# ДГКМ MASE ЧК-6

ДРУШТВО НА ГРАДЕЖНИТЕ КОНСТРУКТОРИ НА МАКЕДОНИЈА

MACEDONIAN ASSOCIATION OF STRUCTURAL ENGINEERS

Партизански одреди 24, П.Фах 560, 1001 Скопје Македонија

Partizanski odredi 24, P. Box 560, 1001 Skopje Macedonia

mase@gf.ukim.edu.mk
http://www.mase.org.mk



Билјана ДЕРЕТИЌ-СТОЈАНОВИЌ[1], Саша СТОШИЌ[2], Божидар СТОШИЌ[3]


## ПРЕСМЕТКА НА КОМПОЗИТНАТА КОНСТРУКЦИЈА НА ПРИСТАПНИТЕ ДЕЛОВИ ОД МОСТОТ ПРЕКУ РЕКАТА ДУНАВ КАЈ БЕШКА, СРБИЈА


### РЕЗИМЕ

Во идејниот проект на мостот преку реката Дунав кај Бешка, кој беше награден проект во меѓународен натпревар покрај главниот мостовски дел кој се протега преку реката, беа предвидени и пристапни мостовски делови над делот за регулација на речното корито во случај на поплави.

Распоните помеѓу столбовите на пристапните мостовски делови, во согласност со условите од натпреварот беа претходно дефинирани и изнесуваа 45.0m. Должината на десната страна од пристапниот мостовски дел е 180m, додека на левата страна е 1492.55m. Бидејќи овие должини се доста големи, а особено на левата страна од мостот, проектантите предложија пристапните мостовски делови да бидат изведени од повеќе композитни континуирани греди. Во трудов е презентирана пресметката на композитната конструкција на овие мостовски делови.



Biljana DERETIC-STOJANOVIC[1], Sasa STOSIC[2], Bozidar STOSIC[3]


## ANALYSIS OF COMPOSITE CONSTRUCTION OF THE ACCESS BRIDGE PARTS OVER THE DANUBE BY BESKA, SERBIA


### SUMMARY

In the conception design of the bridge over the Danube by Beska, which presents the purchased work at the international competition, besides the main bridge part over the river, the access bridge parts over the river inundation should be designed.

The spans between columns for the access bridge parts, according to the conditions of the competition, were defined in advance. These spans are 45.0m. The length of the right side of the access bridge part is 180.0m and the length of the left side is 1492.55m. Since these lengths are too long, especially on the left side, the authors suggested that the access bridge parts should be designed of more composite continuous girders. The analysis of this composite construction is presented in the paper.


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(1) Assoc.Prof, (2) Assist, Faculty of Civil Engineering, University of Belgrade, SCG, Kralja Aleksandra 73 Beograd.Phone+381 11 3218594

(3) CEng., Nehruova 154, 11070 Belgrade, SCG, Phone.+381 11 176 76 41

## 1. Introduction

In the conception design by author B. Stosic with co-authors, of the bridge over the Danube by Beska, which presents the purchased work at the international competition, besides the main bridge part over the river, the access bridge parts over the river inundation should be designed.

The new bridge, according to the conditions of the competition, should be similar to the present concrete bridge and its silhouette should be fully followed. The new bridge should be " twin bridge ". The spans between columns for the access bridge parts, were defined in advance. These spans are 45.0m. The length of the right side of the access bridge part is 180.0m and the length of the left side is 1492.55m.

The author suggested that the access constructions should be designed like composite constructions, which cross sections consist of two open steel boxes whit vertical walls. The top flanges of these steel boxes are composed with reinforced concrete plate. B. Deretic-Stojanovic and S. Stosic designed this composite construction. The detailed analysis was fulfilled for two statically systems: a) system of simple supported beams with length of 45,0m, b) system of continuous girder across three spans (3x45,0=135,0m). According to this analysis, and with desire to reduce the number of separation, it is suggested that the access construction of the right side is consisted of one continuous girder across four spans (4x45,0=180,0m), and the left side of the across construction to be of more parts, started of reinforced concrete beam which length is 7,55m, then of one composite continuous girder across of three spans (3x45,0=135,0m) and six composite continuous girder across five spans (6x(5x45,0))=6x225,0m=1350,m.

