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Site Coefficients and Design Spectral Response Acceleration Evaluation of New Indonesian 2019 Website Response Spectra

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Abstract. Developing ~~ment of~~ site coefficients and design spectral response acceleration are two important steps in the seismic design of buildings. The site coefficient~~s~~ calculation described~~s~~ in the Indonesian Seismic Code 2019 ~~are~~ partially follow~~ing~~ the ~~same~~ method proposed by the American Standard Code for Seismic Design 2016. Two information or data needs for site coefficient~~s~~ calculations are site soil class ~~-~~and Risk-Targeted Maximum Considered Earthquake (MCE_R-Ss and MCE_R-S_1 for short and long periods of spectral acceleration, respectively) values. Three different site soil classes usually used for building designs are hard/SC, medium/SD and soft/SE soils.~~-~~ Two site coefficients (Fa/short and Fv/long periods) are used for surface and design spectral response acceleration~~s~~ calculations. The Indonesian Seismic Code ~~has~~ provides~~d~~ two simple tables for develop~~p~~ing Fa and Fv. If the MCE_R-Ss and MCE_R-S_1 values developed at one site are not exactly equal to the values presented in these tables, the site coefficients can be predicted using straight-line interpolation between the two closest values. Different results are observed when the straight-line interpolation is adjusted for ~~-~~Fa and Fv prediction compared to the same values developed using website ~~facility~~ based software prepared by the Ministry of Public Works and Human Settlements. This study evaluates the site coefficients and design spectral response acceleration predictions at Semarang City, Indonesia~~,~~ based on straight-line interpolation and website software calculation~~s~~. The evaluation was conducted at 203 soil boring positions within the study area. The site soil classes were predicted using average N-SPT (Standard Penetration Test) values ~~at top of~~in the top 30 m soil deposit layer. Three different site soil classes ~~are~~ were observed ~~at~~ in the study area. ~~In~~ On average, the ~~biggest~~ largest difference of site coefficients and design spectral response acceleration were observed for SD and SE class. However, for the SC site soil class, the difference ~~of~~ between the two analysis methods is small and approximately similar.

Keywords: Design spectral response acceleration; MCE_R; N-SPT; Site coefficient; Straight-line interpolation

1. Introduction

The Indonesian Seismic Code for Building~~s~~ ~~d~~Design SNI 1726 (2019) ~~has already~~was announced ~~on~~ in 2019 by the Ministry of Public Works and Human Settlements. Some of the information introduced~~s~~ in this new seismic code ~~are~~ was partially adopted from the American Standard Code for Seismic Design ASCE/SEI 7 (2016). Two important ~~information~~ items adopted from ASCE/SEI 7-16 are the site coefficients and design spectral response acceleration calculation methods. Compared to the previous seismic code 2012, which was totally adopted from ASCE/SEI 7-16, the new 2019 Indonesian seismic code ~~in~~ for developing site coefficients ~~is~~ was partially adopted from ~~the~~ ASCE/SEI 7-16. Another ~~information~~ item used for developing site coefficients ~~is~~ was adopted from (Stewart and Seyhan, 2013). Due to the improved~~ment~~ methods for developing site coefficients for site soil classes SD and SE described~~s~~ in ASCE/SEI 7-16, not all information described~~s~~ in ~~this~~ the American Code ~~are~~ was adopted by SNI 1726:2019.~~-~~ The ~~requirements of~~ site analysis requirements for developing site coefficients for SD and SE classes induced an alternative method for developing these site coefficients. Site coefficients for SD and SE classes present~~s~~ed ~~at~~ in the new Indonesian Seismic Code 2019 are completely adopted from (Stewart and Seyhan, 2013) and partially adopted from ASCE/SEI 7-16.

Following the new Indonesian Seismic Code 2019, especially in developing site coefficients, the Ministry of Public Works and Human Settlements announced a new website facility for response spectral design calculations. Site coordinates or building position coordinates (in terms of longitude and latitude) and site soil class are two ~~information~~ data needs for design spectral response acceleration calculations. Risk-Targeted Maximum Considered Earthquake, MCE_R-S_S, MCE_R-S_1, and two spectral designs, S_{DS} and S_{D1}, are four important ~~information~~ values calculated by the website facility software. No information related ~~with~~ to site coefficients Fa and Fv can be obtained from the new website ~~2019~~. Due to i~~u~~n-complete information related ~~with~~ to the Fa and Fv site coefficients, these values can be calculated using Equation 1 and Equation 2. Ss and S1 present inside these two equations represent MCE_R-S_S and MCE_R-S_1. All S_{DS}, S_S, S_{D1} and S_1 values ~~are~~ were obtained from the website ~~facility~~.

$$Fa = \frac{S_{DS}}{{}^{2}\!/_{3}\, S_S} \tag{1}$$

$$Fv = \frac{S_{D1}}{{}^{2}\!/_{3}\, S_1} \tag{2}$$

To evaluate the Fa and Fv site coefficients calculated using Equations 1 and 2, straight -line interpolation can be conducted using two MCE_R-S_S and MCE_R-S_1 website calculations and applying site coefficient (Fa and Fv) tables data provided by SNI 1726:2019. Fa and Fv are then recalculated following the procedure described by SNI 1726:2019. Equation 3 shows a simple formula for site coefficient~~s~~ calculations for Fa and Fv. Figure 1 shows a schematic diagram for the straight-line interpolation of Fa and Fv values. “F” and “S” represent the site coefficient to be calculated and the MCE_R value obtained from the website ~~facility~~, respectively. M1 and M2 represent two boundary MCE_R values close to M. F1 and F2 represent two site coefficients for M=M1 and M=M2, respectively. M1(SNI), M2(SNI), F1(SNI) and F2(SNI) are four values obtained from SNI 1726:2019 table~~s~~ data. Fa and Fv are calculated separately using Equation 3. The M1, M2, F1 and F2 values used for Fa and Fv calculations are not similar.

$$F = \left(\frac{F2 - F1}{M2 - M1}\right)(M - M1) + F1 \tag{3}$$

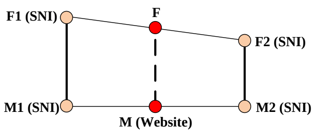

Figure 1 Straight-line interpolation for Fa and Fv calculations

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This paper describes the evaluation of site coefficients Fa and Fv calculated using the website ~~facility~~ and the straight-line interpolation of SNI 1726:2019 and the corresponding design spectral response acceleration calculations developed using these two approaches. The purpose of this study is to evaluate the performance of the website software facility in developing site coefficients Fa and Fv and designing spectral response acceleration. The study was performed at Semarang City, Indonesia and conducted~~ing~~ at 203 soil boring investigation positions. Figure 2~~1~~ shows 203 boring positions within the study area. All boring investigations conducted ~~at~~ in this study ~~having~~ had a minimum ~~of~~ 30 m depth and a maximum ~~of~~ 60 m depth. The a~~A~~verage N-SPT (N30) of the top 30 m soil deposit layer of each boring position ~~are~~ was ~~applied~~ used for site soil class interpretation (Partono et al., 2019a and 2019b; Sengara et al., 2019; Rajesh et al., 2013; Sarfraz and Asif, 2015).~~-~~ The N-SPT (standard penetration test) data for each boring location ~~are~~ was collected from a recorded boring-log prepared by the boring master. The maximum N-SPT data used in this study and collected from boring-logs ~~is~~ was 60. N-SPT values ~~equal to~~of 60 ~~are~~ were applied for N-SPT data greater than 60 (usually recorded using “>60” ~~at~~ in the boring-log). Following the ~~same~~ procedure described~~s~~ by SNI 1726:2019, the N30 ~~is~~ was calculated using Equation 4, where “di” and “Ni” ~~inside this equation~~ represent the thickness and N-SPT value of any soil layer “i”, respectively.

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$$N30 = \frac{30}{\sum_{i=i}^{i=n} \frac{di}{Ni}} \tag{4}$$

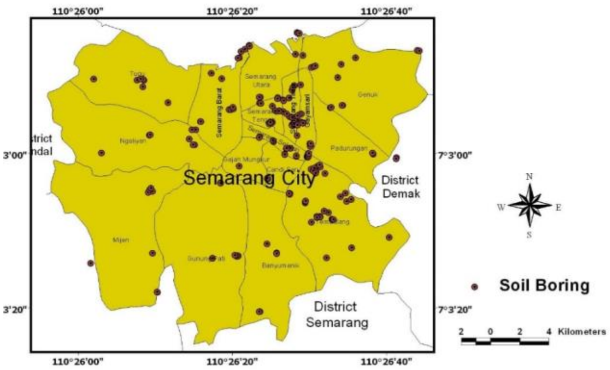

Figure 2 Soil boring position

2. Methods

The e~~E~~valuation of site coefficients within the study area ~~are~~ was conducted following five basic steps~~, such as~~ site class interpretation, Risk-Targeted Maximum Considered Earthquake and design spectral response acceleration calculations using the website ~~facility~~, site coefficient~~s~~ calculations based on the website output, site coefficient~~s~~ calculations using SNI 1726:2019 tables and ~~-~~procedures, and finally, comparative analysis of site coefficients and design spectral response acceleration results calculated using the two different~~ce~~ approaches.

2.1. Site soil class interpretation

The site soil class interpretation was conducted at 203 boring positions using N30 data. Figure 3(a) shows the distribution of~~n~~ N30 within the study area. Based on the N30 data developed at all boring locations, the site soil classes ~~are~~ were interpreted based on SNI 1726:2019. Table 1 shows the basic classification criteria for ~~developing~~ identifying site soil class. Only three different site soil classes are presented in this table. Site class SA, SB and SF are not available within this table. ~~-~~Figure 3(b) shows the corresponding site soil class distribution developed based on site classification, as shown in Table 1. Site class distribution ~~at~~ in the study area is dominated by SD and SE classes. Site class SC~~E~~ ~~are~~ was observed ~~at the~~in small areas in the middle and southern part of the study area.

Table 1 Site Classification

Site Class	N30
SC	> 50
SD	15 - 50
SE	< 15

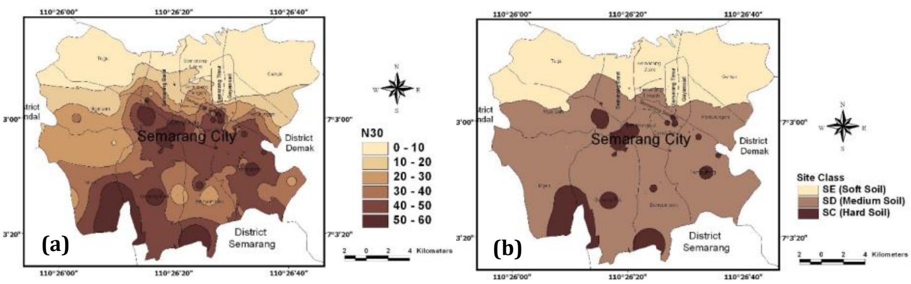

Figure 3 N30 (a) and site soil classes (b) distribution maps

2.2. MCE_R and Design Spectral Response Acceleration Calculation

The MCE_R calculations ~~are~~ were performed at 203 boring positions using the website ~~facility~~. Based on the site class distribution of the study area, three different MCE_R-S_S and MCE_R-S_1 distributions ~~are~~ were also observed in the study area. Table 2 shows the distribution of minimum and maximum MCE_R-S_S and MCE_R-S_1 for the three different site classes. Table 3 shows the distribution of design spectral response acceleration (S_{DS} and S_{D1}) developed ~~from~~using the website.

Table 2 MCE_R-S_S and MCE_R-S_1 Distribution

Site Class	MCE_R-S_S (g)		MCE_R-S_1 (g)	
	minimum	maximum	minimum	maximum
SC	0.8459	0.9668	0.3653	0.4097
SD	0.8098	0.9579	0.3546	0.4071

SE	0.696	0.9274	0.3185	0.3936

2.3. *Site Coefficients Fa and Fv Website*

~~The s~~Site coefficient~~s~~ Fa and Fv calculations were performed based on the MCE_R-S_S, MCE_R-S_1, S_{DS} and S_{D1} values obtained from the website~~ facility~~. The site coefficients were calculated using Equation 1 and 2. Table 4 shows the distribution of minimum and maximum Fa and Fv developed using these four values. Following the boundary values of Fa and Fv described~~s~~ in SNI 1726:2019 tables~~ data~~, the minimum and maximum Fa values developed ~~at~~ in the study area ~~are~~ were divided into two different boundary values. A few MCE_R-S_S ~~data observed at the study area~~ values ~~are~~ were less than 0.75 g. However, most of the MCE_R-S_S values ~~are~~ were distributed ~~in~~ between 0.75~~ g~~ ~~to~~ and 1 g.

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Table 3 S_{DS} and S_{D1} Distribution Developed Using the Website ~~Facility~~

Site Class	S_{DS} (g)		S_{D1} (g)	
	minimum	maximum	minimum	maximum
SC	0.68	0.77	0.37	0.41
SD	0.63	0.71	0.46	0.51
SE	0.64	0.71	0.58	0.63

Table 4 Fa and Fv Distribution Developed Using the Website ~~Facility~~

Site Class	Fa 1st Boundary		Fa 2nd Boundary		Fv	
	min.	max.	min.	max.	min.	max.
SC	-	-	1.19	1.21	1.478	1.519
SD	-	-	1.112	1.167	1.879	1.949
SE	1.323	1.4	1.148	1.292	2.401	2.732

2.4. *Site Coefficients Fa and Fv SNI 1726:2019*

~~The s~~Straight-line interpolation was also performed for Fa and Fv calculations by using Equation 3 and table~~s~~ data provided by SNI 1726:2019. Based on the MCE_R-S_S and MCE_R-S_1 values obtained from the website~~ facility~~, the minimum and maximum boundaries for these two site coefficients can be estimated. Table 5 shows the minimum and maximum boundaries of Fa and Fv values used for straight-line interpolation calculations.

Table 5 Fa and Fv Boundary Values Used for Straight-line Interpolation

Site Class	Fa			Fv	
	MCE_R-S_S (g)			MCE_R-S_1 (g)	
	0.5	0.75	1.0	0.3	0.4
SC	1.2	1.2	1.2	1.5	1.5
SD	1.4	1.2	1.1	2.0	1.9
SE	1.7	1.3	1.1	2.8	2.4

3. Results and Discussion

The MCE$_R$-S$_S$ for the SC site class, as shown in Table 2, are distributed ~~in between~~from 0.8459~~ g~~ through 0.9668 g. The Fa values for the SC site class developed based on the website, ~~facility~~ as shown in Table 4, are distributed~~ in~~ between 1.21 and 1.19. All Fa ~~values~~values developed from the website are consistent and almost equal to the Fa value from SNI 1726:2019. ~~In~~ On average the absolute difference of Fa is zero. The difference ~~of~~ in Fa values developed using the website data are less than 0.01 compared to the Fa requirement of SNI 1726:2019. Figure 4(a) shows the distribution of Fa site coefficients for the SC site class. FaL and FaW ~~present~~ inside this figure represent~~s~~ straight-line and website data acquisition and interpolation. The R^2 value for site class SC is close to zero~~,~~ because the Fa values calculated using these two models are nearly constant for all MCE$_R$-S$_S$ values.

The MCE$_R$-S$_S$ for the SD site class in the study area ~~are~~ were distributed almost equally to the SC site class. Table 2 shows the distribution of MCE$_R$-S$_S$ for the SD site class. The values are distributed ~~in between~~from 0.8098~~ g~~ through 0.9579 g. Following the same procedure ~~conducted~~ as for the SC site class, the Fa site coefficients for the SD site class developed ~~at~~ in the study area should be distributed ~~in~~ between 1.2 and 1.1. Due to the MCE$_R$-S$_S$ being distributed close~~d~~ to 1 g, the Fa values obtained from the study area are close~~d~~ to 1.1. As shown in Table 4, the Fa values ~~are~~ were distributed ~~in~~ between 1.167 and 1.112. Figure 4(b) shows the distribution of Fa values for site class SD in terms of MCE$_R$-S$_S$ values. As ~~it~~ can be seen in Figure 4(b), the R^2 (determination coefficients) value is 0.7858, or less than 1. The straight-line interpolation developed based on the SNI 1726:2019 data and table are better compared to the Fa values developed using the website~~ facility~~. However, ~~in~~ on average, the absolute difference ~~of~~ between Fa values developed using these two models ~~are~~ is 0.0105 and the line distributions are almost similar (coincide).

The MCE$_R$-S$_S$ distribution for the SE site class calculated from the website ~~facility are~~is ~~in~~ between 0.696 and 0.9274 g. Based on SNI 1726:2019, all MCE$_R$-S$_S$ for site class SE ~~are~~ were distributed ~~in~~ between two different boundary values, from 0.5 ~~g~~ through 0.75 g for the 1st boundary and from 0.75~~ g~~ through 1 g for the 2nd boundary. The straight-line interpolation for all MCE$_R$-S$_S$ ~~are~~ was also separated into two different boundary values. The first Fa values ~~are~~ were distributed ~~in~~ between 1.4 and 1.323. Due to the MCE$_R$-S$_S$ values, the Fa site coefficients ~~are~~ were distributed close~~d~~ to 1.3. However, the second Fa site coefficients ~~are~~ were distributed ~~in~~ between 1.292 and 1.148. Figure 4(c) shows the distribution of Fa site coefficients for the SE site class. Two different straight-line interpolations are ~~observed~~ seen in this figure, following the two different boundary values of SNI 1726:2019. The straight-line interpolation for site class SE is better compared to site class SC and SD. The absolute average difference ~~of~~ between Fv for site class SE is 0.02.

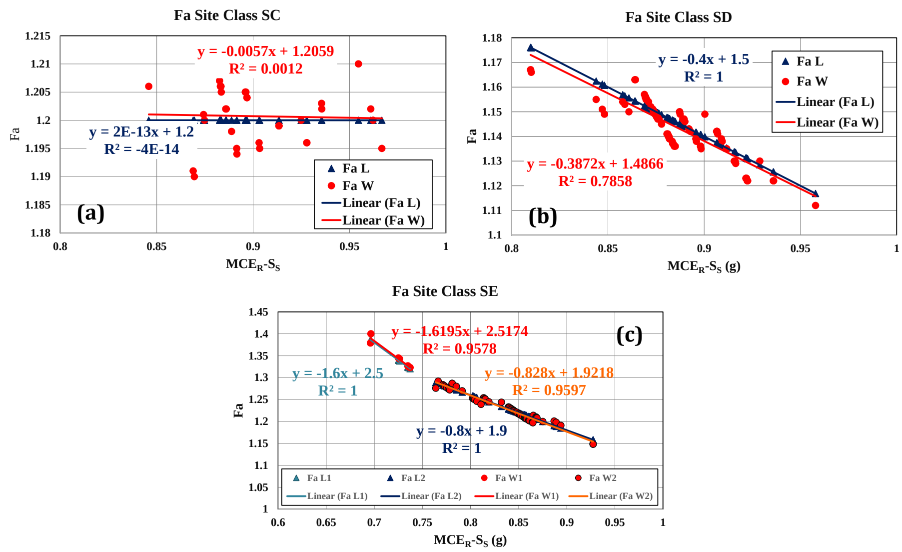

Figure 4 Fa Distributions in Terms of MCE$_R$-S_S Values for Site Class SC (a), SD (b) and SE (c)

The evaluation of site coefficients was also conducted for long period spectral acceleration MCE$_R$-S_1. Using the same procedure used for MCE$_R$-S_S, the evaluation was performed for site soils SC, SD and SE. Based on the minimum and maximum MCE$_R$-S_1 values calculated using the website ~~facility~~, all MCE$_R$-S_1 values ~~at~~ in the study area ~~are~~ were distributed ~~in~~ between 0.3 ~~g through~~and 0.4 g. For site classes SC and SD, there is one boring position having a value of MCE$_R$-S_1 greater than 4 g~~.~~, ~~It is~~making it difficult to perform a straight-linear interpolation. To reduce the difficulties in the analysis, the MCE$_R$-S_1 greater than 4 g ~~is~~ was excluded ~~in~~ from the analysis. Figure 5(a), (b) and (c) shows the distribution of site coefficient~~s~~ Fv for site soil class SC, SD and SE, respectively. All Fv values calculated using the website ~~facility~~ and straight-line interpolation are almost equal or coincide except for site class SD. Most of the Fv values of SD site class developed using the website ~~facility~~ are greater than the same Fv values developed using straight-line interpolation. The R^2 (R squared) value ~~developed at~~for this model is far from 1. The Fv values for site class SD developed ~~at~~ in the study area ~~is~~ were far from the linear model ~~as what~~that SNI 1726:2019 expected. The R^2 for site class SC ~~are~~ is not available (close to zero) because the Fv and MCE$_R$-S_1 correlations are nearly constant. A good performance of Fv and MCE$_R$-S_1 correlation was observed for site class SE, both for website output and straight-line interpolation. The R^2 obtained for this site class nearly is 1. "Fv L" and "Fv W" present ~~at~~ in all figures represent straight-line interpolation (SNI 1726:2019 procedures) and website facility calculations, respectively. ~~In~~ On average, the absolute differences ~~of~~ between Fv are 0.015, 0.036 and 0.033 for site class SC, SD and SE, respectively.

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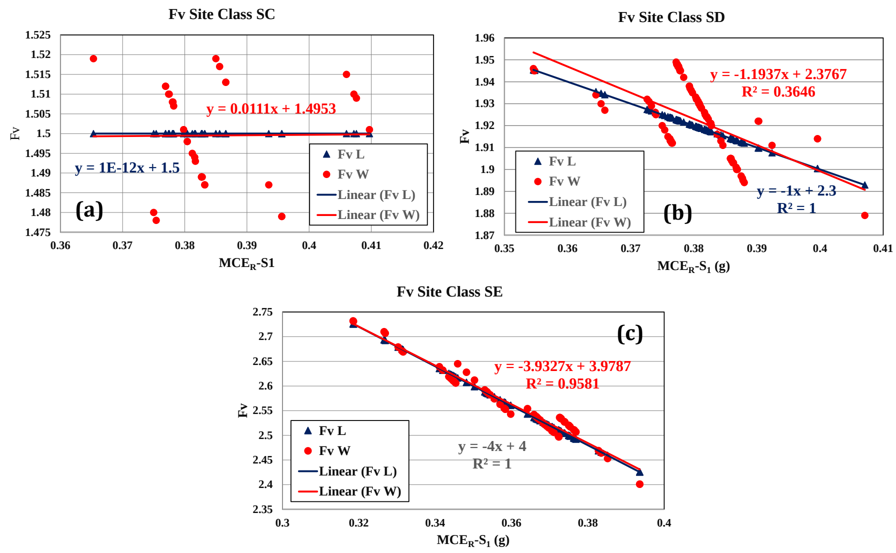

Figure 5 Fv Distributions in Terms of MCE_R-S_1 Values for Site Class SC (a), SD (b) and SE (c)

Fa and Fv are two site coefficients used for developing surface spectral acceleration and design spectral response acceleration. The differen~~ce~~t performances of these two site coefficients ~~Fa and Fv~~ developed using two different procedures can be neglected or avoided ~~as far as~~because there was no significant difference in the design spectral response acceleration results developed using these two methods. The difference in the accuracy value used for both methods will produce different site coefficients and directly impact ~~to~~ the performance of Fa and Fv outputs for all site soil classes. To evaluate the performance of Fa and Fv calculated using these two methods, the design spectral response acceleration calculation was also performed in this study. The purpose of this analysis ~~is~~ was to evaluate the performance of design spectral response acceleration S_{DS} and S_{D1} based on the Fa and Fv values calculated using two different methods. Figure 6 shows the performance of S_{DS} design spectral response acceleration in terms of MCE_R-S_S developed from the website ~~facility~~ and straight-line interpolation. Figure 7 shows the performance of S_{D1} design spectral response acceleration in terms of MCE_R-S_1 calculated using the same methods used for S_{DS} calculation. As ~~it~~ can be seen in Figures 6 and 7, a good correlation performance between S_{DS} and S_{D1} in terms of MCE_R-S_S and MCE_R-S_1, respectively, ~~are~~ was observed in this study. Based on these two figures there are no significan~~ce~~t differences ~~of~~ in S_{DS} and S_{D1} performance calculated based on the website and straight-line interpolation. The S_{DS} and S_{D1} developed ~~at~~ for the study area using the website ~~facility~~ are accepted ~~the~~ according to the requirement criterium of SNI 1726:2019. Table 6 shows the minimum and maximum S_{DS} and S_{D1} values and the average difference of S_{DS} and S_{D1} calculated using the two methods for all site classes. The average difference, as presented in Table 6, is the absolute differences ~~of~~ in S_{DS} and S_{D1}. The maximum average difference~~s~~ (ave. diff.), 0.02 g approximately, ~~are~~ was observed at the SD site class for S_{DS} and S_{D1} spectral design calculation. However, the average difference for site class SC and SE ~~are~~ were less than 0.01 g.

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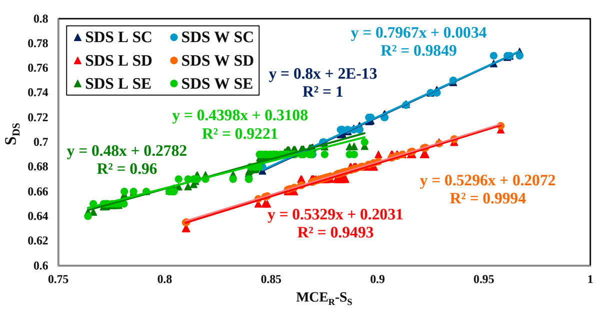

Figure 6 S_{DS} Distribution Charts for Site Class SC, SD and SE

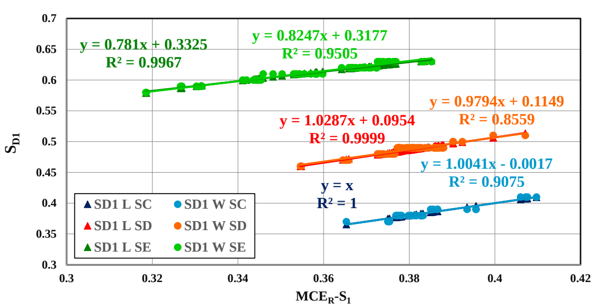

Figure 6 S_{D1} Distribution Charts for Site Class SC, SD and SE

Table 6 SDS and SD1 Performance for Three Site Classes, SC, SD and SE

Site Class	SDS (g)					SD1 (g)				
	Website		Straight-Line		Ave. Diff.	Website		Straight-Line		Ave. Diff.
	min.	max.	min.	max.		min.	max.	min.	max.	
SC	0.68	0.77	0.6767	0.7734	0.0067	0.37	0.41	0.3653	0.4097	0.0044
SD	0.63	0.71	0.6349	0.6925	0.0224	0.46	0.51	0.4599	0.4946	0.0153
SE	0.64	0.71	0.6433	0.706	0.0073	0.58	0.63	0.5788	0.6315	0.0027

4. Conclusions

The new seismic code for building~~s~~ design (SNI 1726:2019) ~~has already~~was announced by the Ministry of Public Works and Human Settlements. A w~~W~~ebsite facility was also announced as a complementary part of the code~~ has also announced~~. One important ~~information~~ thing which should be ~~taken into account~~considered is the design spectral response acceleration calculation for buildings. The design spectral response acceleration can be developed using the website ~~facility~~ and manual calculations using SNI 1726:2019 procedures.

~~The evaluation of~~Evaluations of site coefficients calculated using the website ~~facility~~ and straight-line interpolation were performed at 203 boring positions ~~at the~~in Semarang City. No significant differences ~~of~~ were found in Fa and Fv site coefficients calculated using both methods. The biggest difference ~~of~~ in site coefficient~~s~~ Fa calculations was observed for site classes SD and SE. The difference ~~of~~in site coefficients for site soil class SD and SE ~~are~~ was less than 0.03. However, for site soil class SC, the difference ~~is~~ was less than 0.01. For site coefficient Fv, the biggest difference was observed for site soil classes SD and SE, with a maximum of 0.04. However, the difference ~~of~~in site coefficient Fv for site class SC ~~is~~ was less than 0.02.

The design spectral response accelerations S_{DS} and S_{D1} calculated using site coefficients Fa and Fv ~~are~~ were also evaluated ~~at~~ for the study area. No significant differences ~~of~~in design spectral response accelerations S_{DS} and S_{D1} were found for all site classes. The biggest design spectral response acceleration difference for site class SD calculated using the two methods ~~are~~ was less than 0.02 g~~.~~ However, for site class SC and SE, ~~are~~ the differences were less than 0.01 g.

Acknowledgements

This research was financially supported by The Ministry of Education and Culture, The Republic of Indonesia. The author ~~also~~ would also like to thank ~~to~~ The Ministry of Public Works and Human Settlements of Indonesia and the National Centre for Earthquake Studies

Indonesia (PUSGEN) for providing data and technical support~~s~~ during the development of this research.

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Site Coefficients and Design Spectrum Acceleration Evaluation of New Indonesian 2019 Website Response Spectra

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Abstract. Developing site coefficients and design spectrum response acceleration are two important steps in the seismic design of buildings. Two information needs for site coefficient calculations are site soil class and Risk-Targeted Maximum Considered Earthquake (MCE_R). Three different site soil classes usually used for building designs. Two site coefficients (F_a and F_v spectral acceleration) are used for design spectrum response acceleration calculations. The Indonesian Seismic Code provides two tables for developing these site coefficients. The site coefficients can be predicted using straight-line interpolation between the two closest values. Different results were observed when the straight-line interpolation is adjusted for F_a and F_v prediction compared to the same values developed using website based software. This study evaluates the site coefficients and design spectrum response acceleration predictions at Semarang City, Indonesia according to straight-line interpolation and website software calculations. The evaluation was conducted at 203 soil boring positions within the study area. The site soil classes were predicted using average N-SPT (Standard Penetration Test) values in the top 30 m soil deposit layer. Three different site soil classes were observed in the study area. On average the largest difference of site coefficients and design spectrum response acceleration were observed for SD and SE classes. However, for the SC site soil class the difference between the two analysis methods is small and approximately similar.

Keywords: Design spectrum response acceleration; MCE_R; N-SPT; Site coefficient; Straight-line interpolation

1. Introduction

The new National Seismic Code of Indonesia (SNI 1726:2019) was announced in 2019. Some information introduced in this new seismic code was partially adopted from the American Standard Code for Seismic Design ASCE/SEI 7 (2016). Two important items adopted from ASCE/SEI 7-16 are the site coefficients and design spectrum response acceleration calculation methods. Compared to the SNI 1726:2012, which was totally adopted from ASCE/SEI 7-10, the SNI 1726:2019 for developing site coefficients was partially adopted from ASCE/SEI 7-16.

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Another item used for developing site coefficients was adopted from (Stewart and Seyhan, 2013). Due to the improved methods for developing site coefficients for site soil classes SD and SE describes in ASCE/SEI 7-16, not all information described in the American Code was adopted by SNI 1726:2019. The site analysis requirements for developing site coefficients for SD and SE classes induced an alternative method for developing these site coefficients. Site coefficients for SD and SE classes presented in the new Indonesian Seismic Code 2019 are completely adopted from (Stewart and Seyhan, 2013).

Following the new SNI 1726:2019, especially in developing site coefficients, the Ministry of Public Works and Human Settlements announced a new website facility for response spectrum design calculations. Site or building position coordinates (in terms of longitude and latitude) and site soil class are two data needs for design spectrum response acceleration calculations. Risk-Targeted Maximum Considered Earthquake (MCER) S_S (short periods) and S_1 (long periods) (Luco et al., 2007; Sengara, 2012; Allen et al., 2015; Sengara et al., 2020), and two spectral designs, S_{DS} and S_{D1}, are four important values calculated by the website facility software. No information related to site coefficients F_a and F_v can be obtained from the new website. Due to in-complete information related to the F_a and F_v site coefficients, these values can be estimated using Equation 1 and Equation 2. All S_{DS}, S_S, S_{D1} and S_1 values were obtained from the website.

$$F_a = \frac{S_{DS}}{{}^{2}\!/_{3}\, S_S} \quad (1)$$

$$F_v = \frac{S_{D1}}{{}^{2}\!/_{3}\, S_1} \quad (2)$$

To verify the F_a and F_v site coefficients estimated using Equations 1 and 2, straight-line interpolation can be conducted using two S_S and S_1 website calculations and applying site coefficient (F_a and F_v) tables data provided by SNI 1726:2019. F_a and F_v are then estimated following the procedure described by SNI 1726:2019. Equation 3 shows a simple formula for site coefficient calculations for F_a and F_v. Figure 1 shows a schematic diagram for the straight-line interpolation of F_a and F_v values. “F” and “M_W” represent the site coefficient to be estimated and the MCE_R value obtained from the website, respectively. M_{1S} and M_{2S} represent two boundary MCE_R values close to M_w. F_{1S} and F_{2S} represent two site coefficients for $M_w=M_{1S}$ and $M_w=M_{2S}$, respectively. M_{1S}, M_{2S}, F_{1S} and F_{2S} are four values obtained from SNI 1726:2019 table data. F_a and F_v are estimated separately using Equation 3. The M_{1S}, M_{2S}, F_{1S} and F_{2S} values used for F_a and F_v calculations are not similar.

$$F = \left(\frac{F_{2S} - F_{1S}}{M_{2S} - M_{1S}}\right)(M_W - M_{1S}) + F_{1S} \quad (3)$$

This paper describes the site coefficients and the design spectrum response acceleration verification using the website and the straight-line interpolation of SNI 1726:2019. The study was performed at Semarang City, Indonesia and conducted at 203 soil boring investigation positions. Figure 2 shows 203 boring positions within the study area. All boring investigations conducted in this study had a minimum 30 m depth and a

maximum 60 m depth. The average Standard Penetration Test (N-SPT) of the topmost 30 m soil deposit layer (N_{30}) of every boring position was used for site soil class interpretation (Moghaddam, 2011; Partono et al., 2019a; Partono et al., 2019b; Syaifuddin et al., 2020). The N-SPT data for each boring location was collected from a recorded boring-log prepared by the boring master. The maximum N-SPT data used in this study and collected from boring-log was 60. N-SPT values of 60 were applied for N-SPT data greater than 60 (usually recorded using “>60” in the boring-log). Following the procedure described by SNI 1726:2019, the N_{30} was estimated using Equation 4, where “di” and “Ni” represent the thickness and N-SPT value of any soil layer “i”, respectively.

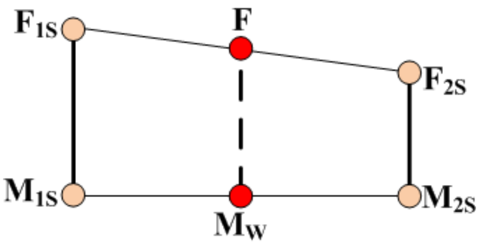


Figure 1 Straight-line interpolation for Fa and Fv calculations

$$N_{30} = \frac{30}{\sum_{i=i}^{i=n} \frac{d_i}{N_i}} \tag{4}$$

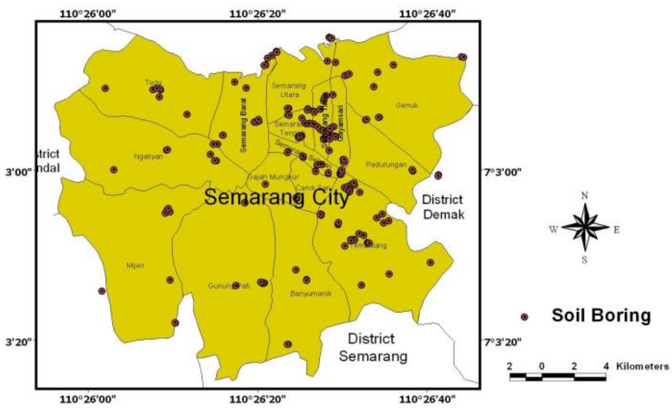


Figure 2 Soil boring position

2. Methods

The evaluation of site coefficients within the study area was conducted following five basic steps:

- Site class interpretation,
- MCE_R (S_S and S_1) and design spectrum response acceleration calculations using the website,
- Site coefficient calculation based on the website output
- Site coefficient calculation based on SNI 1726:2019 tables and procedures

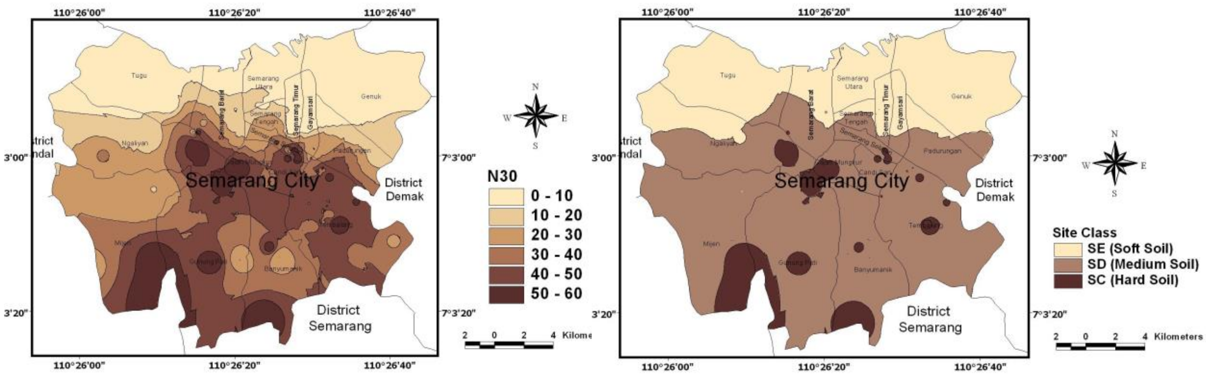
- Comparative analysis of site coefficients and design spectrum response acceleration based on two different approaches.

2.1. Site soil class interpretation

The site soil class interpretation was conducted at 203 boring positions using N_{30} data. Figure 3(a) shows the distribution of N_{30} within the study area. According to the N_{30} data developed at all boring locations, the site soil classes were interpreted according to SNI 1726:2019. Table 1 shows the basic classification criteria for identifying site soil class. Only three different site soil classes are presented in this table. Site class SA, SB and SF are not available within this table. Figure 3(b) shows the corresponding site soil class distribution developed according to site classification as shown in Table 1. Site class distribution in the study area is dominated by SD and SE classes. Site class SC was observed in small areas in the middle and southern part of the study area.

Table 1 Site classification

Site Class	N30
SC	> 50
SD	15 - 50
SE	< 15



(a) (b)

Figure 3 N_{30} (a) and site soil classes (b) distribution maps

2.2. MCE_R and Design Spectrum Response Acceleration Calculation

The MCE_R calculations were performed at 203 boring position using the website. According to the site class distribution of the study area, three different S_S and S_1 distributions were also observed in the study area. Table 2 shows the distribution of minimum and maximum S_S and S_1 for the three different site classes. Table 3 shows the distribution of design spectrum response acceleration (S_{DS} and S_{D1}) developed using the website.

2.3. Site Coefficients F_a and F_v Website

Site coefficient F_a and F_v calculations were performed according to the S_S, S_1, S_{DS} and S_{D1} values obtained from the website. The site coefficients were estimated using Equation 1 and 2. Table 4 shows the distribution of minimum and maximum F_a and F_v developed

using these four values. Following the boundary values of F_a and F_v described in SNI 1726:2019 tables, the minimum and maximum F_a values developed in the study area were divided into two different boundary values. A few S_S values were less than 0.75 g. However, most of the S_S values were distributed between 0.75 to 1 g.

Table 2 S_S and S_1 distribution

Site Class	S_S(g)		S_1 (g)	
	minimum	Maximum	minimum	maximum
SC	0.8459	0.9668	0.3653	0.4097
SD	0.8098	0.9579	0.3546	0.4071
SE	0.696	0.9274	0.3185	0.3936

Table 3 S_{DS} and S_{D1} distribution developed using the website

Site Class	S_{DS} (g)		S_{D1} (g)	
	minimum	maximum	minimum	maximum
SC	0.68	0.77	0.37	0.41
SD	0.63	0.71	0.46	0.51
SE	0.64	0.71	0.58	0.63

Table 4 F_a and F_v distribution developed using the website

Site Class	F_a 1st Boundary		F_a 2nd Boundary		F_v	
	min.	max.	min.	max.	min.	max.
SC	-	-	1.19	1.21	1.478	1.519
SD	-	-	1.112	1.167	1.879	1.949
SE	1.323	1.4	1.148	1.292	2.401	2.732

2.4. Site Coefficients F_a and F_v SNI 1726:2019

Straight-line interpolation was also performed for F_a and F_v calculations by using Equation 3 and table data provided by SNI 1726:2019. According to the S_S and S_1 values obtained from the website, the minimum and maximum boundaries for these two site coefficients can be estimated. Table 5 shows the minimum and maximum boundaries of F_a and F_v values used for straight-line interpolation calculations.

3. Results and Discussion

The S_S for the SC site class as shown in Table 2, are distributed from 0.8459 through 0.9668 g. The F_a values for the SC site class developed according to the website, as shown in Table 4, are distributed between 1.21 and 1.19. All F_a values developed from the website are consistent and almost equal to the F_a value from SNI 1726:2019. On average the absolute difference of F_a is zero. The difference in F_a values developed using the website data are less than 0.01 compared to the F_a requirement of SNI 1726:2019. Figure 4(a) shows the distribution of F_a site coefficients for the SC site class. F_aL and F_aW inside this figure represent straight-line and website data acquisition and interpolation. The R^2 value for site class SC is close to zero, because the F_a values estimated using these two models are nearly constant for all S_S values.

The S_S for the SD site class in the study area were distributed almost equally to the SC site class. Table 2 shows the distribution of S_S for the SD site class. The values are distributed from 0.8098 through 0.9579 g. Following the same procedure as for the SC site class, the F_a site coefficients for the SD site class developed in the study area should be distributed between 1.2 and 1.1. Due to the S_S being distributed close to 1 g, the F_a values obtained from the study area are close to 1.1. As shown in Table 4, the F_a values were distributed between 1.167 and 1.112. Figure 4(b) shows the distribution of F_a values for site class SD in terms of S_S values. As can be seen in Figure 4(b), the R^2 (determination coefficients) value is 0.7858, or less than 1. The straight-line interpolation developed according to the SNI 1726:2019 data and table are better compared to the F_a values developed using the website. However, on average the absolute difference between F_a values developed using these two models is 0.0105 and the line distributions are almost similar (coincide).

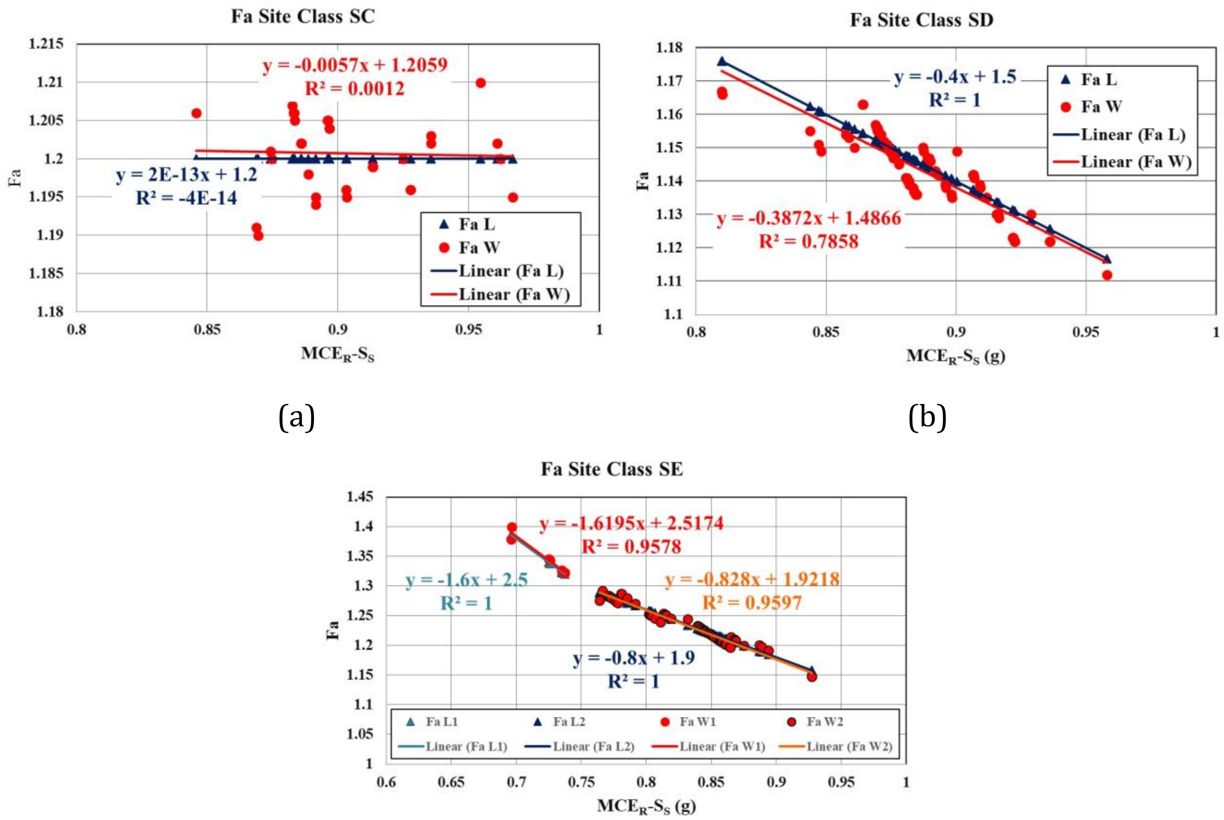
Table 5 F_a and F_v boundary values used for straight-line interpolation

Site Class	F_a			F_v	
	S_S(g)			S_1 (g)	
	0.5	0.75	1.0	0.3	0.4
SC	1.2	1.2	1.2	1.5	1.5
SD	1.4	1.2	1.1	2.0	1.9
SE	1.7	1.3	1.1	2.8	2.4

The S_S distribution for the SE site class estimated from the website is between 0.696 and 0.9274 g. According to SNI 1726:2019, all S_S for site class SE were distributed between two different boundary values, from 0.5 through 0.75 g for the 1st boundary and from 0.75 through 1 g for the 2nd boundary. The straight-line interpolation for all S_S was also separated into two different boundary values. The first F_a values were distributed between 1.4 and 1.323. Due to the S_S values, the F_a site coefficients were distributed close to 1.3. However, the second F_a site coefficients were distributed between 1.292 and 1.148. Figure 4(c) shows the distribution of F_a site coefficients for the SE site class. Two different straight-line interpolations are seen in this figure, following the two different boundary values of SNI 1726:2019. The straight-line interpolation for site class SE is better compared to site class SC and SD. The absolute average difference between F_v for site class SE is 0.02.

The site coefficients evaluation was also conducted for long period spectral acceleration S_1. Using the same procedure used for S_S, the evaluation was performed for SC, SD and SE site classes. According to the minimum and maximum S_1 values estimated using the website, all S_1 values in the study area were distributed between 0.3 and 0.4 g. For site classes SC and SD, there is one boring position having a value of S_1 greater than 0.4 g, making it difficult to perform a straight-linear interpolation. To reduce the difficulties in the analysis, the S_1 greater than 0.4 g was excluded from the analysis. Figure 5(a), (b) and (c) shows the distribution of site coefficient F_v for SC, SD and SE site soil classes, respectively.

All F_v values estimated using the website and straight-line interpolation are almost equal or coincide except for site class SD. Most of the F_v values of SD site class developed using the website are greater than the same F_v values developed using straight-line interpolation. The R^2 (R squared) value for this model is far from 1. The F_v values for site class SD developed in the study area were far from the linear model that SNI 1726:2019 expected. The R^2 for site class SC is not available (close to zero) because the F_v and S_1 correlation are nearly constant. A good performance of Fv and S_1 correlation was observed for site class SE, both for website output and straight-line interpolation. The R^2 obtained for this site class is nearly 1. "F_v L" and "F_v W" present in all figures represent straight-line interpolation (SNI 1726:2019 procedures) and the website calculations, respectively. On average the absolute differences between F_v are 0.015, 0.036 and 0.033 for SC, SD and SE site classes, respectively.



(a) (b)

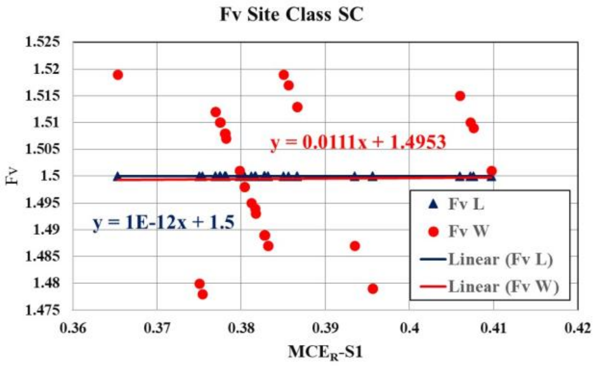
(c)

Figure 4 F_a Distributions in terms of S_S values for SC (a), SD (b) and SE (c) site classes

F_a and F_v are two site coefficients used for developing surface spectral acceleration and design spectrum response acceleration. The different performances of these two site coefficients developed using two different procedures can be neglected or avoided as far as there was no significant difference in the design spectrum response acceleration results developed using these two methods. The difference in the accuracy value used for both methods will produce different site coefficients and directly impact the performance of S_{DS} and S_{D1} outputs for all site soil classes.

To verify the performance of F_a and F_v estimated using these two methods, the design spectrum response acceleration calculation was also conducted in this study. The purpose of the analysis was to verify the performance of design spectrum response acceleration S_{DS} and S_{D1} according to the site coefficients values estimated using two different methods. Figure 6(a) shows the performance of S_{DS} design spectrum response acceleration in terms of S_S developed from the website and straight-line interpolation. Figure 6(b) shows the performance of S_{D1} design spectrum response acceleration in terms of S_1 estimated using

the same methods used for S_{DS} calculation. As can be seen in Figure 6(a) and 6(b), a good correlation performance between S_{DS} and S_{D1} in terms of S_S and S_1, respectively, was observed in this study. According to these two figures there are no significant differences in S_{DS} and S_{D1} performance estimated according to the website and straight-line interpolation.



