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## Design of supporting devices of steel structures of frames of construction machines

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**Abstract.** This article discloses aspects of the determination of the design analogue for support units of U-shaped frames, which are used in construction equipment. When calculating frames of construction machines under the influence of forces located flat within the frame itself, an appropriate model of supports is required: they should be considered either as fixed supports with a hinged connection, or as a spatially defined system.

The difference in approach to the modeling of supporting elements causes significant differences in the definition of loads on the entire frame structure. If we take into account the same frame with the same applied load, but apply different support schemes, we can see that the values of the maximum bending moment in the transverse elements of the frame can differ by about 30-35%. Comparable differences in the degree of loading are observed for the longitudinal components of the frame. This implies an urgent need to develop criteria that will allow you to reasonably choose which design analogue best reflects the design features of the supporting device of the projected frame.

It should be noted that the correct determination of the estimated equivalent for the support units of the construction machine design has a significant impact on the reliability of the data obtained during the calculations, and also simplifies the calculation process itself.

**Keywords:** construction machine, frame, support device, clearance, displacement, force.

### INTRODUCTION

Construction machinery is a specialized technique consisting of mechanisms and parts for performing various construction works

(earthen, loading and unloading, installation), converting one type of energy into another, and is a key element in the mechanization of construction for the construction of objects for various purposes, from housing to roads [1].

Construction machinery is a set of technical means intended for mechanization of construction and installation works, extraction of materials and their transportation. The use of these machines can significantly accelerate the pace of construction, reduce the cost of work and replace the heavy physical labor of people.

In 2025 Caterpillar, Komatsu, Volvo, Liebherr, JCB and John Deere remain key players in the market.

Current trends in the development of construction machinery [2]:

- **Electrification:** Mass adoption of all-electric mini-excavators (e.g. Volvo ECR25, JCB 19C-1E) and loaders to reduce emissions and noise.

- **Autonomy and AI:** The use of 3D leveling systems (for example, FJDynamics) and unmanned vehicles to improve the accuracy of work.

- **Hybrid technologies:** Combining diesel and electric engines for heavy machinery operating in remote areas.

Machines for earthworks - the main means of mechanization of earthworks in construction, mining, melio-walkie-talkie, military engineering, drilling wells, development of the bowels of the World Ocean and space objects

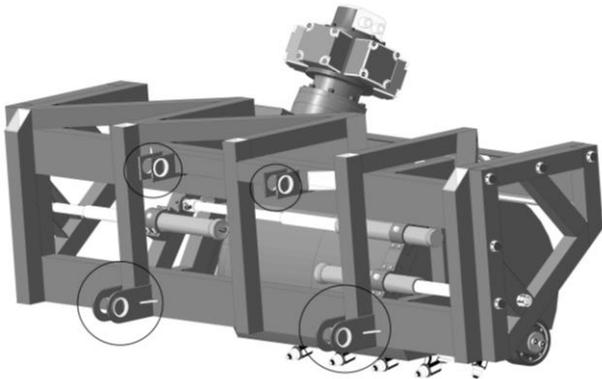
## PURPOSE OF THE ARTICLE

Analyze and investigate options for selection of design equivalent of support devices of steel structures of construction machines.

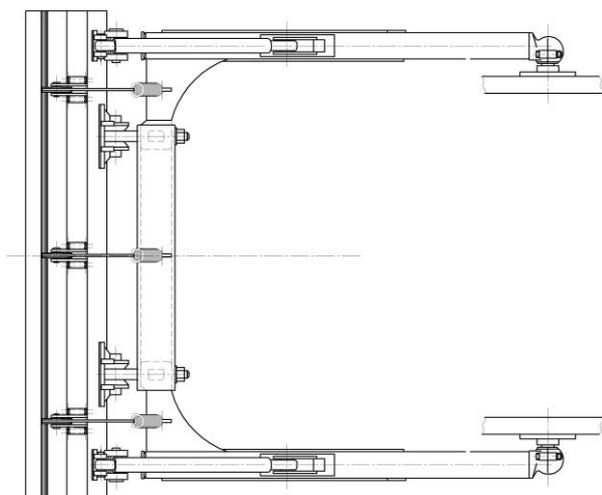
## PRESENTING MAIN MATERIAL

The importance of construction equipment is not only to reduce the amount of manual work, but also to significantly increase the efficiency of construction processes [3, 4].

Each machine, whether lifting, building, road or reclamation, consists of three key components: the mechanical component (mechanisms), the power system (drive) and the main metal frame (frame). This frame is the base on which all the units, mechanisms and units included in the machine are mounted [5, 6] (Fig. 1, 2).