The analysis of composite continuous beam across three spans (Fig.1.) will be presented in this paper. The beam is twice statically indeterminate. Because of symmetry $X_1=X_2$ ,and the design is done for the half of the beam.

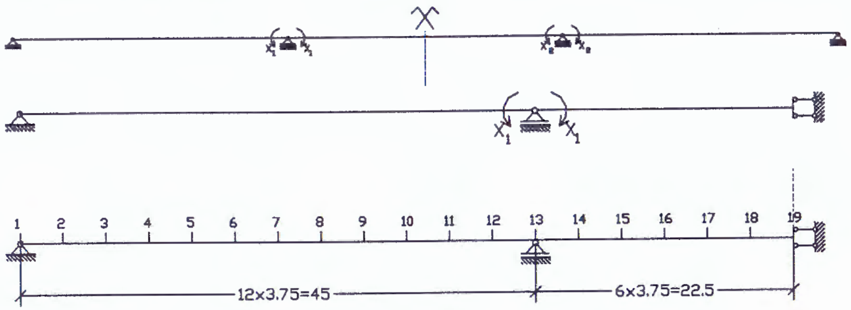


Figure 1. Statically scheme of composite continuous beam across three spans

## 2. The cross section of composite construction

The cross section of composite construction (Fig.2) is consisted of steel profile and reinforced concrete plate as a deck of the bridge. The steel profile consists of two open boxes whit vertical walls with average height (considering the transverse slope of 1,25%) 2,226m with the bottom flange which width is 2,455m and with the top flange which width is 0,3m in the middle of the span and 1,2m in the inside supporting zone. The transverse beams are located longitudinally at the spacing of 3,75m, and they continue in the cantilever footpath. Together with concrete plate they provide transverse flexural stiffness of the cross section. The transverse truss for the rigidity is predicted in the steel boxes, and located in the longitudinal direction at the spacing of 2x3,75=7,5m. The longitudinal truss for the wind is located in the middle of the bottom flange level of steel boxes. The steel C0561 (EC3:Fe510) is adopted.



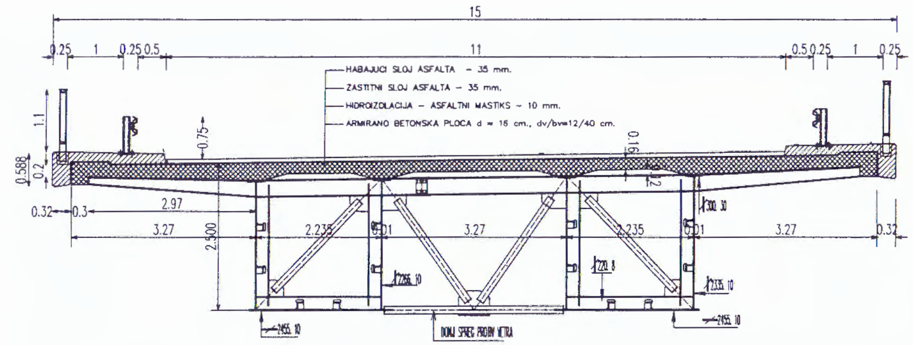

Figure 2. The cross section of composite construction

The reinforced concrete plate, as a deck of a bridge, has the thickness of 16cm, with the haunches on the supports which thickness is 12cm. This plate is supported on the transverse beams in the longitudinal direction, and in the transverse direction on the top flange of steel boxes and on the edging beams, thus the concrete plate carries in both directions. The concrete plate is reinforced with ribbed reinforce. It is designed against cracking in the zone of negative bending moments. The concrete grade is adopted as MB45.

Nineteen cross sections are noticed on the half of the beam, in interval of a=3,75m (spacing within the transverse rigidity) (Fig.1). Characteristic cross sections in which the stresses are calculated are the sections 3,5,7,12,13 and 19.

