Serviceability limit state analysis of a cracked cross-section in accordance with SRPS EN1992-1-1 and PBAB’87

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Serviceability limit state analysis is an important part of the design of reinforced concrete structures in order to meet the requirements of functionality, durability and aesthetics of the structure. The application of European standards (Eurocodes) in construction in the Republic of Serbia has started recently and there are still disagreements in the interpretation of certain provisions of the standards. On a simply supported reinforced concrete beam at an authoritative cracked cross-section was analyzed the applications of different combinations of permanent and variable actions for purpose of calculation characteristic crack width and deflections at the moment after inflicting load of a class S4 structure and at the end of service life. The results of the calculation according to Eurocode are compared with the results of the calculation according to the Standard for Concrete and Reinforced Concrete from 1987 for interpretation and selection of the relevant combination of actions.

Keywords: Serviceability limit state analysis, Reinforced concrete beam, cracked cross-section

1. INTRODUCTION

Design of reinforced concrete (RC) structural elements by ultimate limit state (ULS) does not necessarily provide desired behaviour of structures and their elements in different moments during their service life, due to differences in actions intensity in regard to the intensity that provides equilibrium. Thus, serviceability limit state analysis (SLS) was introduced that evaluates the performance of structures during service life by taking into account criteria of functionality, durability and aesthetics.

SLS is actually an analysis of a stress-strain state of structures and their elements in which, under the combination of actions that occur during service life, some of the criteria for suitability of structures given in construction standards are met. In case of transgression of determined SLS criteria, structures or some of their elements are considered unsuitable for exploitation independently from their load bearing capacity.

These criteria of functionality, durability and aesthetics in SLS are evaluated by controlling parameters:

- Stress levels in materials – concrete and reinforcement steel,
- Width of cracks on RC structural elements,
- Displacement – usually deflection of RC structural elements,
- Vibrations.

In SLS analysis, when carrying out control of mentioned parameters, must be taken into account effects of creep and shrinkage of concrete during time as viscoelastoplastic material with the pronounced trait of aging. Creep and shrinkage of concrete are time dependent deformations. Due to the inhomogeneity of the structure of the concrete itself, the shrinkage cannot take place completely freely and it is uneven inside the concrete. Interferences to free shrinkage represent the occurrence of reinforcement bars, as well as possible connections on the supports and contours of the elements. On the other hand, creep of hardened concrete is a phenomenon of gradual increase of elastic deformations of concrete that occur at the time of loading, under the further action of long-term loads. Differences in rheological properties, between concrete and steel which co-act under long term load, provide significant redistribution of stresses over time and changes stress-strain state in cross-sections of the RC elements. Thus, under long-term load occurs an increase of stress levels, concrete crack width and deflection.

SLS uses the usual calculation models for the characteristic stress-strain states: for the cross-section of structural element without cracks (state I) and the cross-section in element with cracks (state II), but must be used such stress and strain relations in concrete and steel, that as realistically as possible, show the actual behaviour of these materials in the conditions of service life of the RC structures.

The application of European standards in construction in the Republic of Serbia has started recently and there are still disagreements in the interpretation of certain provisions of the standards. The standard for Concrete and Reinforced Concrete from 1987 (PBAB87) that was used in the Republic of Serbia before the introduction of Eurocodes defined that SLS analysis was conducted into two steps:

- Step 1: control of stresses, crack width and deflection at the moment after inflicting load (t_0)
- Step 2: starting from the previous step, calculations of changes of stresses, crack width and deflection were conducted taking into account the effect of creep and shrinkage of concrete in a determined time interval (t_0-t_∞) under the constant intensity of actions on the

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structure. Moment of time t_∞ was usually the end of service life of the concrete structure [1].

On the other hand, new standards for SLS analysis in concrete structures, European standard SRPS EN 1992-1-1:2015, does not give such specific guidelines as PBAB87, and according to it control of stresses, crack width and deflection at the moment after inflicting load (t_0) is optional [2]. This regulation gives appropriate data for SLS analysis with short-term load, which is necessary for control at the moment after inflicting load (t_0), and analysis with long-term load for control during the service life of the structure. The practice has shown that it is preferable to perform SLS analysis for both moments, for the beginning of service life t_0 and for the end of service life t_∞. This is especially true for purpose of service and revitalization of the existing concrete structures, in which analysis for these moments gives engineers better imaging of the development of stresses, cracks and deflection [3-4].

This paper shows SLS analyses (only crack width and deflection control) conducted for a simply supported reinforced concrete beam at an authoritative cracked cross-section conducted with different combinations of permanent and variable actions during the time from moment t_0 to the end of service life, moment t_∞. Different combinations of actions are from two different standards, PBAB87 and SRPS EN 1990:2012 which gives optional combinations for engineers based on the nature of actions and deformation state of the structural elements [5]. The results of the analysis according to Eurocode are compared with the results of the calculation according to the standard PBAB87 for interpretation and selection of the relevant combination of actions.

2. EXPERIMENTAL ANALYSIS

Ultimate limit state designs of the RC elements are conducted with the combination of actions formed by increasing values of permanent and variable actions with partial factors (γ) for accounting model uncertainties, dimensional variations and the possibility of unfavourable deviations of the action values from the representative values. On the other hand, in the serviceability limit state analysis, actions are not increased with partial factors (γ=1), because in the normal exploitation of the RC structures, the serviceability limit state can be achieved, but not exceeded.