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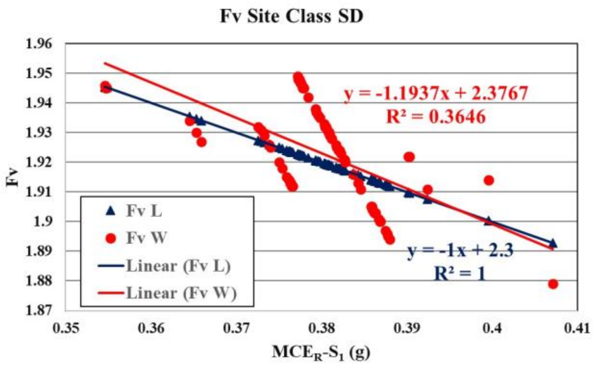

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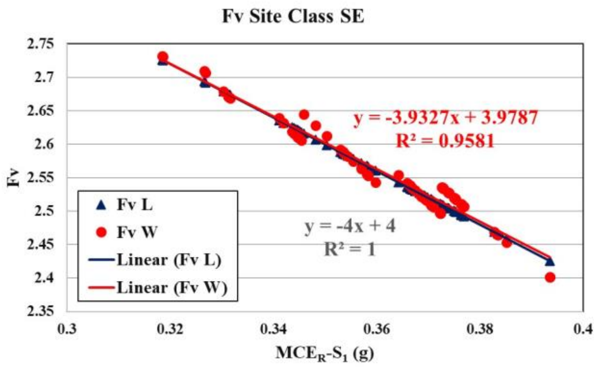


(c)

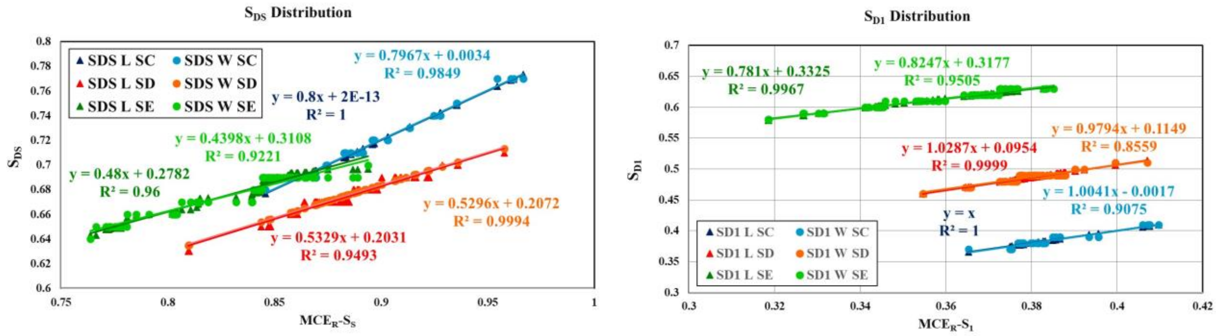
Figure 5 F_v Distributions in terms of S_1 values for SC (a), SD (b) and SE (c) site classes

Table 6 S_{DS} and S_{D1} performance for all site classes

Site Class	S_{DS} (g)					S_{D1} (g)				
	Website		Straight-Line		Ave. Diff.	Website		Straight-Line		Ave. Diff.
	min.	max.	min.	max.		min.	max.	min.	max.	
SC	0.68	0.77	0.6767	0.7734	0.0067	0.37	0.41	0.3653	0.4097	0.0044
SD	0.63	0.71	0.6349	0.6925	0.0224	0.46	0.51	0.4599	0.4946	0.0153
SE	0.64	0.71	0.6433	0.706	0.0073	0.58	0.63	0.5788	0.6315	0.0027

The S_{DS} and S_{D1} developed for the study area using the website are accepted according to the requirement criterium of SNI 1726:2019. Table 6 shows the minimum and maximum S_{DS} and S_{D1} values and the average difference of S_{DS} and S_{D1} estimated using the two methods for SC, SD and SE site classes. The average difference of S_{DS} and S_{D1}, as presented in Table 6, is the absolute differences of S_{DS} and S_{D1}. The maximum average difference (Ave. Diff.), 0.02 g and 0.015 g, were observed at the SD site class for S_{DS} and S_{D1}

spectral design, respectively. However, the average difference of S_{DS} for site classes SC and SE were less than 0.007 g, approximately. The average difference of S_{D1} for SC and SE site classes were less than 0.004 g.



(a) (b)

Figure 6 S_{DS} (a) and S_{D1} (b) distribution charts for SC, SD and SE site classes

4. Conclusions

The new seismic code for buildings design (SNI 1726:2019) was announced in 2019. A website facility was also announced as a complementary part of the code. One important thing which should be considered is the design spectrum response acceleration calculation for buildings. The design spectrum response acceleration can be developed using the website and manual calculation using SNI 1726:2019 procedures.

Evaluations of site coefficients estimated using the website and straight-line interpolation were performed at 203 boring positions in Semarang City. No significant differences were found in F_a and F_v site coefficients estimated using both methods. The largest difference in site coefficients F_a calculations was observed for SD and SE site classes. The difference in site coefficients for SD and SE site soil classes was less than 0.03. However, for SC site soil class, the difference was less than 0.01. For site coefficient F_v, the largest difference was observed for SD and SE site soil classes with a maximum of 0.04. However, the difference in site coefficient F_v for site class SC was less than 0.02.

The design spectrum response accelerations S_{DS} and S_{D1} estimated using site coefficients F_a and F_v were also verified for the study area. No significant differences in design spectrum response accelerations S_{DS} and S_{D1} were found for all site classes. The largest design spectrum response accelerations difference for SD estimated using the two methods was less than 0.02 g. However, for SC and SE site classes the differences were less than 0.01 g.

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Site Coefficients and Design Spectrum Acceleration Evaluation of New Indonesian 2019 Website Response Spectra

[1*]

Abstract. Developing site coefficients and design spectrum response acceleration are two important steps in the seismic design of buildings. The site coefficient calculation described in the Indonesian Seismic Code 2019 partially follow the method proposed by the American Standard Code for Seismic Design 2016. Two information or data needs for site coefficient calculations are site soil class and Risk-Targeted Maximum Considered Earthquake (MCE_R) S_S (short period) and S_1 (long period) spectral acceleration. Three different hard/SC, medium/SD and soft/SE site soil classes usually used for building designs. Two site coefficients (F_a and F_v for short and long periods spectral acceleration) are used for surface and design spectrum response acceleration calculations. The Indonesian Seismic Code provides two simple tables for developing these site coefficients. If the S_S and S_1 values developed at one site are not exactly equal to the values presented in these tables, the site coefficients can be predicted using straight-line interpolation between the two closest values. Different results are observed when the straight-line interpolation is adjusted for F_a and F_v prediction compared to the same values developed using website based software. This study evaluates the site coefficients and design spectrum response acceleration predictions at Semarang City, Indonesia according to straight-line interpolation and website software calculations. The evaluation was conducted at 203 soil boring positions within the study area. The site soil classes were predicted using average N-SPT (Standard Penetration Test) values in the top 30 m soil deposit layer. Three different site soil classes were observed in the study area. On average the largest difference of site coefficients and design spectrum response acceleration were observed for SD and SE classes. However, for the SC site soil class the difference between the two analysis methods is small and approximately similar..

Keywords: Design spectrum response acceleration; MCE_R; N-SPT; Site coefficient; Straight-line interpolation

1. Introduction

The new National Seismic Code of Indonesia (SNI 1726:2019) was announced in 2019. Some information introduced in this new seismic code was partially adopted from the American Standard Code for Seismic Design ASCE/SEI 7 (2016). Two important items adopted from ASCE/SEI 7-16 are the site coefficients and design spectrum response acceleration calculation methods. Compared to the SNI 1726:2012, which was totally adopted from ASCE/SEI 7-10, the SNI 1726:2019 for developing site coefficients was partially adopted from ASCE/SEI 7-16.

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Another item used for developing site coefficients was adopted from (Stewart and Seyhan, 2013). Due to the improved methods for developing site coefficients for site soil classes SD and SE describes in ASCE/SEI 7-16, not all information described in the American Code was adopted by SNI 1726:2019. The site analysis requirements for developing site coefficients for SD and SE classes induced an alternative method for developing these site coefficients. Site coefficients for SD and SE classes presented in the new Indonesian Seismic Code 2019 are completely adopted from (Stewart and Seyhan, 2013).

Following the new SNI 1726:2019, especially in developing site coefficients, the Ministry of Public Works and Human Settlements announced a new website facility for response spectrum design calculations. Site or building position coordinates (in terms of longitude and latitude) and site soil class are two data needs for design spectrum response acceleration calculations. Risk-Targeted Maximum Considered Earthquake (MCER) S_S (short periods) and S_1 (long periods) (Luco et al., 2007; Sengara, 2012; Allen et al., 2015; Sengara et al., 2020), and two spectral designs, S_{DS} and S_{D1}, are four important values calculated by the website facility software. No information related to site coefficients F_a and F_v can be obtained from the new website. Due to in-complete information related to the F_a and F_v site coefficients, these values can be estimated using Equation 1 and Equation 2. All S_{DS}, S_S, S_{D1} and S_1 values were obtained from the website.

$$F_a = \frac{S_{DS}}{{}^2\!/_3\, S_S} \tag{1}$$

$$F_v = \frac{S_{D1}}{{}^2\!/_3\, S_1} \tag{2}$$

To verify the F_a and F_v site coefficients estimated using Equations 1 and 2, straight-line interpolation can be conducted using two S_S and S_1 website calculations and applying site coefficient (F_a and F_v) tables data provided by SNI 1726:2019. F_a and F_v are then estimated following the procedure described by SNI 1726:2019. Equation 3 shows a simple formula for site coefficient calculations for F_a and F_v. Figure 1 shows a schematic diagram for the straight-line interpolation of F_a and F_v values. "F" and "M_W" represent the site coefficient to be estimated and the MCE_R value obtained from the website, respectively. M_{1S} and M_{2S} represent two boundary MCE_R values close to M_w. F_{1S} and F_{2S} represent two site coefficients for M_w=M_{1S} and M_w=M_{2S}, respectively. M_{1S}, M_{2S}, F_{1S} and F_{2S} are four values obtained from SNI 1726:2019 table data. F_a and F_v are estimated separately using Equation 3. The M_{1S}, M_{2S}, F_{1S} and F_{2S} values used for F_a and F_v calculations are not similar.

$$F = \left(\frac{F_{2S} - F_{1S}}{M_{2S} - M_{1S}}\right)(M_W - M_{1S}) + F_{1S} \tag{3}$$

This paper describes the site coefficients and the design spectrum response acceleration verification using the website and the straight-line interpolation of SNI 1726:2019. The study was performed at Semarang City, Indonesia and conducted at 203 soil boring investigation positions. Figure 2 shows 203 boring positions within the study area. All boring investigations conducted in this study had a minimum 30 m depth and a

maximum 60 m depth. The average Standard Penetration Test (N-SPT) of the topmost 30 m soil deposit layer (N_{30}) of every boring position was used for site soil class interpretation (Moghaddam, 2011; Partono et al., 2019a; Partono et al., 2019b; Syaifuddin et al., 2020). The N-SPT data for each boring location was collected from a recorded boring-log prepared by the boring master. The maximum N-SPT data used in this study and collected from boring-log was 60. N-SPT values of 60 were applied for N-SPT data greater than 60 (usually recorded using “>60” in the boring-log). Following the procedure described by SNI 1726:2019, the N_{30} was estimated using Equation 4, where “di” and “Ni” represent the thickness and N-SPT value of any soil layer “i”, respectively.

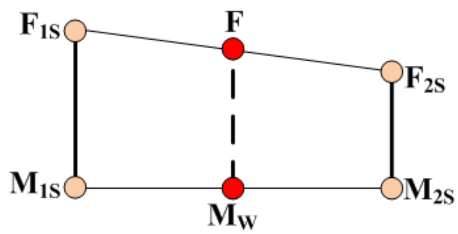


Figure 1 Straight-line interpolation for Fa and Fv calculations

$$N_{30} = \frac{30}{\sum_{i=i}^{i=n} \frac{d_i}{N_i}} \tag{4}$$

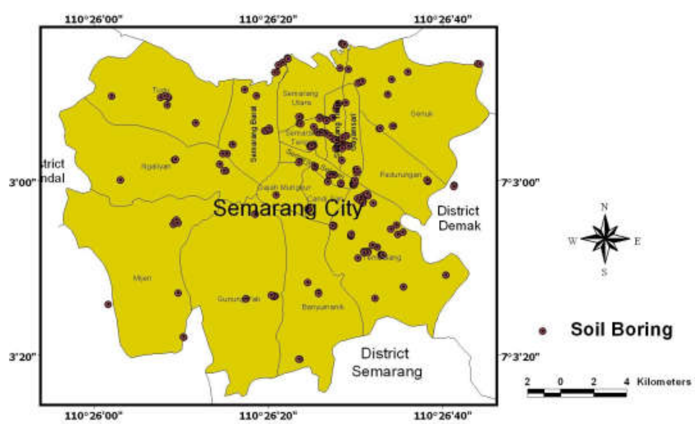


Figure 2 Soil boring position

2. Methods

The evaluation of site coefficients within the study area was conducted following five basic steps:

- Site class interpretation,
- MCE_R (S_S and S_1) and design spectrum response acceleration calculations using the website
- Site coefficient calculation based on the website output
- Site coefficient calculation based on SNI 1726:2019 tables and procedures

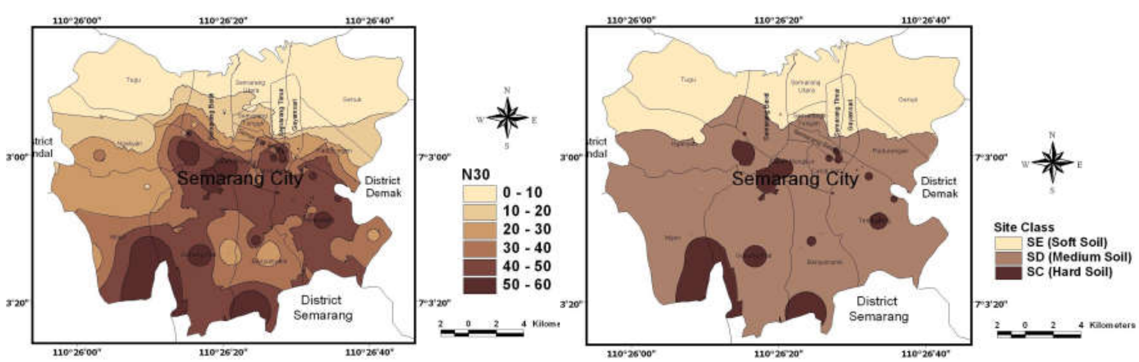
- Comparative analysis of site coefficients and design spectrum response acceleration based on two different approaches.

2.1. *Site soil class interpretation*

The site soil class interpretation was conducted at 203 boring positions using N_{30} data. Figure 3(a) shows the distribution of N_{30} within the study area. According to the N_{30} data developed at all boring locations, the site soil classes were interpreted according to SNI 1726:2019. Table 1 shows the basic classification criteria for identifying site soil class. Only three different site soil classes are presented in this table. Site class SA, SB and SF are not available within this table. Figure 3(b) shows the corresponding site soil class distribution developed according to site classification as shown in Table 1. Site class distribution in the study area is dominated by SD and SE classes. Site class SC was observed in small areas in the middle and southern part of the study area.

Table 1 Site classification

Site Class	N30
SC	> 50
SD	15 - 50
SE	< 15



(a) (b)

Figure 3 N_{30} (a) and site soil classes (b) distribution maps

2.2. *MCE$_R$ and Design Spectrum Response Acceleration Calculation*

The MCE_R calculations were performed at 203 boring position using the website. According to the site class distribution of the study area, three different S_S and S_1 distributions were also observed in the study area. Table 2 shows the distribution of minimum and maximum S_S and S_1 for the three different site classes. Table 3 shows the distribution of design spectrum response acceleration (S_{DS} and S_{D1}) developed using the website.

2.3. *Site Coefficients F_a and F_v Website*

Site coefficient F_a and F_v calculations were performed according to the S_S, S_1, S_{DS} and S_{D1} values obtained from the website. The site coefficients were estimated using Equation 1 and 2. Table 4 shows the distribution of minimum and maximum F_a and F_v developed

using these four values. Following the boundary values of F_a and F_v described in SNI 1726:2019 tables, the minimum and maximum F_a values developed in the study area were divided into two different boundary values. A few S_S values were less than 0.75 g. However, most of the S_S values were distributed between 0.75 to 1 g.

Table 2 S_S and S_1 distribution

Site Class	S_S(g)		S_1 (g)	
	minimum	Maximum	minimum	maximum
SC	0.8459	0.9668	0.3653	0.4097
SD	0.8098	0.9579	0.3546	0.4071
SE	0.696	0.9274	0.3185	0.3936

Table 3 S_{DS} and S_{D1} distribution developed using the website

Site Class	S_{DS} (g)		S_{D1} (g)	
	minimum	maximum	minimum	maximum
SC	0.68	0.77	0.37	0.41
SD	0.63	0.71	0.46	0.51
SE	0.64	0.71	0.58	0.63

Table 4 F_a and F_v distribution developed using the website

Site Class	F_a 1st Boundary		F_a 2nd Boundary		F_v	
	min.	max.	min.	max.	min.	max.
SC	-	-	1.19	1.21	1.478	1.519
SD	-	-	1.112	1.167	1.879	1.949
SE	1.323	1.4	1.148	1.292	2.401	2.732

2.4. Site Coefficients F_a and F_v SNI 1726:2019

Straight-line interpolation was also performed for F_a and F_v calculations by using Equation 3 and table data provided by SNI 1726:2019. According to the S_S and S_1 values obtained from the website, the minimum and maximum boundaries for these two site coefficients can be estimated. Table 5 shows the minimum and maximum boundaries of F_a and F_v values used for straight-line interpolation calculations.

3. Results and Discussion

The S_S for the SC site class as shown in Table 2, are distributed from 0.8459 through 0.9668 g. The F_a values for the SC site class developed according to the website, as shown in Table 4, are distributed between 1.21 and 1.19. All F_a values developed from the website are consistent and almost equal to the F_a value from SNI 1726:2019. On average the absolute difference of F_a is zero. The difference in F_a values developed using the website data are less than 0.01 compared to the F_a requirement of SNI 1726:2019. Figure 4(a) shows the distribution of F_a site coefficients for the SC site class. F_aL and F_aW inside this figure represent straight-line and website data acquisition and interpolation. The R^2 value for site class SC is close to zero, because the F_a values estimated using these two models are nearly constant for all S_S values.

The S_S for the SD site class in the study area were distributed almost equally to the SC site class. Table 2 shows the distribution of S_S for the SD site class. The values are distributed from 0.8098 through 0.9579 g. Following the same procedure as for the SC site class, the F_a site coefficients for the SD site class developed in the study area should be distributed between 1.2 and 1.1. Due to the S_S being distributed close to 1 g, the F_a values obtained from the study area are close to 1.1. As shown in Table 4, the F_a values were distributed between 1.167 and 1.112. Figure 4(b) shows the distribution of F_a values for site class SD in terms of S_S values. As can be seen in Figure 4(b), the R^2 (determination coefficients) value is 0.7858, or less than 1. The straight-line interpolation developed according to the SNI 1726:2019 data and table are better compared to the F_a values developed using the website. However, on average the absolute difference between F_a values developed using these two models is 0.0105 and the line distributions are almost similar (coincide).

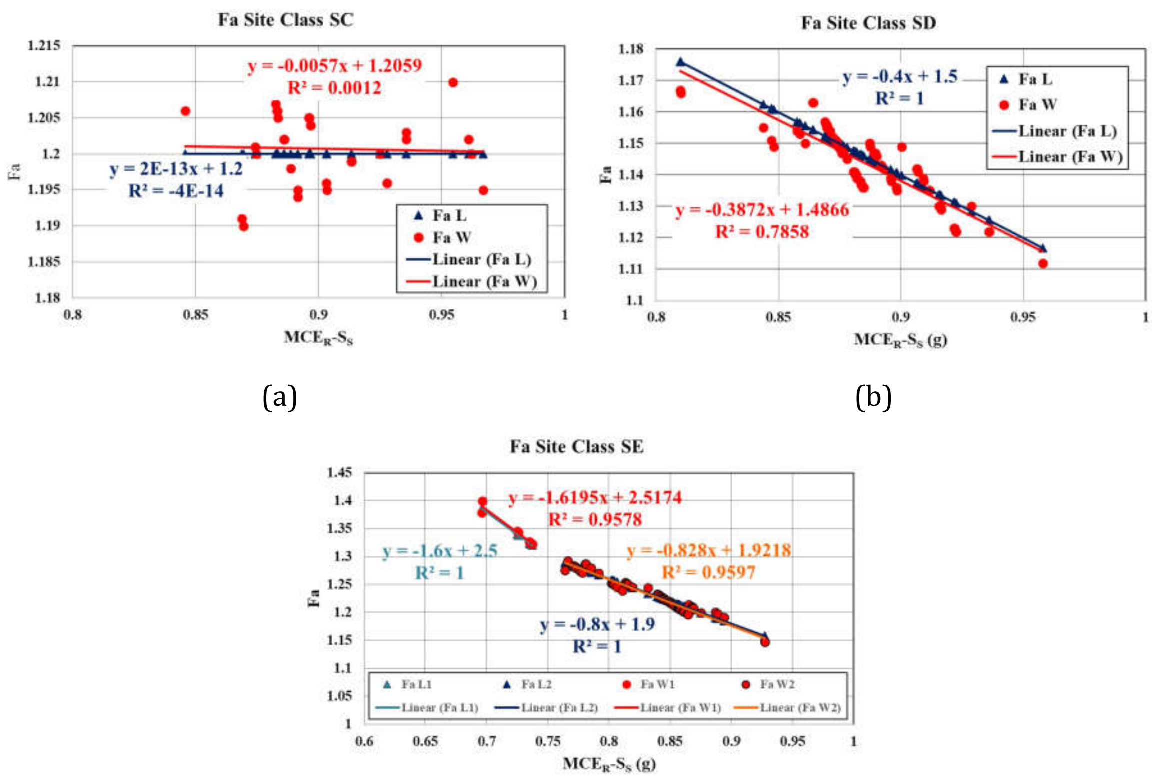
Table 5 F_a and F_v boundary values used for straight-line interpolation

Site Class	F_a			F_v	
	S_S(g)			S_1 (g)	
	0.5	0.75	1.0	0.3	0.4
SC	1.2	1.2	1.2	1.5	1.5
SD	1.4	1.2	1.1	2.0	1.9
SE	1.7	1.3	1.1	2.8	2.4

The S_S distribution for the SE site class estimated from the website is between 0.696 and 0.9274 g. According to SNI 1726:2019, all S_S for site class SE were distributed between two different boundary values, from 0.5 through 0.75 g for the 1st boundary and from 0.75 through 1 g for the 2nd boundary. The straight-line interpolation for all S_S was also separated into two different boundary values. The first F_a values were distributed between 1.4 and 1.323. Due to the S_S values, the F_a site coefficients were distributed close to 1.3. However, the second F_a site coefficients were distributed between 1.292 and 1.148. Figure 4(c) shows the distribution of F_a site coefficients for the SE site class. Two different straight-line interpolations are seen in this figure, following the two different boundary values of SNI 1726:2019. The straight-line interpolation for site class SE is better compared to site class SC and SD. The absolute average difference of F_v for site class SE is 0.02.

The site coefficients evaluation was also conducted for long period spectral acceleration S_1. Using the same procedure used for S_S, the evaluation was performed for SC, SD and SE site classes. According to the minimum and maximum S_1 values estimated using the website, all S_1 values in the study area were distributed between 0.3 and 0.4 g. For site classes SC and SD, there is one boring position having a value of S_1 greater than 0.4 g, making it difficult to perform a straight-linear interpolation. To reduce the difficulties in the analysis, the S_1 greater than 0.4 g was excluded from the analysis. Figure 5(a), (b) and (c) shows the distribution of site coefficient F_v for SC, SD and SE site soil classes, respectively.

All F_v values estimated using the website and straight-line interpolation are almost equal or coincide except for site class SD. Most of the F_v values of SD site class developed using the website are greater than the same F_v values developed using straight-line interpolation. The R^2 (R squared) value for this model is far from 1. The F_v values for site class SD developed in the study area were far from the linear model that SNI 1726:2019 expected. The R^2 for site class SC is not available (close to zero) because the F_v and S_1 correlation are nearly constant. A good performance of Fv and S_1 correlation was observed for site class SE, both for website output and straight-line interpolation. The R^2 obtained for this site class is nearly 1. “F_v L” and “F_v W” present in all figures represent straight-line interpolation (SNI 1726:2019 procedures) and the website calculations, respectively. On average the absolute differences between F_v are 0.015, 0.036 and 0.033 for SC, SD and SE site classes, respectively.



(a) (b)

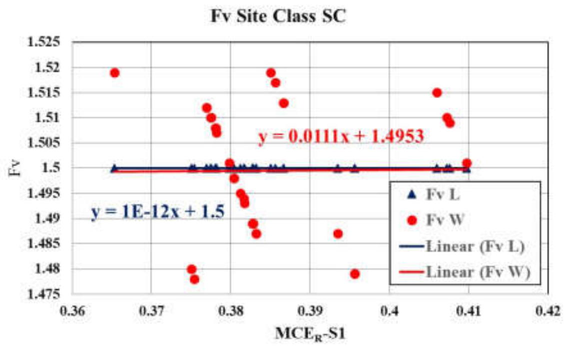
(c)

Figure 4 F_a Distributions in terms of S_S values for SC (a), SD (b) and SE (c) site classes

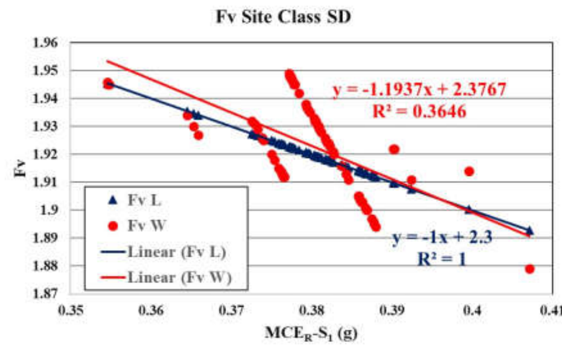
F_a and F_v are two site coefficients used for developing surface spectral acceleration and design spectrum response acceleration. The different performances of these two site coefficients developed using two different procedures can be neglected or avoided as far as there was no significant difference in the design spectrum response acceleration results developed using these two methods. The difference in the accuracy value used for both methods will produce different site coefficients and directly impact the performance of S_{DS} and S_{D1} outputs for all site soil classes.

To verify the performance of F_a and F_v estimated using these two methods, the design spectrum response acceleration calculation was also conducted in this study. The purpose of the analysis was to verify the performance of design spectrum response acceleration S_{DS} and S_{D1} according to the site coefficients values estimated using two different methods. Figure 6(a) shows the performance of S_{DS} design spectrum response acceleration in terms of S_S developed from the website and straight-line interpolation. Figure 6(b) shows the performance of S_{D1} design spectrum response acceleration in terms of S_1 estimated using

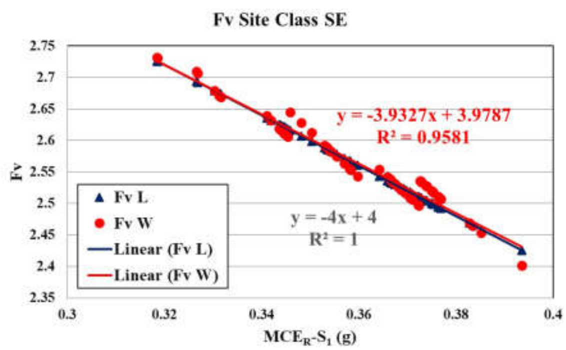
the same methods used for S_{DS} calculation. As can be seen in Figure 6(a) and 6(b), a good correlation performance between S_{DS} and S_{D1} in terms of S_S and S_1, respectively, was observed in this study. According to these two figures there are no significant differences in S_{DS} and S_{D1} performance estimated according to the website and straight-line interpolation of SNI 1726:2019 procedures.



(a)



(b)



(c)

Figure 5 F_v Distributions in terms of S_1 values for SC (a), SD (b) and SE (c) site classes

Table 6 S_{DS} and S_{D1} performance for all site classes

Site Class	S_{DS} (g)					S_{D1} (g)				
	Website		Straight-Line		Ave. Diff.	Website		Straight-Line		Ave. Diff.
	min.	max.	min.	max.		min.	max.	min.	max.	
SC	0.68	0.77	0.6767	0.7734	0.0067	0.37	0.41	0.3653	0.4097	0.0044
SD	0.63	0.71	0.6349	0.6925	0.0224	0.46	0.51	0.4599	0.4946	0.0153
SE	0.64	0.71	0.6433	0.706	0.0073	0.58	0.63	0.5788	0.6315	0.0027

The S_{DS} and S_{D1} developed for the study area using the website are accepted according to the requirement criterium of SNI 1726:2019. Table 6 shows the minimum and maximum S_{DS} and S_{D1} values and the average difference of S_{DS} and S_{D1} estimated using the two methods for SC, SD and SE site classes. The average difference of S_{DS} and S_{D1}, as presented in Table 6, is the absolute differences of S_{DS} and S_{D1}. The maximum average difference (Ave. Diff.), 0.02 g and 0.015 g, were observed at the SD site class for S_{DS} and S_{D1}

spectral design, respectively. However, the average difference of S_{DS} for site classes SC and SE were less than 0.007 g, approximately. The average difference of S_{D1} for SC and SE site classes were less than 0.004 g.

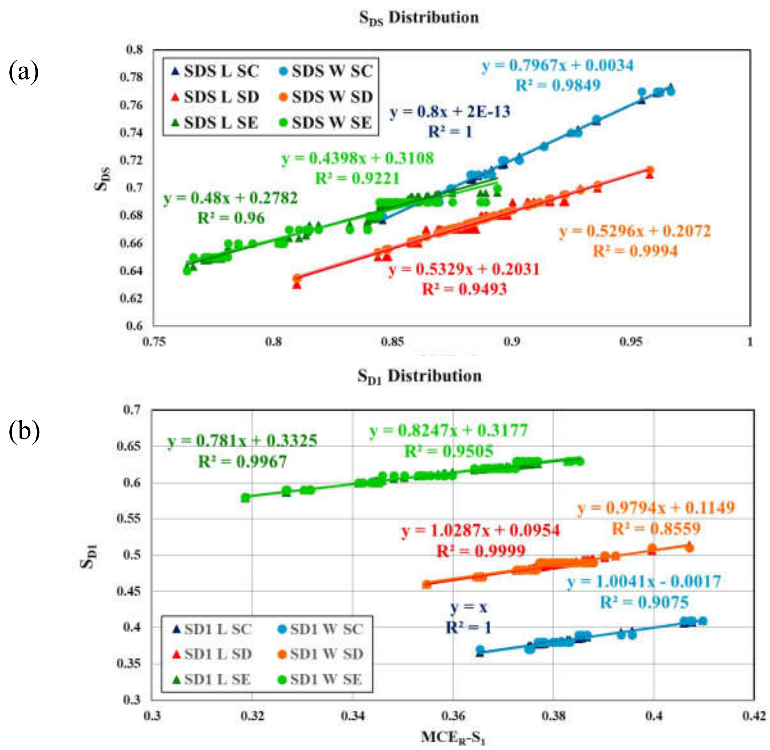


Figure 6 S_{DS} (a) and S_{D1} (b) distribution charts for SC, SD and SE site classes

4. Conclusions

Evaluations of site coefficients estimated using the website and straight-line interpolation were performed at 203 boring positions in Semarang City. No significant differences were found in F_a and F_v site coefficients estimated using both methods. The largest difference in site coefficients F_a calculations was observed for SD and SE site classes. The difference in site coefficients for SD and SE site soil classes was less than 0.03. However, for SC site soil class, the difference was less than 0.01. For site coefficient F_v, the largest difference was observed for SD and SE site soil classes with a maximum of 0.04. However, the difference in site coefficient F_v for site class SC was less than 0.02.

The design spectrum response accelerations S_{DS} and S_{D1} estimated using site coefficients F_a and F_v were also verified for the study area. No significant differences in design spectrum response accelerations S_{DS} and S_{D1} were found for all site classes. The largest design spectrum response accelerations difference for SD estimated using the two methods was less than 0.02 g. However, for SC and SE site classes the differences were less than 0.01 g.

Acknowledgements

This study was financially supported by Engineering Faculty, Diponegoro University, The Ministry of Education and Culture, The Republic of Indonesia. The authors also appreciate the Center for Housing and Settlement Research and Development for supporting data and information during the development of this study.

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Decision

Started : 26 Jul 2021 - 11:08
Decision :

Revisions Required

Notes : 1. Please revise according to the reviewer's comment, and highlights in different color that changed 2. It is suggested to include at least 3 relevant IJTech articles as references

Reviewer	1
Date Review	: 24 Jun 2021 - 10:51
Introduction	: - The writing of the reference should be check. - What is the consideration in choosing Semarang city? - Does the author considers the geological problem, such as land subsidence, structural geology etc
Methodology	: - After writing the figure, it should explain about the picture. - Again, what is the problem with Semarang city?
Results and Discussion	: In the manuscript. Why the author/s write in the result, it is four (4) number after point. The correlation (R squared) is so small. Is it still answer the question?
References	: Please use more up to date references. Especially the journal
Other	:

Originality	3 *(average)*
Technical	3 *(average)*
Methodology	3 *(average)*
Readability	3 *(average)*
Practicability	4 *(above average)*
Organization	4 *(above average)*
Importance	4 *(above average)*

Attachment	: [Review Attachment]
Result	: **Done, Revisions Required**

Reviewer	2
Date Review	: 14 Feb 2021 - 16:40
Introduction	: The aim of the paper is rather unclear, as the site coefficients and design spectrum response acceleration implemented in the "website" are just application of the Indonesian Seismic Code 2019. The differences discussed are not clear whether they are actual fundamental differences or just value rounding / algorithm issues. The authors need to clarify this so that the context and the contribution of this article are clear. Equation 4 needs to revise so that it would be the same as that in SNI 1726:2019.
Methodology	: Are there any locations with site class SF? This is particularly of interest because northern Semarang areas are well known for very deep soft clays deposits. It is suggested that Figure 3a is to have the intervals being easily referenced for Figure 3b. It is suggested that Table 1 is to have the information about how many locations for each site class category. For Tables 2 through 4, it is suggested to change "Site Class" to "Locations with Site Class" to avoid any confusion about what site class in these tables refers to (for example, Ss and S1 are for SBC site class, why there are SC through SE site classes).
Results and Discussion	: Regression analyses of Fa L and Fv L (Figures 4 and 5) may not be conceptually appropriate as Fa L and Fv L are just application of the tabulated values in SNI 1726:2019. Descriptive statistics may be more appropriate for discussing Fa and Fv for Site Class SC (Figures 4a and 5a). Please provide critical discussions whether the differences discussed in Section 3, shown in the figures and summarized in Table 4 are actual fundamental differences or just value rounding / algorithm issues. This is important to highlight the actual contribution of this article to this broad topic.
References	: No comments.
Other	: In general, there are minor grammatical errors that need to be revised.

Originality	3 *(average)*
Technical	3 *(average)*
Methodology	2 *(fair)*
Readability	3 *(average)*
Practicability	2 *(fair)*
Organization	3 *(average)*
Importance	2 *(fair)*

Attachment : -

Result : **Done, Revisions Required**

Windu Partono
Wed 7/28/2021 5:19 PM

To:

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Cc:

- nsuwartha@eng.ui.ac.id

To:
Secretariat, International Journal of Technology, Faculty of Engineering, Universitas Indonesia.

I am writing this email regarding to the information obtained from the IJTech Website which has been released on 26/7/2021. I read the information on Wednesday 28/07/2021. The information related with the review process of my paper ID **#CVE-4132** entitled **"Site Coefficients and Design Spectrum Response Acceleration Evaluation of New Indonesian 2019 Website Response Spectra".** One of the important information related with the revision of the manuscript based on the reviewer's comment and the improvement of the references. I got a problem related with the reviewer's comment to my manuscript and how to download the manuscript which has been reviewed by the reviewer. It is my pleasure if I can get the information of the complete reviewer's comment of my manuscript so that I can directly revise the manuscript. I do apologize for the inconvenient of my email. Thank you for your kind attention.

Best regards,
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Site Coefficients and Design Spectrum Acceleration Evaluation of New Indonesian 2019 Website Response Spectra

[1*]

Abstract. Developing site coefficients and design spectrum response acceleration are two important steps in the seismic design of buildings. The site coefficient calculation described in the Indonesian Seismic Code 2019 partially follow the method proposed by the American Standard Code for Seismic Design 2016. Two information or data needs for site coefficient calculations are site soil class and Risk-Targeted Maximum Considered Earthquake (MCE_R) S_S (short period) and S_1 (long period) spectral acceleration. Three different hard/SC, medium/SD and soft/SE site soil classes usually used for building designs. Two site coefficients (F_a and F_v for short and long periods spectral acceleration) are used for surface and design spectrum response acceleration calculations. The Indonesian Seismic Code provides two simple tables for developing these site coefficients. If the S_S and S_1 values developed at one site are not exactly equal to the values presented in these tables, the site coefficients can be predicted using straight-line interpolation between the two closest values. Different results are observed when the straight-line interpolation is adjusted for F_a and F_v prediction compared to the same values developed using website based software. [redacted] according to straight-line interpolation and website software calculations. The evaluation was conducted at 203 soil boring positions within the study area. The site soil classes were predicted using average N-SPT (Standard Penetration Test) values in the top 30 m soil deposit layer. Three different site soil classes were observed in the study area. On average the largest difference of site coefficients and design spectrum response acceleration were observed for SD and SE classes. However, for the SC site soil class the difference between the two analysis methods is small and approximately similar..

Keywords: Design spectrum response acceleration; MCE_R; N-SPT; Site coefficient; Straight-line interpolation

1. Introduction

The new National Seismic Code of Indonesia (SNI 1726:2019) was announced in 2019. Some information introduced in this new seismic code was partially adopted from the American Standard Code for Seismic Design ASCE/SEI 7 (2016). Two important items adopted from ASCE/SEI 7-16 are the site coefficients and design spectrum response acceleration calculation methods. Compared to the SNI 1726:2012, which was totally adopted from ASCE/SEI 7-10, the SNI 1726:2019 for developing site coefficients was partially adopted from ASCE/SEI 7-16.

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Another item used for developing site coefficients was adopted from (Stewart and Seyhan, 2013). Due to the improved methods for developing site coefficients for site soil classes SD and SE describes in ASCE/SEI 7-16, not all information described in the American Code was adopted by SNI 1726:2019. The site analysis requirements for developing site coefficients for SD and SE classes induced an alternative method for developing these site coefficients. Site coefficients for SD and SE classes presented in the new Indonesian Seismic Code 2019 are completely adopted from [redacted]

Following the new SNI 1726:2019, especially in developing site coefficients, the Ministry of Public Works and Human Settlements announced a new website facility for response spectrum design calculations. Site or building position coordinates (in terms of longitude and latitude) and site soil class are two data needs for design spectrum response acceleration calculations. Risk-Targeted Maximum Considered Earthquake (MCE_R) S_S (short periods) and S_1 (long periods) (Luco et al., 2007; Sengara, 2012; Allen et al., 2015; Sengara et al., 2020), and two spectral designs, S_{DS} and S_{D1}, are four important values calculated by the website facility software. No information related to site coefficients F_a and F_v can be obtained from the new website. [redacted]. All S_{DS}, S_S, S_{D1} and S_1 values were obtained from the website.

$$F_a = \frac{S_{DS}}{\frac{2}{3} S_S} \tag{1}$$

$$F_v = \frac{S_{D1}}{\frac{2}{3} S_1} \tag{2}$$

To verify the F_a and F_v site coefficients estimated using Equations 1 and 2, straight-line interpolation can be conducted using two S_S and S_1 website calculations and applying site coefficient (F_a and F_v) tables data provided by SNI 1726:2019. F_a and F_v are then estimated following the procedure described by SNI 1726:2019. Equation 3 shows a simple formula for site coefficient calculations for F_a and F_v. Figure 1 shows a schematic diagram for the straight-line interpolation of F_a and F_v values. "F" and "M_W" represent the site coefficient to be estimated and the MCE_R value obtained from the website, respectively. M_{1S} and M_{2S} represent two boundary MCE_R values close to M_W. F_{1S} and F_{2S} represent two site coefficients for $M_W=M_{1S}$ and $M_W=M_{2S}$, respectively. M_{1S}, M_{2S}, F_{1S} and F_{2S} are four values obtained from SNI 1726:2019 table data. F_a and F_v are estimated separately using Equation 3. The M_{1S}, M_{2S}, F_{1S} and F_{2S} values used for F_a and F_v calculations are not similar.

$$F = \left(\frac{F_{2S} - F_{1S}}{M_{2S} - M_{1S}} \right) (M_W - M_{1S}) + F_{1S} \tag{3}$$

This paper describes the site coefficients and the design spectrum response acceleration verification using the website and the straight-line interpolation of SNI 1726:2019. The study was performed at Semarang City, Indonesia and conducted at 203 soil boring investigation positions. Figure 2 shows 203 boring positions within the study area. All boring investigations conducted in this study had a minimum 30 m depth and a

maximum 60 m depth. The average Standard Penetration Test (N-SPT) of the topmost 30 m soil deposit layer (N_{30}) of every boring position was used for site soil class interpretation (Moghaddam, 2011; Partono et al., 2019a; Partono et al., 2019b; Syaifuddin et al., 2020). The N-SPT data for each boring location was collected from a recorded boring-log prepared by the boring master. The maximum N-SPT data used in this study and collected from boring-log was 60. N-SPT values of 60 were applied for N-SPT data greater than 60 (usually recorded using “>60” in the boring-log). Following the procedure described by SNI 1726:2019, the N_{30} was estimated using Equation 4, where “di” and “Ni” represent the thickness and N-SPT value of any soil layer “i”, respectively.

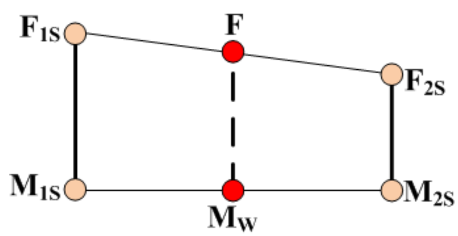


Figure 1 Straight-line interpolation for Fa and Fv calculations

$$N_{30} = \frac{30}{\sum_{i=i}^{i=n} \frac{d_i}{N_i}} \qquad (4)$$

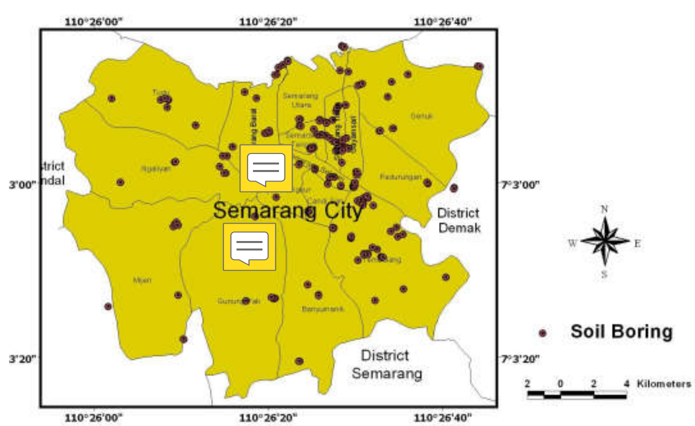


Figure 2 [redacted]

2. Methods

The evaluation of site coefficients within the study area was conducted following five basic steps:

- Site class interpretation,
- MCE_R (S_S and S_1) and design spectrum response acceleration calculations using the website
- Site coefficient calculation based on the website output
- Site coefficient calculation based on SNI 1726:2019 tables and procedures

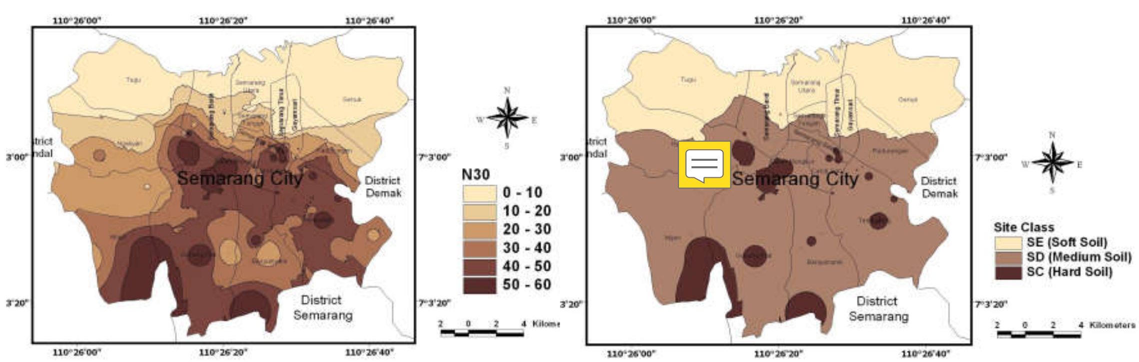
- Comparative analysis of site coefficients and design spectrum response acceleration based on two different approaches.

2.1. *Site soil class interpretation*

The site soil class interpretation was conducted at 203 boring positions using N_{30} data. Figure 3(a) shows the distribution of N_{30} within the study area. According to the N_{30} data developed at all boring locations, the site soil classes were interpreted according to SNI 1726:2019. Table 1 shows the basic classification criteria for identifying site soil class. Only three different site soil classes are presented in this table. Site class SA, SB and SF are not available within this table. Figure 3(b) shows the corresponding site soil class distribution developed according to site classification as shown in Table 1. Site class distribution in the study area is dominated by SD and SE classes. Site class SC was observed in small areas in the middle and southern part of the study area.

Table 1 Site classification

Site Class	N30
SC	> 50
SD	15 - 50
SE	< 15



(a) (b)

Figure 3 N_{30} (a) and site soil classes (b) distribution maps

2.2. *MCE_R and Design Spectrum Response Acceleration Calculation*

The MCE_R calculations were performed at 203 boring position using the website. According to the site class distribution of the study area, three different S_S and S_1 distributions were also observed in the study area. Table 2 shows the distribution of minimum and maximum S_S and S_1 for the three different site classes. Table 3 shows the distribution of design spectrum response acceleration (S_{DS} and S_{D1}) developed using the website.

2.3. *Site Coefficients F_a and F_v Website*

Site coefficient F_a and F_v calculations were performed according to the S_S, S_1, S_{DS} and S_{D1} values obtained from the website. The site coefficients were estimated using Equation 1 and 2. Table 4 shows the distribution of minimum and maximum F_a and F_v developed

using these four values. Following the boundary values of F_a and F_v described in SNI 1726:2019 tables, the minimum and maximum F_a values developed in the study area were divided into two different boundary values. A few S_S values were less than 0.75 g. However, most of the S_S values were distributed between 0.75 to 1 g.

Table 2 S_S and S_1 distribution

Site Class	S_S(g)		S_1 (g)	
	minimum	Maximum	minimum	maximum
SC	0.8459	0.9668	0.3653	0.4097
SD	0.8098	0.9579	0.3546	0.4071
SE	0.696	0.9274	0.3185	0.3936

Table 3 S_{DS} and S_{D1} distribution developed using the website

Site Class	S_{DS} (g)		S_{D1} (g)	
	minimum	maximum	minimum	maximum
SC	0.68	0.77	0.37	0.41
SD	0.63	0.71	0.46	0.51
SE	0.64	0.71	0.58	0.63

Table 4 F_a and F_v distribution developed using the website

Site Class	F_a 1st Boundary		F_a 2nd Boundary		F_v	
	min.	max.	min.	max.	min.	max.
SC	-	-	1.19	1.21	1.478	1.519
SD	-	-	1.112	1.167	1.879	1.949
SE	1.323	1.4	1.148	1.292	2.401	2.732

2.4. *Site Coefficients F_a and F_v SNI 1726:2019*

Straight-line interpolation was also performed for F_a and F_v calculations by using Equation 3 and table data provided by SNI 1726:2019. According to the S_S and S_1 values obtained from the website, the minimum and maximum boundaries for these two site coefficients can be estimated. Table 5 shows the minimum and maximum boundaries of F_a and F_v values used for straight-line interpolation calculations.

3. Results and Discussion

The S_S for the SC site class as shown in Table 2, are distributed from 0.8459 through 0.9668 g. The F_a values for the SC site class developed according to the website, as shown in Table 4, are distributed between 1.21 and 1.19. All F_a values developed from the website are consistent and almost equal to the F_a value from SNI 1726:2019. On average the absolute difference of F_a is zero. The difference in F_a values developed using the website data are less than 0.01 compared to the F_a requirement of SNI 1726:2019. Figure 4(a) shows the distribution of F_a site coefficients for the SC site class. F_aL and F_aW inside this figure represent straight-line and website data acquisition and interpolation. The R^2 value for site class SC is close to zero, because the F_a values estimated using these two models are nearly constant for all S_S values.

The S_S for the SD site class in the study area were distributed almost equally to the SC site class. Table 2 shows the distribution of S_S for the SD site class. The values are distributed from 0.8098 through 0.9579 g. Following the same procedure as for the SC site class, the F_a site coefficients for the SD site class developed in the study area should be distributed between 1.2 and 1.1. Due to the S_S being distributed close to 1 g, the F_a values obtained from the study area are close to 1.1. As shown in Table 4, the F_a values were distributed between 1.167 and 1.112. Figure 4(b) shows the distribution of F_a values for site class SD in terms of S_S values. As can be seen in Figure 4(b), the R^2 (determination coefficients) value is 0.7858, or less than 1. The straight-line interpolation developed according to the SNI 1726:2019 data and table are better compared to the F_a values developed using the website. However, on average the absolute difference between F_a values developed using these two models is 0.0105 and the line distributions are almost similar (coincide).

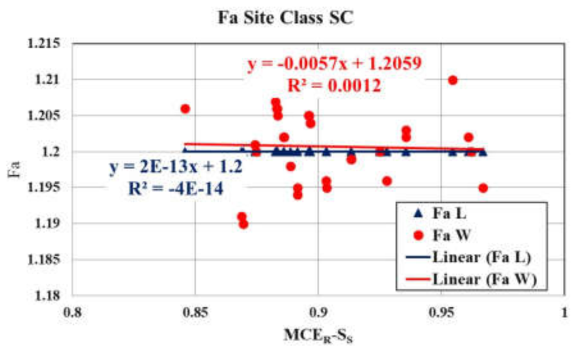
Table 5 F_a and F_v boundary values used for straight-line interpolation

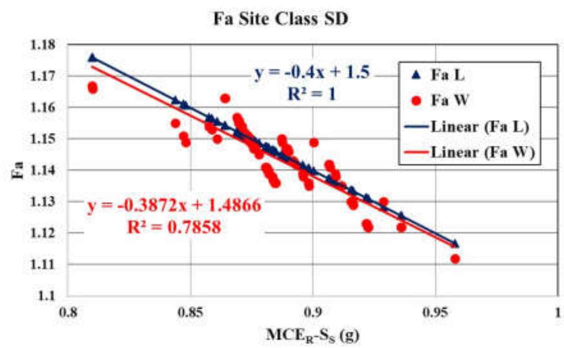
Site Class	F_a			F_v	
	S_S(g)			S_1 (g)	
	0.5	0.75	1.0	0.3	0.4
SC	1.2	1.2	1.2	1.5	1.5
SD	1.4	1.2	1.1	2.0	1.9
SE	1.7	1.3	1.1	2.8	2.4

The S_S distribution for the SE site class estimated from the website is between 0.696 and 0.9274 g. According to SNI 1726:2019, all S_S for site class SE were distributed between two different boundary values, from 0.5 through 0.75 g for the 1st boundary and from 0.75 through 1 g for the 2nd boundary. The straight-line interpolation for all S_S was also separated into two different boundary values. The first F_a values were distributed between 1.4 and 1.323. Due to the S_S values, the F_a site coefficients were distributed close to 1.3. However, the second F_a site coefficients were distributed between 1.292 and 1.148. Figure 4(c) shows the distribution of F_a site coefficients for the SE site class. Two different straight-line interpolations are seen in this figure, following the two different boundary values of SNI 1726:2019. The straight-line interpolation for site class SE is better compared to site class SC and SD. The absolute average difference of F_v for site class SE is 0.02.

The site coefficients evaluation was also conducted for long period spectral acceleration S_1. Using the same procedure used for S_S, the evaluation was performed for SC, SD and SE site classes. According to the minimum and maximum S_1 values estimated using the website, all S_1 values in the study area were distributed between 0.3 and 0.4 g. For site classes SC and SD, there is one boring position having a value of S_1 greater than 0.4 g, making it difficult to perform a straight-linear interpolation. To reduce the difficulties in the analysis, the S_1 greater than 0.4 g was excluded from the analysis. Figure 5(a), (b) and (c) shows the distribution of site coefficient F_v for SC, SD and SE site soil classes, respectively.

All F_v values estimated using the website and straight-line interpolation are almost equal or coincide except for site class SD. Most of the F_v values of SD site class developed using the website are greater than the same F_v values developed using straight-line interpolation. [redacted]. The F_v values for site class SD developed in the study area were far from the linear model that SNI 1726:2019 expected. The R^2 for site class SC is not available (close to zero) because the F_v and S_1 correlation are nearly constant. A good performance of Fv and S_1 correlation was observed for site class SE, both for website output and straight-line interpolation. The R^2 obtained for this site class is nearly 1. "F_v L" and "F_v W" present in all figures represent straight-line interpolation (SNI 1726:2019 procedures) and the website calculations, respectively. On average the absolute differences between F_v are 0.015, 0.036 and 0.033 for SC, SD and SE site classes, respectively.