In the calculation of geometrical properties of cross sections, the variation of the effective width of the concrete plate (JUS U.21.010.1990) and bottom steel flange (DIN 18809), along the span, is taken into account.

The redistribution of stresses in the composite cross section during the time is done due to visco elasticity properties of concrete (creep) and shrinkage of concrete. The analysis of composite continuous construction is performed in the time $t_0$ and time $t_\infty$.

## 3. The design of composite construction in time $t_0$

Execution and design of composite construction are provided in more phases:

**Phase 1**(Fig.3): Between columns which are on the distance of *L=45m* the brackets are formed in the third of the spans. The steel beams with spans of *l*=15m, are being located on the columns and brackets in turn, so that, statically the system of 9 simple supported beams *9xl=9x15=135m* is formed on the span of *3xL=3x45=135m*. The simple supported steel beam carries its own weight. The loud of the phase 1 carries only the steel part of the beam so that the stresses are calculated in the bottom (3) and top (2) edges of steel profile for characteristic cross sections.

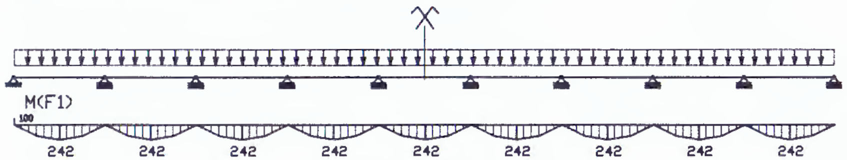


*Figure3. Phase1*

**Phase 2**(Fig.4): The simple supported steel beams are connected and statically we get the continuous girder across nine spans (9x15m). Concreting is done only in the field in the zones of positive bending moment. Distributed load in these zones is the weight of concrete. The load of the phase 2 carries steel part of the girder and the stresses in the bottom (3) and top (2) edges of steel profile for characteristic cross sections are calculated.

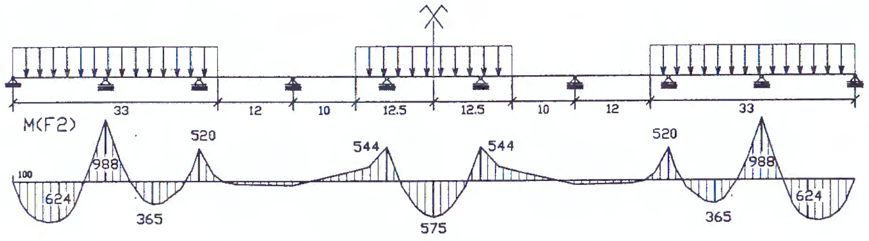


*Figure 4. Phase 2*

**Phase 3** (Fig.5): When the brackets are removed of the girder the reactions of Phase1 ($R_1$) and of Phase2 , $R=R_1+R_2$ are entered. Statically the girder is the continuous girder across three spans (3xL=3x45m).

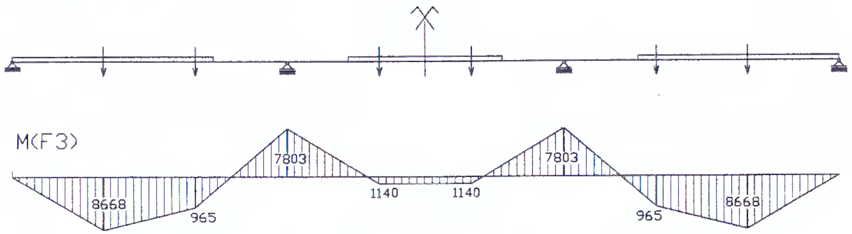


*Figure 5. Phase3*

**Phase4** (Fig.6): The concreting is finished above the interior supports of the continuous girder across three spans according to the Figure 6.