SRPS EN 1990 for SLS analysis gives the following combinations of actions [5]:

- Characteristic combination for irreversible serviceability limit states:
  $\Sigma G_{k,j}+P+Q_{k,1}+\Sigma Q_{k,i}\cdot\psi_{0,i}$ (j≥1,i>1) (1)
- Frequent combination for verification of reversible serviceability limit states involving accidental actions:
  $\Sigma G_{k,j}+P+Q_{k,1}\cdot\psi_{1,i}+\Sigma Q_{k,i}\cdot\psi_{2,i}$ (j,i>1) (2)
- Quasi-permanent combination for verification of reversible serviceability limit states and calculation of the long-term effects:
  $\Sigma G_{k,j}+P+\Sigma Q_{k,i}\cdot\psi_{2,i}$ (j,i≥1) (3)

where are:

$G_{k,j}$ – characteristic value of permanent action j

P – relevant representative value of a prestressing action

$Q_{k,1}$ – characteristic value of the leading variable action 1

$Q_{k,i}$ – characteristic value of the accompanying variable action i

ψ_0 – factor for the characteristic value of a variable action

ψ_1 – factor for the frequent value of a variable action

ψ_2 – factor for the quasi-permanent value of a variable action

SLS analyses conducted in this paper based on SRPS EN 1992-1-1 includes permanent and imposed load for residential buildings as a variable load, thus only characteristic and quasi-permanent combinations were applicable on basis that cracked RC beam is in the irreversible limit state, and controls of crack width and deflection at the end of service life are calculated with the long-term effects.

Analyses based on PBAB87 are using a combination of loads without any factors [1]:

$\Sigma G_{k,j}+P+\Sigma Q_{k,i}$ (j,i≥1) (4)

In total, four combination analysis were made:

1) K-K combination analysis with characteristic (1) combination of actions – load for crack width control and deflection volume control for moments t_0 with short-term effects and t_∞ with long-term effects
2) K-QP combination analysis with characteristic (1) combination of actions – load for crack width control and deflection volume control for moment t_0 with short-term effects and quasi-permanent combination (3) for moments t_∞ during and at the end of service life with long-term effects
3) QP-QP combination analysis with quasi-permanent (3) combination of actions – load for crack width control and deflection volume control for moments t_0 with short-term effects and t_∞ with long-term effects
4) PBAB combination analysis with (4) combination of actions – load for crack width control and deflection volume control for moments t_0 with short-term effects and t_∞ with long-term effects

These combination analyses were conducted to observe a change of crack width and deflection volume through time from moment t_0 to moment t_∞ for a class S4 structure with a life service of 50 years. These SLS parameters are also calculated for moments of 1, 3, 5, 10, 15, 20, 30 and 40 years to complete the display of their change. Also, a change of crack width and deflection volume are observed with modification of characteristic compressive strength of concrete after 28 days of curing.

2.1. Crack width control

Crack width control is usually conducted by calculating the characteristic value of crack width at the specific moment of service life of the RC structure and comparing it with the limit value. Controls based on SRPS EN 1992-1-1 and PBAB87 have the same principles, and their general calculation algorithm is shown in Figure 1.

The calculation of characteristic crack width is based on experimental results and theoretical models. As in figure 1 protocol of calculation consists of:

- Determination of geometrical and mechanical characteristics of effective load bearing cross-section without creep effect for the moment after inflicting load t_0, and with creep effect for the moment t_∞ during and at the end of service life. Creep of concrete changes its modulus of elasticity, increase crack width over time and their propagation depth in an authoritative cracked cross-section, thus decreasing the effective area of a cross-section and decreasing load bearing capacity of the observed RC element.
- Calculation of medium values of concrete strain ε_{cm} and steel strain ε_{sm}. Given that there is a co-act between concrete and steel in the tensile part of cross-section, concrete is tensed to a certain level which is lower than the strain level of reinforcement steel. The difference between these strains represents crack width.
- Calculation of distance between two successive cross-sections with formed cracks on the element.
- The characteristic value of the crack width represents a product of the difference between strains of concrete and steel and maximal distance between cracks. Crack with at the moment t_0 is designated as $w_{k(t0)}$ and at the moment t_∞ as $w_{k(t\infty)}$.