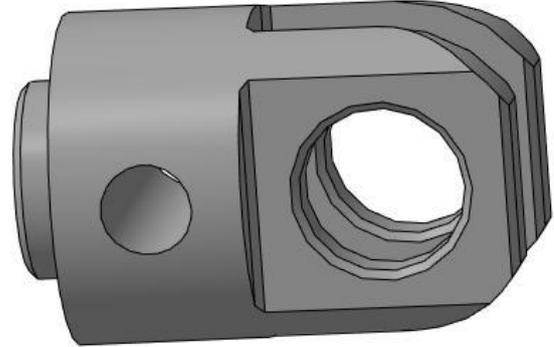


**Fig. 1.** Construction machine frame for hard coating milling



**Fig. 2.** Bulldozer frame

When we calculate related to construction machines and consider the forces acting in the plane of this frame, in most cases the systems for support support are modeled as hinged-fixed (fixed) supports [7 – 9] (Fig. 3).



**Fig. 3.** Construction machine frame support

During excavation, special earth-moving and earthmoving machines are used, which include bulldozers, scrapers, graders, excavators and other machines.

Earth-moving vehicles are divided into knife (bulldozers and motor graders), bucket (scrapers) and with an additional transport body (graders-elevators and plows). Apply them mainly in road, hydraulic and aerodrome construction for planning and profiling works in flat terrain on soils without large stony inclusions.

The main element of the metal structures of many earth-moving vehicles (bulldozers, rippers, scrapers) is a frame, which is fixed on the machine using cylindrical hinges. When calculating such frames for the action of forces that are located in the plane of the frame, support devices, as a rule, are presented in the form of hinged-fixed supports [3] (Fig. 4). This assumption is justified by the presence of a radial gap in the hinged joint (Fig. 5), which allows angular movement of the longitudinal part of the frame (rack). At the same time, the presence of a side gap allowing lateral movements of the longitudinal beam is not taken into account [8, 10].

The difference in which design analogue of supporting structures is chosen causes a significant change in the design stress of the entire frame structure (Fig. 6, 7). If we take into account an identical frame under the same load, but using different versions of supports, ISSN(online)2709-6149. Mining, constructional, road and melioration machines, 106, 2025, 67-72

it is easy to see that the maximum bending moment in the transverse element of the frame (crossbars) can range from 30-35 percent. A significant difference in load is observed in the longitudinal components of the frame. In view of this, there was an urgent need to develop clear criteria on the basis of which it would be possible to make a reasonable conclusion about the compliance of a particular supporting element of the projected frame with a certain design equivalent [11, 12].

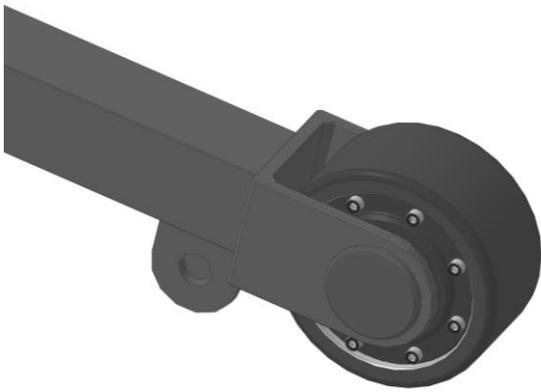


Fig. 4. Hinged fixed support

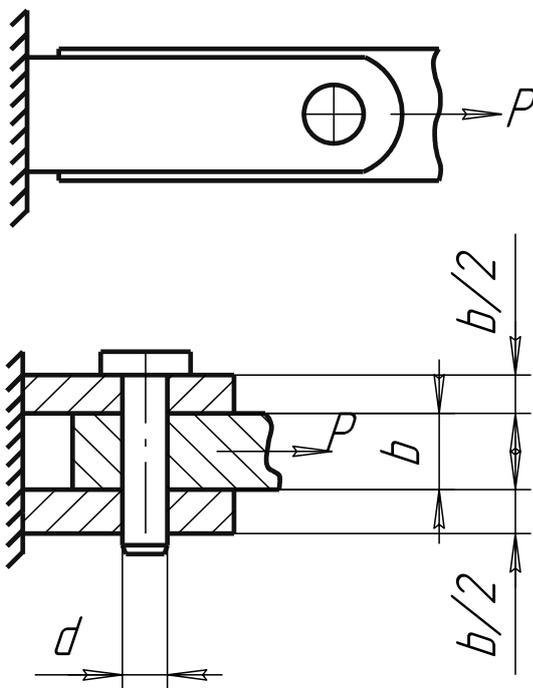


Fig. 5. Scheme of fastening the longitudinal part (wall) of the frame to the machine