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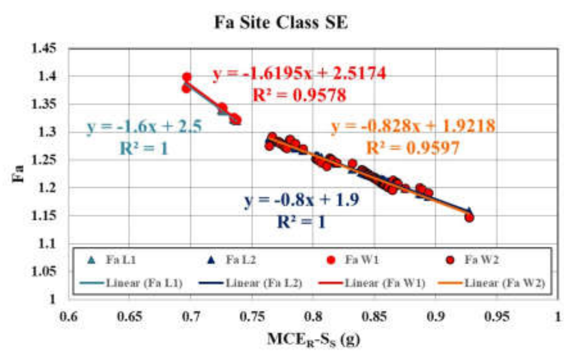

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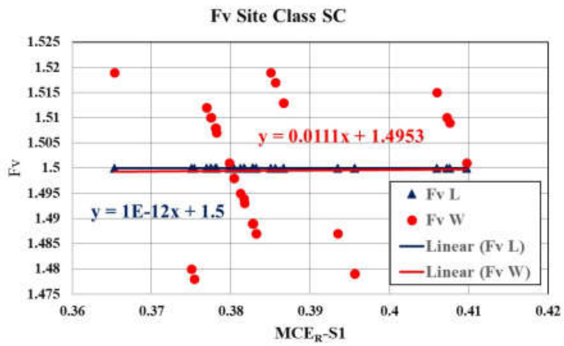
Figure 4 F_a Distributions in terms of S_S values for SC (a), SD (b) and SE (c) site classes

F_a and F_v are two site coefficients used for developing surface spectral acceleration and design spectrum response acceleration. The different performances of these two site coefficients developed using two different procedures can be neglected or avoided as far as there was no significant difference in the design spectrum response acceleration results developed using these two methods. The difference in the accuracy value used for both methods will produce different site coefficients and directly impact the performance of S_{DS} and S_{D1} outputs for all site soil classes.

To verify the performance of F_a and F_v estimated using these two methods, the design spectrum response acceleration calculation was also conducted in this study. The purpose of the analysis was to verify the performance of design spectrum response acceleration S_{DS} and S_{D1} according to the site coefficients values estimated using two different methods. Figure 6(a) shows the performance of S_{DS} design spectrum response acceleration in terms of S_S developed from the website and straight-line interpolation. Figure 6(b) shows the performance of S_{D1} design spectrum response acceleration in terms of S_1 estimated using

the same methods used for S_{DS} calculation. As can be seen in Figure 6(a) and 6(b), a good correlation performance between S_{DS} and S_{D1} in terms of S_S and S_1, respectively, was observed in this study. According to these two figures there are no significant differences in S_{DS} and S_{D1} performance estimated according to the website and straight-line interpolation of SNI 1726:2019 procedures.



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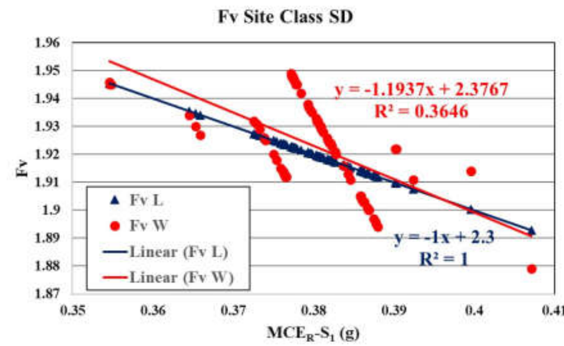

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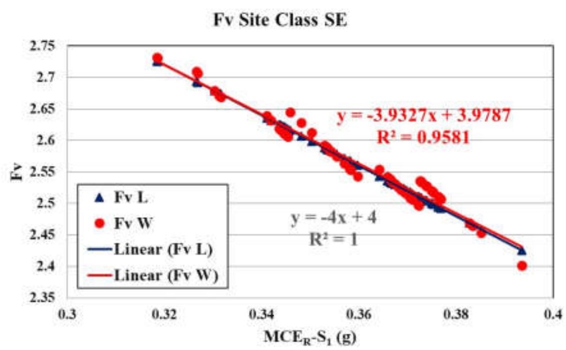

(c)

Figure 5 F_v Distributions in terms of S_1 values for SC (a), SD (b) and SE (c) site classes

Table 6 S_{DS} and S_{D1} performance for all site classes

Site Class	S_{DS} (g)					S_{D1} (g)				
	Website		Straight-Line		Ave. Diff.	Website		Straight-Line		Ave. Diff.
	min.	max.	min.	max.		min.	max.	min.	max.	
SC	0.68	0.77	0.6767	0.7734	0.0067	0.37	0.41	0.3653	0.4097	0.0044
SD	0.63	0.71	0.6349	0.6925	0.0224	0.46	0.51	0.4599	0.4946	0.0153
SE	0.64	0.71	0.6433	0.706	0.0073	0.58	0.63	0.5788	0.6315	0.0027

The S_{DS} and S_{D1} developed for the study area using the website are accepted according to the requirement criterium of SNI 1726:2019. Table 6 shows the minimum and maximum S_{DS} and S_{D1} values and the average difference of S_{DS} and S_{D1} estimated using the two methods for SC, SD and SE site classes. The average difference of S_{DS} and S_{D1}, as presented in Table 6, is the absolute differences of S_{DS} and S_{D1}. The maximum average difference (Ave. Diff.), 0.02 g and 0.015 g, were observed at the SD site class for S_{DS} and S_{D1}

spectral design, respectively. However, the average difference of S_{DS} for site classes SC and SE were less than 0.007 g, approximately. The average difference of S_{D1} for SC and SE site classes were less than 0.004 g.

(a)

(b)

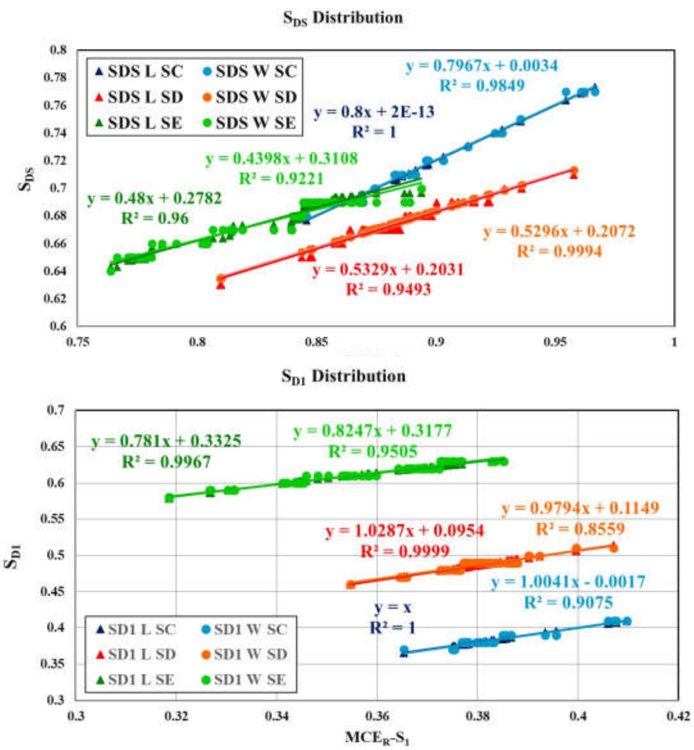

Figure 6 S_{DS} (a) and S_{D1} (b) distribution charts for SC, SD and SE site classes

4. Conclusions

Evaluations of site coefficients estimated using the website and straight-line interpolation were performed at 203 boring positions in Semarang City. No significant differences were found in F_a and F_v site coefficients estimated using both methods. The largest difference in site coefficients F_a calculations was observed for SD and SE site classes. The difference in site coefficients for SD and SE site soil classes was less than 0.03. However, for SC site soil class, the difference was less than 0.01. For site coefficient F_v, the largest difference was observed for SD and SE site soil classes with a maximum of 0.04. However, the difference in site coefficient F_v for site class SC was less than 0.02.

The design spectrum response accelerations S_{DS} and S_{D1} estimated using site coefficients F_a and F_v were also verified for the study area. No significant differences in design spectrum response accelerations S_{DS} and S_{D1} were found for all site classes. The largest design spectrum response accelerations difference for SD estimated using the two methods was less than 0.02 g. However, for SC and SE site classes the differences were less than 0.01 g.

Acknowledgements

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Introduction	: The aim of the paper is rather unclear, as the site coefficients and design spectrum response acceleration implemented in the "website" are just application of the Indonesian Seismic Code 2019. The differences discussed are not clear whether they are actual fundamental differences or just value rounding / algorithm issues. The authors need to clarify this so that the context and the contribution of this article are clear. Equation 4 needs to revise so that it would be the same as that in SNI 1726:2019.
Methodology	: Are there any locations with site class SF? This is particularly of interest because northern Semarang areas are well known for very deep soft clays deposits. It is suggested that Figure 3a is to have the intervals being easily referenced for Figure 3b. It is suggested that Table 1 is to have the information about how many locations for each site class category. For Tables 2 through 4, it is suggested to change "Site Class" to "Locations with Site Class" to avoid any confusion about what site class in these tables refers to (for example, Ss and S1 are for SBC site class, why there are SC through SE site classes).
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Site Coefficients and Design Spectrum Acceleration Evaluation of New Indonesian 2019 Website Response Spectra

[1*],

Abstract. Developing site coefficients and design spectrum response acceleration are two important steps in the seismic design of buildings. The site coefficient calculation described in the Indonesian Seismic Code 2019 partially follows the method proposed by the American Standard Code for Seismic Design 2016. Two information or data needs for site coefficient calculations are the site soil class and the Risk-Targeted Maximum Considered Earthquake (MCE_R) S_S (short period) and S_1 (long period) spectral acceleration. Three different hard/SC, medium/SD and soft/SE site soil classes are usually used for building designs. Two site coefficients (F_a and F_v for short and long period~~s~~ spectral acceleration) are used for surface and design spectrum response acceleration calculations. The Indonesian Seismic Code provides two simple tables for developing these site coefficients. If the S_S and S_1 values developed at a~~one~~ site are not exactly equal to the values presented in these tables, the site coefficients can be predicted using straight-line interpolation between the two closest values. Different results are observed when the straight-line interpolation is adjusted for F_a and F_v prediction compared to the same values developed using website-~~-~~based software. This study evaluates the site coefficients and design spectrum response acceleration predictions at Semarang City, Indonesia, according to straight-line interpolation and website software calculations. The evaluation was conducted at 203 soil boring positions within the study area. The site soil classes were predicted using average N-SPT (Standard Penetration Test) values in the top 30 m soil deposit layer. Three different site soil classes were observed in the study area. On average, the largest differences of the site coefficients and design spectrum response acceleration were observed for the SD and SE classes. However, for the SC site soil class the difference between the two analysis methods is small and they are approximately similar.

Keywords: Design spectrum response acceleration; MCE_R; N-SPT; Site coefficient; Straight-line interpolation

1. Introduction

The new National Seismic Code of Indonesia (SNI 1726:2019) was announced in 2019. Some of the information introduced in this new seismic code was partially adopted from the American Standard Code for Seismic Design ASCE/SEI 7 (2016). Two important types of information adopted from ASCE/SEI 7-16 are the site coefficients and design spectrum response acceleration calculation methods. O~~Ano~~ther information used for developing site coefficients was adopted from (Stewart and Seyhan, 2013). Due to the improved methods for developing site coefficients for site soil classes SD and SE described~~s~~ in ASCE/SEI 7-16, not all the information described in the American Code was adopted by SNI 1726:2019. Site coefficients for the SD and SE classes presented in the new Indonesian Seismic Code 2019 are completely adopted from (Stewart and Seyhan, 2013).

Following the new SNI 1726:2019, especially in developing site coefficients, the Ministry of Public Works and Human Settlements announced a new website facility for response spectrum design calculations. Site or building position coordinates (in terms of longitude and latitude) and site soil class are two data needs for design spectrum response acceleration calculations. Risk-Targeted Maximum Considered Earthquake (MCE_R) S_S (short periods) and S_1 (long periods) (Luco et al., 2007; Allen et al., 2015; Sengara et al., 2020), and two spectral designs, S_{DS} and S_{D1}, are four important values calculated by the website facility software. No information related to site coefficients F_a and F_v can be obtained from the new website, however. Due to in~~-~~complete information related to the F_a and F_v site coefficients, these values can be estimated using Equation 1 and Equation 2. All S_{DS}, S_S, S_{D1} and S_1 values were obtained from the website.

$$F_a = \frac{S_{DS}}{\frac{2}{3} S_S} \tag{1}$$

$$F_v = \frac{S_{D1}}{\frac{2}{3} S_1} \tag{2}$$

To verify the F_a and F_v site coefficients estimated using Equations 1 and 2, straight-line interpolation can be conducted using two S_S and S_1 website calculations and applying site coefficient (F_a and F_v) tables data provided by SNI 1726:2019. F_a and F_v are then estimated following the procedure described by SNI 1726:2019. Equation 3 shows a simple formula for site coefficient calculations for F_a and F_v. Figure 1 shows a schematic diagram for the straight-line interpolation of F_a and F_v values. "F" and "~~M_W~~M_w" represent the site coefficient to be estimated and the MCE_R value obtained from the website, respectively. M_{1S} and M_{2S} represent two boundary MCE_R values close to M_w. F_{1S} and F_{2S} represent two site coefficients for M_w=M_{1S} and M_w=M_{2S}, respectively. M_{1S}, M_{2S}, F_{1S} and F_{2S} are four values obtained from the SNI 1726:2019 tables. F_a and F_v are estimated separately using Equation 3.

$$F = \left(\frac{F_{2S} - F_{1S}}{M_{2S} - M_{1S}}\right)(M_W - M_{1S}) + F_{1S} \tag{3}$$

This paper describes the site coefficients and the design spectrum response acceleration verification using the website and the straight-line interpolation described~~s~~ in SNI 1726:2019. The study was performed at Semarang City, Indonesia, and conducted at 203 soil boring investigation positions. The study was conducted at this city because the boring investigation and N-SPT measurement data for site class calculation were available and distributed over~~at~~ the whole ~~part~~ of the study area. The distribution of the site soil classes can easily be assessed~~performed~~ based on the real distribution of boring investigations. Figure 2 (a) shows the 203 boring positions within the study area and the N_{30} distribution. All boring investigations conducted in this study had a minimum 30 m and a maximum 60 m depth. The average Standard Penetration Test (N-SPT) of the topmost 30 m soil deposit layer (N_{30}) of every boring position was used for site soil class interpretation (Moghaddam, 2011; Partono et al., 2019; Syaifuddin et al., 2020). Figure 2 (b) shows the distribution of site soil~~s~~ classes (Partono et al., 2021) based on the N_{30} data. The maximum N-SPT data used in this study and collected from the boring-log was 60. Following the procedure described by SNI 1726:2019, the N_{30} was estimated using Equation 4, where "d_i" and "N_i" represent the thickness and N-SPT value of any soil layer "i", respectively.

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The same parameter that can be used for site interpretation is the average shear wave velocity (V_S) of the topmost 30 m soil deposit (V_{S30}) (Naji et al., 2020). The V_{S30} value can be calculated using the same method as shown in~~at~~ Eq. 4 and replacing the N_i value by V_{Si}. The V_S value can be collected using seismic refraction MASW (Multichannel Analysis of Surface Waves) or array seismometer investigations. Prakoso et al. (2017) described a~~the~~ comparative~~ison~~ study of V_S investigation based on MASW and soil boring data. The V_S value developed using MASW is more reliable compared to the same Vs value developed based on the boring investigation. Pramono et al. (2018) described the predominant frequency investigation at Lombok I~~i~~sland following the 2018 earthquake event. The greater the V_{S30} value used, the greater the predominant frequency obtained from wavelet analysis of ground motion. The investigation of V_{S30} and predominant frequency correlation was also conducted by Pramono et al. (2017) at the Palu area.

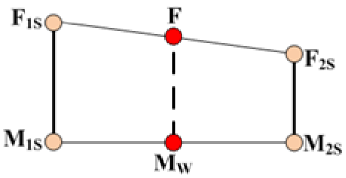

Figure 1 Straight-line interpolation for F_a and F_v calculations

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$$N_{30} = \frac{\sum_{i=i}^{i=n} d_i}{\sum_{i=i}^{i=n} \frac{d_i}{N_i}} \tag{4}$$

2. Methods

The evaluation of site coefficients within the study area was conducted following five basic steps:

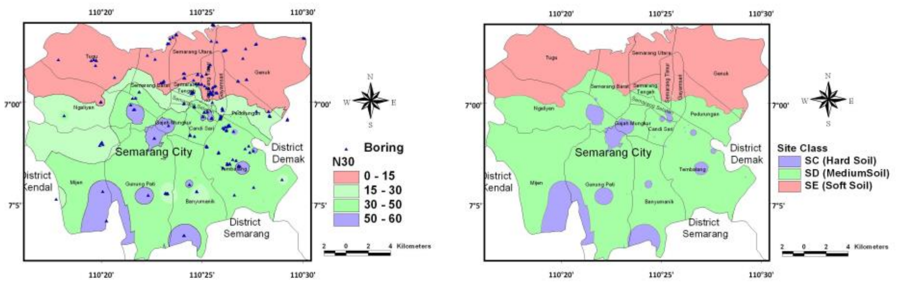
- Site class interpretation~~,~~
- MCE_R (S_S and S_1) and design spectrum response acceleration calculations using the website
- Site coefficient calculation based on the website output
- Site coefficient calculation based on SNI 1726:2019 tables and procedures
- Comparative analysis of site coefficients and design spectrum response acceleration based on the two different approaches, website data and linear interpolation procedure.

2.1. Site S~~s~~oil C~~c~~lass I~~i~~nterpretation

The site soil class interpretation was conducted at 203 boring positions using N_{30} data. According to the N_{30} data developed at all boring locations, the site soil classes were interpreted according to SNI 1726:2019. Table 1 shows the basic classification criteria for identifying the site soil class. Only three different site soil classes are presented in this table. Site classes SA, SB and SF are not available within this table. Figure 2(b) shows the corresponding site soil class distribution developed according to the site classification as shown in Table 1. The s~~S~~ite class distribution in the study area is dominated by the SD and SE classes. Site class SC was observed in small areas in the middle and southern part of the study area (Partono et al., 2021).

Table 1 Site classification

Site Class	N_{30}
SC	> 50
SD	15 - 50
SE	< 15



(a) (b)

Figure 2 Boring investigations and N_{30} distribution (a) and site soil classes (b) distribution maps

2.2. MCE_R and Design Spectrum Response Acceleration Calculation

The MCE_R calculations were performed at 203 boring positions using the website. According to the site class distribution of the study area, three different S_S and S_1 distributions were also observed in the study area. Table 2 shows the total boring investigations for each site class and the distribution of minimum and maximum S_S, S_1, S_{DS} and S_{D1} for the three different site classes developed using the website.

Table 2 S_S, S_1, S_{DS} and S_{D1} distribution

Site c~~C~~lass	Total b~~B~~oring i~~I~~nvest.	S_S(g)		S_{DS} (g)		S_1 (g)		S_{D1} (g)	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
SC	34	0.8459	0.9668	0.68	0.77	0.3653	0.4097	0.37	0.41
SD	90	0.8098	0.9579	0.63	0.71	0.3546	0.4071	0.46	0.51
SE	79	0.696	0.9274	0.64	0.71	0.3185	0.3936	0.58	0.63

2.3. Site Coefficients F_a and F_v Website

Site coefficient F_a and F_v calculations were performed according to the S_S, S_1, S_{DS} and S_{D1} values obtained from the website. The site coefficients were estimated using Equations

1 and 2. Table 3 shows the distribution of minimum and maximum F_a and F_v developed using these four values. Following the boundary values of F_a and F_v described in the SNI 1726:2019 tables, the minimum and maximum F_a values developed in the study area were divided into two different boundary values. A few S_S values were less than 0.75 g. However, most of the S_S values were distributed between 0.75 and~~to~~ 1 g.

2.4. *Site Coefficients F_a and F_v SNI 1726:2019*

Straight-line interpolation was also performed for F_a and F_v calculations by using Equation 3 and table data provided by SNI 1726:2019. According to the S_S and S_1 values obtained from the website, the minimum and maximum boundaries for these two site coefficients can be estimated. Table 3 shows the minimum and maximum boundaries of the F_a and F_v values used for straight-line interpolation calculations. The F_a and F_v minimum and maximum boundary values displayed in Table 3 were obtained from SNI 1726:2019.

Table 3 F_a and F_v distribution developed using the website and SNI 1726:2019 data

Site c~~C~~lass	Total d~~D~~ata	Linear i~~I~~nterpolation (SNI)					Website				Diff. > 0.01 (%)	
		F_a			F_v		F_a		F_v		F_a	F_v
		MCE_R-S_S(g)			MCE_R-S_1 (g)		Min.	Max.	Min.	Max.		
		0.5	0.75	1.0	0.3	0.4						
SC	34	1.2	1.2	1.2	1.5	1.5	1.519	1.21	1.478	1.519	0	58.82
SD	90	1.4	1.2	1.1	2.0	1.9	1.949	1.167	1.879	1.949	3.41	56.82
SE	79	1.7	1.3	1.1	2.8	2.4	2.732	1.4	2.401	2.732	13.92	50.63

3. Results and Discussion

The S_S for the SC site class as shown in Table 2~~,~~ are distributed from 0.8459 through 0.9668 g. The F_a values for the SC site class developed according to the website, as shown in Table 3, are distributed between 1.19 and 1.21. All the F_a values developed from the website are consistent and almost equal to the F_a value from SNI 1726:2019 (Table 3). As can be seen in Table 3, the F_a values of SNI 1726:2019 are constant and equal to 1.2. The difference in F_a values developed using the website data is~~are~~ less than 0.01 compared to the F_a requirement of SNI 1726:2019. According to Table 3, for all 34 data, the total data with a minimum difference of 0.01 is 0%. Figure 3(a) shows the distribution of F_a site coefficients for the SC site class in terms of MCE_R-S_S values. The Linear and Website legends inside this figure represent straight-line interpolation following SNI 1726:2019 and website data acquisition. The R^2 value for site class SC is close to zero, because the F_a values estimated using these two models are nearly constant for all S_S values. The R^2 (coefficient of determination) value is used for evaluation of the fitting line (linear fit model) performance. The evaluation was performed for the distribution of F_a or F_v to the linear regression line model. The minimum and maximum R^2 values are 0 and 1 (100%), respectively. The higher the R^2, the better the linear fitting model difference with the~~to~~ F_a or F_v data distribution.

The distribution of S_S values for the SD site class in the study area was~~ere distributed~~ almost equal~~ly~~ to the SC site class. Table 2 shows the distribution of S_S for the SD site class. The values are distributed from 0.8098 through 0.9579 g. Following the same procedure as for the SC site class, the F_a site coefficients for the SD site class developed in the study area should be distributed between 1.2 and 1.1. Due to the S_S being distributed close to 1

Commented [A1]: Please check this sentence.

g, the F_a values obtained from the study area are close to 1.1. As shown in Table 3, the F_a values were distributed between 1.112 and 1.167. The total data having a minimum difference of 0.01 are 3.41%. Figure 3(b) shows the distribution of F_a values for site class SD in terms of MCE_R-S_S values. As can be seen in Figure 3(b), the R^2 value obtained from the regression analysis is 0.7858, or less than 1. The straight-line interpolation developed according to the SNI 1726:2019 data and table are better compared to the F_a values developed using the website. However, on average the absolute difference between F_a values developed using these two models is 0.0105 and the line distributions are very~~almost~~ similar (coincide).

Commented [A2]: Or 'almost identical'.

The S_S distribution for the SE site class estimated from the website is between 0.696 and 0.9274 g. According to SNI 1726:2019, all S_S for site class SE were distributed between two different boundary values, from 0.5 through 0.75 g for the 1st boundary and from 0.75 through 1 g for the 2nd boundary. The straight-line interpolation for all S_S was also separated into two different boundary values. The first F_a values were distributed between 1.4 and 1.323. Due to the S_S values, the F_a site coefficients were distributed close to 1.3. However, the second F_a site coefficients were distributed between 1.292 and 1.148. Figure 3(c) shows the distribution of F_a values for the SE site class. Two different straight-line interpolations are seen in this figure, following the two different boundary values of SNI 1726:2019. The absolute average difference of F_a for site class SE is 0.02. As can be seen in Table 3, 13.92% of 79 data have~~ing~~ a minimum difference of 0.01.

F_a and F_v are the two site coefficients used for developing surface spectral acceleration and design spectrum response acceleration. The different performances of these two site coefficients developed using two different procedures can be neglected or avoided, since~~ as far as~~ there was no significant difference in the design spectrum response acceleration results developed using these two methods. The difference in the accuracy value used for both methods will sometimes~~ will~~ produce different site coefficients and directly impact the performance of the S_{DS} and S_{D1} outputs for all site soil classes.

To verify the performance of F_a and F_v estimated using these two methods, the design spectrum response acceleration calculation was also conducted in this study. The purpose of the analysis was to verify the performance of the design spectrum response acceleration S_{DS} and S_{D1} according to the site coefficients values estimated using the two different methods. Figure 3(d) shows the performance of the S_{DS} design spectrum response acceleration in terms of MCE_R-S_S developed from the website and straight-line interpolation. As can be seen in Figure 3(d), a good correlation ~~performance~~ between S_{DS} in terms of S_S, was observed in this study. According to this figure, there are no significant differences in the S_{DS} performance estimated according to the website and straight-line interpolation of SNI 1726:2019 procedures for all three site classes SC, SD and SE.

The F_a distribution map developed from the 203 boring positions was also conducted based on the website and linear interpolation analysis. Figure 4 (a) and 4(b) show two F_a distribution maps. The F_a distribution maps developed using the website and linear interpolation are almost equal. The F_a values developed at the study area are distributed between 1.2 and 1.4. The largest Fa values were observed at the small north-eastern area of the city.

The site coefficients evaluation was also conducted for long period spectral acceleration MCE_R-S_1. Using the same procedure as used for S_S, the evaluation was performed for the SC, SD and SE site classes. According to the minimum and maximum S_1 values estimated using the website, all the S_1 values in the study area were distributed between 0.3185 and 0.4097 g (s~~S~~ee Table 2~~.~~) or approximately between 0.3 and 0.4 g. For site classes SC and SD, there is one boring position having a value of S_1 greater than 0.4 g, making it difficult to perform a straight-linear interpolation. To reduce the difficulties in the analysis, the S_1 greater than 0.4 g was excluded from the analysis. Figure 5(a), (b) and (c) show the distribution of the site coefficient F_v for the SC, SD and SE site soil classes, respectively.

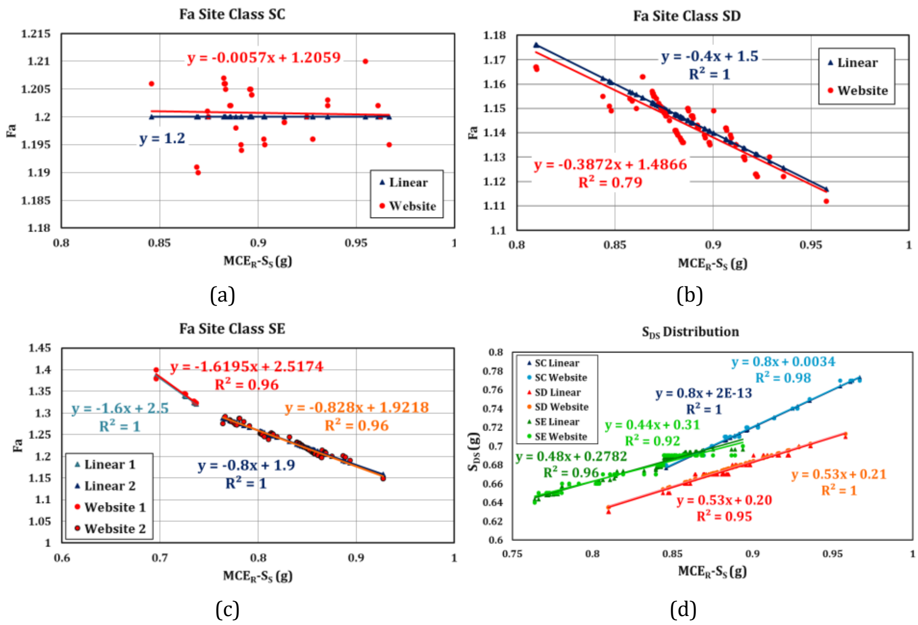


Figure 3 F_a distributions in terms of MCE_R-S_S values for SC (a), SD (b), SE (c) site classes and correlation of S_{DS} and MCE_R-S_S developed based on linear interpolation and w~~W~~ebsite software (d)

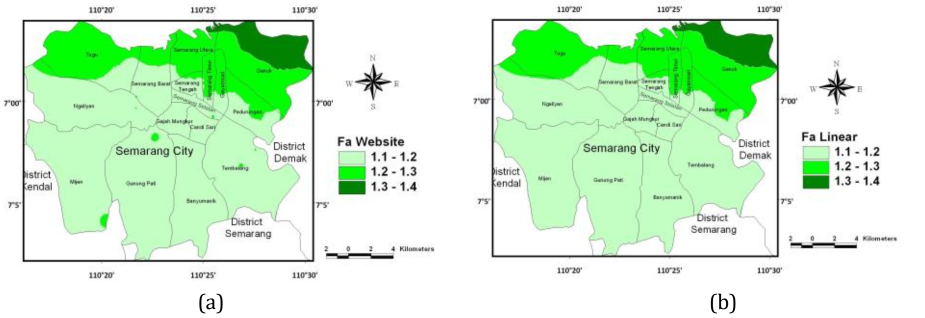
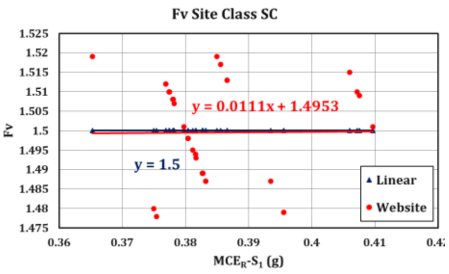


Figure 4 F_a distribution maps developed using website software (a) and linear interpolation (b)

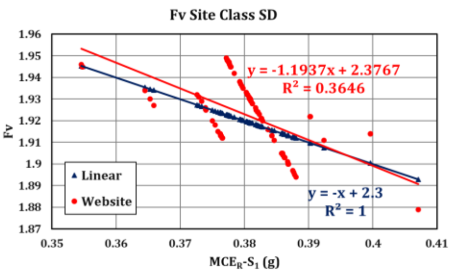
All the F_v values estimated using the website and straight-line interpolation are almost equal or coincide except for site class SD. Most of the F_v values of the SD site class developed using the website are greater than the same F_v values developed using straight-line interpolation. The R^2 (R squared) value for this model is far from 1. The F_v values for site class SD developed based on website calculation were far from the linear model that SNI 1726:2019 expected. The R^2 for site class SC is not available (close to zero) because the F_v and S_1 correlation are nearly constant. A good ~~performance of~~ F_v and S_1 correlation was observed for site class SE, for both the~~for~~ website output and straight-line interpolation. The R^2 obtained for this site class is nearly 1. On average the absolute differences between F_v are 0.015, 0.036 and 0.033 for the SC, SD and SE site classes, respectively. According to Table 3, the total data with a minimum difference of 0.01 for the SC, SD and SE site classes are greater than 50%.

Figure 5(d) shows the performance of S_{D1} design spectrum response acceleration in terms of MCE_R-S_1 estimated using the same methods as used for S_{DS} calculation. As can be seen in Figure 5(d), a good correlation ~~performance~~ between S_{D1} in terms of S_1~~,~~ was observed in this study. According to this figure, there are no significant differences in the S_{D1} performance for the SC, SD and SE site classes, estimated according to the website and straight-line interpolation of SNI 1726:2019 procedures.

The F_v distribution maps were also developed based on the website and linear interpolation analysis. Figure 6(a) and 6(b) show two F_v distribution maps. The F_v distribution maps developed using the website and linear interpolation are almost equal. The F_v values developed using the website were distributed between 1.4 and 2.8. However, the F_v values developed using linear interpolation were distributed between 1.5 and 2.8. The largest F_v values were observed at the northern part of the city.



(a)



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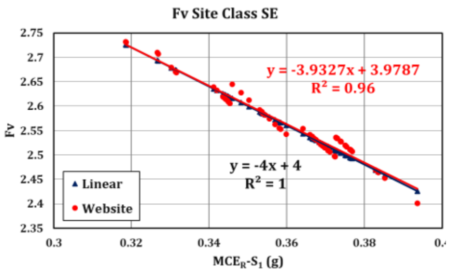
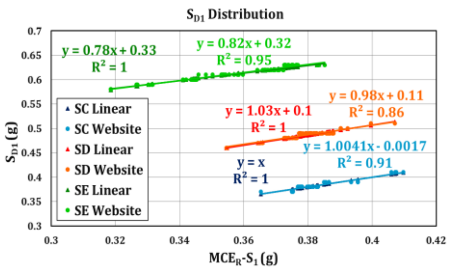


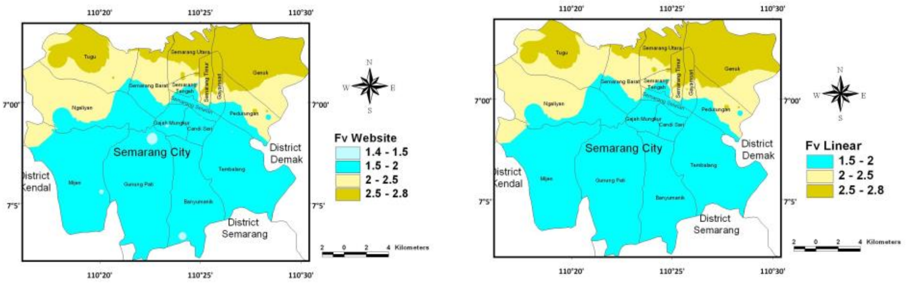
(c)



(d)

Figure 5 F_v d~~D~~istributions in terms of MCE_R-S_1 values for SC (a), SD (b), SE (c) site classes and correlation of S_{D1} and MCE_R-S_1 developed based on linear interpolation and w~~W~~ebsite software (d)

The S_{DS} and S_{D1} developed for the study area using the website are accepted according to the requirement criterion~~um~~ of SNI 1726:2019. Table 4 shows the minimum and maximum S_{DS} and S_{D1} values and the average difference of S_{DS} and S_{D1} estimated using the two methods for the SC, SD and SE site classes. The average difference of S_{DS} and S_{D1}, as presented in Table 4, is the absolute differences of S_{DS} and S_{D1}. The maximum average differences (a~~A~~ve. d~~D~~iff.), 0.02 g and 0.015 g, were observed at the SD site class for S_{DS} and S_{D1} spectral design, respectively. However, the average differences of S_{DS} for site classes SC and SE were less than 0.0044 g, approximately.



(a) (b)

Figure 6 F_v distribution maps developed using website software (a) and linear interpolation (b)

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Table 4 S_{DS} and S_{D1} performance for all site classes

Site c~~C~~lass	S_{DS} (g)					S_{D1} (g)				
	Website		Linear		Ave. d~~D~~iff.	Website		Linear		Ave. d~~D~~iff.
	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.	
SC	0.68	0.77	0.6767	0.7734	0.0067	0.37	0.41	0.3653	0.4097	0.0044
SD	0.63	0.71	0.6349	0.6925	0.0224	0.46	0.51	0.4599	0.4946	0.0153
SE	0.64	0.71	0.6433	0.706	0.0073	0.58	0.63	0.5788	0.6315	0.0027

4. Conclusions

Evaluations of site coefficients estimated using the website and straight-line interpolation were performed at 203 boring positions in Semarang City. No significant differences were found in the F_a and F_v site coefficients estimated using the two~~both~~ methods. The largest difference in site coefficients F_a calculations was observed for the SD and SE site classes. The difference in site coefficients for the SD and SE site soil classes was less than 0.03. However, for the SC site soil class, the difference was less than 0.01. For site coefficient F_v, the largest difference was observed for the SD and SE site soil classes with a maximum of 0.04. However, the difference in site coefficient F_v for site class SC was less than 0.02. When the F_a and F_v site coefficients need to be calculated, the linear interpolation of SNI 1726:2019 is better compared to the same values calculated using MCE_R-S_S, MCE_R-S_1, S_{DS} and S_{D1} obtained from the website.

No significant differences in design spectrum response accelerations S_{DS} and S_{D1} were found for all site classes. The largest design spectrum response accelerations difference for SD estimated using the two methods was less than 0.02 g. However, for the SC and SE site classes the differences were less than 0.005 g.

Acknowledgements

This study was f~~o~~unded by The Directorate Research and Community Devotion, Deputy of Research Empowerment and Development, Ministry of Research and Technology / National Research Council and Innovation, through research grant 2021. The authors also appreciate the Centre for Housing and Settlement Research and Development for supporting data and information during the development of this study.

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doi: 10.14716/ijtech.v0i0.0000

List of Changes

Manuscript:

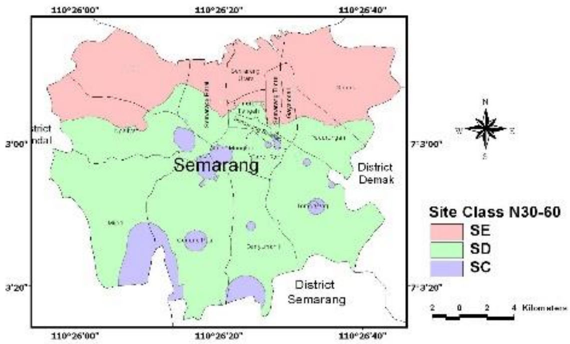
Site Coefficients and Design Spectrum Acceleration Evaluation of New Indonesian 2019 Website Response Spectra

Response and Revision made by Author(s)

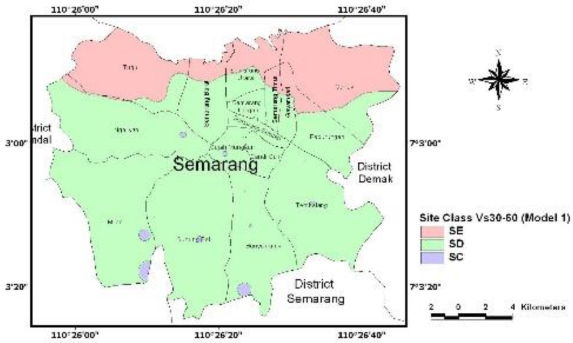
Reviewer #1:

No	Comments	Revision/Changes
1	**Introduction:** 1. The writing of the reference should be check	1. Improvement citation of the references were performed on page 1 and 2. Additional citations and references were also conducted following the IJTech template journal. See improvement citations on page 3 and 4 and additional references on page 10.
	2. What is the consideration in choosing Semarang city?	2. This study was performed as part of the seismic microzonation research of the study area. One of the important information needs for seismic microzonation research is the development of site amplification or site coefficients calculation. To performed the site coefficients or site amplifications, boring investigation, N-SPT (Standard penetration Test) and shear wave velocity (Vs) data are required. Development of site coefficients at the alluvial area as part of the research was also performed at this study area. The next two figures show two example study of V_{S30} and N_{30} developed at the study area (Partono at al. 2021). The alluvial (SE) study related with the development or site amplifications or site coefficients (Submitted, reviewed at another journal and not published yet) was also performed at the study area following ASCE/SEI 7-16 procedures (see the third figure). The study was performed at Semarang due to the completeness boring investigation and N-SPT measurement data that has been

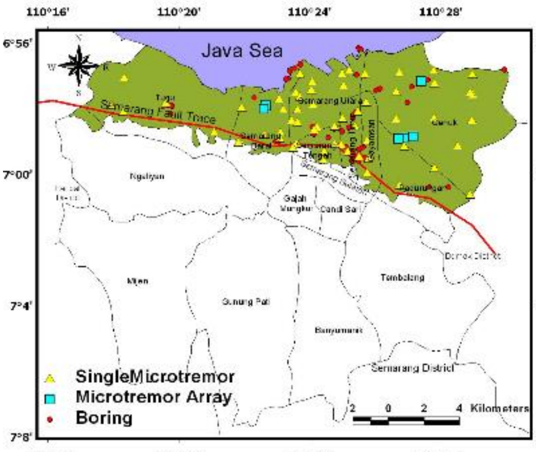
collected from the study area. See page 4.



Site class based on N_{30} data



Site class based on V_{S30} data



Site coefficients investigations on the alluvial area.

See improvement of abstract on page 1 related with the background reason of choosing Semarang as the study area.

Based on the N-SPT data collected from 203 boring investigations, the distribution of F_a and F_v in graphical and

		spatial map formats were carried out in this study. See Figures 3 to 6 on page 7 to 9.
	3. What is the rules and consideration in using this estimation (Equations 1 and 2)	3. The values that can be obtained from the website software are S_S, S_1, S_{DS} and S_{D1}. No F_a and F_v values can be obtained from the website. When the Fa and F_v are two values required for a specific analysis (ex. Research on developing site amplification), following the basic methods described on the SNI 1726, these two values can be obtained based on these three equations $S_{MS} = F_a*S_S$ (1) $F_a = S_{MS}/S_S$ (2) $S_{DS} = 2/3*S_{MS}$ (3) $S_{MS} = S_{DS}/(2/3)$ (4) $\mathbf{F_a = S_{DS}/(2/3*S_S)}$ (5) $\mathbf{F_v = S_{D1}/(2/3*S_1)}$ (6) These two equations (5 and 6) were conducted for developing F_a and F_v based on four values S_S, S_1, S_{DS} and S_{D1} obtained from the website. F_a and F_v can also be calculated using F_a and F_v tables prepared by SNI 1726:2019. These two values can be obtained by using S_S and S_1 obtained from the website.
	4. Does the author considers the geological problem, such as land subsidence, structural geology etc.?	4. Land subsidence and structural geology problems were not reviewed in this study. The site coefficients analysis conducted at the study area was calculated or predicted based on the N-SPT data collected from soil boring investigations and following the procedure described by SNI 1726:2019.

2	**Methodology:** 1. After writing the figure, it should explain about the picture 2. Again, what is the problem with Semarang city?	1. Additional explanation was carried out for all figures seen in the manuscript. See explanation of Figure 1 on page 2; explanation of Figures 2(a) and 2(b) on page 2 and 3. Figure 3(a) to 3(d) on page 6 and 7. See explanation of all figures carried out in the paper. Improvement of figures position and numbers and additional figures were conducted due to the requirement of site coefficients analysis results explanation and the restriction of maximum page of the journal. 2. This study was performed as part of the seismic microzonation research of Semarang (see explanation on introduction part question no 2). This paper describes only the analysis results of the website software performance in calculating F_a and F_v. These two values (not displayed in the website) were calculated using four spectral acceleration MCE_R-S_S, MCE_R-S_1, S_{DS} and S_{D1}. Based on these four spectral acceleration values, the site coefficients F_a and F_v can be calculated, evaluated and compared it with the basic linear interpolation procedure described by SNI 1726:2019. The objective of the analysis is to check whether or not the software following the standard requirement procedure describes in SNI 1726:2019. According to the evaluation performance of Fa and F_v developed in the study area, no significance difference observed at the study area.
3	**Results and discussion:** 1. In the manuscript, why the author/s four (4) number after point? The correlation (R square) is so small. Is it still answer the	1. The R^2 displayed in Figures 4 and 6 were readjusted and the decimal number has changed to maximum 2. The R^2 can be displayed using percent (%) or original value. The maximum R^2 is 1 or 100%. The R^2 for SC site class obtained in this

	question?	study and developed based on the website was too small and close to 0 although the line interpolation of the F_a and F_v is linear and not horizontal. These conditions ($R^2 \approx 0$) can be obtained for horizontal or nearly horizontal line fitting (the dependent values of linear interpolation are constant). According to the F_a and F_v tables of SNI 1726:2019 and the MCE_R-S_S and MCE_R-S_1 values calculated at the study area, the F_a values are equal to 1.2 and the F_v values are equal to 1.5. The R^2 developed for SC site class are equal to zero. See regression line fitting model of F_a and F_v for site class SC in Figures 3(a) and 5(a) on page 7 and 8, respectively.
4	**References:** 1. Please use more up to date references. Especially the journal.	1. Additional and updating references were already carried out in the manuscript. See improvement references on page 10.

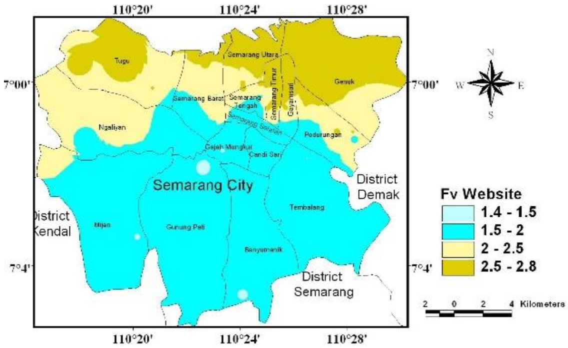
Reviewer #2:

No	Comments	Revision/Changes
1	**Introduction:** 1. The aim of the paper is rather unclear, as the site coefficients and design spectrum response acceleration implemented in the website are just the application of the Indonesian Seismic Code 2019.	1. The background reason why the site coefficients F_a and F_v and design spectrum response acceleration MCE_R-S_S and MCE_R-S_1 obtained from the website were evaluated in this study. All information obtained from the website should be checked whether or not the website performs the analysis following the right procedures described in the SNI 1726:2019. This study was conducted as part of the seismic microzonation research of the City. When the Fa and F_v values are used as the site amplification or site coefficients, as what the team evaluate at the alluvial area, the values obtained from the linear interpolation of the SNI

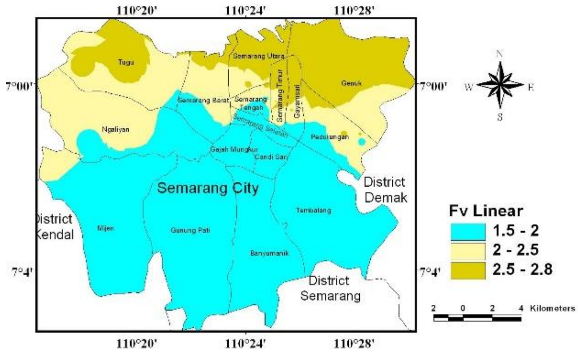
		1726:2019 is better compared to same values developed using S_S, S_1, S_{DS} and S_{D1} obtained from the website The aim of this study is to evaluate or to check that the S_{DS} and S_{D1} obtained from the website were calculated following the SNI 1726:2019 procedure. This paper describes the verification results of the S_S, S_1, S_{DS} and S_{D1} developed using website analysis in calculating F_a and F_v values and compared it with the SNI 1726:2019 results calculation. Two MCE_R-S_S and MCE_R-S_1 developed from the website were conducted as the basic values used for F_a and F_v calculation of SNI 1726:2019. See additional information related with the objective of this study on page 2.
	2. The differences discussed are not clear whether there are actual fundamental differences or just value rounding / or algorithm issues.	2. The differences of F_a and F_v or S_{DS} and S_{D1} values discussed in the manuscript conducted using linear interpolation and the website are real, although the differences are small enough. Especially when the MCE_R-S_S, MCER-S_1, S_{DS} and S_{D1} obtained from the website were used for F_a and F_v calculation. The calculation results developed using the website slightly different to the results calculated based on the SNI 1726:2019 F_a and F_v tables. The differences performance of F_a and F_v calculated using these two methods could be due to the maximum decimal number (2 number after decimal sign, compared to 4 number of MCE_R-S_S and MCE_R-S_1 output of the website) of S_{DS} and S_{D1}. Although the S_{DS} and S_{D1} calculated using these two methods are almost equal. When two site coefficients or site amplification are required for other study, the F_a and F_v values developed using linear interpolation and SNI tables is much better compared to the same two values developed directly from the website. Figures 6(a) and (b) on Page 9 show the

small differences of F_v calculation and distribution at the study area, although the differences are small enough.

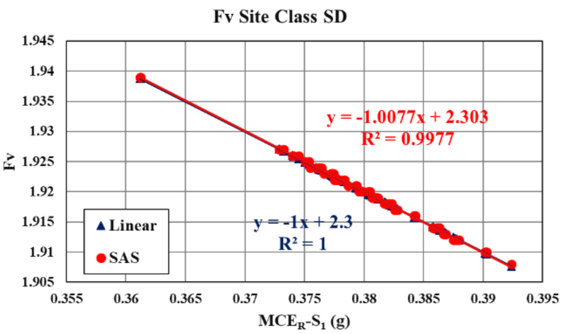
An example comparative performance of the F_v calculation using the website output and the "Stand Alone Software /SAS" (two software developed by Puskim PUPR) was also conducted, to bring a clear information related with the performance of these two software (the differences of F_v calculations not presented in the manuscript).



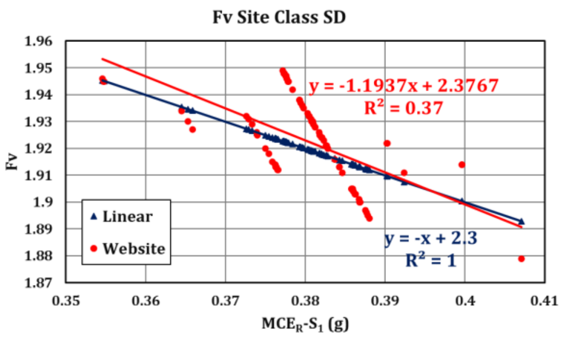
F_v distribution calculated using S_S, S_1, S_{DS} and S_{D1} obtained from the website



F_v distribution calculated using S_S and S_1 obtained from the website and F_v table of SNI 1726:2019



F_v distribution performance for SD site

		class calculated using SAS software.  F_v distribution performance for SD site class calculated using the website software. According to these two figures, no MCE_R-S_1 greater than 0.4 g when the value calculated using SAS software. However, one MCE_R-S_1 greater than 0.4 g was observed when the calculation at the study area was performed using the website.
	3. The authors need to clarify this so that the context and the contribution of this article are clear.	3. The context of these article is clear and give a clear contribution to the reader when the F_a and F_v and maybe F_{PGA} need to be calculated, the calculation using linear interpolation of SNI 1726:2019 is more accurate compared to the same values calculated based on the Website outputs. See conclusion on page 9.
	4. Equation 4 needs to revise so that it would be the same as that in SNI 1726:2019.	4. Improvement of equation 4 was carried out in the paper. See improvement equation 4 on page 3.
2	**Methodology:** 1. Are there any locations with site class SF? This particularly of interest because northern Semarang areas are well known for very deep soft clays deposits.	1. No SF analysis results and investigation data were discussed in this study. Only site class SC, SD and SE were discussed in this paper. All site classes SC, SD and SE were developed based on N-SPT data. All F_a and F_v calculations using the website or SNI procedures were calculated based on the average N-SPT data (N_{30}). It could be the SF site class can be obtained at the northern part of the study area when the detail investigation related with the SF

	2. It suggested Figure 3a is to have the intervals being easily referenced for Figure 3b. 3. It is suggested that Table 1 is to have the information about how many locations for each site class category. 4. For Table 2 through 4, it is suggested to change "Site Class" to "Locations with Site Class" to avoid any confusion what site class in these tables refers to (for example, Ss and S1 are for SBC site class, why there are SC through SE site class).	site class are conducted at this area. 2. Improvement of Figure 3(a) was performed and merged it with Figure 2. The Figure 3(a) and 3(b) has changed to Figure 2(a) and 2(b). The basic spatial data information of Figure 2(b) was rearranged based on Figure 2(a). See improvement of Figures 2(a) and 2(b) on page 4. 3. The information related with the total data for SC, SD and SE were added at Tables 2 and 3. See improvement of Table 2 on page 4 and Table 3 on page 5. 4. No improvement of the column title for "Site class" information. Additional column related with "Location with Site Class" was conducted at Table 2 and 3. Due to the restriction of the total page number Table 3 was readjusted and merged it with Table 2. Table 5 was merged to Table 4 and the title has changed to Table 3. No SBC site class was investigated for this study because the basic analysis for F_a and F_v calculations was performed based on N_{30} data.
3	**Results and discussion:** 1. Regression analyses of FaL and FvL (Figure 4 and 5) may not be conceptually appropriate as FaL and FvL are just application of the tabulated values in SNI 1726:2019. Descriptive statistics may be more appropriate for discussing Fa anf Fv for Site Class SC (Figure 4a and 5a)	1. Regression analysis of F_a and F_v using linear interpolation are important in term of website performance evaluation. The basic requirement of F_a and F_v calculated using the website should be match with the linear interpolation method described by the SNI 1729:2019. Additional information related with the difference results of the website and linear interpolation was conducted at Table 3 on page 5. The minimum difference of 0.01 for F_a and F_v was investigated for all 203 data. The explanation of the difference (%) for site class SC, SD and SE can be seen on page

	2. Please provide critical discussions whether the differences discussed in Section 3, shown in the figures and summarized in Table 4 are actual fundamental differences or just value rounding / algorithm issues. This is important to highlight the actual contribution of this article to this broad topic.	5 – 8. For SC site class the F_a values calculated at 34 boring positions using linear interpolation are constant and equal to 1.2 and the F_v values are also constant and equal to 1.5. The R^2 calculated for F_a and F_v are equal to zero. The same F_a and F_v calculated using the website are nearly constant and the R^2 value obtained from the website are close to zero. 2. Based on the F_a and F_v calculations conducted at 203 boring positions at the study area. When the F_a and F_v values are required (ex in site specific analysis research), it is better to use these two values obtained from the linear interpolation described by SNI and conducting F_a and F_v table of SNI 1726:2019. The information required from the website are the MCE_R-S_S and MCE_R-S_1.
4	**References:** 1. No comments.	