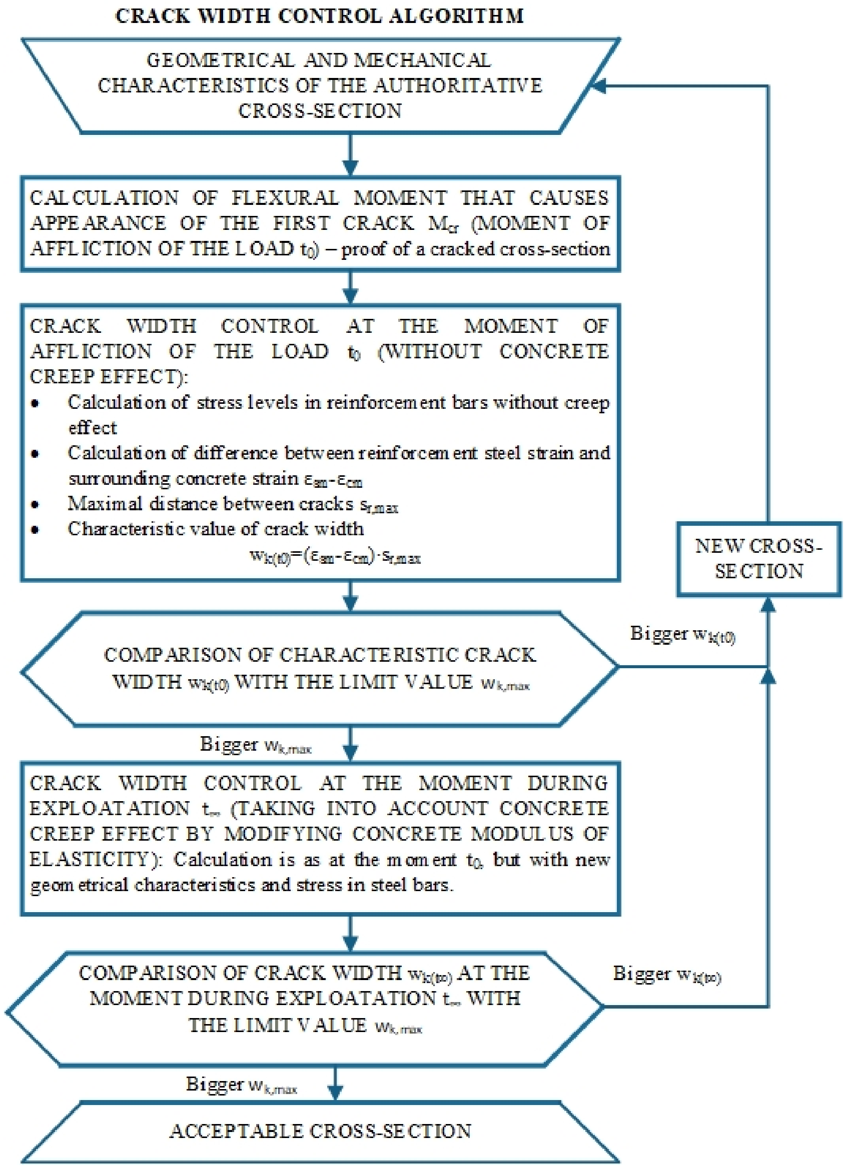


Figure 1: Crack width control algorithm

2.2. Deflection volume control

Independently from the type of their material, all structures under load are deformed. For engineering purposes, usually vertical and horizontal displacements are calculated. Vertical displacements (deflections) are mostly the result of gravitational pull and deformations from flexural moments. Horizontal displacements are mostly the result of horizontal actions like earthquakes and wind.

Deflection with increased volume rarely endangers the stability and durability of structures. Reasons for its control and limitations are the functionality and aesthetics of the structure.