Let us first assume that the frame has hinged-fixed fastenings of both longitudinal parts (Fig. 2). For such a frame, the strut force [13]:

$$X_1 = a(1-a) \frac{l^2}{h^2 P k_1}, \quad (1)$$

and the angle of rotation in the reference section:

$$\varphi = \frac{a(1-a)}{6EI_2} \left[ \frac{\rho}{k_1} + a \right] Pl^2, \quad (2)$$

where  $l, h$  – frame dimensions;  $a$  – parameter that determines the position of the point of application of force  $P$ ;  $\delta = \frac{I_2}{I_1}$  – ratio of the moments of inertia of the cross-sections of the transverse and longitudinal parts of the frame;  $E$  – modulus of elasticity of the material; coefficient  $k_1 = 2 \frac{l}{h} + \frac{4}{3} \delta$ ; coefficient  $\rho = \frac{\delta}{3} - \frac{l}{h}$ .

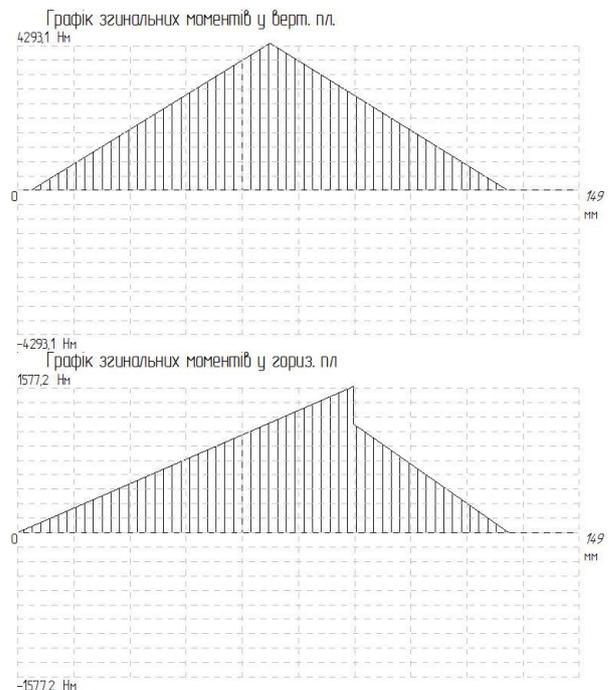
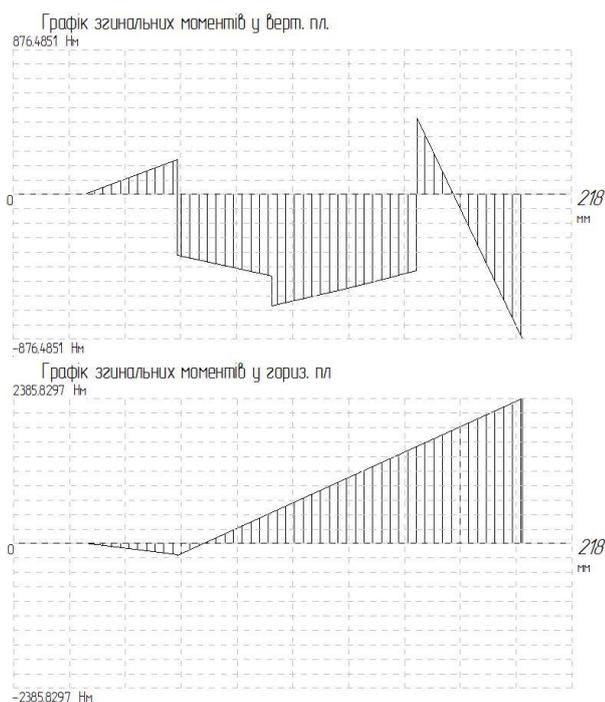


Fig. 6. Diagram of moments of the frame with hinged fixation



**Fig. 7.** Diagram of moments of the frame with hinged fixation

If the force  $P$  is applied in the middle of the transverse part of the frame, that is, at  $a=0,5$ , the expressions are simplified:

$$X_1 = \frac{P}{4} \cdot \frac{l^2}{h^2 k_1}; \quad (3)$$

$$\varphi = \frac{Pl^2}{24EI_2} \left[ \frac{\rho}{k_1} + 0,5 \right]. \quad (4)$$

In the actual design of the articulated joint, the angle of rotation is limited by the amount of radial clearance  $c$ .

