
14	1969	John Hancock Center, USA	344	100
15	1973	Aon Center, USA	346	83
16	1974	Sears Tower, USA	442	108
17	1982	JPMorgan Chase Tower, USA	305	75
18	1989	AT&T Corporate Center, USA	307	60
19	1989	U.S. Bank Tower, USA	310	73
20	1990	Bank of China Tower, Hong Kong	367	70
21	1992	Central Plaza, Hong Kong	374	78
22	1992	Bank of America, USA	312	55
23	1992	Ryugyong Hotel, North Korea	330	105
24	1996	Shun Hing Square, China	384	69
25	1997	Tuntex Sky Tower, Taiwan	348	85
26	1997	Baiyoke Tower II, Thailand	304	85
27	1998	Jin Mao Building, China	421	88
28	1998	Petronas Tower, Malaysia	452	88
29	1998	The Center, Hong Kong	346	73
30	1999	Burj Al Arab, United Arab Emirates	321	60
31	2000	Kingdom Center, Saudi Arabia	311	41
32	2000	Jumeirah Emirates Towers, Dubai	309	56
33	2000	Emirates Office Tower, UAE	355	54
34	2001	Menara Telkom, Malaysia	310	55
35	2003	Two International Finance Center, HK	415	55
36	2003	Taipei 101, Taiwan	509	101
37	2005	Q1 Tower, Australia	323	78
38	2006	Shimao International Plaza, China	333	60
39	2007	Nina Tower I, Hong Kong	319	80
40	2007	New York Times Building, USA	319	52
41	2007	Rose Tower, UAE	333	72
42	2007	Minsheng Bank Building, China	331	68
43	2007	Shanghai World Financial Center, China	492	101
44	2008	Bank of America Tower, USA	366	54
45	2008	Almas Tower, UAE	360	74
46	2008	China World Trade Center 3, China	330	74
47	2008	The Address Down Town Burj Dubai	306	63
48	2008	One Island East, Hong Kong	308	63
49	2009	Nanjing Greenland Fin. Center, China	450	89
50	2009	Burj Dubai, UEA	818	160

completed and at the same time it was declared to be the tallest building in the world. The height of the building is 509m which is 57m higher than the Petronas Twin Tower. This building was supported with modern technology included the high speed elevator with the speed of 1010m/minute. Six year later, in **2009**, the position of Taipei 101 as the tallest building in the world was replaced 160-story building, Khalifa Tower, in Dubai, United Arab Emirates (**UAE**). The height of the building is 818m which is 309m higher than Taipei 101. This is an ambitious project and the completion of this project again when the world was in recession. How long this building will keep the title as the tallest building in the world? From Figure 1, it is obvious that in the twenty first century Asia is dominating the construction of the tall structures not only in terms of height, but also in terms of number. But it is good to observe the knowledge behind the structures and the loads imposed on the several recent tall structures.

3.2 The design aspects of tall structures

In the design of tall structures, most of the time, the lateral loads due to the wind or earthquake will govern. Empire state building, Sears tower, Khalifa tower, the wind loads govern the design. However, the Taipei 101, both wind and earthquake loads have to be considered. Therefore, an efficient structural system to resist these loads has to be devised. Depending upon the location of the buildings, different systems may suite to different locations. For instance, the structure system to resist the earthquake loads might be different from the structure system to resist the wind loads. This is due to the nature of these two loads is different. In general, due to wind loads it is beneficial to develop a stiff structure so that to wind induced vibration can be minimized (Isyumov, Case and Soegiarso, 2001). On the other hands, due to earthquake loads, the flexible structure is better in dissipating energy. Recently, the reduction factor due to ductility of the structure is being introduced in the earthquake resistant design. The push over analysis is adopted to verify the ductility factor of the structure (Soegiarso and Hendra, 1999, Soegiarso, 2002). When both the earthquake and wind loads have to be considered in the design, the compromised solution has to be developed. One of the solutions is to install dampers at the buildings. For instance, Taipei 101 the tuned mass dampers are installed. In order to observe the architects and the structural engineers behind the tall structures let us observe tall structures in Table 2. It is obvious that most recent supper tall structures are in Asia, but the architects and the structural Engineers are dominated by the **USA**.

Table 2: List of Architects and Structural engineers of tallest structures

Building	Architect	Structural Engineer
Empire State Building, USA	Steve, Lamb and Harmon, USA	H.G. Balcom & Associates, USA
World Trade Center, USA	Minoru Yamasaki, USA	Worthington, Skiling, Helle&Jackson, USA
Sears Tower, USA	Bruce Graham (SOM), USA	Skidmore, Owings and Merrill, USA
Petronas Tower, Malaysia	Cesar Pelli & Associates, USA	Thornton Tomasetti, USA
Taipei 101, Taiwan	C.Y. Lee & Partners, Taiwan	Evergreen Consultant, Taiwan Thornton Tomasetti, USA
Burj Khalifa, Dubai	Skidmore, Owings and Merrill, USA	Skidmore, Owings and Merrill, USA
Shanghai Financial Building	Kohn Peterson Fox Associates, USA	Leslie E. Robertson Associates, USA