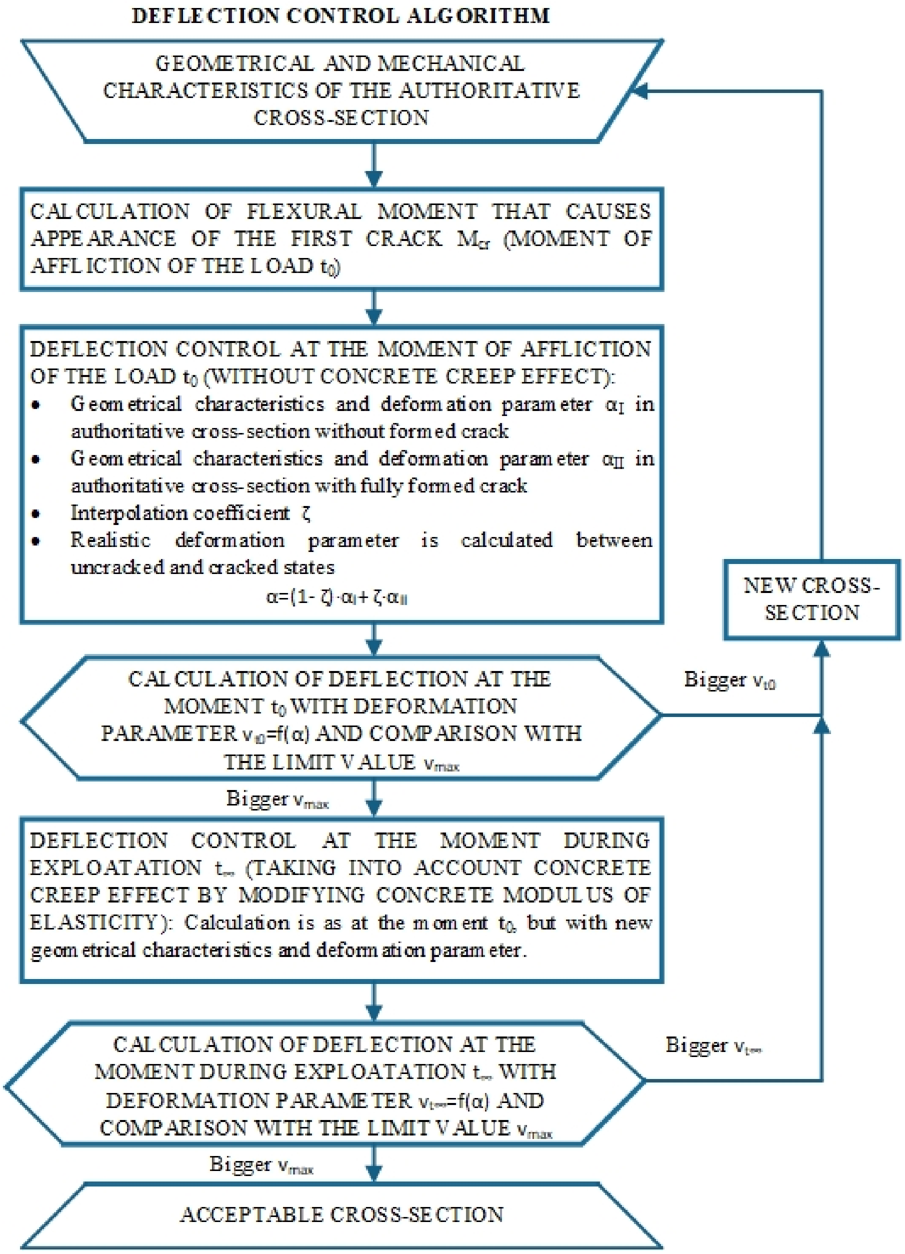


Figure 2: Deflection control algorithm

More than few procedures were developed for deflection volume control, and they are mostly based on a simple principle of determination with two limit values (Figure 2). It is considered that the realistic stress-strain state of the observed RC cracked beam for the SLS deflection control is between one with uncracked cross-section (state I) and one with fully formed crack (state II), thus two deformation parameters (α_I and α_{II}) are calculated and combined with interpolation coefficient ζ as in Figure 2. This is done because in a cracked beam there are cross-sections with cracks and between them cross-sections without cracks in which concrete in the tensile area participates in load bearing capacity of the beam, due to co-act with reinforcement steel bars. As a deformation parameter for deflection control calculation, usually is chosen effective medium curve in a large number of relatively close sections of the RC element.

The characteristic value of deflection at moment t_0 is calculated without creep and shrinkage effects and designated as v_{t0}, and at the moment t_∞ characteristic value of deflection is calculated taking into account creep and shrinkage effects and it is designated as $v_{t\infty}$.

3. RESULTS OF ANALYSIS

With mentioned four different SLS combination analyses, studies were made in which were observed changes of crack width and deflection over time and changes concerning different values of characteristic compressive strength of concrete in two specific moments t_0 and t_∞.

3.1. Analysis in accordance with SRPS EN 1992-1-1

SLS analysis was conducted on a simply supported reinforced concrete beam with a span L=4.5m. Beam had uniformly distributed permanent and variable induced load (category A for residential buildings) g=q=10KN/m' for the first study - SLS parameters through time, and g=q=15KN/m' for the second study – SLS parameters concerning concrete strength. In accordance with the ULS design, the value of flexural moment in beams midspan (authoritative cross-section) was calculated by using appropriate partial factors for actions – loads (γ_G=1.35 for permanent load and γ_Q=1.5 for variable load) and partial factors for materials. Used concrete for the first study was with strength class C30/37 and for the second study four different strength classes were used: C20/25, C25/30, C30/37 and C35/45. Reinforcement steel class B500 was used for both studies. With this data was calculated required main tensile cross-sectional area of reinforcement. For the first study required reinforcement area was $A_{a1,req}$=10.32cm^2 and for the second study value of the required reinforcement area changed with concrete strength ranging $A_{a1,req}$=10.03-11.91cm^2. For all calculated cross-sections were adopted four main reinforcement bars with diameter Ø20mm with total cross-sectional area $A_{a1,req}$=12.57cm^2. Additional two bars with diameter Ø12mm were adopted in corners of the cross-sectional compressed area and also were adopted stirrups UØ8mm. The nominal value of the concrete cover layer was adopted c_{nom}=3cm. The adopted cross-section for analyses is shown in Figure 3 [2].

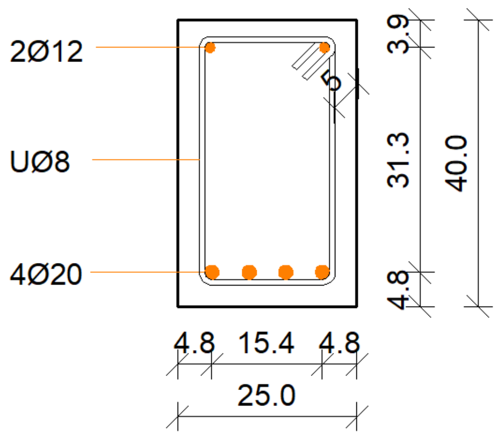


Figure 3: Authoritative cross-section of the observed beam in SLS analysis

For purpose of calculating linear creep coefficient and shrinkage adopted surrounding had a relative humidity of 50%. Concrete cured for 28 days at a temperature of 20°C and was cared for 7 days after casting.