Additional Information to Journal Editor:

No	Comments	Revision/Changes
1		1. See improvement of paragraph on page 2 and 3 related with the improvement and additional references. See improvement references on page 10. 2. Changes to several paragraphs have been made to meet the requirement for the maximum pages for each paper. 3. Improvement of figures and tables were also carried out to meet the requirement of reviewer's comments.
The authors appreciate the valuable comments from the Reviewers.		

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Site Coefficients and Design Spectrum Acceleration Evaluation of New Indonesian 2019 Website Response Spectra

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Abstract. Developing site coefficients and design spectrum response acceleration are two important steps in the seismic design of buildings. The site coefficient calculation described in the Indonesian Seismic Code 2019 partially follows the method proposed by the American Standard Code for Seismic Design 2016. Two information needs for site coefficient calculations are the site soil class and the Risk-Targeted Maximum Considered Earthquake (MCE_R) S_S (short period) and S_1 (long period) spectral acceleration. Three different hard/SC, medium/SD and soft/SE site soil classes are usually used for building designs. Two site coefficients (F_a and F_v for short and long period spectral acceleration) are used for surface and design spectrum response acceleration calculations. The Indonesian Seismic Code provides two tables for developing these site coefficients. If the S_S and S_1 values developed at a site are not exactly equal to the values presented in these tables, the site coefficients can be predicted using straight-line interpolation between the two closest values. Different results are observed when the straight-line interpolation is adjusted for F_a and F_v prediction compared to the same values developed using website-based software. This study evaluates the site coefficients and design spectrum response acceleration predictions at Semarang City, Indonesia according to straight-line interpolation and website software calculations. The evaluation was conducted at 203 soil boring positions and performed as part of seismic microzonation research of the study area. The site soil classes were predicted using average N-SPT (Standard Penetration Test) values in the top 30 m soil deposit layer. Three different site soil classes were observed in the study area. On average the largest differences of the site coefficients and design spectrum response acceleration were observed for the SD and SE classes. However, for the SC site soil class the difference between the two analysis methods is small and they are approximately similar.

Keywords: Design spectrum response acceleration; MCE_R; N-SPT; Site coefficient; Straight-line interpolation

1. Introduction

The new National Seismic Code of Indonesia (SNI 1726:2019) was announced in 2019. Some of the information introduced in this new seismic code was partially adopted from the American Standard Code for Seismic Design ASCE/SEI 7 (2016). Two important types of information adopted from ASCE/SEI 7-16 are the site coefficients and design spectrum response acceleration calculation methods. Other information used for developing site coefficients was adopted from Stewart and Seyhan (2013). Due to the improved methods for developing site coefficients for site soil classes SD and SE described in ASCE/SEI 7-16, not all the information described in the American Code was adopted by SNI 1726:2019. Site coefficients for SD and SE classes presented in the new Indonesian Seismic Code 2019 are completely adopted from Stewart and Seyhan (2013).

Following the new SNI 1726:2019, especially in developing site coefficients, the Ministry of Public Works and Human Settlements announced a new website facility for response spectrum design calculations. Site or building position coordinates (in terms of longitude and latitude) and site soil class are two data needs for design spectrum response acceleration calculations. Risk-Targeted Maximum Considered Earthquake (MCE_R) S_S (short periods) and S_1 (long periods) (Luco et al., 2007; Allen et al., 2015; Sengara et al., 2020), and two spectral designs, S_{DS} and S_{D1}, are four important values calculated by the website facility software. No information related to site coefficients F_a and F_v can be obtained from the new website. Due to incomplete information related to the F_a and F_v site coefficients from the website, these values can be calculated using Equation 1 and Equation 2. All S_{DS}, S_S, S_{D1} and S_1 values were obtained from the website.

$$F_a = \frac{S_{DS}}{{}^2\!/_3\, S_S} \tag{1}$$

$$F_v = \frac{S_{D1}}{{}^2\!/_3\, S_1} \tag{2}$$

To verify the F_a and F_v site coefficients estimated using Equations 1 and 2, straight-line interpolation can be conducted using two S_S and S_1 website calculations and applying site coefficient (F_a and F_v) tables data provided by SNI 1726:2019. F_a and F_v are then estimated following the procedure described by SNI 1726:2019. Equation 3 shows a simple formula for site coefficient calculations for F_a and F_v. Figure 1 shows a diagram for the straight-line interpolation of F_a and F_v values. “F” and “M_W” represent the site coefficient to be estimated and the MCE_R value obtained from the website, respectively. M_{1S} and M_{2S} represent two boundary MCE_R values close to M_W. F_{1S} and F_{2S} represent two site coefficients for M_W=M_{1S} and M_W=M_{2S}, respectively. M_{1S}, M_{2S}, F_{1S} and F_{2S} are four values obtained from the SNI 1726:2019 tables. F_a and F_v are estimated separately using Equation 3.

$$F = \left(\frac{F_{2S} - F_{1S}}{M_{2S} - M_{1S}}\right)(M_W - M_{1S}) + F_{1S} \tag{3}$$

This paper describes the site coefficients and the design spectrum response acceleration verification using the website and the straight-line interpolation described in SNI 1726:2019. The objective of this study is to evaluate whether or not the website performs the analysis following the same procedures used by SNI 1726:2019. The study was performed at Semarang City, Indonesia and conducted at 203 soil boring investigation positions. The study was conducted as part of seismic microzonation research of the city. One of the important information needs for seismic microzonations is the development of soil amplification or site coefficient measurements at the study area. Boring investigation and N-SPT measurement data for site class calculation were available and distributed over the whole of the study area. Figure 2 (a) shows the 203 boring positions within the study area and the N_{30} distribution. All boring investigations conducted in this study had a minimum 30 m and a maximum 60 m depth. The average Standard Penetration Test (N-SPT) of the topmost 30 m soil deposit layer (N_{30}) of every boring position was used for site soil class interpretation (Moghaddam, 2011; Partono et al., 2019; Syaifuddin et al., 2020). Figure 2 (b) shows the distribution of site soil classes developed based on the N_{30} data (Partono et al., 2021). The maximum N-SPT data used in this study and collected from the boring-log was 60. Following the procedure described by SNI 1726:2019, the N_{30} was estimated using Equation 4, where "d_i" and "N_i" represent the thickness and N-SPT value of any soil layer "i", respectively.

The same parameter that can be used for site interpretation is the average shear wave velocity (V_S) of the topmost 30 m soil deposit (V_{S30}) (Naji et al., 2020). The V_{S30} value can be calculated using the same method as shown in Eq. 4 and replacing the N_i value by V_{Si}. The V_S value can be collected using seismic refraction MASW (Multichannel Analysis of Surface Waves) or array seismometer investigations. Prakoso et al. (2017) described a comparative study of V_S investigation based on MASW and soil boring data. The V_S value developed using MASW is more reliable compared to the same V_S value developed based on the boring investigation. Pramono et al. (2018) described the predominant frequency investigation at Lombok Island following the 2018 earthquake event. The greater the V_{S30} value used, the greater the predominant frequency obtained from wavelet analysis of ground motion. The investigation of V_{S30} and predominant frequency correlation was also conducted by Pramono et al. (2017) at the Palu area.

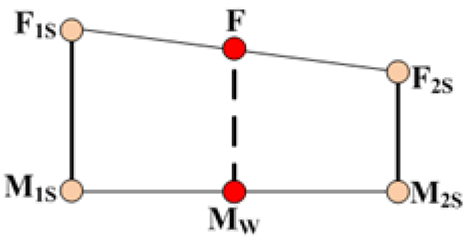


Figure 1 Straight-line interpolation for F_a and F_v calculations

$$N_{30} = \frac{\sum_{i=i}^{i=n} d_i}{\sum_{i=i}^{i=n} \frac{d_i}{N_i}} \tag{4}$$

2. Methods

The evaluation of site coefficients within the study area was conducted following five basic steps:

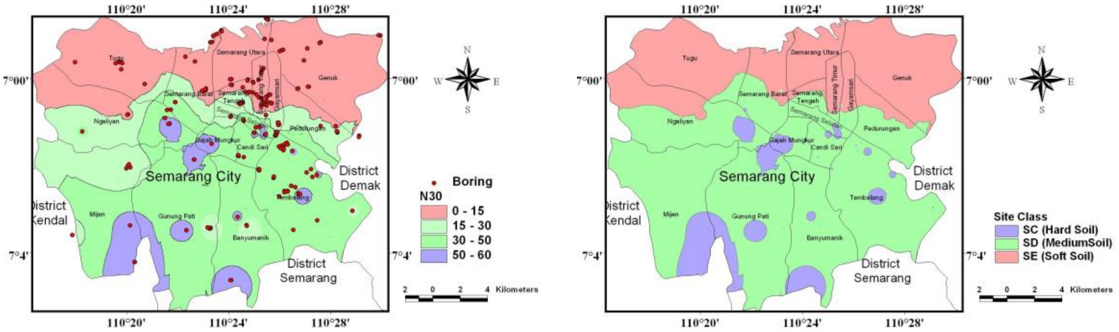
- Site class interpretation,
- MCE_R (S_S and S_1) and design spectrum response acceleration calculations using the website
- Site coefficient calculation based on the website output
- Site coefficient calculation based on SNI 1726:2019 tables and procedures
- Comparative analysis of site coefficients and design spectrum response acceleration based on the two different approaches, website data and straight-line interpolation.

2.1. Site Soil Class Interpretation

The site soil class interpretation (Fig. 2b) was conducted at 203 boring positions using N_{30} data and no geological data used for developing this map. According to the N_{30} data developed at all boring locations, the site soil classes were interpreted according to SNI 1726:2019. Table 1 shows the basic classification criteria for identifying the site soil class. Only three different site soil classes are presented in this table. Site classes SA, SB and SF are not available within this table. Figure 2(b) shows the corresponding site soil class distribution developed according to the site classification as shown in Table 1. The site class distribution in the study area is dominated by the SD and SE classes. Site class SC was observed in small areas in the middle and southern part of the city (Partono et al., 2021).

Table 1 Site classification

Site Class	N_{30}
SC	> 50
SD	15 - 50
SE	< 15



(a) (b)

Figure 2 Boring investigations and N_{30} distribution (a) and site soil classes (b) distribution maps

2.2. *MCE_R and Design Spectrum Response Acceleration Calculation*

The MCE_R calculations were performed at 203 boring position using the website. According to the site class distribution of the study area, three different MCE_R-S_S and MCE_R-S_1 distributions were also observed in the study area. Table 2 shows the total boring investigations for each site class and the distribution of minimum and maximum MCE_R-S_S, MCE_R-S_1, S_{DS} and S_{D1} for the three different site classes developed using the website.

Table 2 S_S, S_1, S_{DS} and S_{D1} distribution obtained from the website

Site class	Total data	MCE_R-S_S(g)		S_{DS} (g)		MCE_R-S_1 (g)		S_{D1} (g)	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
SC	34	0.8459	0.9668	0.68	0.77	0.3653	0.4097	0.37	0.41
SD	90	0.8098	0.9579	0.63	0.71	0.3546	0.4071	0.46	0.51
SE	79	0.696	0.9274	0.64	0.71	0.3185	0.3936	0.58	0.63

2.3. *Site Coefficients F_a and F_v Website*

Site coefficient F_a and F_v calculations were performed according to the MCE_R-S_S, MCE_R-S_1, S_{DS} and S_{D1} values obtained from the website. The site coefficients were estimated using Equation 1 and 2. Table 3 shows the distribution of minimum and maximum F_a and F_v developed using these four values. Following the boundary values of F_a and F_v described in the SNI 1726:2019 tables, the minimum and maximum F_a values developed in the study area were divided into two different boundary values. A few S_S values were less than 0.75 g. However, most of the S_S values were distributed between 0.75 and 1 g.

2.4. *Site Coefficients F_a and F_v SNI 1726:2019*

Straight-line interpolation was also performed for F_a and F_v calculations by using Equation 3 and table data provided by SNI 1726:2019. According to the MCE_R-S_S and MCE_R-S_1 values obtained from the website, the minimum and maximum boundaries for these two site coefficients can be estimated. Table 3 shows the minimum and maximum boundaries of the F_a and F_v values used for straight-line interpolation calculations. The F_a and F_v minimum and maximum boundary values displayed in Table 3 were obtained from SNI 1726:2019.

Table 3 F_a and F_v distribution developed using the website and SNI 1726:2019 tables

Site class	Total data	Linear Interpolation (SNI)					Website				Diff. > 0.01 (%)	
		F_a			F_v		F_a		F_v		F_a	F_v
		MCE_R-S_S(g)			MCE_R-S_1 (g)		Min.	Max.	Min.	Max.		
		0.5	0.75	1.0	0.3	0.4						
SC	34	1.2	1.2	1.2	1.5	1.5	1.19	1.21	1.478	1.519	0	58.82
SD	90	1.4	1.2	1.1	2.0	1.9	1.112	1.167	1.879	1.949	3.41	56.82
SE	79	1.7	1.3	1.1	2.8	2.4	1.148	1.4	2.401	2.732	13.92	50.63

3. Results and Discussion

The MCE_R-S_S for the SC site class as shown in Table 2 are distributed from 0.8459 through 0.9668 g. The F_a values for the SC site class developed according to the website, as shown in Table 3, are distributed between 1.19 and 1.21. All the F_a values developed from the website are consistent and almost equal to the F_a value from SNI 1726:2019 (Table 3). As can be seen in Table 3, the F_a values of SNI 1726:2019 are constant and equal to 1.2. The difference in F_a values developed using the website data is less than 0.01 compared to the F_a requirement of SNI 1726:2019. According to Table 3, for all 34 data, the total data with a minimum difference of 0.01 is 0%. Figure 3(a) shows the distribution of F_a site coefficients for the SC site class in terms of MCE_R-S_S values. The linear and Website legends inside this figure represent straight-line interpolation following SNI 1726:2019 and website data acquisition. The R^2 value for site class SC is close to zero, because the F_a values estimated using these two models are nearly constant for all MCE_R-S_S values. The R^2 (coefficient of determination) value is used for evaluation of the fitting line (linear fit model) performance. The evaluation was performed for the distribution of F_a or F_v to the linear regression line model. The minimum and maximum R^2 values are 0 and 1 (100%), respectively. The higher the R^2, the better the linear fitting model difference with the F_a or F_v data distribution.

The distribution of MCE_R-S_S values for the SD site class in the study area was almost equal to the SC site class. Table 2 shows the distribution of S_S for the SD site class. The values are distributed from 0.8098 through 0.9579 g. Following the same procedure as for the SC site class, the F_a site coefficients for the SD site class developed in the study area should be distributed between 1.2 and 1.1. Due to the S_S being distributed close to 1 g, the F_a values obtained from the study area are close to 1.1. As shown in Table 3, the F_a values were distributed between 1.112 and 1.167. The total data having a minimum difference of 0.01 are 3.41%. Figure 3(b) shows the distribution of F_a values for site class SD in terms of MCE_R-S_S values. As can be seen in Figure 3(b), the R^2 value obtained from the regression analysis is 0.7858, or less than 1. The straight-line interpolation developed according to the SNI 1726:2019 data and table are better compared to the F_a values developed using the website. However, on average the absolute difference between F_a values developed using these two models is 0.0105 and the line distributions are almost identical (coincide).

The MCE_R-S_S distribution for the SE site class estimated from the website is between 0.696 and 0.9274 g. According to SNI 1726:2019, all S_S for site class SE were distributed between two different boundary values, from 0.5 through 0.75 g for the 1st boundary and from 0.75 through 1 g for the 2nd boundary. The straight-line interpolation for all MCE_R-S_S was also separated into two different boundary values. The first F_a values (6 data) were distributed between 1.4 and 1.323. However, the second F_a (73 data) site coefficients were distributed between 1.292 and 1.148. Figure 3(c) shows the distribution of F_a values for the SE site class. Two different straight-line interpolations are seen in this figure, following the two different boundary values of SNI 1726:2019. The absolute average difference of F_a for site class SE is 0.029. As can be seen in Table 3, 13.92% of 79 data have a minimum difference of 0.01.

F_a and F_v are the two site coefficients used for developing surface spectral acceleration and design spectrum response acceleration. The different performances of these two site coefficients developed using two different procedures can be neglected or avoided, since there was no significant difference in the design spectrum response acceleration results developed using these two methods. The difference in the accuracy value used for both methods will sometimes produce different site coefficients and directly impact the performance of the S_{DS} and S_{D1} outputs for all site soil classes.

To verify the performance of F_a and F_v estimated using these two methods, the design spectrum response acceleration calculation was also conducted in this study. The purpose of the analysis was to verify the performance of the design spectrum response acceleration S_{DS} and S_{D1} according to the site coefficients values estimated using the two different methods. Figure 3(d) shows the performance of the S_{DS} design spectrum response acceleration in terms of MCE_R-S_S developed from the website and straight-line interpolation. As can be seen in Figure 3(d), a good correlation between S_{DS} in terms of MCE_R-S_S, was observed in this study. According to this figure there are no significant differences in the S_{DS} performance estimated according to the website and straight-line interpolation of SNI 1726:2019 procedures for all three site classes SC, SD and SE.

The F_a distribution map developed from the 203 boring positions was also conducted based on the website and linear interpolation analysis. Figure 4 (a) and 4(b) show two F_a distribution maps. The F_a distribution maps developed using the website and linear interpolation are almost equal. The F_a values developed at the study area are distributed between 1.2 and 1.4. The largest Fa values were observed at the small north-eastern area of the city.

The site coefficients evaluation was also conducted for long period spectral acceleration MCE_R-S_1. Using the same procedure as used for MCE_R-S_S, the evaluation was performed for the SC, SD and SE site classes. According to the minimum and maximum MCE_R-S_1 values estimated using the website, all the MCE_R-S_1 values in the study area were distributed between 0.3185 and 0.4097 g (see Table 2.) or approximately between 0.3 and

0.4 g. For site classes SC and SD, there is one boring position having a value of MCE_R-S_1 greater than 0.4 g. Figures 5(a), (b) and (c) show the distribution of the site coefficient F_v for the SC, SD and SE site soil classes, respectively.

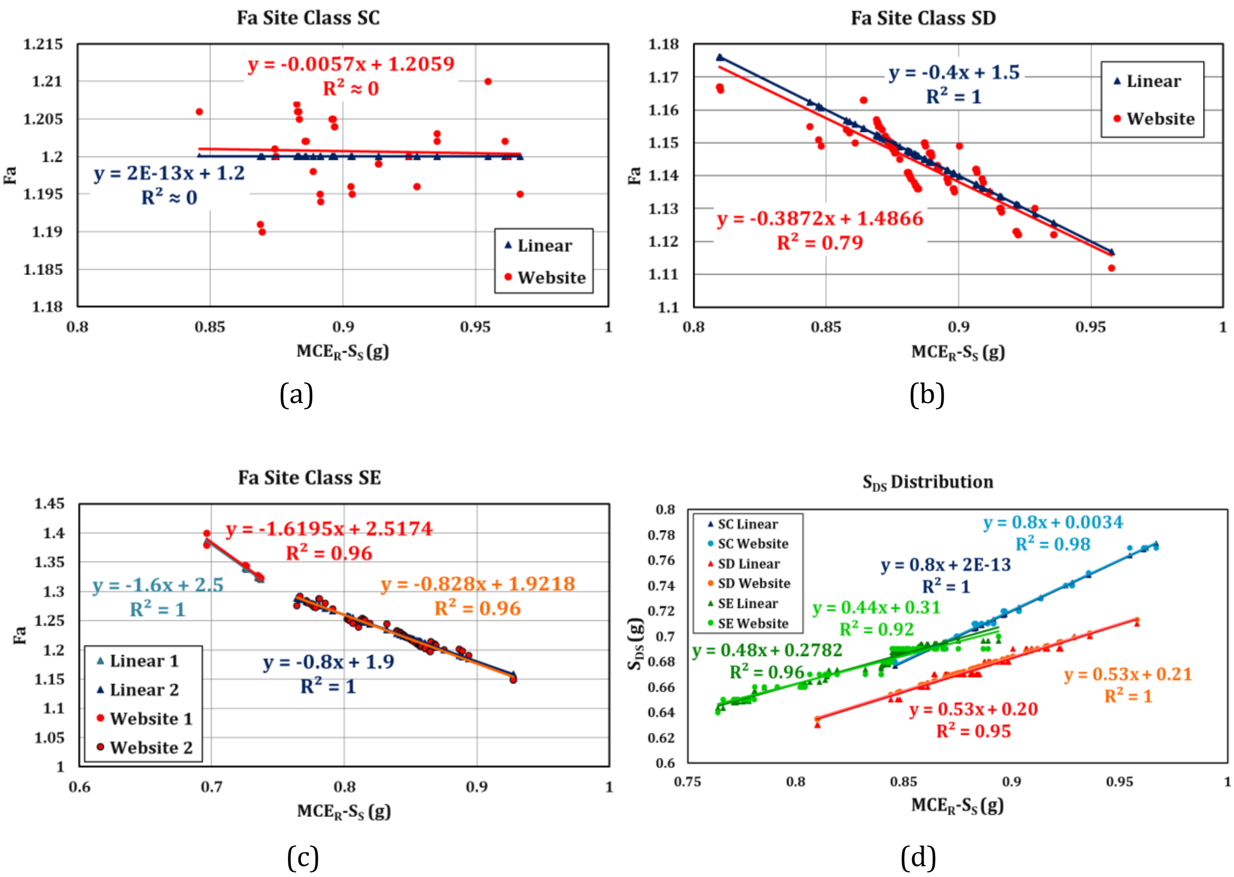


Figure 3 F_a distributions in terms of MCE_R-S_S values for SC (a), SD (b), SE (c) site classes and correlation of S_{DS} and MCE_R-S_S developed based on linear interpolation and website software (d)

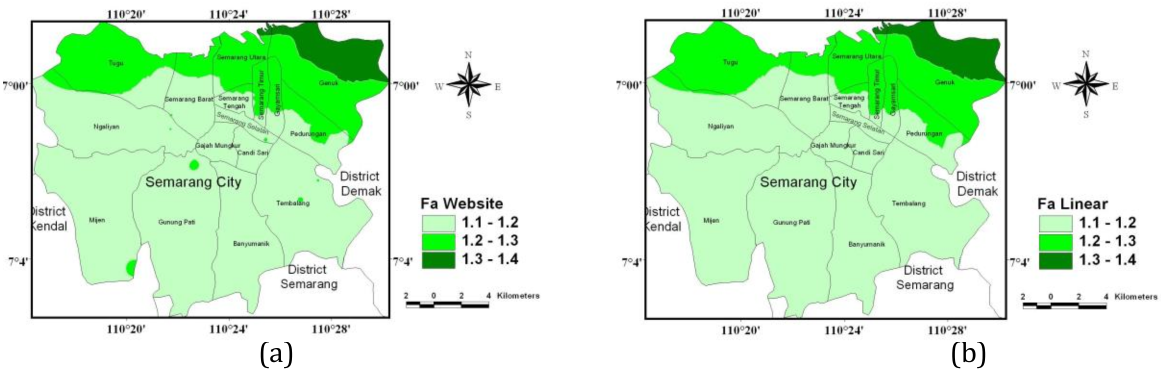


Figure 4 F_a distribution maps developed using website software (a) and linear interpolation (b)

All the F_v values estimated using the website and straight-line interpolation are almost equal or coincide except for site class SD. As shown in Figure 5(b), most of the F_v values of the SD site class developed using the website are greater than the same F_v values developed using straight-line interpolation. The R^2 (R squared) value for this model is far from 1. The F_v values for site class SD developed based on website calculation were far from the linear model that SNI 1726:2019 expected. The R^2 for site class SC is not available (close to zero) because the F_v and MCE_R-S_1 correlation are nearly constant. A good F_v and MCE_R-S_1 correlation was observed for site class SE (see Figure 5(c)), for both the website output and straight-line interpolation. The R^2 obtained for this site class is nearly 1. On average the absolute differences between F_v are 0.015, 0.036 and 0.033 for the SC, SD and SE site classes, respectively. According to Table 3, the total data with a minimum difference of 0.01 for the SC, SD and SE site classes are greater than 50%.

Figure 5(d) shows the performance of S_{D1} design spectrum response acceleration in terms of MCE_R-S_1 estimated using the same methods as used for S_{DS} calculation. As can be seen in Figure 5(d), a good correlation between S_{D1} in terms of S_1 was observed in this study. According to this figure, there are no significant differences in the S_{D1} performance for the SC, SD and SE site classes, estimated according to the website and straight-line interpolation of SNI 1726:2019 procedures.

The F_v distribution maps were also developed based on the website and linear interpolation analysis. Figures 6(a) and 6(b) show two F_v distribution maps. The F_v distribution maps developed using the website and linear interpolation are almost equal. The F_v values developed using the website were distributed between 1.4 and 2.8. However, the F_v values developed using linear interpolation were distributed between 1.5 and 2.8. The largest F_v values were observed at the northern part of the city.

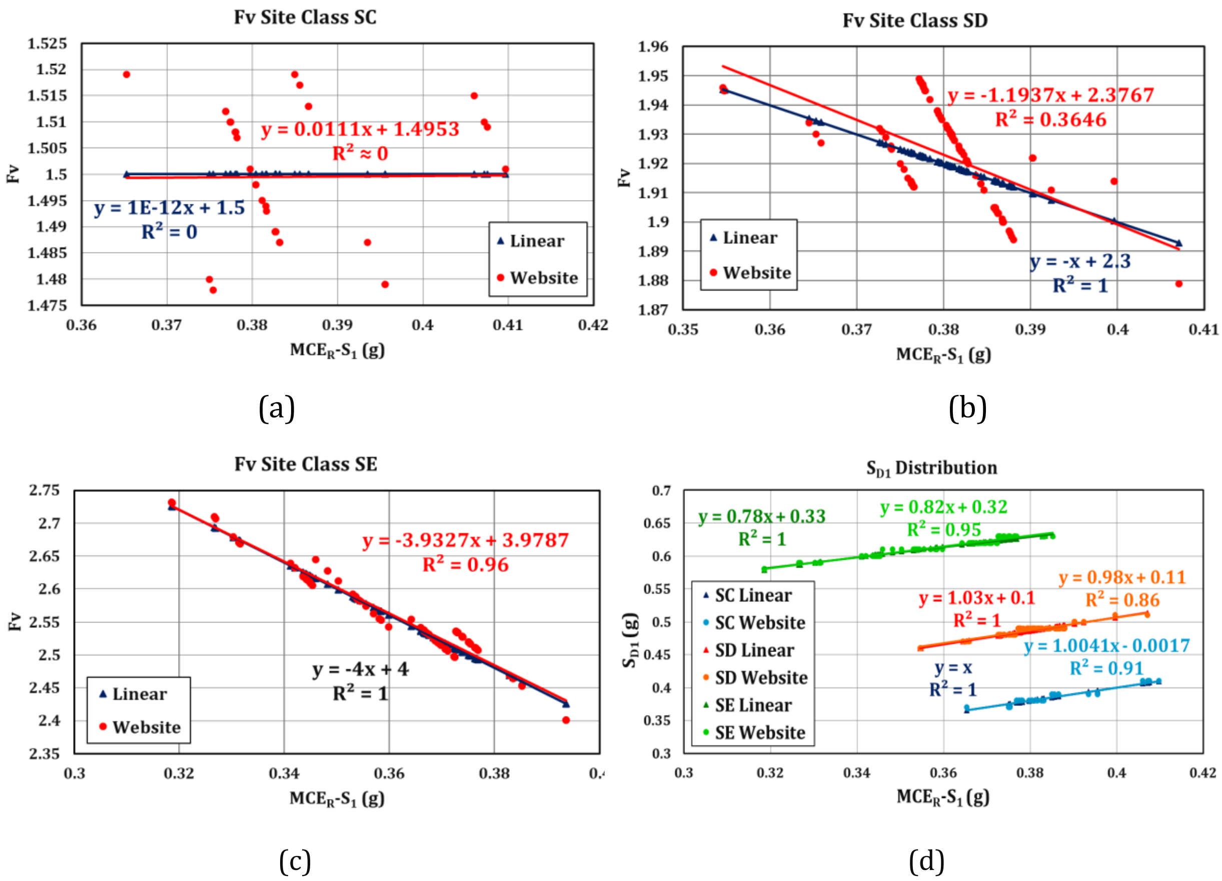
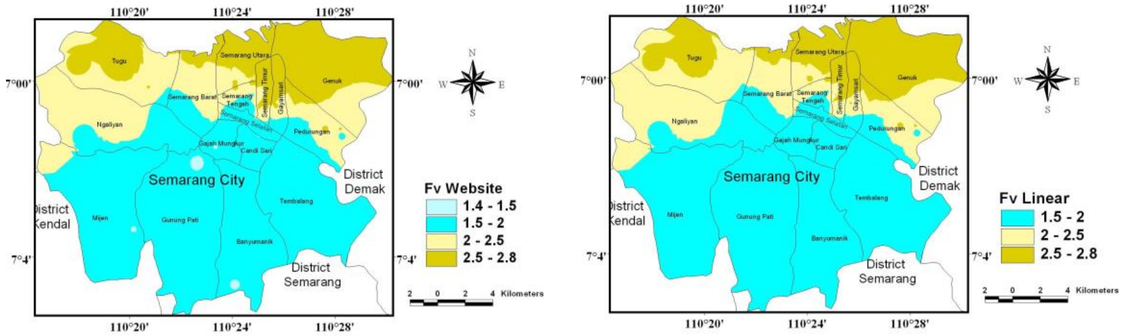


Figure 5 F_v distributions in terms of MCE_R-S_1 values for SC (a), SD (b), SE (c) site classes and correlation of S_{D1} and MCE_R-S_1 developed based on linear interpolation and website software (d)

The S_{DS} and S_{D1} developed for the study area using the website are accepted according to the requirement criterion of SNI 1726:2019. Table 4 shows the minimum and maximum S_{DS} and S_{D1} values and the average difference of S_{DS} and S_{D1} estimated using the two methods for the SC, SD and SE site classes. The average difference of S_{DS} and S_{D1}, as presented in Table 4, is the absolute differences of S_{DS} and S_{D1}. The maximum average difference (Ave. diff.), 0.02 g and 0.015 g, were observed at the SD site class for S_{DS} and S_{D1} spectral design, respectively. However, the average differences of S_{DS} for site classes SC and SE were less than 0.0044 g, approximately.



(a) (b)

Figure 6 F_v distribution maps developed using website software (a) and linear interpolation (b)

Table 4 S_{DS} and S_{D1} performance for all site classes

Site class	S_{DS} (g)					S_{D1} (g)				
	Website		Linear		Ave. diff.	Website		Linear		Ave. diff.
	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.	
SC	0.68	0.77	0.6767	0.7734	0.0067	0.37	0.41	0.3653	0.4097	0.0044
SD	0.63	0.71	0.6349	0.6925	0.0224	0.46	0.51	0.4599	0.4946	0.0153
SE	0.64	0.71	0.6433	0.706	0.0073	0.58	0.63	0.5788	0.6315	0.0027

4. Conclusions

Evaluations of site coefficients estimated using the website and straight-line interpolation were performed at 203 boring positions in Semarang City. No significant differences were found in the F_a and F_v site coefficients estimated using the two methods. The largest difference in site coefficients F_a calculations was observed for the SD and SE site classes. The difference in site coefficients for the SD and SE site soil classes was less than 0.03. However, for the SC site soil class, the difference was less than 0.01. For site coefficient F_v, the largest difference was observed for the SD and SE site soil classes with a maximum of 0.04. However, the difference in site coefficient F_v for site class SC was less than 0.02. When the F_a and F_v site coefficients need to be calculated, the linear interpolation of SNI 1726:2019 is better compared to the same values calculated using MCE_R-S_S, MCE_R-S_1, S_{DS} and S_{D1} obtained from the website.

No significant differences in design spectrum response accelerations S_{DS} and S_{D1} were found for all site classes. The largest design spectrum response accelerations difference for SD estimated using the two methods was less than 0.02 g. However, for the SC and SE site classes the differences were less than 0.005 g.

Acknowledgements

This study was founded by The Directorate Research and Community Devotion, Deputy of Research Empowerment and Development, Ministry of Research and Technology / National Research Council and Innovation, through research grant 2021. The authors also appreciate the

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Site Coefficient~~s~~ and Design ~~Spectrum~~ Spectral Acceleration Evaluation of New Indonesian 2019 Website Response Spectra

Windu Partono[1*], Masyhur Irsyam[2], Ramli Nazir[3], Muhammad Asrurifak[4] and Undayani Cita Sari[1]

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Abstract. ~~Developing~~ Calculation of site coefficient~~s~~ and design ~~spectrum~~ response spectral acceleration are two important steps in the seismic design of buildings. According to Indonesian Seismic Code 2019, ~~The site coefficient calculation described in the Indonesian Seismic Code 2019 partially follows the method proposed by the American Standard Code for Seismic Design 2016.~~ t~~T~~wo information requirements for site coefficient calculations are the site soil class and Risk-~~Targeted~~ targeted Maximum Considered Earthquake (MCE$_R$) ~~-~~ S$_S$ for short ~~(short period)~~ and MCE$_R$-S$_1$ for long period ~~(long period))~~ spectral acceleration. Three different ~~site soil classes~~ ~~(~~hard/~~/~~SC, medium/~~/~~SD, and soft/~~/~~SE~~)~~ are typically site soil classes used for building designs. Two different site coefficients (F$_a$ ~~and F$_v$ for~~ for MCE$_R$-S$_S$ ~~short~~ and F$_v$ for MCE$_R$-S$_1$ ~~long period~~ spectral acceleration) are used for surface and design response ~~spectrum response~~spectral acceleration calculations. The Indonesian Seismic Code provides two ~~tables~~ (F$_a$ and F$_v$) tables for ~~developing~~ calculating ~~these~~ site coefficients. If the MCE$_R$-S$_S$ ~~and~~ or MCE$_R$-S$_1$ values developed for a specific site are not exactly equal to the values in ~~these~~ F$_a$ or F$_v$ tables, the site coefficients can then be predicted using straight-line interpolation between the two closest F$_a$ or F$_v$ values within the tables. When the straight-line interpolation is adjusted for F$_a$ ~~and~~ or F$_v$ ~~prediction~~calculation, different results ~~are~~ were observed in comparison to the values developed using website-based software (prepared by Ministry of Public Works and Human Settlements). This study evaluates site coefficients and design response ~~spectrum response~~spectral acceleration predictions in Semarang City, Indonesia, according to straight-line interpolation method and website software calculations. The study was conducted at 203 soil boring positions ~~and performed as part of seismic microzonation research~~ in the study area. The site soil classes were predicted using average standard penetration test values (N-SPT) of the topmost 30 m soil deposit layer ~~in the top 30 m soil deposit layer~~(N$_{30}$). Three different site soil classes were observed in the study area. On average, the largest differences between the two analysis (linear interpolation and website) methods in the site coefficient values~~s~~ and design response spectral ~~spectrum response~~ acceleration calculation were observed for the SD and SE classes. However, for the SC site soil class, the difference ~~between the two analysis methods~~ was small, with their values approximately similar.

Keywords: Design ~~spectrum~~ response spectral acceleration; MCE$_R$; N-SPT; Site coefficient; Straight-line interpolation

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1. Introduction

The new National Seismic Code of Indonesia (SNI 1726:2019) was announced in 2019. Some of the information introduced in this new seismic code was partially adopted from the American Standard Code for Seismic Design ASCE/SEI 7~~ of ~~-2016, specifically the site coefficient values~~s~~ and design ~~spectrum ~~response spectral acceleration calculation methods. ~~Other ~~Additional information for developing the site coefficients was adopted from Stewart and Seyhan (2013). Due to the improved methods described in ASCE/SEI 7-16 for developing site coefficients for site soil classes SD and SE, not all the information described in the American Code was adopted by SNI 1726:2019. Specifically, the site coefficients for the SD and SE classes presented in ~~the new Indonesian Seismic Code 2019~~SNI 1726:2019 were completely adopted from Stewart and Seyhan (2013).

Following the ~~new ~~SNI 1726:2019, ~~especially in developing site coefficients, ~~the Ministry of Public Works and Human Settlements announced a new website ~~facility~~ software (online facility) for site coefficient and design response ~~spectrum ~~spectral ~~design~~ acceleration calculation~~s~~. Site or building position coordinates (in terms of longitude and latitude) and site soil class are two ~~data ~~information requirements for design ~~spectrum~~ response spectral acceleration calculations~~.~~: Risk-~~Targeted ~~targeted Maximum Considered Earthquake (MCE_R) acceleration, MCE_R-S_S for ~~(~~short ~~periods)~~ and MCE_R-S_1 for ~~(~~long periods,~~)~~ (Luco et al., 2007; Allen et al., 2015; Sengara et al., 2020), and two design response spectral ~~designs~~ acceleration, S_{DS} and S_{D1}, are four important values calculated by the website facility software. However, no information related to site coefficients F_a for short and F_v for long periods can be obtained from the new website. Thus, these values can be calculated using Equation 1 and Equation 2. ~~, while A~~All S_{DS}, S_S (MCE_R-S_S), S_{D1}, and S_1 (MCE_R-S_1) values can be obtained from the website.

$$F_a = \frac{S_{DS}}{\frac{2}{3} S_S} \tag{1}$$

$$F_v = \frac{S_{D1}}{\frac{2}{3} S_1} \tag{2}$$

To verify the F_a and F_v site coefficients estimated using Equations 1 and 2, straight-line interpolation can be conducted using ~~two ~~the S_S and S_1 website calculations and applying site coefficient (F_a and F_v) table data provided by SNI 1726:2019. F_a and F_v are then estimated following the procedure described by SNI 1726:2019. Equation 3 shows a simple formula for F_a and F_v ~~-~~site coefficients calculation~~s~~. Figure 1 shows a diagram of the straight-line interpolation of the F_a and F_v ~~values~~calculation. F and M_w represent the site coefficient to be estimated and the MCE_R value obtained from the website, respectively; M_{1S} and M_{2S} represent two boundary MCE_R values close to M_w; F_{1S} and F_{2S} represent ~~two ~~the site coefficients for ~~M_w = ~~M_{1S} and ~~M_w = ~~M_{2S}, respectively; and M_{1S}, M_{2S}, F_{1S}, and F_{2S} are the four values obtained from the SNI 1726:2019 tables. F_a and F_v are estimated separately using Equation 3.

$$F = \left(\frac{F_{2S} - F_{1S}}{M_{2S} - M_{1S}}\right)(M_W - M_{1S}) + F_{1S} \tag{3}$$

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This paper describes the site coefficients and design response spectral ~~spectrum response~~ acceleration ~~verification~~ verification calculated using the website facility and the straight-line interpolation described in SNI 1726:2019. The objective of the study was to evaluate whether or not the website performed the analysis following the same procedures used by SNI 1726:2019. The study was performed in Semarang City, Indonesia, and conducted at 203 soil boring investigation positions. The study was performed as part of seismic microzonation research ~~in~~ of the city. One of the important information requirements for seismic microzonation~~s~~ is the ~~development~~ development of soil amplification or site coefficient distribution map ~~measurements~~ at the study area. In this study, ~~boring investigation and~~ the standard penetration test (N-SPT) ~~measurement~~ data observed during boring investigation were used for site class calculation. ~~were available and distributed over the whole study area. Figure 2a shows the 203 boring positions within the study area and the N30 distribution.~~ All boring investigations in this study were conducted at a minimum depth of 30 m and a maximum depth 60 m. The average standard penetration test (N-SPT) of the topmost 30 m soil deposit layer (N_{30}) of every boring position was used for site soil class interpretation (Moghaddam, 2011; Partono et al., 2019; Syaifuddin et al., 2020). Figure 2a shows the 203 boring positions and the N_{30} distribution within the study area. Figure 2b shows the distribution of the site soil classes developed based on the N_{30} data (Partono et al., 2021). The maximum N-SPT ~~data~~ data ~~used~~ obtained ~~in this study and collected~~ from the boring ~~log~~ investigation was 60. Following the procedure described by SNI 1726:2019, the N_{30} value was estimated using Equation 4, where d_i and N_i represent the thickness and N-SPT value of any soil layer "i", respectively.

The ~~same~~ parameter that can also be used for site interpretation is the average shear wave velocity (V_S) of the topmost 30 m soil deposit (V_{S30}) (Naji et al., 2020). The V_{S30} value can be calculated using the same method as that shown in ~~Eq. 4~~Equation 4 and replacing the N_i value with V_{Si}. The V_S value can be ~~collected~~ observed using seismic refraction multichannel analysis of surface waves (MASW) or seismometer array investigations. Prakoso et al. (2017) described a comparative study ~~featuring~~ of V_S value obtained ~~investigation based on~~from MASW investigation and soil boring (N-SPT) data. The V_S value developed using MASW ~~is~~ was more reliable compared to that developed based on the ~~boring investigation~~N-SPT data. Pramono et al. (~~2018~~2020) described the predominant frequency investigation at Lombok Island following the 2018 earthquake event. The greater the V_{S30} value used, the greater the predominant frequency obtained from the wavelet analysis of the ground motion. Additionally, ~~an investigation~~development of V_{S30} and predominant frequency correlation was also conducted by Pramono et al. (2017) in the Palu area.

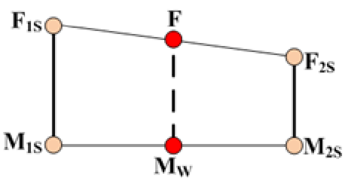

Figure 1 Straight-line interpolation for F_a and F_v calculations

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$$N_{30} = \frac{\sum_{i=i}^{i=n} d_i}{\sum_{i=i}^{i=n} \frac{d_i}{N_i}} \quad (4)$$

2. Methods

The evaluation of the site coefficients ~~within~~ from the study area was conducted following five basic steps:

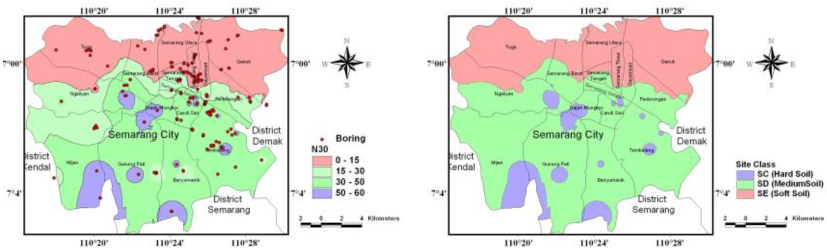
- Site class interpretation;
- MCE_R (S_S and S_1) and design ~~spectrum~~ response spectral acceleration calculation using the website;
- Site coefficient calculation based on the website output;
- Site coefficient calculation based on SNI 1726:2019 tables and procedures;
- Comparative analysis of the two different approaches in terms of their calculated site coefficients and design ~~spectrum~~ response spectral acceleration: the website ~~data~~ output and straight-line interpolation.

2.1. Site Soil Class Interpretation

Site soil class interpretation (Fig~~ure.~~ 2b) was conducted for the 203 boring positions using N_{30} data ~~(no geological data used in developing this map)~~, with the site soil classes interpreted according to SNI 1726:2019. Table 1 shows the basic classification criteria for each site soil class. Only three different site soil classes are presented in this table, ~~with~~ site classes SA/hard rock, SB/rock, and SF/specific soil unavailable. Figure 2b shows the corresponding site soil class distribution according to the site classification information in Table 1. The site class distribution in the study area ~~is~~ is dominated by the SD and SE classes; meanwhile, site class SC was observed in small areas in the middle and southern parts of the city (Partono et al., 2021).

Table 1 Site classification

Site Class	N_{30}
SC	> 50
SD	15–50
SE	< 15



(a) (b)

Figure 2 Boring investigation and N_{30} ~~distribution~~(a) and~~:~~ site soil classes (~~a~~b) ~~and~~ distribution maps ~~(b)~~

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2.2. MCE_R and Design ~~Spectrum~~ Response Spectral Acceleration Calculation

MCE_R calculations were performed for the 203 boring positions using the website. According to the site class distribution of the study area, ~~three~~ different MCE_R-S_S and MCE_R-S_1 distributions were also observed in the study area. Table 2 shows the total ~~boring investigations~~data for each site class as well as the distribution of the minimum and maximum MCE_R-S_S, MCE_R-S_1, S_{DS}, and S_{D1} for the three different site classes developed using the website.

Table 2 S_S, S_1, S_{DS}, and S_{D1} spectral acceleration ~~distribution~~ values obtained from the website

Site Class	Total Data	MCE_R-S_S(g)		S_{DS} (g)		MCE_R-S_1 (g)		S_{D1} (g)	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
SC	34	0.8459	0.9668	0.68	0.77	0.3653	0.4097	0.37	0.41
SD	90	0.8098	0.9579	0.63	0.71	0.3546	0.4071	0.46	0.51
SE	79	0.696	0.9274	0.64	0.71	0.3185	0.3936	0.58	0.63

2.3. ~~Site Coefficients F_a and F_v~~ Website-calculated Fa and Fv values

F_a and F_v site coefficient calculations were performed according to the MCE_R-S_S, MCE_R-S_1, S_{DS}, and S_{D1} values obtained from the website. The site coefficients were then estimated using Equation 1 and 2. Table 3 shows the distribution of the minimum and maximum F_a and F_v values using these four values. ~~Following~~ According to the boundary values of F_a and F_v described in the SNI 1726:2019 tables, the minimum and maximum F_a values developed in the study area were divided into two different boundary values. A few MCE_R-S_S values were lower than 0.75 g; however, most of the MCE_R-S_S values were between 0.75 and 1 g.

2.4. Site Coefficients F_a and F_v SNI 1726:2019

Straight-line interpolation was also performed for F_a and F_v calculation using Equation 3 and the F_a and F_v tables ~~data~~ provided by SNI 1726:2019. According to the MCE_R-S_S and MCE_R-S_1 values obtained from the website, the minimum and maximum boundaries for these two site coefficients could be estimated. Thus, Table 3 shows the ~~minimum and maximum~~ boundaries of the F_a and F_v values used for the straight-line interpolation calculations. The F_a and F_v ~~minimum and maximum~~ boundary values displayed in Table 3 were obtained from SNI 1726:2019.

Table 3 F_a and F_v distribution developed using the website and SNI 1726:2019 tables

Site Class	Total Data	Linear Interpolation (SNI)					Website				Diff. > 0.01 (%)	
		F_a			F_v		F_a		F_v		F_a	F_v
		MCE_R-S_S(g)			MCE_R-S_1 (g)		Min.	Max.	Min.	Max.		
		0.5	0.75	1.0	0.3	0.4						
SC	34	1.2	1.2	1.2	1.5	1.5	1.19	1.21	1.478	1.519	0	58.82
SD	90	1.4	1.2	1.1	2.0	1.9	1.112	1.167	1.879	1.949	3.41	56.82
SE	79	1.7	1.3	1.1	2.8	2.4	1.148	1.4	2.401	2.732	13.92	50.63

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3. Results and Discussion

The MCE_R-S_S values for the SC site class (Table 2) range from 0.8459 to 0.9668 g, while the F_a values for the SC site class developed according to the website (Table 3) range between 1.19 and 1.21. All the F_a values developed from the website are consistent with and almost equal to those from SNI 1726:2019 (Table 3). As can be seen in Table 3, the F_a values from SNI 1726:2019 are constant and equal to 1.2. The difference between the F_a values developed using the website data and those from SNI 1726:2019 is less than 0.01. According to Table 3, for all 34 data, the percentage of total data with a minimum difference of 0.01 is 0%. Figure 3a shows the distribution of the F_a site coefficients for the SC site class in terms of the MCE_R-S_S values. The linear and website legends inside this figure represent the straight-line interpolation following SNI 1726:2019 and the website data acquisition. The R^2 (coefficient of determination) value for site class SC is close to 0, because the F_a values estimated using these two models are nearly constant for all MCE_R-S_S values. The R^2 value is used for evaluation of the fitting line (linear fit model) performance. The evaluation was performed for the distribution of F_a or F_v to the linear regression line model. The minimum and maximum R^2 values are 0 and 1 (100%), respectively. The higher the R^2, the better the linear fitting model difference ~~with~~ for the F_a or F_v data distribution.

The distribution of the MCE_R-S_S values for the SD site class in the study area was almost equal to that of the SC site class. Table 2 shows the distribution of MCE_R-S_S for the SD site class, with the values ranging from 0.8098 to 0.9579 g. Following the same procedure as that of the SC site class, the F_a site coefficients for the SD site class in the study area range between 1.2 -and 1.1. Due to the MCE_R-S_S being distributed around 1 ~~g~~, the F_a values obtained from the study area are close to 1.1: As shown in Table 3, the F_a values range between 1.112 and 1.167. The total percent of data with a minimum difference of 0.01 ~~is~~ are 3.41%. Figure 3b shows the distribution of the F_a values for site class SD in terms of the MCE_R-S_S values. As can be seen in Figure 3b, the R^2 value obtained from the regression analysis is 0.7858, ~~—o~~or less than 1. The straight-line interpolation values developed according to the SNI 1726:2019 data and tables were better compared to the F_a values developed using the website. However, on average, the absolute difference in the F_a values developed between these two models was 0.0105, and the line distributions were almost identical (i.e., coincided).

The MCE_R-S_S distribution of the SE site class values estimated from the website ranged between 0.696 and 0.9274 g. According to SNI 1726:2019, all MCE_R-S_S for site class SE were distributed between two different boundary values, from 0.5 through 0.75 g for the first boundary and from 0.75 through 1 g for the second boundary. The straight-line interpolation for all MCE_R-S_S was also separated into two different boundary values. The first F_a boundary values (6 data) were distributed between 1.4 and 1.323; however, the second F_a (73 data) site coefficients were distributed between 1.292 and 1.148. Figure 3c shows the distribution of the F_a values for the SE site class. Two different straight-line interpolations can be observed in this figure in accordance with the two different boundary values from SNI 1726:2019. The absolute average difference in F_a for site class SE is 0.029. As can be seen in Table 3, 13.92% of the 79 data have a minimum difference of 0.01.