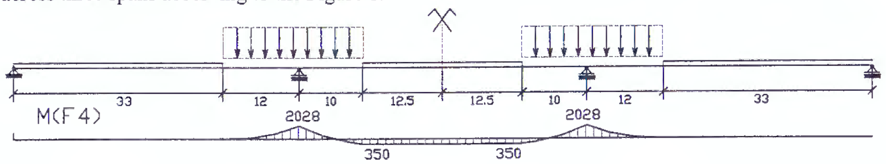


*Figure6. Phase 4*

**Phase 5**(Fig.7): The interior supports are lowered for c=0,60m.

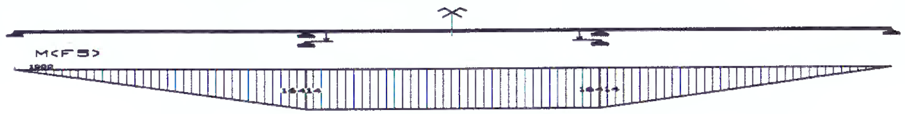


Figure7. Phase5- The interior supports are lowered

**Phase 6** (Fig.8): The whole girder is composed and it carries additional (permanent) louds (hydroisolation, asfalt, footpath...)



**Movable load:** The bridge is louded by movable imposed load. The bridge belongs to the first classe (the bridge on the motorway), and it is calculated according to the scheme of the louding bridges with type of cars 600+300. The torsional rigidity of the girder qualified that the bending moments were calculated according to the 0.7-0.3, while for transverse forces the coefficient of the distribution is 1,0-0,0.

**Temperature difference $\Delta t=15C^0$:** The effect of the temperature difference $\Delta t=15C^0$ , as an indirect action, is calculated (unequally heating concrete plate and steel profile).

**Overall effects in $t_0$** were calculated for the composite continuous girder across three spans according to the additional statically effects of Phases 3,4,5 and 6 and movable load in the fields and Phases 5 and 6 and movable load above. After analysis of obtained effects it can be noticed that the tension stresses in the steel (C0561) in the bottom flange are a bit larger than the permissive stresses ($\sigma_{per.}$=237Mpa for primary load) and it is recommended that the steel is of better grade or that the thickness of the bottom flange is increased. With increase of the thickness of the bottom flange for 3mm ($t_b$=13mm) the stresses are satisfied (Table1).

*Table1: Overall effects in $t_0$ [Mpa]*

| Overall primary ((1+2)+3+4)+5+6(with max mov.)+lower supp. t=to | | | | | | |
|---|---|---|---|---|---|---|
| | Section 3 | Section 5 | Section 7 | Section 12 | Section 13 | Section 19 |
| $\sigma_{c3}$= | 137.13 | 207.02 | 234.27 | 65.63 | 11.99 | 228.06 |
| $\sigma_{c2}$= | -30.19 | -10.59 | -37.21 | 67.51 | 44.02 | -40.06 |
| $\sigma_{b2}$= | -2.67 | -4.40 | -4.58 | -3.22 | -2.31 | -4.50 |
| $\sigma_{b1}$= | -5.62 | -9.44 | -9.83 | -6.48 | -4.95 | -9.56 |
| $\sigma a1$= | -32.34 | -54.24 | -56.53 | -37.32 | -28.46 | -54.97 |
| $\sigma a2$= | -25.02 | -41.72 | -43.48 | -29.23 | -21.91 | -42.38 |

**4. The design of composite structures in $t_\infty$**

Concrete is treated like a linear viscoelastic material. The deformation of creep and the shrinkage in the concrete occur during the time. The value of the creep coefficient $\varphi_\infty$ and shrinkage coefficient $\varepsilon_{sk}=\varepsilon_{s\infty}$ is determinated according to the Rules BAB87.

- age of concrete in the moment of the louding is t=28 days
- the relative humidity of the environment is 80% (interpolation is used)
- the middle thickness of the section of the element $d_m=2A_c/O$, wher is

$A_c$ - area of the section of the concrete element in $cm^2$, $A_c\approx16000cm^2$

O – volume of the section of the element in contact with air in cm, O≈16000cm, so thet is $d_m=2A_c/O\approx20cm$

According to BAB87 the creep coefficient $\varphi_\infty$=2,05,and shrinkage coefficient $\varepsilon_{s\infty}=-0,23\cdot10^{-3}$.