After ULS design, SLS combination analyses were conducted by following protocols from Figures 1-2 with two different combinations of permanent and variable loads (ψ_0=0.7 and ψ_2=0.3 for category A) [2, 5]. Characteristic load value in accordance with (1) was $q_K=g+q\cdot\psi_0$=17KN/m' for the first study and $q_K=g+q\cdot\psi_0$=25.5KN/m' for the second study. Quasi-permanent load value in accordance with (3) was $q_{QP}=g+q\cdot\psi_2$=16KN/m' for the first study and $q_{QP}=g+q\cdot\psi_2$=24KN/m' for the second study. These load values were used in three analyses, K-K, K-QP and QP-QP, as previously said [2].

3.2. Analysis in accordance with PBAB87

In order to make analyses with two different standards comparative, it was used same load values on the same RC beam with the same materials, steel with characteristic yield strength f_{yk}=500MPa and concrete with same characteristic compressive strength. While SRPS EN 1992-1-1 uses compressive strength of concrete measured on cylindrical specimens (the first number in designation in MPa) and cube specimens with edge length 15cm (the second number in designation in MPa), standard PBAB87 uses compressive strength measured on cube specimens with edge length 20cm, thus calibration of input parameters from SRPS EN 1992-1-1 analysis was required by multiplying strength with coefficient 0.95 to gain values similar to strength measured on cubes with edge 20cm. For example concrete class C30/37 ($f_{ck,cube,15}$=37MPa) is equal to concrete class MB35 in PBAB 87 ($f_{ck,cube,20}$=37·0.95=35MPa) [1]. An important difference between the two standards is the way that they trait reinforcement capacity and ductility of materials in cross-section. While PBAB87 allows strain in reinforcement up to $\varepsilon_{s,PBAB}\leq$-10‰, SRPS EN 1992-1-1 allows higher strains in reinforcement ($\varepsilon_{s,SRPSEN}\leq$-20‰) by taking into account ductility. For this reason, ULS design in both studies is limited to strain $\varepsilon_{s,PBAB}$= $\varepsilon_{s,SRPSEN}\leq$-10‰.

Permanent and variable loads in PBAB87 analyses were multiplied with different partial factors (γ_G=1.6 for permanent load and γ_Q=1.8 for variable load) than those from SRPS EN 1992-1-1 analyses. ULS design in accordance with PBAB87 gave similar values of required reinforcement area, $A_{a1,req}$=10.43cm^2 for the first study, and values ranging $A_{a1,req}$=10.19-11.34cm^2 for the second study, thus the same authoritative cross-section was adopted (Figure 3).

SLS analyses was performed with principles shown in figures 1-2 in accordance with standard PBAB87 and with load combination (4) and values q_{PBAB}=g+q =20KN/m' for the first study and q_{PBAB}=g+q =30KN/m' for the second study.

3.3. Changes of crack width and deflection through time

Results for this study with four different combinations of loads in accordance with SRPS EN1992-1-1 and PBAB87 are shown in Figures 4-5, statistically processed with common logarithmic equations and presented as diagrams [6]. In Table 1 are given exact values of crack width and deflection, as well as calculated linear creep coefficient and shrinkage volume of concrete in specific moments of service life of the observed simply supported RC beam for S4 class structure (service life of 50 years). Calculations were conducted for time periods of t_0=28days, 1 year, 3 years, 5 years, 10 years, 15 years, 20 years, 30 years, 40 years and t_∞=50years.

Table 1: Values of crack width, deflections, creep coefficients and shrinkage trough time for combination analyses K-K, K-QP. QP-QP and PBAB

t	t_0	1	3	5	10	15	20	30	40	50	[years]
$\varphi_{(t,\infty)}$	-	1.896	2.208	2.298	2.375	2.408	2.418	2.433	2.441	2.445	-
ε_{cs}	-	0.414	0.464	0.475	0.484	0.487	0.489	0.49	0.491	0.491	[mm/m']
w_{K-K}	0.208	0.229	0.23	0.231	0.231	0.231	0.232	0.232	0.232	0.232	[mm]
w_{K-QP}	0.208	0.149	0.151	0.152	0.152	0.152	0.152	0.152	0.152	0.152	[mm]
w_{QP-QP}	0.127	0.149	0.151	0.152	0.152	0.152	0.152	0.152	0.152	0.152	[mm]
w_{PBAB}	0.244	0.257	0.258	0.258	0.258	0.258	0.258	0.259	0.259	0.259	[mm]
v_{K-K}	1.613	2.041	2.137	2.162	2.183	2.19	2.194	2.197	2.199	2.201	[cm]
v_{K-QP}	1.613	1.411	1.487	1.506	1.521	1.527	1.53	1.533	1.534	1.535	[cm]
v_{QP-QP}	1.108	1.411	1.487	1.506	1.521	1.527	1.53	1.533	1.534	1.535	[cm]
v_{PBAB}	1.104	1.72	1.794	1.816	1.834	1.842	1.846	1.851	1.855	1.858	[cm]