F_a and F_v are the two site coefficients used for ~~developing~~ calculating surface spectral acceleration and design ~~spectrum~~ response spectral acceleration. The performance of the different values of these coefficients developed using the two different procedures

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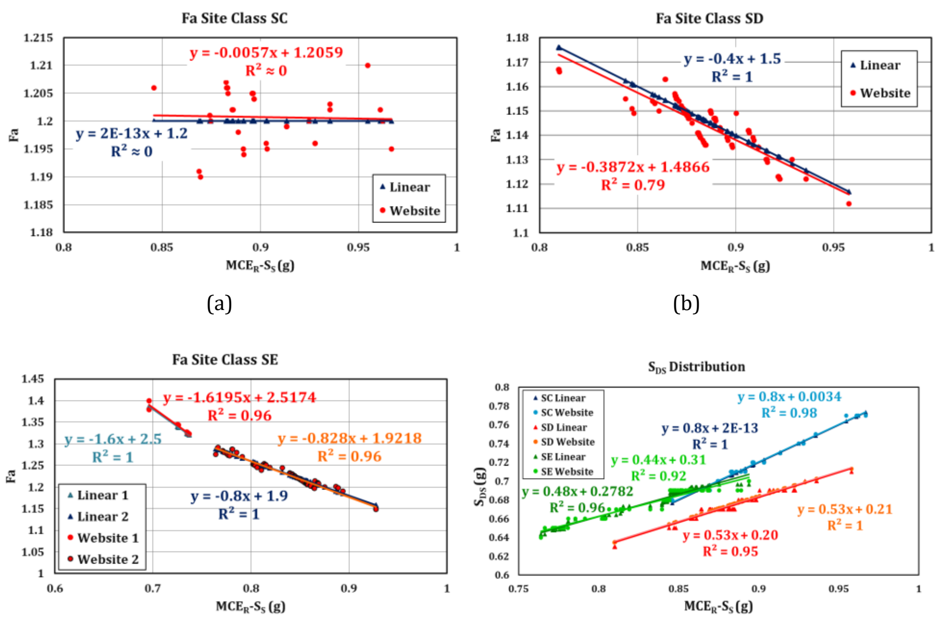
To verify the performance of the F_a and F_v values estimated using these two methods, design ~~spectrum r~~response spectral acceleration calculation was also conducted in this study. The purpose of this analysis was to verify the performance of the design ~~spectrum~~ response spectral acceleration S_{DS} and S_{D1} values according to the site coefficient values ~~estimated~~ calculated using the two different methods. Figure 3d shows the performance of the S_{DS} design ~~spectrum~~ response spectral acceleration in terms of MCE_R-S_S developed from the website and straight-line interpolation. As can be seen in Figure 3d, a ~~good~~ strong correlation between S_{DS} in terms of MCE_R-S_S was observed in this study. According to this figure, there are no significant differences in the S_{DS} performance estimated using the website versus SNI 1726:2019 ~~-~~straight-line interpolation procedures for all three site classes (SC, SD, and SE).

The F_a distribution map developed from the 203 boring positions was also constructed based on the website and linear interpolation analysis. Figure 4a and 4b show~~s~~ the two F_a distribution maps, which are almost equal. Specifically, the F_a values from the study area range between 1.2 and 1.4, with the largest Fa values observed in a small north-eastern portion of the city.

Site coefficient evaluation was also conducted for long-period MCE_R-S_1 spectral acceleration. Using the same procedure as that used for MCE_R-S_S, the evaluation was performed for the SC, SD, and SE site classes. Based on the minimum and maximum MCE_R-S_1 values estimated using the website, all MCE_R-S_1 values in the study area were distributed between 0.3185 and 0.4097 g (see Table 2) or approximately between 0.3 and 0.4 g. For site classes SC and SD, there was one boring position with a MCE_R-S_1 value greater than 0.4 g. Figures 5a, b, and c show the distribution of the site coefficient F_v for the SC, SD, and SE site soil classes, respectively.



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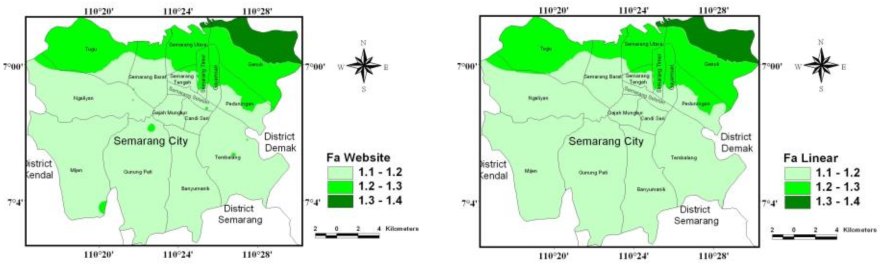
(c) (d)

Figure 3 F_a distributions in terms of MCE_R-S_S values for SC (a), SD (b), and SE (c) site classes and the correlation of S_{DS} and MCE_R-S_S from the linear interpolation and website software (d)



(a) (b)

Figure 4 F_a distribution maps developed using website software (a) and linear interpolation (b)

All the F_v values estimated using the website and straight-line interpolation were almost equal or coincided~~—~~ except for ~~in~~ site class SD. As shown in Figure 5b, most of the F_v values of the SD site class developed using the website are greater than ~~the~~ those developed using straight-line interpolation. The R^2 value for this model was far from 1. The F_v values for site class SD from the website calculation were far from the linear model ~~expected~~ described by SNI 1726:2019. The R^2 for site class SC was not available (close to 0), because the F_v and MCE_R-S_1 correlations were nearly constant or almost equal. A good F_v and MCE_R-S_1 correlation was observed for site class SE (see Figure 5c) for the website output and straight-line interpolation methods. The R^2 obtained for this site class was nearly 1. On average the absolute differences between F_v were 0.015, 0.036, and 0.033 for the SC, SD, and SE site classes, respectively. According to Table 3, the percent of total data with a minimum difference of 0.01 for the SC, SD, and SE site classes is greater than 50%.

Figure 5d shows the S_{D1} design ~~spectrum~~ response spectral acceleration performance in terms of MCE_R-S_1 values estimated using the same methods as used in the S_{DS} calculation. As can be seen in Figure 5d, a good correlation between S_{D1} in terms of MCE_R-S_1 was observed in this study. Also, according to this figure, there are no significant differences in the S_{D1} performance for the SC, SD, and SE site class estimates between the website and straight-line interpolation of SNI 1726:2019 procedures.

~~F_v distribution maps were also developed based on the website and linear interpolation analysis. Figures 6a and 6b show two F_v distribution maps, which are almost~~

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~~equal. The F_v values developed using the website ranged between 1.4 and 2.8, while the F_v values developed using linear interpolation ranged between 1.5 and 2.8. The largest F_v values were observed in the northern part of the city.~~

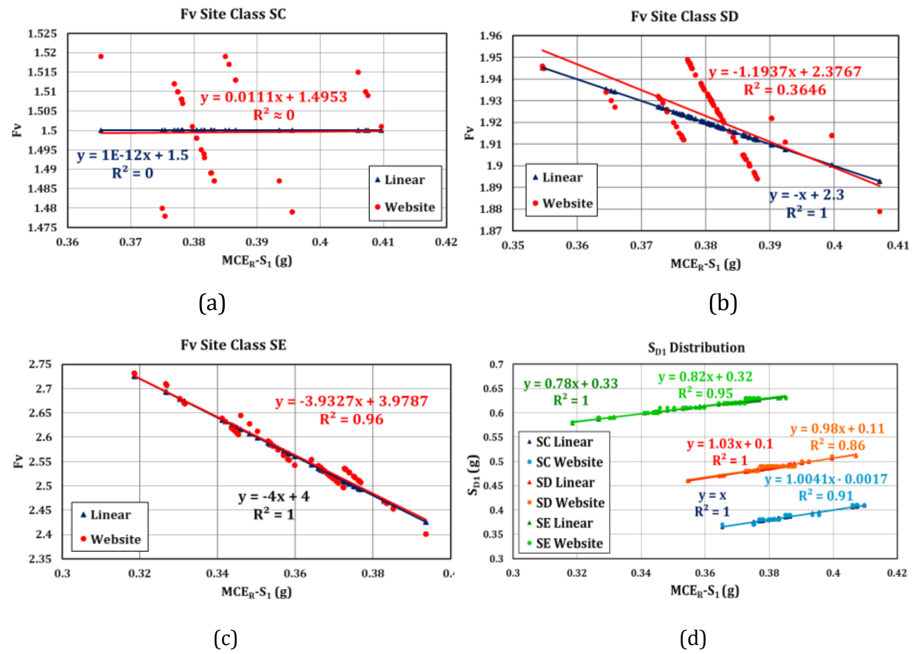

Figure 5 F_v distributions in terms of MCE_R-S_1 values for SC (a), SD (b), SE (c) site classes and the correlation of S_{D1} and MCE_R-S_1 developed based on linear interpolation and website software (d)

F_v distribution maps were also developed based on the website and linear interpolation analysis. Figures 6a and 6b show two F_v distribution maps, which are almost equal. The F_v values developed using the website ranged between 1.4 and 2.8, while the F_v values developed using linear interpolation ranged between 1.5 and 2.8. The largest F_v values were observed in the northern part of the city.

The S_{DS} and S_{D1} developed for the study area using the website were ~~accepted~~ acceptable according to the requirement criterion of SNI 1726:2019. Table 4 shows the minimum and maximum S_{DS} and S_{D1} values and the average difference in the S_{DS} and S_{D1} values between the two methods for the SC, SD, and SE site classes. As shown in Table 4, the average difference of S_{DS} and S_{D1} is the absolute ~~differences~~ values of S_{DS} and S_{D1}. The maximum average difference (ave. diff.) for S_{DS} and S_{D1}, 0.0224 g and 0.0153 g, respectively, were observed in the SD site class. However, the average differences in S_{DS} and ~~S_{DS}~~–S_{D1} for site classes SC and SE were less than 0.0073 g and 0.0044 g, ~~approximately~~respectively.

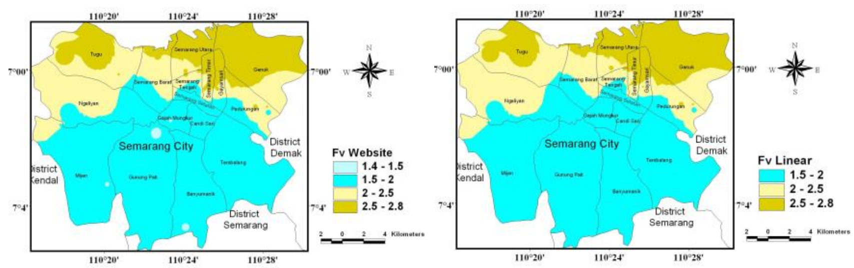

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Figure 6 F_v distribution maps developed using website software (a) and linear interpolation (b)

Table 4 S_{DS} and S_{D1} performance for all site classes

Site Class	S_{DS} (g)					S_{D1} (g)				
	Website		Linear		Ave. diff.	Website		Linear		Ave. diff.
	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.	
SC	0.68	0.77	0.6767	0.7734	0.0067	0.37	0.41	0.3653	0.4097	0.0044
SD	0.63	0.71	0.6349	0.6925	0.0224	0.46	0.51	0.4599	0.4946	0.0153
SE	0.64	0.71	0.6433	0.706	0.0073	0.58	0.63	0.5788	0.6315	0.0027

4. Conclusions

Evaluations of site coefficients estimated using the website and straight-line interpolation methods were performed for 203 boring positions in Semarang City. No significant differences were found in the F_a and F_v site coefficients between the two methods. The largest difference in the F_a site coefficient calculations was observed for the SD and SE site classes. The difference in site coefficients for the SD and SE site soil classes was less than 0.03, while, for the SC site soil class, the difference was less than 0.01. In terms of site coefficient F_v, the largest difference was observed for the SD and SE site soil classes with a maximum of 0.04. However, the difference in site coefficient F_v for site class SC was less than 0.02. When calculating F_a and F_v site coefficients, the linear interpolation method from SNI 1726:2019 is better compared to the calculated using MCE_R-S_S, MCE_R-S_1, S_{DS}, and S_{D1} values obtained from the website.

No significant differences in the design ~~spectrum~~ response spectral acceleration S_{DS} and S_{D1} values were found for any of the site classes. The largest design ~~spectrum~~ response spectral acceleration difference in SD between the two methods was less than 0.02 g, while, for the SC and SE site classes, the differences were less than 0.005 g.

Acknowledgements

This study was funded by the Directorate Research and Community ~~Devotion~~Service, Deputy of Research Empowerment and Development, Ministry of Research and Technology/National Research Council and Innovation, through its 2021 research grant ~~2021~~. The authors also appreciate the Centre for Housing and Settlement Research and Development for supporting data and information collection during the development of this study.

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Site Coefficient and Design Spectral Acceleration Evaluation of New Indonesian 2019 Website Response Spectra

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Abstract. Calculation of site coefficient and design response spectral acceleration are two important steps in the seismic design of buildings. According to Indonesian Seismic Code 2019, two information requirements for site coefficient calculations are the site soil class and Risk-targeted Maximum Considered Earthquake (MCER-SS for short and MCER-S1 for long period) spectral acceleration. Three different hard/SC, medium/SD and soft/SE are typically site soil classes used for building designs. Two different site coefficients (Fa for MCER-SS and Fv for MCER-S1 spectral acceleration) are used for surface and design response spectral acceleration calculations. The Indonesian Seismic Code provides two (Fa and Fv) tables for calculating site coefficients. If the MCER-SS or MCER-S1 values developed for a specific site are not exactly equal to the values in Fa or Fv tables, the site coefficients can then be predicted using straight-line interpolation between the two closest Fa or Fv values within the tables. When the straight-line interpolation is adjusted for Fa or Fv calculation, different results were observed in comparison to the values developed using website-based software (prepared by Ministry of Public Works and Human Settlements). This study evaluates site coefficients and design response spectral acceleration predictions in Semarang City, Indonesia, according to straight-line interpolation method and website software calculations. The study was conducted at 203 soil boring positions in the study area. The site soil classes were predicted using average standard penetration test values (N-SPT) of the topmost 30 m soil deposit layer (N30). Three different site soil classes were observed in the study area. On average, the largest differences between the two analysis (linear interpolation and website) methods in the site coefficient values and design response spectral acceleration calculation were observed for the SD and SE classes. However, for the SC site soil class, the difference was small, with their values approximately similar.

Keywords: Design response spectral acceleration; MCER; N-SPT; Site coefficient; Straight-line interpolation

1. Introduction

The new National Seismic Code of Indonesia (SNI 1726:2019, 2019) was announced in

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2019. Some of the information introduced in this new seismic code was partially adopted from the American Standard Code for Seismic Design ASCE/SEI 7-16, specifically the site coefficient values and design response spectral acceleration calculation methods. Additional information for developing the site coefficients was adopted from Stewart and Seyhan (2013). Due to the improved methods described in ASCE/SEI 7-16 for developing site coefficients for site soil classes SD and SE, not all the information described in the American Code was adopted by SNI 1726:2019. Specifically, the site coefficients for the SD and SE classes presented in SNI 1726:2019 were completely adopted from Stewart and Seyhan (2013).

Following the SNI 1726:2019, the Ministry of Public Works and Human Settlements announced a new website software (online facility) for site coefficient and design response spectral acceleration calculation. Site or building position coordinates (in terms of longitude and latitude) and site soil class are two information requirements for design response spectral acceleration calculations. Risk-targeted Maximum Considered Earthquake (MCE_R) acceleration, MCE_R-S_S for short and MCE_R-S_1 for long periods, (Luco et al., 2007; Allen et al., 2015; Sengara et al., 2020), and two design response spectral acceleration, S_{DS} and S_{D1}, are four important values calculated by the website facility software. However, no information related to site coefficients F_a for short and F_v for long periods can be obtained from the new website. Thus, these values can be calculated using Equation 1 and Equation 2. All S_{DS}, S_S (MCE_R-S_S), S_{D1}, and S_1 (MCE_R-S_1) values can be obtained from the website.

$$F_a = \frac{S_{DS}}{\frac{2}{3} S_S} \tag{1}$$

$$F_v = \frac{S_{D1}}{\frac{2}{3} S_1} \tag{2}$$

To verify the F_a and F_v site coefficients estimated using Equations 1 and 2, straight-line interpolation can be conducted using the S_S and S_1 website calculations and applying site coefficient (F_a and F_v) table data provided by SNI 1726:2019. F_a and F_v are then estimated following the procedure described by SNI 1726:2019. Equation 3 shows a simple formula for F_a and F_v site coefficients calculation. Figure 1 shows a diagram of the straight-line interpolation of the F_a and F_v calculation. F and M_W represent the site coefficient to be estimated and the MCE_R value obtained from the website, respectively; M_{1S} and M_{2S} represent two boundary MCE_R values close to M_W; F_{1S} and F_{2S} represent the site coefficients for M_{1S} and M_{2S}, respectively; and M_{1S}, M_{2S}, F_{1S}, and F_{2S} are the four values obtained from the SNI 1726:2019 tables. F_a and F_v are estimated separately using Equation 3.

$$F = \left(\frac{F_{2S} - F_{1S}}{M_{2S} - M_{1S}}\right)(M_W - M_{1S}) + F_{1S} \tag{3}$$

This paper describes the site coefficients and design response spectral acceleration verification calculated using the website facility and the straight-line interpolation described in SNI 1726:2019. The objective of the study was to evaluate whether or not the website performed the analysis following the same procedures used by SNI 1726:2019. The study was performed in Semarang City, Indonesia, and conducted at 203 soil boring investigation positions. The study was performed as part of seismic microzonation research of the city. One of the important information requirements for seismic microzonation is the development of soil amplification or site coefficient distribution map at the study area. In

this study, the standard penetration test (N-SPT) data observed during boring investigation were used for site class calculation. All boring investigations in this study were conducted at a minimum depth of 30 m and a maximum depth 60 m. The average standard penetration test (N-SPT) of the topmost 30 m soil deposit layer (N_{30}) of every boring position was used for site soil class interpretation (Moghaddam, 2011; Partono et al., 2019; Syaifuddin et al., 2020). Figure 2a shows the 203 boring positions and the N_{30} distribution within the study area. Figure 2b shows the distribution of the site soil classes developed based on the N_{30} data (Partono et al., 2021). The maximum N-SPT data obtained from the boring investigation was 60. Following the procedure described by SNI 1726:2019, the N_{30} value was estimated using Equation 4, where d_i and N_i represent the thickness and N-SPT value of any soil layer "i", respectively.

The parameter that can also be used for site interpretation is the average shear wave velocity (V_S) of the topmost 30 m soil deposit (V_{S30}) (Naji et al., 2020). The V_{S30} value can be calculated using the same method as that shown in Equation 4 and replacing the N_i value with V_{Si}. The V_S value can be observed using seismic refraction multichannel analysis of surface waves (MASW) or seismometer array investigations. Prakoso et al. (2017) described a comparative study of V_S value obtained from MASW investigation and soil boring (N-SPT) data. The V_S value developed using MASW was more reliable compared to that developed based on the N-SPT data. Pramono et al. (2020) described the predominant frequency investigation at Lombok Island following the 2018 earthquake event. The greater the V_{S30} value used, the greater the predominant frequency obtained from the wavelet analysis of the ground motion. Additionally, development of V_{S30} and predominant frequency correlation was also conducted by Pramono et al. (2017) in the Palu area.

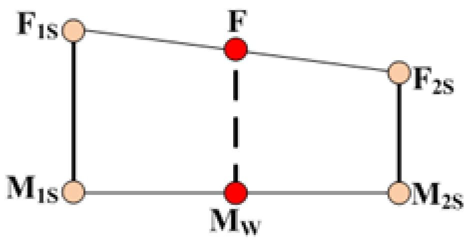


Figure 1 Straight-line interpolation for F_a and F_v calculations

$$N_{30} = \frac{\sum_{i=i}^{i=n} d_i}{\sum_{i=i}^{i=n} \frac{d_i}{N_i}} \tag{4}$$

2. Methods

The evaluation of the site coefficients from the study area was conducted following five basic steps:

- Site class interpretation;
- MCE_R (S_S and S_1) and design response spectral acceleration calculation using the website;
- Site coefficient calculation based on the website output;
- Site coefficient calculation based on SNI 1726:2019 tables and procedures;

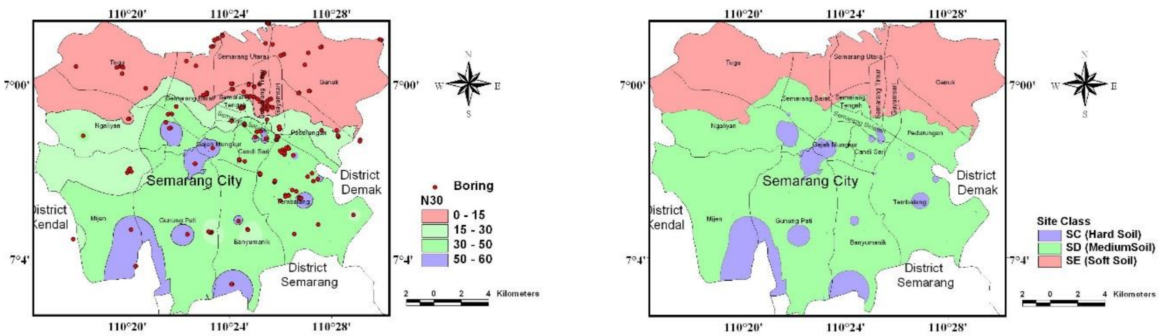
- Comparative analysis of the two different approaches in terms of their calculated site coefficients and design response spectral acceleration: the website output and straight-line interpolation.

2.1. Site Soil Class Interpretation

Site soil class interpretation (Figure 2b) was conducted for the 203 boring positions using N_{30} data, with the site soil classes interpreted according to SNI 1726:2019. Table 1 shows the basic classification criteria for each site soil class. Only three different site soil classes are presented in this table, site classes SA/hard rock, SB/rock, and SF/specific soil unavailable. Figure 2b shows the corresponding site soil class distribution according to the site classification information in Table 1. The site class distribution in the study area is dominated by the SD and SE classes; meanwhile, site class SC was observed in small areas in the middle and southern parts of the city (Partono et al., 2021).

Table 1 Site classification

Site Class	N_{30}
SC	> 50
SD	15–50
SE	< 15



(a) (b)

Figure 2 (a) Boring investigation and N_{30}; and (b) site soil classes distribution maps

2.2. MCE$_R$ and Design Response Spectral Acceleration Calculation

MCE$_R$ calculations were performed for the 203 boring positions using the website. According to the site class distribution of the study area, different MCE$_R$-S_S and MCE$_R$-S_1 distributions were also observed in the study area. Table 2 shows the total data for each site class as well as the distribution of the minimum and maximum MCE$_R$-S_S, MCE$_R$-S_1, S_{DS}, and S_{D1} for the three different site classes developed using the website.

Table 2 S_S, S_1, S_{DS}, and S_{D1} spectral acceleration values obtained from the website

Site Class	Total Data	MCE$_R$-S_S(g)		S_{DS} (g)		MCE$_R$-S_1 (g)		S_{D1} (g)	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
SC	34	0.8459	0.9668	0.68	0.77	0.3653	0.4097	0.37	0.41
SD	90	0.8098	0.9579	0.63	0.71	0.3546	0.4071	0.46	0.51
SE	79	0.696	0.9274	0.64	0.71	0.3185	0.3936	0.58	0.63

2.3. Website-calculated Fa and Fv values

F_a and F_v site coefficient calculations were performed according to the MCE$_R$-S_S, MCE$_R$-S_1, S_{DS}, and S_{D1} values obtained from the website. The site coefficients were then estimated

using Equations 1 and 2. Table 3 shows the distribution of the minimum and maximum F_a and F_v values using these four values. According to the boundary values of F_a and F_v described in the SNI 1726:2019 tables, the minimum and maximum F_a values developed in the study area were divided into two different boundary values. A few MCE_R-S_S values were lower than 0.75 g; however, most of the MCE_R-S_S values were between 0.75 and 1 g.

2.4. Site Coefficients F_a and F_v SNI 1726:2019

Straight-line interpolation was also performed for F_a and F_v calculation using Equation 3 and the F_a and F_v tables provided by SNI 1726:2019. According to the MCE_R-S_S and MCE_R-S_1 values obtained from the website, the minimum and maximum boundaries for these two site coefficients could be estimated. Thus, Table 3 shows the boundaries of the F_a and F_v values used for the straight-line interpolation calculations. The F_a and F_v boundary values displayed in Table 3 were obtained from SNI 1726:2019.

Table 3 F_a and F_v distribution developed using the website and SNI 1726:2019 tables

Site Class	Total Data	Linear Interpolation (SNI)					Website				Diff. > 0.01 (%)	
		F_a			F_v		F_a		F_v		F_a	F_v
		MCE_R-S_S(g)			MCE_R-S_1 (g)		Min.	Max.	Min.	Max.		
		0.5	0.75	1.0	0.3	0.4						
SC	34	1.2	1.2	1.2	1.5	1.5	1.19	1.21	1.478	1.519	0	58.82
SD	90	1.4	1.2	1.1	2.0	1.9	1.112	1.167	1.879	1.949	3.41	56.82
SE	79	1.7	1.3	1.1	2.8	2.4	1.148	1.4	2.401	2.732	13.92	50.63

3. Results and Discussion

The MCE_R-S_S values for the SC site class (Table 2) range from 0.8459 to 0.9668 g, while the F_a values for the SC site class developed according to the website (Table 3) range between 1.19 and 1.21. All the F_a values developed from the website are consistent with and almost equal to those from SNI 1726:2019 (Table 3). As can be seen in Table 3, the F_a values from SNI 1726:2019 are constant and equal to 1.2. The difference between the F_a values developed using the website data and those from SNI 1726:2019 is less than 0.01. According to Table 3, for all 34 data, the percentage of total data with a minimum difference of 0.01 is 0%. Figure 3a shows the distribution of the F_a site coefficients for the SC site class in terms of the MCE_R-S_S values. The linear and website legends inside this figure represent the straight-line interpolation following SNI 1726:2019 and the website data acquisition. The R^2 (coefficient of determination) value for site class SC is close to 0, because the F_a values estimated using these two models are nearly constant for all MCE_R-S_S values. The R^2 value is used for evaluation of the fitting line (linear fit model) performance. The evaluation was performed for the distribution of F_a or F_v to the linear regression line model. The minimum and maximum R^2 values are 0 and 1 (100%), respectively. The higher the R^2, the better the linear fitting model difference for the F_a or F_v data distribution.

The distribution of the MCE_R-S_S values for the SD site class in the study area was almost equal to that of the SC site class. Table 2 shows the distribution of MCE_R-S_S for the SD site class, with the values ranging from 0.8098 to 0.9579 g. Following the same procedure as that of the SC site class, the F_a site coefficients for the SD site class in the study area range between 1.2 and 1.1. Due to the MCE_R-S_S being distributed around 1, the F_a values obtained from the study area are close to 1.1: As shown in Table 3, the F_a values range between 1.112 and 1.167. The total percent of data with a minimum difference of 0.01 are 3.41%. Figure 3b shows the distribution of the F_a values for site class SD in terms of the MCE_R-S_S values.

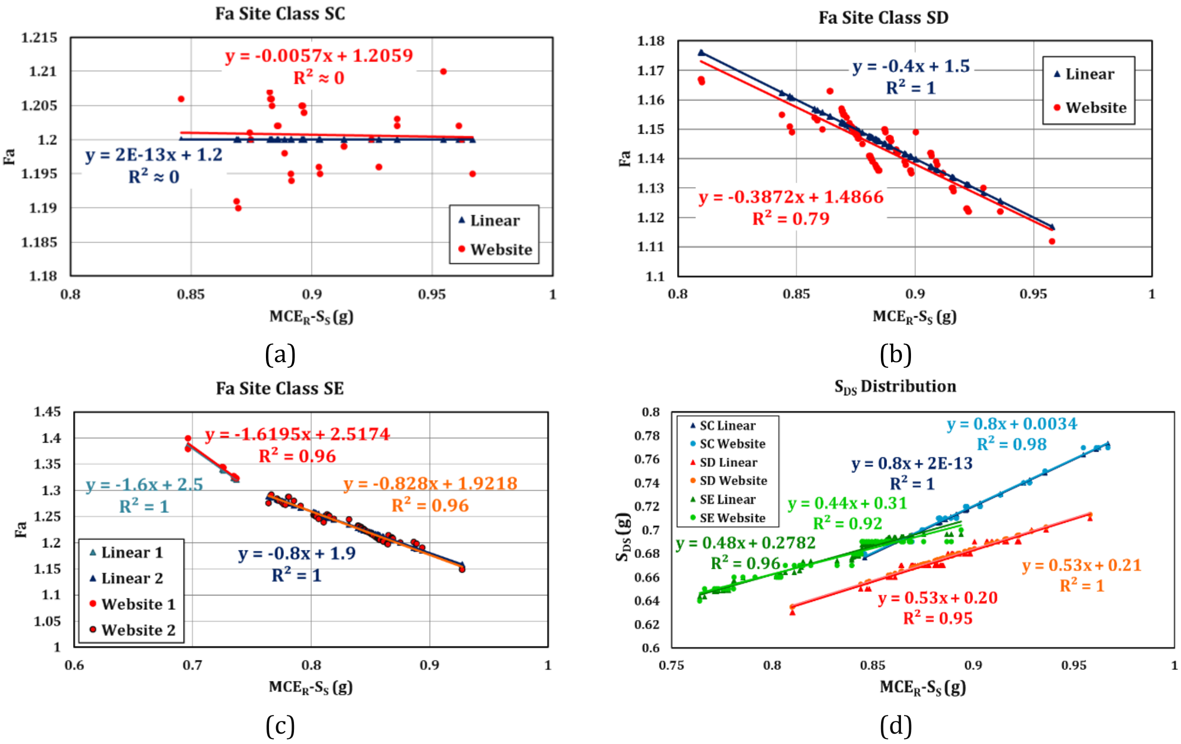


Figure 3 F_a distributions in terms of MCE_R-S_S values for: (a) SC; (b) SD; and (c) SE site classes; and (d) the correlation of S_{DS} and MCE_R-S_S from the linear interpolation and website software

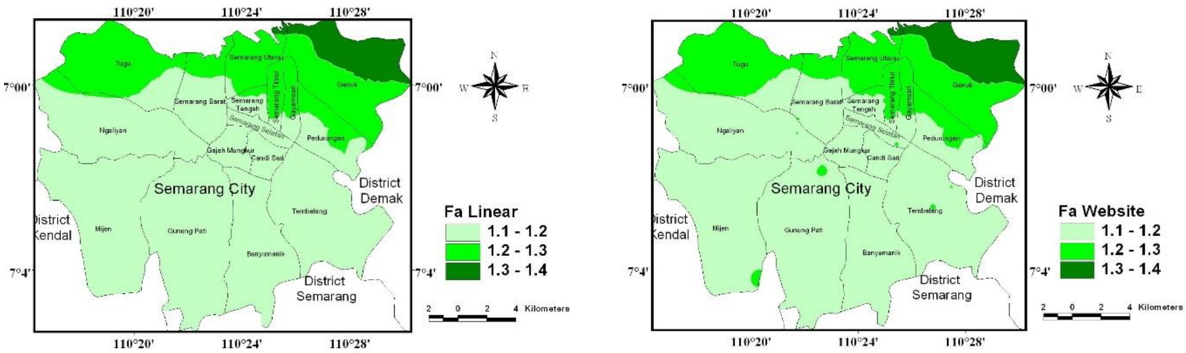
As can be seen in Figure 3b, the R^2 value obtained from the regression analysis is 0.7858, or less than 1. The straight-line interpolation values developed according to the SNI 1726:2019 data and tables were better compared to the F_a values developed using the website. However, on average, the absolute difference in the F_a values developed between these two models was 0.0105, and the line distributions were almost identical (i.e., coincided).

The MCE_R-S_S distribution of the SE site class values estimated from the website ranged between 0.696 and 0.9274 g. According to SNI 1726:2019, all MCE_R-S_S for site class SE were distributed between two different boundary values, from 0.5 through 0.75 g for the first boundary and from 0.75 through 1 g for the second boundary. The straight-line interpolation for all MCE_R-S_S was also separated into two different boundary values. The first F_a boundary values (6 data) were distributed between 1.4 and 1.323; however, the second F_a (73 data) site coefficients were distributed between 1.292 and 1.148. Figure 3c shows the distribution of the F_a values for the SE site class. Two different straight-line interpolations can be observed in this figure in accordance with the two different boundary values from SNI 1726:2019. The absolute average difference in F_a for site class SE is 0.029. As can be seen in Table 3, 13.92% of the 79 data have a minimum difference of 0.01.

F_a and F_v are the two site coefficients used for calculating surface spectral acceleration and design response spectral acceleration. The performance of the different values of these coefficients developed using the two different procedures (straight line interpolation and using website facility) can be neglected or avoided, since there was no significant difference in the design response spectral acceleration results between these two methods. The difference in the accuracy value used for both methods will sometimes produce different site coefficients and directly impact the performance of the S_{DS} and S_{D1} outputs for all site soil classes.

To verify the performance of the F_a and F_v values estimated using these two methods, design response spectral acceleration calculation was also conducted in this study. The purpose of this analysis was to verify the performance of the design response spectral acceleration S_{DS} and S_{D1} values according to the site coefficient values calculated using the two different methods. Figure 3d shows the performance of the S_{DS} design response spectral acceleration in terms of MCE_R-S_S developed from the website and straight-line interpolation. As can be seen in Figure 3d, a strong correlation between S_{DS} in terms of MCE_R-S_S was observed in this study. According to this figure, there are no significant differences in the S_{DS} performance estimated using the website versus SNI 1726:2019 straight line interpolation procedures for all three site classes (SC, SD, and SE).

The F_a distribution map developed from the 203 boring positions was also constructed based on the website and linear interpolation analysis. Figure 4a and 4b show the two F_a distribution maps, which are almost equal. Specifically, the F_a values from the study area range between 1.2 and 1.4, with the largest Fa values observed in a small north-eastern portion of the city.



(a) (b)

Figure 4 F_a distribution maps developed using: (a) website software; and (b) linear interpolation

Site coefficient evaluation was also conducted for long-period MCE_R-S_1 spectral acceleration. Using the same procedure as that used for MCE_R-S_S, the evaluation was performed for the SC, SD, and SE site classes. Based on the minimum and maximum MCE_R-S_1 values estimated using the website, all MCE_R-S_1 values in the study area were distributed between 0.3185 and 0.4097 g (see Table 2) or approximately between 0.3 and 0.4 g. For site classes SC and SD, there was one boring position with a MCE_R-S_1 value greater than 0.4 g. Figures 5a, b, and c show the distribution of the site coefficient F_v for the SC, SD, and SE site soil classes, respectively.

All the F_v values estimated using the website and straight-line interpolation were almost equal or coincided except for site class SD. As shown in Figure 5b, most of the F_v values of the SD site class developed using the website are greater than those developed using straight-line interpolation. The R^2 value for this model was far from 1. The F_v values for site class SD from the website calculation were far from the linear model described by SNI 1726:2019. The R^2 for site class SC was not available (close to 0), because the F_v and MCE_R-S_1 correlations were nearly constant or almost equal. A good F_v and MCE_R-S_1 correlation was observed for site class SE (see Figure 5c) for the website output and straight-line interpolation methods. The R^2 obtained for this site class was nearly 1. On average the absolute differences between F_v were 0.015, 0.036, and 0.033 for the SC, SD, and SE site classes, respectively. According to Table 3, the percent of total data with a minimum difference of 0.01 for the SC, SD, and SE site classes is greater than 50%.

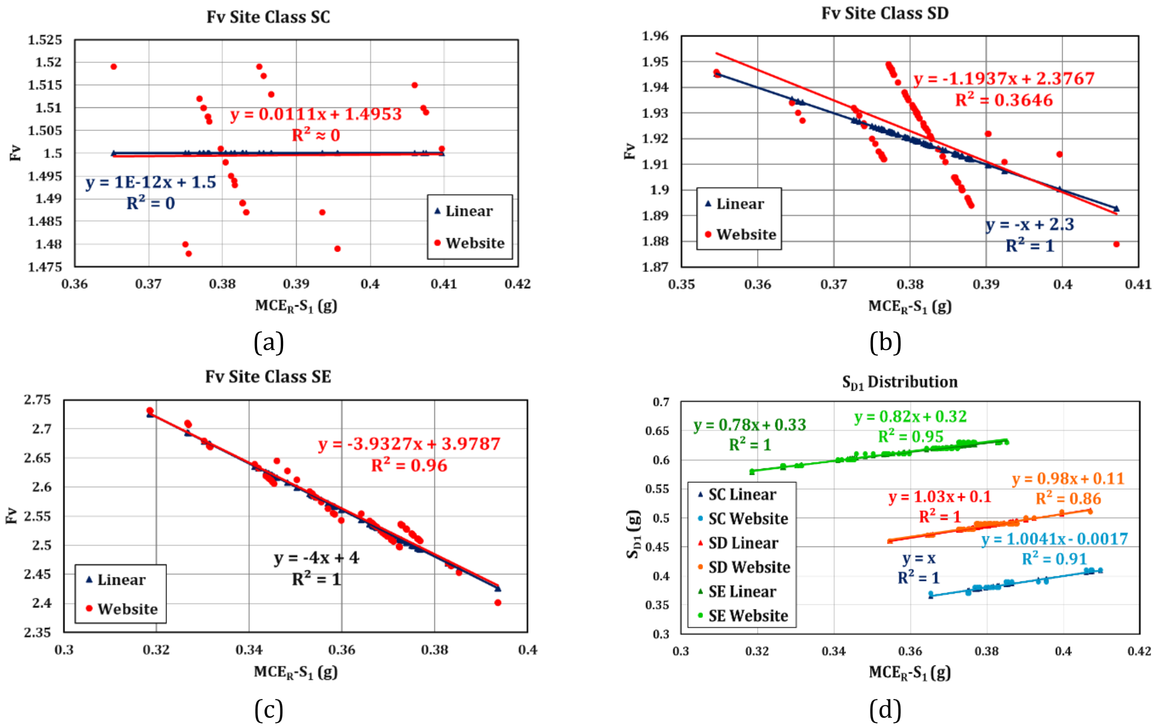


Figure 5 F_v distributions in terms of MCE_R-S_1 values for: (a) SC; (b) SD; (c) SE site classes; and (d) the correlation of S_{D1} and MCE_R-S_1 developed based on linear interpolation and website software

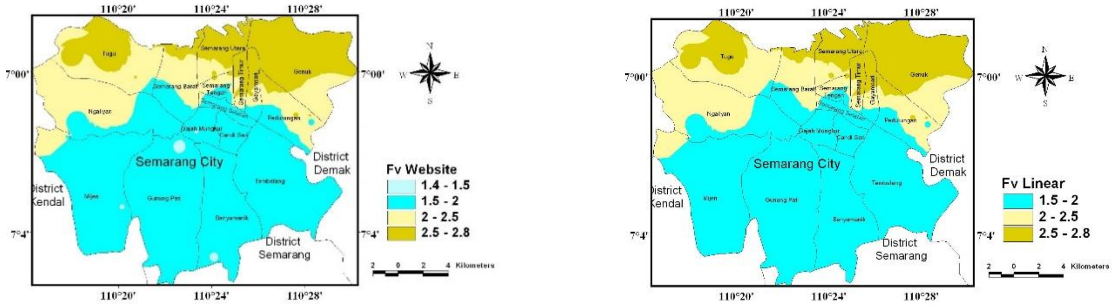
Figure 5d shows the S_{D1} design response spectral acceleration performance in terms of MCE_R-S_1 values estimated using the same methods as used in the S_{DS} calculation. As can be seen in Figure 5d, a good correlation between S_{D1} in terms of MCE_R-S_1 was observed in this study. Also, according to this figure, there are no significant differences in the S_{D1} performance for the SC, SD, and SE site class estimates between the website and straight-line interpolation of SNI 1726:2019 procedures.

F_v distribution maps were also developed based on the website and linear interpolation analysis. Figures 6a and 6b show two F_v distribution maps, which are almost equal. The F_v values developed using the website ranged between 1.4 and 2.8, while the F_v values developed using linear interpolation ranged between 1.5 and 2.8. The largest F_v values were observed in the northern part of the city.

The S_{DS} and S_{D1} developed for the study area using the website were acceptable according to the requirement criterion of SNI 1726:2019. Table 4 shows the minimum and maximum S_{DS} and S_{D1} values and the average difference in the S_{DS} and S_{D1} values between the two methods for the SC, SD, and SE site classes. As shown in Table 4, the average difference of S_{DS} and S_{D1} is the absolute values of S_{DS} and S_{D1}. The maximum average difference (ave. diff.) for S_{DS} and S_{D1}, 0.0224 g and 0.0153 g, respectively, were observed in the SD site class. However, the average differences in S_{DS} and S_{D1} for site classes SC and SE were less than 0.0073 g and 0.0044 g, respectively.

Table 4 S_{DS} and S_{D1} performance for all site classes

Site Class	S_{DS} (g)					S_{D1} (g)				
	Website		Linear		Ave. diff.	Website		Linear		Ave. diff.
	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.	
SC	0.68	0.77	0.6767	0.7734	0.0067	0.37	0.41	0.3653	0.4097	0.0044
SD	0.63	0.71	0.6349	0.6925	0.0224	0.46	0.51	0.4599	0.4946	0.0153
SE	0.64	0.71	0.6433	0.706	0.0073	0.58	0.63	0.5788	0.6315	0.0027



(a) (b)

Figure 6 F_v distribution maps developed using website software (a) and linear interpolation (b)

4. Conclusions

Evaluations of site coefficients estimated using the website and straight-line interpolation methods were performed for 203 boring positions in Semarang City. No significant differences were found in the F_a and F_v site coefficients between the two methods. The largest difference in the F_a site coefficient calculations was observed for the SD and SE site classes. The difference in site coefficients for the SD and SE site soil classes was less than 0.03, while, for the SC site soil class, the difference was less than 0.01. In terms of site coefficient F_v, the largest difference was observed for the SD and SE site soil classes with a maximum of 0.04. However, the difference in site coefficient F_v for site class SC was less than 0.02. When calculating F_a and F_v site coefficients, the linear interpolation method from SNI 1726:2019 is better compared to the calculated using MCE_R-S_S, MCE_R-S_1, S_{DS}, and S_{D1} values obtained from the website.

No significant differences in the design response spectral acceleration S_{DS} and S_{D1} values were found for any of the site classes. The largest design response spectral acceleration difference in SD between the two methods was less than 0.02 g, while, for the SC and SE site classes, the differences were less than 0.005 g.

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Site Coefficient and Design Spectral Acceleration Evaluation of New Indonesian 2019 Website Response Spectra

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Abstract. Calculation of site coefficient and design response spectral acceleration are two important steps in the seismic design of buildings. According to Indonesian Seismic Code 2019, two information requirements for site coefficient calculations are the site soil class and Risk-targeted Maximum Considered Earthquake (MCE_R-S_S for short and MCE_R-S_1 for long period) spectral acceleration. Three different hard/SC, medium/SD and soft/SE are typically site soil classes used for building designs. Two different site coefficients (Fa for MCE_R-S_S and Fv for MCE_R-S_1 spectral acceleration) are used for surface and design response spectral acceleration calculations. The Indonesian Seismic Code provides two (Fa and Fv) tables for calculating site coefficients. If the MCE_R-S_S or MCE_R-S_1 values developed for a specific site are not exactly equal to the values in Fa or Fv tables, the site coefficients can then be predicted using straight-line interpolation between the two closest Fa or Fv values within the tables. When the straight-line interpolation is adjusted for Fa or Fv calculation, different results were observed in comparison to the values developed using website-based software (prepared by Ministry of Public Works and Human Settlements). This study evaluates site coefficients and design response spectral acceleration predictions in Semarang City, Indonesia, according to straight-line interpolation method and website software calculations. The study was conducted at 203 soil boring positions in the study area. The site soil classes were predicted using average standard penetration test values (N-SPT) of the topmost 30 m soil deposit layer (N30). Three different site soil classes were observed in the study area. On average, the largest differences between the two analysis (linear interpolation and website) methods in the site coefficient values and design response spectral acceleration calculation were observed for the SD and SE classes. However, for the SC site soil class, the difference was small, with their values approximately similar.

Keywords: Design response spectral acceleration; MCE_R; N-SPT; Site coefficient; Straight-line interpolation

1. Introduction

The new National Seismic Code of Indonesia (SNI 1726:2019, 2019) was announced in

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2019. Some of the information introduced in this new seismic code was partially adopted from the American Standard Code for Seismic Design ASCE/SEI 7-16, specifically the site coefficient values and design response spectral acceleration calculation methods. Additional information for developing the site coefficients was adopted from Stewart and Seyhan (2013). Due to the improved methods described in ASCE/SEI 7-16 for developing site coefficients for site soil classes SD and SE, not all the information described in the American Code was adopted by SNI 1726:2019. Specifically, the site coefficients for the SD and SE classes presented in SNI 1726:2019 were completely adopted from Stewart and Seyhan (2013).

Following the SNI 1726:2019, the Ministry of Public Works and Human Settlements announced a new website software (online facility) for site coefficient and design response spectral acceleration calculation. Site or building position coordinates (in terms of longitude and latitude) and site soil class are two information requirements for design response spectral acceleration calculations. Risk-targeted Maximum Considered Earthquake (MCE_R) acceleration, MCE_R-S_S for short and MCE_R-S_1 for long periods, (Luco et al., 2007; Allen et al., 2015; Sengara et al., 2020), and two design response spectral acceleration, S_{DS} and S_{D1}, are four important values calculated by the website facility software. However, no information related to site coefficients F_a for short and F_v for long periods can be obtained from the new website. Thus, these values can be calculated using Equation 1 and Equation 2. All S_{DS}, S_S (MCE_R-S_S), S_{D1}, and S_1 (MCE_R-S_1) values can be obtained from the website.

$$F_a = \frac{S_{DS}}{\frac{2}{3} S_S} \tag{1}$$

$$F_v = \frac{S_{D1}}{\frac{2}{3} S_1} \tag{2}$$

To verify the F_a and F_v site coefficients estimated using Equations 1 and 2, straight-line interpolation can be conducted using the S_S and S_1 website calculations and applying site coefficient (F_a and F_v) table data provided by SNI 1726:2019. F_a and F_v are then estimated following the procedure described by SNI 1726:2019. Equation 3 shows a simple formula for F_a and F_v site coefficients calculation. Figure 1 shows a diagram of the straight-line interpolation of the F_a and F_v calculation. F and M_W represent the site coefficient to be estimated and the MCE_R value obtained from the website, respectively; M_{1S} and M_{2S} represent two boundary MCE_R values close to M_W; F_{1S} and F_{2S} represent the site coefficients for M_{1S} and M_{2S}, respectively; and M_{1S}, M_{2S}, F_{1S}, and F_{2S} are the four values obtained from the SNI 1726:2019 tables. F_a and F_v are estimated separately using Equation 3.

$$F = \left(\frac{F_{2S} - F_{1S}}{M_{2S} - M_{1S}} \right) (M_W - M_{1S}) + F_{1S} \tag{3}$$

This paper describes the site coefficients and design response spectral acceleration verification calculated using the website facility and the straight-line interpolation described in SNI 1726:2019. The objective of the study was to evaluate whether or not the website performed the analysis following the same procedures used by SNI 1726:2019. The study was performed in Semarang City, Indonesia, and conducted at 203 soil boring investigation positions. The study was performed as part of seismic microzonation research of the city. One of the important information requirements for seismic microzonation is the development of soil amplification or site coefficient distribution map at the study area. In

this study, the standard penetration test (N-SPT) data observed during boring investigation were used for site class calculation. All boring investigations in this study were conducted at a minimum depth of 30 m and a maximum depth 60 m. The average standard penetration test (N-SPT) of the topmost 30 m soil deposit layer (N_{30}) of every boring position was used for site soil class interpretation (Moghaddam, 2011; Partono et al., 2019; Syaifuddin et al., 2020). Figure 2a shows the 203 boring positions and the N_{30} distribution within the study area. Figure 2b shows the distribution of the site soil classes developed based on the N_{30} data (Partono et al., 2021). The maximum N-SPT data obtained from the boring investigation was 60. Following the procedure described by SNI 1726:2019, the N_{30} value was estimated using Equation 4, where d_i and N_i represent the thickness and N-SPT value of any soil layer "i", respectively.

The parameter that can also be used for site interpretation is the average shear wave velocity (V_S) of the topmost 30 m soil deposit (V_{S30}) (Naji et al., 2020). The V_{S30} value can be calculated using the same method as that shown in Equation 4 and replacing the N_i value with V_{Si}. The V_S value can be observed using seismic refraction multichannel analysis of surface waves (MASW) or seismometer array investigations. Prakoso et al. (2017) described a comparative study of V_S value obtained from MASW investigation and soil boring (N-SPT) data. The V_S value developed using MASW was more reliable compared to that developed based on the N-SPT data. Pramono et al. (2020) described the predominant frequency investigation at Lombok Island following the 2018 earthquake event. The greater the V_{S30} value used, the greater the predominant frequency obtained from the wavelet analysis of the ground motion. Additionally, development of V_{S30} and predominant frequency correlation was also conducted by Pramono et al. (2017) in the Palu area.

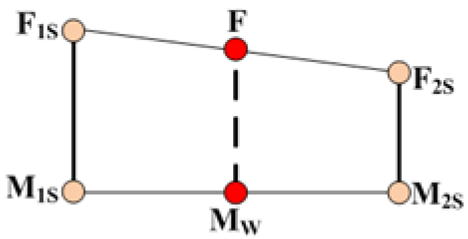


Figure 1 Straight-line interpolation for F_a and F_v calculations

$$N_{30} = \frac{\sum_{i=i}^{i=n} d_i}{\sum_{i=i}^{i=n} \frac{d_i}{N_i}} \tag{4}$$

2. Methods

The evaluation of the site coefficients from the study area was conducted following five basic steps:

- Site class interpretation;
- MCE_R (S_S and S_1) and design response spectral acceleration calculation using the website;
- Site coefficient calculation based on the website output;
- Site coefficient calculation based on SNI 1726:2019 tables and procedures;

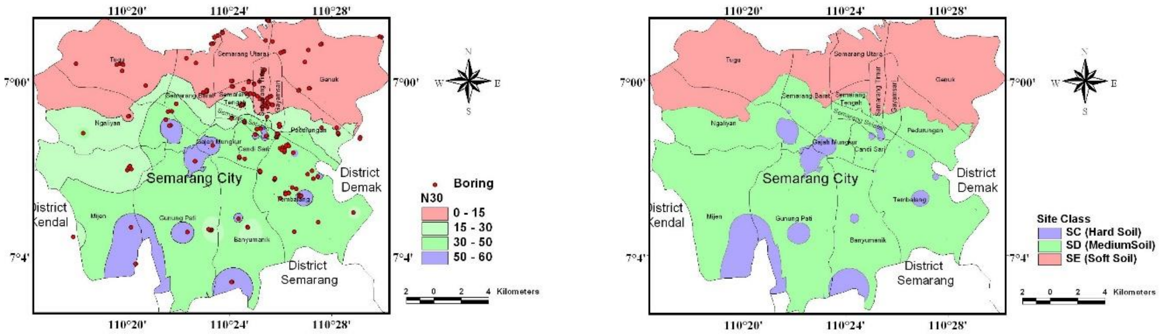
- Comparative analysis of the two different approaches in terms of their calculated site coefficients and design response spectral acceleration: the website output and straight-line interpolation.

2.1. Site Soil Class Interpretation

Site soil class interpretation (Figure 2b) was conducted for the 203 boring positions using N_{30} data, with the site soil classes interpreted according to SNI 1726:2019. Table 1 shows the basic classification criteria for each site soil class. Only three different site soil classes are presented in this table, site classes SA/hard rock, SB/rock, and SF/specific soil unavailable. Figure 2b shows the corresponding site soil class distribution according to the site classification information in Table 1. The site class distribution in the study area is dominated by the SD and SE classes; meanwhile, site class SC was observed in small areas in the middle and southern parts of the city (Partono et al., 2021).