In this case, the limiting angle of rotation frame (assuming it is sufficiently small):

$$\beta = c/b, \quad (5)$$

where  $b$  – eyelet width.

By equating expressions (5) and (2), we can obtain the value of the limiting force, under the action of which the possibilities of angular movement of the frame will be exhausted and a moment will arise in the supporting device. In the general case, the limiting force at  $a=0,5$ :

$$F = \frac{24EI_2ck_1}{bl^2\delta}. \quad (6)$$

The presence of an axial clearance in the support device allows us to simplify the scheme and consider the frame as a statically determined system. But the lateral movement is opposed by the force of friction  $F_f$ , which arises from the action of the vertical reaction at the support. Lateral movement will be impossible if

$$F_f = R_{res}f \geq X_1, \quad (7)$$

where  $f$  – coefficient of friction;  $R_{res}$  – vertical reaction at the support.

Using expression (1) and defining  $R_{res}$ , it is possible to obtain the value of the limiting coefficient of friction at which there is no lateral movement. In the general case, the limiting coefficient of friction where  $a=0,5$ :

$$f_{lim} = 0,5 \cdot \frac{l^2}{h^2 k_1}. \quad (8)$$

Thus, to calculate the frame, you should determine  $F$  i  $f_{lim}$  and depending on the results of comparing their values with the values of the force actually acting on the frame  $P$  and the real coefficient of friction  $f$  choose a calculation scheme.

Let us define, as an example, the stress in the dangerous cross-section of the pushing beam of the working equipment of a bulldozer (see Fig. 2) with the following initial data:

$$I = h = 290 \text{ cm}; \quad a = 0,5; \quad \delta = \frac{I_2}{I_1} = 5;$$

$d_n = 10 \text{ cm}; \quad c = 0,013 \text{ cm}; \quad e = 0,2 \dots 0,25 \text{ cm};$   
 $b = 10 \text{ cm}; \quad P = 120 \text{ kN};$  cross-sectional plane of the beam  $S = 68,8 \text{ cm}^2$ , moment of resistance  $W = 200 \text{ cm}^3$ . According to the proposed dependencies  $f_{lim} = 0,058$  and  $F = 100 \text{ kN}$ .

Considering that the coefficient of friction of steel on steel under conditions of limited lubrication can be taken equal to

$f = 0,12...0,15$ , we get that in our case  $P > F$  and  $f > f_{lim}$ . Performing the calculation in accordance with the above recommendations, we obtain that the stress in the dangerous cross-section of the beam is  $60115 \text{ kN/m}^2$ .

## CONCLUSION

As a result of the study, dependencies have been derived that allow, with the correct choice of the design equivalent of the supporting devices of the frame of the metal structure of the construction machine, to simplify the design results and significantly reduce the calculation time [3, 5].

During the study, the criteria are formulated by which it can be concluded that the design equivalent corresponds to the support device of the frame being designed.

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### Проектування опорних пристроїв металоконструкцій каркасів будівельних машин

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**Анотація.** Дана стаття розкриває аспекти визначення розрахункового аналога для

опорних вузлів рам металоконструкцій, які використовуються у будівельній техніці. При проведенні розрахунків рам будівельних машин під дією сил, плоскорозташованих у межах самої рами, потрібна відповідна модель опор: їх слід розглядати або як нерухомі опори з шарнірним з'єднанням, або як просторово визначувану систему.

Різниця у підході до моделювання опорних елементів спричиняє суттєві відмінності у визначенні навантажень на всю конструкцію рами. Якщо взяти до уваги одну й ту саму раму з ідентичним застосованим навантаженням, але застосувати різні схеми опираючі, можна побачити, що величини максимального згинального моменту у поперечних елементах рами можуть відрізнятися приблизно на 30-35%. Співмірні розбіжності у степені завантаження спостерігаються і для поздовжніх

складових рами. З цього випливає нагальна потреба у розробці критеріїв, котрі дозволять обґрунтовано обрати, який саме розрахунковий аналог найкраще відображає конструктивні особливості опорного пристрою рами, що проєктується.

Варто зазначити, що коректне визначення розрахункового еквівалента для опорних вузлів конструкції будівельної машини має суттєвий вплив на достовірність отриманих під час розрахунків даних, а також спрощує сам процес обчислень.

**Ключові слова:** будівельна машина, рама, опорний пристрій, зазор, переміщення, сила.

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