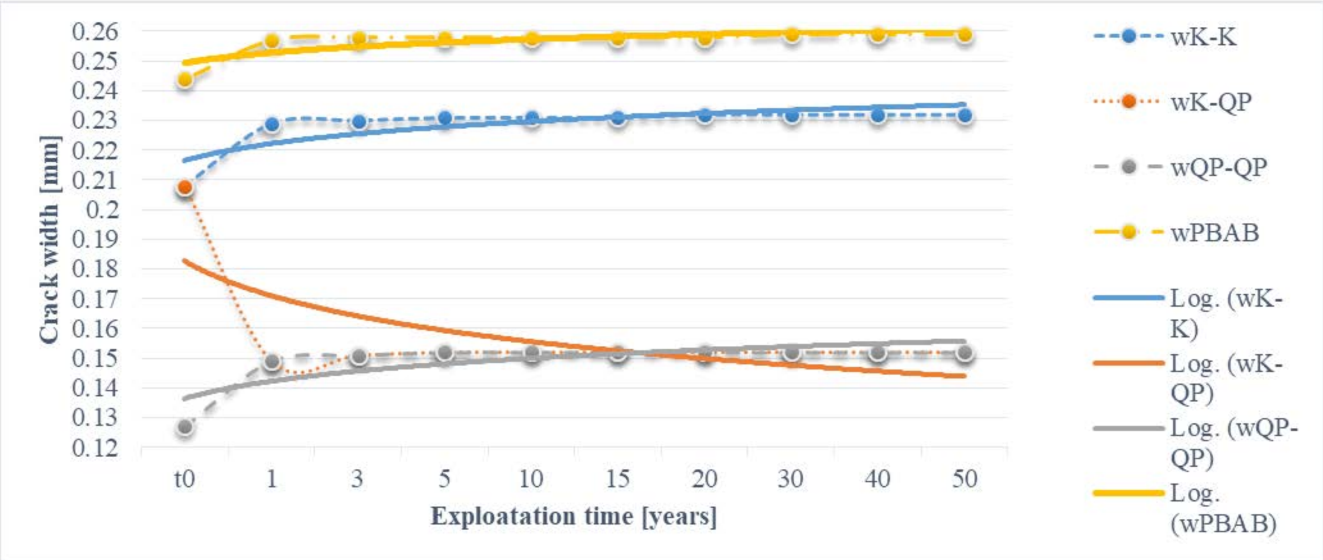


Figure 4: Change of crack width in concrete through time

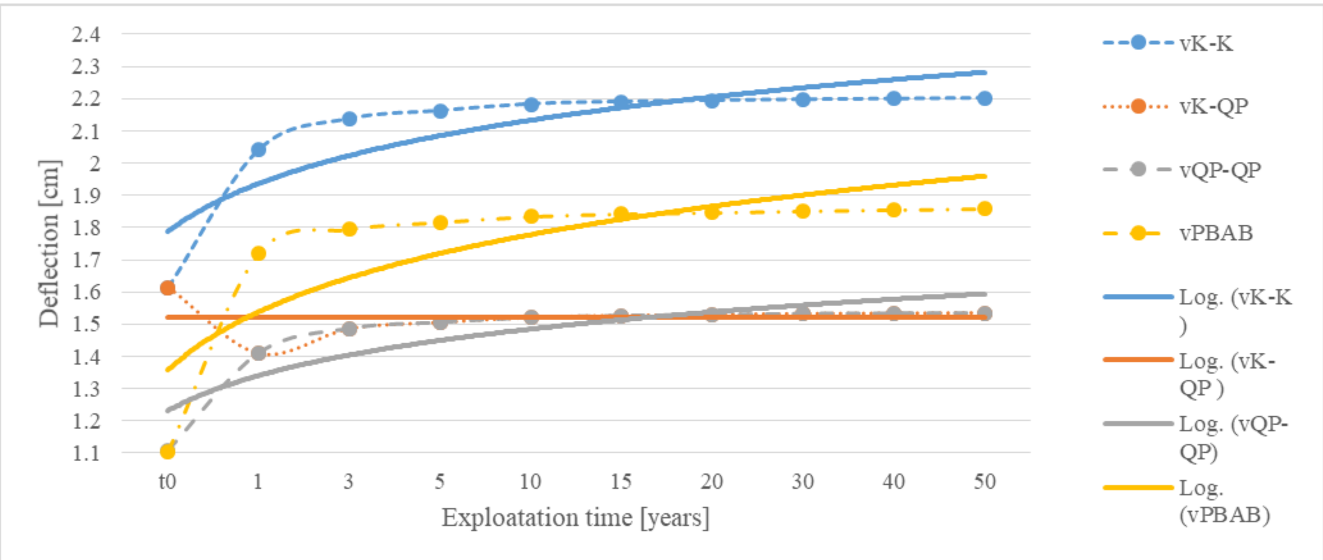
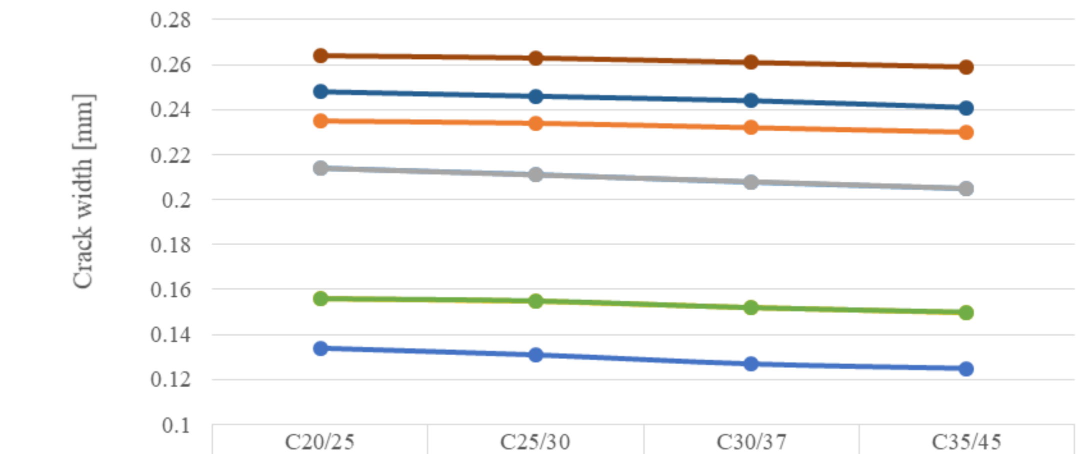