Table 1 Site classification

Site Class	N_{30}
SC	> 50
SD	15–50
SE	< 15



(a) (b)

Figure 2 (a) Boring investigation and N_{30}; and (b) site soil classes distribution maps

2.2. MCE_R and Design Response Spectral Acceleration Calculation

MCE_R calculations were performed for the 203 boring positions using the website. According to the site class distribution of the study area, different MCE_R-S_S and MCE_R-S_1 distributions were also observed in the study area. Table 2 shows the total data for each site class as well as the distribution of the minimum and maximum MCE_R-S_S, MCE_R-S_1, S_{DS}, and S_{D1} for the three different site classes developed using the website.

Table 2 S_S, S_1, S_{DS}, and S_{D1} spectral acceleration values obtained from the website

Site Class	Total Data	MCE_R-S_S(g)		S_{DS} (g)		MCE_R-S_1 (g)		S_{D1} (g)	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
SC	34	0.8459	0.9668	0.68	0.77	0.3653	0.4097	0.37	0.41
SD	90	0.8098	0.9579	0.63	0.71	0.3546	0.4071	0.46	0.51
SE	79	0.696	0.9274	0.64	0.71	0.3185	0.3936	0.58	0.63

2.3. Website-calculated Fa and Fv values

F_a and F_v site coefficient calculations were performed according to the MCE_R-S_S, MCE_R-S_1, S_{DS}, and S_{D1} values obtained from the website. The site coefficients were then estimated

using Equations 1 and 2. Table 3 shows the distribution of the minimum and maximum F_a and F_v values using these four values. According to the boundary values of F_a and F_v described in the SNI 1726:2019 tables, the minimum and maximum F_a values developed in the study area were divided into two different boundary values. A few MCE_R-S_S values were lower than 0.75 g; however, most of the MCE_R-S_S values were between 0.75 and 1 g.

2.4. Site Coefficients F_a and F_v SNI 1726:2019

Straight-line interpolation was also performed for F_a and F_v calculation using Equation 3 and the F_a and F_v tables provided by SNI 1726:2019. According to the MCE_R-S_S and MCE_R-S_1 values obtained from the website, the minimum and maximum boundaries for these two site coefficients could be estimated. Thus, Table 3 shows the boundaries of the F_a and F_v values used for the straight-line interpolation calculations. The F_a and F_v boundary values displayed in Table 3 were obtained from SNI 1726:2019.

Table 3 F_a and F_v distribution developed using the website and SNI 1726:2019 tables

Site Class	Total Data	Linear Interpolation (SNI)					Website				Diff. > 0.01 (%)	
		F_a			F_v		F_a		F_v		F_a	F_v
		MCE_R-S_S(g)			MCE_R-S_1 (g)		Min.	Max.	Min.	Max.		
		0.5	0.75	1.0	0.3	0.4						
SC	34	1.2	1.2	1.2	1.5	1.5	1.19	1.21	1.478	1.519	0	58.82
SD	90	1.4	1.2	1.1	2.0	1.9	1.112	1.167	1.879	1.949	3.41	56.82
SE	79	1.7	1.3	1.1	2.8	2.4	1.148	1.4	2.401	2.732	13.92	50.63

3. Results and Discussion

The MCE_R-S_S values for the SC site class (Table 2) range from 0.8459 to 0.9668 g, while the F_a values for the SC site class developed according to the website (Table 3) range between 1.19 and 1.21. All the F_a values developed from the website are consistent with and almost equal to those from SNI 1726:2019 (Table 3). As can be seen in Table 3, the F_a values from SNI 1726:2019 are constant and equal to 1.2. The difference between the F_a values developed using the website data and those from SNI 1726:2019 is less than 0.01. According to Table 3, for all 34 data, the percentage of total data with a minimum difference of 0.01 is 0%. Figure 3a shows the distribution of the F_a site coefficients for the SC site class in terms of the MCE_R-S_S values. The linear and website legends inside this figure represent the straight-line interpolation following SNI 1726:2019 and the website data acquisition. The R^2 (coefficient of determination) value for site class SC is close to 0, because the F_a values estimated using these two models are nearly constant for all MCE_R-S_S values. The R^2 value is used for evaluation of the fitting line (linear fit model) performance. The evaluation was performed for the distribution of F_a or F_v to the linear regression line model. The minimum and maximum R^2 values are 0 and 1 (100%), respectively. The higher the R^2, the better the linear fitting model difference for the F_a or F_v data distribution.

The distribution of the MCE_R-S_S values for the SD site class in the study area was almost equal to that of the SC site class. Table 2 shows the distribution of MCE_R-S_S for the SD site class, with the values ranging from 0.8098 to 0.9579 g. Following the same procedure as that of the SC site class, the F_a site coefficients for the SD site class in the study area range between 1.2 and 1.1. Due to the MCE_R-S_S being distributed around 1, the F_a values obtained from the study area are close to 1.1: As shown in Table 3, the F_a values range between 1.112 and 1.167. The total percent of data with a minimum difference of 0.01 are 3.41%. Figure 3b shows the distribution of the F_a values for site class SD in terms of the MCE_R-S_S values.

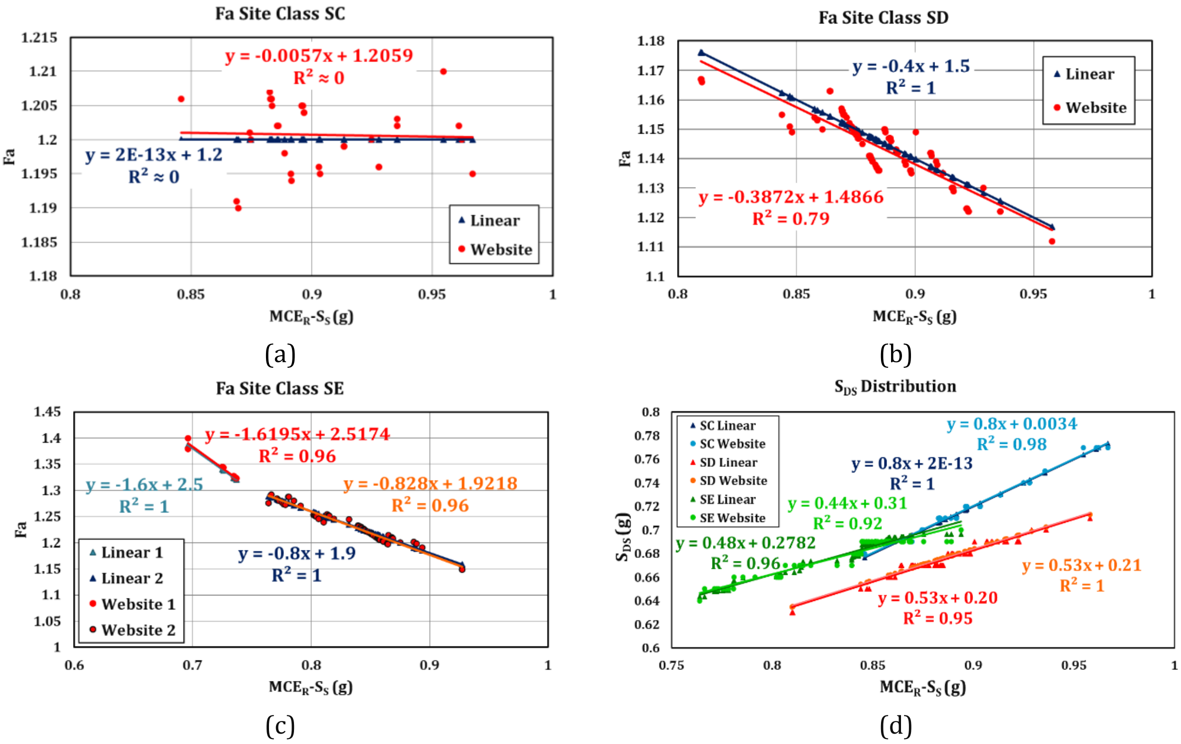


Figure 3 F_a distributions in terms of MCE_R-S_S values for: (a) SC; (b) SD; and (c) SE site classes; and (d) the correlation of S_{DS} and MCE_R-S_S from the linear interpolation and website software

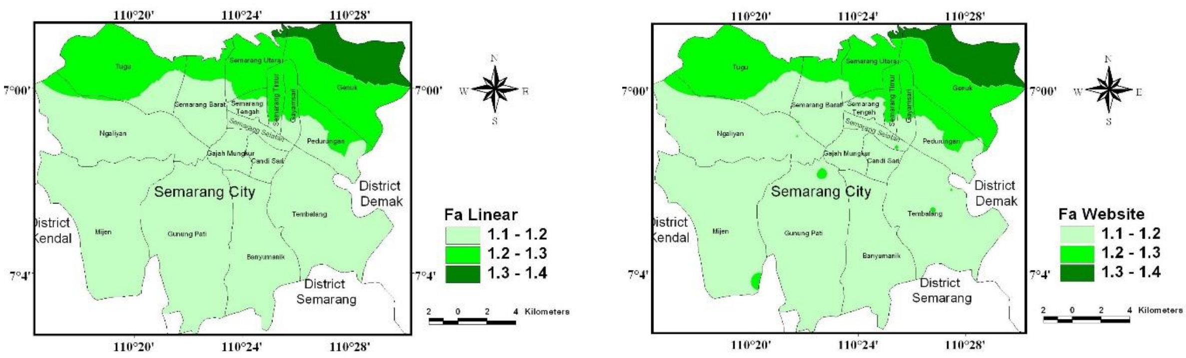
As can be seen in Figure 3b, the R^2 value obtained from the regression analysis is 0.7858, or less than 1. The straight-line interpolation values developed according to the SNI 1726:2019 data and tables were better compared to the F_a values developed using the website. However, on average, the absolute difference in the F_a values developed between these two models was 0.0105, and the line distributions were almost identical (i.e., coincided).

The MCE_R-S_S distribution of the SE site class values estimated from the website ranged between 0.696 and 0.9274 g. According to SNI 1726:2019, all MCE_R-S_S for site class SE were distributed between two different boundary values, from 0.5 through 0.75 g for the first boundary and from 0.75 through 1 g for the second boundary. The straight-line interpolation for all MCE_R-S_S was also separated into two different boundary values. The first F_a boundary values (6 data) were distributed between 1.4 and 1.323; however, the second F_a (73 data) site coefficients were distributed between 1.292 and 1.148. Figure 3c shows the distribution of the F_a values for the SE site class. Two different straight-line interpolations can be observed in this figure in accordance with the two different boundary values from SNI 1726:2019. The absolute average difference in F_a for site class SE is 0.029. As can be seen in Table 3, 13.92% of the 79 data have a minimum difference of 0.01.

F_a and F_v are the two site coefficients used for calculating surface spectral acceleration and design response spectral acceleration. The performance of the different values of these coefficients developed using the two different procedures (straight line interpolation and using website facility) can be neglected or avoided, since there was no significant difference in the design response spectral acceleration results between these two methods. The difference in the accuracy value used for both methods will sometimes produce different site coefficients and directly impact the performance of the S_{DS} and S_{D1} outputs for all site soil classes.

To verify the performance of the F_a and F_v values estimated using these two methods, design response spectral acceleration calculation was also conducted in this study. The purpose of this analysis was to verify the performance of the design response spectral acceleration S_{DS} and S_{D1} values according to the site coefficient values calculated using the two different methods. Figure 3d shows the performance of the S_{DS} design response spectral acceleration in terms of MCE_R-S_S developed from the website and straight-line interpolation. As can be seen in Figure 3d, a strong correlation between S_{DS} in terms of MCE_R-S_S was observed in this study. According to this figure, there are no significant differences in the S_{DS} performance estimated using the website versus SNI 1726:2019 straight line interpolation procedures for all three site classes (SC, SD, and SE).

The F_a distribution map developed from the 203 boring positions was also constructed based on the website and linear interpolation analysis. Figure 4a and 4b show the two F_a distribution maps, which are almost equal. Specifically, the F_a values from the study area range between 1.2 and 1.4, with the largest Fa values observed in a small north-eastern portion of the city.



(a) (b)

Figure 4 F_a distribution maps developed using: (a) website software; and (b) linear interpolation

Site coefficient evaluation was also conducted for long-period MCE_R-S_1 spectral acceleration. Using the same procedure as that used for MCE_R-S_S, the evaluation was performed for the SC, SD, and SE site classes. Based on the minimum and maximum MCE_R-S_1 values estimated using the website, all MCE_R-S_1 values in the study area were distributed between 0.3185 and 0.4097 g (see Table 2) or approximately between 0.3 and 0.4 g. For site classes SC and SD, there was one boring position with a MCE_R-S_1 value greater than 0.4 g. Figures 5a, b, and c show the distribution of the site coefficient F_v for the SC, SD, and SE site soil classes, respectively.

All the F_v values estimated using the website and straight-line interpolation were almost equal or coincided except for site class SD. As shown in Figure 5b, most of the F_v values of the SD site class developed using the website are greater than those developed using straight-line interpolation. The R^2 value for this model was far from 1. The F_v values for site class SD from the website calculation were far from the linear model described by SNI 1726:2019. The R^2 for site class SC was not available (close to 0), because the F_v and MCE_R-S_1 correlations were nearly constant or almost equal. A good F_v and MCE_R-S_1 correlation was observed for site class SE (see Figure 5c) for the website output and straight-line interpolation methods. The R^2 obtained for this site class was nearly 1. On average the absolute differences between F_v were 0.015, 0.036, and 0.033 for the SC, SD, and SE site classes, respectively. According to Table 3, the percent of total data with a minimum difference of 0.01 for the SC, SD, and SE site classes is greater than 50%.

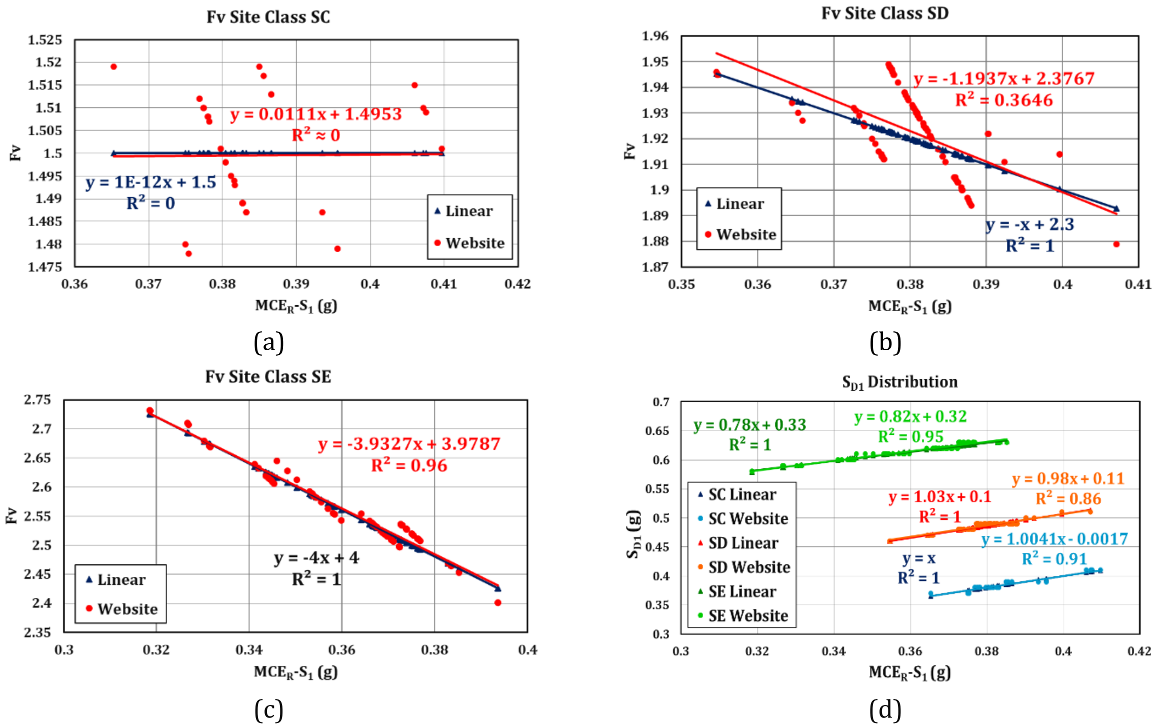


Figure 5 F_v distributions in terms of MCE_R-S_1 values for: (a) SC; (b) SD; (c) SE site classes; and (d) the correlation of S_{D1} and MCE_R-S_1 developed based on linear interpolation and website software

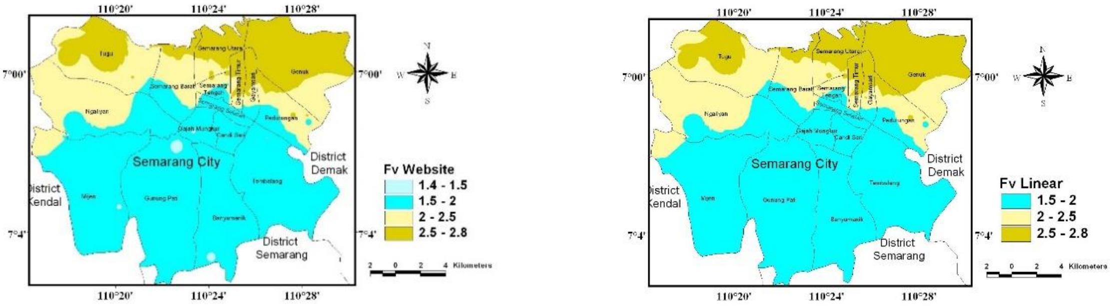
Figure 5d shows the S_{D1} design response spectral acceleration performance in terms of MCE_R-S_1 values estimated using the same methods as used in the S_{DS} calculation. As can be seen in Figure 5d, a good correlation between S_{D1} in terms of MCE_R-S_1 was observed in this study. Also, according to this figure, there are no significant differences in the S_{D1} performance for the SC, SD, and SE site class estimates between the website and straight-line interpolation of SNI 1726:2019 procedures.

F_v distribution maps were also developed based on the website and linear interpolation analysis. Figures 6a and 6b show two F_v distribution maps, which are almost equal. The F_v values developed using the website ranged between 1.4 and 2.8, while the F_v values developed using linear interpolation ranged between 1.5 and 2.8. The largest F_v values were observed in the northern part of the city.

The S_{DS} and S_{D1} developed for the study area using the website were acceptable according to the requirement criterion of SNI 1726:2019. Table 4 shows the minimum and maximum S_{DS} and S_{D1} values and the average difference in the S_{DS} and S_{D1} values between the two methods for the SC, SD, and SE site classes. As shown in Table 4, the average difference of S_{DS} and S_{D1} is the absolute values of S_{DS} and S_{D1}. The maximum average difference (ave. diff.) for S_{DS} and S_{D1}, 0.0224 g and 0.0153 g, respectively, were observed in the SD site class. However, the average differences in S_{DS} and S_{D1} for site classes SC and SE were less than 0.0073 g and 0.0044 g, respectively.

Table 4 S_{DS} and S_{D1} performance for all site classes

Site Class	S_{DS} (g)					S_{D1} (g)				
	Website		Linear		Ave. diff.	Website		Linear		Ave. diff.
	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.	
SC	0.68	0.77	0.6767	0.7734	0.0067	0.37	0.41	0.3653	0.4097	0.0044
SD	0.63	0.71	0.6349	0.6925	0.0224	0.46	0.51	0.4599	0.4946	0.0153
SE	0.64	0.71	0.6433	0.706	0.0073	0.58	0.63	0.5788	0.6315	0.0027



(a) (b)

Figure 6 F_v distribution maps developed using website software (a) and linear interpolation (b)

4. Conclusions

Evaluations of site coefficients estimated using the website and straight-line interpolation methods were performed for 203 boring positions in Semarang City. No significant differences were found in the F_a and F_v site coefficients between the two methods. The largest difference in the F_a site coefficient calculations was observed for the SD and SE site classes. The difference in site coefficients for the SD and SE site soil classes was less than 0.03, while, for the SC site soil class, the difference was less than 0.01. In terms of site coefficient F_v, the largest difference was observed for the SD and SE site soil classes with a maximum of 0.04. However, the difference in site coefficient F_v for site class SC was less than 0.02. When calculating F_a and F_v site coefficients, the linear interpolation method from SNI 1726:2019 is better compared to the calculated using MCE_R-S_S, MCE_R-S_1, S_{DS}, and S_{D1} values obtained from the website.

No significant differences in the design response spectral acceleration S_{DS} and S_{D1} values were found for any of the site classes. The largest design response spectral acceleration difference in SD between the two methods was less than 0.02 g, while, for the SC and SE site classes, the differences were less than 0.005 g.

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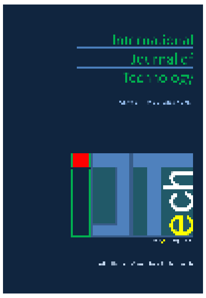

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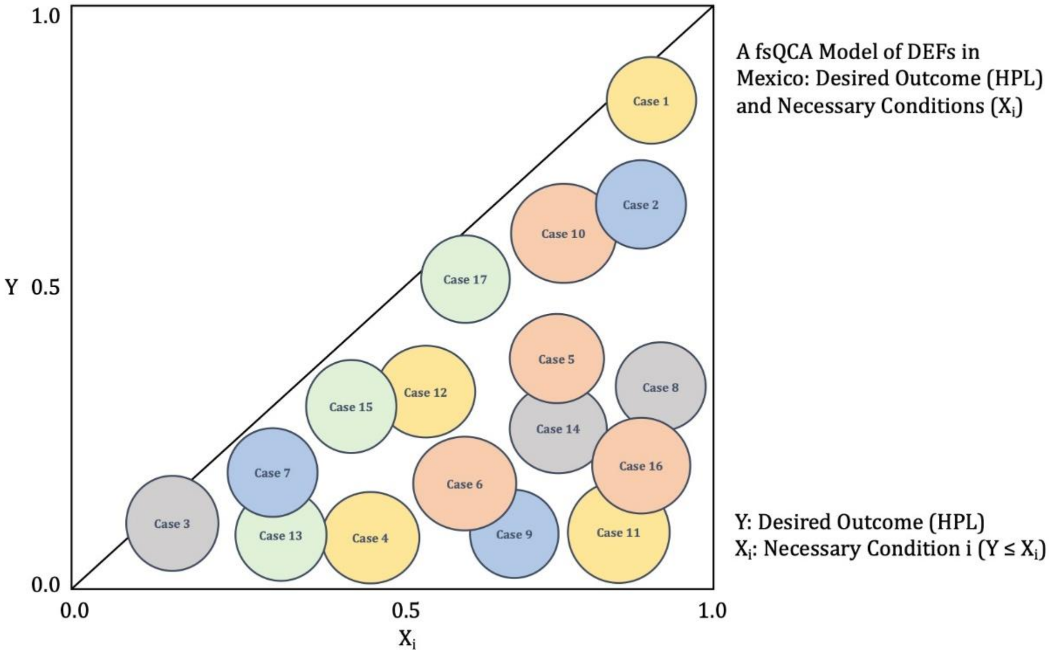

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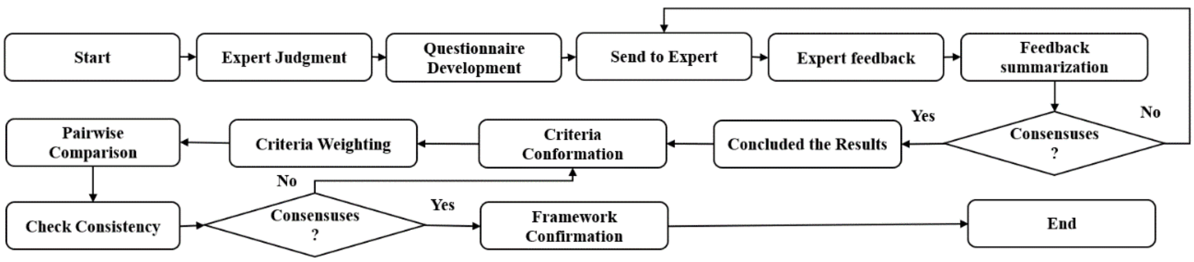

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Demographic	Classification	n	(%)
Main business activity	Automobile, auto parts	19	15.20
	Food, beverages, tobacco	13	10.40
	Plastic, rubber products	11	8.80
	More than one main product	9	7.20
	Chemicals, chemical products	6	4.80
	Iron, steel	6	4.80
	Other electronics and components	6	4.80
	Metal products	5	4.00
	Machinery, equipment, tools	5	4.00
	Non-ferrous metals	4	3.20
	Textiles	3	2.40
	Other non-metallic mineral products	2	1.60
	Other manufacturing	36	28.80
Company size	Large (≥ 200 employees)	55	44.00
	Medium (50–199 employees)	35	28.00
	Small (< 50 employees)	35	28.00
Gender of CEO	Male	117	93.60
	Female	8	6.40
Nationality of CEO	Thai	96	76.80
	Foreign	29	23.20

The Role of Leader and the Effect of Customer's Smart Factory Investment on Firm's Industry 4.0 Technology Adoption in Thailand

Kwanchanok Chumnumporn, Chawalit Jeenanunta, Suchinthara Simpan, Kornkanok Srivat, Vararat Sanprasert

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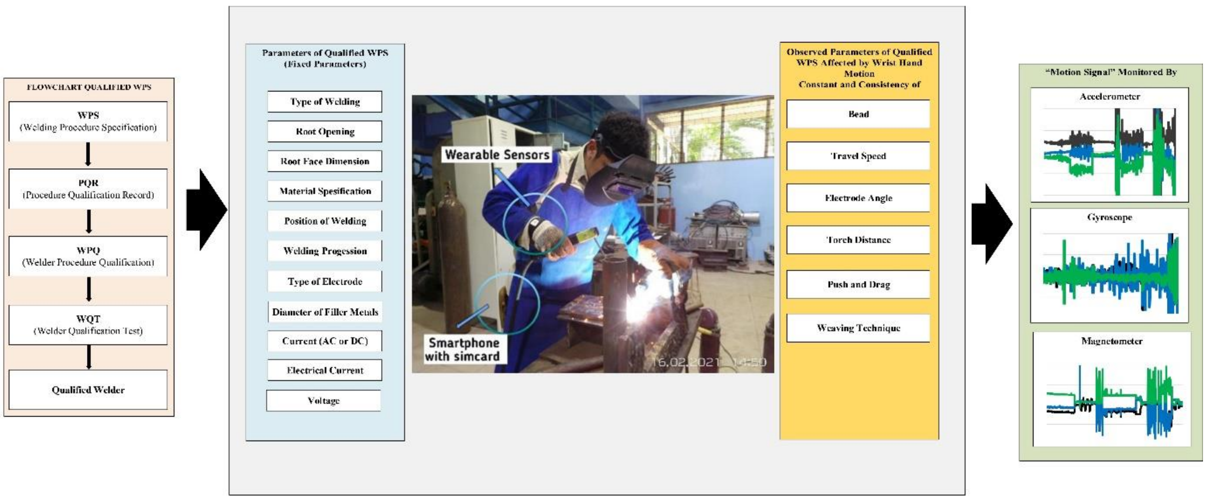

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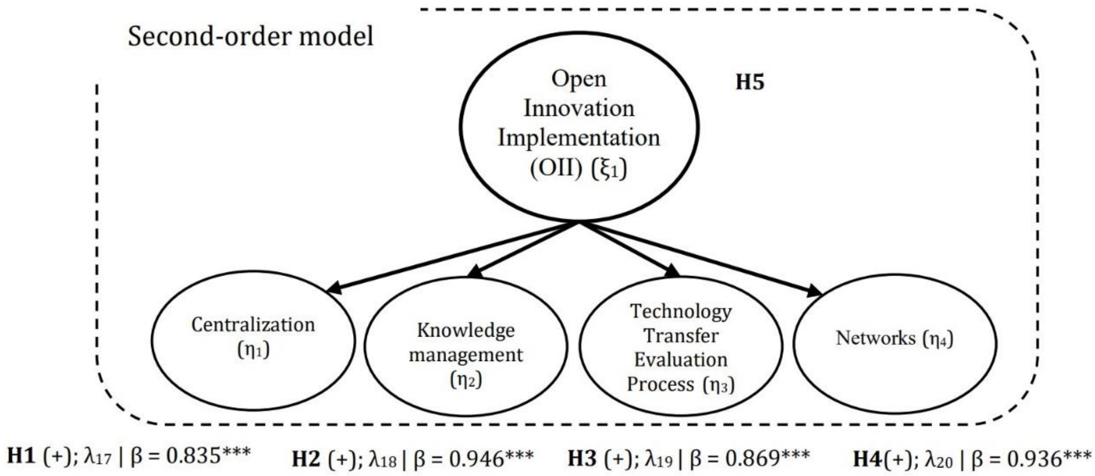

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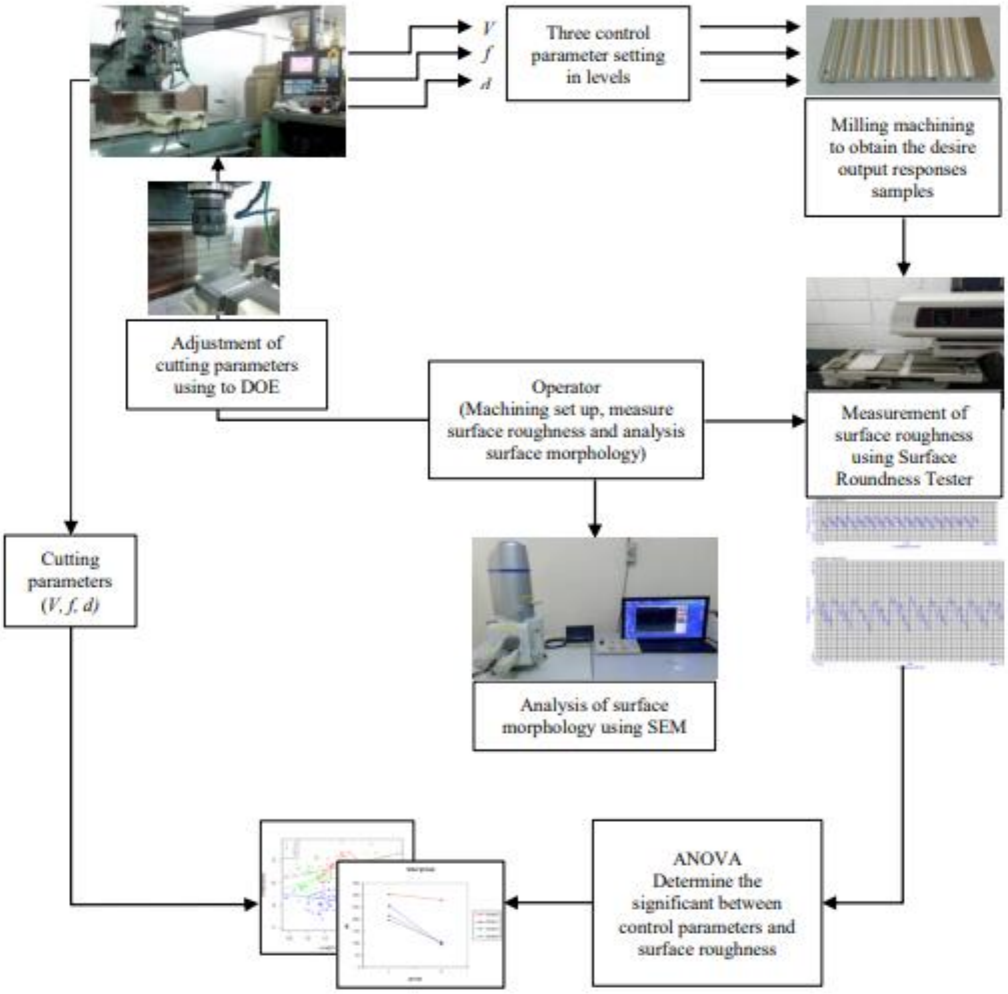

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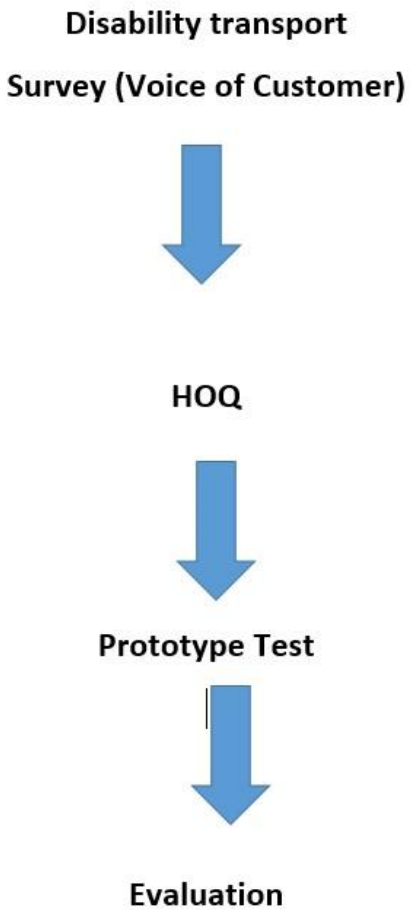

[House-of-Quality Approach for the Design of a Minibus to Transport Visually Impaired and Wheelchair-bound Passengers](https://doi.org/10.14716/ijtech.v13i1.4290)

Sugiono Sugiono, Adam Pratomo, Willy Satrio Nugroho

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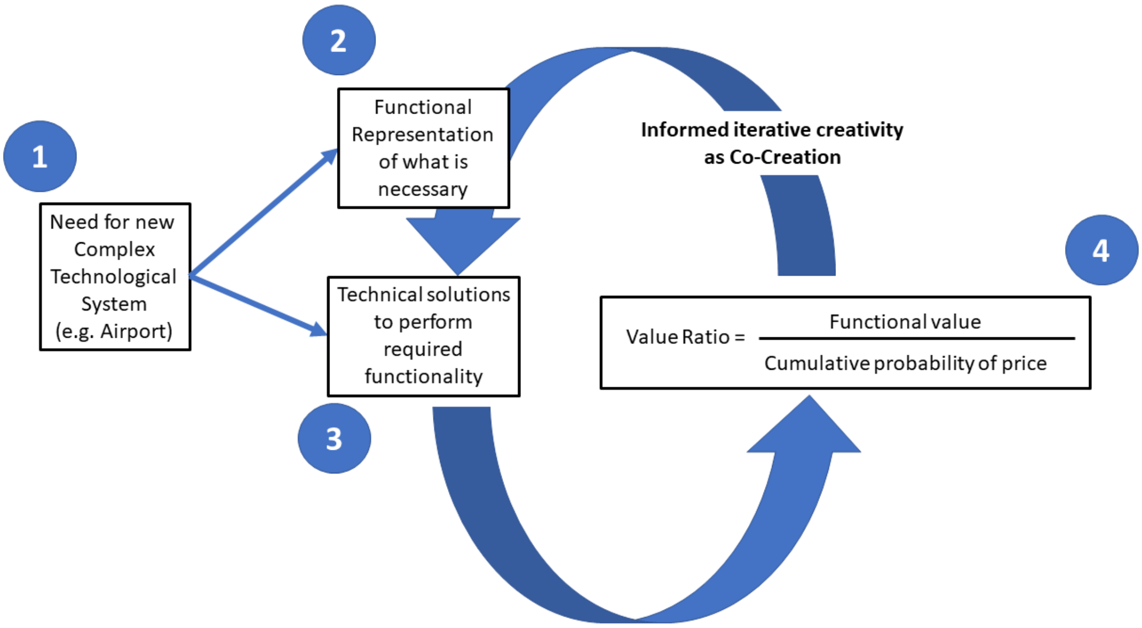

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Roy Woodhead, Mohammed Ali Berawi

Publication Date (Online):
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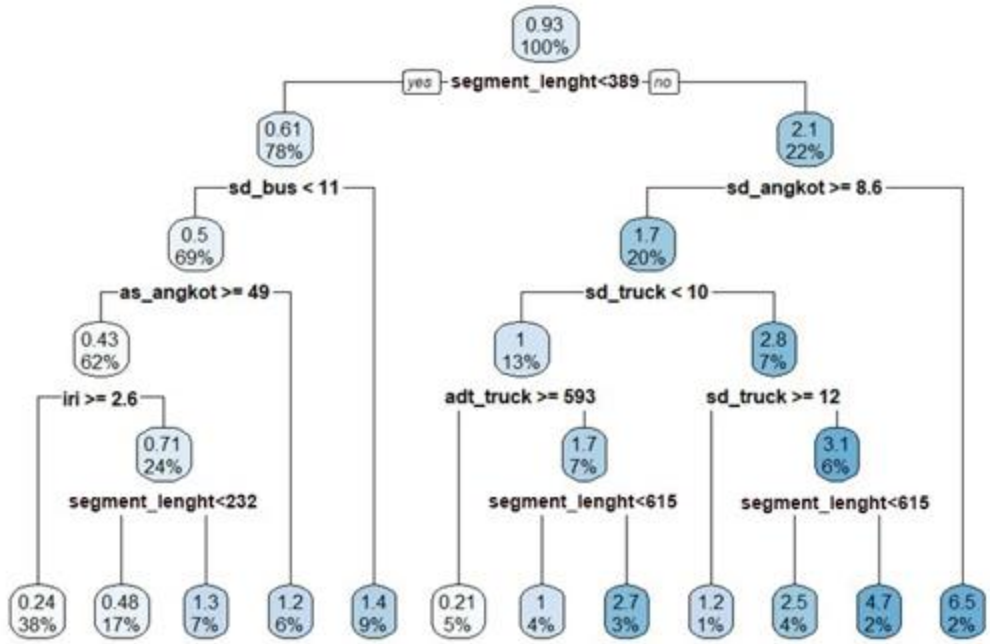

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Martha Leni Siregar, Tri Tjahjono, Nahry Yusuf

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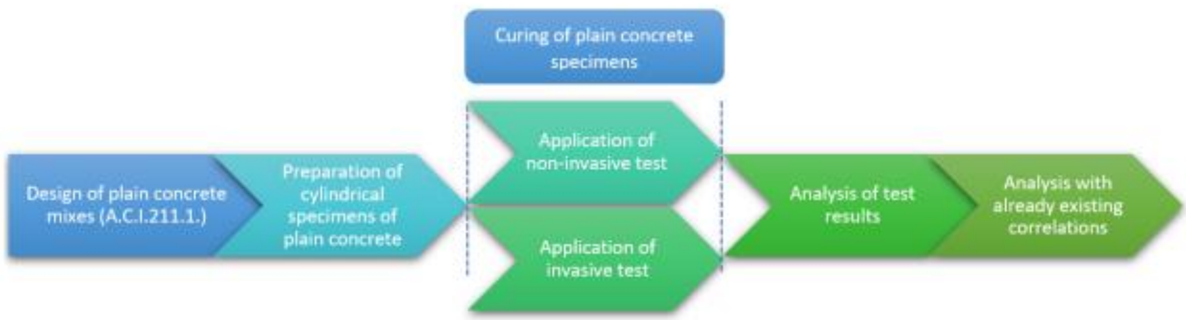

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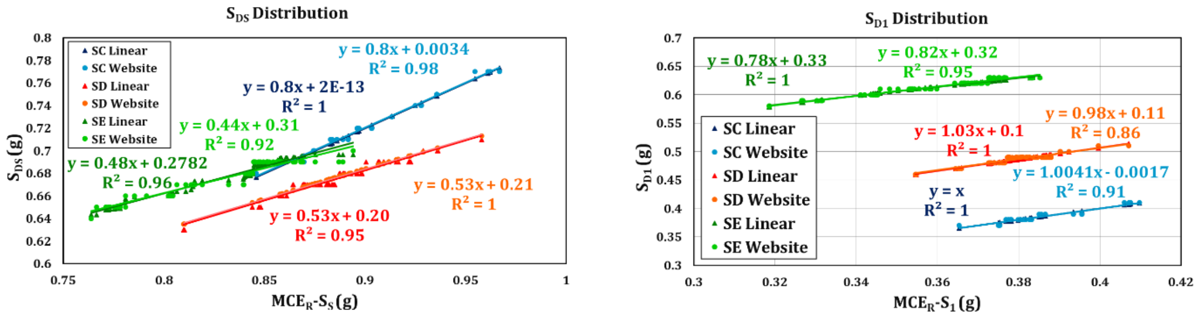

[Site Coefficient and Design Spectral Acceleration Evaluation of New Indonesian 2019 Website Response Spectra]

Windu Partono, Masyhur Irsyam, Ramli Nazir, Muhammad Asrurifak, Undayani Cita Sari

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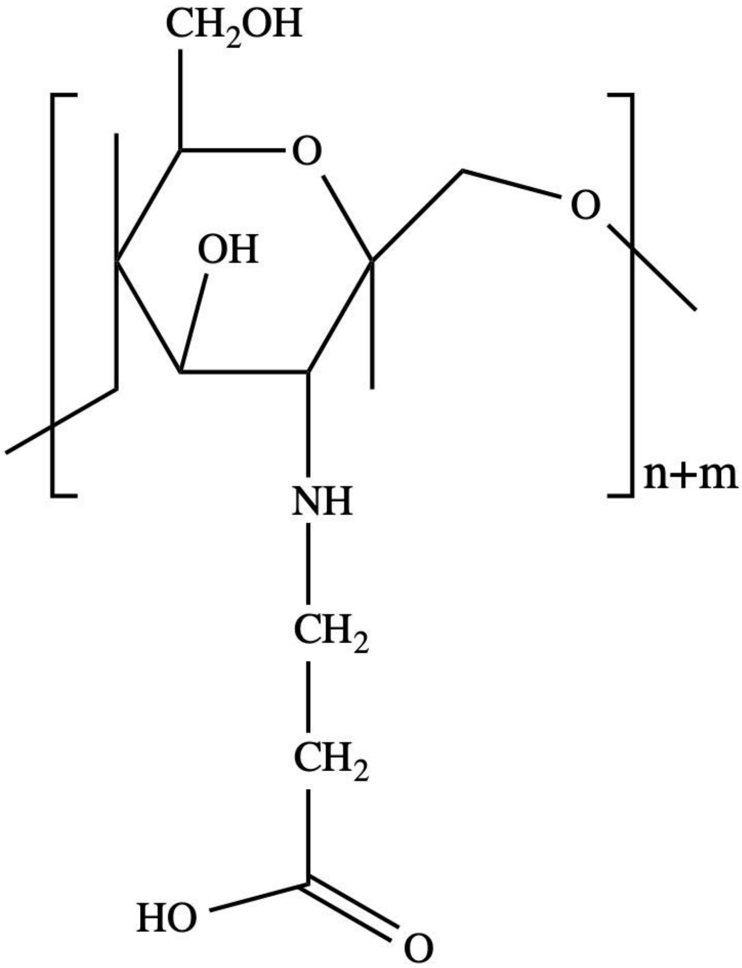

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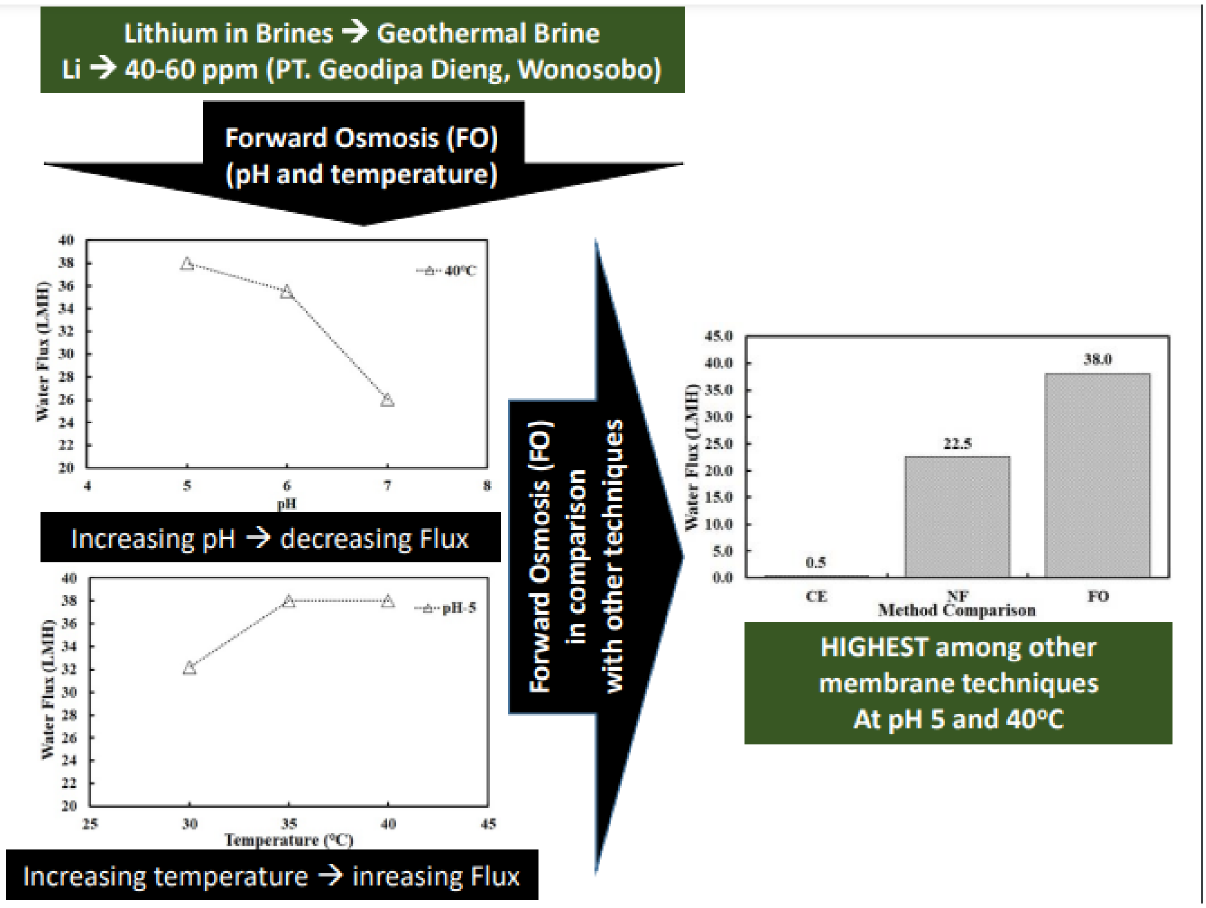

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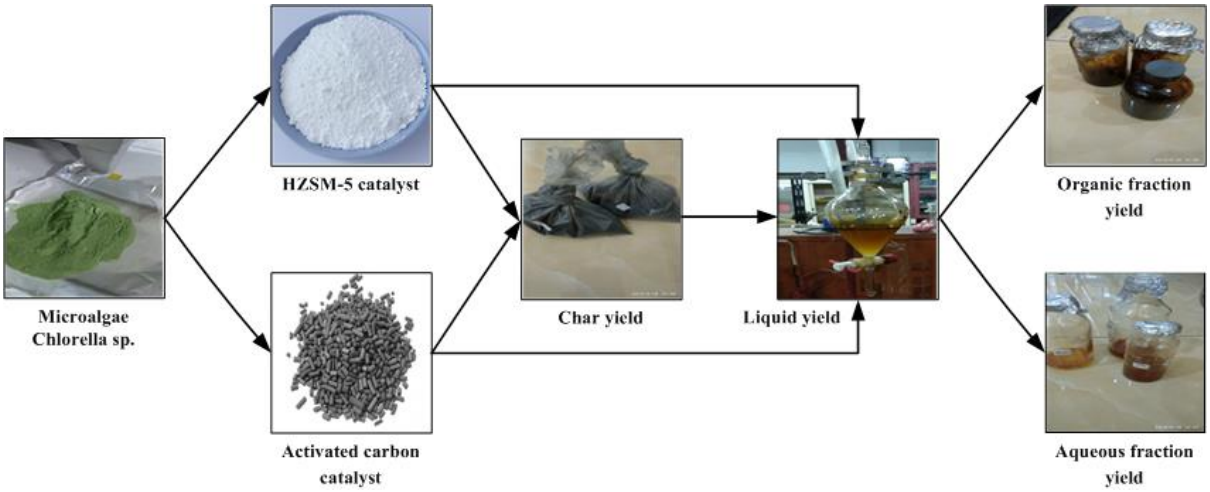

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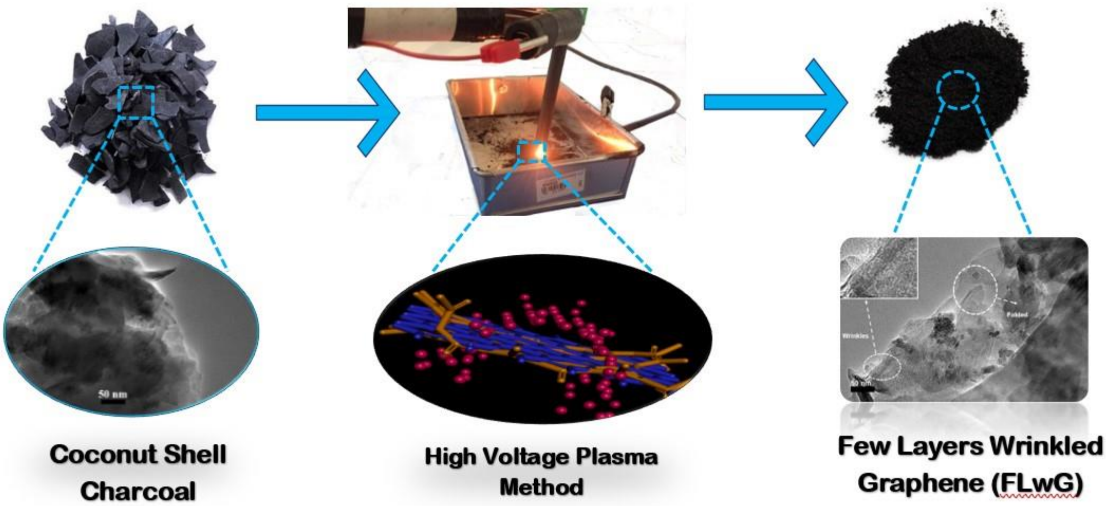

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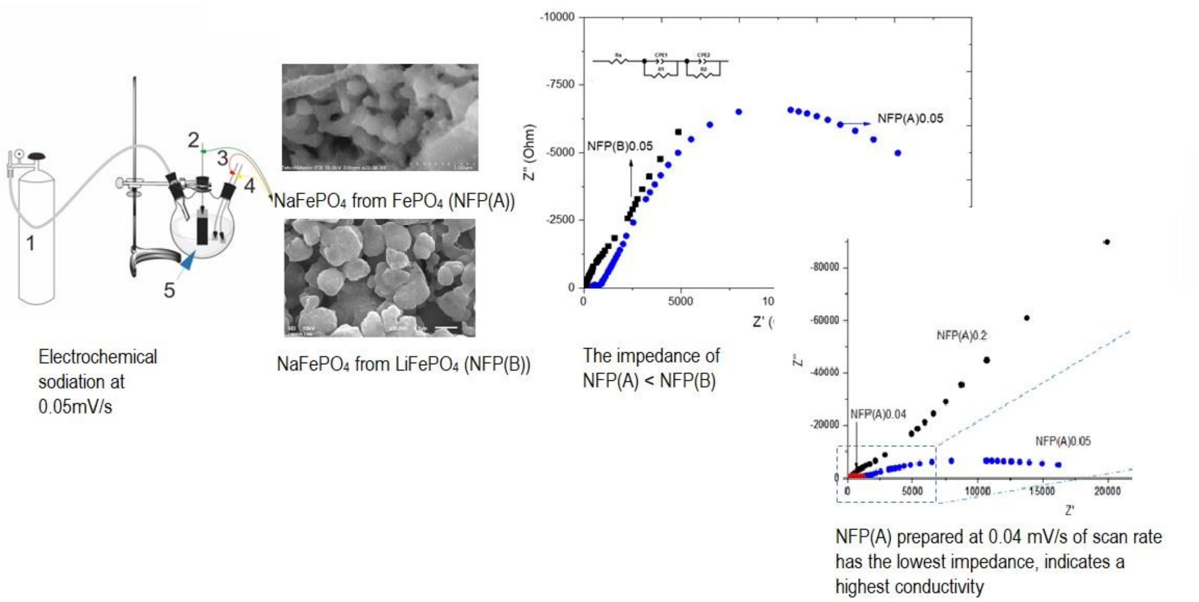