3.3 The Sustainability construction

Recently, many conferences and seminars have been conducted on the issues of sustainability. There are at least three international organizations actively involved in discussing and finding the solution to the sustainable problems. They are; *International Initiative for sustainable Built Environment* (**iiSBE**), *Council for Research and Innovation in Building and Construction* (**CIB**) and *United Nation Environment Program* (**UNEP**). Besides these three organizations, there are many regional organizations to support these organizations. One of the issues discussed is Sustainable Construction. The construction has a significant contribution to the global warming and consequently, it will deteriorate the sustainability of the world. Besides construction, there are many other parameters contribute to the deterioration of the world. The engineers from different disciplines have important rolls in solving the issue of deterioration of our planet. Among them are; Mechanical Engineering and Electrical Engineering, Structural Engineering, Architects and Environmental Engineering and many others. When the issues are elevated to the sustainable of the world, there are more parties involved. In order to show the interrelated among disciplines, the sustainable triangle is presented and Sustainable Construction is introduced in a systematic chart (Soegiarso, Gondokusumo and Jap, 2007). However, in the design, the application is still limited. Probably, people in general still believe that the design by adopting the sustainable integrated design concept is more expensive than the traditional design approach. In the last several years, more buildings are designed to meet the requirements as green buildings. It is important to note that the integrated issues related to Sustainable Construction have to be studied and optimized prior to the traditional design process. This concept is still not accepted as a common practice in the design and this is a challenge for civil engineers to convince the related parties the need in protecting our planet. In recent development, the concern of the academics, pressure groups and organizations on the sustainable development started after the second world-war. Researchers started to realize the future of this planet and therefore, a number of meetings/conferences were held. Among them several important milestones are listed as follows:

1968: The United Nations Educational Scientific and Culture Organization (**UNESCO**) Intergovernmental Conference for Rational Use and Conservation of Biosphere provided a forum for early discussions of the concept of ecologically sustainable development.
1971: The International Institute of Environment and Development (**IIED**) was formed to seek ways to make economic progress without destroying the environmental resource base.
1972: The UN Conference on Human Environment cohesively argued that the sustainable development presented satisfactory resolution to the dilemma of environment and development, leading to establishment of numerous environmental protection agencies and the UN Environment Program (**UNEP**).
1980: The World Conservation Strategy defined development as modification of the biosphere and the application of human, financial, living and non-living resources to satisfy human needs and improve the quality of human life.
1982: The UN World Charter for Nature called for an understanding of our dependence on natural resources and the need to control our use of them.
1987: The UN Report of the World Commission on Environment and Development. Gro Harlem Brundtland, the Prime Minister of Norwegian gave direction for comprehensive global solutions to problems of environment and development and popularized the term "**Sustainable Development**"
1992: The United Nations Conference on Environment and Development, known as "Earth Summit of the World" was held in Rio de Janeiro. In that conference the ground work for solving global environmental problems was discussed.
1994: The first International green building conference was held in London (**UK**).
1998: Larger conference on this issue was held in Paris. Later on in 1998 the sustainable building conference in Vancouver has brought attention of the people on this subject. More than 600 people attended this conference. In this conference a permanent series of world Sustainable Building conferences is established with generic abbreviation **SB**.
1999: The Sustainable Construction conference supported by Conseil International du Batiment (**CIB**), World Building Congress was held in Cape Town. The conclusion is that the construction industry and the built environment are two key areas if a sustainable development is to be attained in present societies. As mentioned earlier, this is due to buildings consume more than 40% of the total energy in the European Union, and the construction industry generates approximately 40% of all man-made waste.
2000: (**SB00**): A three day world Sustainable Building conference was held in Maastricht, Netherlands. Broad range of topics was presented in this conference. Among them are policy, sustainable engineering design, Sustainable Construction, sustainable building service and many others. Issues related to energy efficiency, material and environment are presented. In Sustainable Construction, the concept of multi disciplines approach plays an important role in future development. There are over 850 people attended this conference.
2002: (**SB02**): The Sustainable Building conference was held in Oslo, Norway. There are over 1000 people attended this conference and wide rage of topics have been presented. In this conference the Sustainable Building Conference was planed to be held every three years.
2005: (**SB05**): Three years after the **SB02** conference, the subsequent conference was held in Tokyo in 2005. This conference was considered as a big conference on sustainability issues.
2008: (**SB08**): The world Sustainable Building conference was held in Melbourne, three years after Tokyo **SB05**. Four performance indicators were outlined in this conference. The first is physical and functional aspects, the second is environmental aspects, the third is economic aspects and the fourth is the social aspects.
2011: (**SB11**): The world Sustainable Building conference will be held in Helsinki, Finland, three years after Melbourne **SB08**.

4. CONCLUDING REMARKS

The developments of civil engineering and sustainable construction have been elaborated. The following concluding remarks can be taken:

1. The aggressive development in civil engineering occurred after the theory of elasticity was introduced and the computer was invented.
2. The construction of tall structures was started in Africa and move to Europe in the nineteenth century. In the twentieth century **USA** was dominant in the development and construction of tall structures. In the

twenty-first century, Asia is dominating in the construction of tall structures. However, the theoretical and design aspects are still dominating by **USA**.

3. Asia will be the future developments in tall structures, and the civil engineers have to be ready to face the challenge of globalization.
4. Many developments in other disciplines have triggered the developments in civil engineering. The trend will be continued for the future development.
5. The concern of the people as the results of this planet being explored has triggered another research topic called sustainable construction. Several other engineering disciplines are actively involved in research of building a better environment for our future generation.
6. The challenge for civil engineers to develop a better and integrated solution is ahead of us. The roles of Indonesian civil engineers have to be increased along with the improvement of our knowledge.
7. The icon of the development may be shifted from the tallest to the most challenging concept to minimize the use of oil and to optimize the use of solar. The sustainability concept will be further developed in the twenty-first century.
8. Particularly in Indonesia, the infrastructure development is still becoming an important issue. An efficient concept still needs to be devised.

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