Figure 5: Change of deflection volume in concrete through time

3.4. Crack width and deflection with regard to different concrete compressive strengths

Results for this study with four different combinations of loads in accordance with SRPS EN1992-1-1 and PBAB87 are shown in Figures 6-7. Crack width and deflection were calculated for two moments, t_0=28days after inflicting loads and t_∞=50years at the end of service life of the RC beam.

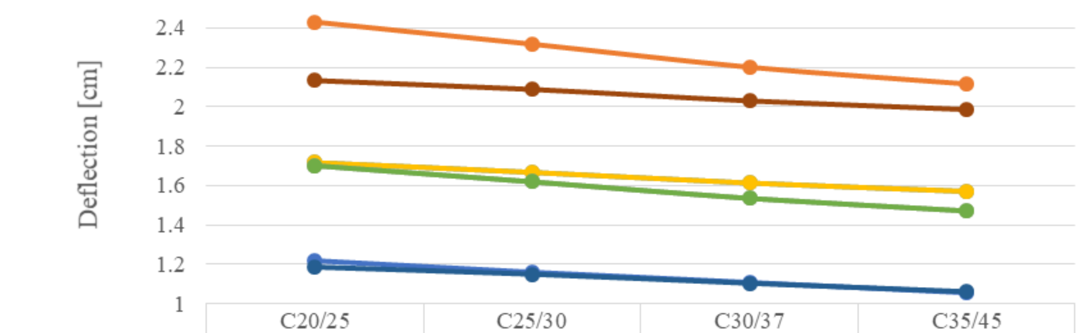
In Table 2 are given values of compressive strengths used in analyses from both standards ($f_{ck,cube,15}$ from SRPS EN 1992-1-1 and $f_{ck,cube,15}$ from PBAB), as well as steel strains calculated in ULS design and linear creep coefficients and shrinkage values for different strength classes of concrete.



	C20/25	C25/30	C30/37	C35/45
wK-K (t,0)	0.214	0.211	0.208	0.205
wK-K (t,∞)	0.235	0.234	0.232	0.23
wK-QP (t,0)	0.214	0.211	0.208	0.205
wK-QP (t,∞)	0.156	0.155	0.152	0.15
wQP-QP (t,0)	0.134	0.131	0.127	0.125
wQP-QP (t,∞)	0.156	0.155	0.152	0.15
wPBAB (t,0)	0.248	0.246	0.244	0.241
wPBAB (t,∞)	0.264	0.263	0.261	0.259

Compressive strength [MPa]

Figure 6: Change of crack width with regard to different concrete compressive strengths



	C20/25	C25/30	C30/37	C35/45
vK-K (t,0)	1.716	1.667	1.613	1.57
vK-K (t,∞)	2.43	2.318	2.201	2.116
vK-QP (t,0)	1.716	1.667	1.613	1.57
vK-QP (t,∞)	1.701	1.619	1.535	1.471
vQP-QP (t,0)	1.219	1.163	1.108	1.059
vQP-QP (t,∞)	1.701	1.619	1.535	1.471
vPBAB (t,0)	1.186	1.15	1.104	1.061
vPBAB (t,∞)	2.133	2.088	2.03	1.986

Compressive strength [MPa]

Figure 7: Change of deflection volume with regard to different concrete compressive strengths

Table 2: Values of characteristic compression strength of concrete, strains of reinforcement, creep coefficient and shrinkage for combination analyses K-K, K-QP. QP-QP and PBAB

$f_{ck,cube,15}$	**C20/25**	**C25/30**	**C30/37**	**C35/45**	**[MPa]**
$f_{ck,cube,20}$	**23.75**	**28.5**	**35.15**	**42.75**	[MPa]
$\varphi_{(t,\infty)}$	3.218	2.797	2.445	2.156	-
ε_{cs}	0.523	0.506	0.491	0.478	[mm/m']
A_{a1}	12.57	12.57	12.57	12.57	[cm^2]
$\varepsilon_{s,PBAB}$	3.73	5.513	7.534	9.583	[‰]
$\varepsilon_{s,SRPSEN}$	1.96	3.999	5.946	7.859	[‰]

4. DISCUSSION OF THE RESULTS

4.1. Changes of crack width and deflection through time

4.1.1. Crack width

The highest value of crack width is 0.259mm, calculated at t_∞=50years of the age, of the RC beam with PBAB combination of actions – loads, and the lowest value of crack width is 0.127mm, calculated at the moment after inflicting load t_0=28days with quasi-permanent combination analysis QP-QP.