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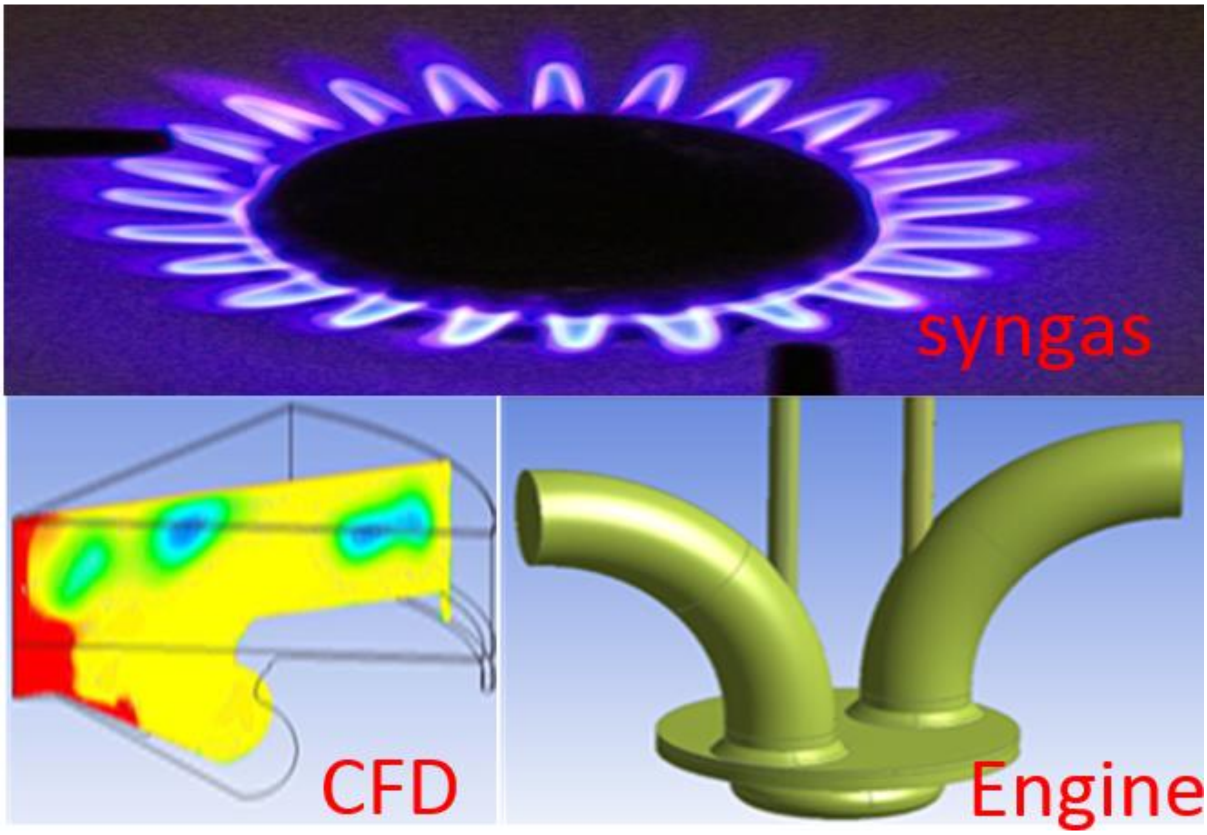

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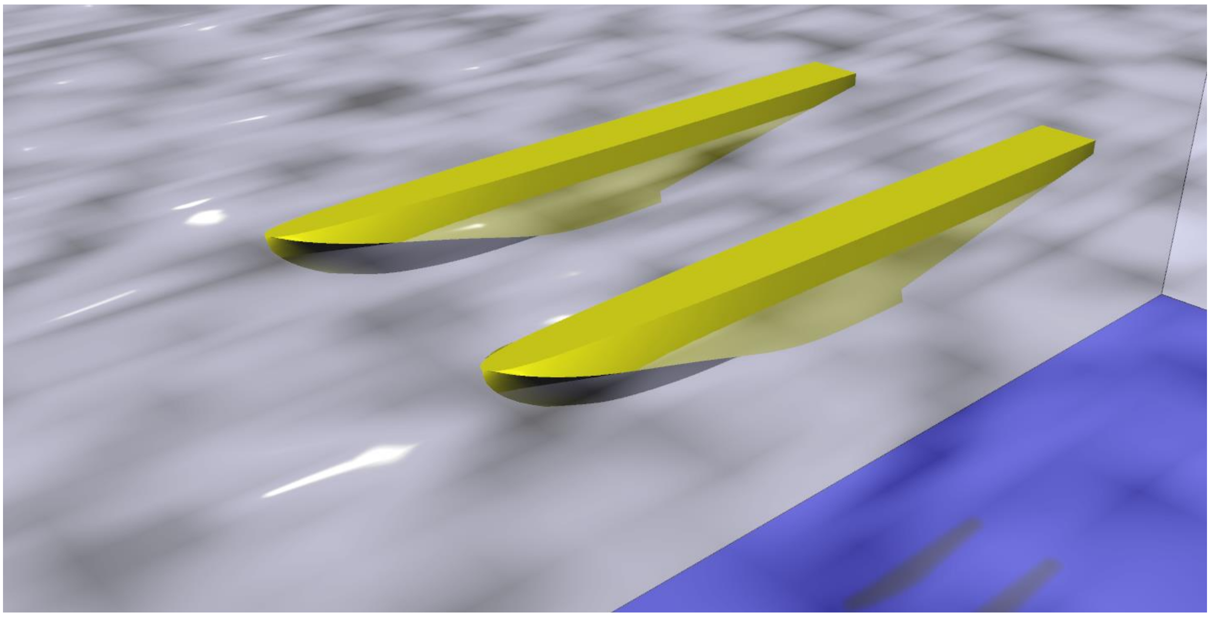

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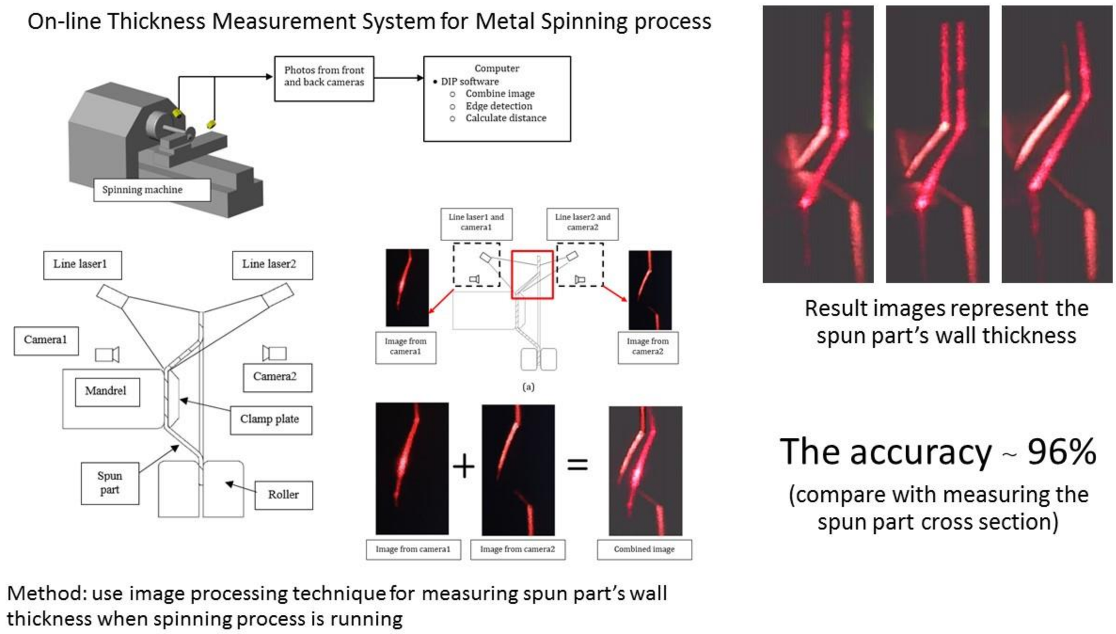

[On-line Thickness Measurement System for the Metal Spinning Process](https://doi.org/10.14716/ijtech.v13i1.5025)

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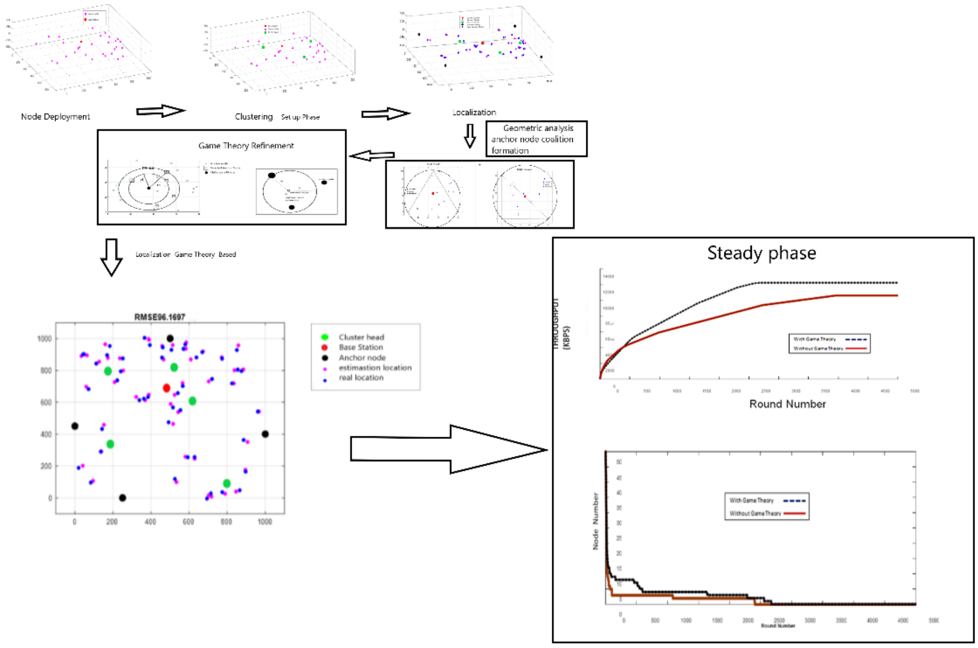

[Wireless Sensor Networks Optimization with Localization-Based Clustering using Game Theory Algorithm](https://doi.org/10.14716/ijtech.v13i1.4850)

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Site Coefficient and Design Spectral Acceleration Evaluation of New Indonesian 2019 Website Response Spectra

Site Coefficient and Design Spectral Acceleration Evaluation of New Indonesian 2019 Website Response Spectra

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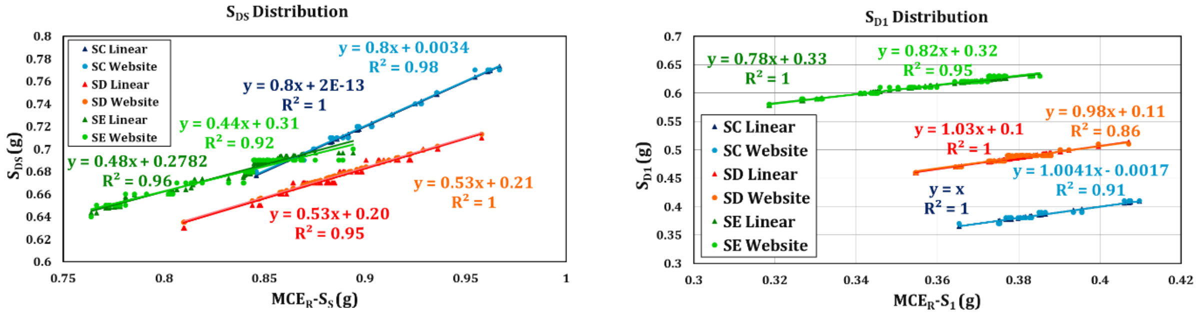
Abstract



Calculation of site coefficient and design response spectral acceleration are two important steps in the seismic design of buildings. According to Indonesian Seismic Code 2019, two information requirements for site coefficient calculations are the site soil class and Risk-targeted Maximum Considered Earthquake (MCE_R-S_S for short and MCE_R-S_1 for long period) spectral acceleration. Three different hard/SC, medium/SD and soft/SE are typically site soil classes used for building designs. Two different site coefficients (Fa for MCE_R-S_S and Fv for MCE_R-S_1 spectral acceleration) are used for surface and design response spectral acceleration calculations. The Indonesian Seismic Code provides two (Fa and Fv) tables for calculating site coefficients. If the MCE_R-S_S or MCE_R-S_1 values developed for a specific site are not exactly equal to the values in Fa or Fv tables, the site coefficients can then be predicted using straight-line interpolation between the two closest Fa or Fv values within the tables. When the straight-line interpolation is adjusted for Fa or Fv calculation, different results were observed in comparison to the values developed using website-based software (prepared by Ministry of Public Works and Human Settlements). This study evaluates site coefficients and design response spectral acceleration predictions in Semarang City, Indonesia, according to straight-line interpolation method and website software calculations. The study was conducted at 203 soil boring positions in the study area. The site soil classes were predicted using average standard penetration test values (N-SPT) of the topmost 30 m soil deposit layer (N30). Three different site soil classes were observed in the study area. On average, the largest differences between the two analysis (linear interpolation and website) methods in the site coefficient values and design response spectral acceleration calculation were observed for the SD and SE classes. However, for the SC site soil class, the difference was small, with their values approximately similar.

Keywords

Design response spectral acceleration; MCER; N-SPT; Site coefficient; Straight-line interpolation

Introduction

The new National Seismic Code of Indonesia (SNI 1726:2019, 2019) was announced in 2019. Some of the information introduced in this new seismic code was partially adopted from the American Standard Code for Seismic Design ASCE/SEI 7-16, specifically the site coefficient values and design response spectral acceleration calculation methods. Additional information for developing the site coefficients was adopted from Stewart and Seyhan (2013). Due to the improved methods described in ASCE/SEI 7-16 for developing site coefficients for site soil classes SD and SE, not all the information described in the American Code was adopted by SNI 1726:2019. Specifically, the site coefficients for the SD and SE classes presented in SNI 1726:2019 were completely adopted from Stewart and Seyhan (2013).

Following the SNI 1726:2019, the Ministry of Public Works and Human Settlements announced a new website software (online facility) for site coefficient and design response spectral acceleration calculation. Site or building position coordinates (in terms of longitude and latitude) and site soil class are two information requirements for design response spectral acceleration calculations. Risk-targeted Maximum Considered Earthquake (MCE_R) acceleration, MCE_R-S_S for short and MCE_R-S_1 for long periods, (Luco et al., 2007; Allen et al., 2015; Sengara et al., 2020), and two design response spectral acceleration, S_{DS} and S_{D1}, are four important values calculated by the website facility software. However, no information related to site coefficients F_a for short and F_v for long periods can be obtained from the new website. Thus, these values can be calculated using Equation 1 and Equation 2. All S_{DS}, S_S (MCE_R-S_S), S_{D1}, and S_1 (MCE_R-S_1) values can be obtained from the website.

$$F_a = \frac{S_{DS}}{2/3\, S_S} \quad (1)$$

$$F_v = \frac{S_{D1}}{2/3\, S_1} \quad (2)$$

To verify the F_a and F_v site coefficients estimated using Equations 1 and 2, straight-line interpolation can be conducted using the S_S and S_1 website calculations and applying site coefficient (F_a and F_v) table data provided by SNI 1726:2019. F_a and F_v are then estimated following the procedure described by SNI 1726:2019. Equation 3 shows a simple formula for F_a and F_v site coefficients calculation. Figure 1 shows a diagram of the straight-line interpolation of the F_a and F_v calculation. F and M_w represent the site coefficient to be estimated and the MCE_R value obtained from the website, respectively; M_{1S} and M_{2S} represent two boundary MCE_R values close to M_w; F_{1S} and F_{2S} represent the site coefficients for M_{1S} and M_{2S}, respectively; and M_{1S}, M_{2S}, F_{1S}, and F_{2S} are the four values obtained from the SNI 1726:2019 tables. F_a and F_v are estimated separately using Equation 3.

$$F = \left(\frac{F_{2S} - F_{1S}}{M_{2S} - M_{1S}}\right)(M_W - M_{1S}) + F_{1S} \quad (3)$$

This paper describes the site coefficients and design response spectral acceleration verification calculated using the website facility and the straight-line interpolation described in SNI 1726:2019. The objective of the study was to evaluate whether or not the website performed the analysis following the same procedures used by SNI 1726:2019. The study was performed in Semarang City, Indonesia, and conducted at 203 soil boring investigation positions. The study was performed as part of seismic microzonation research of the city. One of the important information requirements for seismic microzonation is the development of soil amplification or site coefficient distribution map at the study area. In this study, the standard penetration test (N-SPT) data observed during boring investigation were used for site class calculation. All boring investigations in this study were conducted at a minimum depth of 30 m and a maximum depth 60 m. The average standard penetration test (N-SPT) of the topmost 30 m soil deposit layer (N_{30}) of every boring position was used for site soil class interpretation (Moghaddam, 2011; Partono et al., 2019; Syaifuddin et al., 2020). Figure 2a shows the 203 boring positions and the N_{30} distribution within the study area. Figure 2b shows the distribution of the site soil classes developed based on the N_{30} data (Partono et al., 2021). The maximum N-SPT data obtained from the boring investigation was 60. Following the procedure described by SNI 1726:2019, the N_{30} value was estimated using

Equation 4, where d_i and N_i represent the thickness and N-SPT value of any soil layer "i", respectively.

The parameter that can also be used for site interpretation is the average shear wave velocity (V_S) of the topmost 30 m soil deposit (V_{S30}) (Naji et al., 2020). The V_{S30} value can be calculated using the same method as that shown in Equation 4 and replacing the N_i value with V_{Si}. The V_S value can be observed using seismic refraction multichannel analysis of surface waves (MASW) or seismometer array investigations. Prakoso et al. (2017) described a comparative study of V_S value obtained from MASW investigation and soil boring (N-SPT) data. The V_S value developed using MASW was more reliable compared to that developed based on the N-SPT data. Pramono et al. (2020) described the predominant frequency investigation at Lombok Island following the 2018 earthquake event. The greater the V_{S30} value used, the greater the predominant frequency obtained from the wavelet analysis of the ground motion. Additionally, development of V_{S30} and predominant frequency correlation was also conducted by Pramono et al. (2017) in the Palu area.

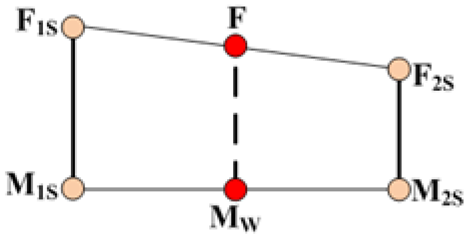


Figure 1 Straight-line interpolation for F_a and F_v calculations

$$N_{30} = \frac{\sum_{i=i}^{i=n} d_i}{\sum_{i=i}^{i=n} \frac{d_i}{N_i}} \quad (4)$$

Conclusion

Evaluations of site coefficients estimated using the website and straight-line interpolation methods were performed for 203 boring positions in Semarang City. No significant differences were found in the F_a and F_v site coefficients between the two methods. The largest difference in the F_a site coefficient calculations was observed for the SD and SE site classes. The difference in site coefficients for the SD and SE site soil classes was less than 0.03, while, for the SC site soil class, the difference was less than 0.01. In terms of site coefficient F_v, the largest difference was observed for the SD and SE site soil classes with a maximum of 0.04. However, the difference in site coefficient F_v for site class SC was less than 0.02. When calculating F_a and F_v site coefficients, the linear interpolation method from SNI 1726:2019 is better compared to the calculated using MCE_R-S_S, MCE_R-S_1, S_{DS}, and S_{D1} values obtained from the website.

No significant differences in the design response spectral acceleration S_{DS} and S_{D1} values were found for any of the site classes. The largest design response spectral acceleration difference in SD between the two methods was less than 0.02 g, while, for the SC and SE site classes, the differences were less than 0.005 g.

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Supplementary Material

Filename	**Description**
R2-CVE-4132-20210820110617.pdf	Supplementary File

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Site Coefficient and Design Spectral Acceleration Evaluation of New Indonesian 2019 Website Response Spectra

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Abstract. Calculation of site coefficient and design response spectral acceleration are two important steps in the seismic design of buildings. According to Indonesian Seismic Code 2019, two information requirements for site coefficient calculations are the site soil class and Risk-targeted Maximum Considered Earthquake (MCE_R-S_S for short and MCE_R-S_1 for long period) spectral acceleration. Three different hard/SC, medium/SD and soft/SE are typically site soil classes used for building designs. Two different site coefficients (Fa for MCE_R-S_S and Fv for MCE_R-S_1 spectral acceleration) are used for surface and design response spectral acceleration calculations. The Indonesian Seismic Code provides two (Fa and Fv) tables for calculating site coefficients. If the MCE_R-S_S or MCE_R-S_1 values developed for a specific site are not exactly equal to the values in Fa or Fv tables, the site coefficients can then be predicted using straight-line interpolation between the two closest Fa or Fv values within the tables. When the straight-line interpolation is adjusted for Fa or Fv calculation, different results were observed in comparison to the values developed using website-based software (prepared by Ministry of Public Works and Human Settlements). This study evaluates site coefficients and design response spectral acceleration predictions in Semarang City, Indonesia, according to straight-line interpolation method and website software calculations. The study was conducted at 203 soil boring positions in the study area. The site soil classes were predicted using average standard penetration test values (N-SPT) of the topmost 30 m soil deposit layer (N30). Three different site soil classes were observed in the study area. On average, the largest differences between the two analysis (linear interpolation and website) methods in the site coefficient values and design response spectral acceleration calculation were observed for the SD and SE classes. However, for the SC site soil class, the difference was small, with their values approximately similar.

Keywords: Design response spectral acceleration; MCE_R; N-SPT; Site coefficient; Straight-line interpolation

1. Introduction

The new National Seismic Code of Indonesia (SNI 1726:2019, 2019) was announced in

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$$F_a = \frac{S_{DS}}{\frac{2}{3} S_S} \tag{1}$$

$$F_v = \frac{S_{D1}}{\frac{2}{3} S_1} \tag{2}$$

To verify the F_a and F_v site coefficients estimated using Equations 1 and 2, straight-line interpolation can be conducted using the S_S and S_1 website calculations and applying site coefficient (F_a and F_v) table data provided by SNI 1726:2019. F_a and F_v are then estimated following the procedure described by SNI 1726:2019. Equation 3 shows a simple formula for F_a and F_v site coefficients calculation. Figure 1 shows a diagram of the straight-line interpolation of the F_a and F_v calculation. F and M_w represent the site coefficient to be estimated and the MCE_R value obtained from the website, respectively; M_{1S} and M_{2S} represent two boundary MCE_R values close to M_w; F_{1S} and F_{2S} represent the site coefficients for M_{1S} and M_{2S}, respectively; and M_{1S}, M_{2S}, F_{1S}, and F_{2S} are the four values obtained from the SNI 1726:2019 tables. F_a and F_v are estimated separately using Equation 3.

$$F = \left(\frac{F_{2S} - F_{1S}}{M_{2S} - M_{1S}} \right)(M_W - M_{1S}) + F_{1S} \tag{3}$$

This paper describes the site coefficients and design response spectral acceleration verification calculated using the website facility and the straight-line interpolation described in SNI 1726:2019. The objective of the study was to evaluate whether or not the website performed the analysis following the same procedures used by SNI 1726:2019. The study was performed in Semarang City, Indonesia, and conducted at 203 soil boring investigation positions. The study was performed as part of seismic microzonation research of the city. One of the important information requirements for seismic microzonation is the development of soil amplification or site coefficient distribution map at the study area. In

this study, the standard penetration test (N-SPT) data observed during boring investigation were used for site class calculation. All boring investigations in this study were conducted at a minimum depth of 30 m and a maximum depth 60 m. The average standard penetration test (N-SPT) of the topmost 30 m soil deposit layer (N_{30}) of every boring position was used for site soil class interpretation (Moghaddam, 2011; Partono et al., 2019; Syaifuddin et al., 2020). Figure 2a shows the 203 boring positions and the N_{30} distribution within the study area. Figure 2b shows the distribution of the site soil classes developed based on the N_{30} data (Partono et al., 2021). The maximum N-SPT data obtained from the boring investigation was 60. Following the procedure described by SNI 1726:2019, the N_{30} value was estimated using Equation 4, where d_i and N_i represent the thickness and N-SPT value of any soil layer "i", respectively.

The parameter that can also be used for site interpretation is the average shear wave velocity (V_S) of the topmost 30 m soil deposit (V_{S30}) (Naji et al., 2020). The V_{S30} value can be calculated using the same method as that shown in Equation 4 and replacing the N_i value with V_{Si}. The V_S value can be observed using seismic refraction multichannel analysis of surface waves (MASW) or seismometer array investigations. Prakoso et al. (2017) described a comparative study of V_S value obtained from MASW investigation and soil boring (N-SPT) data. The V_S value developed using MASW was more reliable compared to that developed based on the N-SPT data. Pramono et al. (2020) described the predominant frequency investigation at Lombok Island following the 2018 earthquake event. The greater the V_{S30} value used, the greater the predominant frequency obtained from the wavelet analysis of the ground motion. Additionally, development of V_{S30} and predominant frequency correlation was also conducted by Pramono et al. (2017) in the Palu area.

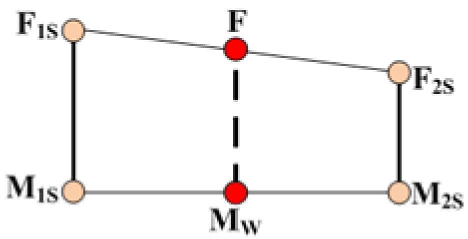


Figure 1 Straight-line interpolation for F_a and F_v calculations

$$N_{30} = \frac{\sum_{i=i}^{i=n} d_i}{\sum_{i=i}^{i=n} \frac{d_i}{N_i}} \tag{4}$$

2. Methods

The evaluation of the site coefficients from the study area was conducted following five basic steps:

- Site class interpretation;
- MCE_R (S_S and S_1) and design response spectral acceleration calculation using the website;
- Site coefficient calculation based on the website output;
- Site coefficient calculation based on SNI 1726:2019 tables and procedures;

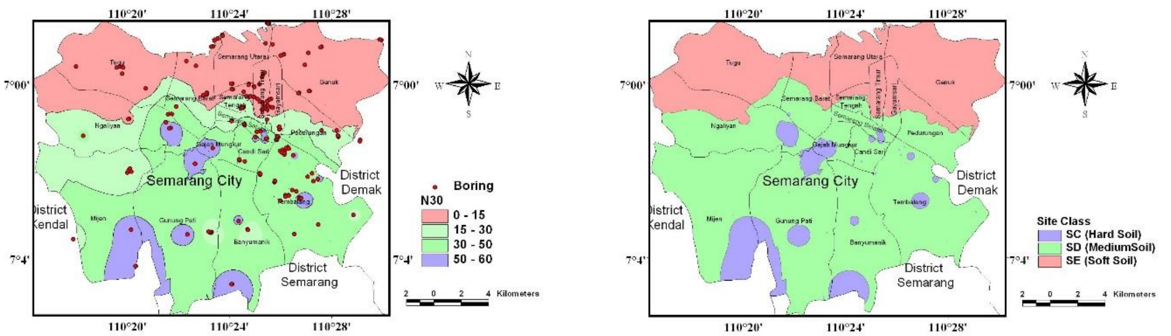
- Comparative analysis of the two different approaches in terms of their calculated site coefficients and design response spectral acceleration: the website output and straight-line interpolation.

2.1. Site Soil Class Interpretation

Site soil class interpretation (Figure 2b) was conducted for the 203 boring positions using N_{30} data, with the site soil classes interpreted according to SNI 1726:2019. Table 1 shows the basic classification criteria for each site soil class. Only three different site soil classes are presented in this table, site classes SA/hard rock, SB/rock, and SF/specific soil unavailable. Figure 2b shows the corresponding site soil class distribution according to the site classification information in Table 1. The site class distribution in the study area is dominated by the SD and SE classes; meanwhile, site class SC was observed in small areas in the middle and southern parts of the city (Partono et al., 2021).

Table 1 Site classification

Site Class	N_{30}
SC	> 50
SD	15–50
SE	< 15



(a) (b)

Figure 2 (a) Boring investigation and N_{30}; and (b) site soil classes distribution maps

2.2. MCE_R and Design Response Spectral Acceleration Calculation

MCE_R calculations were performed for the 203 boring positions using the website. According to the site class distribution of the study area, different MCE_R-S_S and MCE_R-S_1 distributions were also observed in the study area. Table 2 shows the total data for each site class as well as the distribution of the minimum and maximum MCE_R-S_S, MCE_R-S_1, S_{DS}, and S_{D1} for the three different site classes developed using the website.

Table 2 S_S, S_1, S_{DS}, and S_{D1} spectral acceleration values obtained from the website

Site Class	Total Data	MCE_R-S_S(g)		S_{DS} (g)		MCE_R-S_1 (g)		S_{D1} (g)	
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
SC	34	0.8459	0.9668	0.68	0.77	0.3653	0.4097	0.37	0.41
SD	90	0.8098	0.9579	0.63	0.71	0.3546	0.4071	0.46	0.51
SE	79	0.696	0.9274	0.64	0.71	0.3185	0.3936	0.58	0.63

2.3. Website-calculated Fa and Fv values

F_a and F_v site coefficient calculations were performed according to the MCE_R-S_S, MCE_R-S_1, S_{DS}, and S_{D1} values obtained from the website. The site coefficients were then estimated

using Equations 1 and 2. Table 3 shows the distribution of the minimum and maximum F_a and F_v values using these four values. According to the boundary values of F_a and F_v described in the SNI 1726:2019 tables, the minimum and maximum F_a values developed in the study area were divided into two different boundary values. A few MCE_R-S_S values were lower than 0.75 g; however, most of the MCE_R-S_S values were between 0.75 and 1 g.

2.4. Site Coefficients F_a and F_v SNI 1726:2019

Straight-line interpolation was also performed for F_a and F_v calculation using Equation 3 and the F_a and F_v tables provided by SNI 1726:2019. According to the MCE_R-S_S and MCE_R-S_1 values obtained from the website, the minimum and maximum boundaries for these two site coefficients could be estimated. Thus, Table 3 shows the boundaries of the F_a and F_v values used for the straight-line interpolation calculations. The F_a and F_v boundary values displayed in Table 3 were obtained from SNI 1726:2019.

Table 3 F_a and F_v distribution developed using the website and SNI 1726:2019 tables

Site Class	Total Data	Linear Interpolation (SNI)					Website				Diff. > 0.01 (%)	
		F_a			F_v		F_a		F_v		F_a	F_v
		MCE_R-S_S(g)			MCE_R-S_1 (g)		Min.	Max.	Min.	Max.		
		0.5	0.75	1.0	0.3	0.4						
SC	34	1.2	1.2	1.2	1.5	1.5	1.19	1.21	1.478	1.519	0	58.82
SD	90	1.4	1.2	1.1	2.0	1.9	1.112	1.167	1.879	1.949	3.41	56.82
SE	79	1.7	1.3	1.1	2.8	2.4	1.148	1.4	2.401	2.732	13.92	50.63

3. Results and Discussion

The MCE_R-S_S values for the SC site class (Table 2) range from 0.8459 to 0.9668 g, while the F_a values for the SC site class developed according to the website (Table 3) range between 1.19 and 1.21. All the F_a values developed from the website are consistent with and almost equal to those from SNI 1726:2019 (Table 3). As can be seen in Table 3, the F_a values from SNI 1726:2019 are constant and equal to 1.2. The difference between the F_a values developed using the website data and those from SNI 1726:2019 is less than 0.01. According to Table 3, for all 34 data, the percentage of total data with a minimum difference of 0.01 is 0%. Figure 3a shows the distribution of the F_a site coefficients for the SC site class in terms of the MCE_R-S_S values. The linear and website legends inside this figure represent the straight-line interpolation following SNI 1726:2019 and the website data acquisition. The R^2 (coefficient of determination) value for site class SC is close to 0, because the F_a values estimated using these two models are nearly constant for all MCE_R-S_S values. The R^2 value is used for evaluation of the fitting line (linear fit model) performance. The evaluation was performed for the distribution of F_a or F_v to the linear regression line model. The minimum and maximum R^2 values are 0 and 1 (100%), respectively. The higher the R^2, the better the linear fitting model difference for the F_a or F_v data distribution.

The distribution of the MCE_R-S_S values for the SD site class in the study area was almost equal to that of the SC site class. Table 2 shows the distribution of MCE_R-S_S for the SD site class, with the values ranging from 0.8098 to 0.9579 g. Following the same procedure as that of the SC site class, the F_a site coefficients for the SD site class in the study area range between 1.2 and 1.1. Due to the MCE_R-S_S being distributed around 1, the F_a values obtained from the study area are close to 1.1: As shown in Table 3, the F_a values range between 1.112 and 1.167. The total percent of data with a minimum difference of 0.01 are 3.41%. Figure 3b shows the distribution of the F_a values for site class SD in terms of the MCE_R-S_S values.

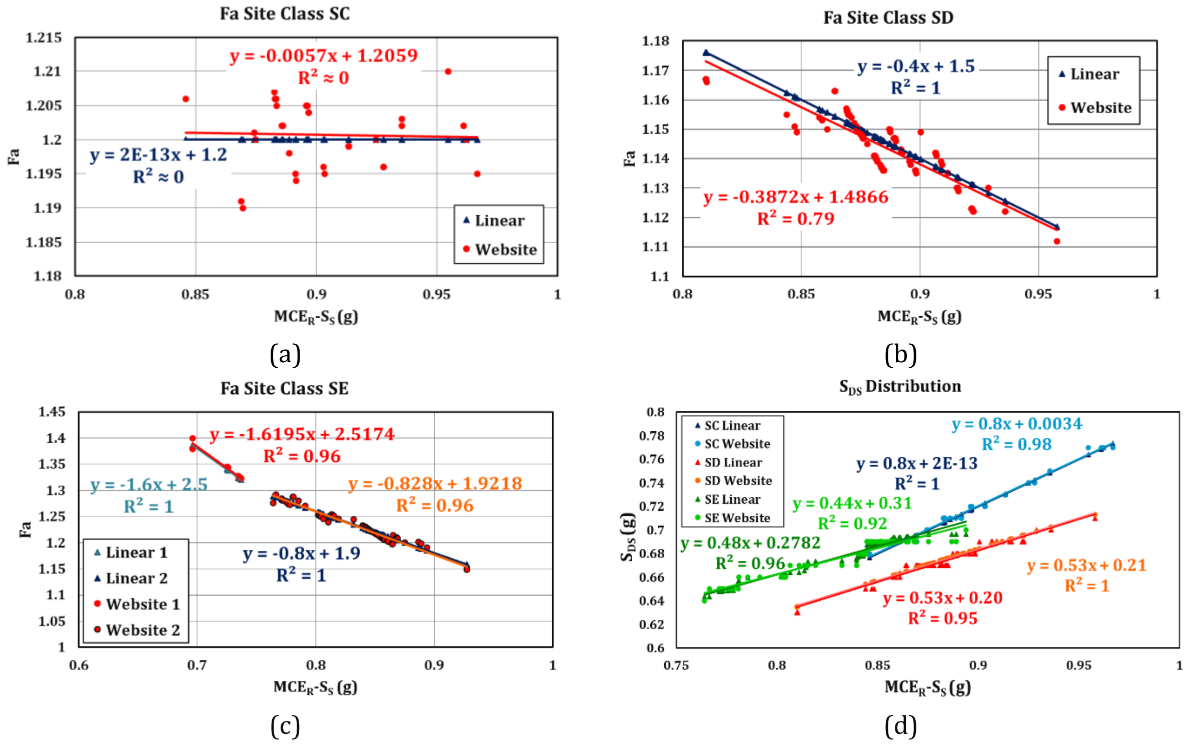


Figure 3 F_a distributions in terms of MCE_R-S_S values for: (a) SC; (b) SD; and (c) SE site classes; and (d) the correlation of S_{DS} and MCE_R-S_S from the linear interpolation and website software

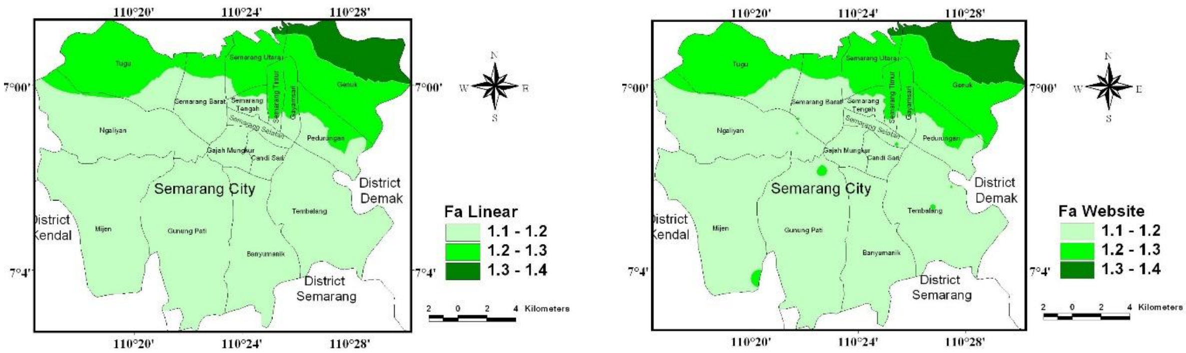
As can be seen in Figure 3b, the R^2 value obtained from the regression analysis is 0.7858, or less than 1. The straight-line interpolation values developed according to the SNI 1726:2019 data and tables were better compared to the F_a values developed using the website. However, on average, the absolute difference in the F_a values developed between these two models was 0.0105, and the line distributions were almost identical (i.e., coincided).

The MCE_R-S_S distribution of the SE site class values estimated from the website ranged between 0.696 and 0.9274 g. According to SNI 1726:2019, all MCE_R-S_S for site class SE were distributed between two different boundary values, from 0.5 through 0.75 g for the first boundary and from 0.75 through 1 g for the second boundary. The straight-line interpolation for all MCE_R-S_S was also separated into two different boundary values. The first F_a boundary values (6 data) were distributed between 1.4 and 1.323; however, the second F_a (73 data) site coefficients were distributed between 1.292 and 1.148. Figure 3c shows the distribution of the F_a values for the SE site class. Two different straight-line interpolations can be observed in this figure in accordance with the two different boundary values from SNI 1726:2019. The absolute average difference in F_a for site class SE is 0.029. As can be seen in Table 3, 13.92% of the 79 data have a minimum difference of 0.01.

F_a and F_v are the two site coefficients used for calculating surface spectral acceleration and design response spectral acceleration. The performance of the different values of these coefficients developed using the two different procedures (straight line interpolation and using website facility) can be neglected or avoided, since there was no significant difference in the design response spectral acceleration results between these two methods. The difference in the accuracy value used for both methods will sometimes produce different site coefficients and directly impact the performance of the S_{DS} and S_{D1} outputs for all site soil classes.

To verify the performance of the F_a and F_v values estimated using these two methods, design response spectral acceleration calculation was also conducted in this study. The purpose of this analysis was to verify the performance of the design response spectral acceleration S_{DS} and S_{D1} values according to the site coefficient values calculated using the two different methods. Figure 3d shows the performance of the S_{DS} design response spectral acceleration in terms of MCE_R-S_S developed from the website and straight-line interpolation. As can be seen in Figure 3d, a strong correlation between S_{DS} in terms of MCE_R-S_S was observed in this study. According to this figure, there are no significant differences in the S_{DS} performance estimated using the website versus SNI 1726:2019 straight line interpolation procedures for all three site classes (SC, SD, and SE).

The F_a distribution map developed from the 203 boring positions was also constructed based on the website and linear interpolation analysis. Figure 4a and 4b show the two F_a distribution maps, which are almost equal. Specifically, the F_a values from the study area range between 1.2 and 1.4, with the largest Fa values observed in a small north-eastern portion of the city.



(a) (b)

Figure 4 F_a distribution maps developed using: (a) website software; and (b) linear interpolation

Site coefficient evaluation was also conducted for long-period MCE_R-S_1 spectral acceleration. Using the same procedure as that used for MCE_R-S_S, the evaluation was performed for the SC, SD, and SE site classes. Based on the minimum and maximum MCE_R-S_1 values estimated using the website, all MCE_R-S_1 values in the study area were distributed between 0.3185 and 0.4097 g (see Table 2) or approximately between 0.3 and 0.4 g. For site classes SC and SD, there was one boring position with a MCE_R-S_1 value greater than 0.4 g. Figures 5a, b, and c show the distribution of the site coefficient F_v for the SC, SD, and SE site soil classes, respectively.

All the F_v values estimated using the website and straight-line interpolation were almost equal or coincided except for site class SD. As shown in Figure 5b, most of the F_v values of the SD site class developed using the website are greater than those developed using straight-line interpolation. The R^2 value for this model was far from 1. The F_v values for site class SD from the website calculation were far from the linear model described by SNI 1726:2019. The R^2 for site class SC was not available (close to 0), because the F_v and MCE_R-S_1 correlations were nearly constant or almost equal. A good F_v and MCE_R-S_1 correlation was observed for site class SE (see Figure 5c) for the website output and straight-line interpolation methods. The R^2 obtained for this site class was nearly 1. On average the absolute differences between F_v were 0.015, 0.036, and 0.033 for the SC, SD, and SE site classes, respectively. According to Table 3, the percent of total data with a minimum difference of 0.01 for the SC, SD, and SE site classes is greater than 50%.

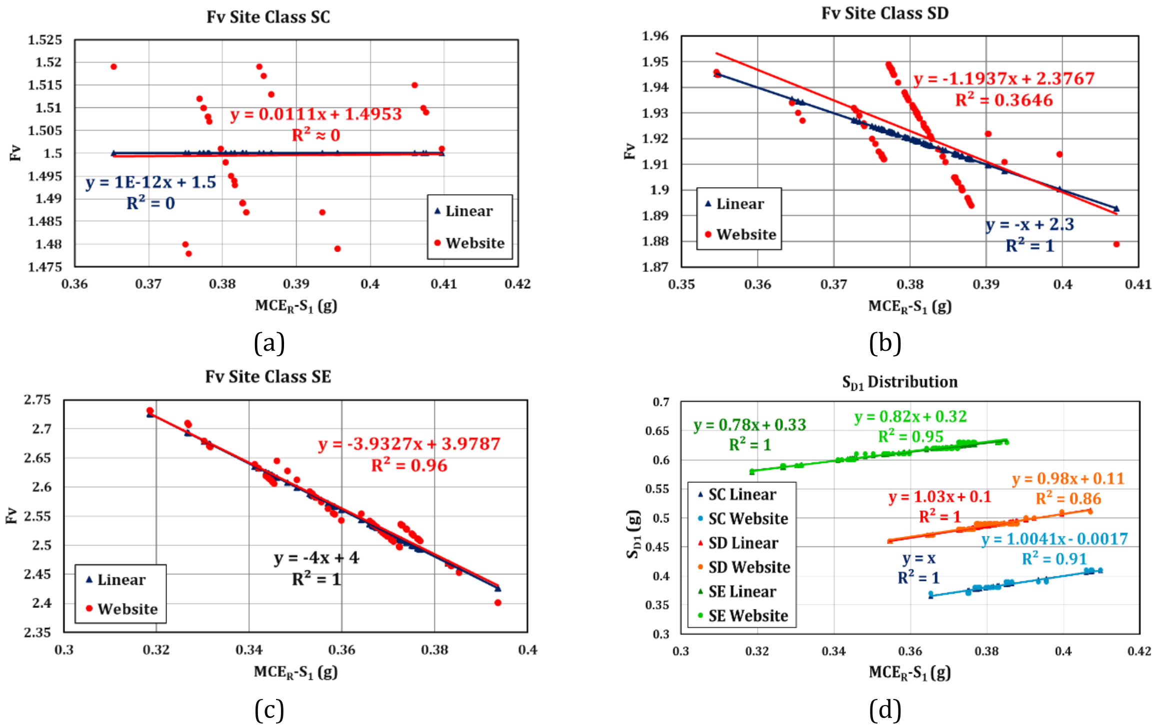


Figure 5 F_v distributions in terms of MCE_R-S_1 values for: (a) SC; (b) SD; (c) SE site classes; and (d) the correlation of S_{D1} and MCE_R-S_1 developed based on linear interpolation and website software

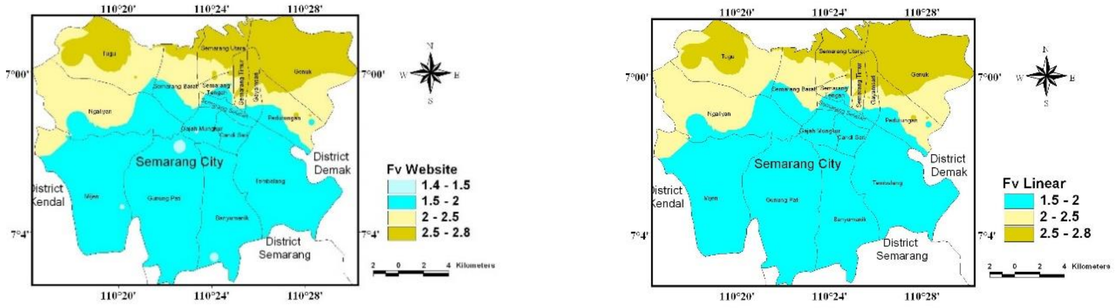
Figure 5d shows the S_{D1} design response spectral acceleration performance in terms of MCE_R-S_1 values estimated using the same methods as used in the S_{DS} calculation. As can be seen in Figure 5d, a good correlation between S_{D1} in terms of MCE_R-S_1 was observed in this study. Also, according to this figure, there are no significant differences in the S_{D1} performance for the SC, SD, and SE site class estimates between the website and straight-line interpolation of SNI 1726:2019 procedures.

F_v distribution maps were also developed based on the website and linear interpolation analysis. Figures 6a and 6b show two F_v distribution maps, which are almost equal. The F_v values developed using the website ranged between 1.4 and 2.8, while the F_v values developed using linear interpolation ranged between 1.5 and 2.8. The largest F_v values were observed in the northern part of the city.

The S_{DS} and S_{D1} developed for the study area using the website were acceptable according to the requirement criterion of SNI 1726:2019. Table 4 shows the minimum and maximum S_{DS} and S_{D1} values and the average difference in the S_{DS} and S_{D1} values between the two methods for the SC, SD, and SE site classes. As shown in Table 4, the average difference of S_{DS} and S_{D1} is the absolute values of S_{DS} and S_{D1}. The maximum average difference (ave. diff.) for S_{DS} and S_{D1}, 0.0224 g and 0.0153 g, respectively, were observed in the SD site class. However, the average differences in S_{DS} and S_{D1} for site classes SC and SE were less than 0.0073 g and 0.0044 g, respectively.

Table 4 S_{DS} and S_{D1} performance for all site classes

Site Class	S_{DS} (g)					S_{D1} (g)				
	Website		Linear		Ave. diff.	Website		Linear		Ave. diff.
	Min.	Max.	Min.	Max.		Min.	Max.	Min.	Max.	
SC	0.68	0.77	0.6767	0.7734	0.0067	0.37	0.41	0.3653	0.4097	0.0044
SD	0.63	0.71	0.6349	0.6925	0.0224	0.46	0.51	0.4599	0.4946	0.0153
SE	0.64	0.71	0.6433	0.706	0.0073	0.58	0.63	0.5788	0.6315	0.0027



(a) (b)

Figure 6 F_v distribution maps developed using website software (a) and linear interpolation (b)

4. Conclusions

Evaluations of site coefficients estimated using the website and straight-line interpolation methods were performed for 203 boring positions in Semarang City. No significant differences were found in the F_a and F_v site coefficients between the two methods. The largest difference in the F_a site coefficient calculations was observed for the SD and SE site classes. The difference in site coefficients for the SD and SE site soil classes was less than 0.03, while, for the SC site soil class, the difference was less than 0.01. In terms of site coefficient F_v, the largest difference was observed for the SD and SE site soil classes with a maximum of 0.04. However, the difference in site coefficient F_v for site class SC was less than 0.02. When calculating F_a and F_v site coefficients, the linear interpolation method from SNI 1726:2019 is better compared to the calculated using MCE_R-S_S, MCE_R-S_1, S_{DS}, and S_{D1} values obtained from the website.

No significant differences in the design response spectral acceleration S_{DS} and S_{D1} values were found for any of the site classes. The largest design response spectral acceleration difference in SD between the two methods was less than 0.02 g, while, for the SC and SE site classes, the differences were less than 0.005 g.