The calculation of the composite construction in time $t_\infty$ is done by using the algebraic relation for the stresses and deformations for the concrete according to Fritz: $\sigma=E_{ct}(\varepsilon-\varepsilon_s)$. This procedure is known as the procedure with "effective" modulus of concrete: $E_{ct}=E_{co}/(1+\psi\varphi_\infty)$.

Where $\psi$ is the reparation factor and its value is 0,52 for the effect of shrinkage and 1,1 for effect of creep (due to permanent loud).

***Calculation of the shrinkage:*** The "effective" modulus according to Fritz which corresponds to shrinkage, is $E_{cs}=E_{co}/(1+0,52\varphi_\infty)$. The ratio between elastic modulus of steel and "effective" modulus of concrete is determined $n_s=E_s/E_{cs}$ (instead $n=E_s/E_{co}$ in $t=t_0$) and it is used for determination of geometrical properties of composite sections in time $t_\infty$ which corresponds to shrinkage. Deformation of shrinkage corresponds to axial force $N_s=\varepsilon_s E_{bs} F_b$ which acts in the center of concrete plate. The reduction of this force to the center of composite section gives the axial force $N_s$ and the bending moment $M_s$. The internal forces of the statically indeterminate girder due to shrinkage are determined, and the stresses for characteristic cross sections are calculated.

***Calculation of the creep*:** The "effective" modulus according to Fritz which corresponds to creep is $E_{cf} = E_{co}/(1+1,1\varphi_\infty)$. Geometrical properties of composite sections in time $t_\infty$ which correspond to creep are calculated with new coefficient $n_f = E_c/E_{cf}$. For determination of statically indeterminate values the average effective width of the section along the span is used. On that way the girder is treated as girder of constant sections, so the statically indeterminate values due to creep do not change in $t_\infty$. The creep occurs due to permanent loud which acts on the composite girder. It is loud of Phases 3,4 and 6 for the sections in field, of Phases 5 for the sections above supports, while the effects caused with the lowered interior supports are determined separately.

**Overall effects (stresses) in $t_\infty$:** The overall stresses for characteristic cross sections in $t_\infty$ due to loading of Phase 1 and 2 , shrinkage, creep, lowing of supports, movable load and temperature difference are calculated using superposition. After analysis of obtained stresses it can be noticed that tension stresses for the sections 7 and 19in the steel (C0561) in the bottom flange are a bit larger than permissive stresses ($\sigma_{per.}$=237Mpa for primary load) and it is recommended that the steel is of better grade or that the thickness of the bottom flange is increased. With increase of the thickness of the bottom flange for 3mm ($t_b$=13mm) the stresses are satisfied (Table2).

*Table 2: Stresses in $t_\infty$ Mpa*

1+2+creep+shrinkage+mov-max+ low.of supp.

| | Section 3 | Section 5 | Section 7 | Section 12 | Section 13 | Section 19 |
|---|---|---|---|---|---|---|
| $\sigma_{c3}$= | 138.0667 | 200.037 | 215.4283 | 11.60878 | -49.1227 | 172.7917 |
| $\sigma_{c2}$= | -77.7078 | -70.4378 | -92.3844 | 21.32793 | 18.09063 | -92.0957 |
| $\sigma_{b2}$= | -0.97406 | -2.40365 | -2.14314 | -0.53897 | 1.080483 | -1.78708 |
| $\sigma_{b1}$= | -3.27995 | -5.7592 | -5.7002 | -1.85738 | 0.308066 | -4.18741 |
| σa1= | -87.3019 | -121.977 | -120.5 | -83.8486 | -50.3851 | -104.745 |
| σa2= | -77.4043 | -106.663 | -105.377 | -76.1056 | -45.6345 | -92.4151 |