Combination analyses PBAB, K-K and QP-QP have an increase in values from moment t_0 to moment t_∞=50years. This increase is more intense at the beginning of service life and through time it approaches constant values which are in accordance with theoretical knowledge and experimental data, and it follows an increase in creep and shrinkage of concrete, time dependent deformations. Crack width for combination analysis PBAB is in the range 0.244-0.259mm, for combination analysis K-K is in the range 0.208-0.232mm and for combination analysis QP-QP is in the range 0.127-0.152mm. Combination analysis K-QP has a decrease in crack width from moment t_0 with a value of 0.208mm to moment t_∞ with a value of 0.152mm, due to calculation with two different load combinations used for moments t_0 and t_∞ (a characteristic combination for moment at t_0 gives higher values of crack width than those with quasi-permanent combination) [7-11].

4.1.2. Deflection values

The highest value of deflection is 2.201cm, calculated at t_∞=50years of the age of the RC beam with K-K characteristic combination of actions – loads, and the lowest value of deflection is 1.104cm, calculated at the moment after inflicting load t_0=28days with combination analysis PBAB.

Combination analyses PBAB, K-K and QP-QP have an increase in values from moment t_0 to moment t_∞=50years. This increase is more intense at the beginning of service life and through time it approaches constant values which are in accordance with theoretical knowledge and experimental data, and it follows an increase in creep and shrinkage of concrete. Deflection for combination analysis PBAB is in the range 1.104-1.858cm, for combination analysis K-K is in the range 1.613-2.201cm and for combination analysis QP-QP is in the range 1.108-1.535cm. Combination analysis K-QP has a decrease in deflection volume from moment t_0 with value 1.613cm to moment t_∞ with value 1.535cm, due to calculation with two different load combinations used for moments t_0 and t_∞ [7-11].

4.2. Crack width and deflection with regard to different concrete compressive strengths

4.2.1. Crack width

The lowest calculated crack width at moment t_0=28days is 0.125mm for C35/45 with quasi-permanent load combination analysis QP-QP and the highest at the same moment is 0.248mm for C20/25 with combination analysis PBAB. The lowest calculated crack width at moment t_∞=50years is 0.15mm for C35/45 with quasi-permanent load combination analysis QP-QP and the highest at the same moment is 0.264mm for C20/25 with combination analysis PBAB. All combination analyses for both moments of time have a decrease in crack width when increasing the compressive strength class of the concrete, due to an increase in tensile strength of concrete. Higher strength is followed by an appropriate decrease of creep and shrinkage and lower deformations [7-11].

4.2.2. Deflection values

The lowest calculated deflection at moment t_0=28days is 1.059cm for C35/45 with quasi-permanent load combination analysis QP-QP and the highest at the same moment is 1.716cm for C20/25 with characteristic combination analysis K-K. The lowest calculated deflection at moment t_∞=50years is 1.471cm for C35/45 with quasi-permanent load combination analysis QP-QP and the highest at the same moment is 2.43cm for C20/25 with characteristic combination analysis K-K. All combination analyses for both moments of time have a decrease in deflection when increasing the compressive strength class of the concrete and it is followed by an appropriate decrease of creep and shrinkage and lower deformations.

Standard PBAB87 comparing to Eurocodes was designed for use of materials with lower strengths. Previously for reinforcement bars was used steel with characteristic yield strength f_{yk}=240-400MPa instead of now commonly used reinforcement B500 with characteristic yield strength f_{yk}=500MPa. The use of concrete and steel with higher strengths allowed the design of smaller cross-sections and elements with larger spans.

Also, new materials kept a similar modulus of elasticity to older materials, thus the same ULS requirements are now met with elements with lower stiffness, but with a higher volume of deflections, thus shown results from PBAB87 combination analyses should be lower if reinforcement strains from SRPS EN 1992-1-1 are considered as more realistic [7-11].

5. CONCLUSION

The primary objective of this study was to evaluate referent load combination for moments t_0 and t_∞ in SLS analysis. Results from the study indicate the following:

- It is not possible to use different combinations of actions – loads for different moments in one same SLS analysis,
- Crack width calculated with standard PBAB are higher in volume than crack width calculated with any possible combinations with standard SRPS EN 1992-1-1,
- Deflections calculated with standard PBAB are higher in volume than deflections calculated with quasi-permanent combination and lower than those calculated with characteristic combination in accordance with standard SRPS EN 1992-1-1.

This research has shown that, in comparison with standard PBAB87, a quasi-permanent combination of actions in standard SRPS EN 1992-1-1 is most adequate to use in SLS controls, but with reserve, due to incompatibility of two standards which is observed in strains of reinforcement steel.

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