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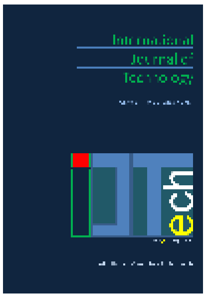

G20 Presidency of Indonesia: Collective and Inclusive Agendas for World Development

Mohammed Ali Berawi

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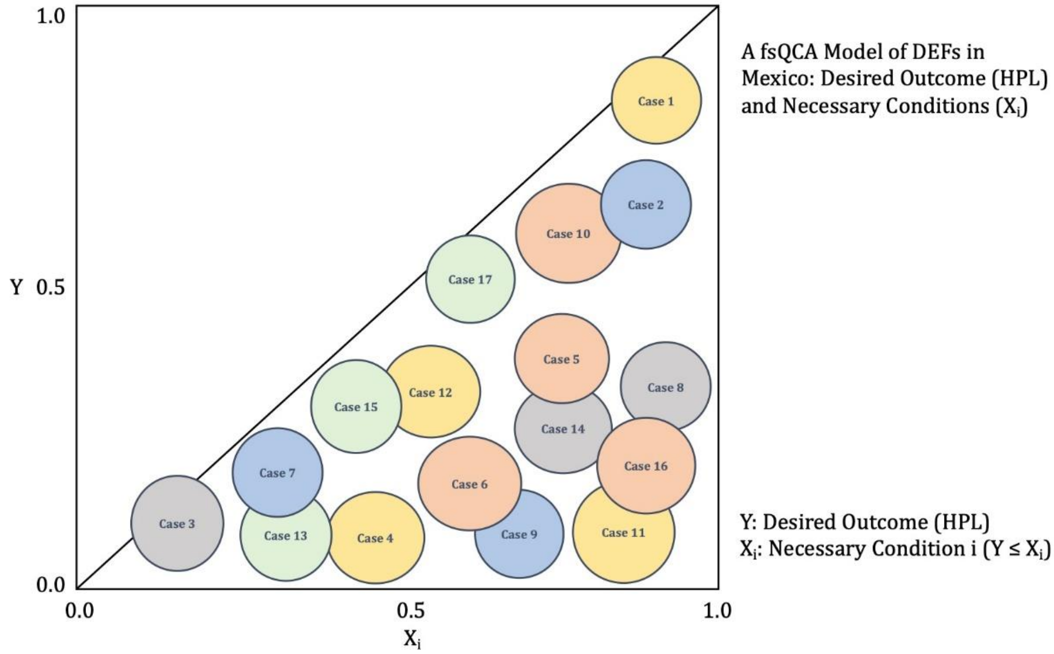

[Ensuring the High Performance of Design and Engineering Firms in Mexico's Aerospace Industry: A Qualitative Comparative Analysis]

María Aline Manzo, José Carlos Rodríguez

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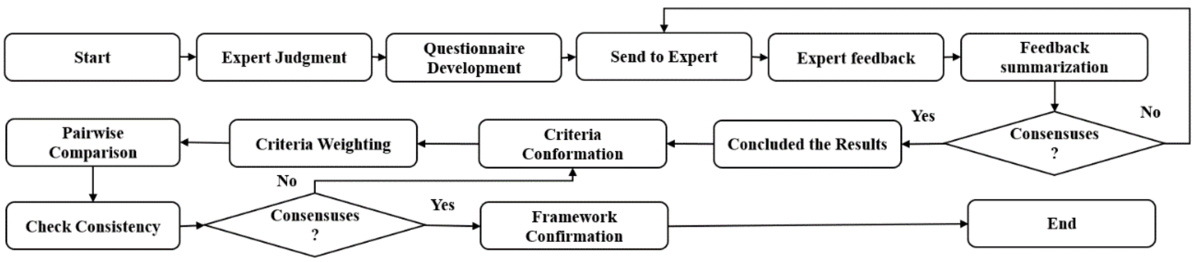

[An Integrated Approach for Supplier Evaluation and Selection using the Delphi Method and Analytic Hierarchy Process (AHP): A New Framework]

Muataz Hazza Al Hazza, Alaa Abdelwahed, Mohammad Yeakub Ali, Atiah Bt. Abdullah Sidek

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Demographic	Classification	n	(%)
Main business activity	Automobile, auto parts	19	15.20
	Food, beverages, tobacco	13	10.40
	Plastic, rubber products	11	8.80
	More than one main product	9	7.20
	Chemicals, chemical products	6	4.80
	Iron, steel	6	4.80
	Other electronics and components	6	4.80
	Metal products	5	4.00
	Machinery, equipment, tools	5	4.00
	Non-ferrous metals	4	3.20
	Textiles	3	2.40
	Other non-metallic mineral products	2	1.60
	Other manufacturing	36	28.80
Company size	Large (≥ 200 employees)	55	44.00
	Medium (50–199 employees)	35	28.00
	Small (< 50 employees)	35	28.00
Gender of CEO	Male	117	93.60
	Female	8	6.40
Nationality of CEO	Thai	96	76.80
	Foreign	29	23.20

The Role of Leader and the Effect of Customer's Smart Factory Investment on Firm's Industry 4.0 Technology Adoption in Thailand

Kwanchanok Chumnumporn, Chawalit Jeenanunta, Suchinthara Simpan, Kornkanok Srivat, Vararat Sanprasert

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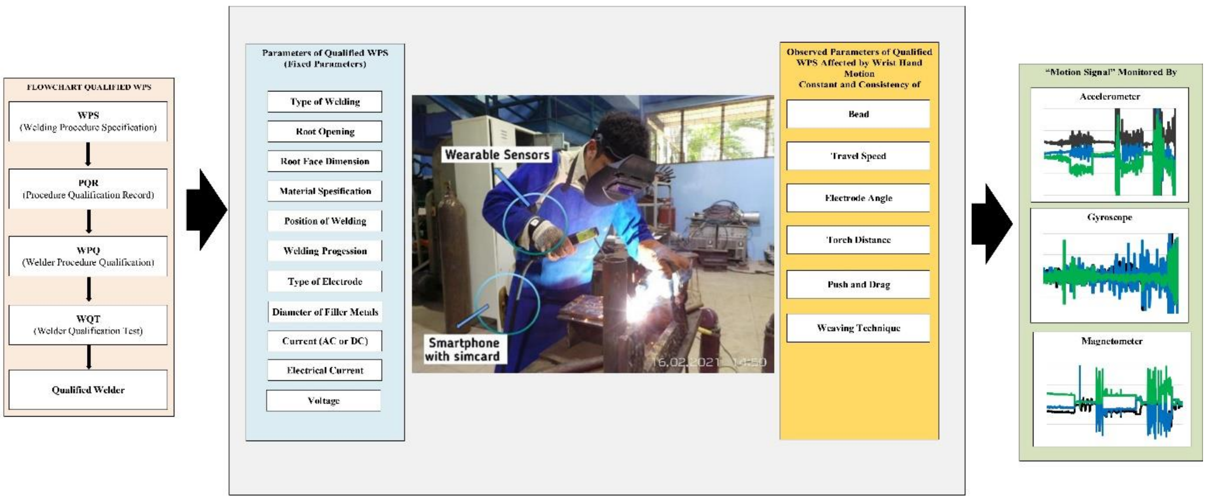

[Hand Motion Analysis for Recognition of Qualified and Unqualified Welders using 9-DOF IMU Sensors and Support Vector Machine (SVM) Approach](https://doi.org/10.14716/ijtech.v13i1.4813)

Triwilaswandio Wuruk Pribadi, Takeshi Shinoda

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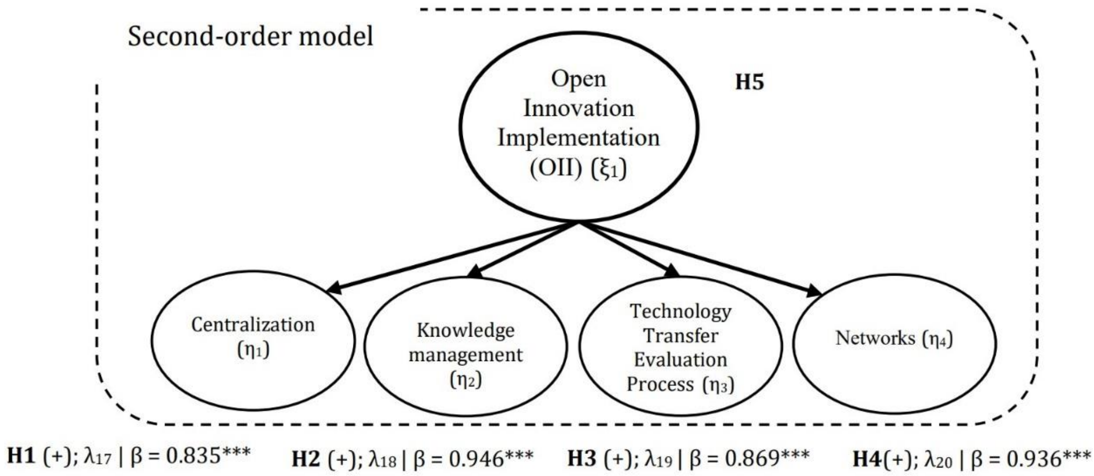
Pages : 38-47



[Industry 4.0 for Thai SMEs: Implementing Open Innovation as Innovation Capability Management](https://doi.org/10.14716/ijtech.v13i1.4746)

Phaninee Naruetharadhol, Wutthiya A. Srisathan, Nathatenee Gebsombut, Peerapong Wongthahan, Chavis Ketkaew

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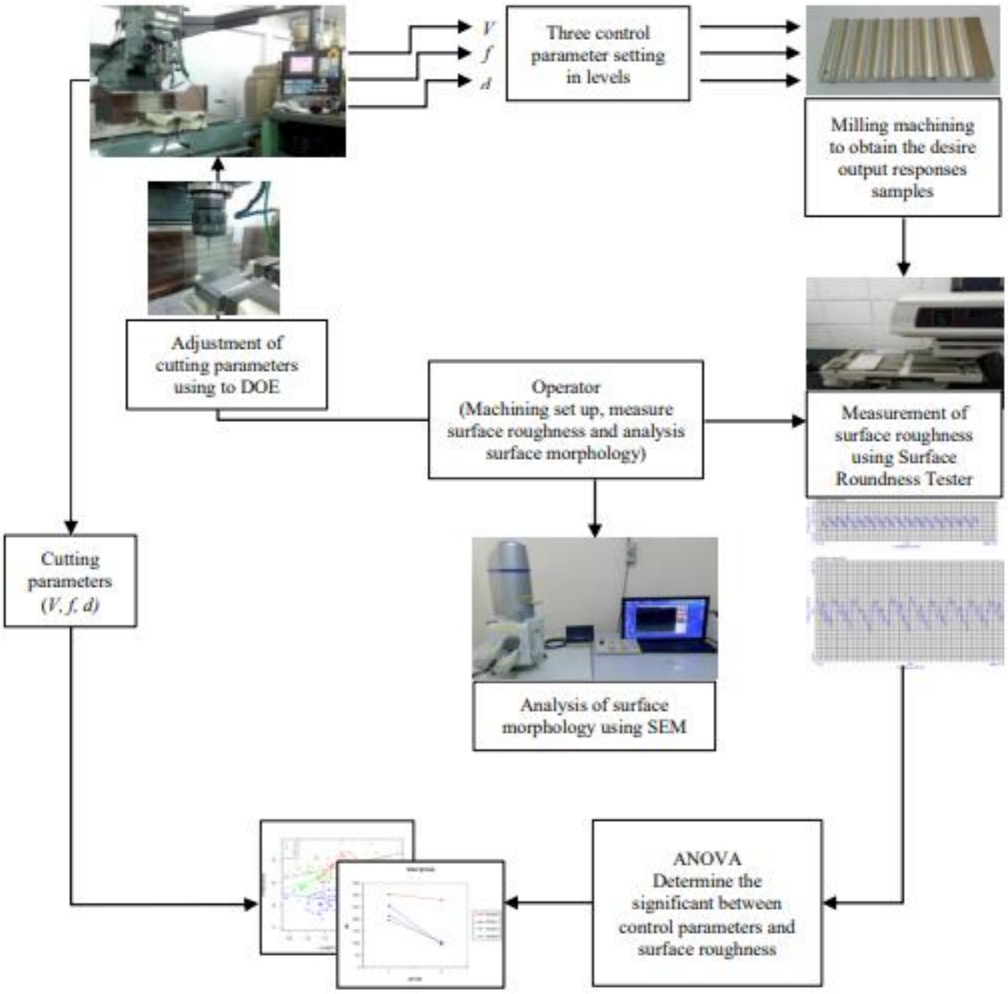

[Dry Milling Machining: Optimization of Cutting Parameters Affecting Surface Roughness of Aluminum 6061 using the Taguchi Method](https://doi.org/10.14716/ijtech.v13i1.4208)

Shamsuddin Sulaiman, Mohammad Sh Alajmi, Wan Norizawati Wan Isahak, Muhammad Yusuf, Muhammad Sayuti

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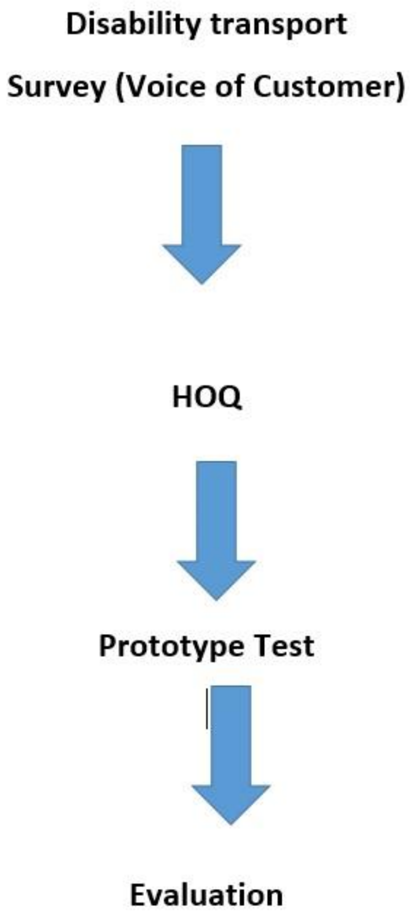

House-of-Quality Approach for the Design of a Minibus to Transport Visually Impaired and Wheelchair-bound Passengers

Sugiono Sugiono, Adam Pratomo, Willy Satrio Nugroho

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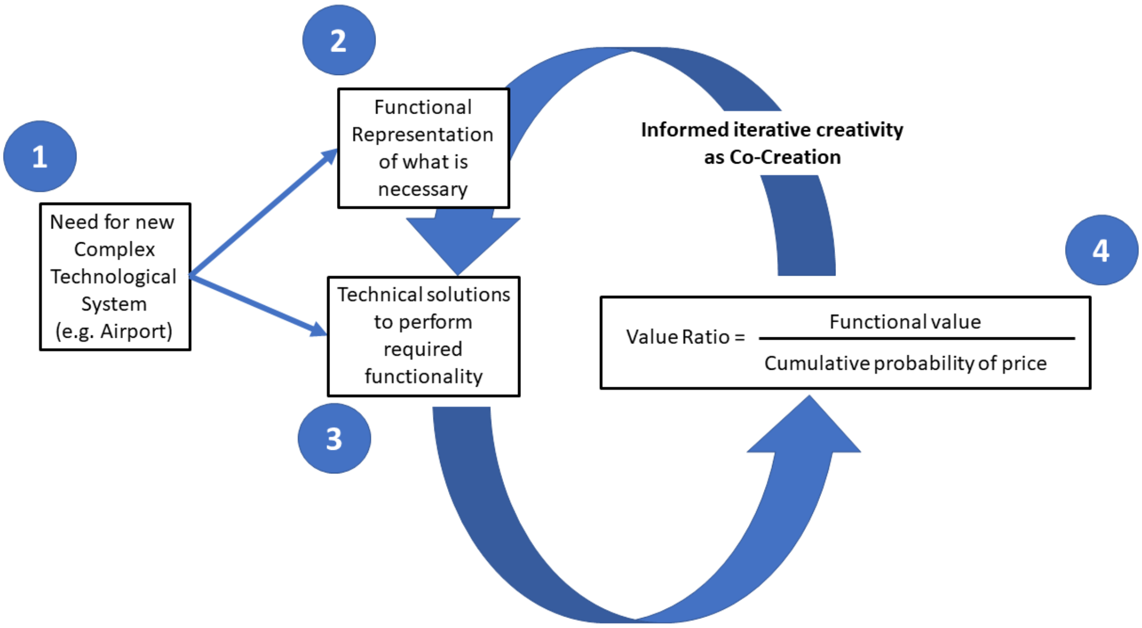

Evolution of Value Engineering to Automate Invention in Complex Technological Systems

Roy Woodhead, Mohammed Ali Berawi

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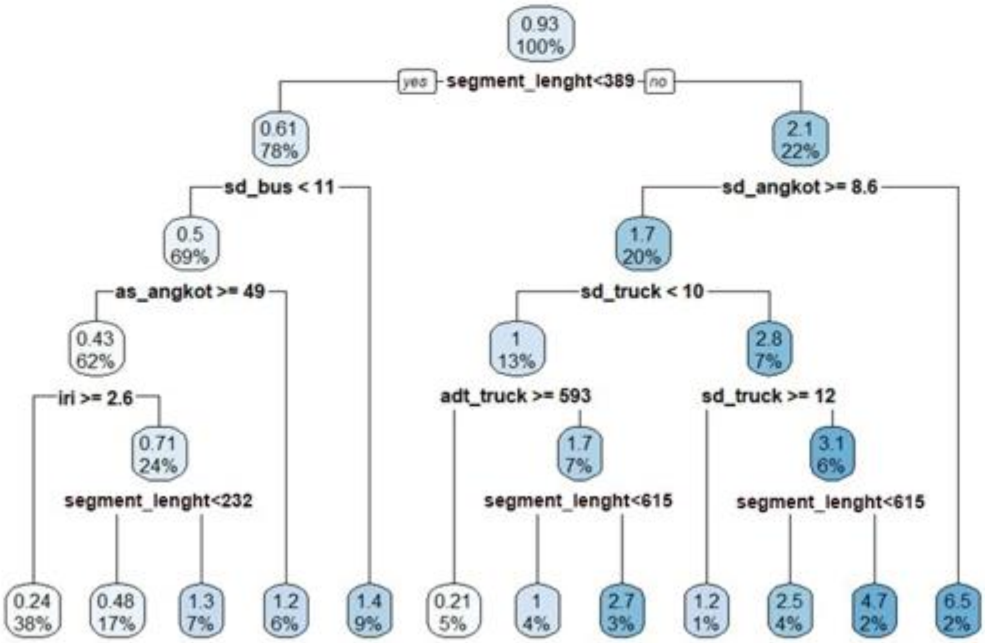

[Predicting the Segment-Based Effects of Heterogeneous Traffic and Road Geometric Features on Fatal Accidents](https://doi.org/10.14716/ijtech.v13i1.4450)

Martha Leni Siregar, Tri Tjahjono, Nahry Yusuf

Publication Date (Online):
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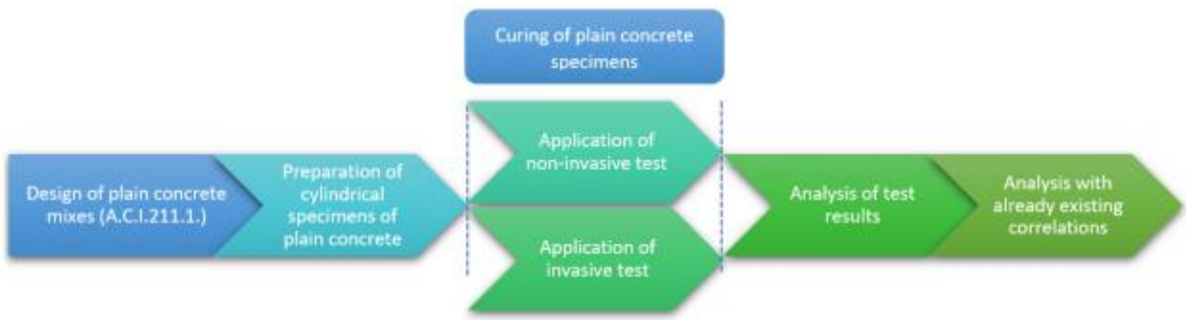

Figure 1 Research methodology

[Strength of Concrete through Ultrasonic Pulse Velocity and Uniaxial Compressive Strength](#)

Daniel Melo Zárate, Fernando Cárdenas, Edwin Francisco Forero, Ferney Oswaldo Peña

Publication Date (Online):
Jan 20, 2022
DOI: https://doi.org/10.14716/ijtech.v13i1.4819
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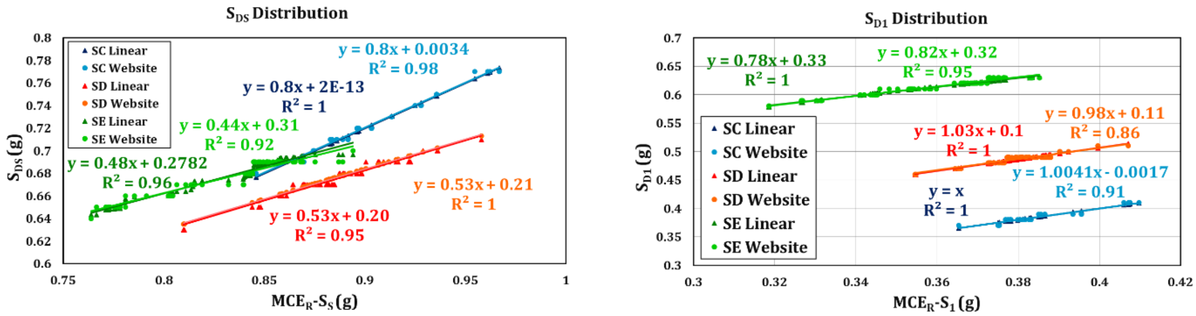

[Site Coefficient and Design Spectral Acceleration Evaluation of New Indonesian 2019 Website Response Spectra](#)

Windu Partono, Masyhur Irsyam, Ramli Nazir, Muhammad Asrurifak, Undayani Cita Sari

Publication Date (Online):
Jan 20, 2022
DOI: https://doi.org/10.14716/ijtech.v13i1.4132
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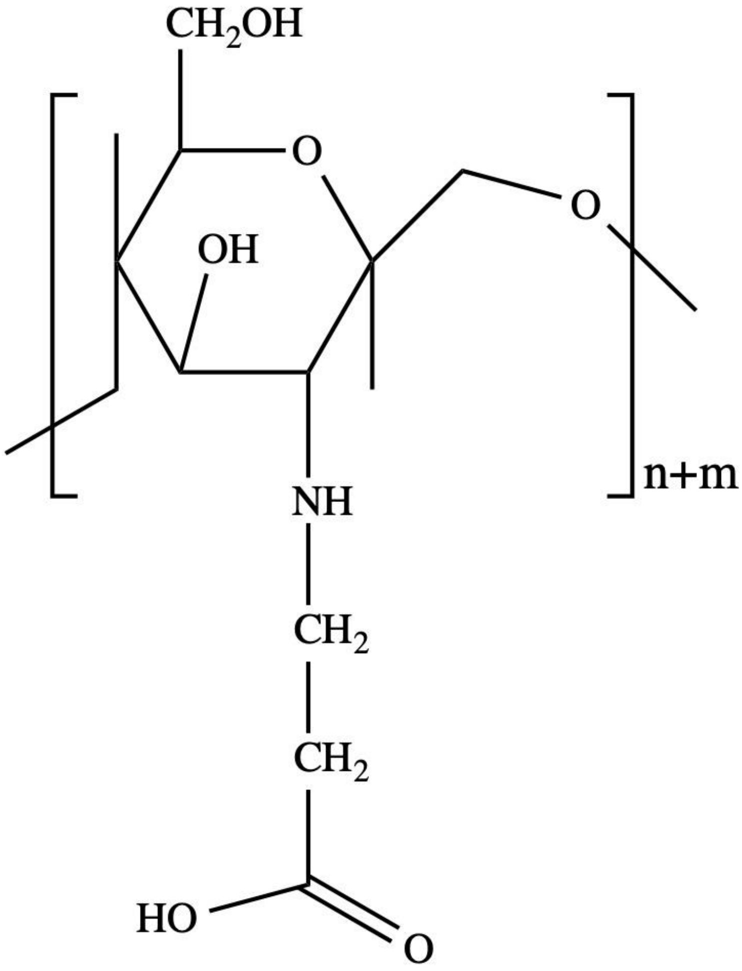

Sheme 1. Structure of P(Ch-g-AA).

The Effects of Modified Chitosan on the Physicomechanical Properties of Mortar

Lyazzat Bekbayeva, El-Sayed Negim, Rimma Niyazbekova , Zhanar Kaliyeva, Gulzhakhan Yeligbayeva, J. Khatib

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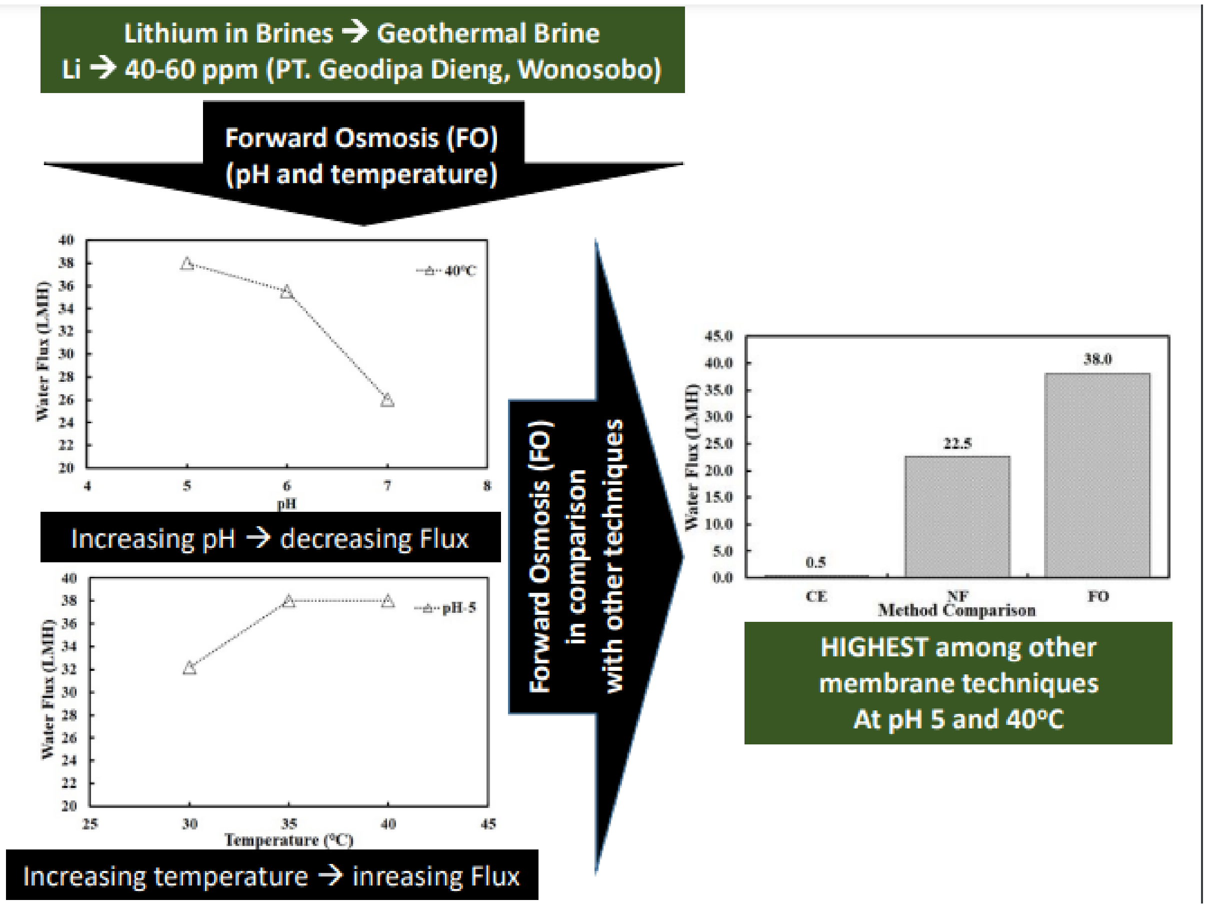

[Forward Osmosis to Concentrate Lithium from Brine: The Effect of Operating Conditions (pH and Temperature)](https://doi.org/10.14716/ijtech.v13i1.4371)

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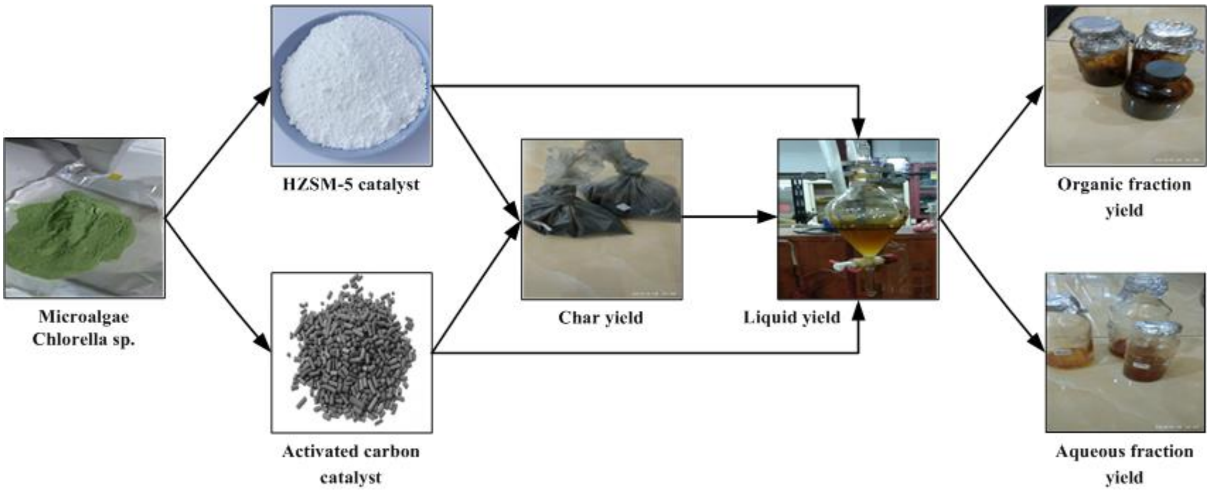

[Production of Liquid Biofuels from Microalgae Chlorella sp. via Catalytic Slow Pyrolysis]

Bambang Sardi, Rifa Fatwa Ningrum, Vicky Azis Ardianyah, Lailatul Qadariyah, Mahfud Mahfud

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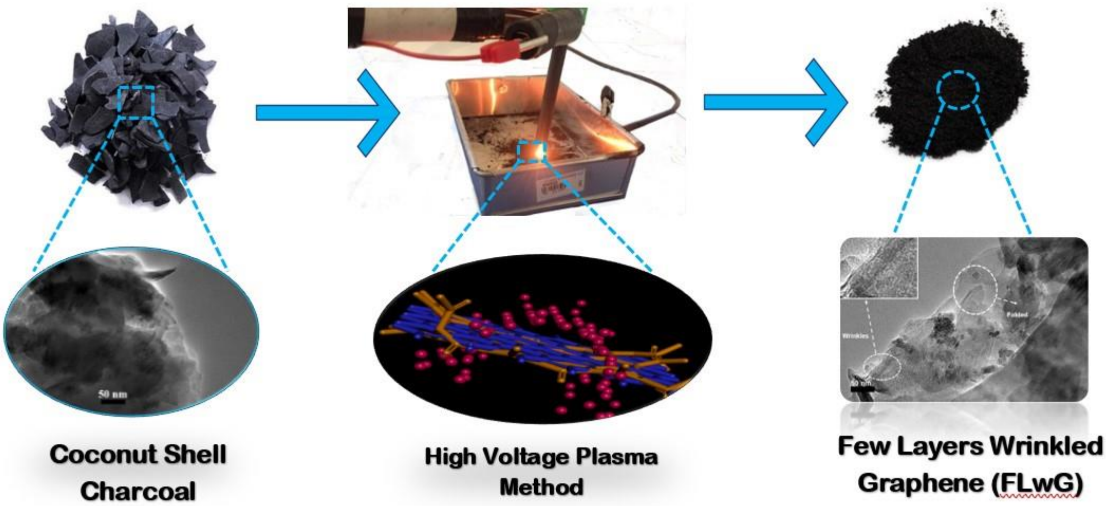

[Few-Layer Wrinkled Graphene (FLwG) Obtained from Coconut-Shell-Based Charcoal using a High-Voltage Plasma Method]

Fri Murdiya, Yola Bertilsya Hendri, Amir Hamzah, Neni Frimayanti, Amun Amri

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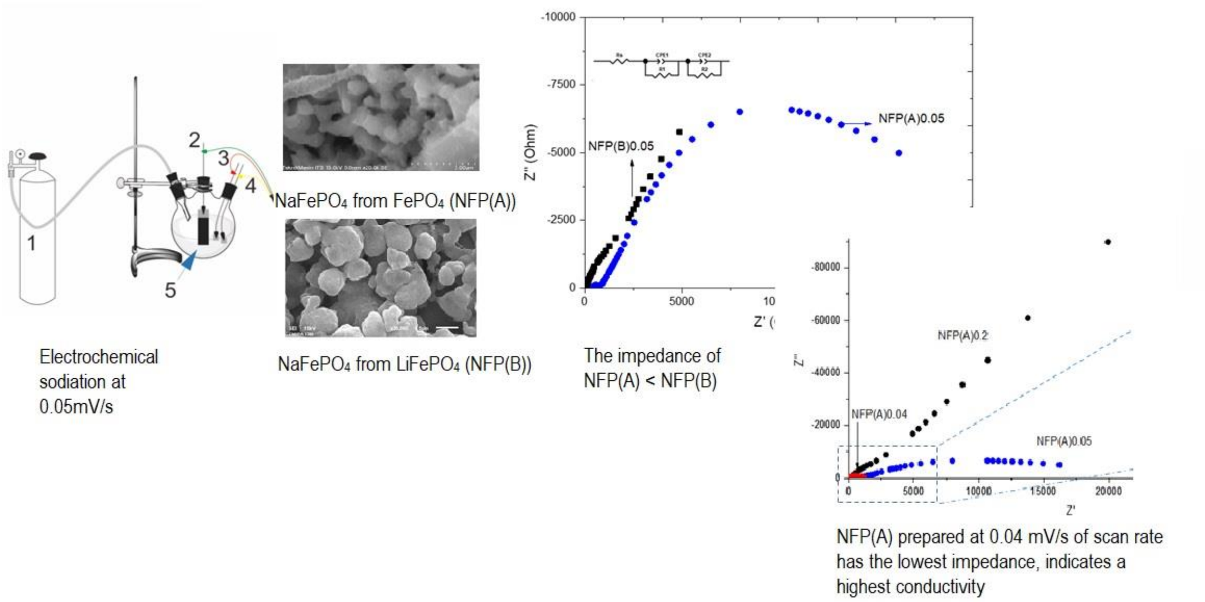

Preparation of a NaFePO4 Cathode Material via Electrochemical Sodiation of FePO4 Layers on Al Substrates

Fitria Rahmawati, Dwi Aman Nur Romadhona, Desi Dyah Paramita, Witri Wahyu Lestari

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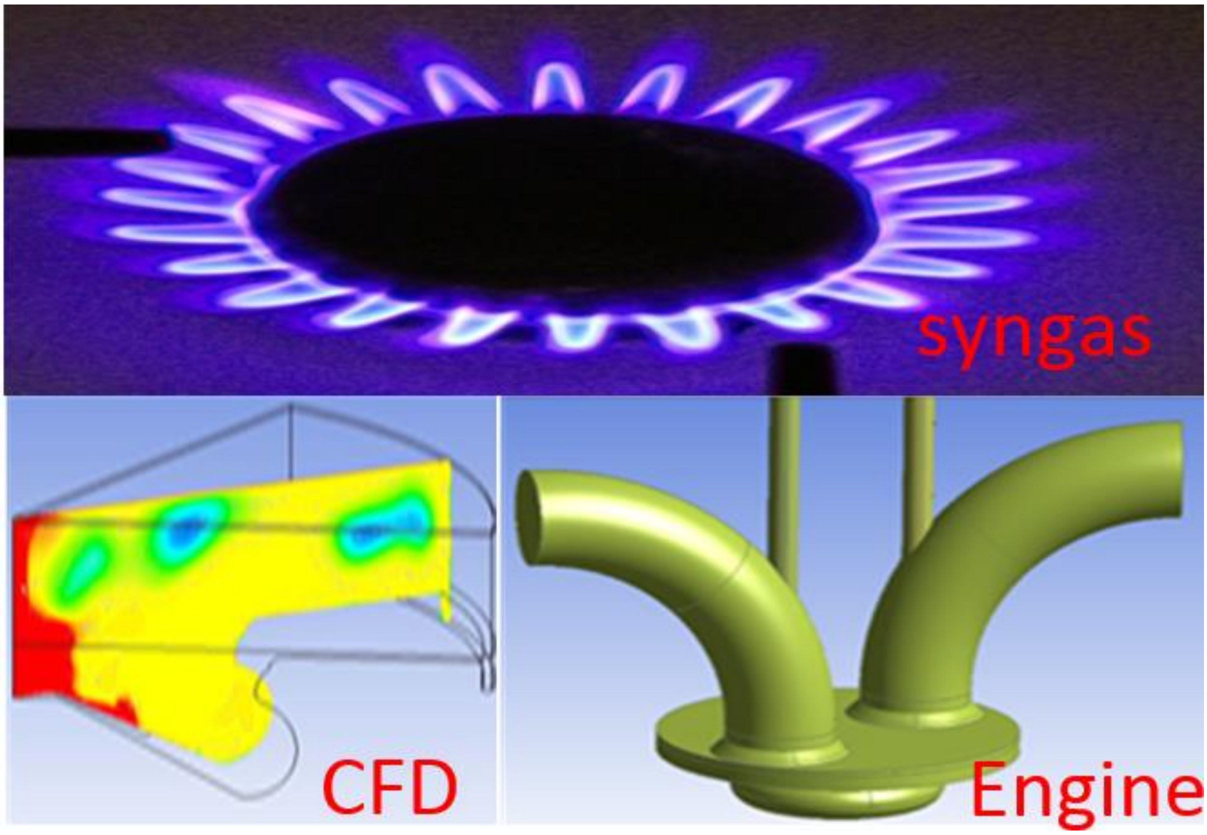

Impact of Lambda Value on Combustion Characteristics and Emissions of Syngas-Diesel Dual-Fuel Engine

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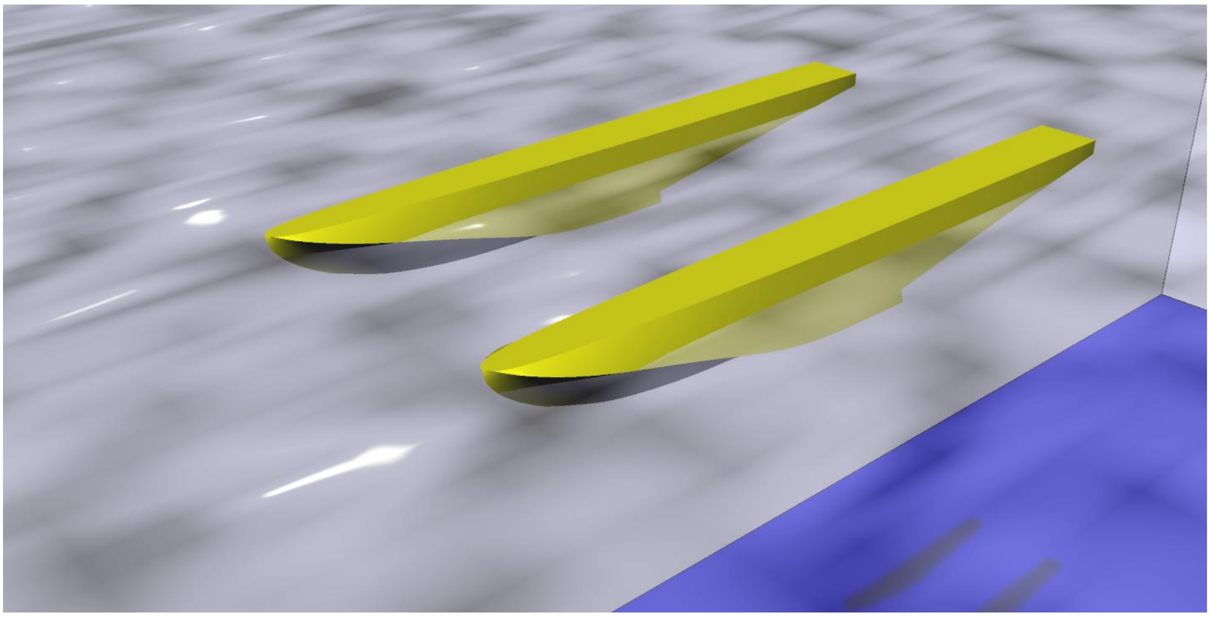

Numerical Analysis of Floatplane Porpoising Instability in Calm Water During Takeoff

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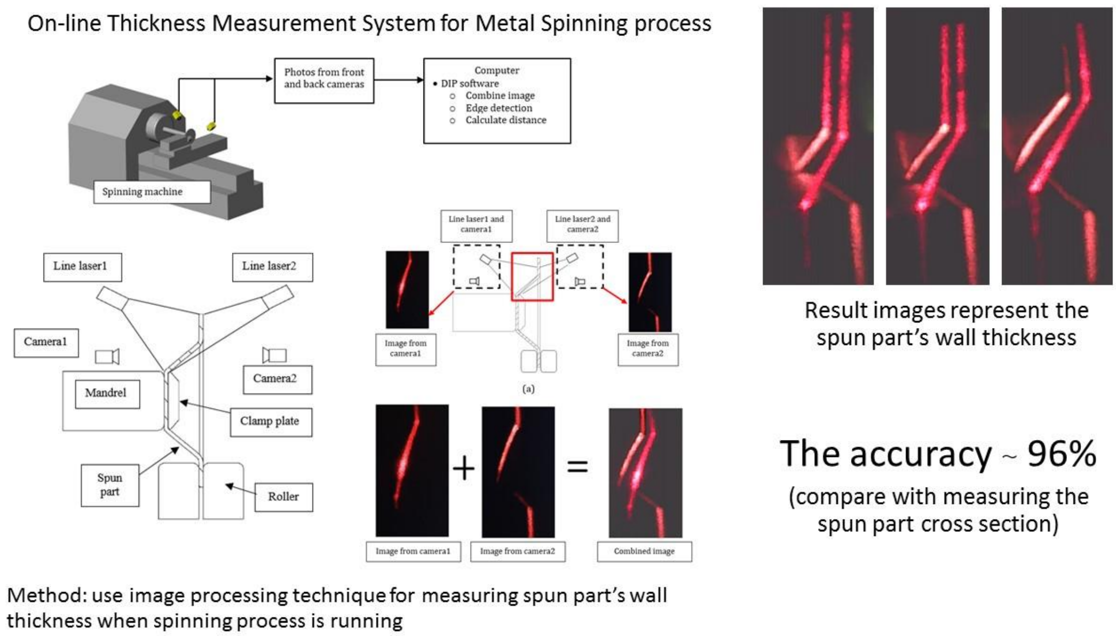

[On-line Thickness Measurement System for the Metal Spinning Process]

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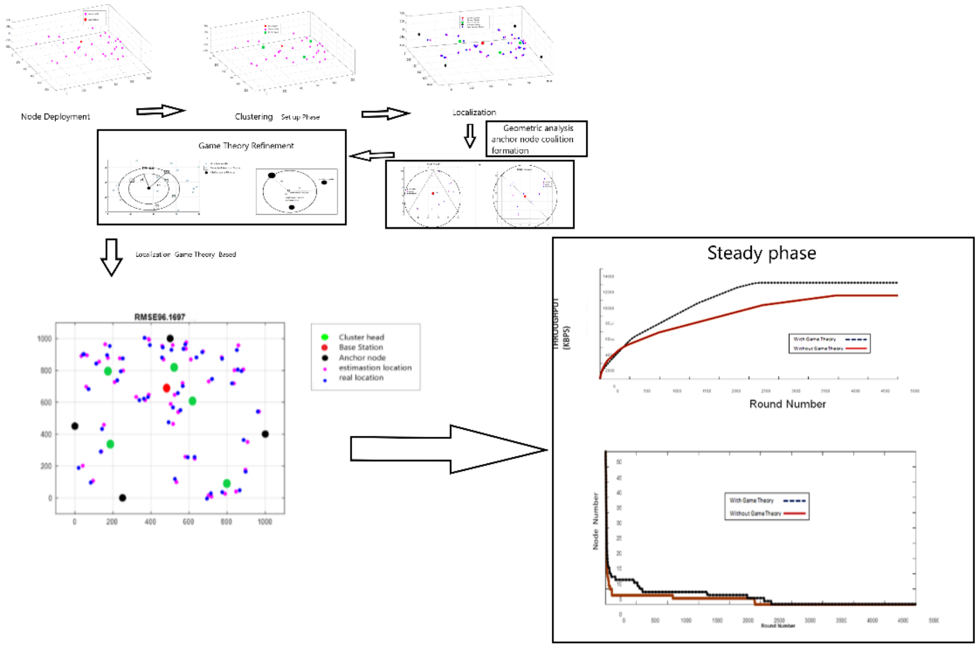

[Wireless Sensor Networks Optimization with Localization-Based Clustering using Game Theory Algorithm]

Nina Hendrarini, Muhamad Asvial, Riri Fitri Sari

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Site Coefficient and Design Spectral Acceleration Evaluation of New Indonesian 2019 Website Response Spectra

Site Coefficient and Design Spectral Acceleration Evaluation of New Indonesian 2019 Website Response Spectra

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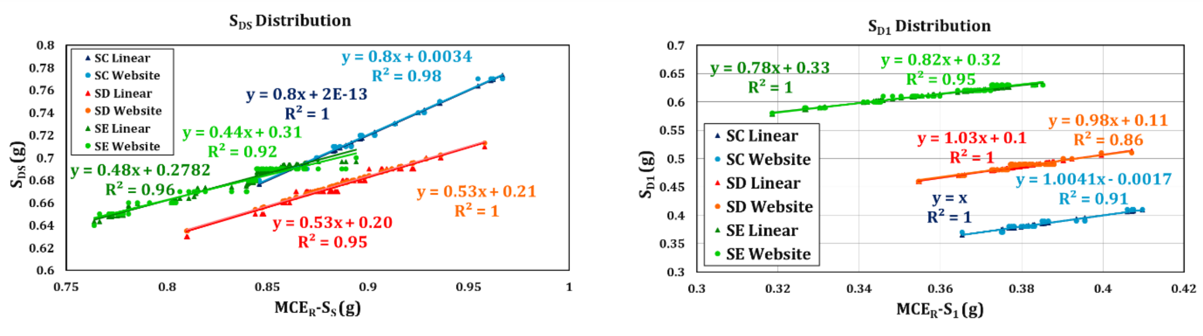
Abstract



Calculation of site coefficient and design response spectral acceleration are two important steps in the seismic design of buildings. According to Indonesian Seismic Code 2019, two information requirements for site coefficient calculations are the site soil class and Risk-targeted Maximum Considered Earthquake (MCE_R-S_S for short and MCE_R-S_1 for long period) spectral acceleration. Three different hard/SC, medium/SD and soft/SE are typically site soil classes used for building designs. Two different site coefficients (Fa for MCE_R-S_S and Fv for MCE_R-S_1 spectral acceleration) are used for surface and design response spectral acceleration calculations. The Indonesian Seismic Code provides two (Fa and Fv) tables for calculating site coefficients. If the MCE_R-S_S or MCE_R-S_1 values developed for a specific site are not exactly equal to the values in Fa or Fv tables, the site coefficients can then be predicted using straight-line interpolation between the two closest Fa or Fv values within the tables. When the straight-line interpolation is adjusted for Fa or Fv calculation, different results were observed in comparison to the values developed using website-based software (prepared by Ministry of Public Works and Human Settlements). This study evaluates site coefficients and design response spectral acceleration predictions in Semarang City, Indonesia, according to straight-line interpolation method and website software calculations. The study was conducted at 203 soil boring positions in the study area. The site soil classes were predicted using average standard penetration test values (N-SPT) of the topmost 30 m soil deposit layer (N30). Three different site soil classes were observed in the study area. On average, the largest differences between the two analysis (linear interpolation and website) methods in the site coefficient values and design response spectral acceleration calculation were observed for the SD and SE classes. However, for the SC site soil class, the difference was small, with their values approximately similar.

Keywords

Design response spectral acceleration; MCER; N-SPT; Site coefficient; Straight-line interpolation

Introduction

The new National Seismic Code of Indonesia (SNI 1726:2019, 2019) was announced in 2019. Some of the information introduced in this new seismic code was partially adopted from the American Standard Code for Seismic Design ASCE/SEI 7-16, specifically the site coefficient values and design response spectral acceleration calculation methods. Additional information for developing the site coefficients was adopted from Stewart and Seyhan (2013). Due to the improved methods described in ASCE/SEI 7-16 for developing site coefficients for site soil classes SD and SE, not all the information described in the American Code was adopted by SNI 1726:2019. Specifically, the site coefficients for the SD and SE classes presented in SNI 1726:2019 were completely adopted from Stewart and Seyhan (2013).

Following the SNI 1726:2019, the Ministry of Public Works and Human Settlements announced a new website software (online facility) for site coefficient and design response spectral acceleration calculation. Site or building position coordinates (in terms of longitude and latitude) and site soil class are two information requirements for design response spectral acceleration calculations. Risk-targeted Maximum Considered Earthquake (MCE_R) acceleration, MCE_R-S_S for short and MCE_R-S_1 for long periods, (Luco et al., 2007; Allen et al., 2015; Sengara et al., 2020), and two design response spectral acceleration, S_{DS} and S_{D1}, are four important values calculated by the website facility software. However, no information related to site coefficients F_a for short and F_v for long periods can be obtained from the new website. Thus, these values can be calculated using Equation 1 and Equation 2. All S_{DS}, S_S (MCE_R-S_S), S_{D1}, and S_1 (MCE_R-S_1) values can be obtained from the website.

$$F_a = \frac{S_{DS}}{2/3\, S_S} \qquad (1)$$

$$F_v = \frac{S_{D1}}{2/3\, S_1} \qquad (2)$$

To verify the F_a and F_v site coefficients estimated using Equations 1 and 2, straight-line interpolation can be conducted using the S_S and S_1 website calculations and applying site coefficient (F_a and F_v) table data provided by SNI 1726:2019. F_a and F_v are then estimated following the procedure described by SNI 1726:2019. Equation 3 shows a simple formula for F_a and F_v site coefficients calculation. Figure 1 shows a diagram of the straight-line interpolation of the F_a and F_v calculation. F and M_w represent the site coefficient to be estimated and the MCE_R value obtained from the website, respectively; M_{1S} and M_{2S} represent two boundary MCE_R values close to M_w; F_{1S} and F_{2S} represent the site coefficients for M_{1S} and M_{2S}, respectively; and M_{1S}, M_{2S}, F_{1S}, and F_{2S} are the four values obtained from the SNI 1726:2019 tables. F_a and F_v are estimated separately using Equation 3.

$$F = \left(\frac{F_{2S} - F_{1S}}{M_{2S} - M_{1S}} \right) (M_W - M_{1S}) + F_{1S} \qquad (3)$$

This paper describes the site coefficients and design response spectral acceleration verification calculated using the website facility and the straight-line interpolation described in SNI 1726:2019. The objective of the study was to evaluate whether or not the website performed the analysis following the same procedures used by SNI 1726:2019. The study was performed in Semarang City, Indonesia, and conducted at 203 soil boring investigation positions. The study was performed as part of seismic microzonation research of the city. One of the important information requirements for seismic microzonation is the development of soil amplification or site coefficient distribution map at the study area. In this study, the standard penetration test (N-SPT) data observed during boring investigation were used for site class calculation. All boring investigations in this study were conducted at a minimum depth of 30 m and a maximum depth 60 m. The average standard penetration test (N-SPT) of the topmost 30 m soil deposit layer (N_{30}) of every boring position was used for site soil class interpretation (Moghaddam, 2011; Partono et al., 2019; Syaifuddin et al., 2020). Figure 2a shows the 203 boring positions and the N_{30} distribution within the study area. Figure 2b shows the distribution of the site soil classes developed based on the N_{30} data (Partono et al., 2021). The maximum N-SPT data obtained from the boring investigation was 60. Following the procedure described by SNI 1726:2019, the N_{30} value was estimated using

Equation 4, where d_i and N_i represent the thickness and N-SPT value of any soil layer "i", respectively.

The parameter that can also be used for site interpretation is the average shear wave velocity (V_S) of the topmost 30 m soil deposit (V_{S30}) (Naji et al., 2020). The V_{S30} value can be calculated using the same method as that shown in Equation 4 and replacing the N_i value with V_{Si}. The V_S value can be observed using seismic refraction multichannel analysis of surface waves (MASW) or seismometer array investigations. Prakoso et al. (2017) described a comparative study of V_S value obtained from MASW investigation and soil boring (N-SPT) data. The V_S value developed using MASW was more reliable compared to that developed based on the N-SPT data. Pramono et al. (2020) described the predominant frequency investigation at Lombok Island following the 2018 earthquake event. The greater the V_{S30} value used, the greater the predominant frequency obtained from the wavelet analysis of the ground motion. Additionally, development of V_{S30} and predominant frequency correlation was also conducted by Pramono et al. (2017) in the Palu area.

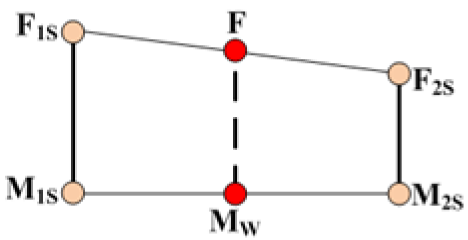


Figure 1 Straight-line interpolation for F_a and F_v calculations

$$N_{30} = \frac{\sum_{i=i}^{i=n} d_i}{\sum_{i=i}^{i=n} \frac{d_i}{N_i}} \qquad (4)$$

Conclusion

Evaluations of site coefficients estimated using the website and straight-line interpolation methods were performed for 203 boring positions in Semarang City. No significant differences were found in the F_a and F_v site coefficients between the two methods. The largest difference in the F_a site coefficient calculations was observed for the SD and SE site classes. The difference in site coefficients for the SD and SE site soil classes was less than 0.03, while, for the SC site soil class, the difference was less than 0.01. In terms of site coefficient F_v, the largest difference was observed for the SD and SE site soil classes with a maximum of 0.04. However, the difference in site coefficient F_v for site class SC was less than 0.02. When calculating F_a and F_v site coefficients, the linear interpolation method from SNI 1726:2019 is better compared to the calculated using MCE_R-S_S, MCE_R-S_1, S_{DS}, and S_{D1} values obtained from the website.

No significant differences in the design response spectral acceleration S_{DS} and S_{D1} values were found for any of the site classes. The largest design response spectral acceleration difference in SD between the two methods was less than 0.02 g, while, for the SC and SE site classes, the differences were less than 0.005 g.

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Supplementary Material

Filename	Description
R2-CVE-4132-20210820110617.pdf	Supplementary File

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